Weather, Climate and Water Services in the Middle East and North Africa

Climate and Hydrometeorological Services Atlas in the Region

CONTENTS

List of acronyms and abbreviations

ACMAD	African Centre of Meteorological Application for Development
ADB	Asian Development Bank
AEMET	*Agencia Estatal de Meteorología*
ALADIN	*Aire Limitée, Adaptation dynamique, Développement InterNational*
AMCOMET	African Ministerial Conference on Meteorology
AROME	Applications of Research to Operations at Mesoscale
ARPÈGE	Action de Recherche Petite Echelle Grande Echelle
ASDF	Atmospheric Sand and Dust-storm Forecasts
AWS	Automatic Weather Stations
BIP	Basic Instruction Package
BMD	Bahrain Meteorological Directorate
BSC	Barcelona Supercomputing Center
BSMEFFGS	Black Sea and Middle East Flash Flood Guidance System
CAMA	Civil Aviation and Meteorological Authority (Yemen)
CAP	Common Alert Protocol
CIMO	WMO Commission for Instruments and Methods of Observation
CMA	China Meteorological Administration
COSMO	Consortium for Small-scale Modeling
CPT	Climate Prediction Tools
DAR	WIS Discover, Access and Retrieval
DCPC	WMO/WIS Data Collection or Production Centre
DGMET	Directorate General of Meteorology (Oman)
DIAM	Department of Irrigation and Agrometeorology
DNM	Directorate of National Meteorology (Morocco)
DWD	*Deutscher Wetterdienst*

ECMWF	European Centre for Medium-range Weather Forecasts
EFI	Extreme Forecast Index (ECMWF)
EMA	Egyptian Meteorological Authority
EPS	Ensemble Prediction System
ESCAP	UN Economic and Social Commission for Asia and the Pacific
ESCWA	United Nations Economic and Social Commission for Western Asia
EWS	Early Warning System
FAO	Food and Agriculture Organization of the United Nations
FCV	Fragility, Conflict and Violence
FFGS	Flash Flood Guidance System
FTP	File Transfer Protocol
GAMEP	General Authority for Meteorology and Environmental Protection
GCF	Green Climate Fund
GDPFS	WMO Global Data-processing and Forecasting System
GFCS	Global Framework for Climate Services
GFDRR	WB Global Facility for Disaster Risk Reduction
GFS	Global Forecast System
GHACOF	Great Horn of Africa Climate Outlook Forum
GISC	WMO Global Information System Centre
GloFAS	Global Flood Awareness System
GPC-LRF	WMO Global Producing Centres for Long-range Forecasts
GTS	WMO Global Telecommunication System
HKO	Hong Kong Observatory
HPC	High Performance Computer
HRC	US Hydrological Research Center
IBM	International Business Machines Corporation

ICAO	International Civil Aviation Organization
ICPAC	Climate Prediction and Application Center
ICT	Information and Communications Technology
IDAG	Inter-governmental Authority on Development
IMD	India Meteorological Department
IMO	Iraqi Meteorological Organization
IMoWR	Iraqi Ministry of Water Resources
IP	Internet Protocol
IPCC	Intergovernmental Panel on Climate Change
IRIMO	Islamic Republic of Iran Meteorological Organization
IsDB	Islamic Development Bank
ISO	International Organization for Standards
IT	Information and Technology
ITCZ	Inter-Tropical Convergence Zone
JMA	Japan Meteorological Agency
JMD	Jordan Meteorological Department
KMA	Korea Meteorological Administration
KMD	Kuwait Meteorological Department
LAM	Limited Area Model
LMD	Lebanon Meteorological Department
LNMC	Libya's National Meteorological Center
MedCOF	Mediterranean Climate Outlook Forum
MENA	Middle East and North Africa
METAR	Meteorological Terminal Aviation Routine Weather Report or Meteorological Aerodrome Report
METEOSAT	Meteorological Satellite
MFI	Météo-France International

MSG	Meteosat Second Generation
NAO	North Atlantic Oscillation
NCEP	National Centers for Environmental Prediction
NCMS	National Center of Meteorology and Seismology (UAE)
NHS	National Hydrological Service
NIM	National Institute of Meteorology (Tunisia)
NMA	National Meteorological Agency (Djibouti)
NMHS	National Meteorological and Hydrological Service
NMO	National Meteorological Office (Algeria)
NMS	National Meteorological Service
NOAA	US National Oceanic and Atmospheric Administration
NORAD	Norwegian Agency for Development Cooperation
NWP	Numerical Weather Prediction
NWRA	National Water Resources Authority (Yemen)
NWS	NOAA National Weather Service
OP	Operating Plan
OPMET	Operational Meteorological Data
PMD	Palestinian Meteorological Department
PRESANORD	*Prévisions Climatiques Saisonnières en Afrique du Nord*
PSTN	Public Switched Telephone Network
PTC	WMO/ESCAP Panel on Tropical Cyclones
PWS	Public Weather Services
QAC	Qatar Aeronautical College
QMD	Qatar Meteorological Department
QMS	Quality Management System
RA	WMO Regional Association

RBSN	Regional Basic Synoptic Network
RCC	WMO Regional Climate Centre
RCOF	WMO Regional Climate Outlook Forum
RCP	Regional Climate Prediction
RIC	WMO Regional Instrument Centre
RRC	WMO Regional Radiation Centre
RSMC	WMO Regional Specialized Meteorological Centre
RTC	WMO Regional Training Centre
RTH	WMO Regional Telecommunication Hub
SADIS	Satellite Distribution System (supported by ICAO)
SDC	Swiss Agency for Development and Cooperation
SDS	Sand- and Dust-Storm
SEECOF	South East European Climate Outlook Forum
SESNAMHI	*Servício Nacional de Meteorología e Hidrología del Perú*
SGBD	ORACLE *Système de Gestion de Bases de Données*
SIGMET	Significant Meteorological Information
SMS	Short Message Service
SSOP	Standardized Standard Operating Procedures
TAF	Terminal Aerodrome Forecast
TSMS	Turkish State Meteorological Service
TX	Transmitter
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization

US	United States
USAid	United States Agency for International Development
USD	United States Dollar
USGS	US Geological Survey
VPN	Virtual Private Network
VSAT	Very Small Aperture Terminal
WAFS	World Area Forecast System
WAM	Wave Model
WB	World Bank
WDT	Weather Decision Technologies
WHYCOS	World Hydrological Cycle Observing System
WIS	WMO Information System
WMC	WMO World Meteorological Centre
WMO	World Meteorological Organization
WRF	Weather Research and Forecasting
WWIS	World Weather Information Service
WWW	WMO World Weather Watch
YMS	Yemen Meteorological Service

Executive Summary

The Middle East and North Africa (MENA) region is highly vulnerable to natural hazards. Hydrometeorological hazards, such as heat extremes and heatwaves, droughts, floods and flash floods, heavy rainfall and strong winds associated with tropical cyclones, and sand- and dust-storms, pose a direct threat to lives and impact livelihoods by damaging and destroying infrastructure, assets, and land; and they ultimately disrupt development outcomes. Underlying processes, including climate change, population growth, land use changes, and urbanization, are increasing the number of people in MENA at risk from hydrometeorological hazards, especially those in coastal lower lying areas. The MENA region is one of the world's most water-scarce and dry regions; with a high dependency on climate-sensitive agriculture and a large share of its population and economic activity in flood-prone urban coastal zones. Despite a long history of adaptation to weather, climate, hydrological variability, and extreme events, the MENA region continues to face serious challenges in managing the risk of disasters.

While natural hazards and disasters do not necessarily cause conflict in-and-of- themselves, **natural disasters can exacerbate the challenges people already face in fragile states, create new risks, stress already weakened governance systems and fuel grievances**. In addition, conflicts have caused irreparable damage to water security infrastructure and lowered resilience to climate change in the region. While noting that in recent years, there has been some work carried out to prepare MENA countries for climate change, it has been extremely uneven due to differences in economic wealth and stability across MENA countries.

Given the current and expected future impacts of hydromet-related hazards on countries in the region, governments need high-quality hydromet information to protect people, economies, and development gains. Strengthening Hydromet structures in the MENA region is an urgent necessity because state fragility is amplified by weather-, water- and climate-related hazards. To minimize growing economic losses from hydromet hazards, facilitate adaptation to climate change, and guide economic development across different sectors, countries need to invest in stronger national and regional capacity to improve their multi-hazard early warning systems, and weather, climate, and hydrological (hydromet) services. National Meteorological and Hydrological Services (NMHSs) historically played a critical role providing and tailoring these services for different users. National investments typically include upgrading of observing networks and related information and communication technology (ICT), real-time access to reliable and accurate numerical forecast products, post-processing and dissemination mechanisms, and cross-cutting institutional and technical capacity building.

Strategically, **the stability of target countries, including that of the government and economy, can be an enabling and, at the same time, a limiting factor in the pace of NMHS' development.** A key factor affecting stability is security, which can restrict the implementation of development plans. Very little can be done within any technical assistance designed to develop the capacity of these NMHSs, and their key stakeholders to prevent the short-term risk. However, as part of a holistic development picture, technical assistance itself may contribute to stability by reducing loss of life and attendant trauma, and increasing trust in government, particularly when food, water and economic security improve as a result of hydromet services.

Increasing resilience to natural hazards directly supports the World Bank's twin goals of eradicating extreme poverty and boosting shared prosperity. The World Bank and other development partners have been supporting countries' efforts to modernize their NMHSs. This report seeks to understand regional and national aspects of the development and delivery of hydromet services in MENA; assess regional activities and national capacities; identify gaps; and discuss potential actions to strengthen NMHSs' capacities in the MENA region. The report undertakes a desk review of literature and the World Meteorological Organization (WMO) documentation on the state of hydromet capacities in the targeted MENA countries (including its Country-profile Database), and project portfolios of relevant development partners and donors. A benchmark survey was undertaken to guide the process and establish a common methodology for this preliminary assessment of the NMHSs' capacities. It was noted that there were limited resources available for the review, and some of those available are outdated. Notwithstanding, the information provided in this report is believed to fairly profile hydromet capacities in the targeted MENA countries. However, additional information, and validation of existing information, is required through interviews with individual countries. The report concludes with recommendations.

The NMHSs have different capabilities – these vary considerably among the MENA countries. **International good practice suggests that, in addition to national investments, a regional approach applied to countries facing common hydromet conditions has advantages.** Although further investments are required at the national level for proper monitoring, forecasting, and warning systems and services, a regional approach enables enhanced networking; allows for robust interoperability, efficiencies, and optimization of infrastructure costs with sustainable operations and maintenance; and results in greater harmonization, integration, and complementarity within the region. Global frameworks (including the international system for monitoring and forecasting that cascades across global, regional, and national hydrometeorological service providers), and regional initiatives and programs could help address some of the major challenges that national hydrometeorological service providers face. For example, very costly functions could be handled at a regional level by the most advanced NMHSs in the region. In this context, **at the regional level, it is recommended**:

(i) *To introduce an agenda for hydromet modernization in a regional forum for knowledge sharing, and for pursuing regional hydromet strategies;*
(ii) *For NMHSs in the MENA region to use existing international frameworks and initiatives, including the recent WB and WMO agreement for technical assistance – this is particularly useful for basic training and accessing WMO regional technical centers;*
(iii) *For advanced NMHSs in the MENA region to make their numerical products available to neighboring countries;*
(iv) *To establish twinning arrangements between more advanced NMHSs in the MENA region and those with less ability for capacity building and technology transfer.*

At the **national level, it is recommended**:

(i) *To confirm/validate the information in this report through interviews with individual countries;*
(ii) *To assess stakeholder and user requirements as the driver for hydromet modernization;*
(iii) *To assist NMHSs to develop business plans and models (which involve socioeconomic benefit studies), a roadmap, and to implement the strategy within an operating plan (a Concept of Operations – CONOPS);*
(iv) *To introduce the agenda for hydromet modernization in country assistance and partnership strategies;*
(v) *Strengthen relationships between National Meteorological Services (NMSs) and National Hydrological Services (NHSs).*

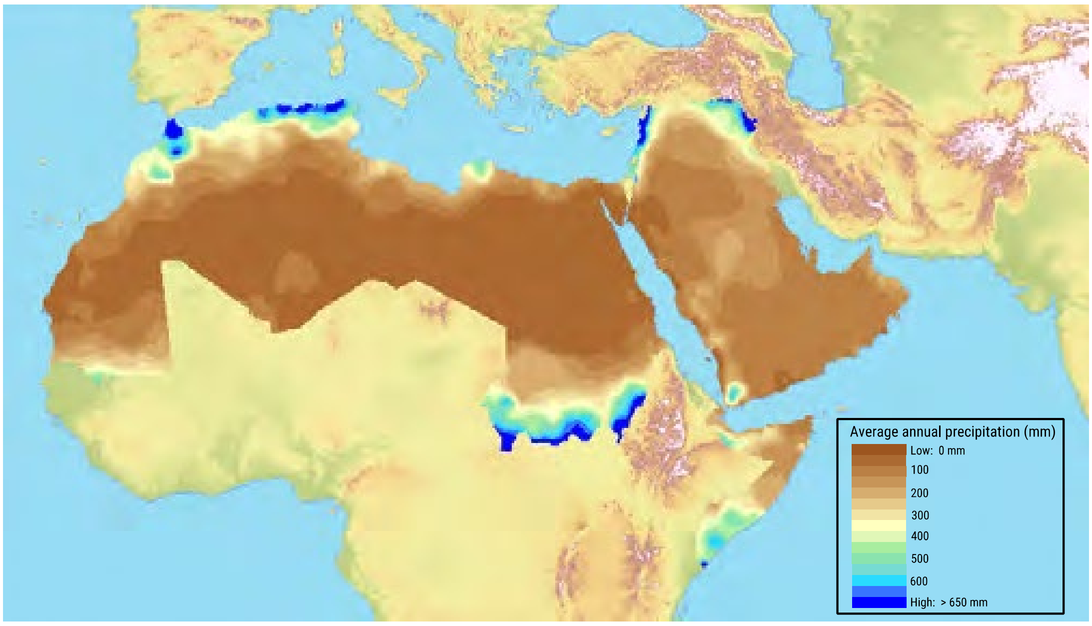
Chapter 1 – Weather and climate in the Middle East and North Africa

This chapter describes the main weather and climate characteristics of the Middle East and North Africa (MENA), summarizing current and projected conditions linked to climate change. In recent years, extreme temperatures and precipitation in the region have caused weather-, climate- and water-related hazards. ***Box 1*** *highlights the top five hydrometeorological hazards in the MENA region (i.e. heat extremes and heatwaves, droughts, floods and flash floods, heavy rains and strong winds associated with tropical cyclones, and sand- and dust-storms) and illustrates their impacts.*

CLIMATE AND WEATHER CONDITIONS IN THE MENA REGION

The MENA region extends from the Maghreb in North-west Africa to the Arabian Peninsula in South-west Asia at the junction of Africa and Asia. In many climate assessments, this region is treated as parts of two continents (i.e. North Africa as part of Africa; and the Middle East and part of Asia). However, recent studies are now addressing the MENA region as a whole due to its common climatic characteristics. In addition, as part of large continents (with climates from tropical to polar), climate change trends and projections of a region with common climatic characteristics (such as the MENA region) can be masked, and results can be misleading. While most of the MENA region is located in the northern hemisphere sub-tropics, and is characterized by semi-arid to arid climate conditions with generally dry and hot summers and mild winters, atmospheric circulation and rainfall patterns vary across the region (see ***Figure 1***) mainly due to topographic feature and air-sea/water interactions.

Figure 1 – Mean Annual Precipitation Distribution Across the Arab Region, Including MENA countries (1986-2005)



Source: ESCWA et al. (2017).

The Sahara Desert, which constitutes most of the surface area of North Africa, has one of the harshest climates in the world, with an annual rainfall of less than 25 mm (see ***Figure 1***) and temperatures rising to over 50°C in the hottest months to below freezing in the winter. The extreme south of Algeria extends to the south of the Sahara Desert (where the Sahel region is located), which is characterized by a tropical and hot steppe climate, with constant heat, little variation in temperatures, a long dry season (8 to 10 months) and irregular rainfall (100-600 mm of rain annually) during the remaining 2 to 4 months.

Although mostly arid or semi-arid, the MENA region also encompasses temperate zones in the northern and higher elevations of the Maghreb (i.e. Morocco, Algeria, Tunisia and Libya) and Mashreq (I.e. Lebanon, Jordan, Syria, Iraq and Iran), such as the Atlas Mountains (located in the northern parts of Morocco, Algeria, and Tunisia), with cooler temperatures and higher precipitation of up to 1,500 mm/year. The northern parts of Libya and Egypt, and western areas of Jordan, Lebanon, and Syria exhibit a Mediterranean climate, with warm, dry summers, and rainy, cool winters. In the highlands of Lebanon, northern Syria, and north-eastern Iraq, on average temperatures are below 10°C in winter (January), and annual precipitation is higher than 1,000 mm/year, with the possibility of snowfall in mountainous areas above 1,500 m. A cold semi-arid steppe climate with cold winters occurs in the south of the mountainous region, i.e. along a narrow stretch of Morocco, Algeria and Tunisia, and in Jordan, Syria, and Iraq in the Mashreq region (ESCWA et al., 2017).

A hot desert climate (with less than 100 mm/year of rainfall) characterizes most of the Arabian Peninsula. Average temperatures range from 40°C to 50°C in summer, and 5°C to 15°C in winter, with very high daily fluctuations. Exceptions to these conditions occur in the coastal zones of eastern Oman, south-western Saudi Arabia (Hijaz) and Yemen, where rainfall is higher (up to 1,500 mm/year on the south-western mountain slopes of Yemen), due to seasonal monsoon winds and northward expansion of the Inter-Tropical Convergence Zone (ITCZ) (Shahin, 2007; UNEP, 2013).

In the MENA region, average evaporation rates often exceed 2,000 mm/year. Observations along the southern and eastern shores of the Mediterranean indicate annual evaporation rates of 1,000 mm/year, increasing to 2,000 mm/year or more inland; in the Arabian Peninsula, the annual evaporation rate ranges from 2,500 mm in the coastal areas to more than 4,500 mm inland (Shahin, 2007).

[ADD MENA MAP OR CARTOON, HIGHLIGHTING THE ABOVE FEACTURES]

HAZARDS IN THE MENA REGION

In recent years, the MENA region has experienced more frequent and more severe extreme temperatures and precipitation (see ***Figure 2***) that have frequently led to a variety of weather-, climate- and water-related hazards, including heatwaves, droughts, floods, heavy rainfall and strong winds associated with tropical cyclones, and sand- and dust-storms (SDS). These conditions have had substantial and widespread social and economic consequences in many areas. When associated with unstable conditions (such as the development of informal, unsafe settlements or limited access to transport, health, education and other basic services), these emerging climatic conditions call for risk reduction on a large-scale. Some examples of hazardous events in the last decade, as indicated in the *World Meteorological Organization (WMO) Statements on the Status of the Global Climate*[1], are presented in ***Box 1***.

Box 1 – Hazardous events in the Arab region *[ADD MENA MAP OR CARTOON, HIGHLIGHTING THE HAZARDOUS EVENTS BELOW; KEEP THE DEFINITIONS IN THE BOX, POSSIBLY WITH A RELATED CARTOON FOR EACH TYPE OF HAZARD]*

Heat extremes and heatwaves – a heat extreme is abnormal and uncomfortable hot weather, which may qualify as a heatwave when it lasts from a few days to a few weeks (IPCC, 2014). In 2010, extreme heat affected northern Africa, Turkey, and the Arabian Peninsula at times during the summer, with notable readings including 52°C at Jeddah (Saudi Arabia), 50.4°C at Doha, and 47.7°C at Taroudant (Morocco). Record or near-record temperatures occurred in parts of the MENA on a number of occasions from late July to early September 2016. The highest temperature observed was 54°C at Mitribah (Kuwait) on 21 July, which (subject to verification) is the highest temperature on record for Asia. Other extremely high temperatures included 53.9°C at Basra (Iraq) and 53°C at Delhoran (the Islamic Republic of Iran – a national record), both on 22 July, while significant high temperatures were also reported in Morocco, Tunisia, Libya, and the United Arab Emirates. IPCC (2014) recognized that these hot weather extremes cause a loss of work capacity and aggravate societal stresses, especially for disadvantaged people and vulnerable populations. There is a general consensus that heat extremes impact human health, contribute to the spread of food- and water-borne diseases, and that more intense heatwaves increase premature mortality.

Drought – a period with an abnormal precipitation deficit is defined as a meteorological drought. This is a relative term, and therefore any discussion of precipitation deficit must refer to the particular hydrometdependent activity (e.g. hydrology, agriculture)[2] (IPCC, 2014). Devastating droughts occurred in Syria in 1998–2000 and 2007–2010, which were the most severe in some 1,100 years, causing considerable economic losses and the displacement of more than one million people. In August-September 2013, moderate to extreme drought struck the Islamic Republic of Iran. The 2015/2016 winter season was dry in Morocco and north-west Algeria, where rainfall for the period September 2015 to April 2016 was 15%–40% below average at most Moroccan locations. The wheat harvest in Morocco was 65% below that of 2015. The impacts of these events on livelihoods were severe, and included decreased water supplies, and loss of harvests and livestock, which, in turn, threaten food security and often cause widespread malnutrition, and in some cases, caused human losses.

Floods and flash floods – floods are defined as the overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas not normally submerged; while flash floods are floods that rise rapidly with little or no warning (IPCC, 2014). Typically, they occur after intense and short-duration rainstorms over a small area, causing severe damage to infrastructure and often leading to human losses. Major floods

[1] Every year, WMO issues a *Statement on the State of the Global Climate* based on data provided by National Meteorological and Hydrological Services (NMHSs) and other national and international organizations. More information available at https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate.

[2] For example, shortage of precipitation during the growing season affects crop production or ecosystem function in general (due to soil moisture drought, also termed agricultural drought), and during the runoff and percolation season primarily affects water supplies (known as hydrological drought).

have struck Saudi Arabia since 2009, the most recent of which – in February 2017 – caused the loss of several human lives. Other countries, such as Oman, experienced similar events with heavy flooding in early 2017, which led to four deaths and destroyed hundreds of settlements. During the last decade, many floods occurred in the MENA region. In 2008, extreme precipitation and floods in Morocco affected tens of thousands of people and caused severe infrastructure damage; the worst floods in a century for Algeria; and the heaviest snowfall in January in the Islamic Republic of Iran in which about 50 people died, and over 15 000 animals perished from cold. In 2010, heavy rain led to the worst floods in over a decade in Egypt. Rare snowstorms occurred in western Syria and Jordan in mid-December 2013. Heavy rain in late November 2014 triggered severe flooding in southern Morocco – some locations recorded more than the yearly average rainfall in only a few days. In 2015, over 13 times the monthly precipitation average was recorded in Marrakesh (Morocco) in one hour on 6 August; heavy rain in the western coastal region of Libya on 24 September, with more than 90 mm rainfall in 24 hours at Sorman, led to flash floods. On 29 September 2016, 232 mm of rain fell in 24 hours at Hiboun-Monastir (Tunisia); and more recently (on 21 September 2018), 200 mm in Nabeul, and up to 225 mm in the city of Beni Khaled. Heavy rain in November 2019 led to significant floods in Djibouti city.

Heavy rainfall and strong winds associated with tropical cyclones – a tropical cyclone is a strong, cyclonic-scale disturbance originating over tropical oceans[3] (IPCC, 2014). Tropical cyclone *Gonu*, the strongest tropical cyclone on record in the Arabian Sea, struck Oman in June 2007, leaving 49 dead and costing about US$4 billion in widespread damage, while tropical cyclone Phet caused major floods and landslides in May-June 2010. Tropical cyclone *Chapala* hit coastal Yemen in November 2015 and was the first tropical cyclone-strength storm known to make landfall in Yemen, submerging hundreds of dwellings. More recently (May 2018), the severe tropical storm Mekunu was the most intense tropical cyclone to make landfall in the Arabian Peninsula, and affected Oman, Yemen, and Saudi Arabia, with an estimated 31 fatalities and US$400 million of damage. Also in May 2018, tropical cyclone Sagar caused significant damage in Djibouti and Yemen.

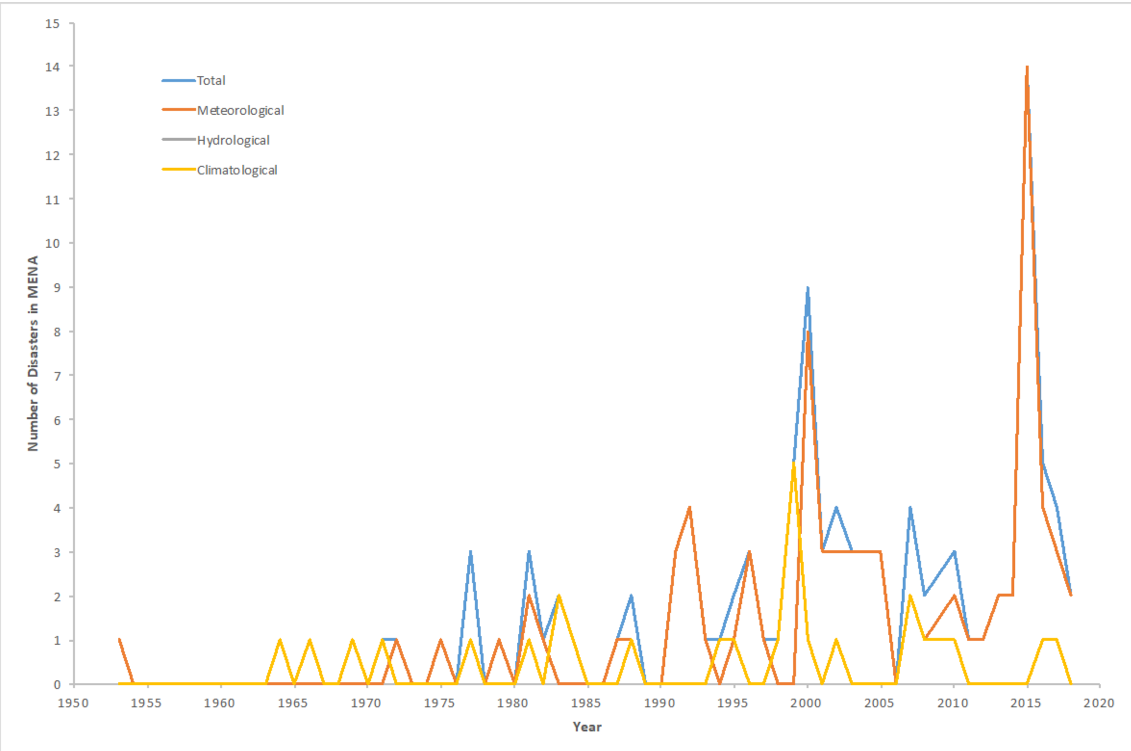
Sand- and dust-storms – characterized by sand or dust energetically lifted to great heights by strong and turbulent winds associated with extreme heat. Examples include a dust-storm on the Arabian Peninsula in late February 2015, when a low-pressure system triggered strong north-westerly winds which carried dust from as far as northern Saudi Arabia, Iraq, and Kuwait to the shores of the Persian Gulf and the Arabian Sea. The Mashreq region also widely witnessed such phenomena, with a massive dust-storm in September 2015, which lasted for several days, striking Syria and Iraq and spreading through Lebanon, Egypt and Jordan. The storm was unprecedented in recent Lebanese history, and led to five deaths and 750 cases of asphyxiation or shortness of breath (ESCWA et al., 2017). In many Arab countries, sand- and dust-storms have led to serious adverse impacts on human health and agricultural productivity, and traffic accidents and airline delays. It is estimated that about US$13 billion of gross domestic product are lost every year to dust-storms in the MENA region.

[3] Distinguished from weaker systems (often called tropical disturbances or depressions) by exceeding a threshold wind speed defined for each ocean basin.

A CHANGING CLIMATE

Seneviratne et al. (2012) show that a changing climate, in general, leads to changes in the frequency, intensity, spatial extent, duration, and timing of weather and climate events. Many countries in the MENA region are already feeling the impact of climate change, including more frequent heat waves and extensive droughts. Severe storms and associated floods, and coastal inundation from sea-level rise are likely to happen along the coast, especially in cities and settlements at sea level. According to IPCC (2014), sea levels are expected to rise at least 1 m during this century. ***Figure 2*** shows a slightly increased trend in hydromet disasters, especially meteorological disasters, in MENA over the last three decades.

Figure 2 – Number of Meteorological, Climate, and Hydrological Disasters in MENA Countries from 1950 to August 2018



Source: EM-DAT: The Emergency Events Database – Université Catholique de Louvain (UCL) – CRED, D. Guha-Sapir – www.emdat.be, Brussels, Belgium.

Note: Meteorological disasters include extreme temperatures, fog, and storms; climate disasters include droughts and wildfires; and hydrological disasters include floods and landslides.

Donat et al. (2013) show that there are consistent warming trends since the middle of the 20th Century across the MENA region, which appear to be particularly strong since the early 1970s. This is evident in increased frequencies of warm days and nights, higher extreme temperatures, fewer cold days and nights, and shorter cold spells. While consensus among climate models suggests confidence in projections for extreme heat and drought, there is evidence that precipitation trends are generally less significant. Changes in precipitation are generally less consistent and characterized by high spatial and temporal variability. However, in the western part of the MENA region, there is a trend towards wetter conditions. In contrast, in the eastern part, there are more drying trends, although these are of low significance.

The state of the North Atlantic Oscillation (NAO) (see ***Box 2***) largely governs annual variations in rainfall in the Maghreb, most of the Mashreq and the northern part of the Arabian Peninsula. Precipitation variability in the Arabian Peninsula is affected by the Indian seasonal monsoon winds (see ***Box 2***) which bring moist air masses from the Indian Ocean, causing rainfall in the coastal zones of eastern Oman, Saudi Arabia (Hijaz region) and Yemen. Most of the precipitation occurs in May and continues until August in the uplands, but often appears as early as March. In this area, rain falls mainly as heavy showers followed by flash floods. Occasionally, these countries also experience serious consequences of tropical cyclones generated in the Arabian Sea (Krishnamurti et al., 2013).

Box 2 – Primary Atmospheric Patterns Affecting Climate Variability in the MENA Region

[ADD CARTOON, HIGHLIGHTING THE BELOW PATTERNS]

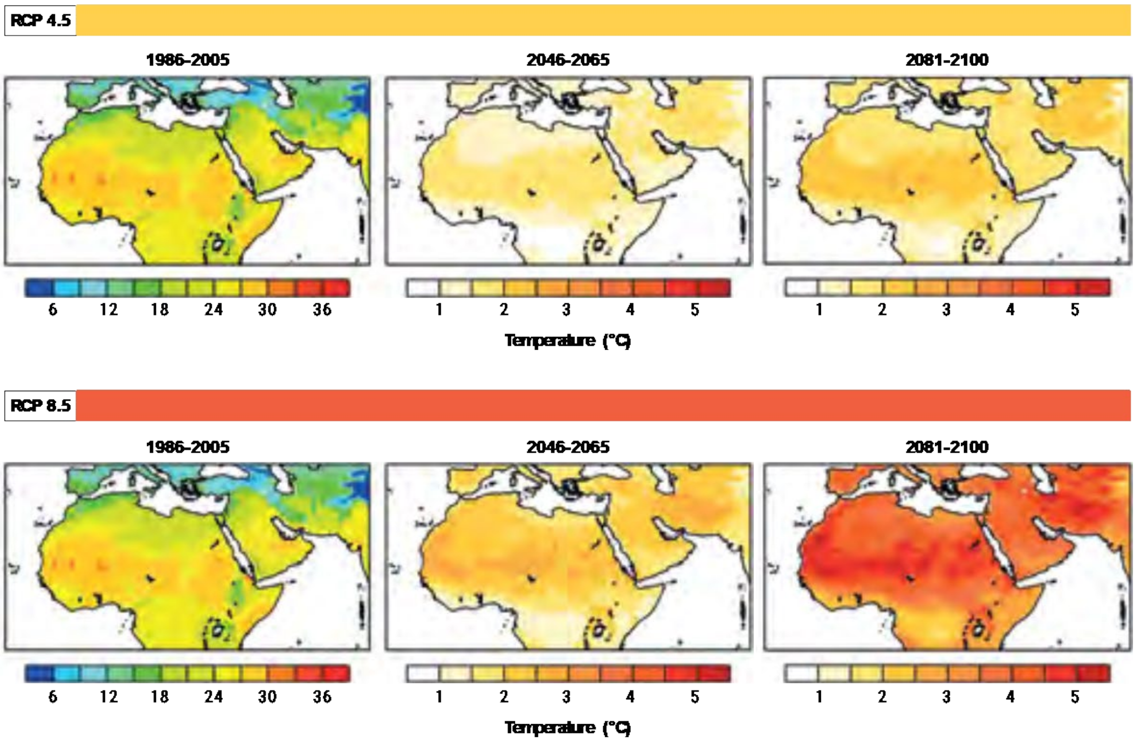
The **North Atlantic Oscillation (NAO)** refers to large scale changes in pressure that occur naturally in the North Atlantic region, and is the principal feature affecting climate variability in the northern hemisphere. The NAO consists of opposing variations between areas of low pressure centered over Iceland (sub-polar or Iceland low) and high pressure zones in the south of the Azores islands (known as the sub-tropical or Azores high) in the Atlantic Ocean. The interaction of these two poles modifies the circulation of westerly winds across the Atlantic into Europe and the Mediterranean, with important impacts on both weather and climate patterns (such as temperature, rainfall, and wind strength/direction) on surrounding continents. When the pressure difference is high (positive NAO phase), westerly winds are stronger and track more to the north, leading to higher-than-normal temperatures and precipitation across northern Europe in winter, but causing drier conditions in the Mediterranean. In the opposite (i.e. negative NAO phase), westerlies and the storms they bring track farther south, leading to cold winters in Europe, but more storms in the Mediterranean and more rain in North Africa (Brandimarte et al., 2011; Hurrell et al., 2013).

The **Indian Monsoon System** is largely controlled by the position of the Inter-Tropical Convergence Zone (ITCZ), a zone of low pressure at the Equator, where the northeast and southeast trade winds converge to form a band of increased convection, cloudiness, and precipitation, that moves seasonally south and north of the Equator. The Indian Monsoon is the most prominent of the world's monsoon systems, and primarily affects India and its surrounding water bodies (the Arabian Sea and the Bay of Bengal). It is characterized by a seasonal reversal of the direction of surface winds and associated precipitation caused by differential heating of the continental land mass and the adjacent ocean (Krishnamurti et al., 2013).

The MENA region is particularly vulnerable to climate change, and is expected to experience warming greater than the global annual mean (see ***Figure 3***), with a predicted increase of 1.2°C–1.9°C at mid-century (2046-2065) to 1.5°C–2.3°C by end century (2081-2100) for the

RCP4.5[4] (intermediate emissions) scenario. For the RCP8.5[4] (high emissions) scenario, temperatures are predicted to increase to 1.7°C–2.6°C by mid-century and 3.2°C–4.8°C towards end-century (ESCWA et al., 2017). The range of these values reflects the variation in predictions for different areas in the region. Results (ESCWA et al., 2017) also imply that climate warming in the MENA is strongest in summer, while elsewhere, it is typically stronger in winter. Recent observations and models consistently show increasing heat extremes, which are projected to accelerate in the future (Lelieveld et al., 2016). The number of warm days and nights may increase sharply, with important consequences for human health and society.

Figure 3 – Mean Change in Annual Temperature (°C) for Mid- (2046-2065) and End-century (2081-2100) for RCP4.5 and RCP8.5 Scenarios Compared to the Reference Period (1986-2005)



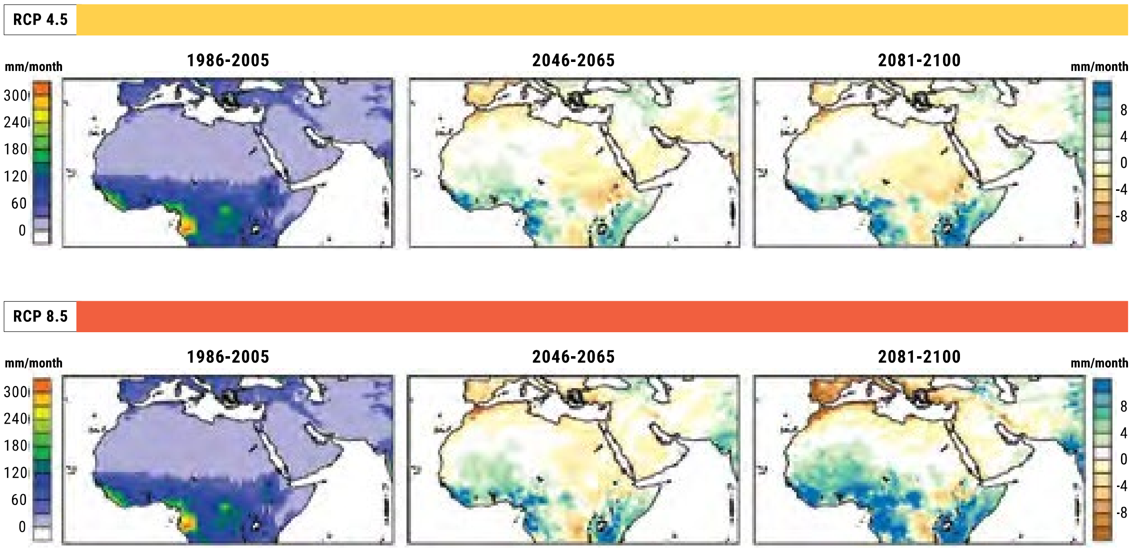
Source: ESCWA et al., 2017.

Uncertainty evaluation of climate projections indicates strong model agreement for temperature but less so for precipitation. Predicted changes in precipitation vary considerably across the MENA region with no overall trend for annual or seasonal results. Decreasing trends are evident in most of the MENA region at mid-century (2046-2065) (see ***Figure 4***). By the end of the century (2081-2100), both scenarios suggest a reduction in average monthly precipitation. At the seasonal level, a number of studies have confirmed the strong influence of the North Atlantic Oscillation (NAO) on precipitation variability, especially

4 Representative Concentration Pathway (RCP) 4.5/8.5 is a scenario that stabilizes radiative forcing at 4.5/8.5 Watts per meter squared in the year 2100 without ever exceeding that value.

in Morocco (Donat et al., 2013). Regarding precipitation extremes, there is considerable variation over the region. The projections for the maximum length of dry spell suggest trends towards drier conditions with an increase in the number of consecutive dry days specifically for the Mediterranean, and the western and northern parts of the Arabian Peninsula by the end of the century (ESCWA et al., 2017).

Figure 4 – Mean Change in Annual Precipitation (mm/month) for Mid- (2046-2065) and End-century (2081-2100) for RCP4.5 and RCP8.5 Scenarios Compared to the Reference Period (1986-2005)



Source: ESCWA et al., 2017.

Chapter 2 – How Hydromets Function

This chapter briefly outlines the roles, and responsibilities of national hydromet service providers and discusses how the World Meteorological Organization (WMO) global and regional network could strengthen national capabilities in the MENA region. This Chapter also highlights major international and regional initiatives relevant to MENA.

CORE FUNCTIONS OF NATIONAL METEOROLOGICAL AND HYDROLOGICAL SERVICES AND HOW WMO'S GLOBAL AND REGIONAL NETWORK SUPPORT THEM

To minimize growing economic losses from hydrometeorological hazards, facilitate adaptation to climate change, and guide economic development across different sectors, countries invest in national capacity to provide improved multi-hazard early warnings and weather, climate, and hydrological (hydromet) services. According to WMO (2015), the National Meteorological and Hydrological Services (NMHSs) are the national institutions responsible for observing and understanding weather and climate and for providing related services in support of national needs, especially as they pertain to (a) protecting life and property; (b) safeguarding the environment; (c) contributing to sustainable development; (d) promoting long-term observation and collection of meteorological, hydrological, and climate data, including related environmental data; (e) promoting endogenous capacity development; (f) meeting international commitments; and (g) contributing to international cooperation.

The institutional form of NMHSs depends on national legislation, national policies on public services, and the role of the private sector, and hence varies from country to country. However, the majority of NMHSs are government institutions, including the NMHSs of countries featured in this report. They may be independent departments or agencies (reporting directly to a minister, with their own budget and funding) or part of a larger department (often transport, civil aviation, and environment).

The scope of an NMHS will depend on its mandate, national arrangements and policies, and geography (e.g. coastal or land-locked). The diagram presented in ***Figure 5*** below shows, in the interior of the big grey hexagon, the overall breadth of core functions as part of an integrated end-to-end system[5]. It shows the flow of meteorological, hydrological, and related information to produce services, but there is also a counter- flow from users on requirements and feedback on the quality of services. Almost all NMHSs cover the gathering and exchange of observations and the provision of core forecasts and warnings.

Below is a description of more-or-less the usual order of NMHSs' functions, from observations to service delivery, including support provided by research. For NMHSs to serve their purpose, however, all elements of this chain must contribute to services that are relevant and valued by users and customers, who ultimately provide or influence the resources that NMHSs require to operate. Many NMHSs still have limited capacity due to human and budgetary

[5] An integrated end-to-end system is a "system-of-systems" which includes production systems, delivery systems, enabling systems and capacity building.

constraints, and therefore the WMO's global and regional network (see *Annex*) has been established to facilitate the exchange of data and products, and/or to assist NMHSs to carry out their functions and to fulfill their national and international obligations. These functions are:

a) **Observations and monitoring** – Observations of the Earth's atmosphere, oceans, land and related environments are essential for monitoring hydromet conditions, conducting research to improve services, assessing changes in the climate system and developing and operating systems in weather- and climate-dependent sectors, such as agriculture, water, transport, and energy, in support of communities' efforts to reduce disaster risks and adapt to climate variability and change. Maintenance and operations, including calibration of instruments, are critical to standardize measurements that are shared worldwide for monitoring and forecasting. NMHSs that don't have their own calibration laboratories benefit from the support provided by WMO Regional Instrument Centres (RICs) and Regional Radiation Centres (RRCs), which in the MENA region are hosted by the NMHSs of Algeria, Egypt and Morocco/Tunisia (see *Annex*).

b) **Information systems** – effective and reliable information systems are needed both nationally to acquire data and deliver services, and internationally for NMHSs to exchange and share standardized data and products for the benefit of all. So that NMHSs can access data and products from global and regional initiatives, and contribute observational data to improve numerical forecast accuracy, a key priority is for countries to acquire the WMO Information System (WIS)/Global Telecommunication System (GTS). This allows communication with the international community through *WMO Data Collection or Production Centres (DCPC)* and *WMO Global Information System Centres (GISCs)*. In the MENA region, the DCPC is hosted by the NMHS of Egypt, and the GISCs by the NMHSs of Morocco, Saudi Arabia, and Iran.

c) **Modeling and forecasting** – the observations and data gathered by NMHSs are processed to generate products to support decision-making during events such as tropical cyclones, heatwaves, flash floods, and droughts. The quality of the products is dependent on the adequacy of processing facilities and human resources. All NMHSs contribute to these products by sharing observations which are used to generate forecasts and warnings. However, not all NMHSs have the capacity to run their own numerical models. Nowadays, *WMO World Meteorological Centres (WMCs)*, *Regional Specialized Meteorological Centres (RSMCs)* and *Regional Climate Centres (RCCs)* have the capacity to run very high resolution numerical models, with full data-assimilation. Outputs from these models (i.e. global and regional forecast products; and boundary conditions for limited area numerical prediction) are made available through the WIS/GTS for the benefit of all NMHSs. The NMHSs in the MENA region can access products from all WMCs and RSMCs/RCCs, even if they are not hosted by NMHSs in the region. As an example, the RSMC for tropical cyclones which assists MENA countries is located in New Delhi, India. In the MENA region, the North Africa RCC-Network is hosted by the NMHSs of Morocco, Tunisia, Algeria, Egypt, and Libya (see Annex).

d) **Research & development** – all NMHSs have benefited from scientific progress achieved through sustained investment in global and national research programs.

e) **Service delivery, including:**

- **Public Weather Services, and early warning systems** – public weather services, including forecasts and warnings, are an essential component of NMHSs and one of the most visible returns for taxpayers. Early warnings and alerts of extreme events can reduce the impacts of such events when coupled with effective emergency response systems. NMHSs rely on communications infrastructure to issue timely warnings. One important issue is that an NMHS should be the single authoritative voice on weather warnings within its country in order to avoid public confusion. Severe weather warnings are increasingly not about the weather elements themselves, but rather the impacts of the weather. See, for example, the Météo-France *Vigilance* display, which is implemented in the NMHS of Morocco, and color codes likely impacts. Sharing of NMHSs' information facilitates cross-boundary monitoring and forecasting, which is especially important for severe events. For this reason, many NMHSs make their forecasts available to the *WMO World Weather Information Service* (see *Annex*).

  NMHSs also provide forecasts and warnings of floods, water levels and discharge within river basins, watersheds, and coastal areas. These products are critical for protecting life and property, for safeguarding the environment and to manage water resources as part of sustainable development. For the countries featured in this report, National Meteorological Services (NMSs) and National Hydrological Services (NHSs) are separate institutions which need to collaborate to deliver services.

- **Aviation meteorological services** – for the civil aviation sector, NMHSs provide data, products, and services that contribute to the safety of aviation and the economic operation of the sector both nationally and internationally. The measurements and forecasts of conditions en route, at, or on the approach to terminal aerodromes are useful for minimizing aviation operating costs. By increasing the efficiency of aviation operations, NMHSs also contribute to reduced aircraft emissions and their impacts on climate change and stratospheric ozone. This sector provides a major contribution to many NMHS budgets through cost recovery, important developments in quality management, and the competence of NMHS personnel. Many NMHSs use products provided by WMCs and RSMCs for aviation meteorological services.

- **Marine Meteorological Services** (only applied to coastal countries, islands, or countries with large lakes) – many Members' areas of responsibility may be composed in large part of the ocean and marine environment under their country's jurisdiction. Marine conditions significantly influence the weather, but can also affect peoples' safety, economic development, and management of coastal resources. NMHSs have a public responsibility to mitigate weather and weather-related events that develop or intensify in oceans, such as tropical cyclones. Many NMHSs make use of marine meteorological services products provided by WMCs and RSMCs. In particular, the RSMC for tropical cyclones and marine related hazards (i.e. high waves and storm surges) which assists MENA countries is in New Delhi, India.

- **Agricultural meteorological services** – more than ever, agrometeorological services are essential in the face of increasing climate variability, associated extreme events, and climate change, all of which have socio-economic impacts, especially in developing countries. Again, products from WMCs and RSMCs/RCCs can be used by NMHSs to provide agrometeorological services.

- **Climate services** – NMHSs are ideally placed to play a major role in the delivery of climate services. In most cases, they are the prime national source for high-quality weather and climate observations that are archived into climate databases and available for analysis and to underpin services. Given that billions of people worldwide have climate-sensitive livelihoods, climate information may determine progress in many sectors and countries, particularly in developing and least-developed countries. In this context, and due to the limited capacity of many NMHSs to run their own climate models, the use of RCC products and regional consensus statements (issued during the *Regional Climate Outlook Forums – RCOFs*) by NMHSs can greatly contribute to their climate services. See the section below for RCOFs in the MENA region.

CompetentThe **competence of NMHS personnel** is critical for the provision of weather-, climate- and water-related services. Following the *WMO Manual on the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083), NMHS personnel must complete the *Basic Instruction Packages (BIPs) for Meteorologists, for Meteorological Technicians, for Hydrologists, and for Hydrological Technicians*. This is part of the competencies requirements as part of their career path, which is complentary to the university degrees. BIPs are usually carried out at *WMO Regional Training Centres (RTCs)*. In the MENA region, NMHS staff can be trained at RTCs in Algeria, Egypt, Iran, Iraq, and Qatar (see *Annex*).

Based on these descriptions, ***Table 1*** summarizes how WMO's global and regional network can benefit NMHSs in MENA, highlighting functions which may strengthen NMHSs' capacities; and ***Figure 5*** shows how various centers interact with NMHSs in MENA countries.

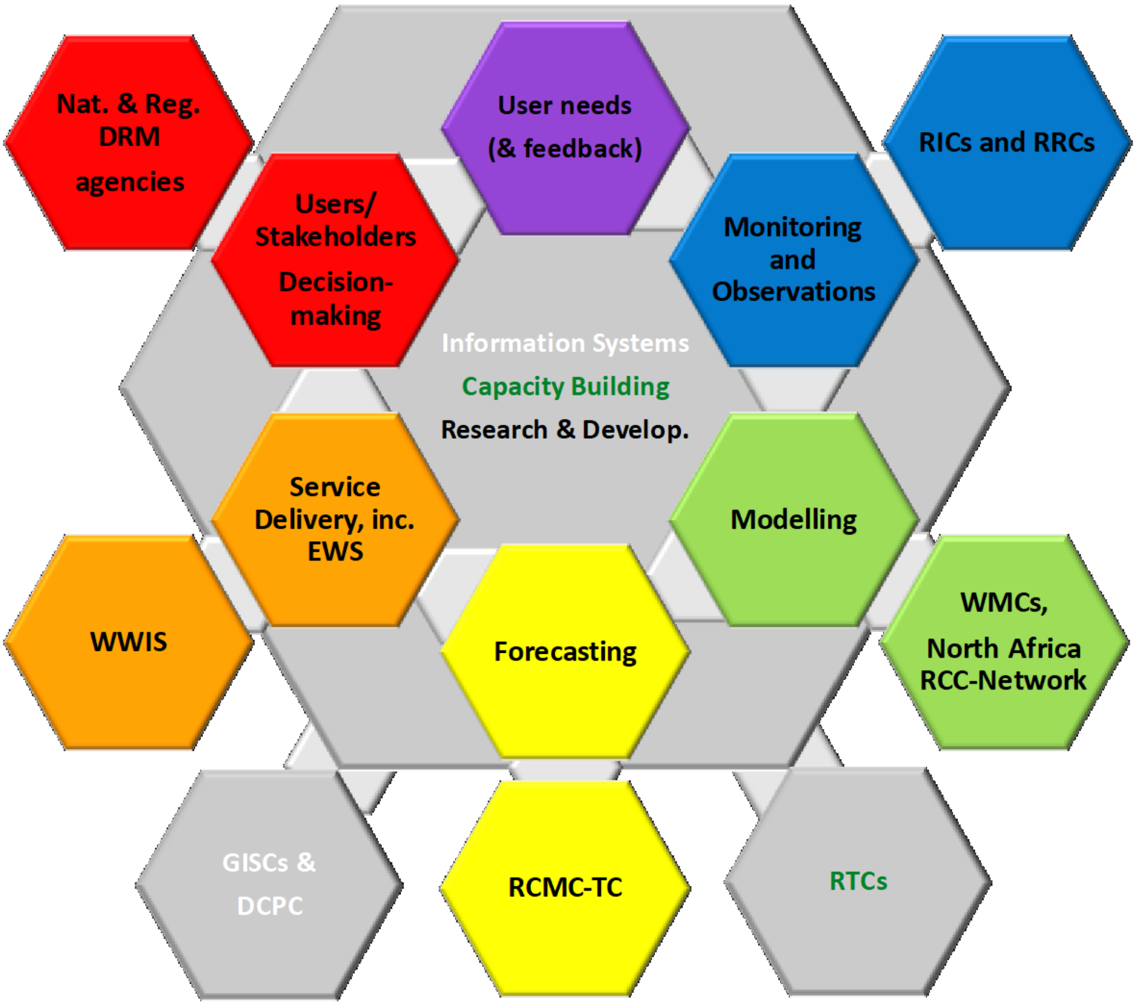
Table 1 – Summary of Activities of Global and Regional Centers that Benefit NMHSs in MENA

Regional center	Activities within the context of the regional initiative	Activities which can be strengthened by NMHSs within the context of the regional initiative
RICs	Calibration of national meteorological standards and	Improved data quality; capacity building

	related environmental monitoring instruments; capacity building	
RRCs	Inter-regional comparisons of radiation instruments; maintain standard instruments necessary for this purpose; capacity building	Improved radiation data quality; capacity building
GISCs and DCPCs	Observational and numerical model data sharing	Improved monitoring and forecasting through data sharing
WMCs, RSMCs/RCCs	High-quality NWP/EPS forecast data and products; climate predictions; flood forecasts; monitoring and forecasting of tropical cyclones and associated phenomena; monitoring and forecasting of sand- and dust-storms, capacity building	Improved forecasting; impact-based forecasting and risk-based warnings; capacity building
WWIS	Centralized source of hydromet information worldwide	NMHS visibility; authoritative source of hydromet information
RTCs	Education and training	Capacity building on competencies aligned with career paths

Note: EPS = Ensemble Prediction System.

Figure 5 – How WMO Global and Regional Centers and DMR Agencies Interact with NMHSs in MENA Countries



Source: N/A.

INTERNATIONAL HYDROMET INITIATIVES IN THE MENA REGION

Weather, climate, and water know no national borders. Transboundary issues related to political conflict, history, socioeconomic conditions, geography, laws, and institutions may exist in the MENA region, but there is coordination and cooperation among MENA countries (and also with outside neighboring countries, and internationally) on hydrometeorological services. Some of these regional and international initiatives are described below. Based on the descriptions of international initiatives on regional cooperation and regional frameworks in MENA, ***Table 2*** identifies the activities of regional initiatives that can benefit NMHSs in MENA.

WMO/ESCAP Panel on Tropical Cyclones

The *WMO/ESCAP Panel on Tropical Cyclones (PTC)* for the Bay of Bengal and Arabian Sea[6] is an intergovernmental organization established in 1973 as a regional body of the WMO and the United Nations Economic and Social Commission for Asia and the Pacific (UN/ESCAP). The PTC's purpose is to promote and coordinate programs, and implement measures to mitigate disasters and reduce loss of lives and properties caused by tropical cyclones in the North Indian Ocean rim countries. The Panel of Tropical Cyclones is currently composed of nine members, of which two are MENA countries: Oman and Yemen.

A major PTC milestone is the Operational Manual (PTC, 2017), which defines responsibilities among PTC members for components of the tropical cyclone warning system for the Bay of Bengal and the Arabian Sea, and records the coordination and cooperation achieved. It specifies the activities of the Regional Specialized Meteorological Centre (RSMC) New Delhi and states regional cooperation procedures and agreements among PTC members. It also describes national practices and procedures. Training is supported by RSMC New Delhi. The PTC Operational Manual is annually revised and refined through experience gained in its use.

Regional Climate Outlook Forums

Regional Climate Outlook Forums (RCOFs)[7] produce consensus-based, user-relevant climate outlook products[8] (generally probabilistic predictions of seasonal mean rainfall, surface air temperature, and other weather parameters, and the likely evolution of key drivers of seasonal climate variability relevant to the region, such as NAO) in real time in order to reduce climate-related risks and support sustainable development for the coming season in sectors of critical socioeconomic significance for the region in consideration. These forums bring together national, regional, and international climate experts to produce regional climate outlooks based on climate predictions from all participants. By bringing together countries with common climate characteristics, the forums promote consistency in access to, and interpretation of, climate information. By interacting with users in key economic sectors of each region, and with extension agencies and policy makers, the forums assess how the outlooks will likely affect the most pertinent socioeconomic sectors in a given region, and how they may be used to mitigate negative impacts.

In the MENA region, there are two relevant RCOFs:

- The *Regional Climate Outlook Forum For Northern Africa* (known by its French acronym: *PRESANORD – Prévisions Climatiques Saisonnières en Afrique du Nord*), which is coordinated by the African Centre of Meteorological Application for Development (ACMAD) in Niamey, Niger. It covers five countries in North Africa, namely Algeria, Egypt, Libya, Morocco, and Tunisia.

[6] For more information, see the PTC website at http://www.wmoescap-ptc.org/index.htm.
[7] See WMO, "Regional Climate Outlook Forums", https://public.wmo.int/en/our-mandate/climate/regional-climate-outlook-products.
[8] The archives of RCOFs consensus statements are available at http://www.wmo.int/pages/prog/wcp/wcasp/clips/outlooks/climate_forecastsV2.html.

- The *Mediterranean Climate Outlook Forum (MedCOF)*, which is coordinated by the Meteorological Service of Spain (known by its Spanish acronym AEMET), covers the entire Mediterranean region, cutting across two WMO Regional Associations (RA I – Africa and RA VI – Europe), promoting inter-regional cooperation and partnership. MedCOF brings together the countries involved in the *North African Climate Outlook Forum (PRESANORD)* and *South East European Climate Outlook Forum (SEECOF)*, and nine other countries in the Mediterranean region, of which three are in the MENA region: Jordan, Lebanon, and Syria.

Black Sea and Middle East Flash Flood Guidance System

The *Black Sea and Middle East Flash Flood Guidance System (BSMEFFGS)*[9] has been developed by the WMO Commission for Hydrology and the WMO Commission for Basic Systems in collaboration with the US National Weather Service, the US Hydrologic Research Center (HRC), and the US Agency for International Development/Office of US Foreign Disaster Assistance. The system provides operational forecasters and disaster management agencies with real-time information on the threat of small-scale flash flooding. It is a robust system for regional/national rainfall and flash flood warnings using remote sensed precipitation (e.g. radar and satellite-based rainfall estimates) and hydrological models. An FFGS has been implemented for the Black Sea and Middle East, where the Turkish State Meteorological Service (TSMS) has been functioning as the FFGS regional center, and provides regional FFG products to ten NMHSs, of which four are MENA countries: Iraq, Jordan, Lebanon and Syria.

Table 2 – Summary of Activities Under Regional Initiatives that Benefit NMHSs in MENA

Regional Initiative	Activities within the context of the regional initiative	Activities that can be strengthened by the NMHSs within the context of the regional initiative
PTC	Tropical cyclone monitoring, forecasting and warning system	Improved tropical cyclone monitoring, forecasting and warning; capacity building
RCOFs	Seasonal outlooks	Improved seasonal forecasting; capacity building
BSMEFFGS	Flash flood guidance	Improved flash flood forecasting; capacity building

[9] See WMO, "Flash Flood Guidance System (FFGS) with Global Coverage", http://www.wmo.int/pages/prog/hwrp/flood/ffgs/index_en.php.

Chapter 3 – The MENA Hydromet Services – Country Profiles

This chapter presents the findings in relation to the capacities of the National Meteorological and Hydrological Services (NMHSs) of:

- *Morocco, Algeria, Tunisia, Libya, and Malta (under Maghreb and Malta);*
- *Lebanon, Jordan, Syria, Iraq, and Iran (under Mashreq);*
- *Saudi Arabia, Kuwait, Bahrain, Qatar, United Arab Emirates, and Oman (under Gulf Cooperation Council Countries);*
- *Egypt, Djibouti, and Yemen; and,*
- *West Bank and Gaza, and Israel (under Other Countries).*

METHODOLOGY

This desk review is based on literature and WMO documents[10] on the state of hydromet capacities in the abovementioned MENA countries, and on web research (primarily the NMHSs' individual websites, the WMO Country-profile Database[11], the World Weather Information Services[12], the Severe Weather Information Service[13], the Météo-France International (MFI) website[14], and the Corobor website[15]) and consultations with WMO staff who have recently visit the targeted MENA countries.

Project portfolios of relevant development partners and donors were also consulted. These include: World Bank Global Facility for Disaster Risk Reduction (WB/GFDRR)[16], United States Agency for International Development (USAid)[17], African Development Bank (ADB)[18], Islamic Development Bank (IsDB)[19], Green Climate Fund (GCF)[20], Global Framework for Climate Services (GFCS)[21], African Ministerial Conference on Meteorology (AMCOMET)[22], Food and Agriculture Organization (FAO)[23], and United Nations Educational, Scientific and Cultural Organization (UNESCO)[24]. However, there are projects which may strengthen hydromet capacities even if not explicitly identified as hydromet initiatives; such projects are sometimes reflected as outputs or activities of larger projects and may not be reflected in the review.

A benchmark survey was prepared to guide the process and establish a common methodology for this preliminary assessment of the NMHSs' capacities. It was noted that there were limited

[10] See WMO, "WMO Technical Progress Report on the Global Data-processing and Forecasting System (GDPFS) and Numerical Weather Prediction (NWP) Research", https://www.wmo.int/pages/prog/www/DPFS/GDPFS-Progress-Reports.html.
[11] See WMO, "Country-profile Database", https://www.wmo.int/cpdb/.
[12] See WMO, "World Weather Information Services", http://worldweather.wmo.int/em/home.html.
[13] See WMO, "World Weather Information Services", http://severe.worldweather.wmo.int/.
[14] See MFI, http://www.mfi.fr/en/.
[15] See Corobor, https://www.corobor.com.
[16] See WB, "Where we work", https://www.gfdrr.org/en/gfdrr-engagements.
[17] See USAid, "Where we work", https://www.usaid.gov/where-we-work.
[18] See ADB, "Projects", https://www.adb.org/projects.
[19] See IsDB, "Projects", https://www.isdb.org/projects.
[20] See GCF, "Projects-programmes", https://www.greenclimate.fund/what-we-do/projects-programmes.
[21] See GFCS, "Projects", http://www.wmo.int/gfcs/projects-list.
[22] See AMCOMET, "Projects", https://www.wmo.int/amcomet/en/pages/projects.
[23] See FAO, "Projects", http://www.fao.org/in-action/fao-projects/en/.
[24] See UNESCO, "Projects", https://en.unesco.org/programme/ipdc/projects.

resources available for the review, and that some of those available were outdated. Nonetheless, the information provided in this report is believed to fairly profile hydromet capacities in the targeted MENA countries. However, additional information, and verification of the existing information, is required through interviews with individual countries.

MAGHREB AND MALTA

Morocco

Socioeconomic context[25]

The GDP growth has been dropping from 4.1% in 2017 to 2.9% in 2019, owing mainly to the decline of agricultural value-added growth. Mining activities contributed the most to growth apart from agriculture and are mostly driven by phosphate production and exports. Fiscal deficit has been constant since 2017, at 3.6% of GDP, and the public debt ratio has been stable at around 65% of GDP. The external position remains stable, despite the recent deterioration of the current account due to the impact of higher prices of imported energy. Consistent with the government's fiscal controls, the current account deficit has fallen considerably since 2012, but the trade deficit has risen, reflecting lack of competitiveness and increasing energy dependence. The unemployment rate slightly decreased to 9.8%, yet it masked a protracted decline in labor force participation.

Over the medium term, economic performance is expected to improve, enabled by sound fiscal and monetary policies, more consistent sector strategies, and an improved investment environment, all of which support gradual competitiveness gains. It is expected that growth will stabilize around an average of 3.6% over the medium term. External public financing requirements are a moderate concern, given the relatively low public external debt and Morocco's investment-grade ratings on international markets. Regarding external imbalances, the current account deficit is expected to stay below 4% of GDP due to growth of exports, tourism receipts, and remittances, which will offset increasing energy import costs.

Climate[26]

Morocco's climate varies according to its geography, ranging from desert to alpine conditions in the highlands. In the interior of the country, temperatures vary from 25-30°C in the summer (July-September) to less than 15°C in the winter (January-March). In the coastal regions temperatures fall between 22-25°C in summer and 10-12°C in winter. The northern parts of Morocco experience a wet season from November to March. Sharqi (chergui) winds (which are hot and dusty), coming from the Sahara, are experienced in the whole country. Key historical climate trends include:

- Mean annual temperature has increased at an average rate of 0.2°C per decade. This trend varies by season, and is only statistically significant in April-June and September-November.
- No sufficient daily rainfall observations are available to determine changes in the extreme indices for daily rainfall.

[25] See further information at http://www.worldbank.org/en/country/morocco
[26] See further information at https://climateknowledgeportal.worldbank.org/country/morocco

Climate projections for Morocco indicate that:

- By 2060, the mean annual temperature will increase by 1.1 to 3.5°C. The projected rate of warming is faster in the interior than in coastal areas.
- Mean annual precipitation decreases by 17% by 2050. Climate models are consistent in projecting seasonal decreases in annual rainfall, with the greatest decrease during June-August (31%) and the smallest during March-May (11%).

Governance, organization, and management

The Directorate of National Meteorology (DNM) is a government agency established in 1961. Since 2011, it has been supervised by the Ministry of Energy, Mines, Water and Environment. The DNM's functions are described in decree N° 2-94-724 of 21 November 1994, as follows:

(a) Support activities related to meteorology and climatology to meet the needs of users nationally, and to exchange data internationally according to agreements ratified by the Kingdom of Morocco;
(b) Conduct theoretical, experimental and applied research on the atmosphere, meteorology, and climatology, and on DNM's mission;
(c) Participate in the preparation of international agreements concerning its areas of competence, and in the development of regulatory materials relating to meteorology; pursue implementation of these agreements.

In 1992, the DNM became an autonomous government department, which allowed it to implement a commercial policy and to develop services in the fields of weather and climate. As part of its remit, the DNM is responsible for observing and forecasting weather, climate, and environmental conditions, thus providing 24/7/365 meteorological and environmental services, and has the legal authority to issue warnings, hence contributing to the preservation of life and property, disaster risk reduction, climate change adaptation, and the socio-economic development of the country. Nowadays, the DNM is a well-recognized agency by its users, and its know-how and competence have positioned DNM has one of the best NMHSs in the region.

The DNM's main source of funding is from government, commercial activities, and cost recovery (e.g. for the provision of meteorological services for aviation). The budget of DNM in 2017 was 115,9 million Moroccan dinar (equivalent to approximately US$12,13 million). In the last 3-5 years, its budget has been stable. It has Quality Management Systems (QMS) implemented for the whole DNM.

The DNM has a development/strategic plan in place, covering the next 3-5 years. Its vision includes: (a) to confirm DNM's presence at national level as an efficient, reliable partner, which meets the needs and expectations of users in terms of meteorological observations, weather forecasting, climatology and meteorological assistance in general; and (b) to be a reference for the Mediterranean basin, especially in the areas of numerical weather prediction and climate change. The development plan focuses on three main areas:

- Strengthen observing, telecommunication and data-processing systems;
- Improve forecasting tools and meteorological assistance for decision-making;

- Modernize management and boost commercial activities focused on users.

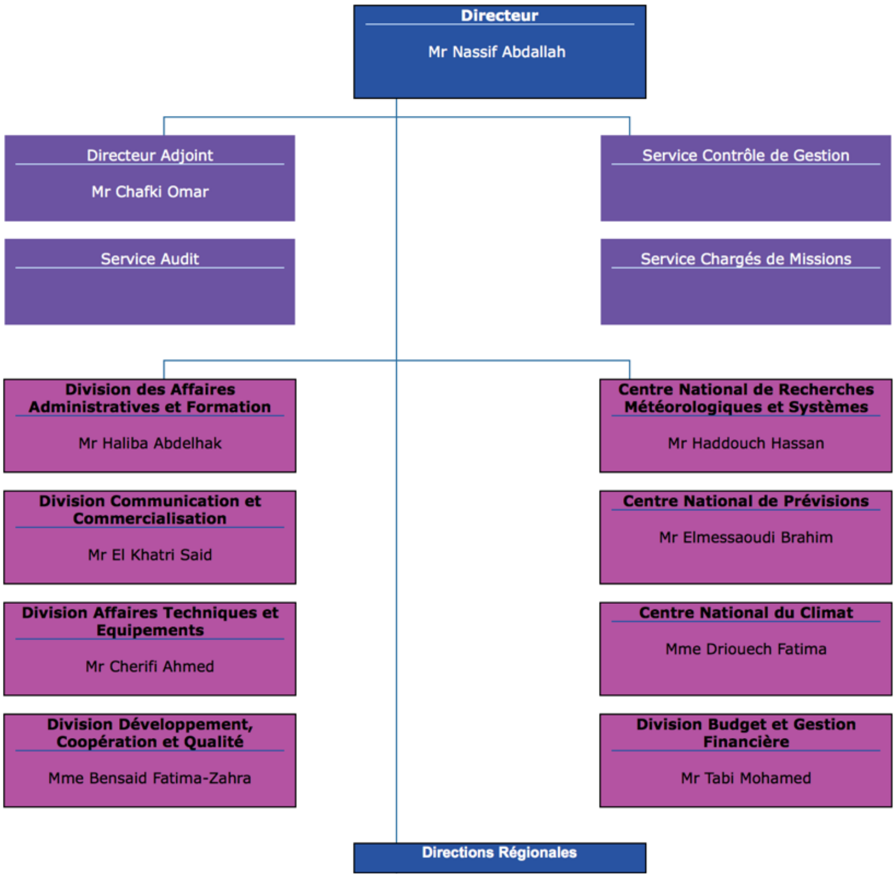
The DNM is headed by a Director and Deputy Director who oversee services related to management, audit, and missions. There are three operational and technical Centres/Divisions; three divisions for administration, human and financial resources, communication and commercialization; and five Regional Departments – Center, South, North, Northeast, and Laayoune – to enable the deployment, development, and provision of services more adapted to the regions (see ***Figure 6***).

The DNM has 762 personnel at headquarters and regional offices, of which 531 are male and 231 are female. The DNM has 15 staff at the management level, 153 meteorologists, 301 meteorological technicians, 23 climatologists, 40 researchers, 63 support staff, and 177 classified as other staff. The number of DNM staff with a university degree is 218. The age of the staff ranges as follows: (a) 20-30 years: 118 staff; (b) 30-40 years: 67 staff; (c) 40-50 years: 274 staff; and (d) over 50 years: 303 staff.

The DNM maintains cooperation with the NMHSs of countries in Africa and Europe, and plays an important role with the World Meteorological Organization (WMO), which it joined in 1956, and with other international bodies in the field of meteorology. This cooperation focuses on scientific and technical collaboration, exchange of expertise, training, and development. Bilateral or multilateral agreements have been concluded with Météo-France[27], the *Aire Limitée, Adaptation dynamique, Développement InterNational* (ALADIN) Consortium[28], the European Centre for Medium-range Weather Forecasts (ECMWF)[29], and the African Centre for Meteorological Application for Development (ACMAD)[30].

Figure 6 – Organization of the Directorate of National Meteorology (DNM)

[27] See Météo-France, http://www.meteofrance.com/accueil.
[28] For more information, see the ALADIN Consortium website at http://www.umr-cnrm.fr/aladin/.
[29] See ECMWF, https://www.ecmwf.int.
[30] See ACMAD, http://www.acmad.net/new/.



Source: Directorate of National Meteorology (DNM), "Organigramme", http://www.marocmeteo.ma.

Major socio-economic user sectors and their needs

The DNM contributes to the economic and social development of the country by meeting the weather, climate, and environmental-related information requirements of various socio-economic sectors. These include: transport (air, sea, and land); agriculture; hydrology; environment; energy; construction, land use and planning; military; and tourism and recreation. The DNM has good visibility, including exposure to the media and rapport with various socio-economic sectors through its provision of meteorological and environmental-related services. The DNM has a press relations office that regularly interacts with the media and reaches out to the general public through information materials, activities, etc.

The DNM has developed a catalog of data, products and information based on specific user requirements (by sectors), and a form for users to request and access data, products, and information. In particular, the DNM provides the following services to:

- Administration and Civil Protection: short- to medium-range forecasts, and information and advisories on severe meteorological phenomena;
- National Defense: joint projects and programs such as Al-Ghait (which aims to increase precipitation in the High Atlas using weather modification techniques; and assistance for locust control;
- Aviation: assistance in certification, weather bulletins, and maps;
- Marine: wave forecasts, tide prediction, meteorological warnings (strong winds > force 8, and dangerous waves > 4m), regular sea state forecasts for coastal zones and high seas;

- Agriculture: daily observations, forecasts for agro-climatic zones, and meteorological warnings (e.g. hail, thunderstorms, heat/cold waves, etc.);
- Water and Energy: short- to medium-range forecasts, warnings in case of landslides, quantitative precipitation estimates, seasonal forecasts, extremes and return period;
- Construction and Transport: short- to medium-range forecasts, and warnings in case of landslides;
- Industry and Trading: specialized bulletins, certificate of weather conditions, focus on dangerous weather, statistics and climate studies;
- Media, Cinema, and General Public: dissemination of meteorological information, and organization of events;
- Tourism: weather forecasts and climate predictions.

In recent years, these users have requested better meteorological products and services in terms of diversity, reliability, availability, and lead time. In this context, DNM has included in its commercial and communications plan, strong actions to augment its revenue, attract new customers, and work on new activities and in new areas. ***Table 3*** describes the requirements of user sectors, and actions required by DNM to address these needs (adapted from WB, 2015).

Table 3 – User Requirements and Services Needed

User Sector	Requirements	What still needs to be done
Aviation	- Meteorological assistance during takeoff and landing (observations and forecasts) - Flight forecasts to optimize routing conditions to avoid turbulence and severe weather phenomena	- Automation of observations at all airports - Provide meteorological assistance at new airports
Construction	- Site specific forecasts to assist daily planning of works - Impact-based forecasts for the land transport network	- Studies on climate change impacts on infrastructures - Climate services for the architectural and engineering design of buildings and for urban planning
Water Resources	- Primarily rainfall observations - Weather forecasts and warnings	- Expand the observing network - Establish a hydrometeorological system

		- Flood forecasting and risk management - Drought monitoring - Studies on impacts of climate change on hydrology in the country - Probabilistic hydrological forecasts
Tourism and Sport	- Studies on the impacts of climate change on tourism - Assist with tourism development strategies - Studies on air quality, to avoid diseases due to pollution	- High resolution forecasts - Climate Atlas - Seasonal forecasts - Meteorological services for mountain regions - Meteorological services for vacations
Transport (land, air and sea)	- Data and studies (weather and climate) specific for each sector - Meteorological services for air, sea, and land transport	- Specialized forecasts for each of these sectors
Industry	- Studies on climate hazards - Forecasts of temperature, humidity, and wind - Decision-making tools - Studies on impacts of climate change on industry - Studies on impacts of gas emissions from industry on air quality	- Climate studies specific to the industrial sector - Location of industries for reduced environmental impact, and climate change mitigation - Improve forecasts of weather parameters relevant to industry
Environment and Health	- Heat/cold wave watch - Air quality and UV monitoring - Studies on climate change impacts on health - Comfort indices	- Advisory system for meteorological phenomena that affect human health - Weather and climate services specific to the health sector - Expand air and sea quality networks

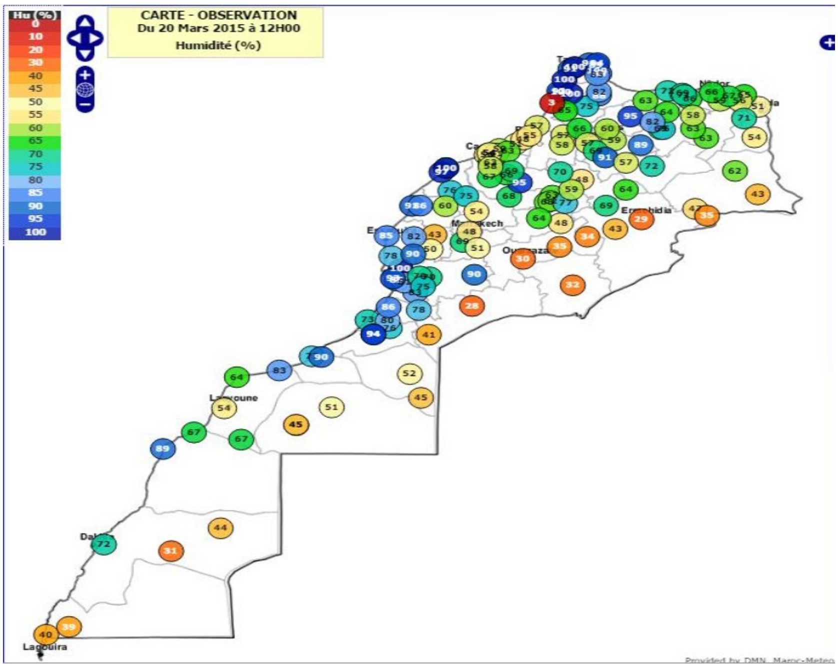
	- Climate Atlas focus on health and environment	- Establish air and sea quality forecast systems - Establish a partnership with health sector
Urban planning	- Vulnerability maps - Impact-based forecasts for risk assessment	- Expand the climate network
Media	- Provision of meteorological information through multiple channels	- Develop and implement a communications strategy

Source: Adapted from WB (2015).

Observing systems (weather, climate, water and environment-related)

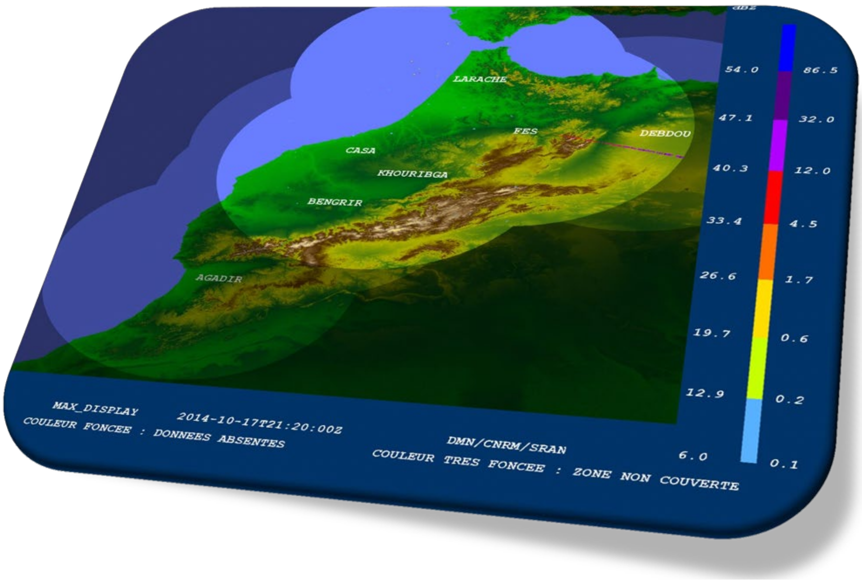
The meteorological, marine, and environmental observation network covers a large part of the territory. The DNM's network consists of 156 automatic weather stations (see ***Figure 7***), 44 regional basic synoptic network (RBSN) surface stations, three agrometeorological stations, five marine stations, three upper-air radiosonde stations, and a network of seven radars (TX Type: Magnetron; Polarization: Single; Band: C) to monitor severe weather events in Morocco. These radars are located in Agadir, Benguerir, Debdou, Fes, Khouribga, Larache, and Nouaceur (see ***Figure 8*** for radar coverage).

Figure 7 – DNM Network of Automatic Weather Stations



Source: Directorate of National Meteorology (DNM).

Figure 8 – DNM Radar Network



Source: Directorate of National Meteorology (DNM).

The DNM also has a network of specific observation stations, including: 29 fixed stations and two mobile stations for measuring air quality; one station to measure ozone (at Casablanca); a lightning detection network located at Larache, Casablanca, Fès, Oujda et Ouarzazate; and two stations to measure atmospheric pollution. Satellite images are received by the DNM through three ground receiving systems and the internet.

The DNM stores measuring equipment and sensors in compliance with international standards and maintains their accuracy with its calibration laboratory, which also serves as the WMO Regional Instrument Centre (see *Annex*).

Information and communications technology (ICT)

A telecommunication system has been established at the DNM to collect local meteorological data and for international data exchange through the WMO Information System (WIS) / Global Telecommunication System (GTS). The DNM hosts a *WMO Global Information System Centre (GISC) in Casablanca*, which acts as a regional coordinator for the real-time operations of the WIS network and provides entry points to WIS through (a) the *GISC Cache Services* function; and (b) the Discovery, Access and Retrieval (DAR) Catalog (see *Annex*). The domestic telecommunication system uses a Virtual Private Network (VPN) combining radio, computer network, and VSAT to collect and disseminate meteorological information and data nationally. The DNM uses Transmet as an automatic message switching system cluster (supported by MFI), required to manage the data process through scripts to pull/push the data.

Data-processing and forecasting systems

The DNM has an IBM high performance computer (HPC) with 8,3 Tflops. A new HPC is expected to be installed in 2018. The DNM has been an associated member of the European Centre for Medium-range Weather Forecasts (ECMWF) since 2008, and has access to the full set of ECMWF global deterministic and probabilistic products. Through bilateral cooperation with Météo-France, the DNM has access to the full range of products from the global Arpège model. The DMH also has access to outputs from the UK Met Office Unified Model. The DNM does not currently make full use of the ensemble prediction system (EPS) products to which it has access; however, it has plans for further utilization.

With current HPC capacity, the DNM is able to run high resolution regional models for short- to medium-range forecasts (namely ALADIN/NORAF[31] and ALBACHIR[32]), and climate prediction and marine circulation models. The DNM carries out research on environmental prediction using statistical and dynamic air quality models.

The DNM makes use of Synergie, supported by MFI, as a Forecaster Workstation and decision-making tool for forecasting and warning.

Public weather services

The DNM provides nowcasting (0-12 hours ahead); short-range forecasts (12 hours to two days); and medium-range forecasts (three to five days). Weather forecasts are produced for decision makers and the public, and specialized products for the aviation, marine, and other sectors. These forecasts and warnings are disseminated through radio, website, and social media.

Climate services

Data have been gathered for nearly a century, and all data have been digitized, archived, and processed using the Clisys Data Management System supported by MFI. The DNM has automatic data reception and near-real-time archiving.

The DNM prepares and issues climate information and statistics, and makes them easily available to users. The DNM participates in the *Regional Climate Outlook Forum For Northern Africa* (known by its French acronym: *PRESANORD*) and in the *Mediterranean Climate Outlook Forum (MedCOF)* (see *Annex*). It uses the regional outlooks, and statistical and dynamic downscaling of the products from the WMO Global Producing Centres for Long-range Forecasts (GPC-LRF), and to issue monthly and seasonal forecasts over Morocco from one to four months. The DNM participates in regional and national research studies related to climate change projects.

As indicated in the *Annex*, the DNM provides overall coordination of the North Africa RCC-Network and is responsible for the Casablanca Node on Long-Range Forecasting.

[31] See DNM, "Noraf", http://www.marocmeteo.ma/aladinoraf.
[32] See DNM, "Albachir", http://www.marocmeteo.ma/albachir.

Agricultural meteorological services

The DNM provides agrometeorological information and forecasts to users, which include: (a) the meteorological bulletin for agriculture; (b) data of recent observations and surveys (<48 hours); (c) decadal bulletin; (d) decadal precipitation report; (e) monthly bulletin; (f) cumulative studies; (g) bulletin with forecasts by agro-climatic zone.

There is no information on the existence or use of crop models by the DNM, or blending in-situ and remote-sensing data to produce products and information for the agricultural community.

Aeronautical meteorological services

The DNM is the designated aeronautical meteorological service provider in Morocco. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The DNM receives OPMET and WAFS products operationally. The DNM uses the AeroWeb, supported by MFI, as a pilot briefing system.

The DNM practices cost-recovery for aeronautical meteorological services. It has a quality management system meeting international standards, and its aeronautical meteorological personnel meet competency, and education and training requirements. The DNM's aeronautical meteorological services, and other services, are ISO certified, and certification is kept up-to-date.

Marine meteorological and/or oceanographic services

Daily marine meteorological forecasts and warnings for high seas and coastal areas are broadcast via national and local radio, television programs, and also via special channels for fishermen and ships.

Hydrological forecasts and assessments

Hydrological monitoring and forecasting services in Morocco are dispersed across multiple departments, including the General Directorate of Hydraulics and the Agency of Hydraulics Basins under the Secretary of State to the Minister of Equipment, Transport, Logistics and Water. The AHB maintains and monitors hydrological stations along Morocco's rivers; while the GDH is responsible for flood forecasting. The DNM collaborates with these institutions to monitor annual averages and extreme rainfall inflow on watersheds.

Morocco's hydrological network plays an important role in managing the country's water resources, particularly in situations of drought and heavy rainfall. To meet the needs of water user sectors, the hydrological network was designed to obtain data on the spatial and temporal variability of various hydrometric parameters (water level and water flow rates) and climate parameters (rainfall, temperature, evaporation, wind speed and direction, humidity, insolation). The current network includes 265 hydrometric stations and 380 rainfall stations.

Other related aspects, partnerships, and investments

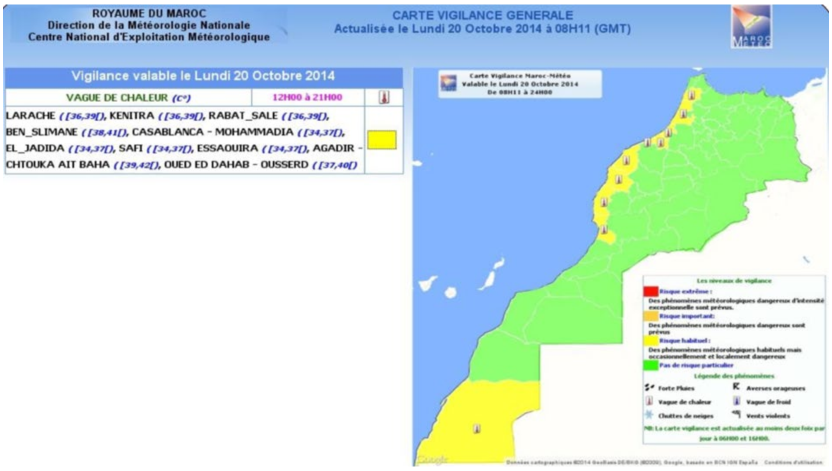
Currently, the DNM does not contribute operational weather forecasts and climate information for the capital city to the WMO's World Weather Information Service.

In 2015, the DNM considered embarking on an ambitious modernization program (WB, 2015) based on an institutional and budgetary analysis to evaluate the conditions under which this program could have the best chance of success. More specifically, this study has addressed: (a) constraints related to the status of government departments with autonomous management; (b) an assessment of current activities in different sectors and in which the quality of services could be improved through the new status; (c) an analysis of the sustainability of the estimated budget and loan; and (d) an assessment of the consequences of the change of status on staff.

Early Warning Systems

The DNM has a robust observing system to monitor hazardous weather events. Severe weather forecasts and warnings are issued. With the support of Météo-France (which has developed an early warning system with a multi-hazard approach), the DNM implemented the *Vigilance*[33] system in collaboration with the Civil Protection Authority. This system consists of color-coded warnings based on impacts (see ***Figure 9*** for weather-related hazards; and ***Figure 10*** for marine-related hazards). The *Vigilance* maps are disseminated to the various responsible bodies for action.

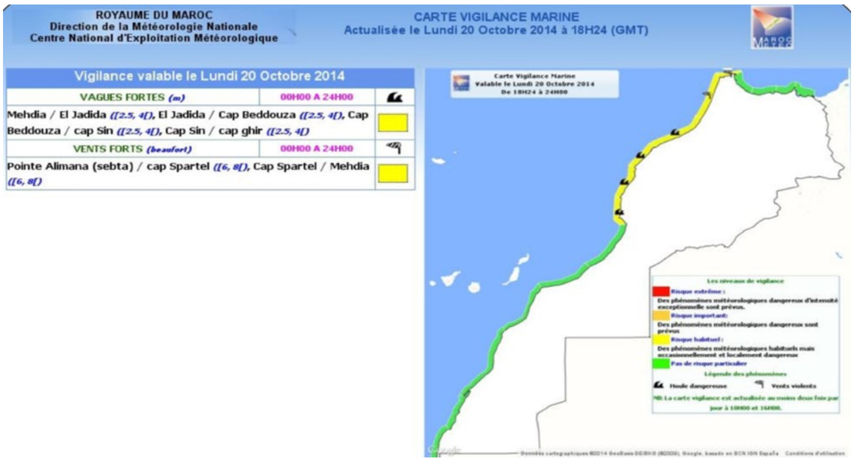
Figure 9 – *Vigilance* System



Source: Directorate of National Meteorology (DNM).

Figure 10 – *Marine Vigilance* System

[33] «Vigilance» is a French word meaning both awareness and carefulness or caution; it could be translated as watchfulness, depending on the case; also by vigilance.



Source: Directorate of National Meteorology (DNM).

Summary of DNM status and challenges

The DNM is a government service with a commercial arm which supports its maintenance, operations, and further development. It has a well-organized structure, with a significant number of experienced staff. It maintains strong collaborations with NMHSs in Africa and Europe, and cooperation agreements mainly in the area of numerical weather prediction. The DNM operates 24/7/365. The observing network covers a large part of the country. It has robust information and communication technologies. The DNM has strong numerical weather prediction capacities, however, it needs to strengthen the use of ensemble prediction systems and probabilistic forecasts. The DNM takes a leading role in seasonal forecasting for the North Africa region. It provides conventional agrometeorological monitoring and forecast products, however more advanced crop modeling is still required. The DNM is a designated aeronautical meteorological service provider in Morocco, and has the authority to issue warnings in the country. It has well-established marine forecasting capabilities, and early warning systems. Major challenges include: a significant number of staff close to retirement age, and limited coordination and collaboration with the departments responsible for hydrology.

Algeria

Socioeconomic context[34]

Ranked as the third most important economy in the MENA region and a leader in the Maghreb, Algeria is one of the few countries to have achieved 20% poverty reduction in the last two decades. The Algerian government took significant steps to improve the wellbeing of its people by implementing social policies in line with the *United Nations Sustainable Development Goals*. Among other major achievements, the country's oil boom has enabled the authorities to clear Algeria's debt, invest in infrastructure projects, and improve the country's Human Development Indicators.

Algeria's economic growth decelerated in 2017 due to a slight decline in hydrocarbon production and continued modest non-hydrocarbon growth. Real GDP growth has been declining due to a slowdown in hydrocarbon production. Meanwhile, growth in the non-hydrocarbon sector remains modest. Following difficulties in pursuing budget targets, public spending decreased by less than expected. Despite the decline in the current account deficit, its overall level of country trade remained high, given the modest growth of the economy.

[34] See further information at http://www.worldbank.org/en/country/algeria.

Imports increased slightly, by 2.7% in 2017 while exports increased significantly, by 16.5%. Overall, the current account balance (-14.7% of GDP) is indicative of the lack of adjustment of imports to the large reduction in export revenues since 2014. With the current level of oil prices and the high external account deficit, further efforts are required to increase the domestic supply of goods to maintain medium-term sustainability of the current account and reduce the depletion of gross official reserves.

The unemployment rate increased by almost 1.5 percentage points, reflecting sluggish non-hydrocarbon growth. Unemployment is particularly high among the educated, the youth, and women. This is considered to partially reflect a preference to wait for formal sector employment. The rise in unemployment undermines poverty reduction. 10% of the population is considered vulnerable to falling into poverty, and important regional disparities persist.

Climate[35]

Algeria experiences two distinct climates: a Mediterranean climate in northern part of the country and a desert climate in the remaining parts. The sub-humid Mediterranean climate on the coast and in the Tell Atlas Mountains is characterized by wet and mild winters and hot and dry summers. The rest of the country is covered by the Sahara Desert, in which seasonal average winter temperatures are between 15°C and 28°C, and 40°C to 45°C in summer. In the north, moist winds from the sea bring rain from autumn to spring. Algeria's climate is also influenced by the Sirocco winds, which raise temperatures with dusty and dry conditions, and storms in the Mediterranean Sea. Key historical climate trends include:

- Annual mean temperatures have risen across Algeria since the 1960's. Inter-annual and decadal data show a warming of about 2.7°C per century since the 1900's.
- Variability in rainfall is high. Seasonal averages and linear trends indicate a reduction of 12.4 mm/month per century since the 1960's.

Climate projections for Algeria indicate that:

- By 2050, mean temperatures are expected to increase by 2.6°C, with more frequent heat waves and fewer frost days.
- While future rainfall projections differ, some models project a 6% increase by 2050, but with a 5% reduction in country-wide average values. The greatest reductions are projected for March-May by 16% and the greatest increases projected during September-November by 22%. Daily rainfall intensity is projected to increase by 7%. Algeria will become wetter by the end of the century. The maximum amount of rain that falls in any 5-day period is projected to increase.

Governance, organization, and management

The National Meteorological Office (NMO) is a government agency with commercial services, supervised by the Ministry of Public Works and Transport. The NMO's functions are described in decree N° 98/258, which describes its public mission and commercial services. The NMO's main mission is "to carry out national and international policy in the field of security of goods

[35] See further information at https://climateknowledgeportal.worldbank.org/country/algeria.

and people, through the continuous weather watch, the weather forecast, the processing and the archive of the data constituting the national memory in meteorology". The NMO has been a member of the World Meteorological Organization (WMO) since 1963.

The NMO is a government institution with autonomous management, a commercial policy, and multiple products and services in the fields of weather and climate. The NMO is responsible for observing and forecasting weather, climate, and environmental conditions, and providing 24/7/365 meteorological and environmental services, and has the legal authority to issue warnings, hence contributing to the preservation of life and property, disaster risk reduction, climate change adaptation, and to the socio-economic development of the country. The NMO is the meteorological authority (as per ICAO Annex 3) and also the met service provider for aviation.

The NMO's main source of funding is from cost recovery for the provisions of meteorological services for aviation (78%), commercial services (12%), and government (10%). The total budget of NMO in 2018 was 1,6 billion Algerian dinar (equivalent to approximately US$13,56 million). In the last 3-5 years its budget has been steadily decreasing. It has Quality Management Systems (QMS) for meteorological services for national and international aviation, including 31 certified meteorological stations, and plans to gradually expand its provision of services.

The NMO has a development/strategic plan in place, covering the next 3-5 years. Its strategic pillars include: (a) measuring the satisfaction of interested parties and allowing feedback to inform improvements; (b) the provision of reliable weather information within the time required for the automation and optimization of the observational network; (c) continuous improvement of weather forecasts and early warning systems by automating the production chain; (d) maintenance and modernization of monitoring equipment, and information and telecommunication systems; and (e) training and continuous improvement and qualification of staff to ensure the quality of the services provided in accordance with standards and its commitments.

The NMO has a total of 1001 personnel at headquarters and regional offices, of which 876 are male and 125 are female. The NMO has 16 staff at the management level, 152 meteorologists, 454 meteorological technicians, 15 climatologists, 3 researchers, and 458 support staff. The number of NMO staff with a university degree is 720. The age of the staff ranges as follows: (a) 20-30 years: 191 staff; (b) 30-40 years: 210 staff; (c) 40-50 years: 350 staff; and (d) over 50 years: 250 staff. 22 staff will retire in the next 5 years.

Major socio-economic user sectors and their needs

The NMO contributes to the economic and social development of the country by providing weather, climate, and environmental information to various socio-economic sectors. These include: transport (air, sea, and land); agriculture; hydrology; environment; energy; construction, land use and planning; health, tourism, insurance, and education.

The NMO has developed a catalog of data, products and information for its customers. In particular, the NMO provides the following:

- 1-3 day, and 5 day national and regional weather forecasts;

- Warnings;
- A marine meteorological bulletin;
- An agrometeorological bulletin;
- Climate data;
- Climatological normal.

The NMO also issues weather certificates based on user requests that can be used for insurance purposes.

Observing systems (weather, climate, water and environment-related)

The meteorological observation network covers mainly the northern part of the country, near the coast. The NMO's network consists of 43 regional basic synoptic network (RBSN) surface stations, and 67 climate stations. There are no radars. The NMO also has 1 station to measure ozone (at Tamanrasset), which acts as the WMO Regional Radiation Centre (RRC). The NMO uses MESSIR-SAT, supported by Corobor, to access Meteosat satellite imagery.

The NMO keeps measuring equipment and sensors in working conditions compliant with international standards and maintains the accuracy of these instruments with its own calibration laboratory. It hosts the WMO Regional Instrument Centre (RIC) to support regional calibration activities.

Information and communications technology (ICT)

A telecommunication system has been established at the NMO to collect local meteorological data and for international data exchange through the WMO Global Telecommunication System (GTS). The domestic telecommunication system uses a Virtual Private Network (VPN) combining radio, computer network, and VSAT to collect and disseminate meteorological information and data nationally. The NMO uses MESSIR-COMM as an automatic message switching system cluster (supported by Corobor) to manage the data through scripts to pull/push the data in TCP/IP and ftp modes.

Data-processing and forecasting systems

The NMO has an IBM high performance computer (HPC) with 10 Tflops, 26 nodes with 16 processors each. Through bilateral cooperation with Météo-France, the NMO has access to the full range of products from the global Arpège model. At this stage, the NMO does not make full use of the ensemble prediction system (EPS) products to which it has access, and only uses some EPS fields, EPSgrams and the Extreme Forecast Index (EFI) from ECMWF, obtained via the internet. It also uses other model outputs available on the Internet, such as GFS, UKMO, and Eta/Greece.

With its current HPC capacity, the NMO is able to run high resolution regional models for short- to medium-range forecasts, namely ALADIN-Algeria, ALADIN-DUST, and AROME-Algeria, as LAMs with horizontal resolutions of 8 km, 14 km, and 3 km, respectively, up to 72h ahead for ALADIN and 48h for AROME, all with data assimilation. The NMO also runs ALADIN_DUST, which is a version of ALADIN used to simulate the atmospheric dust cycle. For wave forecasting, the NMO runs WAVEWATCH-III up to 72h ahead, forced by ALADIN winds.

For the seasonal forecast, NMO uses the output products of the Climate Forecast System (from NCEP) with 40 km of horizontal resolution. A new system of seasonal forecasts based on ALADIN-CLIMAT is being tested prior to implementation. ALADIN-CLIMAT runs on an Algeria-HPC supercomputer with 12.5 km horizontal resolution and 91 levels. This model is forced by ARPEGE-CLIMAT.

The NMO makes use of MESSIR-VISION and MESSIR-NET, supported by Corobor, as a Forecaster Workstation and decision-making tool for forecasting and warning. The NMO has over 30 workstations dedicated to the forecasters.

Public weather services

The NMO provides nowcasting (0-12 hours ahead); short-range forecasts (12 hours to 2 days); and medium-range forecasts (3 to 5 days). Weather forecasts are produced for decision makers and the public. The NMO issues site-specific forecasts for 48 cities. It also provides specialized products to aviation, marine, and other sectors. These forecasts and warnings are disseminated through the radio, website, mobile APP, and social media.

Climate services

There is no information available on the Data Management System at NMO. More than 75% of its data has been digitized, archived, stored, and processed.

The NMO prepares and issues climate information and statistics to specific users, and a climate bulletin for the public, on its website. The NMO participates in the *Regional Climate Outlook Forum For Northern Africa* (known by its French acronym: *PRESANORD*) and in the *Mediterranean Climate Outlook Forum (MedCOF)* (see *Annex*). It uses regional outlooks, and statistical and dynamic downscaling of products from the WMO Global Producing Centres for Long-range Forecasts (GPC-LRF), to issue monthly and seasonal forecasts over Algeria. The NMO participates in regional and national research studies related to climate and dust.

As indicated in the *Annex*, the NMO provides climate monitoring products under the framework of the North Africa RCC-Network and is responsible for the Algiers Node on Data Services.

Agricultural meteorological services

The NMO provides agrometeorological information and forecasts to users, which include: (a) the meteorological bulletin for agriculture; (b) decadal bulletin; (c) decadal precipitation report; and (d) monthly bulletin.

There is no information on the existence or use of crop models by the NMO, or on blending in-situ and remote-sensing data to produce products and information for the agricultural community.

Aeronautical meteorological services

The NMO is the designated aeronautical meteorological service provider in Algeria. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The NMO receives OPMET and WAFS products operationally via SADIS, and uses the MESSIR-AERO, supported by Corobor, as a pilot briefing system.

The NMO practices cost-recovery for aeronautical meteorological services. It has a quality management system meeting international standards, and its aeronautical meteorological personnel meet competency, and education and training requirements. The NMO's aeronautical meteorological services, and other services have current ISO certification.

Marine meteorological and/or oceanographic services

Daily marine meteorological forecasts and warnings for high seas in the Mediterranean Sea and coastal areas are broadcasted via national and local radio, television programs, and also via special channels for fishermen and ships.

As indicated above, the NMO runs a wave model, namely WAVEWATCH-III.

Hydrological forecasts and assessments

Algeria is pursuing a strategy based on the rational use of water resources, while meeting the population's needs for drinking water and those relating to the country's economic development.

Rainfall data and database for monthly discharges are available at the National Agency of Hydraulic Resources (ANRH). Rainfall data are recorded from 23 NMO rainfall stations distributed over the country's watersheds; time series for discharge data are generally from 1975.

Other related aspects, partnerships, and investments

Currently, the NMO contributes operational weather forecasts and climate information for 12 cities to the WMO's World Weather Information Service.

The NMO hosts a WMO Regional Training Centre (RTC), which provides Basic Instruction Packages (BIPs) for Meteorologists and Meteorological Technicians.

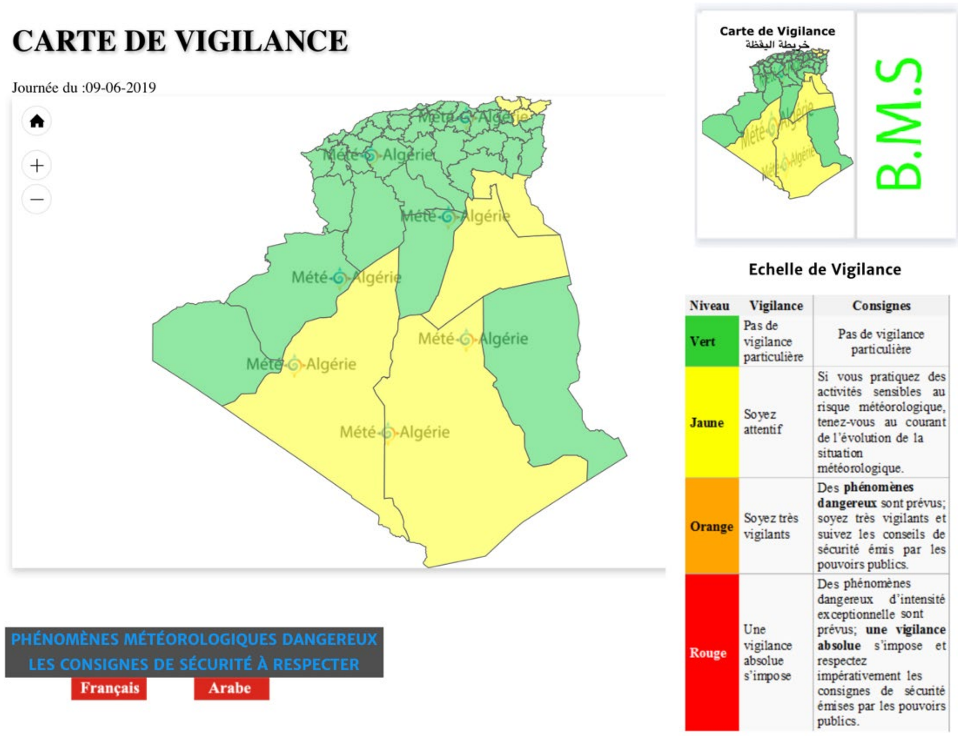
Early Warning Systems

The NMO doesn't have a robust observing system to monitor hazardous weather events, but severe weather forecasts and warnings are issued. The NMO implemented the *Vigilance* system in collaboration with the Civil Protection Authority. This system consists of color-coded warnings based on impacts (see ***Figure 11***). The *Vigilance* maps are disseminated to responsible bodies for action, and made available on NMO's website.

Summary of NMO status and challenges

The NMO is a government service with a commercial arm. Cost recovery from aviation services greatly supports NMO's maintenance and operations (78% of its overall budget), and further development. It has a significant number of experienced staff. It maintains strong collaborations with NMHSs in Africa as part of the RCC-Network and with Europe (Météo-France), and has cooperation agreements mainly in the area of numerical weather prediction. The NMO operates 24/7/365. The observing network covers mainly the northern part of the country. It has no radars. The NMO has satisfactory information and communication technologies. While the NMO has good numerical weather prediction capacities, it needs to strengthen the use of ensemble prediction systems and probabilistic forecasts. The NMO takes a leading role in climate monitoring for the North Africa region. It provides conventional agrometeorological monitoring and forecast products, but more advanced crop modeling is required. The NMO is a designated aeronautical meteorological service provider in Algeria with the authority to issue warnings. It has well-established marine forecasting capabilities, and early warning systems. Major challenges include: a limited observing network to monitor hazardous weather conditions, and limited coordination and collaboration with the departments responsible for hydrology.

Figure 11 – *Vigilance* System *at NMO*



Niveau	Vigilance	Consignes
Vert	Pas de vigilance particulière	Pas de vigilance particulière
Jaune	Soyez attentif	Si vous pratiquez des activités sensibles au risque météorologique, tenez-vous au courant de l'évolution de la situation météorologique.
Orange	Soyez très vigilants	Des **phénomènes dangereux** sont prévus; soyez très vigilants et suivez les conseils de sécurité émis par les pouvoirs publics.
Rouge	Une vigilance absolue s'impose	Des phénomènes dangereux d'intensité exceptionnelle sont prévus; **une vigilance absolue** s'impose et respectez impérativement les consignes de sécurité émises par les pouvoirs publics.

Source: NMO website.

Tunisia

Socioeconomic context[36]

Important progress has been made on the political transition of Tunisia to an open and democratic system of governance; however, economic transition has not kept pace. Internal constraints related to the difficulties in reaching consensus on key economic reforms, associated with external conflicts in neighboring Libya and the continued threat of instability, have slowed economic recovery. After recovering modestly to 2% in 2017, growth accelerated to 2.5% in Q1 of 2018 and 2.8% in Q2 (y-o-y), supported by agriculture, tourism, and export-oriented manufacturing, particularly electrical and mechanical industries.

According to official figures, the 2015 poverty rate in the country was 15.2%, significantly lower than the rate of 20.5% in 2010. However, these figures do not describe the country at large, and are more evident in the northern regions, which have larger populations and more industrial development. This may be due in part to the climate characteristics of the country.

[36] See further information at http://www.worldbank.org/en/country/tunisia.

At the same time, the country is experiencing rapid urbanization, which increases the exposure of people and economic assets to disasters.

Climate[37]

Tunisia's diverse geography influences its climate, which can be divided into three regions. The northern mountainous region has a Mediterranean climate with mild, rainy winters and hot, dry summers. The south has a hot, dry, and semiarid climate as it enters the Sahara Desert, while the eastern coastal area has an arid steppe climate. Rainfall also varies by region, with average annual rainfall at 158 mm per year for the whole country, but less than 100 mm annually in the south and over 700 mm annually in the north. Historically, average temperatures likewise vary seasonally and regionally; in the northern coastal region, temperature ranges from a low of 10°C in winter (December-February) to a high of 27°C in summer (June-August), while in the central western and southern regions temperature ranges from a winter low of 11°C to a summer high of 32°C. In the southern semiarid to arid areas, droughts may be frequent, while the coastal region experiences floods. Key historical climate trends include:

- Mean average temperature rose by 1.4°C in the twentieth century; with an average of 0.4°C per decade over the last 30 years.
- While on average no significant change in annual precipitation was observed from 1901 to 2013, over the past 30 years, average annual precipitation has decreased by about 3%.

Climate projections for Tunisia indicate that:

- Annual maximum temperature is likely to increase by 1.5°C to 2.5°C by 2030 and 1.9°C to 3.8°C by 2050. Annual minimum temperature is likely to rise from 0.9°C to 1.5°C by 2030 and from 1.2°C to 2.3°C by 2050. The number of hot days is projected to increase by about 1.3 days per year between 2020 and 2039. The duration of heatwaves is likely to increase by 4 to 9 days by 2030 and by 6 to 18 days by 2050. The duration of cold spells is likely to decrease by 1 to 3 days by 2030 and by 2 to 4 days by 2050.
- All models project a likely decrease in overall precipitation by 2050, with most projecting a minimum decrease of around 4% and maximum decrease varying from 7% to as much as 22%. The duration of dry spells is likely to increase by 1 to 21 days by 2030 and by 1 to 30 days by 2050. The decrease in precipitation is accompanied by an anticipated increase in the frequency and intensity of droughts and floods.

Governance, organization, and management

The National Institute of Meteorology (NIM) is a government agency established in 1974, but meteorological observations began in 1873. The NIM is currently supervised by the Ministry of Transport. The NIM's mission is described in decree No. 2009-10 of 16 February 2009, as follows:

[37] See further information at https://climateknowledgeportal.worldbank.org/country/tunisia.

(a) Satisfying user needs for meteorological, geophysical and climate information in various economic sectors, including meteorological services to aviation, maritime navigation, agriculture, and tourism;
(b) The design of programs and policies to develop meteorology, geophysics, and climatology following technological and scientific progress;
(c) Contribute to sustainable development by participating in programs in environmental protection, nature conservation and quality of life;
(d) Technical coordination of meteorological and geophysical programs;
(e) Management and maintenance of meteorological and geophysical data.

In 2010, the NIM became an autonomous government department. Decree N° 2010-213 of 9 February 2010 defined the administrative and financial organization, and operating procedures of the NIM; and decree N° 2011-89 of 11 January 2011 fixed the fees for the services it provides. Since then, the NIM has adopted a commercial policy, and offers multiple products and services to customers and partners in the fields of weather, climate, and seismology. The NIM is responsible for two major fields:

(i) Meteorology, which is the backbone of NIM's activity and accounts for many of its facilities. It covers activities related to:
    a. Observation, storage, exchange and processing of meteorological data;
    b. Weather forecasting;
    c. Climatology and applied meteorology.
(ii) Geophysics and astronomy, which have been added to NIM's activities for national purposes. It covers activities related to:
    a. Measurement and observation of seismic activity and applied geophysical studies;
    b. Observation of the lunar crescent and preparation of the lunar calendar for religious purposes;
    c. Setting lunar and solar eclipse dates and drawing up ephemeris;
    d. Measurement and processing of different types of solar radiation.

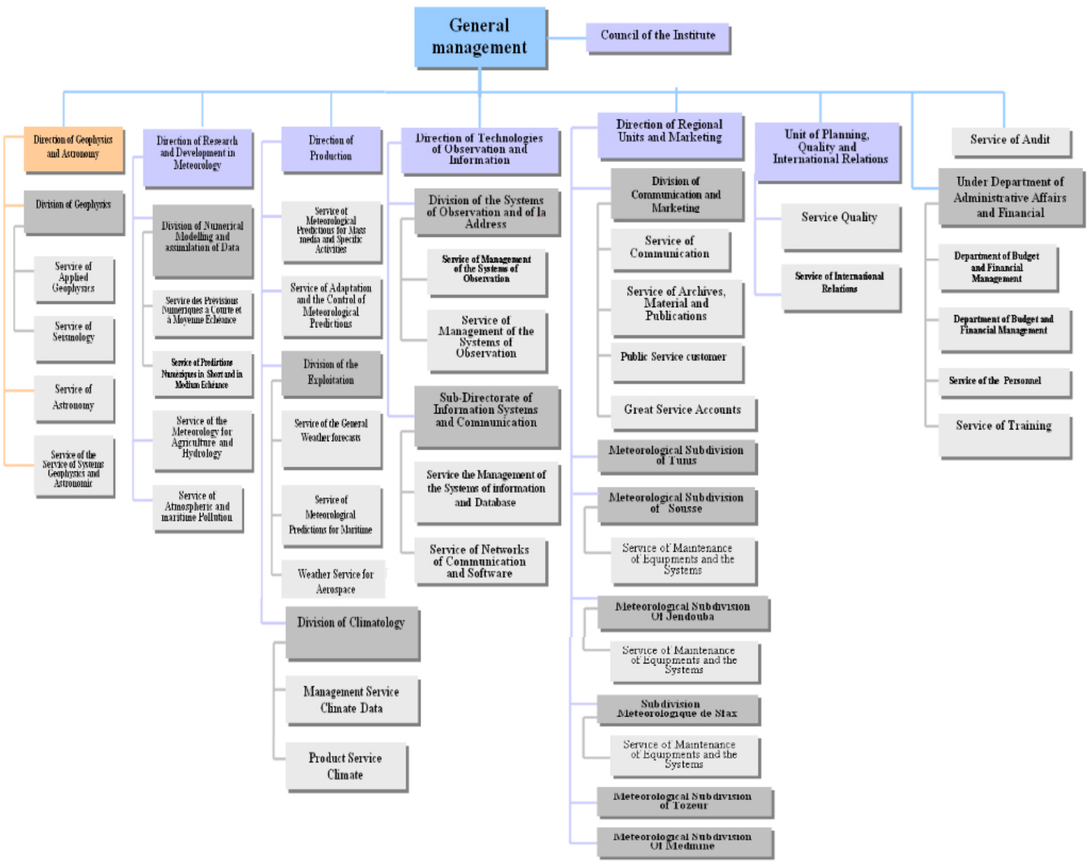
The NIM's main source of funding is from government, commercial activities, and cost recovery (e.g. for meteorological services to aviation). The total budget of NIM in 2017 was 10,9 million Tunisian dinar (equivalent to approximately US$4 million), of which 78% comes from a non-government budget (fee-based services). Over the last 3-5 years its budget has been stable. It has Quality Management Systems (QMS) for the aviation branch.

The NIM has a development/strategic plan covering the next 3-5 years. This strategy has enabled NIM to better fulfil its mission to provide meteorological, climate, and seismological information that is relevant and reliable at local and regional spatial and temporal scales.

The NIM is headed by a General Manager supported by a Council. There are 4 operational and technical departments; 3 departments for administration, human and financial resources, planning, international relations, communications and marketing; and 6 regional sub-divisions – Tunis, Jendouba, Sousse, Sfax, Tozeur, and Medenine – to: (a) implement the directives of central administration; (b) provide meteorological assistance to air and marine navigation; (c) take part in studies of meteorological factors and their impacts on regional economic development; and (d) manage the activities of meteorological stations of the branch (see ***Figure 12***).

The NIM has a total of 346 personnel at headquarters and regional offices, of which 270 are male and 76 are female. The NIM has 27 males and 10 females at the management level, 30 meteorologists (20 males and 10 females), 140 meteorological technicians (120 males and 20 females), 15 climatologists (7 males and 8 females), 13 researchers (9 males and 4 females), 53 support staff (39 males and 14 females), and 52 classified as other staff (45 males and 7 females). The number of NIM staff with a university degree is 154 (97 males and 57 females). The age of the staff ranges as follows: (a) 20-30 years: 30 staff; (b) 30-40 years: 134 staff; (c) 40-50 years: 83 staff; and (d) over 50 years: 93 staff. In the next 5 years, it is expected that 66 staff will retire. Staff numbers have steadily decreased over the last 3-5 years. Capacity building requirements have been identified in the areas of: (1) observations and instrumentation; (2) numerical weather prediction; (3) early warning systems; (4) climate change prediction and adaptation; and (5) institutional and project management.

Figure 12 – Organizational Chart of the National Institute of Meteorology (NIM)



Source: National Institute of Meteorology (NIM), "Central organization", http://www.meteo.tn/htmlen/presentation/organisation.html.

Within the framework of the twinning projects supported by the European Commission, an institutional program to strengthen the technical capacities of NIM was established in 2015 through a twinning contract between Tunisia and France. This program focuses on technical collaboration in the fields of observations, information systems and production; training; and development of commercial services for aviation. Tunisia has been a member of the World Meteorological Organization (WMO) since 1957.

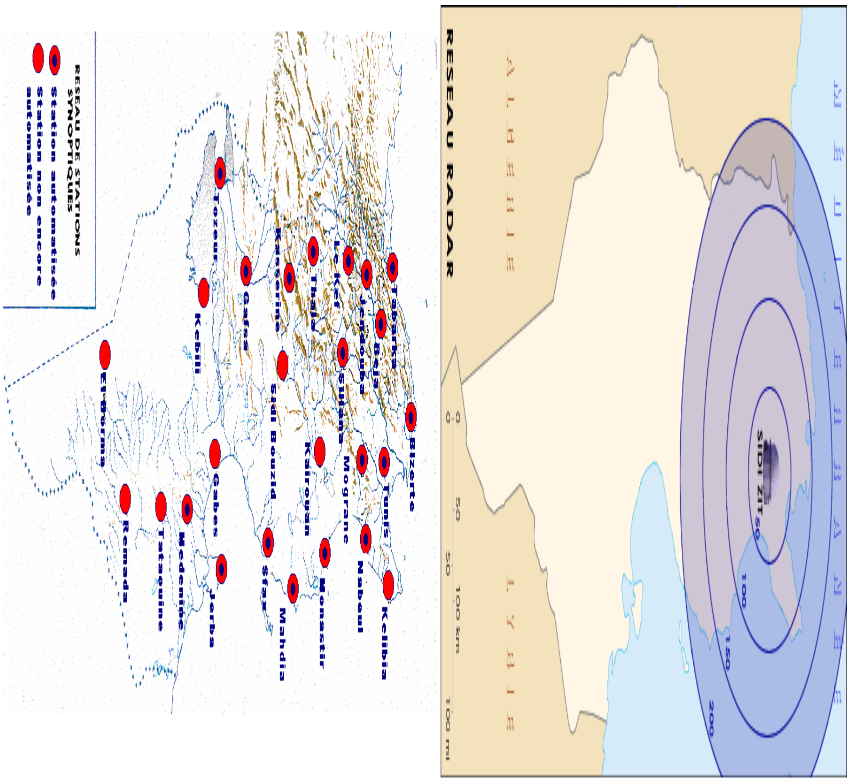
Major socio-economic user sectors and their needs

The NIM contributes to the economic and social development of the country by meeting the weather, climate, and geophysics-related information requirements of the various socio-economic sectors. These include: transport (air, sea, and land); agriculture; hydrology; environment; energy; industry, health; sports; tourism and recreation; and the media. In its awareness of the importance of meteorological information for socio-economic development, the NIM is constantly working to (a) meet the demands of its customers and provide them with timely meteorological information; and (b) to enhance the quality of its products and services. For this purpose, NIM has set up a user service unit to provide quality information promptly through telephone and email.

Observing systems (weather, climate, water and environment-related)

The NIM's network consists of 27 synoptic stations, mostly outdated and non-fully functioning (of which 10 are located at airports; 18 are automatic weather stations and the remaining are manual stations, which only operate for 6-12 hours per day due to limited human resources), 31 agrometeorological stations, 58 climate, 208 rainfall gauges; 7 marine stations, 1 station to measure atmospheric pollution, and 1 radar (TX Type: Magnetron; Polarization: Single; Band: C – apparently non-functioning) to monitor severe weather in Tunisia. This network provides limited coverage of the country (see ***Figure 13***). Procuring a radar system is included in the government's five-year plan (around 30 million Dinars). The NIM has identified 5 potential sites and contacted potential suppliers.

Figure 13 – NIM Synoptic Network and Radar



Source: National Institute of Meteorology (NIM).

The NIM makes use of MESSIR-SAT (supported by Corobor) to obtain satellite images from Eumetsat.

Information and communications technology (ICT)

A communication system dedicated to meteorological data handles data exchange. Observation data obtained from national stations are dispatched to internal and external users while data obtained from external sources are dispatched to local users. The national telecommunication system uses a Virtual Private Network (VPN) combining radio, computer network, and VSAT to collect and disseminate meteorological information and data nationally. The NIM uses MESSIR-COMM as an automatic message switching system (supported by Corobor) to manage the data process through scripts to pull/push the data from/to the WMO Global Telecommunication System (GTS).

Data-processing and forecasting systems

The NIM has been a member of the ALADIN Consortium since 2001. An initial pre-operational version of the Tunisia-adapted ALADIN Model was installed on Météo-France computers in Toulouse in September 2001, and an extract by domain has been sent daily to Tunis via the Internet. An objective model output verification process has been established at NIM to help its forecasters understand the model's strengths and weaknesses over Tunisia. In 2002, the NIM purchased a high performance computer (HPC; which is currently outdated) to locally run the ALADIN-Tunisia. With its current computer capacity, the NIM is able to run the model at 7.5km horizontal resolution and 70 vertical levels. Experiments have been conducted with the assistance of Météo-France to run the AROME model at 2.5km horizontal resolution and 60 vertical levels. The NIM has procured a new HPC in April 2019.

The NIM makes use of *Synergie*, supported by MFI, as a Forecaster Workstation and decision-making tool for forecasts and warnings.

Public weather services

The NIM operates a 24/7/365 Forecasting Office. It provides nowcasting (0-12 hours ahead); short-range forecasts (12 hours to 2 days); and medium-range forecasts (3 to 6 days). Weather forecasts (in the form of bulletins, directives, or files) are produced for decision makers and the public, and disseminated by radio, TV, teletext, website and vocal server. See ***Figure 14*** for the number of times NIM forecasts and warnings are disseminated. It also provides specialized products to aviation, marine, and other sectors.

Figure 14 – NIM's Dissemination and Regularity of Forecasts

	Normal Day	Extreme Phenomena
Radio	28	>35
TV	5	~7
Teletext	12	12
Web Site	3	>3
Vocal Server	3	>3

Source: National Institute of Meteorology (NIM).

Climate services

The NIM has climate observations which date back to the early 20th century. After collection and validation, the data are processed and stored. All data from 1950 onwards are available on magnetic tapes. The climate database is managed by an information system that comprises software and analysis tools to enable internal and external users to use NIM climate data. An open system using the latest version of ORACLE SGBD guarantees data security and supplies quality climate products to various sectors and users. The main features of the database include: (a) acquisition of recent data and populating tables; (b) quality control of data; (c) interactive management allowing visualization and updating; (d) data-processing; (e) storage and filing of all climate data; (f) information provision, regular editing and transmitting of climate tables and statistics; (g) preparation and worldwide distribution of CLIMAT messages; and (h) use of methods that combine climate data and socio-economic and physical data which meet the requirements of planners and decision-makers for impact-based information.

The NIM participates in the *Regional Climate Outlook Forum For Northern Africa* (known by its French acronym: *PRESANORD*) and in the *Mediterranean Climate Outlook Forum (MedCOF)* (see *Chapter 2*). As indicated in the *Annex*, the NIM participates in the North Africa RCC-Network, and is responsible for the Tunis Node on Climate Monitoring.

Analysis of the principal climate elements (temperature, precipitation, moisture, evaporation, etc.) has made it possible to identify the major climate features of the country. Other research on climate trends in Tunisia during the previous century are also in progress.

Agricultural meteorological services

The NIM provides agrometeorological information and forecasts to assist (a) agriculture and farming; (b) irrigation planning and management; and (c) combatting diseases and natural disasters (drought, frost, hail, forest fires, etc.). No further information is available on the type of agrometeorological products and services provided by NIM.

There is no information on the existence or use of crop models by the NIM, or on blending in-situ and remote-sensing data to produce products and information for the agricultural community.

Aeronautical meteorological services

The NIM is the designated aeronautical meteorological service provider in Tunisia. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The NIM receives OPMET and WAFS products operationally, and uses the AerometWeb, supported by MFI, as a pilot briefing system.

The NIM recovers costs through its aeronautical meteorological services, and has an up-to-date ISO certified quality management system for aeronautical meteorological services.

Marine meteorological and/or oceanographic services

Daily marine meteorological forecasts and warnings for high seas in coastal areas are broadcast via national and local radio, television programs, and via special channels for fishermen and ships. No further information is available.

Hydrological forecasts and assessments

Most aspects of hydrology and water management are carried out by agencies within the Ministry of Agriculture.

Pluviometric records go back more than a century, and the Mannoubia-Tunis station, established in 1873, is the oldest. The network is currently made up of 808 stations located throughout the country. In addition, Tunisia has a hydrometric observation network which developed mainly in the last three decades; the oldest of these stations date back to 1898. This network is currently composed of 183 hydrometric measurement stations.

Monitoring of groundwater in Tunisia is currently carried out via 3,015 monitoring devices located at 2,209 surface wells, 712 piezometers, and 94 drilled sites. The network for groundwater quality monitoring consists of 874 observation points, including 578 surface wells and 296 drilled wells.

These pluviometric, hydrologic and hydrogeologic data have made it possible to take stock of the country's water resources, providing precious information for local, regional and national water resource planning. This information is stored in hydrological databases hosted and maintained by the General Directorate for Water Resources (under supervision of the Ministry of Agriculture), while precipitation data are managed by the NIM. In the field of hydrometeorology, the NIM provides rainfall data (pluviometric records) and statistics in support of hydraulic work.

Other related aspects, partnerships, and investments

The NIM does not contribute operational weather forecasts for the capital city, but it provides climate information for Tunis-Carthage to the WMO’s World Weather Information Service.

Early Warning Systems

The NIM has an inadequate observing system to monitor hazardous weather events. The NIM is piloting early warning maps in collaboration with the Civil Protection Authority, however, in order to be effective, there is a need for more refined data. Currently, these maps provide color-coded warnings at the *governorate* level, but not at the *delegation* level. In addition to improved weather monitoring and forecast information, the NIM and the Civil Protection Authority need to work on risk and vulnerability maps to establish thresholds for issuing warnings.

Summary of NIM status and challenges

The NIM is a government service with cost recovery for the aviation services. It has a well-organized structure but lacks well-trained staff in relation to meteorological competencies (not to a university degree). It maintains a long-standing relationship with Météo-France. While the NIM runs a 24/7/365 Forecasting Office, most of its limited observing network only operates for 6-12 hours/day due to lack of staff and maintenance. It has modest information and communication technologies but with government funding it is expected that they can be upgraded in the next 3 to 5 years. The NIM relies mostly on French numerical weather prediction outputs, but expects to have a new HPC in 2019 with which it is expected to implement a limited area model to refine forecasts over the country. It does not use the ensemble prediction systems and probabilistic forecasts which are critical for improved early warning systems. The NIM plays an important role in climate monitoring in the North Africa region. It provides traditional agrometeorological monitoring and forecast products, but more advanced crop modeling is required. The NIM is a designated aeronautical meteorological service provider in Tunisia. It provides marine forecasts, and is working to improve its early warning systems. Major challenges include: a significant number of staff close to retirement age, limited human and financial resources to operate and maintain systems, lack of well-trained staff, inadequate monitoring and forecasting tools, and limited coordination and collaboration with stakeholders.

Libya

Socioeconomic context[38]

Given its high reliance on oil, the performance of the economy remains strongly affected by security conditions, especially around the main oil fields and terminals. Improved political and security arrangements in the latter half of 2017 had allowed Libya to more than double its production of oil and to register record growth last year (up 26.7%) after four years of recession. While this dynamic was not sustained over the first half of 2018, GDP grew at 7.2% in 2018, driven by higher government expenditures and investment. While declining, inflation remains high, reflecting market disruptions due to supply shortages of goods and services and an active parallel currency exchange market. This has almost certainly pushed more Libyans into poverty and hardship, and worsened inequality.

Public finances are expected to improve slightly, but the inflexibility of current expenditures, and volatile oil revenues keep the overall fiscal stance under severe stress. The budget deficit, while slightly improving, remained high at around 26% of GDP in 2018 (34.5% of GDP in 2017). Immediate challenges with respect to financial planning include how to manage fiscal spending pressures while restoring and improving basic public services. A longer-term goal is to help develop the framework and institutions for a more diversified market-based economy, and to broaden the economic base beyond the oil and gas sector. The World Bank's post-conflict engagement includes creating a more vibrant and competitive economy with a level playing field for the private sector to create sustainable jobs and wealth. It also aspires to

[38] See further information at http://www.worldbank.org/en/country/libya.

better manage oil revenues so that they are used in the best interests of the country and to the benefit of all citizens equally.

Climate[39]

Libya's climate is influenced by the Mediterranean Sea in the north and the Sahara Desert in the south, resulting in abrupt transitions in weather conditions across the country. Rainfall in Libya occurs during the winter months, with an average annual rainfall of 26 mm for the desert areas and great variations from place-to-place and year-to-year for the remaining regions. The Mediterranean coastal strip experiences dry summers and relatively wet winters. The Jabal Natusah and Jabal Akhdal highlands have a plateau climate, with high rainfall and humidity, and low winter temperatures. The northern Tripoli regions of Jabal Nafusah and Jifarah Plain, and the northern Benghazi region of Jabal al Akhdar receive the highest average annual rainfall of 300 mm.

Pre-desert and desert conditions, with scorching temperatures and daily thermal variations occur in the southern part of the interior in which rain is rare and irregular. Approximately 93% of the land surface receives less than 100 mm of rain per year. Key historical climate trends include:

- Temperature has decreased by 0.89°C per century, from 1901-2000.
- Rainfall has decreased by 20.92 mm per month per century since the 1950's.

Climate projections for Libya indicate that:

- By 2050, the mean annual temperature is projected to increase by 2°C, and the warming rate is projected to increase, with frequent heat waves and fewer frost days.
- Mean annual precipitation is expected to decrease by 7%. Rainfall intensity is expected to increase, the maximum period between rainy days is expected to decrease, and maximum rainfall in any 5-day period is projected to increase. However, models do not agree on whether the country will become wetter or drier.

Governance, organization, and management

Libya's National Meteorological Center (LNMC) is a government agency which was established in 1950 under the supervision of the Ministry of Transport. Meteorology in Libya began with a few meteorological stations which issued weather reports and forecasts for air navigation. In 1991, law No. 13 specified the activities of the meteorology sector in Libya, and in 2000, the LNMC went through a major modernization process supported by UNDP.

The LNMC provides public weather services and other meteorological services to the government and the public only, and commercial activities are not permitted. The LNMC is responsible for observing and forecasting weather, climate, and environmental conditions, providing 24/7/365 meteorological and environmental services, and has the legal authority to issue warnings.

[39] See further information at https://climateknowledgeportal.worldbank.org/country/libya.

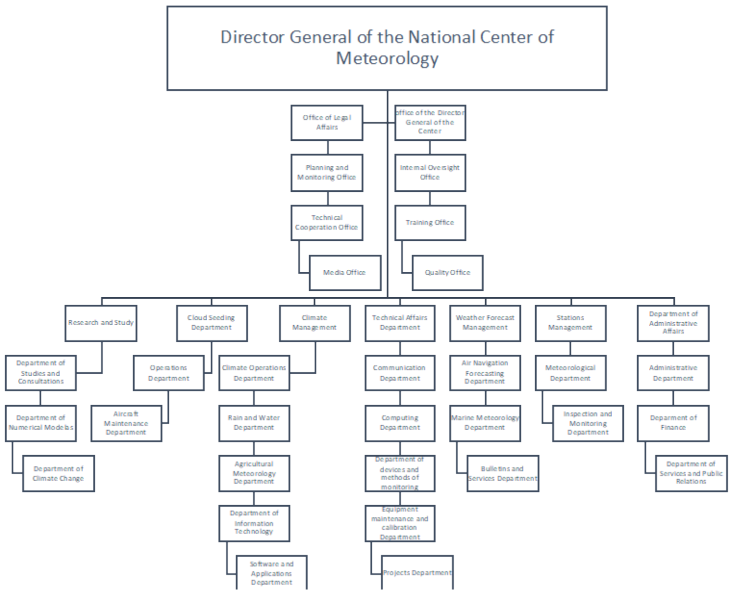
The LNMC is funded by the Government; in 2017 its budget was 18,0 million Libyan Dinar (equivalent to approximately US$12,87 million). In the last 3-5 years its budget has increased steadily. It has Quality Management Systems (QMS) for its aviation services.

The LNMC has a development/strategic plan covering the next 3-5 years, but no further information is available.

The LNMC is headed by a Director-General who oversees services related to management, audit, legal aspects, external relations, customer liaison, public communications, metadata recording, and coordination of projects. It has 7 operational and technical departments dealing with: (1) forecasting; (2) instruments and calibration; (3) observation systems; (4) climate; (5) research; (6) cloud seeding; and (7) education and training (see ***Figure 15***).

The LNMC has a total of 845 personnel, of which 753 are male and 92 are female. It has 68 staff at the management level, 73 meteorologists, 502 meteorological technicians, 35 climatologists, 3 researchers, 116 support staff, and 51 classified as other staff. The LNMC has 138 staff with a university degree, of which 103 are male and 35 are female. The age of the staff ranges as follows: (a) 20-30 years: 12 staff; (b) 30-40 years: 161 staff; (c) 40-50 years: 292 staff; and (d) over 50 years: 378 staff. In the next 5 years, it is expected that 44 staff will retire. In the last 3-5 years staff numbers have steadily decreased. Capacity building requirements have been identified for: (1) meteorologists; (2) meteorological technicians; (3) climatologists; and (4) support staff.

Figure 15 – Organogram of the Libyan National Meteorological Center (LNMC)



Source: Libya's National Meteorological Center (LNMC), "Organogram", http://www.lnmc.ly/.

Libya has been a member of the World Meteorological Organization (WMO) since 1955. Bilateral or multilateral cooperation agreements have been concluded with Météo-France[40], and the African Centre for Meteorological Application for Development (ACMAD)[41].

Major socio-economic user sectors and their needs

The LNMC contributes to the economic and social development of the country by meeting weather, climate, and environmental-related information requirements of various socio-economic sectors. These include: transport (air and sea); agriculture; energy; industry; housing and utilities; strategic projects; planning; sports; health; tourism; education; media, military and defense; justice; universities and scientific centers.

Observing systems (weather, climate, water and environment-related)

The LNMC's network consists of 31 automatic weather stations, 1 upper-air station, and 25 climate stations. The LNMC has a fixed weather radar and a mobile weather radar. It makes use of an MSG system (supported by Eumetsat) to obtain satellite images from METEOSAT. The LNMC used to have 2 marine automatic weather stations, which apparently are not operating at the moment.

The LNMC is responsible for the follow-up and implementation of the equipment, operation, maintenance, and calibration of instruments.

Information and communications technology (ICT)

The LNMC makes use of ObsMet (supported by MFI) as a generic observation data collection system and centralized database, which allows easy and efficient management of the complete weather station network. This system carries out quality control of observations, data visualization, and automatic data export to other meteorological systems (e.g. Forecaster Workstation, etc.).

The LNMC uses Transmet as an automatic message switching system (supported by MFI), required to manage the data process through scripts to pull/push the data. In addition, the LNMC uses RETIM-Africa and RETIM-Europe[42] to receive data files from Météo-France, following standard procedures (IP, FTP) that are recommended for the WMO Information System (WIS) / Global Telecommunication System (GTS).

Data-processing and forecasting systems

The LNMC makes use of numerical weather prediction (NWP) data and products made available by Météo-France via RETIM-Africa and RETIM-Europe (global atmospheric model ARPÈGE, limited-area model ALADIN, and wave model), and by the ECMWF on WIS/GTS. The LNMC does not have any local NWP, does not use ensemble prediction system (EPS) products, and is unable to undertake probabilistic forecasting. The LNMC does not have a nowcasting

[40] See Météo-France, http://www.meteofrance.com/accueil.
[41] See ACMAD, http://www.acmad.net/new/.
[42] RETIM uses satellite-based Digital Video Broadcast (DVB-S) technology, which was designed for digital TV broadcasting, with low cost receiving stations. DVB is a digital high-capacity transmission system.

system.

The LNMC makes use of Synergie (supported by MFI) as a Forecaster Workstation and decision-making tool for forecasting and warnings.

Public weather services

The LNMC operates a 24/7/365 Forecasting Office. It issues daily weather bulletins with forecasts for three days, temperature forecasts for some cities and regions of Libya for two days, and a rainfall bulletin during the rainy season. It also issues warnings for severe weather events.

By using MeteoFactory (a Public Weather Service (PWS) – Early Warning System (EWS) tool for forecasting and warning), weather forecasts (in the form of bulletins) are produced for decision makers and the public and private sectors, and are disseminated by radio, TV, telephone, fax, and website (still demo version).

Climate services

The LNMC has climate observations that date back to the mid-20th century. After collection and validation, the data are processed and stored. The LNMC uses ObsMet (supported by MFI) as a data collection system. More than 25% of the data have been digitized and rescued. The LNMC uses the Clisys Data Management System (supported by MFI) for quality control of observations.

The LNMC participates in the *Regional Climate Outlook Forum For Northern Africa* (known by its French acronym: *PRESANORD*)The LNMC participates in the North Africa RCC-Network, and is co-responsible for the Node on Training (in conjunction with the Egypt Meteorological Authority) (Soares, 2018).

The LNMC prepares statistical products for the past season, and issues monthly and seasonal bulletins. There is no information on whether the LNMC studies climate trends or performs climate change projections.

Agricultural meteorological services

The LNMC provides agrometeorological information and forecasts to assist agriculture and farming, and irrigation planning and management. However, there is no reference to the products that are provided.

There is no information on the existence or use of crop models by the LNMC, however, it is noted that it uses blending (in-situ and remote-sensing) products for agriculture purposes.

Aeronautical meteorological services

The LNMC is the designated aeronautical meteorological service provider in Libya. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The LNMC uses SADIS (a Satellite Distribution System supported by ICAO) and the AerometWeb (supported by MFI) as a pilot briefing system.

The LNMC uses a quality management system which meets international standards and is ISO certified for aeronautical meteorological services.

Marine meteorological and/or oceanographic services

The LNMC makes use of wave model outputs from Météo-France and the ECMWF. Daily marine meteorological forecasts and warnings for the Mediterranean and coastal areas are broadcasted via national and local radio and via special channels for fishermen and ships.

Hydrological forecasts and assessments

Most aspects of hydrology and water management are carried out by the General Water Authority. There is no information available on the hydrological network in Libya.

Other related aspects, partnerships, and investments

Currently, the LNMC contributes operational weather forecasts and climate information for six cities to the WMO's World Weather Information Service.

Early Warning Systems

The LNMC has an observing system to monitor hazardous weather with adequate coverage of the country. It also has one fix and one mobile weather radar. There is an indication that severe weather forecasts and warnings are issued by LNMC. While noting that there is no reference to links to disaster management authorities, these may exist as the LNMC issues impact-based forecasts and risk-based warning services for extreme heat, and typically these are developed in collaboration with these authorities. The LNMC has been designated as an alerting authority for meteorological hazard threats and uses the Common Alert Protocol (CAP) for the dissemination of warnings.

Summary of LNMC status and challenges

The LNMC is a fully public service with budget provided by the Government and no commercial activity. It has a significant number of staff, but a significant number are close to retirement. The LNMC operates 24/7/365. Its observing system includes radars for monitoring severe weather events and extrapolation for the next few hours, but the LNMC does not have a nowcasting system. It has robust information and communication technologies. The LNMC does not run a limited-area model, and does not use ensemble prediction systems and probabilistic forecasts, which are critical for improved early warning systems. The LNMC plays an important role in climate-related training for countries in North Africa. It provides standard agrometeorological monitoring and forecast products, however more advanced crop modeling is required. The LNMC is the designated aeronautical meteorological service provider in Libya, and also provides marine forecasts. The LNMC is the alerting authority for meteorological hazard threats and uses the Common Alert Protocol (CAP) for the dissemination of warnings. Major challenges include: a significant number of staff close to retirement age, inadequate nowcasting system, limited specialized products for applications (e.g. agrometeorology), no use of probabilistic forecasts, and limited coordination and collaboration with stakeholders.

Malta

Socioeconomic context[43]

The Maltese archipelago consists of six islands, namely Malta, Gozo, Comino, Cominotto, Filfla and St. Paul's. The latter three are uninhabited. The Archipelago is located in the center of the Mediterranean Sea and the main islands, Malta, Gozo and Comino cover a land area of approximately 320 km² and 140 km of coastline. In 2020 the population numbered approximately 440,000. Land is scarce, and its loss or degradation from climate change may have significant effects.

The Maltese economy is highly dependent on foreign trade services; it relies heavily on trade in both goods and services, principally with Europe. Malta produces less than a quarter of its food needs, has limited fresh water supplies, and few domestic energy sources. Human resources remain the most important asset in the island's economy.

The agriculture and fishing sector is relatively small, at around 2.5% of GDP, and in long term decline. Industry and construction accounted for over a quarter of Malta's GDP up to 2003. However, as from 2004, the relative contribution of these sectors started to decline due to the expansion of the services sector. Service activities include distributive trades, financial services, transport, communication, tourism, and personal services.

Climate[44]

Malta has mild, wet winters and hot, dry summers. The average annual rainfall is about 508 mm. Temperatures vary between an average of 6°C in Winter to 32°C in Summer. Heavy, often over-localized downpours (accompanied by rapid run-off) in which the bulk of the rainfall occurs, together with summer droughts and high evaporation, are factors which greatly reduce the benefit of Malta's limited precipitation.

Temperature:

- An increase in the mean annual temperature of about 0.5°C in 77 years was observed, in line with the regional value over the Mediterranean during the last century.
- The maximum local temperature increased by 1.5°C, while the minimum decreased by 0.8°C over the same period. Observed extremes in the maximum and minimum temperatures are typical of desert regions.

Precipitation:

- Rainfall patterns show a relatively high spatial variability over Malta with no clear trends in precipitation.

[43] See further information at https://eacea.ec.europa.eu/national-policies/eurydice/content/political-and-economic-situation-49_en.

[44] See further information at https://climateknowledgeportal.worldbank.org/country/malta.

- Since 1923, there has been little change in rainfall during winter and summer, whereas there has been a decrease of 0.14 mm per year during spring and an increase of 0.8 mm per year during autumn.

Climate projections for Malta indicate that:

- By 2050, the mean annual temperature is expected to increase by 1.2°C to 1.4°C. The number of tropical nights (Temp > 20°C) is projected to increase.
- Annual precipitation is expected to increase, while the maximum 5-day rainfall is expected to decrease.

Governance, organization and management

The first Meteorological Office in Malta was opened in 1922 in Guardamangia, moving to St John's Cavalier five years later; however, observations of rainfall and temperature date back to 1851 and 1865, respectively. In 1943 the Meteorological Office moved to Luqa, and then became part of Civil Aviation in 1979. In 1976, the Malta Meteorological Office (MMO) joined the World Meteorological Organization (WMO). There is no specific legislative act that regulates meteorology (or hydrometeorology) in Malta, except the agreement between the Central Government and the Malta International Airport plc that determines the functions of the MMO. It provides Public Weather Services, climate services, aviation, marine and agrometeorological services. The MMO operates 24/7/365.

The MMO's funds come from international and national agencies. There is no further information related to MMO's budget. There is a development/strategic plan for the next 3-5 years.

It is not known whether MMO has a Quality Management System (QMS); however, MMO falls under Civil Aviation, which requires QMS and ISO certification.

The MMO has 10 meteorologists, of which 9 are male and 1 is female. The number of staff has decreased over the last 3-5 years. 4 staff (1 manager and 3 meteorologists) are retiring in the next 5 years.

Major socio-economic user sectors and their needs

The MMO contributes to the economic and social development of Malta by meeting the weather and climate-related information requirements of various socio-economic sectors, including transport (especially aviation and marine), agriculture, and the public sector.

Observing systems (weather, climate, water and environment-related)

The network includes 8 synoptic meteorological observation stations at Xaghra, Xewkija, Selmun, Luqa, Msida, Dingli, Valletta, and Benghajsa reporting hourly according to WMO standards on wind speed and direction, temperature, atmospheric pressure, relative humidity, dew point, rainfall, and global solar irradiance.

The MMO operates a weather radar located at 14°E 36°N, altitude 100m, with a range of 100km. It has access to EUMETSAT/Meteosat satellite imagery.

Information and communications technology (ICT)

The WMO Information System / Global Telecommunication System (GTS) transmission and reception is via a link to the WMO GISC Exeter.

Data-processing and forecasting systems

There is no information available.

Public weather services

The MMO issues public forecasts up to 7 days ahead; these appear on its website.

Climate services

The MMO participates in the *Mediterranean Climate Outlook Forum (MedCOF)* (see *Annex*).

Agricultural meteorological services

There is no information available.

Aeronautical meteorological services

The MMO is the meteorological authority (as per ICAO Annex 3) and also the met service provider for aviation. It issues TAFs and METARs, and provides flight documentation to airlines. The MMO receives OPMET and WAFS products operationally.

Marine meteorological and/or oceanographic services

The MMO issues marine forecasts up to 3 days ahead.

Hydrological forecasts and assessments

The Water Service Corporation manages 12 rain gauges in Malta and 3 in Gozo. All of them are mechanical. There are 3 climate stations. There are no permanent rivers in Malta. Discharges are measured with mechanical floats, but water levels are not recorded (4 locations in Malta and 1 in Gozo). 30 automatic stations monitor piezometric levels.

For the Med-Hycos Programme, there are two stations; one in the largest catchment of Malta Island (50 km²), and the second in the largest catchment of Gozo Island (in the North).

Other related aspects, partnerships and investments

The MMO contributes operational weather forecasts and climate information for Luqa to the WMO's World Weather Information Service.

Early Warning Systems

The MMO has a surface observing system (synoptic stations and weather radar) to monitor hazardous weather events, however its status and conditions are not clear. Severe weather forecasts and alerts are issued. The MMO is the alerting authority for meteorological hazards and uses the Common Alert Protocol (CAP). The MMO issues alerts via the European meteoalam system.

Summary of MMO status and challenges

The MMO is a government service with no commercial services. It has a limited staff. The MMO operates 24/7/365. The observing network covers the whole country, but the status and conditions of this network are unknown. There is no information on its ICT and modeling capacities. The MMO is the designated aeronautical meteorological service provider in Malta. It has an early warning system in place. Major challenges include: limited staff, primary role in aviation services, and limited coordination and collaboration with the departments responsible for hydrology.

MASHREQ

Lebanon

Socioeconomic context[45]

One of the key issues facing Lebanon is the economic and social impact of the Syrian crisis. According to government and independent sources, up to 1.5 million Syrians, about a quarter of the Lebanese population, have taken refuge in Lebanon since the conflict erupted in March 2011. This has strained Lebanon's public finances, service delivery, and the environment. The crisis is expected to worsen poverty for Lebanese citizens and widen income inequality. In particular, it is estimated that, as a result of the Syrian crisis, some 200,000 Lebanese have been pushed into poverty, adding to the 1 million poor. An additional 250,000 to 300,000 Lebanese citizens are estimated to have become unemployed, most of them unskilled youth.

Within this challenging environment, GDP growth in Lebanon in 2018 has only grown by 0.2%, compared to 0.6% in 2017. The deceleration in economic activity is linked to policy-based tightening of liquidity. Inflation soared in 2018, averaging 6.1% for the year, compared to 4.7% in 2017. The fiscal position deteriorated sharply in 2018 due to a higher debt service; increased transfers to *Electricité du Lebanon* (EdL) due to more expensive fuel; and a surge in transfers to municipalities, likely motivated by electioneering. The debt-to-GDP ratio is expected to persist in an unsustainable path, at 151% by end-2018. Lebanon accumulated a loss of US$4,823 million in 2018, compared to a loss of US$156 million in 2017.

Climate[46]

Lebanon has a Mediterranean climate, which is characterized by short, cool winters and long, hot summers. Lebanon receives 80 to 90 days of rain per year, mainly in winter. During winter, Lebanon is affected by cold winds from Europe, bringing cool, wet conditions to the northern part of the country, while during spring and fall, the Khymsin winds bring warmer temperatures. In coastal areas, the temperature ranges from 13°C in winter to 27°C in summer (with an annual average of 20°C). Key historical climate trends indicate:

- While there is high seasonal variability, temperature records extrapolated from Askaniia-Nova show a linear increase of 0.7°C from 1951-2000.
- Mean rainfall has decreased by 11 mm/month per century since 1950.

Climate projections for Lebanon indicate that:

- By 2050, mean annual temperature is expected to increase by 2°C.
- Mean annual rainfall is projected to decrease by 11% by 2050. The maximum amount of rain that falls in any 5-day period is expected to decrease. There is substantial uncertainty regarding runoff projections.

Governance, organization, and management

The Lebanese Meteorological Department (LMD) is supervised by the Directorate General of Civil Aviation. Its year of establishment is not known, but Lebanon has been a member of the

[45] See further information at http://www.worldbank.org/en/country/lebanon.
[46] See further information at https://climateknowledgeportal.worldbank.org/country/lebanon.

WMO since 1948. The LMD's mission is to observe and understand weather and climate, and to provide meteorological, hydrological and related services to support national needs inthe following areas:

- Protection of life and property;
- Safeguarding the environment;
- Contributing to sustainable development;
- Promoting long-term observation and collection of meteorological, hydrological and e data, including related environmental data;
- Promotion of capacity building;
- Meeting international commitments;
- Contributing to international cooperation.

The LMD's main source of funding is from the Government. There is no indication of its budget. The LMD does not have a development/strategic plan or a Quality Management System (QMS).

The LMD consists of 3 Divisions: (a) the Forecasting Division; (b) the Observation Division; and (c) the Climatology Division. The LMD has a total of 38 personnel, of which 34 are male and 4 are female. The LMD has 4 staff at the management level, 8 meteorologists, 4 meteorological technicians, 10 climatologists, 3 supporting staff, and 9 classified as other staff. The age of the staff ranges as follows: (a) 20-30 years: 0 staff; (b) 30-40 years: 5 staff; (c) 40-50 years: 23 staff; and (d) over 50 years: 10 staff. Capacity building requirements have been identified in the areas of: (1) forecasting; (2) climatology; (3) observations; and (4) research.

Major socio-economic user sectors and their needs

The LMD contributes to the economic and social development of the country by meeting the weather, water and climate-related information requirements of the civil and military aviation and marine sectors, and the public.

Observing systems (weather, climate, water and environment-related)

The LMD's network consists of 36 automatic weather stations (of which 10 are in the North, 8 in Mount Lebanon, 2 in Beirut, 8 in the South, and 8 in the Bekaa Valley), 3 climate stations, and 1 marine station. Weather and wind shear radars at the airport are broken. The LMD maintains measuring equipment and sensors to international standards. There is no information on the access and use of satellite imagery.

Information and communications technology (ICT)

A communication system dedicated to meteorological data handles data exchange. The national telecommunication system uses 15 PSTN connected stations which are automatically polled on an hourly basis, while the remaining stations are visited by LMD staff once per month, and data are retrieved on removable memory cards. The LMD uses MESSIR-COMM and Transmet as automatic message switching systems (supported by Corobor and MFI, respectively) to manage the data process through scripts to pull/push the data from/to the WMO Global Telecommunication System (GTS). Apparently, some systems are duplicated, but this may be due to replacement scheduling, and no metadata are available.

Data-processing and forecasting systems

The LMD Forecasting Division draws weather charts, produces weather forecasts, and issues early warnings. It uses numerical weather prediction products made available through the WIS/GTS and on the Internet.

The LMD makes use of *Synergie*, supported by MFI, as a Forecaster Workstation and decision-making tool for forecasting and warning.

Public weather services

LMD operating times are not known, but 24 hour weather forecasts (in the form of bulletins) are produced for decision makers and the public. The LMD does not have a website.

The LMD makes use of *MeteoFactory*, supported by MFI, as a service delivery platform for customized forecasts and warnings to target end-users.

Climate services

The Climatology Division archives and analyses data, and prepares climate reports; however, it does not have a proper Climate Data Management System, database, or quality control system.

The LMD participates in the *Mediterranean Climate Outlook Forum (MedCOF)* (Soares, 2018), and uses regional consensus statements to issue seasonal forecasts.

Agricultural meteorological services

The LMD provides climate reports to the agricultural community. However, agrometeorology is an integral function of the Department of Irrigation and Agrometeorology (DIAM). DIAM issues weather forecasts for agriculture, early warnings for pests and diseases, drought warnings and irrigation advice to farmers and the public via SMS.

Aeronautical meteorological services

While LMD is not formally the designated aeronautical meteorological service provider in Lebanon, it issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The LMD receives OPMET and WAFS products operationally, and uses the AerometWeb, supported by MFI, as a pilot briefing system.

There is no information on cost-recovery for aeronautical meteorological services. The LMD has no QMS, and is not ISO certified for aeronautical meteorological services.

Marine meteorological and/or oceanographic services

The LMD has 1 marine station, and issues daily marine meteorological forecasts and warnings for Lebanon sea waters. No further information is available.

Hydrological forecasts and assessments

Hydrology is an integral function of the Department of Irrigation and Agrometeorology (DIAM). No further information is available.

Other related aspects, partnerships, and investments

The LMD does not contribute operational weather forecasts or climate information to the WMO's World Weather Information Service.

Lebanon is a beneficiary country of the following projects:

- *South-east European Multi-hazard Early Warning Advisory System*[47], supported by USAid, and implemented in partnership with the Finnish Meteorological Institute (FMI) and WMO. The project will provide operational forecasters with effective and tested tools to forecast hazardous weather events and their possible impacts in order to improve the accuracy of warnings and their relevance to stakeholders and users.

- *Strategic Management of Hydro-Meteorological Data and Information Product Generation - A contribution to the Blue Peace Initiative*[48], supported by Swiss Agency for Development and Cooperation (SDC), and implemented in partnership with the Hydrologic Research Center (HRC), Jordanian Meteorological Department, Lebanese Agricultural Research Institute, Lebanese Meteorology Department, Litani River Authority, MeteoSwiss, National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS), and the Servício Nacional de Meteorología e Hidrología del Perú (SENAMHI). The overall goal of the Blue Peace project is to strengthen the delivery of weather, water, and climate services in Jordan and Lebanon, and to support economic development and disaster risk management. The project goal is to improve monitoring, data management and information sharing to enhance regional coordination and collaboration, through training (on quality management, improved field measurement), provision of equipment (observation equipment and data management tools), and support for institutional cooperation. Through the project Lebanon has also accessed the *Flash Flood Guidance System for Black Sea and Middle East* (Soares, 2018).
- LMD participates in the *Mediterranean Climate Outlook Forum (MedCOF)* (see *Annex*).

Early Warning Systems

The LMD has a surface observing system with adequate coverage of the country; however, it does not have an operating weather radar, which is critical to monitor hazardous weather. There is an indication that severe weather forecasts and warnings are issued by LMD, but there is no reference to linkages to disaster management authorities. However, LMD has been designated as an alerting authority for meteorological hazard threats and uses the Common Alert Protocol (CAP) to disseminate warnings.

Summary of NIM status and challenges

The LMD is a government service. There is no information about its budget. It has a structure, with a significant number of experienced staff. Staff require training in forecasting, climatology, observations, and research. The surface observing network covers a large part of

[47] See WMO, "South-east European Multi-hazard Early Warning Advisory System", https://public.wmo.int/en/projects/see-mhews-a.

[48] See WMO, "Strategic Management of Hydro-Meteorological Data and Information Product Generation - A contribution to the Blue Peace Initiative", https://public.wmo.int/en/projects/strategic-management-hydro-meteorological-data-and-information-product-generation.

the country; however, it does not have an operating radar. The LMD makes use of NWP data and products available on WIS/GTS and on Internet, and has no local modeling capability. It does not make use of ensemble prediction systems and probabilistic forecasts. The LMD provides very simple climate services based on statistics, and provides seasonal forecasts based on the *MedCOF consensus statement*. Agrometeorological and hydrological monitoring are under the Department of Irrigation and Agrometeorology. Major challenges include: a significant number of staff close to retirement, lack of modern remote-sensing observing systems, and limited use of numerical weather prediction capabilities.

Jordan

Socioeconomic context[49]

A major challenge facing Jordan remains to reinvigorate the economy in the context of a challenging external environment. Adverse regional developments, in particular the Syria and Iraq crisis, remain the largest recent shock affecting Jordan. This is reflected in an unprecedented refugee influx, disrupted trade routes, less investment, and declining tourism (particularly as a result of economic slowdown in GCC). Continued regional uncertainty and reduced external assistance will continue to put pressure on Jordan.

Jordan's real GDP registered a growth of 2% in 2018, constrained by structural impediments and a difficult regional setting. A high unemployment rate (18.6% annual average in 2018), high dependency on grants, and reduced remittances and official inflows from Gulf economies pose a serious challenge. Jordan's fiscal efforts in 2018 remained below the budget target as the fiscal deficit (including grants) widened to 3.4% of GDP in 2018, 1.6% higher than the budgeted target for 2018. This was mainly due to limited revenue growth (vis-à-vis the budget targets) and limited flexibility to curtail recurrent spending. However, Jordan pursued reforms in education, health, the economy, privatization and liberalization, as evident from the enactment of amended income tax legislation in November 2018. The public debt-to-GDP ratio declined marginally for the first time in a decade.

Climate[50]

While Jordan's climate ranges between a desert climate to a more Mediterranean climate, the land is generally very arid. Winter temperatures in the desert regions range from 19°C to 22°C, while the southern and northern highlands range between 9°C and 13°C. In the summer, the temperatures in the desert regions vary between 26°C and 29°C, and in the Jordanian Valley between 38°C and 39°C. About 75% of precipitation falls during the winter. The Dry Sirocco (Khamsin) winds lead to large temperature anomalies in Jordan and may increase temperatures by up to 15°C. The Shammal Winds (which blow from the north/northeast) also influence the climate of Jordan, causing high daytime temperatures. Key historical climate trends indicate:

- That since 1900, the mean annual temperature has increased by 0.89°C. The annual maximum temperature has increased by 0.3-1.8°C since the 1960's, while the annual minimum temperature has increased by 0.4-2.8°C.

[49] See further information at http://www.worldbank.org/en/country/jordan.
[50] See further information at https://climateknowledgeportal.worldbank.org/country/jordan.

- A 2.92 mm/month per century reduction in the average annual precipitation since 1900.

Climate projections for Jordan indicate that:

- By 2050, the mean annual temperature is expected to increase by 2°C. By mid-century, it is expected that Jordan will become warmer, with more frequent heat waves and fewer frost days.
- The country will become drier, however, rainfall intensity is expected to increase. The maximum period between rainy days is expected to decrease.

Governance, organization, and management

The Jordan Meteorological Department (JMD) is a government agency established as a monitoring and forecasting office at the Jerusalem Airport in 1951, and is supervised by the Ministry of Transport. At that time, the number of meteorological stations was inadequate, and the JMD's tasks were limited to issuing aerial bulletins, meteorological forecasts, and climatic information. The JMD's role has improved, and nowadays, in addition to weather bulletins, it also provides services in support of aviation, agriculture, climate change adaptation, and construction. In 1967, under Regulation N° 19, JMD became an independent department under the supervision of the Ministry of Transport. The JMD has been a member of the World Meteorological Organization (WMO) since 1955, and a member of the Subcommittee of Meteorology of the Standing Committee for Transport at the Arab League since 1955, which was renamed in 1972 to Permanent Arab Meteorological Committee.

The JMD's mission is to monitor weather and climate phenomena, and issue early warnings of weather and climate events, to minimize loss of life and property and contribute to sustainable development. The JMD is the meteorological authority as per the International Civil Aviation Organization (ICAO) (Annex 3), and is also the meteorological service provider for aviation.

The JMD has a development/strategic plan in place. Its vision is to be "a pilot department and reference specialist in the field of meteorology". The JMD's national goals include: (a) effective participation in sustainable development; (b) reducing natural hazards to communities; and (c) maintain the integrity of life and property. Its strategic objectives are: (a) development of services for all sectors (media, agriculture, water, tourism, environment, construction, and transport sector, especially aviation); (b) keep abreast of the constant modernization of administrative and financial works; and (c) spread community awareness in the field of meteorological concepts, climate change and environmental conservation. JMD's institutional objectives include:

- Establishment of a network of meteorological stations to measure and sustain weather services;
- Exchange of meteorological information between the Kingdom of Jordan and the world;
- Building a national climate database;
- Implementing WMO programs;
- Following-up scientific developments in the field of weather forecasts; and,

- Providing official and private bodies with climate data for the Kingdom of Jordan.

The JMD's main source of funding is from the government. It has very limited commercial activities. The total budget of JMD is 2,0 million Jordan Dinars (equivalent to approximately US$2,82 million). The implementation of Quality Management Systems (QMS) at the JMD is in progress.

The JMD has 3 Directorates for administration, human and financial resources, planning, internal control, and international relations; and 8 operational and technical Directorates related to equipment and maintenance, external stations, applied meteorology, national center (including a weather forecasts section, meteorological section, and systems section), information technology, and research and studies.

The JMD has 48 staff with university degrees. The number of staff is steadily decreasing. Therefore, the JMD is inviting applications from meteorologists and meteorological technicians, and offering specialized training as per WMO guidelines.

Major socio-economic user sectors and their needs

The JMD contributes to the economic and social development of the country by meeting the weather and climate-related information requirements of various socio-economic sectors. These include: aviation, agriculture, and the media.

Observing systems (weather, climate, water and environment-related)

The JMD Directorate of Equipment and Maintenance is in charge of (i) supervising the preparation of studies and technical specifications for electrical appliances, radiosonde, radar and computer devices; (ii) establishment, installation and maintenance of meteorological stations, ground surveyors and the development of specifications for various monitoring devices; and (iii) calibration of various meteorological devices and periodic maintenance of equipment. Departments associated with this Directorate are: (i) Hardware Section; and (ii) Maintenance Department.

The JMD Directorate of External Stations (i) supervises the operation of air monitoring stations throughout the Kingdom of Jordan at the National Center for Weather Forecasts in Amman to ensure the arrival and utilization of meteorological information for the purposes of weather forecasts; and (ii) provides administrative supervision and organization of work in external stations and secure access to the monthly reports of the Directorate of Applied Meteorology. Departments associated with this Directorate include: (i) Department of External Stations; and (ii) Agricultural Stations Department.

The JMD's network consists of 23 synoptic stations, 7 agrometeorological stations, 3 climate stations, and 1 radar (TX Type: Magnetron; Polarization: Dual; Band: S) to monitor severe weather events in Jordan. The JMD makes use of MESSIR-SAT (supported by Corobor) to obtain satellite images.

Information and communications technology (ICT)

A communication system dedicated to meteorological data handles data exchange. The JMD uses MESSIR-COMM as an automatic message switching system (supported by Corobor), required to manage the data process through scripts to pull/push the data from/to the WMO Global Telecommunication System (GTS).

Data-processing and forecasting systems

The JMD uses numerical weather prediction products from the World Area Forecast Centre (WAFC) Washington, which is a meteorological center that provides real-time meteorological information broadcasts for aviation purposes, under the framework of ICAO. The role of the WAFCs is to provide meteorological messages with worldwide coverage for pilot briefing. They are usually part of the Pre-Flight Information Bulletin.

The JMD makes use of MESSIR-VISION, supported by Corobor, as a Forecaster Workstation and decision-making tool for forecasting and warnings.

Public weather services

The JMD Directorate of the National Center is responsible for issuing weather forecasts, forecasts, and warnings for citizens and for keeping abreast of scientific developments in meteorological monitoring and prediction. Departments associated with the Directorate: (i) Weather Forecasts Section; (ii) Meteorological Section; and (iii) Systems Section.

The JMD provides weather bulletins up to 4 days to the public, special bulletins for aviation purposes, and farmers' bulletins. It also provides weather forecasts for provinces and a forecast bulletin for Aqaba. The JMD issues warnings in special and emergency weather situations for farmers, pilots, the public, civil defense, public works, municipalities, and various media. The JMD issues bulletins through various dissemination channels, including the media and on its website. It provides information to researchers and students.

Climate services

The JMD Directorate of Applied Meteorology supervises the collection, quality control, and archiving of data from all meteorological stations in the Kingdom of Jordan, issues monthly reports, and provides authorities with various information on climate elements.

The JMD participates in *Mediterranean Climate Outlook Forum (MedCOF)* (see *Chapter 2*). Based on the information gathered, it issues press releases with seasonal forecasts for 3 months.

Agricultural meteorological services

The JMD provides services to agriculture; in particular it issues seasonal rainfall statistics. No further information is available.

Aeronautical meteorological services

In addition to public weather services, the JMD Directorate of the National Center is responsible for issuing aeronautical meteorological forecasts in accordance with the instructions of WMO and ICAO, and for following up on amendments to their instructions.

The JMD is the designated aeronautical meteorological service provider in Jordan. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The JMD receives OPMET and WAFS products operationally. The JMD uses the AerometWeb, supported by MFI, as a pilot briefing system.

The JMD is implementing a quality management system meeting international standards and is ISO certified for aeronautical meteorological services.

Marine meteorological and/or oceanographic services

As part of the 4-day weather forecast for Aqaba, the JMD provides marine forecasts for the Red Sea coastal area.

Hydrological forecasts and assessments

Most aspects of hydrology and water management are carried out by agencies within the Ministry of Water and Irrigation. This is the official body responsible for overall monitoring of the water sector, water supply and wastewater system and related projects, planning and management, the formulation of national water strategies and policies, research and development, and information systems. Its role also includes the provision of centralized water-related data, standardization, and consolidation of data.

Other related aspects, partnerships, and investments

The JMD does not contribute operational weather forecasts for the capital city, however, it provides climate information for Amman, Aqaba, and Irbid to the WMO's World Weather Information Service.

Jordan is a beneficiary country of the following projects:

- *South-east European Multi-hazard Early Warning Advisory System*[51], supported by USAid, and implemented in partnership with the Finnish Meteorological Institute (FMI) and WMO. The project will provide operational forecasters with effective and tested tools to forecast hazardous weather events and their possible impacts in order to improve the accuracy of warnings and their relevance to stakeholders and users.

- *Strategic Management of Hydro-Meteorological Data and Information Product Generation - A contribution to the Blue Peace Initiative*[52], supported by the Swiss Agency for Development and Cooperation (SDC), and implemented in partnership with the Hydrologic Research Center (HRC), Jordanian Meteorological Department, Lebanese Agricultural Research Institute, Lebanese Meteorology Department, Litani River Authority, MeteoSwiss, National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS), and the Servício Nacional de Meteorología e Hidrología del Perú (SENAMHI). The overall goal of Blue Peace project is to

[51] See WMO, "South-east European Multi-hazard Early Warning Advisory System", https://public.wmo.int/en/projects/see-mhews-a.

[52] See WMO, "Strategic Management of Hydro-Meteorological Data and Information Product Generation - A contribution to the Blue Peace Initiative", https://public.wmo.int/en/projects/strategic-management-hydro-meteorological-data-and-information-product-generation.

strengthen the delivery of weather, water and climate services in Jordan and Lebanon, and to support economic development and disaster risk management. The project goal is to improve monitoring, data management, and information sharing to enhance regional coordination and collaboration, through training (on quality management, improved field measurement), provision of equipment (observation equipment and data management tools), and support for institutional cooperation. Through the project, Lebanon and Jordan have also accessed the *Flash Flood Guidance System for Black Sea and Middle East* (see *Chapter 2*).

- JMD participates in the *Mediterranean Climate Outlook Forum (MedCOF)* (see *Annex*).

Early Warning Systems

The JMD has a satisfactory observing system to monitor hazardous weather events. Severe weather forecasts and warnings are issued by JMD. It benefits from the Flash Flood Guidance System for the Black Sea and the Middle East. However, there is no indication of the level of coordination with disaster management authorities.

Summary of NMHS status and challenges

The JMD is a government service but with very limited commercial activities. Most of its staff have a university degree. The JMD operates 24/7/365. The observing network covers a large part of the country. It has adequate information and communication technologies. The JMD makes use of model outputs available from the World Area Forecast Centre (WAFC) Washington. The JMD primarily provides services to aviation, agriculture, and the public (through media). It provides basic climate, marine, and agrometeorological services, and would benefit from introducing modern techniques. The JMD is the designated aeronautical meteorological service provider in the Kingdom of Jordan. Major challenges include: the number of staff is decreasing and there is limited ability to recruit new staff, limited forecasting capabilities, and limited coordination and collaboration with other departments and stakeholders.

Syria

Socioeconomic context[53]

The conflicts in Syria continue to take a heavy toll on the life of Syrian people and on the Syrian economy. The death toll in Syria directly related to the conflict as of early 2016 is estimated between 400,000 (UN, Apr 2016) and 470,000 (Syrian Center for Policy Research, Feb 2016), with many more injured, and many lives in upheaval. About 6.2 million people, including 2.5 million children, are internally displaced, and over 5.6 million are officially registered as refugees (UNHCR, 2019).

The lack of sustained access to health care, education, housing, and food have exacerbated the impact of the conflict and pushed millions of people into unemployment and poverty. In addition, a severe decline in oil receipts and disruptions of trade has placed even more pressure on Syria’s external balances, resulting in the rapid depletion of its international reserves.

[53] See further information at https://www.worldbank.org/en/country/syria.

The human toll of the conflict (casualties and forced displacement) and damage to productive factors and economic activity has been extensive, damaging capital stock (e.g. about one-third of housing stock and one-half of health and education facilities damaged or destroyed), while disrupting economic activity. From 2011 to 2016, cumulative GDP loss is estimated at US$226 billion.

Climate[54]

Largely, Syria experiences a Mediterranean climate. The proximity of the sea and elevation influence the temperature of the country. The annual average temperature is 18.1°C on the coastal plain, while in the mountains, it is 15.2°C. During the winter, temperatures are moderate to cold, while summer temperatures tend to exceed 30°C. Usually, summers are very dry, with high evaporation rates. Key historical climate trends indicate:

- That since 1950, the mean annual temperature has increased by 0.8°C per century.
- Mean rainfall has decreased by 18.23 mm/month per century (1901-2000). Autumn precipitation has increased in the northern and central regions of the country, while the western part has experienced higher than average rainfall of up to 25 mm/month compared to less than 2 mm/month on average in other parts of the country.

Climate projections for Syria indicate that:

- By 2050, the mean annual temperature is projected to increase by 2°C. The highest temperature increase is projected for June to August. Warming is projected to be more rapid in the interior regions than in coastal areas. Higher warming is projected in the northwest and southeast. The number of consecutive dry days is projected to increase by 5, while the number of frost days is projected to decrease by 13.
- By 2050, the mean annual precipitation is projected to decrease by 11%. The greatest reduction is expected from September to November and from March to May. Precipitation during June to August is projected to increase by 2% in the western part of Syria and by 1% in the northeast.

Governance, organization, and management

The Syrian Meteorological Department (SMD) is a government organization responsible for the provision of public and other related weather services to the State. The SMD is under the supervision of the Ministry of Defense. The Syrian Arab Republic became a Member of WMO in 1952. There is no further information available related to SMD's responsibilities and functions, budget, and human resources.

Major socio-economic user sectors and their needs

The SMD's main client is defense/military. There is no further information available on other potential clients.

[54] See further information at https://climateknowledgeportal.worldbank.org/country/syria.

Observing systems (weather, climate, water and environmental-relatedal)

The SMD meteorological observation network consists of 20 surface stations, of which 10 are climate stations; and 5 agromet stations. All these stations are currently not reporting.

Information and communications technology (ICT)

There is no information on the telecommunication system at SMD for the collection of local meteorological data and for international data exchange through the WMO Information System / Global Telecommunication System (GTS). The SMD uses MESSIR-COM (supported by Corobor), and Trasmet AMSS (supported by MFI) as automatic message switching system clusters required to manage the data process through scripts to pull/push the data.

Data-processing and forecasting systems

Some of the NWP products for use in the forecasting office may be made available via two visualizations systems: MESSER-VISION (supported by Corobor) and Synergie supported by MFI). There is no detailed information on the NWP models, but noting that SMD uses Synergie, it most likely has access to Arpège (Météo-France global model), and ECMWF model outputs at coarse resolutions.

Public weather services

The SMD provides 24 hour weather forecasts. It also provides specialized products to aviation. The SMD has a website that is not always functional. There is indication that SMD uses MESSIR-Media (supported by Corobor) for dissemination of its forecasts. The SMD is identified as an alerting authority for meteorological hazard threats and uses CAP.

Climate services

The SMD prepares and issues climate information and statistics for 10 locations, and makes them available on the WWIS website.

Agricultural meteorological services

No information is available on other agrometeorological products and services.

Aeronautical meteorological services

No information is available on other aeronautical meteorological services.

Marine meteorological and/or oceanographic services

No information is available on marine meteorological and/or oceanographic services.

Hydrological forecasts and assessments

No information is available on hydrological monitoring, forecasts, and assessments by SMD.

Other related aspects, partnerships, and investments

Currently, the SMD contributes operational weather forecasts and climate information for 10 cities to the WMO's World Weather Information Service.

Syria is a beneficiary country of the *Black Sea and Middle East Flash Flood Guidance System (BSMEFFGS)*[55], and SMD participates in the *Mediterranean Climate Outlook Forum (MedCOF)*.

Early Warning Systems

No information is available on Early Warning Systems.

Summary of SMD status and challenges

SMD is a government organization. In general, there is a lack of information on its capabilities. It has an observing network that is not reporting. It appears that SMD uses MESSIR tools (supported by Corobor).

Iraq

Socioeconomic context[56]

Iraq's economy is gradually recovering following the deep economic strains of the last four years. Real GDP has grown by 0.6% in 2018, thanks to a notable improvement in security conditions and higher oil prices. The non-oil economy grew at 4%, while oil production was slightly less than in 2017, in line with the OPEC+ agreement. Recently, Iraq's economy received a boost of confidence with the signing of several trade agreements with its neighbors. Reconstruction efforts have been proceeding at a moderate pace. Inflation remained low at 0.4% in 2018, due to higher domestic demand and rising food and transport costs.

The overall fiscal balance swung from a 1.7% deficit in 2017, to a 6.2% surplus in 2018. Growth and the positive overall fiscal balance in 2018 were estimated to reduce the public debt-to-GDP to 48.4% in 2018 from 66% in 2016. Poverty rate is expected to decline on the back of recent economic growth and improvement in the security situation but will remain unevenly distributed across the country. The standard of living in conflict-affected areas is possibly still below the 2014 level because of disruptions in the labor market and general economic stagnation. Internally displaced persons (IDPs) have also likely experienced severe welfare loss through loss of jobs and livelihoods. These conditions have the potential to sustain a low-level, but persistent insecurity focused on northern Iraq. There has recently been an improvement in several non-income dimensions of welfare. The multidimensional poverty headcount ratio dropped from 6.8% in 2014 to 3.3% in 2017/18. Increase in school enrollment, expansion of drinking water provision, and sewage disposal services have contributed to a fall in multidimensional poverty. However, labor market outcomes continue to be a concern, especially for women and youth. At 48.7%, the country has one of the lowest labor force participation rates in the world, especially for women (12%) and youth (26%).

Climate[57]

Iraq's climate is mainly continental and subtropical semi-arid, except in the northern and northeastern mountainous regions which have a Mediterranean climate. The country typically experiences winters that vary between cool and cold, and summers that are dry with variations between hot and extremely hot. Rainfall is seasonal and occurs mostly during the winter (December to February) for most of the country, except in the north and northeast,

[55] See WMO, "Flash Flood Guidance System (FFGS) with Global Coverage", http://www.wmo.int/pages/prog/hwrp/flood/ffgs/index_en.php.
[56] See further information at http://www.worldbank.org/en/country/iraq.
[57] See further information at https://climateknowledgeportal.worldbank.org/country/iraq.

where the rainy season is from November to April. South and Southeasterly Sharqi (dry and dusty) winds influence the climate of Iraq from April to June and September to November. The North, Northwest Shamal Winds also impact the climate, leading to extensive surface heating. Key historical climate trends indicate:

- That since 1950, mean annual temperatures have risen across Iraq at a rate of 0.7°C per century.
- For the period 1951 to 2000, the nearest station precipitation records for the northeast of Iraq show an increase of 2.4 mm/month per century, while the nearest station records for the southeast indicate a decline of 0.88 mm/month per century. The nearest station record to the west indicates a decline of 5.93 mm/month per century.

Climate projections for Iraq indicate that:

- By 2050, the mean annual temperature is projected to increase by 2°C.
- By 2050, the mean annual rainfall is projected to decrease by 9%. The greatest reduction (17%) is expected during the period of December to February. The maximum amount of rain that falls in any 5-day period is projected to decrease, as is the maximum period between rainy days.

Governance, organization, and management

The Iraqi Meteorological Organization and Seismology (IMO) is a government agency under the Ministry of Transportation, established by British Forces in 1923. At that time, it had three meteorological departments to serve military purposes in Mosel, Habaniya, and Sheaba districts. In 1936, the IMO was under the Iraqi Civil Aviation Administration, as part of the Ministry of Defense. It is currently under the supervision of the Ministry of Transport and Communications. The IMO's functions are described in Act No. 7 of 1994. The IMO is responsible for weather forecasting and monitoring, and provides technical consultancy to major socioeconomic projects.

The IMO's main source of funding is from the Government. The total budget of IMO in 2017 was 9000 million Iraqi Dinar (equivalent to approximately US$7,56 million). In the last 3-5 years its budget has been stable, and it has Quality Management Systems (QMS).

The IMO has a development/strategic plan for the next 3-5 years, but no further information is available.

The IMO is headed by a Director that oversees services related to management, audit, and missions. There are 7 operational and technical departments; 5 departments for administration, follow-up and planning, legal, financial and auditing; and 1 WMO Regional Training Centre (see Soares, 2018) for training technical and professional staff of IMOs and other NMHSs of Arabian countries. Iraq has been a member of the World Meteorological Organization (WMO) since 1950.

The IMO has a total of 484 personnel at headquarters and regional offices, of which 109 are male and 375 are female. The DNM has 12 staff at the management level, 322 meteorologists, 8 meteorological technicians, 9 hydrologists, 2 hydrological technicians, 8 climatologists, 7 researchers, 104 support staff, and 12 classified as other staff. The number of DNM staff with a university degree is 217. The age of the staff ranges as follows: (a) 20-30 years: 52 staff; (b) 30-40 years: 85 staff; (c) 40-50 years: 138 staff; and (d) over 50 years: 191 staff. The number of IMO staff has increased steadily over the last 3-5 years. Areas in which IMO staff training is needed include (in order of priority): (1) forecasting; (2) observation systems; (3) hydrology; and (4) instrumentation.

Major socio-economic user sectors and their needs

The IMO contributes to the economic and social development of the country by meeting weather, climate, and environmental-related information requirements of various socio-economic sectors. These include: transport (air, sea, and land); agriculture; hydrology; environment; energy; construction, land use and planning; and military.

Observing systems (weather, climate, water and environmental-related)

The IMO's observational network consists of 2 automatic weather stations (one at the Baghdad international airport; and the other in Basra), 9 climate stations, and 40 regional basic synoptic network (RBSN) surface stations in different Iraqi provinces. There is no reference to a radar network.

The IMO also has 1 station to measure ozone (at Hawr al Habbaniyah / Ar Ramadi). It appears that the IMO makes use of satellite images available on the Internet. There is no indication if IMO has a ground receiving system to receive satellite images.

The IMO keeps measuring equipment and sensors in working conditions compliant with international standards and maintains their accuracy with its own calibration laboratory.

Information and communications technology (ICT)

A telecommunication system has been established at the IMO for international data exchange through the WMO Information System (WIS) / Global Telecommunication System (GTS). At the national level, data from the 40 RBSN stations are transmitted every three hours to IMO headquarters (Forecasting Office) by phone.

Data-processing and forecasting systems

The IMO makes use of numerical weather prediction (NWP) data and products made available by WMO World Meteorological Centres (WMCs) (Soares, 2018) on WIS/GTS, and GFS model outputs from the NOAA National Weather Service (US), available on the Internet. There is no information on any local NWP or the use of ensemble prediction system (EPS) products for probabilistic forecasting. Apparently, the IMO does not use Forecaster Workstations or decision-making tools for forecasting and warning services.

Public weather services

The IMO operates a 24/7/365 Forecasting Office. The IMO provides 24-hour forecasts and short- to medium-range forecasts (2 to 5 days). Weather forecasts are produced for decision makers and the public. It also provides specialized products to aviation, agriculture, and other sectors. These forecasts and warnings are disseminated through the radio, website, and social media.

Climate services

Data are available for nearly a century, and collected data are being digitized, archived, stored, and processed. There is no information on the IMO's Data Management System, and related database.

The IMO prepares and issues climate information and statistics (primarily monthly bulletins containing averages for temperature and precipitation), and makes them available to students, researchers, and agricultural, industrial, and irrigation offices. There is no reference to the use of products from WMO Global Producing Centres for Long-range Forecasts (GPC-LRF), to issue monthly and seasonal forecasts.

Agricultural meteorological services

The IMO has an agricultural and hydrological department, which is responsible for establishing and installing rain gauge stations in Iraq. This department collects and analyzes these data and produces monthly and yearly bulletins with statistical information, which are used by irrigation and agricultural offices, students, and researchers.

There is no information on the existence or use of crop models by the IMO, or blending in-situ and remote-sensing data to produce products and information for the agricultural community.

Aeronautical meteorological services

The IMO is the designated aeronautical meteorological service provider in Iraq. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The IMO receives OPMET and WAFS products operationally.

It is not known if the IMO has implemented cost-recovery of aeronautical meteorological services. It has a quality management system meeting international standards, and its aeronautical meteorological personnel meet competency, and education and training requirements. The IMO offers ISO certified aeronautical meteorological services and keeps certifications up-to-date.

Marine meteorological and/or oceanographic services

While noting that Iraq has a short coastline in the Persian Gulf, there is no reference to IMO's marine forecasts for this region.

Hydrological forecasts and assessments

Hydrological monitoring services in Iraq are under the Iraqi Ministry of Water Resources (IMoWR). In 2007, the US Geological Survey (USGS) assisted the IMoWR to set up a country-wide Hydrological Monitoring Network of over 100 remote gauging stations with METEOSAT communications and a data collection Central Receive Site, installed at IMoWR headquarters in Baghdad.

According to the WB (2006), despite Iraq's extensive hydraulic network, flood risks remain due to lack of flood control in the Great Zab River, and lack of appropriate modeling and forecasting tools.

As indicated earlier, the IMO has an agricultural and hydrological department, which is responsible for establishing and installing rain gauge stations in Iraq. Based on these data, IMO produces monthly and yearly bulletins with statistic information, which are used by irrigation offices.

Other related aspects, partnerships, and investments

Currently, the IMO contributes operational weather forecasts and climate information for 6 cities to the WMO's World Weather Information Service.

Iraq is a beneficiary country of the *Black Sea and Middle East Flash Flood Guidance System (BSMEFFGS)*[58], developed by the WMO Commission for Hydrology and the WMO Commission for Basic Systems, and in collaboration with the US National Weather Service, the US Hydrologic Research Center (HRC), and the US Agency for International Development/ Office of US Foreign Disaster Assistance.

Early Warning Systems

The IMO has an observing system to monitor hazardous weather events with adequate coverage of the country. However, the lack of radar, and use of phones to transmit observational data can cause errors. There is an indication that severe weather forecasts and warnings are issued by IMO, but no links to disaster management authorities are evident. However, IMO is an alerting authority for meteorological hazard threats and uses the Common Alert Protocol (CAP) to disseminate warnings.

Summary of IMO status and challenges

The IMO is a government service with a steady, regular budget. It has a well-organized structure, with a significant number of experienced staff close to retirement. However, the number of staff has increased steadily over the last 3-5 years. The staff require training in forecasting, observation systems, hydrology, and instrumentation. The observing network covers a large part of the country; however, it is still manual, and the transmission of data to IMO's headquarters is by phone, which is not reliable and often inaccurate. The IMO makes use of NWP data and products available on WIS/GTS and the Internet, and has no local modeling capability. It does not use ensemble prediction systems and probabilistic forecasts, which are required for impact-based forecasting and risk-based warnings. The IMO provides basic climate services , but no seasonal forecasts. Agrometeorological and hydrological monitoring, and very limited forecast products are prepared by IMO for irrigation and agricultural offices. The IMO is a designated aeronautical meteorological service provider in Iraq, and has the authority to issue warnings in the country. The IMO is ISO certified for all services. Major challenges include: a significant number of staff close to retirement, lack of modern in-situ and remote-sensing observing systems, and limited use of numerical weather prediction capabilities.

[58] See WMO, "Flash Flood Guidance System (FFGS) with Global Coverage", http://www.wmo.int/pages/prog/hwrp/flood/ffgs/index_en.php.

Iran

Socioeconomic context[59]

Iran had an estimated GDP in 2017 of US$447.7 billion, and a population of 80.6 million people. Iran's economy is characterized by the hydrocarbon sector, agriculture and services sectors, and a noticeable state presence in manufacturing and financial services. Economic activity and government revenues still depend to a large extent on oil revenues and therefore remain volatile. Iran's GDP growth in 2017/2018 dropped 3.8% as the effect of a large surge in oil revenues in the previous year dissipated. Most growth came from the non-oil sectors/services. Oil, agriculture, and services sectors have returned to their pre-sanctions levels of 2012/2013. But in the past two years, there has not been a strong recovery in key sectors such as construction and trade, restaurant and hotel services, following the stagnation in growth during sanctions and the knock-on effects of problems in the banking sector.

Poverty is estimated to have fallen from 13.1% to 8.1% between 2009 and 2013. This was likely due to a universal cash transfer program in late 2010, which preceded the elimination of subsidies on energy and bread. The program appears to have more than compensated for the likely increase in energy expenditures of less-well-off households, thus contributing to positive consumption growth of the bottom 40% of the population, even though overall consumption growth between 2009 and 2013 was negative. However, poverty increased in 2014, which may have been associated with declining social assistance in real terms due to inflation. Looking ahead, the falling real value of cash transfers due to inflation may counterbalance the positive impact on wellbeing from economic growth in 2016/2017 and 2017/2018 and exacerbate the impact of predicted negative growth after 2017/2018.

Climate[60]

Key historical climate trends indicate that:

- Mean annual temperature is 16.9°C (1901-2016)
- Mean annual precipitation is 223.1mm (1901-2016)

Climate projections for Iran indicate that:

- Mean annual temperature will rise by 2.5°C by 2050. Total annual hot days of temperature above 35°C will rise by 28.6 days by 2050.
- Mean annual precipitation will rise by 4.7mm by 2050.

Governance, organization, and management

The Islamic Republic of Iran Meteorological Organization (IRIMO) is a government agency established in 1955 providing public weather services and other services to the State and public. The IRIMO is under the supervision of the Ministry of Roads and Urban Development. In the Islamic Republic of Iran, meteorology (or hydrometeorology) is regulated by a legislative act. The IRIMO's areas of responsibility encompass: meteorology, climate, air/water quality, and oceanography. The IRIMO has Memoranda of Understanding (MoU) with the Environmental Protection Organization for warning information, with the National Risk & Hazard Management Organization for warning information, and with the Aviation

[59] See further information at https://www.worldbank.org/en/country/iran.
[60] See further information at https://climateknowledgeportal.worldbank.org/country/iran.

Sector for providing aviation products. The Islamic Republic of Iran became a Member of WMO in 1959.

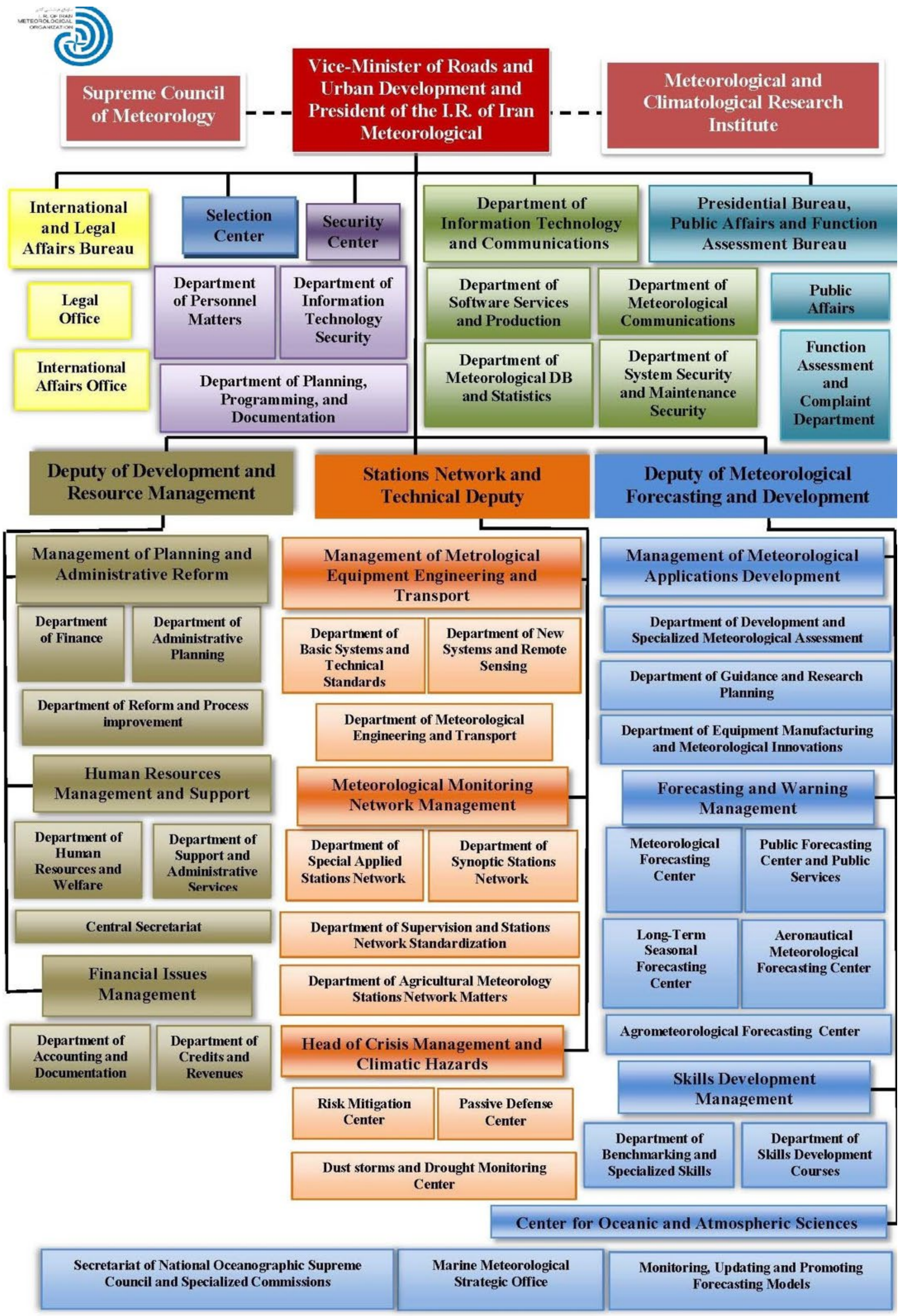
The IRIMO's main objectives are: (i) protecting life and property of people against weather, climate, and water-related hazards; and (ii) achieving national and international goals. The IRIMO's mission includes: (i) conduct research on the atmosphere and atmospheric phenomena; (ii) collect, organize and analyze meteorological data and information; and (iii) support sustainable development in agriculture, livestock, water management and irrigation, urbanization, dam construction, urban infrastructure, energy, land and marine communications, environmental studies, marine activities, and air pollution.

The IRIMO's functions include: (i) maintaining and equipping networks for atmospheric observations and other observations related to meteorology; (i) collecting observed meteorological data from all internal and external stations, quality control and transmitting data to other countries via the international meteorological communication network; (iii) establishment, maintaining and equipping telecommunication systems to facilitate meteorological data and information transfer at national and international levels; (iv) processing meteorological data and products; (v) preparing and issuing quality weather forecasts and warnings; (vi) providing meteorological services to aviation, maritime, transport, water resources, agriculture sectors, and other human activities; (vii) maintaining a climate database and preparing statistics; and (viii) performing research, development and training activities. The IRIMO provides 24/7/365 weather, climate, and water-related services, and has the legal authority to issue warnings, hence contributing to the preservation of life and property, disaster risk reduction, climate change adaptation, and to the socio-economic development of the country.

The IRIMO's only source of funding is from the government, as commercial activities are not permitted. There is no information on IRIMO's budget, however, it is understood that in the last 3-5 years its budget has steadily increased. It is not known whether IRIMO has Quality Management Systems (QMS). The IRIMO has a development/strategic plan in place, covering the next 3-5 years.

The IRIMO is headed by a President and three deputies who deal with development and resource management, technical and station networks, and meteorological forecasting and development. The Deputy of Development and Resource Management is responsible for: (i) management of planning and administration reform; (ii) human resources management and support; and (iii) financial management. The Stations Network and Technical Deputy are responsible for: (i) management of equipment engineering and transport; (ii) meteorological monitoring network management; and (iii) crisis management and climate hazards. The Deputy of Forecasting and Development is responsible for: (i) skills development management; (ii) Center of Oceanic and Atmospheric Sciences; (iii) management of meteorological applications development; and (d) forecasting and warning management. A Supreme Council of Meteorology drives the work of IRIMO. The IRIMO established the Atmospheric Science and Meteorological Research Center in 1995 (see ***Figure 23***).

Figure 23 – Organizational Chart of the IRIMO



Source: IRIMO website.

The IRIMO has a total of 2639 personnel at headquarters and regional offices, of which 2228 are male and 411 are female. The IRIMO has 89 staff at the management level, 1041 meteorologists, 214 meteorological technicians, 84 researchers, 808 support staff, and 403 classified as other staff. The number of IRIMO staff with a university degree is 40. The age of the staff ranges as follows: (a) less than 20 year: 0; (b) 20-30 years: 149 staff; (c) 30-40 years: 1280 staff; (d) 40-50 years: 850 staff; and (e) over 50 years: 360 staff. Number of staff due to retire in next 5 years: 287. Staff numbers have decreased over the last 3-5 years. Areas in which IRIMO staff training is needed are: (a) forecasting; (b) research; (3) observations; and (4) instrumentation and ICT.

Major socio-economic user sectors and their needs

The IRIMO contributes to the economic and social development of the country by meeting the weather, climate and environmental information requirements of various public and private socio-economic sectors, including transport (aviation, marine, and road), agriculture, water management, irrigation, construction, energy, health, and environment.

Observing systems (weather, climate, water and environmental-related)

The meteorological and environmental observation network covers a large part of the territory. The IRIMO's network consists of 79 regional basic synoptic network (RBSN) surface stations, of which 9 are climate stations; and a network of 9 radars (7 Band C; 1 Band S; and 1 Band X) to monitor severe weather in the Islamic Republic of Iran (see ***Figure 24*** for radar locations). The IRIMO uses satellite imagery, but it is not clear from where these are obtained.

Figure 24 – IRIMO Radar Network

Source: IRIMO website (green – Band C; blue – Band S; and red – Band X).

Information and communications technology (ICT)

A telecommunication system has been established at the IRIMO to collect local meteorological data and for international data exchange through the WMO Information System / Global Telecommunication System (GTS). The DNM hosts a *WMO Global Information System Centre (GISC) in Tehran*, which acts as regional coordinator for the real-time operations of the WIS network and provides entry points to WIS through (a) the *GISC Cache Services* function; and (b) the Discovery, Access, and Retrieval (DAR) Catalog. The domestic telecommunication system uses radio and VSAT to collect and disseminate meteorological information and data nationally. The IRIMO uses MESSIR-COM (supported by Corobor) and Transmet (supported by MFI) as automatic message switching system clusters required to manage the data process through scripts to pull/push the data.

Data-processing and forecasting systems

The IRIMO has two PC-Cluster systems: (1) 8-Nodes with dual 3.8GHZ Intel CPU for research; and (2) 32-Nodes with dual 3.2GHZ Intel CPU for operational purposes. It runs a MM5 model providing forecasts up to 102h, using initial and boundary conditions from the GFS model. The IRIMO does not use ensemble prediction systems. The IRIMO carries out verification of its MM5 outputs, and post-processing (applies Kalman filters) of temperature. NWP model outputs are made available on a website for the public, media, and other authorities.

The IRIMO retrieves data from ECMWF, UKMO, and NOAA/NCEP on the WIS/GTS, which are used in the forecasting office via two visualizations systems: MESSER-VISION (supported by Corobor) and Synergie (supported by MFI).

Public weather services

The IRIMO provides forecasts up to 3 days ahead, weekly, monthly, and seasonal. Weather forecasts are produced for government decision makers and for the public. It also provides specialized products to aviation, marine, and other public and private sectors. These forecasts and warnings are disseminated through the radio, Dial-a-weather System (134), website, and social media. The IRIMO provides live and recorded TV weather presentations, publishes in newspapers, and issues statements.

Climate services

The IRIMO uses MESSIR-CLIM (supported by Corobor) database to store and analyze climate data. The IRIMO prepares and issues climate information and statistics, and monthly and seasonal forecasts.

Agricultural meteorological services

The IRIMO has a National Drought Warning and Monitoring Center, which was established in 2008. This Center issues daily, weekly, monthly, seasonal, and annual products for agriculture and social purposes. Some products include: (a) drought index maps; (b) agriculture drought maps; (c) mean temperature maps and anomalies; (d) snow cover extent maps, anomalies, graphs, and tables; (e) dust maps with horizontal visibility; and (f) relative humidity, evaporation and sun hours maps. No further information on agrometeorological products and services by IRIMO is available.

Aeronautical meteorological services

The IRIMO is the designated aeronautical meteorological service provider in the Islamic Republic of Iran. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The IRIMO receives OPMET and WAFS products operationally. The IRIMO uses AeroWeb (supported by MFI) as a pilot briefing system.

Marine meteorological and/or oceanographic services

Daily marine meteorological forecasts and warnings for the Persian Gulf and the Caspian Sea are broadcasted via national and local radio, television programs, and also via special channels for fishermen and ships. The IRIMO runs the SWAN model for the Persian Gulf and the Caspian Sea for up to 3 days.

Hydrological forecasts and assessments

Hydrological monitoring and forecasting services in the Islamic Republic of Iran are under the responsibility of the Department of Hydrology of the Ministry of Water and Power. No details have been found in relation to the hydrological network.

Other related aspects, partnerships, and investments

Currently, the IRIMO contributes operational weather forecasts and climate information for 30 cities to the WMO's World Weather Information Service.

The IRIMO hosts a WMO Regional Training Center.

Early Warning Systems

The IRIMO has a robust observing system to monitor hazardous weather. Severe weather forecasts and warnings are issued. The IRIMO is the alerting authority for meteorological hazards using the Common Alert Protocol (CAP).

Summary of IRIMO status and challenges

The IRIMO is a government service with no commercial services. It has a well-organized structure, with a significant number of experienced staff. The IRIMO operates 24/7/365. The observing network covers the whole country. It has robust information and communication technologies. The IRIMO has limited numerical weather prediction capacities, and does not use ensemble prediction systems and probabilistic forecasts. The IRIMO is the designated aeronautical meteorological service provider in the Islamic Republic of Iran, and has the authority to issue warnings in the country. It has well-established marine forecasting capabilities, and early warning systems. Major challenges include: limited numerical weather prediction capabilities, and limited coordination and collaboration with the departments responsible for hydrology.

GULF COOPERATION COUNCIL (GCC) COUNTRIES

Saudi Arabia

Socioeconomic context[61]

Saudi Arabia is one of the six Gulf Cooperation Council (GCC) countries. The Saudi Arabian economy grew at a moderate rate of 1.7% in 2016 as oil prices continued to remain below US$50 per barrel for almost the entire year. The data for the first half of 2017 indicates that GDP in the first quarter deteriorated, registering a 0.5% contraction on a year-over-year basis. The crude oil production index declined by 4.4% due to the OPEC agreement to curb production. However, non-oil GDP grew by around 0.7% in the same period. Saudi Arabia's GDP growth rate slowed to 0.4% in 2019 and was predicted to rise to an average of 2.1% over 2020-2021.

The fiscal deficit slightly deteriorated to 16.6% of GDP in 2016 compared to 15.8% a year earlier. In September 2016, the authorities drove fiscal consolidation within the Fiscal Balance Program by cutting the civil service remuneration of approximately two-thirds of employed nationals. However, a decision was taken in April 2017 to reverse some of the cuts (including all allowances, financial benefits, and bonuses, but not including the thirteenth month salary payments) after 6 months amidst reports of better than anticipated effects of other measures of fiscal consolidation that had also been implemented.

Climate[62]

Saudi Arabia is characterized by a desert climate, with the exception of the southwestern part of the country, which has a semi-arid climate. The country experiences dry and cool winters with freezing nighttime temperatures; and severe frost and snow occur in the mountainous regions for several weeks. Summers in the central region are extremely hot and dry, with temperatures exceeding 50°C, while the eastern and western regions experience hot and humid summers. Key historical climate trends indicate:

- That general warming has been reported all over the country. Since 1950, the average annual temperature has increased by 0.15°C in Tabuk, Makkah, and Al Ahssa, and by 0.75°C in Khamis Mushait, Wadi Al Dawasser, and Yanbu.
- During the 20th century, there has been great variability in precipitation, and decreases of up to 50 mm in the northern and southwestern parts of the country.

Climate projections for Saudi Arabia indicate that:

- By 2050, the mean annual temperature is projected to increase by 2°C. With increased frequency and duration of heat waves, the highest increases are projected for the northern parts of the country by up to 3°C from June to August.
- Mean annual precipitation is expected to increase by 7% by 2050.

[61] See further information at http://www.worldbank.org/en/country/gcc.

[62] See further information at https://climateknowledgeportal.worldbank.org/country/saudi-arabia.

Governance, organization, and management

The General Authority for Meteorology and Environmental Protection (GAMEP) is a government agency established in 1950, responsible for the provision of public and other related weather services to the State or to the public. The GAMEP is under the supervision of the Ministry of Environment, Water, and Agriculture. The GAMEP's functions are described in a Royal Decree. The GAMEP represents the Kingdom of Saudi Arabia in all aspects related to environmental protection and meteorology, both at regional and international levels. At the national level, the GAMEP plays an important role in spreading meteorological and environmental awareness in Saudi society . Saudi Arabia became a Member of WMO in 1959.

Among its tasks, the GAMEP is responsible for (a) monitoring weather and issuing forecasts to protect life and property through an integrated system compliant with international standards in meteorology; and (b) monitoring and predicting environmental conditions to support the optimization and rationalization of the Kingdom's natural resources. Through effective coordination with relevant authorities in all environmental topics, the GAMEP contributes to the development of strategies, plans, legislation, and regulations to protect the environment, in addition to monitoring, studying and analyzing the impacts of all activities affecting the environment. The GAMEP provides 24/7/365 meteorological and environmental services, and has the legal authority to issue warnings, hence contributing to the preservation of life and property, disaster risk reduction, climate change adaptation, and to the socio-economic development of the country.

The GAMEP's only source of funding is from the government, as commercial activities are not permitted. The total budget of GAMEP in 2017 was 457,8 million Saudi Riyal (equivalent to approximately US$122,07 million). In the last 3-5 years its budget has been stable. The GAMEP has implemented Quality Management Systems (QMS) for aviation services.

In 2013 the Kingdom of Saudi Arabia formulated ambitious plans to diversify its economy away from its heavy dependence on oil resources. It has adopted Vision 2030 for the Kingdom of Saudi Arabia, an ambitious strategy to transform the Kingdom's oil-dependent economy through diversification and privatization of substantial State assets. The Vision 2030 has environmental sustainability as an important pillar for the future development and economic growth of the Kingdom. The Vision 2030 reads as follows:

"By preserving our environment and natural resources, we fulfill our Islamic, human, and moral duties. Preservation is also our responsibility to future generations and essential to the quality of our daily lives. We will seek to safeguard our environment by increasing the efficiency of waste management, establishing comprehensive recycling projects, reducing all types of pollution, and fighting desertification. We will also promote the optimal use of our water resources by reducing consumption and utilizing treated and renewable water. We will direct our efforts towards protecting and rehabilitating our beautiful beaches, natural reserves, and islands, making them open to everyone. We will *seek the participation of the private sector and government funds in these efforts."*

A National Transformation Plan (NTP) provides the framework for operationalizing this *Vision*, and spells out the specific initiatives to be implemented by the Government, including those on the environment. The GAMEP has been tasked with the implementation of environmental initiatives. There are 18 NTP initiatives (see ***Table 4***) with various initiatives related to weather, climate, and the environment.

Table 4 - National Transformation Plan initiatives

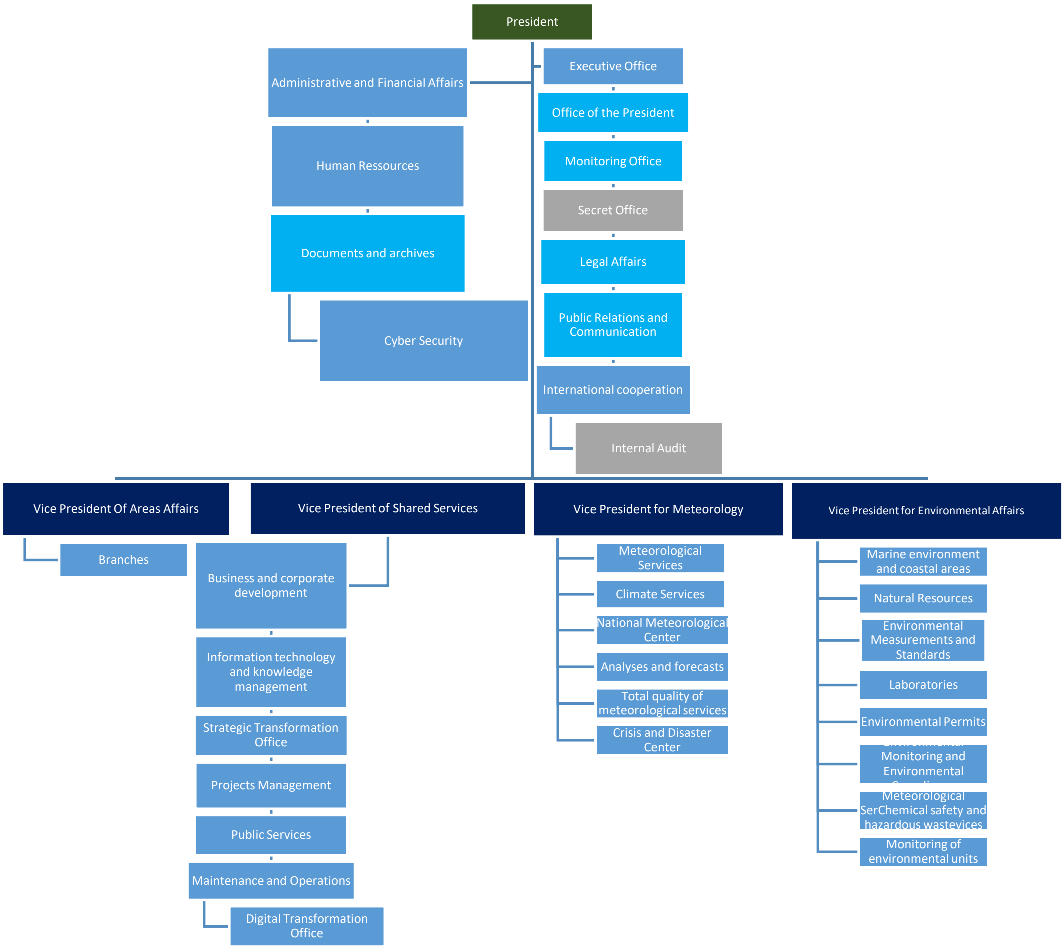
Initiative	Description	Strategic Objective
1	Establish a central unit to monitor air quality and emissions from source	Improve air quality monitoring in Kingdom of Saudi Arabia
2	Establish a national program for environmental monitoring of ground and surface water	Improve environmental control of water
3	Marine and Coastal Environmental Protection	
4	Effluent Discharge Monitoring	
5	Rehabilitation of contaminated areas	
6	Manage municipal solid waste and encourage recycling	Sound management of chemicals and waste
7	National Program of Chemical Safety	
8	Integrated management of industrial and hazardous waste	
9	Modernize meteorological services and expand funding sources, strengthening governance, health, safety and environmental sustainability	Strengthening governance, health ,safety and environmental sustainability
10	National program of environmental awareness and sustainable development	
11	Strategic environmental assessment of initiatives within the National Transformation Plan	
12	Upgrade environmental accreditation and licensing	
13	Periodic environmental inspection of gas stations and service centers	
14	Establish a Climate Change Centre	Mitigation of and adaptation to climate change
15	Increase the geographical coverage of monitoring stations (surface and upper atmosphere) and remote sensing	Develop and provide services for weather, climate, and environmental monitoring to contribute to the safety and welfare of the community, and promote sustainable development
16	Develop numerical models to improve the accuracy of weather forecasts	
17	Establish a center for environmental meteorological information and early warnings on weather and pollution	

18	Develop the meteorology system and the implementation of meteorological related regulations	

Source: GAMEP.

The GAMEP is headed by a President and four Vice-Presidents. GAMEP has a Crisis and Disaster Center and 7 regional offices – Makkah, Riyadh, Tabuk, Eastern, Madinah, Southern, and Jazan – to provide services adapted to the regions (see ***Figure 20***).

Figure 20 – Organizational Chart of the GAMEP



Source: GAMEP website.

The GAMEP has a total of 659 personnel at headquarters and regional offices, of which 653 are male and 6 are female. The GAMEP has 91 staff at the management level, 156 meteorologists, 315 meteorological technicians, 52 climatologists, 2 researchers, 21 support staff, and 22 classified as other staff. The number of GAMEP staff with a university degree is 186. The age of the staff ranges as follows: (a) less than 20 years: 11 staff; (b) 20-30 years: 144 staff; (c) 30-40 years: 218 staff; (d) 40-50 years: 172 staff; and (e) over 50 years: 105 staff. Number of staff due to retire in next 5 years: 45.

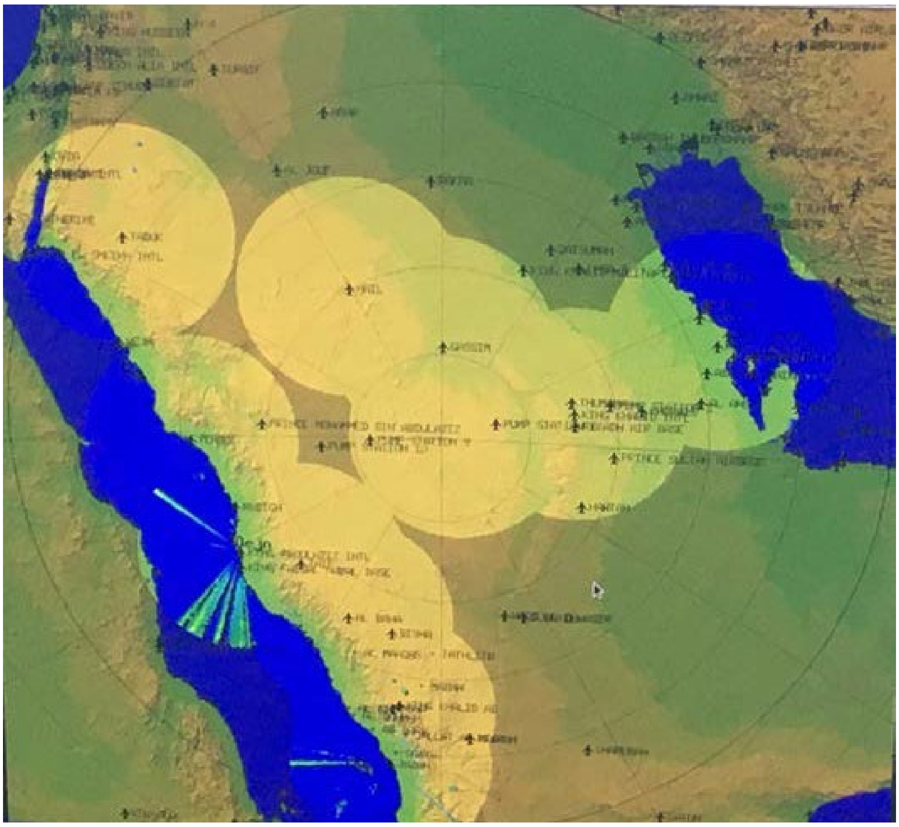
Major socio-economic user sectors and their needs

The GAMEP contributes to the economic and social development of the country by meeting the weather, climate, and environmental-related information requirements of various public socio-economic sectors. The GAMEP has a press relations office that regularly interacts with the press.

Observing systems (weather, climate, water and environmental-related-related)

The meteorological and environmental observation network covers a large part of the territory. The GAMEP's network consists of 109 regional basic synoptic network (RBSN) surface stations, of which 44 are climate stations; and a network of 13 radars to monitor severe weather events in Saudi Arabia (see ***Figure 21*** for radar coverage). The surface observing network requires upgrade. The GAMET uses MESSIR-SAT and Tecnavia System to retrieve satellite imagery.

Figure 21 – GAMEP Radar Network



Source: GAMEP website.

Information and communications technology (ICT)

A telecommunication system has been established at the GAMEP to collect local meteorological data and for international data exchange through the WMO Information System / Global Telecommunication System (GTS). The domestic telecommunication system uses a Unified Data Collection System (UDCS) combining radio, computer network, and VSAT to collect and disseminate meteorological information and data nationally. The GAMEP uses MESSIR-COM (national) and MESSIR-WIS (international) (both supported by Corobor), and

Moving Weather (supported by IBL) as automatic message switching system clusters required to manage the data process through scripts to pull/push the data.

Data-processing and forecasting systems

The GAMEP has a DELL 670 Precision with 2 Processors. 4 GB RAM, 400 GB disk storage; it runs the WRF (NCEP) limited area model (three nested domains) in two configurations, with and without data assimilation, on two different clusters which are used for operational activities. No computing resources are available for research activities to improve the model. The version with no data assimilation runs with an outer domain at 54km resolution and inner domain at 2km resolution and provides forecasts up to 48h. The version with data assimilation runs with an outer domain of 27km and inner domain of 2.4 km. The forecast range for this model configuration is 72h for the outer domain and 48h for the inner domain. Both model versions are initialized with the global model (GFS) from NCEP, which also provides boundary conditions. If initialization and boundary conditions files are not available, the model cannot run, and no products are available for forecasters. The NWP models are run using simple scheduling, with no monitoring tools to maintain operational activities 24/7. Verification of model outputs to assess performance of the system is not done routinely. Verification scores (using the MET package) are calculated when needed. NWP model outputs are post-processed to generate website products for forecasters, the public, media, and other authorities. Some products are password protected.

In collaboration with NCAR, the GAMEP developed a WRF-CHEM based dust forecast system for the Saudi Arabian area. The preliminary WRF-Chem dust forecasts for the Saudi Arabian domain at 21.6 km resolution began in 2013. The daily dust forecasts are displayed on the website. The displayed variables include aerosol optical depth at 600 nm, dust concentrations at surface, and vertically integrated dust concentrations. The dust forecasts are constantly examined and compared with WMO dust observations and forecasts in an effort to understand the strengths and weaknesses of the modeling system.

Some NWP products for use in the forecasting office are made available via two visualization systems: MESSER-VISION (supported by Corobor) and Visual Weather (supported by IBL). Forecasters have access to global model data, but visualization of ECMWF data (they have a license to access ECMWF data) is not fully functional on these systems.

The GAMET uses the IRIS System (supported by the Finnish Meteorological Institute) for radar data processing and display.

Public weather services

The GAMET provides nowcasting (0-12 hours ahead); short-range forecasts (12 hours to 2 days); and medium-range forecasts (3 to 5 days). Weather forecasts are produced for government decision makers and for the public. It also provides specialized products to aviation, marine, and other public sectors. These forecasts and warnings are disseminated through the radio, website, and social media.

Currently, weather forecasts and warnings are presented by GAMEP staff at studios in Riyadh using visualization software and hardware organized by Saudi TV.

Climate services

More than 75% of data have been digitized, archived, stored and processed, using MESSIR-CLIM, supported by Corobor.

The GAMEP prepares and issues climate information and statistics, and makes them available on its website and in the Climate Bulletin. It uses regional outlooks, and statistical and dynamic downscaling of products from WMO Global Producing Centres for Long-range Forecasts (GPC-LRF), and to issue monthly and seasonal forecasts over Saudi Arabia.

Agricultural meteorological services

The GAMEP issues a drought monitoring report. No other information is available on agrometeorological products and services from GAMEP.

Aeronautical meteorological services

The GAMEP is the designated aeronautical meteorological service provider in Saudi Arabia. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The GAMEP receives OPMET and WAFS products operationally. The GAMEP uses MESSIR-AERO, supported by Corobor, as a pilot briefing system.

The GAMEP has no cost-recovery for aeronautical meteorological services. It has a quality management system meeting international standards, and its aeronautical meteorological personnel meet competency, and education and training requirements. The GAMET is ISO certified to provide aeronautical meteorological services, and for other services, and keeps the certification up-to-date.

Marine meteorological and/or oceanographic services

Daily marine meteorological forecasts and warnings for the Red Sea and the Arabian Gulf are broadcast via national and local radio, television programs, and also via special channels for fishermen and ships.

Hydrological forecasts and assessments

Hydrological monitoring and forecasting services in Saudi Arabia are dispersed across multiple departments, including the Ministry of Agriculture and Water, and the Saudi Geological Survey. Saudi Arabia's hydrological network plays an important role in the management of the country's water resources, particularly in situations of drought and heavy rainfall. No details have been found on the hydrological network.

Other related aspects, partnerships, and investments

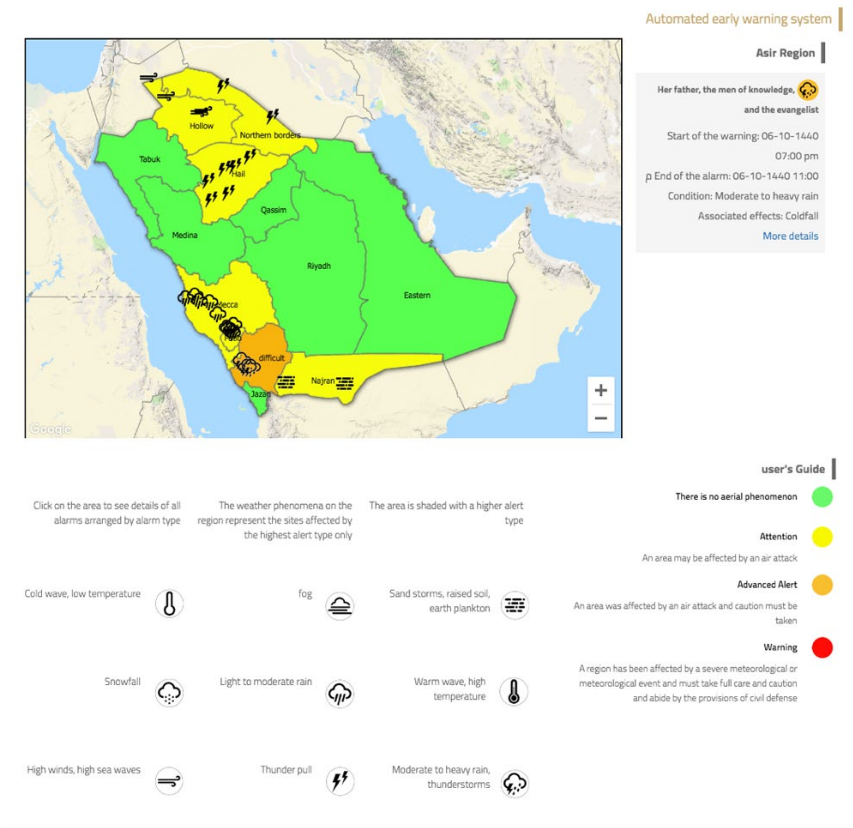
Currently, the GAMEP contributes operational weather forecasts and climate information for 17 cities to the WMO's World Weather Information Service.

Since 2018, Saudi Arabia has been a member of the ESCAP/WMO Panel on Tropical Cyclones.

Early Warning Systems

The GAMEP has a robust observing system to monitor hazardous weather events. Severe weather forecasts and warnings are issued. The GAMEP implemented a color-coded warning system (see ***Figure 22***). The GAMEP does not use the Common Alert Protocol (CAP).

Figure 22 – *Color-coded Warning System*



Source: GAMEP website.

Summary of GAMEP status and challenges

The GAMEP is a government service with no commercial services. It has a well-organized structure, with a significant number of experienced staff. The GAMEP operates 24/7/365. The observing network covers a large part of the country. It has robust information and communication technologies. The GAMEP has limited numerical weather prediction capacities, and does not use ensemble prediction systems and probabilistic forecasts. The GAMEP is the designated aeronautical meteorological service provider in Saudi Arabia, and has the authority to issue warnings. It has well-established marine forecasting capabilities, and early warning systems. Major challenges include: limited numerical weather prediction capabilities, a surface observing network requiring upgrade, and limited coordination and collaboration with the departments responsible for hydrology.

Kuwait

Socioeconomic context[63]

Kuwait is one of the Gulf Cooperation Council (GCC) countries. OPEC-related oil production cuts have weighed on growth, and GDP was anticipated to shrink by 1% in 2017, following a 3.6% increase in 2016. Hydrocarbons account for nearly half of GDP, and the OPEC's June decision to extend production cuts until the first quarter of 2018 has weighed on oil output and exports. Outside the oil sector, economic activity has been supported by the five-year Development Plan (2015/16-2019/20), which contains several large infrastructures,

[63] See further information at http://www.worldbank.org/en/country/gcc

transport, and refinery projects. In January, the government released the New Kuwait 2035 Strategic Plan, which aims to transform the country into a regional, financial and commercial hub as part of long-term economic diversification efforts. Growth dipped to 0.4% (y/y) in 2019, and was expected to pick up to 2.2% in 2020, when the OPEC production cuts are due to expire, and 2% in 2021.

Incoming data suggest that non-oil-related economic activity in Kuwait is continuing to expand. Consumer confidence rose in July 2017 to its highest level in almost two years, although it remains well below 2014 levels prior to the fall in global oil prices. Consumer spending, as reflected in point-of-sale transactions, strengthened in Q2, rising 9% year-per-year. The correction in property markets over the past two years appears to have run its course: real estate prices have stabilized in recent months, and residential sector sales rose by a robust 43% year-per-year. While the banking sector remains well capitalized and generally healthy, bank lending to both firms and households has slowed over the past year. However, growth in lending to "productive" business sectors (this excludes real estate and securities lending) remained resilient at 8.4% year-per-year.

Climate[64]

Kuwait's climate ranges from subtropical desert to arid throughout the country. The Sudanese low pressure and Africa and Siberian high pressure systems influence the climate of Kuwait by controlling the duration of the hot, humid Al-Kaus Winds. Kuwait receives practically no rain between June and September, and high-speed northeastern winds dominate in May and June. The rainy season begins in October and goes through May. Key historical climate trends indicate:

- Warming of about 4.19°C per century since the 1950's in Askaniia Nova.
- A reduction in precipitation of 0.88 mm/month per century for the period 1951-2000 at Kuwait International Airport.

Climate projections for Kuwait indicate that:

- Mean annual temperature is expected to increase by 2°C by mid-century. Frost days are projected to decrease by 2 days, while the heat wave duration index is projected to increase by 15 days (heat waves are projected to become regular).
- Mean annual rainfall is projected to decrease by 3%. The greatest precipitation reduction is projected to occur from December to February. However, rainfall intensity is projected to increase, although projections diverge as to whether the country will become wetter or drier. The maximum amount of rain that falls in any 5-day period is projected to increase by 32%, while the maximum period between rainy days is expected to decrease.

Governance, organization, and management

The Kuwait Meteorological Department (KMD) is a government agency established in 1953. It is currently under the supervision of the Directorate General of Civil Aviation. The KMD's functions are described in a ministerial decree. Its goal is to monitor, and study the weather

[64] See further information at https://climateknowledgeportal.worldbank.org/country/kuwait.

and climate in Kuwait. The KMD has been a member of the World Meteorological Organization (WMO) since 1962. It is also an active member of the Permanent Committee for Meteorology and Climate of the Gulf Cooperation Council and the Permanent Arab Meteorological Committee of the League of Arab States. The KMD is the sole authority for providing weather and climate services in the country.

The KMD provides 24/7/365 weather and climate-related services, and has the legal authority to issue warnings, hence contributing to the preservation of life and property, disaster risk reduction, and climate change adaptation. The KMD is the meteorological authority (as per ICAO Annex 3) and met service provider for aviation.

The KMD's sole source of funding is from the Government. Commercial services are not permitted. Its annual budget is around US$6,6 million. In the last 3-5 years its budget has been stable. The KMD has five superintendents who supervise sections dealing with Forecasting, Climate, Observing Network, Communications, and Instrument Maintenance. It has Quality Management Systems (QMS) and a development/strategic plan for the next 3-5 years.

The KMD has a total of 145 staff, of which 115 are male and 30 are female. The KMD has 15 staff at the management level, 20 meteorologists, 25 meteorological technicians, 5 climatologists, 5 researchers, 70 support staff, and 5 classified as other staff. The number of KMD staff with a university degree is 48. It is expected that 29 staff will retire in the next 5 years. Staff numbers have increased steadily over the last 3-5 years. Areas in which KMD staff training is needed are: (a) forecasting; (b) climatology; (3) instruments; and (4) computer skills.

Major socio-economic user sectors and their needs

The KMD is government or state owned, and provides public weather services or other services to government sectors (including Air Force, National Guard, Ministry of Transport, Ministry of Interior, Ministry of Electricity and Water, Navy, Coast Guard, Kuwait Ports, Marine Operations and Fire Department) and to the public. It also provides climate statistics to educational institutions and other sectors.

Observing systems (weather, climate, water and environmental-related-related)

The meteorological, marine, and environmental observation network covers a large part of the territory. The KMD's network consists of 27 automatic weather stations, of which 12 are synoptic, 4 agrometeorological stations, 6 marine stations, and 5 climate stations. The KMD operates 1 doppler weather radar to monitor dust (clouds, height and density) over Kuwait, 14 wind-shear alert systems and 6 independent automatic weather stations at the Kuwait Airport which are used primarily to improve flight safety. The KMD's network also includes specialized systems to measure radiation and elements of the upper atmosphere (from Ozone layers up to 16km in vertical height). The KMD maintains measuring equipment and sensors in working conditions compliant with international standards. The KMD uses MESSIR-SAT, supported by Corobor, to access Meteosat satellite imagery.

Information and communications technology (ICT)

A telecommunication system has been established at the KMD to collect local meteorological data and for international data exchange through the WMO Global Telecommunication System (GTS).

Data-processing and forecasting systems

The KMD runs 3 models: KMeso for the region, KLaps for the Middle East, and KMet WAM for the Gulf Waters, up to 48 hours ahead.

The KMD makes use of MESSIR-VISION, supported by Corobor, as a Forecaster Workstation and decision-making tool for forecasting and warning.

Public weather services

The KMD provides national forecasts up to 48 hours ahead, and localized forecasts for 16 cities. Weather forecasts are produced for government decision makers and for the public. It also provides specialized products to aviation, marine, and other sectors. These forecasts and warnings are disseminated through the automatic telephone service, website, KuwaitMet App for smart phones, and through KuwaitMet accounts on Twitter and Instagram.

Climate services

The KMD prepares and issues climate information and statistics which are available to users on its website. These products are: (a) climate reports (for annual rainfall); (b) dust statistics; (c) climate over Kuwait per season; (d) climate statistics (daily and monthly) per stations and per climate elements (i.e. temperature, humidity, and wind speed).

Agricultural meteorological services

No information is available on agrometeorological services provided by KMD.

Aeronautical meteorological services

The KMD is the designated aeronautical meteorological service provider in Kuwait. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The KMD uses the MESSIR-AERO, supported by Corobor, as a pilot briefing system. It has password-protected web pages to provide additional meteorological services for aviation. The KMD is ISO certified for aeronautical meteorological services.

Marine meteorological and/or oceanographic services

Daily marine meteorological forecasts and warnings for the Gulf Waters are issued up to 48 hours ahead. As indicated, the KMD runs a KMet WAM model for wave forecasts.

Hydrological forecasts and assessments

Water-related aspects are managed by the Water Research Center and Kuwait Institute for Scientific Research. No information is available on the monitoring system.

Other related aspects, partnerships, and investments

Currently, the KMD does not contribute operational weather forecasts and climate information for the capital city to the WMO's World Weather Information Service.

Early Warning Systems

The KMD has a robust observing system to monitor hazardous weather. Watches (up to 24 hours before expected severe weather events) and warnings (up to 6 hours before the severe weather event) are issued for light rain, wind, fog, thunderstorms, dust, general alert, high wave, frost and heavy rain. The KMD uses a color-coded watch and warning system (i.e. yellow for watch, and red for warning). It uses the Common Alert Protocol (CAP) for emergency alerts and public warnings.

Summary of KMD status and challenges

The KMD is a government service with no commercial activities. It has an adequate number of experienced staff (mostly foreigners from Egypt). It operates 24/7/365. It maintains a robust observing network, especially at airports. The KMD has adequate information and communication technologies. The KMD has good numerical weather prediction capacities, however, it needs to strengthen the use of ensemble prediction systems and probabilistic forecasts. It provides adequate climate services. There is no information available on its agrometeorological monitoring and forecast services. The KMD is a designated aeronautical meteorological service provider in Kuwait, and has the authority to issue warnings in the country. It has well-established marine forecasting capabilities, and early warning systems. Major challenges include: a significant number of staff close to retirement age.

Bahrain

Socioeconomic context[65]

Bahrain is one of the Gulf Cooperation Council (GCC) countries. Bahrain has maintained an expansionary fiscal stance since 2009, resulting in general government deficits, and its economy has been negatively affected by hydrocarbon prices. The situation worsened in 2016 following a 10% decline in oil revenues and an overall fiscal deficit of 13% of GDP (up from 12.8% in 2015). The deficit spending helped maintain economic growth at 3%, but brought reserves down to a concerning 1.2 months of imports and increased public debt to 65% of GDP.

Data for the first quarter of 2017 indicated a slight up-tick in growth, especially in the non-oil sector which grew by 4.4% annually compared to 2016 (3.7%). Bahrain has introduced fiscal consolidation, and revenue enhancing measures such as higher tobacco and alcohol taxes, and fees for government services. The proposed GCC-wide introduction of VAT, which was expected to be implemented from the beginning of 2018. Inflation increased in 2016 primarily due to ongoing subsidy reform and in spite of weakening demand: the headline Consumer Price Index (CPI) rose by 2.8%. The financial sector assessment by the International Monetary Fund (IMF) indicates that the banking sector has remained resilient with adequate capitalization and liquidity levels, as regulation and supervision of the sector were strengthened by the central bank. However, lower credit growth of 2.8% in 2016, compared to the 9.8% average for the five years prior to this, and along with a quarterly drop of more than 2.5% in the number of people employed in the first quarter of 2017, highlights the problem of weak demand in the economy. Climate[66]

[65] See further information at http://www.worldbank.org/en/country/gcc.

[66] See further information at https://climateknowledgeportal.worldbank.org/country/bahrain.

Key historical climate trends in Bahrain indicate:

- Mean annual temperature is 27°C (1901-2016)
- Mean annual precipitation is 73.6mm (1901-2016)

Climate projections for Bahrain indicate that by 2050:

- The mean annual temperature will rise by 2.3°C. The annual number of hot days above 35°C will rise by 26.2 days.
- The mean annual precipitation will rise by 10.3mm.

Governance, organization, and management

The Bahrain Meteorological Directorate (BMD) is a government agency established in 1943, but the first meteorological records were made in 1902. The NIM is currently supervised by the Ministry of Transport and Telecommunications. The Kingdom of Bahrain joined the World Meteorological Organization (WMO) in 1980.

The BMD's mission is described in a decree, as to "develop and strengthen meteorological services to keep up with international standards and developments which will reflect on the quality of services to meet the requirements of various sectors in the Kingdom and to achieve public safety and the reduction of natural disasters and environmental losses, and contribute to the Bahrain Economic Vision 2030". The BMD's main objectives are: (a) to operate and maintain observations; (b) to provide a meteorological service that meets the needs of aviation, mariners, and the military; (c) to issue weather forecasts to the general public and the media; (d) to satisfy the needs of Government Departments and various companies involved in agriculture, industry, health and the environment; and (e) to meet the needs of future Bahraini generations for reliable climate records.

The BMD's main functions include:

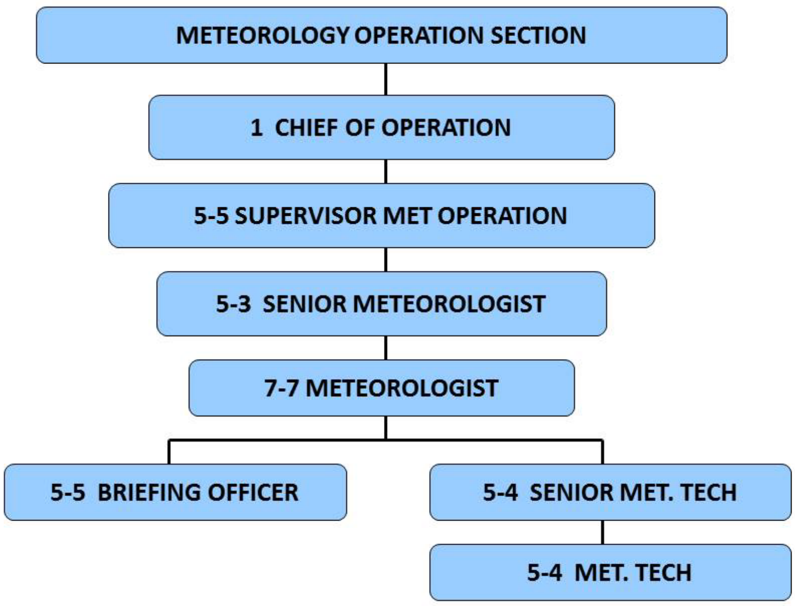
(a) To provide timely and accurate weather forecasts for the public, civil aviation, defense forces, agriculture, marine, and other human activities, all on a routine basis;
(b) To issue early warnings for critical weather and dangerous sea conditions to the public and agencies involved in disaster mitigation;
(c) To strengthen BMD's engagement with high-level decision makers and stakeholders in government and the media – to emphasize the value of public warnings;
(d) To exchange meteorological data, forecasts, and warnings to meet national and international obligations;
(e) To support research and training in meteorology, and education programs to promote understanding of the importance of weather and climate information;
(f) To provide climate services to all sectors of the economy;
(g) To perform climate change and environment studies;
(h) To maintain a technically advanced observation station network to monitor weather conditions;
(i) To discharge international obligations (WMO/ICAO) in meteorology;
(j) To represent the Government at regional and international forums.

The BMD's funding is from the Government, with limited cost recovery from the provision of meteorological services for aviation. The total budget of BMD is 1,2 million Bahrain dinars (equivalent to approximately US$3,2 million). In the last 3-5 years its budget has steadily increased. It has Quality Management Systems (QMS).

The BMD has a development/strategic plan in place covering the next 3-5 years. The BMD's development strategy has enabled it to provide effective meteorological services for improved protection of life, property, and the environment; increase safety on land, at sea, and in the air; enhance quality of life and contribute to the national economic vision; and support international obligations to WMO and ICAO, among others. Its vision is to achieve the highest global standards of service provision for public safety and sustainable development.

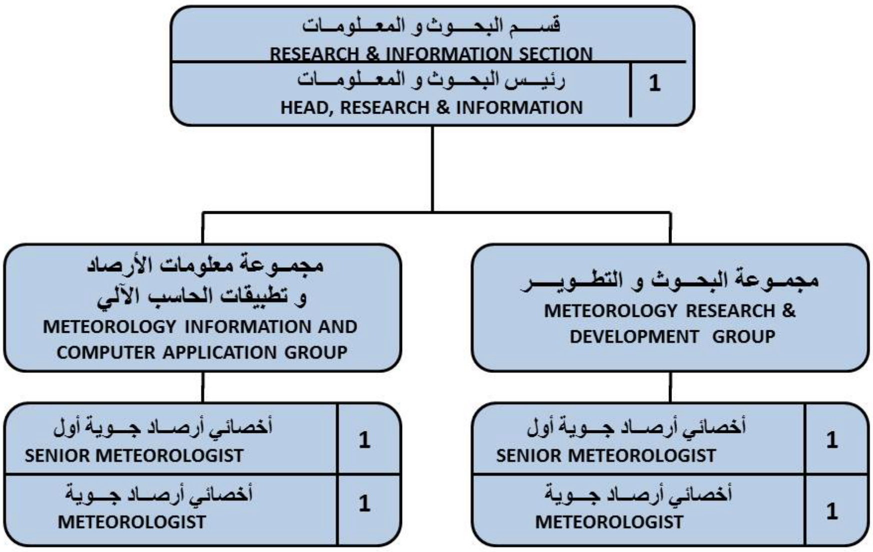
The BMD has a total of 43 staff, of which 36 are male and 7 are female. The BMD has 5 staff at the management level, 18 meteorologists, 12 meteorological technicians, 3 climatologists, 1 researcher, 3 support staff, and 1 classified as other staff. The number of BMD staff with a university degree is 16. The age of the staff ranges as follows: (a) 20-30 years: 10 staff; (b) 30-40 years: 7 staff; (c) 40-50 years: 10 staff; and (d) over 50 years: 16 staff. In the next 5 years, it is expected that 9 staff will retire. Staff numbers have decreased over the last 3-5 years. Capacity building requirements have been identified in the areas of: (1) forecasting; (2) management; (3) climatology; and (4) research. The BMD has a meteorology section and a research and information section which are presented in ***Figures 25*** and ***26*** respectively. A Senior Meteorologist and a Meteorologist are attached to the Meteorological Research and Information Section, whose setup rapidly addresses operational issues requiring research and facilitates quick transfer of research results to operations.

Figure 25 – Organization of the Meteorology Section of the BMD



Source: Bahrain Meteorological Department (BMD)

Figure 26 – Organization of the Research and Information Section of the BMD



Source: Bahrain Meteorological Department (BMD)

Major socio-economic user sectors and their needs

The BMD contributes to the economic and social development of the country by meeting the weather, climate, and geophysics-related information requirements of various socio-economic sectors. These include: The Government of Bahrain, its ministries, the armed forces, civil aviation, the media, marine operations including international waters, commerce and industry, and the people of Bahrain. Specialized services are provided to special events such as Formula1 and the Bahrain International Air Show. The BMD is also responsible for carrying out research into meteorological and related subjects for Bahrain and the region, and investigating the factors responsible for climate change.

Observing systems (weather, climate, water and environmental-related)

The BMD's network consists of 5 automatic weather stations, a wind profiler, a Doppler Radar, and one mobile observing station to support special events. The BMD has a satellite receiver to obtain Meteosat satellite images.

Information and communications technology (ICT)

From the available documentation, the BMD organizational structure (see ***Figures 15*** and ***16***) seems adequate for operations, but the source and structure of IT support is not apparent.

Data-processing and forecasting systems

The BMD has access to a number of model outputs via the WMO/GTS and SADIS (satellite distribution system supported by the ICAO). These model outputs are from: DWD (Germany), GFS (USA), ECMWF, COSMO (from Oman) and WRF (from Saudi Arabia). At the moment, the BMD does not run any model, but plans for the capability to run a high resolution limited area model (LAM) over its area of responsibility. In this context, the BMD is currently considering two proposals for (NWP) Systems: IBL and Weather Decision Technologies (WDT) systems. These proposals may be funded either by the Government or a donor agency.

The Forecasters (17 in total), working on a 24/7/365 basis, use IBL[67] workstations (3 in Operations room and 1 in Briefing room).

Public weather services

The BMD operates a 24/7/365 Forecasting Office. The BMD produces aviation forecasts for the Bahrain International Airport, Bahrain Defense Force, Ministry of Interior and US navy. The BMD also provide public forecasts via the telephone, Bahrain TV, Bahrain radio, and in newspapers, their website and social media. One of the primary objectives of the BMD is to meet the needs of clients for forecasts of up to 10 days.

Climate services

The BMD uses climate observations from 1943 onwards in its climate studies. After collection and validation, the data are processed. The BMD makes available the following climate products: (a) mean annual temperature and its trend; (b) wind rose; (c) number of days with dust, dust storm and sandstorm; (d) monthly minimum and maximum relative humidity; and (e) annual total precipitation and its trend. A description of the climate in Bahrain is given on BMD's website.

Agricultural meteorological services

There is no clear information available on BMD's agricultural meteorological services.

Aeronautical meteorological services

The BMD is the designated aeronautical meteorological service provider in Bahrain for national and international air navigation. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The BMD receives OPMET and WAFS products operationally. These services are provided by BMD in accordance with ICAO/WMO regulations and standards. BMD conforms to all WMO recommendations in its operations and services. It also strictly conforms to all ICAO recommendations for practices and procedures in civil aviation. The BMD has cost-recovery for aeronautical meteorological services.

Marine meteorological and/or oceanographic services

Daily marine meteorological forecasts and warnings for Bahrain sea areas, and a special forecast from north of the Arabian Gulf to the Gulf of Oman are broadcasted via national and local radio, television, and special channels for fishermen and ships. No further information is available.

Hydrological forecasts and assessments

Most aspects of hydrology and water management/production are carried out by the Electricity and Water Authority of the Kingdom of Bahrain[68].

Other related aspects, partnerships, and investments

The BMD contributes operational weather forecasts and climate information for Bahrain/Manama to the WMO's World Weather Information Service.

[67] See IBL, https://www.iblsoft.com.
[68] See Electricity and Water Authority of the Kingdom of Bahrain, http://www.ewa.bh/en/Pages/default.aspx.

Early Warning Systems

The BMD has a robust observing system to monitor hazardous weather. It issues warnings, but there is no clear information on its early warning systems, and relationship with disaster management authorities.

Summary of BMD status and challenges

The BMD is a government service with cost recovery for aeronautical meteorological services. It has a well-organized structure, with an adequate number of staff. The BMD operates 24/7/365. The BMD has a robust observing system, especially at the airport. It has adequate information and communication technologies. The BMD has access to outputs from many numerical models, and plans to run its own limited area model soon. The BMD provides adequate climate services and marine forecasts. There is no information on agrometeorological services or early warning systems. The BMD is a designated aeronautical meteorological service provider in Bahrain. Major challenges include: a significant number of staff close to retirement.

Qatar

Socioeconomic context[69]

Qatar is one of the six Gulf Cooperation Council (GCC) countries (see footnote 47). Qatar's economy grew by 0.5% in 2019 and was projected to grow to 1.5% in 2020 and 3.2% in 2021 as the country gradually recovered from the effects of a diplomatic rift between Qatar and some of its GCC neighbors, and benefited from high service sector growth generated by the FIFA World Cup. Downside risks stem from volatility in energy prices and continued diplomatic tensions with Gulf neighbors. The diversification of the economy away from hydrocarbons remains a key challenge.

Climate[70]

Qatar has a desert climate. The country experiences long summers from May to September characterized by intense dry heat, with temperatures rising above 45°C. Winter temperatures are mild but may fall below 5°C. Rainfall is only experienced during the winter, with the northern parts of the country receiving 30% more rainfall than the south. Shamal winds bring sand and dust storms throughout the year. Key historical climate trends indicate:

- That annual mean temperature has increased by 0.3°C over the last 40 years.
- A 1.74 mm/month per century increase in precipitation.

Climate projections for Qatar indicate that:

- The mean annual temperature is projected to increase by 2°C by 2050.
- The mean annual precipitation is projected to decrease by 5% by 2050. The maximum amount of rainfall in any 5-day period is projected to increase, and the maximum period between rainy days is expected to decrease.

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[69] See further information at https://www.worldbank.org/en/country/gcc.
[70] See further information at https://climateknowledgeportal.worldbank.org/country/qatar.

Governance, organization, and management

The Qatar Meteorological Department (QMD) is a government agency re-established by Decree No. 47 of 2009, responsible for the provision of public and other weather services to the State, focused on aviation. The QMD is under the supervision of the Qatar Civil Aviation Authority (QCCA). Qatar became a member of WMO in 1975.

The QMD functions are: (1) manage, maintain, develop and operate integrated systems of air, sea and upper atmosphere monitoring stations, including automatic monitoring stations, marine platforms and buoys, weather radars and earthquake monitoring stations and others, to undertake meteorological, hydrologic and geophysical observations regarding weather, climate and atmospheric conditions; (2) observe air and sea conditions and monitor, collect, exchange and publish their results, analyse and market information and data and issue weather and sea forecasts and alerts; (3) develop methods and techniques to collect and analyze meteorological information to improve weather forecasts; (4) prepare and issue weather forecast bulletins and reports to bodies in charge of air traffic, air navigation, and sea navigation, and to other government bodies and private bodies in the State whose activities are affected by weather; (5) provide meteorological and weather forecasting services and issue licenses to bodies to render these services, according to the standards of WMO; (6) prepare studies and reports and provide recommendations and technical advice regarding different weather and climate changes to government bodies; (7) follow up and contribute studies jointly with national bodies regarding air pollution and the impact of weather conditions on the movement of air pollutants and monitoring and controlling them in the atmosphere using satellites and other methods and techniques; (8) cooperate and coordinate with WMO and other international organizations related to meteorology and other countries and take part in scientific forums and conferences held by them in coordination with concerned bodies; and (9) propose fees and charges for meteorological services. The QMD provides 24/7/365 meteorological services, and has the legal authority to issue warnings, hence contributing to the preservation of life and property, disaster risk reduction, climate change adaptation, and to the socio-economic development of the country.

The QMD's only source of funding is from the government. The budget of QMD has no specific limitations. In the last 3-5 years its budget has been stable. The QMD has Quality Management Systems (QMS) for aviation services.

The QMD is headed by a Director and has 4 sections: (1) Networks; (2) Observation maintenance; (3) Forecasting and Analysis; and (4) Climatology.

The QMD has a total of 191 personnel, of which 151 are male and 40 are female. The QMD has 22 staff at the management level, 61 meteorologists, 41 meteorological technicians, 26 climatologists, and 41 support staff. The number of QMD staff with a university degree is 110. The age of the staff ranges as follows: (a) less than 20 years: 20 staff; (b) 20-30 years: 30 staff; (c) 30-40 years: 70 staff; (d) 40-50 years: 50 staff; and (e) over 50 years: 21 staff. Number of staff due to retire in next 5 years: 23. Staff numbers have steadily grown over the last 3-5 years. The areas in which QMD staff need training are (in order of priority): (1) instrumentation; (2) observations and data assimilation techniques; and (3) impact- and risk-based forecasting.

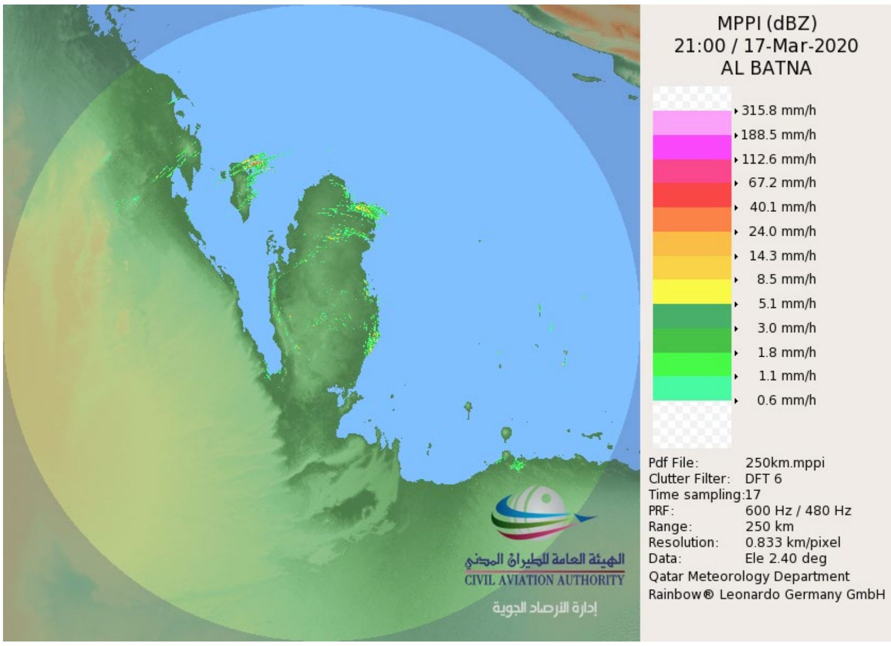
Major socio-economic user sectors and their needs

The QMD contributes to the economic and social development of the country by meeting the weather- and climate-related information requirements of all government sectors and public and private businesses. It provides services to support all activities related to economic, industrial, and agricultural development.

Observing systems (weather, climate, water and environmental-related)

The meteorological and environmental observation network covers a large part of the territory. The QMD's network consists of 13 regional basic synoptic network (RBSN) surface stations; 1 radar Band C to monitor severe weather in Qatar (see ***Figure 27*** for radar coverage), LLWAS, and the wind profilers (LIDAR). The QMD uses the Tecnavia System to retrieve satellite imagery. The QMD uses ObsMet (supported by MFI) as an observation data collection system that allows the management of a complete weather station network irrespective of whether these stations are from one unique supplier of from different suppliers.

Figure 27 – QMD Radar Network



Source: QMD website.

Information and communications technology (ICT)

A telecommunication system has been established at the QMD to collect local meteorological data and for international data exchange through the WMO Information System / Global Telecommunication System (GTS). There is no information about the domestic telecommunication system to collect and disseminate meteorological information and data nationally. The QMD uses both Transmet (supported by MFI) and MESSIR-COMM (supported by Corobor) as automatic message switching system clusters required to manage the data process through scripts to pull/push the data.

Data-processing and forecasting systems

The QMD has an Intel Xeon E5-2690,8.00 GT/s QPI, 2 x Socket CPU, 8-Core with 16 cores for running WRF (4 km), QRM (18 km) and WAM models, without data assimilation. The forecast range for these models is 72h. Models are initialized with the global model (GFS) from NCEP, which also provides boundary conditions. Verification of model output to assess performance of the system over time is not done routinely. NWP model outputs are made available on the QMD website.

Some of the NWP products are made available via two visualizations systems: MESSER-VISION (supported by Corobor) and Synergie (supported by MFI). Forecasters have access to global model data from ECMWF, UKMO, GME, ARPEGE, and GFS.

Public weather services

The QMD provides nowcasting (0-12 hours ahead); and short-range forecasts (12 hours to 3 days). Weather forecasts are produced for government decision makers and for the public. It also provides specialized products to aviation, marine, and other public sectors. These forecasts and warnings are disseminated through the radio, website, and social media. The QMD uses MeteoFactory (supported by MFI) as a service delivery platform which allows it to target specific users with customized products.

Climate services

More than 50% (but less than 75%) of data have been digitized, archived, stored and processed, using Clisys (supported by MFI).

The QMD prepares and issues climate information and statistics, and makes them available on its website in the Climate Bulletin (called Almanac). It also issues monthly and seasonal forecasts over Qatar and prepares annual reports.

Agricultural meteorological services

No other information is available on agrometeorological products and services from QMD.

Aeronautical meteorological services

The QMD is the designated aeronautical meteorological service provider in Qatar. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The QMD receives OPMET and WAFS products operationally. The QMD uses AerometWeb (supported by MFI), as a pilot briefing system.

The QMD has a quality management system meeting international standards, and its aeronautical meteorological personnel meet competency and education and training requirements. The QMD is ISO certified for aeronautical meteorological services, and keeps the certification up-to-date.

Marine meteorological and/or oceanographic services

Daily marine meteorological forecasts and warnings are prepared by QMD and made available on its website. The QMD runs the WAM wave model.

Hydrological forecasts and assessments

Hydrological monitoring in Qatar is managed by the Ministry of Municipalities and Environment. Qatar's hydrological network plays an important role in the management of the country's water resources. No details have been found on the hydrological network.

Other related aspects, partnerships, and investments

Currently, the QMD contributes operational weather forecasts and climate information for 4 cities to the WMO's World Weather Information Service.

Since 2018, Qatar has been a member of the ESCAP/WMO Panel on Tropical Cyclones.

Early Warning Systems

The QMD has a robust observing system to monitor hazardous weather events. Severe weather forecasts and warnings are issued. The QMD is responsible for issuing weather warnings for decision makers, however, further research is required to understand whether there is a collaboration with disaster management authorities in assessing weather-related impacts. The QMD is the alerting authority for meteorological hazards using the Common Alert Protocol (CAP).

Summary of QMD status and challenges

The QMD is a government service. It is not clear whether it has commercial services. It has a well-organized structure, with a significant number of experienced staff. The QMD operates 24/7/365. The observing network covers a large part of the country. It has robust information and communication technologies. The QMD does not use ensemble prediction systems and probabilistic forecasts. The QMD is the designated aeronautical meteorological service provider in Qatar, and has the authority to issue warnings. It has well-established marine forecasting capabilities and early warning systems. Major challenges include: limited use of ensemble prediction systems, and limited coordination and collaboration with the departments responsible for hydrology.

United Arab Emirates

Socioeconomic context[71]

The United Arab Emirates is one of the six Gulf Cooperation Council (GCC) members. The UAE's GDP growth rate was projected to accelerate from 1.7% in 2018 to 3% by 2021. Oil production is expected to rise due to investments in oilfield development. Non-oil growth is also projected to rebound (i) as the expected improvement in oil prices and its positive effects on confidence and financial conditions dampen the effects of fiscal consolidation; (ii) as megaproject implementation accelerates ahead of Dubai's hosting of Expo 2020; and (iii) as the lifting of sanctions on Iran translates into increased trade.

Climate[72]

Key historical climate trends indicate:

- Mean annual temperature is 26.8°C (1901-2016).

[71] See further information at https://www.worldbank.org/en/country/gcc.
[72] See further information at https://climateknowledgeportal.worldbank.org/country/united-arab-emirates.

- Mean annual precipitation is 64.8mm (1901-2016).

Climate projections for UAE indicate that:

- Mean annual temperature will rise by 2.4°C in 2050. Total annual hot days of temperature above 35°C will rise by 26.7 days by 2050.
- Mean annual precipitation will fall by 2.7mm by 2050.

Governance, organization, and management

The National Centre of Meteorology and Seismology (NCMS) is a government agency established in 2007, by a federal decree Law No. (6) of 2007, under the Ministry of Presidential Affairs. It is responsible for monitoring the changes that occur in the atmosphere, providing meteorological and seismic information and services to all sectors in accordance with applicable laws and regulations in the country, in addition to the exchange of data and information at the regional and international levels, keeping pace with scientific progress and conducting research. The United Arab Emirates became a member of WMO in 1986.

The NCMS' aims to unite the sources of meteorological and seismological information across the UAE, to monitor changes occurring in the atmosphere and the earth's crust, and to deliver meteorological services. Its vision is: "to achieve excellence in meteorological and seismological services and contribute to the development of science through the promotion of the sustainable development goals of the UAE". The NCMS' values are: (a) leadership and excellence; (b) institutional loyalty; (c) credibility; (d) communal responsibility; and (e) customer satisfaction.

The NCMS provides 24/7/365 meteorological and seismic-related services, and has the legal authority to issue warnings, hence contributing to the preservation of life and property, disaster risk reduction, climate change adaptation, and the socio-economic development of the country.

The NCMS's only source of funding is from the Government, as commercial activities are not permitted. There is no information on the budget of NCMS, however, it is understood that in the last 3-5 years its budget has been stable. It is not clear whether the NCMS has a Quality Management Systems (QMS).

The NCMS is headed by a Director and has five departments: (a) Meteorology Department; (b) Seismology Department; (c) Research and Development Department; (d) Technical Services Department; and (e) Support and Customers Services Department.

The NCMS has a total of 226 personnel, of which 184 are male and 42 are female. The NCMS has 4 staff at the management level, 130 meteorologists, 20 meteorological technicians, 3 hydrologists, 1 hydrological technician, 10 climatologists, 10 researchers, 38 support staff, and 10 classified as other staff. The number of NCMS staff with a university degree is 133. The age of the staff ranges as follows: (a) less than 20 years: 0 staff; (b) 20-30 years: 25 staff; (c) 30-40 years: 83 staff; (d) 40-50 years: 55 staff; and (e) over 50 years: 64 staff. Number of staff due to retire in next 5 years: 24. Staff numbers have grown over the last 3-5 years. The areas in which QMD staff require training are (in order of priority): (1) forecasting; (2) climatology; (3) instrumentation; and (4) NWP.

Major socio-economic user sectors and their needs

The NCMS contributes to the economic and social development of the country by meeting the weather, climate, and environmental-related information requirements of various public socio-economic sectors, including aviation, marine, agriculture, industry, and oil.

Observing systems (weather, climate, water and environmental-related)

The meteorological and environmental observation network covers the whole territory. The NCMS's network consists of 94 regional basic synoptic network (RBSN) surface stations (51 on land; 18 at the coast; 8 in the mountains; 10 on the islands; and 7 at airports); and a network of 9 radars to monitor severe weather in the UAE (7 operational; 2 closed and 1 mobile Band X). There is no information on how the NCMS retrieves satellite imagery.

Information and communications technology (ICT)

A telecommunication system has been established at the NCMS to collect local meteorological data and for international data exchange through the WMO Information System / Global Telecommunication System (GTS). There is no information on the national telecommunication system. The NCMS uses MESSIR-COM (supported by Corobor) as an automatic message switching system cluster required to manage the data process through scripts to pull/push the data.

Data-processing and forecasting systems

NWP model outputs (global and national) are made available on the NCMS website for the use of forecasters, public, media, and other authorities, however, there is no information on which models are used. NWP products for use in the forecasting office are made available via MESSER-VISION (supported by Corobor).

Public weather services

The NCMS provides weather forecasts up to 5 days ahead to government decision makers and to the general public, the media, and sporting bodies. It also provides specialized products to aviation and marine sectors. These forecasts and warnings are disseminated through its website and social media. The NCMS uses MESSIR-Media (supported by Corobor) to broadcast weather forecasts; and MESSIR-Net (supported by Corobor) to publish meteorological information on the web.

Climate services

The NCMS prepares and issues climate information and statistics, and makes them available on its website in the Climate Yearly Report and Climate Daily Report. There is no further information on NCMS climate services.

Agricultural meteorological services

There is no information on agrometeorological products and services issued by NCMS.

Aeronautical meteorological services

The NCMS is the designated aeronautical meteorological service provider in the UAE. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The NCMS receives OPMET and WAFS products operationally. The NCMS uses MESSIR-AERO (supported by Corobor) as a pilot briefing system.

There is no information on whether the NCMS has cost-recovery for aeronautical meteorological services or a Quality Management System.

Marine meteorological and/or oceanographic services

Daily marine meteorological forecasts (up to 5 days) and warnings for the Arabian Gulf and the Eastern Coast are broadcasted via national and local radio, television, the NCMS website, and via special channels for fishermen and ships. It seems that the NCMS runs a wave model, as its outputs are available on the NCMS website, however, there is no indication of which model is used.

Hydrological forecasts and assessments

The UAE relies on non-conventional water resources, in addition to conventional resources, to meet ever-increasing demands. Conventional water resources include seasonal floods, springs, falajs, and groundwater. Non-conventional resources are desalinated water and treated-sewage water. The hydrological monitoring and forecasting services in the UAE are dispersed across multiple departments, including the Ministry of Agriculture and Fisheries, and the Ministry of Electricity and Water. No details have been found in relation to the hydrological network.

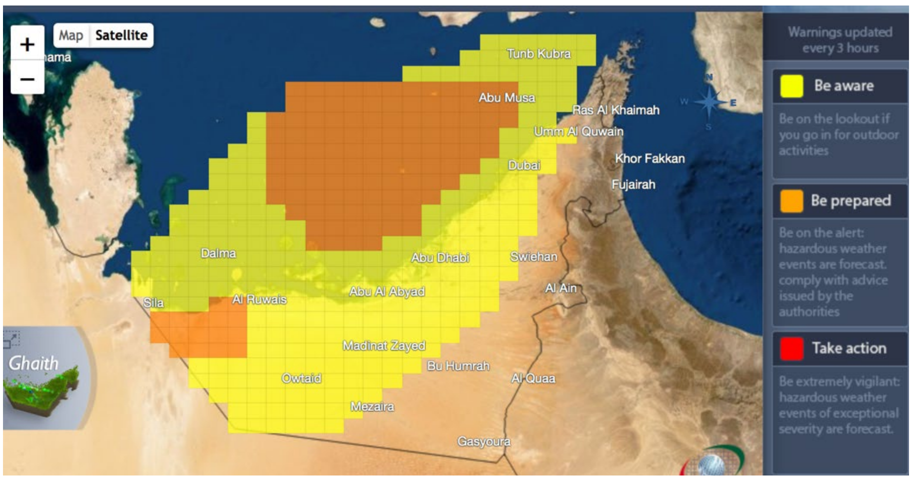
Other related aspects, partnerships, and investments

Currently, the NCMS contributes operational weather forecasts and climate information for 3 cities to the WMO's World Weather Information Service.

Early Warning Systems

The NCMS has a very robust observing system to monitor hazardous weather. Severe weather forecasts and warnings . The NCMS implemented a color-coded warning system (see ***Figure 28***). The NCMS is the alerting authority for meteorological hazards and uses the Common Alert Protocol (CAP).

Figure 28 – *Color-coded Warning System*



Source: NCMS website.

Summary of NCMS status and challenges

The NCMS is a government service with no commercial services. It has a well-organized structure, with a significant number of experienced staff. The NCMS operates 24/7/365. The observing network covers the whole country. It has robust information and communication technologies. The NCMS has modest numerical weather prediction capacities, and does not use ensemble prediction systems and probabilistic forecasts. The NCMS is the designated aeronautical meteorological service provider for the UAE, and has the authority to issue warnings. It has well-established marine forecasting capabilities, and early warning systems. Major challenges include: modest numerical weather prediction capabilities, and limited coordination and collaboration with the departments responsible for hydrology.

Oman

Socioeconomic context[73]

Oman is one of the six Gulf Cooperation Council (GCC) countries (see footnote 47). In 2018 growth recovered to 2.1%, supported by rising non-hydrocarbon activity and higher oil output. However, the December 2018 OPEC+ agreement to cut oil production dampened this recovery in 2019, and growth slowed to 1.2%. While narrowing, fiscal and current account deficits remain high, and debt ratios continue to worsen. The potential boost from diversification investment spending was predicted to support growth in 2021 and the medium term. The main risk to the economic outlook is a delay in fiscal adjustment, which will impede debt reduction and negatively affect business confidence and external financing costs in an adverse global environment. Job creation is an important challenge, given the 49% youth unemployment rate.

Climate[74]

Oman has a subtropical, dry climate with summer monsoons and hot, dusty winds. During the summer months of June and July, temperatures can reach 48°C during day, and average about 32°C at night. Winter seasons are cooler, with occasional rainfall, and spring and autumn are warm and mostly dry, with maximum temperatures between 25°C and 35°C. Key historical climate trends indicate:

- On average, annual mean temperatures have increased in Oman by around 0.4°C per decade since the 1980s. Extreme temperatures in Oman – both maximums and minimums – have been increasing over the past decade.
- There is a high change in rainfall from year to year, with Saiq showing high fluctuations during the 1980s and 1990s. Overall, rainfall has been decreasing since the 1980s.

Climate projections for Oman indicate that:

[73] See further information at https://www.worldbank.org/en/country/gcc.
[74] See further information at https://climateknowledgeportal.worldbank.org/country/oman.

- Mean annual temperature is projected to increase by 1°C by 2050. The maximum amount of rainfall in any 5-day period is projected to increase, while the maximum period between rainy days is expected to decrease.
- Mean annual precipitation is projected to increase by 2%.

Governance, organization, and management

Meteorological observations in the Sultanate of Oman date back to 1900 when they were made by private agencies. In 1893 a Meteorological Station was established in Muscat, and in 1942 three more stations were established in Salalah, Masirah, and Thumrait. During the 1960's Petroleum Development Oman (PDO) established new stations in coastal and interior areas, and His Majesty Sultan Qaboos established meteorological services for aviation when he inaugurated Seeb International Airport in 1973 (now renamed as Muscat International Airport). From 1975, Meteorological services were extended to the public as Weather Forecasts broadcast through Oman TV and Radio, which became an essential part of daily programs in both Arabic and English languages. In 1976, a ministerial decision was issued to establish National Meteorological Services as one of the sections of the Directorate General of Civil Aviation under the Ministry of Transportation. In 1982, a Royal Decree was issued to establish the Directorate General of Meteorology (DGMET) under the Ministry of Transportation/Public Authority of Civil Aviation. In 1975 the Sultanate of Oman became an active member of WMO.

The DGMET's only source of funding is from the Government. There is no information on the total budget of DGMET, however, it is understood that it is steadily increasing. The DGMET has implemented Quality Management Systems (QMS) for aviation services.

The DGMET is headed by a Director-General and has two departments consisting of various sections providing meteorological services as follows: (a) Department of Operation and Technical Services, which includes a telecommunications and network section, outside stations section, systems and data processing section, and numerical weather prediction section; and (b) Department of Forecasting and Observation Practices, which includes air navigation and marine meteorology section, remote sensing and studies section, general forecasting section, and a meteorological services and media section.

The DGMET has a total of 225 personnel, of which 212 are male and 13 are female. The DGMET has 22 staff at the management level, 52 meteorologists, 102 meteorological technicians, 4 climatologists, 5 researchers, 36 support staff, and 4 classified as other staff. The number of DGMET staff with a university degree is 86. The age of the staff ranges as follows: (a) less than 20 years: 0 staff; (b) 20-30 years: 100 staff; (c) 30-40 years: 53 staff; (d) 40-50 years: 35 staff; and (e) over 50 years: 37 staff. Number of staff due to retire in next 5 years: 14. Staff numbers have grown over the last 3-5 years. The areas in which the DGMET staff require training are (in order of priority): (1) meteorology; (2) programming and engineering; (3) research; and (4) meteorological techniques.

Major socio-economic user sectors and their needs

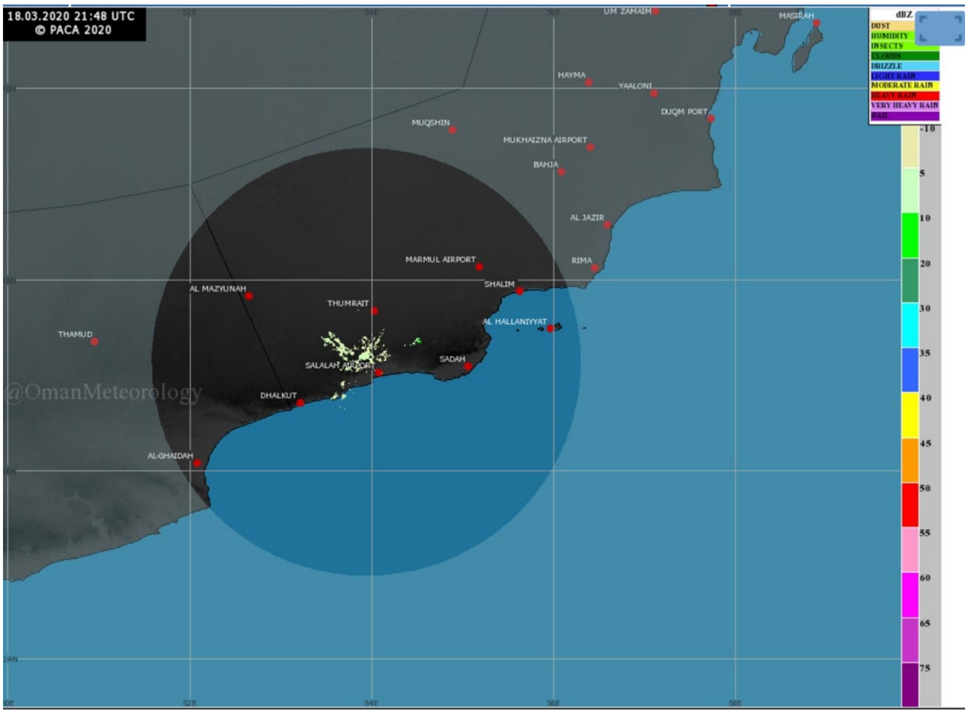
The DGMET contributes to the economic and social development of the country by meeting the weather, climate, and environmental-related information requirements of various public socio-economic sectors.

The DGMET conducts all meteorological services and applications, generates general weather forecasts, annual and monthly reports, and undertakes research. The DGMET extended its services to all government Ministries and the private sector in terms of information, data, and applications, technical cooperation, standardizing the specifications and measurement of weather stations, and organizing periodic maintenance.

Observing systems (weather, climate, water and environmental-related)

The meteorological and environmental observation network covers a large part of the territory. The DGMET's network consists of 60 meteorological stations, of which 23 are part of the WMO's regional basic synoptic network (RBSN) surface stations, including 2 upper-air radiosondes, 12 climate stations; and 1 operational radar (Band S) to monitor severe weather in Oman (see ***Figure 29*** for radar coverage). There are 3 radars on stand-by and another one is planned. An additional 13 Automatic Weather Stations are to be installed.

Figure 29 – DGMET Radar Network



Source: DGMET website.

The DGMET uses EUMETSAT satellite imagery. A Centre of Excellence for satellite meteorology was established at DGMET in 2006, for South West Asia and the Middle East Countries. This Centre is sponsored by EUMETSAT and supervised by WMO. The DGMET installed a Second Generation Satellite ground-receiving station for retrieving geostationary satellites operated by EUMETSAT. Meteorological data are being received through a satellite distribution (SADIS) receiver. Moreover, high resolution images from polar orbiting satellites operated by NOAA and EUMETSAT, and images from Chinese satellites are received operationally.

One wave radar measurement station was installed offshore of Qalhat (Sur) by the Oman liquid Gas Company, and another two wave measurement stations are located offshore of Sohar Station and Mina Salalah Station. Seven tide gauges were installed at Diba, Sohar, Wudam, Quriyat, Sur, Alashkhara, and Duqm as part of the Tsunami Network.

Weather reports from ships are received through GTS and from the Muscat Coastal Radio Station. In addition, ship reports are received from the Royal Oman Navy.

Information and communications technology (ICT)

A telecommunication system has been established at the DGMET to collect local meteorological data and for international data exchange through the WMO Information System / Global Telecommunication System (GTS). All the meteorological stations are connected to an automatic message switching system (MSS) located at the Central Forecasting Office at the Muscat International Airport by reliable telephone lines and GSM Network links. The MSS is connected to the GISC in Jeddah by a dedicated link at 64 kbps based on the TCP/IP protocol. In addition, a 4 mbps internet leased line has been established for transmitting and receiving meteorological data with different meteorological centers, such as New Delhi and Abu Dhabi. A bilateral internet circuit, which was established between these centers and Muscat for the exchange of meteorological data, has proved to be very effective, useful, and stable.

Data-processing and forecasting systems

The DGMET has a 2x Intel Xeon E5-2630 (2.30 GHz Hexacore) with 80 nodes, 960 cores; where it runs operationally 2 Atmospheric High Resolution Models (COSMO and WRF) up to 96 hours ahead. The German global model ICON is used to provide necessary initial and lateral boundary conditions for COSMO, and GFS global model (from US) is used for WRF. Currently, COSMO model, with data assimilation, runs operationally with two resolutions: 7 and 2.8 km. WRF model runs during Tropical Cyclone events and provides the forecast with three resolutions: 27, 9 and 3 km. Verification of model outputs to assess performance of the system over time is carried out routinely. Verification scores are calculated. NWP model outputs are made available on the DGMET website for the use of forecasters, the public, media, and other authorities. Forecasters also have access to global model data (from ECMWF, UKMO, and DWD) via Internet, WIS/GTS, and directly from DWD Sat.

Public weather services

The DGMET provides forecasts for up to 3 days. Weather forecasts are produced for government decision makers and for the public. It also provides specialized products to aviation, marine, and other public sectors. These forecasts and warnings are disseminated through the radio, its website, and social media.

Climate services

More than 75% of data have been digitized, archived, stored, and processed. The DGMET prepares and issues climate information and statistics, and makes them available on the website in the Climate Bulletin. No further information is available on DGMET climate services.

Agricultural meteorological services

No other information is available on agrometeorological products and services from DGMET.

Aeronautical meteorological services

The DGMET is the designated aeronautical meteorological service provider in Oman. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The DGMET receives OPMET and WAFS products operationally. The DGMET uses the SADIS system.

There is no information on DGMET cost-recovery for aeronautical meteorological services. It has a quality management system meeting international standards, and its aeronautical meteorological personnel meet competency and education and training requirements. The DGMET is ISO certified for aeronautical meteorological services, and for other services, and keeps the certification up-to-date.

Marine meteorological and/or oceanographic services

Daily marine meteorological forecasts and warnings for Oman's Economic Exclusive Zone are broadcasted via national and local radio, website, and special channels for fishermen and ships.

The DGMET runs a regional wave model called WAM, with two resolutions: 14 and 3.5 km, which was obtained from HZG (former GKSS) of Germany. The DGMET also runs a tsunami model called COMCOT (Cornell Multi-grid Coupled Tsunami Model), capable of simulating the entire lifespan of a tsunami, from its generation, propagation, and run-up in coastal regions – the model is used for earthquakes within the Oman Sea and India Ocean region. The DGMET also runs a storm surge model to calculate storm surge, stress, and currents due to tropical cyclone events by inserting the track location, pressure drop, time step, and distance of maximum wind from the center.

Hydrological forecasts and assessments

The hydrological monitoring and forecasting services in Oman are the responsibility of the Ministry of Regional Municipalities and Water Resources. The hydrological network of dams includes 47 rainfall stations, 18 falaj stations, 31 wadi flow stations, and 264 monitoring wells. In general, there are nearly 341 rainfall stations for which data are available since the early 1970s.

Other related aspects, partnerships, and investments

Currently, the DGMET contributes operational weather forecasts and climate information for 35 cities to the WMO's World Weather Information Service.

Early Warning Systems

The DGMET has a robust observing system to monitor hazardous weather events. Severe weather forecasts and warnings are issued. The DGMET is the alerting authority for meteorological hazards and uses the Common Alert Protocol (CAP).

Summary of DGMET status and challenges

The DGMET is a government service. It has a well-organized structure, with a significant number of experienced staff. The DGMET operates 24/7/365. The observing network covers the whole country. It has robust information and communication technologies. The DGMET does not use ensemble prediction systems and probabilistic forecasts. The DGMET is the designated aeronautical meteorological service provider in Oman, and has the authority to issue warnings. It has well-established marine forecasting capabilities, and early warning systems. Major challenges include: limited climate services capabilities, and limited coordination and collaboration with the departments responsible for hydrology.

EGYPT, DJIBOUTI AND YEMEN

Egypt

Socioeconomic context[75]

In 2018, real GDP grew by 5.3%, compared to an average of 4.3% in the three years before. This pickup in growth was driven by public investments, private consumption, and exports of goods and services, but the role of the private sector was not clear. Although still high, inflation slowed from a record 33% in mid-2017 to 12.7% in January 2019. The positive impact of macroeconomic and policy reforms markedly improved Egypt's external position. The current account deficit narrowed to 2.4% of GDP in 2018, down from 6% in the previous year, and driven primarily by strong remittances and the recovery in tourism. Important fiscal reforms in both expenditure and revenue prompted a gradual decline in the fiscal deficit, but the public debt ratio remains elevated. The value-added tax (VAT) regime, introduced in 2016, boosted tax revenues, while energy subsidy reforms and measures to rein in the wage bill reduced expenditures as a share of GDP. Still, the debt ratio remained high at 98.7% of GDP in 2018.

To alleviate the adverse effects of economic reforms on the poor and vulnerable, and increase investments in Egypt's human capital, the government has scaled up key short-term social protection mitigating measures, including through higher allocations of food smart cards and targeted conditional and unconditional cash transfer programs. To effectively achieve human development through social protection measures, the conditionality of cash transfer programs is related to health and education, and complemented by the launch of ambitious reforms in the education and health sectors to strengthen the supply side of the equation and improve Egypt's human capital outcomes. The country's social protection measures are shifting from generalized energy and food subsidies to more integrated poverty and human development targeted programs. Job creation to reduce unemployment, especially for the youth, and absorb around 700,000 new entrants to the labor market over the coming five years is a key challenge ahead.

Climate[76]

During the winter season (December-February), Egypt's temperatures are mild with some rain, primarily over the coastal areas. During the summer season (June-August), the climate is hot and dry throughout the country. The Khamsin Wind brings sand and dust storms during spring, increases temperatures, and lowers humidity.

Key historical climate trends indicate the following:

- A warming of about 0.03°C per century since the 1900's.
- A reduction of 2.76 mm/month since 1960, although there is high annual variability in rainfall records.

Climate projections for Egypt indicate that:

[75] See further information at http://www.worldbank.org/en/country/egypt.
[76] See further information at https://climateknowledgeportal.worldbank.org/country/egypt.

- Mean annual temperature is expected to increase by 2 to 3°C by 2050, with warming increasing more rapidly in the interior regions.
- By 2050, there may be a 7% reduction in rainfall near the coast, while a 9% reduction is projected for the central parts of the country, with the greatest reductions projected from June to August at 22%, followed by September to November by 11%. However, model projections diverge for the central regions. The highest reductions are projected for June to August by 27% and September to November by 11%.

Governance, organization, and management

The Egyptian Meteorological Authority (EMA) is a government agency established in 1971 under the supervision of the Ministry of Civil Aviation. However, meteorological activities in the country date to the beginning of the century. The EMA includes a scientific research department that conducts multi-disciplinary research that serves the current needs of Egyptian society. The main areas are: (a) numerical weather prediction; (b) seasonal forecasting; (c) air pollution forecasting; (d) surface solar radiation, ozone, and air pollution monitoring; and (e) agrometeorology. In addition to its meteorological services for aviation, the EMA routinely provides 5-day weather forecasts, 3-month seasonal forecasts, 4-day air pollution forecasts, 10-day agrometeorological reports, flood forecasts, and marine meteorological services for shipping in the Mediterranean and Red Seas. Egypt has been a member of the World Meteorological Organization (WMO) since 1950.

The EMA functions are described in the Regulation of the President of the Arab Republic of Egypt N° 2934/1971. The EMA's main source of funding is from the Government. It has no commercial activities. The total budget of EMA in 2017 was 30 million Egyptian Pounds (equivalent to approximately US$1,68 million). Over the last 3-5 years its budget has been stable. It has Quality Management Systems (QMS) for its aviation, training, and environment branches.

The EMA has a development/strategic plan in place, covering the next 3-5 years, which has been guiding its development to fulfill its mission more effectively. The organizational chart and structure of EMA are not available.

The EMA has a total of 1120 personnel, of which 770 are male and 350 are female. The EMA has 20 staff at the management level, 225 meteorologists, 750 meteorological technicians, 40 hydrologists, 60 hydrological technicians, 5 climatologists, 20 researchers. The age of the staff ranges as follows: (a) 20-30 years: 120 staff; (b) 30-40 years: 250 staff; (c) 40-50 years: 450 staff; and (d) over 50 years: 300 staff. In the next 5 years, it is expected that 169 staff will retire. Capacity building requirements have been identified for: (1) meteorologists; (2) researchers; (3) managers; and (4) meteorological technicians.

Major socio-economic user sectors and their needs

The EMA contributes to the economic and social development of the country by meeting the weather, climate, and environmental information requirements of various socio-economic sectors. These include: transport (air and sea); agriculture; hydrology; environment; energy; tourism; construction and housing planning. The EMA's meteorological services for the civil aviation, marine, and agriculture sectors are described below.

The EMA aims to provide tourists and tourism companies with climate data which will enable them to match their destinations with the best seasons in which to visit, and to take full advantage of Egypt's 365 sunny days per year.

The information provided by the EMA observational network is used to plan economic projects, to establish companies and choose the most suitable locations for them, and to provide production sites which limit environmental pollution. Meteorological information (such as wind direction and speed, sunshine, and relative humidity) is of great value for construction and housing planning.

In the field of clean energy, solar radiation measurements, in addition to regular weather observations, give the EMA an important role in the fields of solar and wind power.

Observing systems (weather, climate, water and environmental-related)

The EMA's network consists of 40 automatic weather stations, 120 regional basic synoptic network (RBSN) surface stations, 6 upper-air stations, 35 climate stations, 10 agrometeorological stations, 4 stations to measure atmospheric pollution, and 2 stations that measure ozone. The EMA does not have a radar. The EMA makes use of MESSIR-SAT (supported by Corobor) to obtain satellite images from METEOSAT.

Information and communications technology (ICT)

A telecommunication system has been established at the EMA to collect local meteorological data and for international data exchange through the WMO Information System (WIS) / Global Telecommunication System (GTS). The DNM hosts a *WMO Data Collection and Production Centre (DCPC) in Cairo* which serves as a *Regional Telecommunication Hub (RTH)* within the framework of the *WMO GTS*, and collects and disseminates meteorological data and products within its geographical area of responsibility, and exchanges these data and products with other RTHs and GISCs for their global distribution (see *Annex*). The EMA uses MESSIR-WIS to manage the distribution of the data through the WIS.

The domestic telecommunication system uses a Virtual Private Network (VPN) combining radio, computer network, and VSAT to collect and disseminate meteorological information and data nationally. The EMA uses MESSIR-COMM as an automatic message switching system (supported by Corobor) required to manage the data process through scripts to pull/push the data.

Data-processing and forecasting systems

The physical and numerical research department, as a part of the Central Administration for Meteorology and Climate Research of EMA supervises the operation and follow-up of the following numerical models: (a) high-resolution run of WRF at 6km horizontal resolution; (b) MOZART Model for Ozone and related chemical tracers; (c) RegCM4 at 20km horizontal resolution, as an air quality model; (d) Flex part and Hysplit4 air dispersion model; (e) ETA model with dust module to predict the dust load (gram per meter square); (f) statistical model using Climate Prediction Tools (CPT) to issue seasonal forecasts over North Africa and the Arab world; (g) WAM model for wave forecasts; and (h) RegCM4-Agro to predict agrometeorological elements such as potential evapotranspiration, and diurnal temperature range. ***Figure 16*** describes the computer equipment used by EMA for operational forecasting.

Figure 16 – Computer Equipment Used by EMA for Operational Forecasting

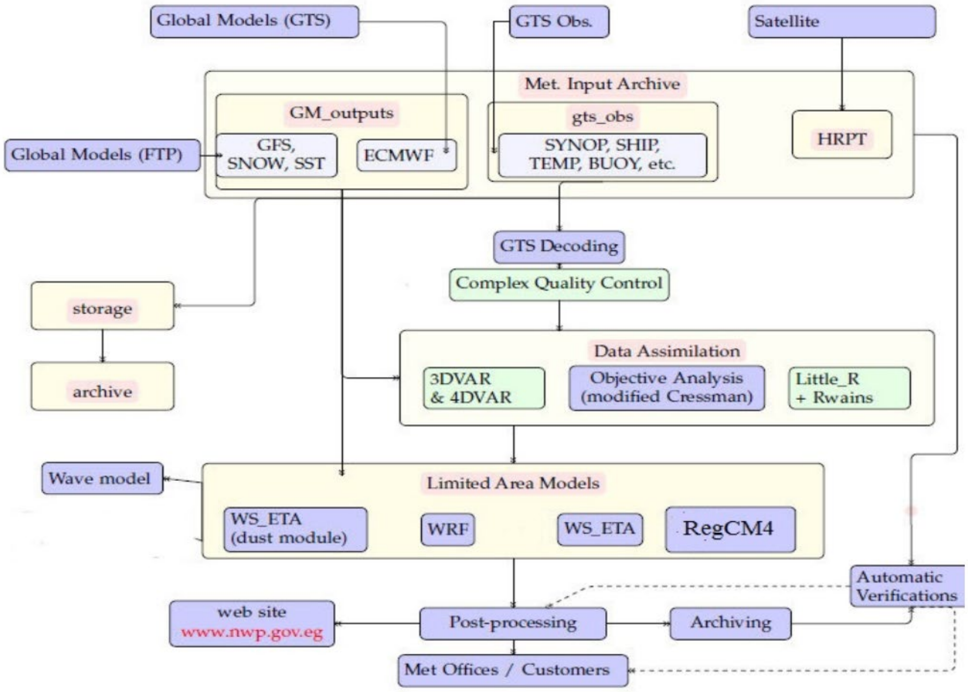
Machine	Processors	Memory (GB)	Storage
Dell Precision	8× 3.2GHz	12 GB	4.5TB
IBM workstation	32 × 1.2 GHz	32 GB	2 TB
IBM Workstation	32 ×1.2 GHZ	32 GB	2 TB
Workstations	8 Intel Xeon workstations	8×2.4 GHZ dual core	8 ×1 TB
IBM x3650 M4	2 X 2.4 GHZ/ 8-core/ 20MB cache	32 GB, DDR3 RAM	
HP Elite 7500 series	MT 8 processors CORE I7	8 GB	1 TB
DELL Power Edge	T630 16 processors	16 GB	8 TB

Source: Egyptian Meteorological Authority (EMA).

The general structure of the forecasting component of EMA's numerical weather prediction (NWP) system is illustrated in ***Figure 17***. In EMA's system there are three operational models used for short-range and medium-range forecasts: WRF, ETA, and RegCM. They run twice a day, based on initial conditions at 00UTC and 12UTC. As illustrated below, some models are coupled with EMA's limited area models, including the dust model and the WAM model, used to predict sea waves over the Mediterranean and Red Seas. The EMA has an agreement with the National Oceanic and Atmospheric Administration (NOAA) to support these developments.

The EMA makes use of Synergie, supported by MFI, as a Forecaster Workstation and decision-making tool for forecasting and warning.

Figure 17 – Operational Forecasting at EMA



Source: Egyptian Meteorological Authority (EMA).

Public weather services

The EMA operates a 24/7/365 Forecasting Office. It provides nowcasting (0-12 hours ahead); short-range forecasts (12 hours to 2 days); and medium-range forecasts (3 to 6 days). By using MeteoFactory (a Public Weather Services (PWS) – Early Warning System (EWS) tool for forecasting and warning), weather forecasts (in the form of bulletins) are produced for decision makers and for the public, and are disseminated by radio, TV, website, mobile App, and social media.

Climate services

The EMA has climate observations that date back to the early 20th century. After collection and validation, the data are processed and stored. The EMA uses ObsMet, supported by MFI, as a data collection system. More than 75% of the data have been digitized and rescued. The EMA uses Clisys Data Management System, supported by MFI, which applies quality control of observations.

The EMA participates in the *Regional Climate Outlook Forum For Northern Africa* (known by its French acronym: *PRESANORD*) and in the *Mediterranean Climate Outlook Forum (MedCOF)* (see *Chapter 2*). The EMA participates in the North Africa RCC-Network, and is co-responsible for the Node on Training (at its Regional Training Centre).

Agricultural meteorological services

Since 1955, the EMA has provided agrometeorological information and forecasts to assist agriculture and farming, and irrigation planning and management. It provides daily data and 10-day agrometeorological reports.

There is no information on the existence or use of crop models by the EMA, however, it uses blending (in-situ and remote-sensing) products for agriculture purposes.

Aeronautical meteorological services

The EMA is the designated aeronautical meteorological service provider in Egypt. It issues TAFs, METARs, and SIGMETs, and provides flight documentation to airlines. The EMA receives OPMET and WAFS products operationally. The EMA uses the AerometWeb, supported by MFI, as a pilot briefing system.

The EMA has a quality management system which meets international standards and is ISO certified for aeronautical meteorological services.

Marine meteorological and/or oceanographic services

Daily marine meteorological forecasts and warnings for the Mediterranean and Red Seas and coastal areas are broadcast via national and local radio and special channels for fishermen and ships. No further information is available.

Hydrological forecasts and assessments

Most aspects of hydrology and water management are carried out by agencies within the Ministry of Water Resources and Irrigation. In particular, the Water Resources Research Institute is one of twelve research institutes comprising the National Water Research Center of the Ministry of Water Resources and Irrigation, which is responsible for hydrology studies, flash flood risks, the Nile River basin studies, groundwater development, and integrated water resources management.

Monitoring of ground water in Egypt is currently carried out by 300 hydrometric stations and 14 ground water level monitoring stations. This information is stored in hydrological databases hosted and maintained by the National Water Research Center, while precipitation data are managed by the EMA. In the field of hydrometeorology, the EMA has conducted research using its meteorological stations at Aswan (on-shore), a floating station at the High Dam, and a hydroclimate station in Abu Simble. These studies estimate water losses in the High Dam lake. In addition, EMA is carrying out research on flood modeling.

Other related aspects, partnerships, and investments

The EMA does not contribute operational weather forecasts for the capital city; however, it makes available climate information for the capital city to the WMO's World Weather Information Service.

Early Warning Systems

The EMA does not have radar(s) to monitor hazardous weather and extrapolate for the next few hours. The EMA is responsible for issuing weather warnings for decision makers; however, further research is required to understand whether there is collaboration with disaster management authorities to define warning criteria and assess weather-related impacts.

Summary of EMA status and challenges

The EMA is a public service with budget provided by the Government and no commercial activity, except cost recovery for aviation services. It has a significant number of staff, both in meteorology and hydrology. The EMA operates 24/7/365. Its observing system lacks radar(s) for monitoring severe weather and extrapolation for the next few hours. It has robust information and communication technologies. The EMA has good computing facilities for running its own limited area models. It does not use of ensemble prediction systems and probabilistic forecasts, which are critical for improved early warning systems. The EMA plays an important role in climate-related training for North Africa countries. It provides standard agrometeorological monitoring and forecast products, but more advanced crop modeling is required. The EMA is a designated aeronautical meteorological service provider in Egypt. It provides marine forecasts. There is no clear information on its early warning systems. Major challenges include: a significant number of staff close to retirement age, an inadequate nowcasting system, and limited coordination and collaboration with stakeholders.

Djibouti

Socioeconomic context[77]

Strategically located in the Horn of Africa, at the southern entrance to the Red Sea, Djibouti forms a bridge between the Middle East and Africa. Djibouti is one of the smallest countries in Africa, and therefore the size of its economy limits its ability to diversify production, and increases its reliance on foreign markets. With less than 1,000km^2 of arable land (0.04% of the country's total land area) and an average annual rainfall of approximately 150mm, Djibouti depends completely on imports to meet its food needs.

Djibouti has enjoyed rapid and sustained growth over the past 15 years with per capita GDP increasing by 3.1% on average per annum in 2001-2017. Despite this growth, however, an estimated 16% of the population lived below the international poverty line of US$1.90 per day in 2017. At the same time, the country is experiencing rapid urbanization, which increases the exposure of people and economic assets to disaster events. Djibouti's economy is currently driven by the country's state-of-the-art port complex, which is among the most sophisticated in the world. Djibouti plays, therefore, an important role in international economics and political issues. Trade through Djibouti's port is expected to grow rapidly in parallel with the expanding economy of its main trading partner, Ethiopia. Sea level rise due to climate change may, therefore, pose a significant socio-economic risk.

Djibouti is endowed with natural assets for the development of tourism, untapped marine resources that could support growth in artisanal fishing, and a significant infrastructure of undersea telecommunications cables on which it could draw to develop new service industries. Energy trade may also be a source of growth for the country. Djibouti's agricultural and industrial sectors are underdeveloped, but represent key livelihoods.

Climate[78]

Djibouti's climate varies across the country. The interior is hot, with average temperatures above 30°C during the summer (May to September), while in the cooler season (October to March/April) the average temperature is 25°C. Nights are generally warm, with average temperatures around 17°C. At the peak of the hot season, temperatures of up to 45°C have been recorded. At the coast, Djibouti's climate varies from the north to the south. Average temperatures are around 24-25°C and the wettest months are April, July, and August, with a monthly average of 30 mm. January, June and December are the driest months, with an

[77] See further information at http://www.worldbank.org/en/country/djibouti.
[78] See further information at https://climateknowledgeportal.worldbank.org/country/djibouti.

average rainfall of 10 mm or less. The humidity is very high with peaks of 90%. Key historical climate trends indicate:

- Over the past century, temperatures have increased, with 1991-2000 the warmest decade on record. The maximum temperature has increased by 0.5°C to 1.5°C over the past three decades, and the minimum temperature has increased by 1.5°C.
- Since 1960 rainfall has decreased significantly from April to July, and increased in January and October.

Climate projections for Djibouti indicate that:

- Temperatures across Djibouti are projected to increase between 0.6°C and 2.4°C by 2050.
- Future precipitation changes for Djibouti remain unclear due to large model uncertainties. However, there is high confidence that climate variability and extreme events in Djibouti will increase in the future.

Governance, organization, and management

In Djibouti, meteorological activities date from 1901 with the first meteorological station established at Plateau Snake. An Aeronautical Meteorological Service was created in 1961, and later, in 2012, the Djibouti National Meteorological Agency (NMA) was established under the supervision of the Ministry of Equipment and Transport by law N° 108/AN/10/6. The NMA's mission is described in decree N° 2012-167/PR of 11 July 2012, as follows:

(a) In the context of international and regional responsibilities:
  a. To coordinate, and negotiate agreements and conventions, in the field of meteorology; and,
  b. To represent Djibouti with regional and international organizations in the field of meteorology.

(b) In the context of national responsibilities, for the safety of life and property:
  a. To conduct weather and climate activities covering the country;
  b. To implement, maintain and operate weather and climate infrastructures;
  c. To collect and archive meteorological data, and provide statistical analysis to characterize the climate of the country; and,
  d. To participate in hydromet disaster risk prevention and management.

The Republic of Djibouti has been a member of the World Meteorological Organization (WMO) since 1978 and of the International Civil Aviation Organization (ICAO). It is also a member of regional and sub-regional organizations such as the *African Center for Meteorological Applications for Development* (ACMAD) and the *Climate Prediction and Application Center* (ICPAC).

The NMA's main source of funding is from the international airport and the government. Its budget is 146 million Djiboutian Francs per annum (equivalent to US$817,600). The NMA is headed by a Director-General that oversees services related to management, administration, and human resources, auditing, and technical aspects. Under the Technical Direction, there are 5 operational and technical Centres/Divisions, including: (a) aeronautical meteorology;

(b) forecasting and communications; (c) climatology and applied meteorology; (d) informatics and network management; and (e) national observing network.

The NMA has a total of 31 staff in Djibouti, and 35 volunteers who maintain and operate the rain gauge stations spread over the country. The NMA has 6 meteorologists, 16 meteorological technicians, 3 support staff, and 6 newly recruited staff. The level of recruitment per year has not been regular. It is anticipated that 8 staff will retire in the next 5 years.

The NMA has a development/strategic plan in place covering the next 3-5 years. Its vision is to produce and provide users with weather and climate products and services in a timely manner, in order to contribute to the socio-economic development of Djibouti, in particular in support of agriculture, water resources, air, and maritime transportation, and infrastructure/construction sectors.

Major socio-economic user sectors and their needs

As indicated in its vision, the NMA intends to support general public and socio-economic sectors, including agriculture, water resources, air, and maritime transportation, and infrastructure/construction.

Observing systems (weather, climate, water and environmental-related)

The NMA’s network consists of 2 synoptic stations (located at the airport and in Oboleh), 35 rain gauges, and 9 automatic weather stations (AWSs). These 9 AWSs were provided by the World Bank (WB; 5 stations) and the United Nations Environment Programme (UNEP; 4 stations) in 2013. The *Centre d’études et de Recherche de Djibouti* (CERD) operates 10 rain gauges.

Information and communications technology (ICT)

The NMA has no connection to the WMO Global Telecommunication System (GTS). It receives satellite imagery and global model outputs through the Meteosat Second Generation (MSG) station.

Observational data are transmitted to NMA by telephone. These data are collected in Excel files, allowing the preparation of some climate products.

Data-processing and forecasting systems

The NMA has access to global model outputs through the MSG station, and from the Internet.

Public weather services

The NMA provides meteorological bulletins and warnings to government departments and the general public through email and telephone. The NMA does not have a website.

Climate services

The NMA provides climate normal only for its longer-term station at the airport.

The NMA participates *in the Greater Horn of Africa Climate Outlook Forum* (GHACOF), coordinated by the Inter-Governmental Authority on Development (IGAD) Climate Prediction and Application Centre (ICPAC) in Nairobi, Kenya. Based on GHACOF consensus statements (four times per year) supported by ICPAC, the NMA issues seasonal forecasts for Djibouti.

Agricultural meteorological services

There is no information on the agrometeorological services of NMA.

Aeronautical meteorological services

The NMA issues TAFs, METARs, and SPECIs (special observations at aerodromes), and provides flight documentation to airlines.

Marine meteorological and/or oceanographic services

Daily marine meteorological forecasts and warnings are broadcast via national and local radio, and via special channels for fishermen and ships.

Hydrological forecasts and assessments

There are 9 hydrological stations in Djibouti managed by the Inter-Governmental Authority on Development (IGAD) in the context of the WMO Hydrological Cycle Observing System[79].

The CERD addresses hydrological aspects, however, this falls technically under the Ministry of Agriculture. A flood monitoring system was installed in 2006-2007 with the support of USAid, but it is not currently functioning.

Other related aspects, partnerships, and investments

Currently, the NMA does not contribute operational weather forecasts and climate information for the capital city to the WMO's World Weather Information Service.

Djibouti is a beneficiary country of the following projects:

- *Establishment of a Climate Prediction Analysis System in Djibouti*, which is a Global Framework for Climate Services (GFCS) project (ongoing), supported by the Korea Meteorological Administration (KMA), with the participation of the IGAD Climate Prediction and Application Centre (ICPAC). This project focuses on building capacity to use scientific weather and climate information in decision-making at national level.
- Adaptation and disaster risk reduction in Africa, which is a GFCS projected (completed in 2016), supported by the Norwegian Agency for Development Cooperation (NORAD), with the participation of the UK Met Office. This project focuses on capacity building to use timely and accurate climate and weather services for disaster risk reduction and increased resilience in agriculture.

Status of Early Warning Systems

The NMA has no observing system to monitor hazardous weather. There are no standard/defined thresholds for issuing warnings. The NMA does not have adequate means to disseminate warnings. Coordination and collaboration with disaster management authorities are required to establish early warning systems in Djibouti.

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[79] See WMO, "WHYCOS Portal", http://www.whycos.org/whycos/.

Summary of NMA status and challenges

The NMA is a fully public service with a very limited budget provided by the government and no commercial activity. It has insufficient, old and poorly qualified staff, but is willing to learn and support the modernization of the Service. The NMA does not operate 24/7/365. Its observing system is very poor, as are its forecasting, telecommunication, and service delivery capacities. The Regional Climate Centre (RCC) ICPAC supports NMA by providing some seasonal forecast products. The NMA would benefit from products for short-to medium-range forecasting from other regional centers. Major challenges include: insufficient budget to support its activities, no financial autonomy, a significant number of staff close to retirement, no human resource management, very inadequate (or non existent) monitoring, forecasting (at various time scales) and telecommunication systems, and limited coordination and collaboration with stakeholders.

Yemen

Socioeconomic context[80]

Yemen has endured conflict since early 2015. Already the poorest country in the MENA region before the conflict broke out, the UN says that Yemen is now suffering the worst humanitarian crisis in the world. Fighting has devastated the country's economy, destroyed critical infrastructure, and led to food insecurity verging on famine.

In 2019, the UN estimated that 24.1 million people (80% of the population) were "at risk" of hunger and disease, of which roughly 14.3 million were in acute need of assistance. An estimated 17.8 million people were without safe water and sanitation, and 19.7 million lacked adequate healthcare.

More than 40% of Yemeni households are estimated to have lost their primary source of income and consequently find it difficult to buy even the minimum amount of food. Poverty is worsening: before the crisis, it affected almost half the population, and it now affects an estimated up to 78% of Yemenis. Women are more severely affected than men.

Climate[81]

Yemen's climate is largely arid sub-tropical. The temperature depends on elevation and distance from the sea. Mean temperatures in the highlands range from below 15°C in winter to 25°C in summer, and in the coastal lowlands from 22.5°C in winter to up to 35°C in summer. Rainfall regimes differ between the highlands and coastal areas, with relatively little precipitation in the center of the country. The annual frequency of rain days increases with elevation, with the mean number of wet days showing a strong decline from west to east. Coastal areas receive 80% of the annual rainfall during winter, while rainfall in the highlands follows two distinct rainy seasons: the Saif (April to May) and the Kharif (July to September). Kharif rains typically fall in short events. Key historical climate trends indicate:

- Annual mean temperatures have risen across Yemen since 1960, particularly at high elevations (such as Sana'a). During the 20th century, the country has warmed by 0.5°C on average, and by approximately 1.4°C at the Aden Station (the highest on record).

[80] See further information at https://www.worldbank.org/en/country/yemen.
[81] See further information at https://climateknowledgeportal.worldbank.org/country/yemen.

- High year-to-year variability makes it difficult to detect a trend in precipitation. Since 1950, summer precipitation totals appear to have declined across the Yemen highlands, although local data for Yemen are lacking, and there are differences between datasets.

Climate projections for Yemen indicate that:

- By 2060, the mean annual temperature is expected to increase by 1.2 to 3.3°C. The projected rate of warming is more rapid in the interior regions than in coastal areas. The number of hot days and nights is projected to increase. The frequency of cold days and nights is projected to decrease.
- There is uncertainty in future rainfall patterns. There is high confidence that heavy precipitation events are expected to increase in Autumn (September to November).

Governance, organization, and management

Meteorological observations began in the port of Aden in 1870 during the colonial administration. A Department of Meteorology was established with the opening of the Airport in Aden in 1945. In 1967, Meteorological services became the responsibility of Yemenis, and thereafter in southern Yemen, there was further expansion of the observing networks. In 1969, the southern Yemen Meteorological Service joined the World Meteorological Organization (WMO). The Meteorological Services in the north of Yemen joined the WMO in 1971. After reunification in 1990, the two services merged as the General Authority for Civil Aviation and Meteorology/Yemen Meteorological Service (CAMA/YMS). There is no legislative act that regulates meteorology (or hydrometeorology) in Yemen. The CAMA/YMS operates 24/7/365.

Main objectives of the CAMA/YMS include: (a) providing accurate and reliable meteorological services in support of socio-economic sectors, including transport (especially aviation), water resources, energy, agriculture, media, tourism, environment, etc.; (b) contributing to public awareness in the areas of meteorology, climate change, and environmental conservation; (c) contributing to sustainable development; (d) contributing to reducing the risks of weather and hazardous climate events, thereby contributing to safety of life and property; (e) establishing and maintaining a network of meteorological stations; (f) ensuring exchange of meteorological information between the country and the world; (g) building a national climate database; (h) implementing WMO programs; and (i) following scientific developments in the areas of weather forecasts and climate predictions.

The CAMA/YMS' vision reads as follows: "A pioneer in technical expertise and a specialized reference in the areas of weather and climate to protect lives in the air, land, and sea, and contribute to economic and sustainable development to raise the standard of living and welfare of the Yemeni citizen".

The CAMA/YMS' only source of funding is from the Government. The total budget of CAMA/YMS is 378,5 million Riyal (equivalent to approximately US$1,51 million). In the last 3-5 years its budget has steadily increased. There is no information on whether CAMA/YMS has implemented a Quality Management System (QMS).

The administrative structure of CAMA/YMS consists of a central headquarters in Sana'a, which includes the following sections: observations, meteorological center, forecasting and instruments, research and renewable energy, climate departments, and finance and administration. Services are managed from a central headquarters in the capital. CAMA/YMS has six regional meteorological offices at the airports located in Seiyuon, Al Mukallah, Hodeidah, Ta'iz, Aden and Sana'a. Each of these offices is responsible for components of the observing network in their region and local weather briefings for pilots.

The CAMA/YMS has a total of 228 personnel at headquarters and regional offices, of which 214 are male and 14 are female. The CAMA/YMS has 18 staff at the management level, 23 meteorologists, 141 meteorological technicians, 11 climatologists, 7 researchers, and 28 classified as other staff. The number of CAMA/YMS staff with a university degree is 48. The age of the staff ranges as follows: (a) less than 20 years: 0 staff; (b) 20-30 years: 12 staff; (c) 30-40 years: 84 staff; (d) 40-50 years: 32 staff; and (e) over 50 years: 100 staff. Seventy-four staff are located at headquarters and rest in field offices. Over one-third of the staff work in operations. There has been no significant change in the number of staff in the last 3-5 years. Areas in which staff training is required (in order of priority) are: (1) forecasting; (2) observations; (3) climate; and (4) research.

In 2013, the WB initiated the Project Climate Information System and PPCR Coordination (P132116) to modernize hydromet services, but due to the situation in the country, the Project has not been completed.

Major socio-economic user sectors and their needs

The CAMA/YMS contributes to the economic and social development of the country by meeting the weather, climate, and environmental-related information requirements of various public socio-economic sectors, including transport (especially aviation), agriculture, renewable energy, and the public. The CAMA/YMS issues annual climate reports and supports integrated studies of climate and climate change in Yemen. The CAMA/YMS also supports research.

Observing systems (weather, climate, water and environmental-related)

The network includes 22 synoptic meteorological observation stations at Sa'dah, Hodeidah, Sana'a, Marib, Dhamar, Hajjah, Ibb, Ta'iz, Aden, Sahareeg, Ataq, Seiyuon, Al Mukallah, Ghaidah, Kood (Abian), Amran, Towahi (Minaa), Anad, Al Mahweet, Al Mokha, and Socotra. These stations provide hourly reports on temperature, wet bulb temperature, wind speed and direction, soil temperature, evaporation, sunshine duration, global radiation, rainfall, pressure, and other visual weather phenomena according to WMO standards.

Integrated Automated Airport Weather Observing Systems (AWOS) are located at each of the six airports – Hodeidah, Ta'iz, Seiyuon, Riyan, Aden, and Sana'a. These AWOS, installed in 2008 by Micro-Step Company, continue to operate.

MESSIR-Sat (supported by Corobor) provides access to MSG, EUMETCast, and GEOS products, providing a comprehensive set of satellite products and access to the global network of airborne, satellite, and in situ data sets distributed via satellite.

Information and communications technology (ICT)

A telecommunication system links observation sites with regional offices and the central processing and analysis system at CAMA/YMS. This system uses several technologies including dial up modems, WAN, SSB radio, satellite, VPN, internet, and fax.

The WMO Information System / Global Telecommunication System (GTS) transmission and reception operate via a link to the WMO Jeddah Regional Meteorological Center. The telecommunication system is based on MESSIR-Comm (supported by Corobor) installed in 2002 and upgraded in late 2008. This system is the heart of the meteorological center, which includes WMO Information System / Global Telecommunication System (WIS/GTS) message switching and real-time meteorological data processing.

Data-processing and forecasting systems

The central processing and analysis system at CAMA/YMS headquarters in Sana'a includes the National Meteorological Center, Forecasting Office, Observations server, and TV studio links to Pilot Briefing Offices at six airports – Seiyun, Al Mukallah, Hodeidah, Ta'iz, Aden and Sana'a. The forecasting system is based on products available on the WIS/GTS and visualized through the MESSIR-Vision (supported by Corobor), which is a forecaster workstation.

Public weather services

The CAMA/YMS National Center broadcasts special weather bulletins and warnings via various print, audio, and visual media for the public. It also provides a weather forecast that is broadcast daily through local and satellite channels on TV, and on its website. Meteorological services are provided according to the needs of parties and beneficiaries, and special forecasts are prepared for industrial, maritime and land transport, and commercial, agricultural and military uses. The CAMA/YMS uses MESSIR-Media (supported by Corobor), which is a dedicated system for the production of complete weather shows for television broadcast.

Climate services

The CAMA/YMS uses MESSIR-Clim (supported by Corobor), which is a climate database and workstation that produces an extensive set of graphs, diagrams, and tables for a wide range of clients and applications. There is no information on un-digitized data, or the types of climate services provided.

Agricultural meteorological services

The CAMA/YMS issues agromet forecasts to help farmers, agricultural research workers, and universities in determining the valid days for agricultural activities; and studying the phases of plant growth, frost, droughts, and relationship between weather and diseases. No other information is available on agrometeorological products and services from CAMA/YMS.

The Ministry of Agriculture and Irrigation (MAI) has been managing an agromet network, however, its current status and conditions are not clear. Prior to 2010, the system consisted of 13 sets of meteorological observations from manual weather stations, 90 automatic and 13 manual rainfall stations, and 30 automatic water flow stations. Additionally, water monitoring in wells included 50 automatic and 50 manual water level, 15 water quality measurements, and 606 water abstraction monitors. After 2010 regular data collection collapsed, and there is no systematic inventory of the condition of instruments and sites at the observation stations. There are reasons to believe that many stations have to be rehabilitated, and require equipment.

Aeronautical meteorological services

The CAMA/YMS is the meteorological authority (as per ICAO Annex 3) and the met service provider for aviation. It issues TAFs and METARs, and provides flight documentation to airlines. The CAMA/YMS receives OPMET and WAFS products operationally. The CAMA/YMS uses MESSIR-AERO (supported by Corobor), as a pilot briefing system, which accesses and visualizes WFAS and OPMET products from SADIS.

The CAMA/YMS has cost-recovery of aeronautical meteorological services. It is not clear whether it has a quality management system meeting international standards, or whether its staff meet competency, education and training requirements.

Marine meteorological and/or oceanographic services

The CAMA/YMS issues marine forecasts. There is no further information available.

Hydrological forecasts and assessments

The National Water Resources Authority (NWRA), established in 1996, is the sole authority for water resources management and enforcement of water-related laws in Yemen. Since 2003, NWRA has operated under the MWE, which includes most but not all water related agencies in Yemen. NWRA is still developing capacity at branches in some water basins, and at its headquarters in Sana'a. Monitoring is an essential activity of NWRA. The General Department of Monitoring Network (GDMN) / Hydrological Department measures rainfall, temperature, humidity, wind speed and direction, solar insolation, surface water, flooding, and water quality. The NWRA network had 354 stations in 2010 which undertook meteorological and wadi flow measurements, among others. Currently, only 196 of these stations seem to be operational, and even this figure is in doubt due to the effects of conflict and lack of funding.

The total number of NWRA staff is 324 (133 permanent staff) of which 34% are in Sana'a headquarters; the others are distributed in the 7 NWRA branch offices and 5 operational units. Thirty-two staff work in the Hydrological Department. Twenty-seven junior specialists and technicians conduct field monitoring including data collection.

In 2010 the NWRA budget for operations and maintenance of its hydrological network was 14 million YER (US$65,000); in 2011-2012 there was no O&M budget, and the projected budget for 2013 was 15 million YER (US$70,000).

Other related aspects, partnerships, and investments

Currently, the CAMA/YMS does not contribute operational weather forecasts and climate information to the WMO's World Weather Information Service.

Since 2016, Yemen has been a member of the ESCAP/WMO Panel on Tropical Cyclones.

Early Warning Systems

The CAMA/YMS has a surface observing system to monitor hazardous weather, however, its status and conditions are not clear. It does not have a weather radar. Severe weather forecasts and warnings are issued. The CAMA/YMS uses color-coded messages to identify the severity of weather conditions. The CAMA/YMS is the alerting authority for meteorological hazards and uses the Common Alert Protocol (CAP).

Summary of CAMA/YMS status and challenges

The CAMA/YMS is a government service with no commercial operations. It has a number of experienced staff. The CAMA/YMS operates 24/7/365. The observing network covers a large part of the country, but the status and conditions of this network are unknown. It has modest information and communication technologies. The CAMA/YMS has no numerical weather prediction capacities, and does not use ensemble prediction systems and probabilistic forecasts. The CAMA/YMS is the designated aeronautical meteorological service provider in Yemen. It has a modest early warning system. Major challenges include: lack of legal and regulatory framework, limited numerical weather prediction capabilities, its surface observing network requires upgrade, and limited coordination and collaboration with the departments responsible for hydrology.

West Bank and Gaza

West Bank and Gaza

Socioeconomic context[82]

The lack of progress towards peace and reconciliation creates an unsustainable economic situation. The internal Palestinian polity is sharply divided between Gaza and the West Bank. Due to a steep deterioration in Gaza and a slowdown in the West Bank, the Palestinian economy witnessed no real growth in 2018. The unemployment rate was 31% in 2018 — with 52% of Gaza's labor force unemployed, including two out of every three youth. The Palestinian Authority's financing gap persisted in 2018, mainly due to insufficient budget support, and was financed through additional arrears.

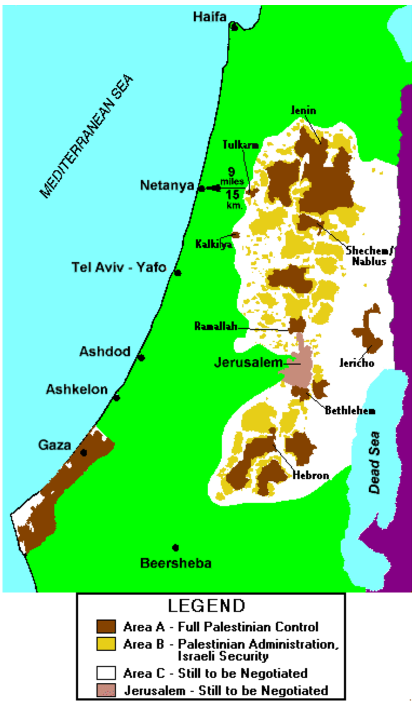
Climate

No information available at the WB Climate Portal.

Governance, organization, and management

The Palestinian Territory is comprised of the Gaza strip and the West Bank, separated by Israel. The Gaza strip is under an Israeli and US-led international economic and political boycott, initiated in 2007 when Hamas took power in the sub-region. The West Bank is subdivided into three Areas: Area A is fully under the Palestinian Authority (Administration and security), Area B: Palestinian Authority has civil authority, but Israel is responsible for security, and Area C: under full control of Israel (see ***Figure 18***).

Figure 18 – The Palestinian Territories, including West Bank and Gaza.



Source: IRIS: Information Regarding Israel's Security.

Note: Palestinian Territories following the Oslo II Agreement.

[82] See further information at http://www.worldbank.org/en/country/westbankandgaza.

The Palestinian Meteorological Department (PMD) is a government agency under the Ministry of Transport, established in 1997, with headquarters in Ramallah, the West Bank. However, meteorological observations began under the British mandate in Jerusalem, Jericho, Beit Qad (Jenin), Tulkarm, Arroub, and Wadi Fara in 1923. After 1948, the meteorological stations in the West Bank were affiliated to the Jordan Meteorological Department, and the Gaza station to the Egyptian Meteorological Authority. In 1967, following occupation by Israel, all existing and newly established meteorological stations in some West Bank and Gaza cities were affiliated to the Israel Meteorological Service. By that time, staff only measured and recorded meteorological parameters. In 1994 responsibility for these stations moved to the Palestinian National Civil Aviation Authority, which sent 25 staff to be trained at the Egyptian Meteorological Authority, with the intention to establish a specialized group which formed the PMD in 1997. The PMD's responsibilities cover Areas A and B of the Palestinian Territories (see ***Figure 18***); however, their forecasts are available to all in the West Bank and Gaza. The PMD's main functions include:

- Measuring meteorological elements such as temperature, atmospheric pressure, wind, etc.;
- Maintaining and operating a meteorological observing network;
- Issuing meteorological bulletins, and weather forecasts and warnings, including in support of air and sea navigation;
- Maintaining a climate database and issuing climate studies, including in support of structural and economic planning.

The PMD's mission is the optimum exploitation of climate conditions to serve society and contribute effectively to the development of the national economy in various sectors, including agriculture, water resource management, energy, aviation and sea navigation; and maintaining the safety of lives and property through accurate forecasts and warnings.

There is no reference to the development of a PMD development/strategic plan. However, the PMD has a vision of "excellence in providing accurate and detailed weather and climate services to users in a timely manner".

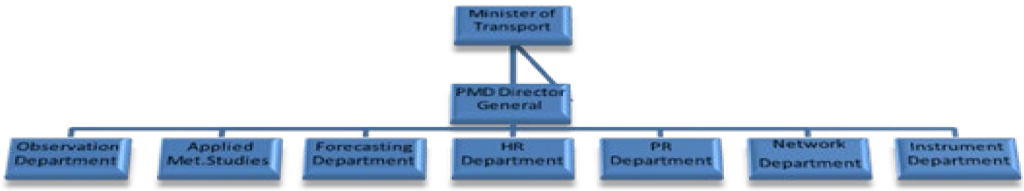
The PMD's main source of funding is from the Government, however, there is an indication that the budget is extremely limited. No reference to the budget is available.

The Palestine Meteorological Department is led by a Director General who reports to the Minister of Transport. There are 7 Divisions under the Director General (see organizational chart in ***Figure 19***). The PMD has 39 staff in West Bank out of which 6 are Observers/Forecasters working 24/7. Retirement has taken a toll over the last few years (15 retired). There are 26 staff in Gaza, but they are not operational because of the embargo, and they cannot be moved to the West Bank. The PMD has 2 IT personnel, but they require training to update their competencies. Some forecasters have been trained at the Jordan Meteorological Department under a JICA funding project. The staff's background in Maths and Physics mitigates against advanced training.

From 1997 to 2009, other NMHSs in the region (including Morocco, Jordan, Turkey, and Egypt) have provided training to PMD staff in various fields of meteorology. The NMHS of China trained PMD staff in 2007-2008. There is no information on any further training since 2009.

In 1999, Palestine became an observer State with the World Meteorological Organization (WMO) and a permanent member of the Permanent Arab Committee for meteorology in the league of Arab States.

Figure 19 – Organization of the PMD.



Source: PMD.

Major socio-economic user sectors and their needs

The PMD contributes to the economic and social development of the West Bank and Gaza by meeting weather and climate-related information requirements of various socio-economic sectors. These include: aviation; sea navigation; agriculture; civil defense; construction; and the media.

The PMD provides special information to researchers and university students, and climate data to the public and private sectors.

There is excellent collaboration between PMD and the National Council of Civil Defense and its members; PMD is highly visible in the Council which is chaired by the Prime Minister.

Observing systems (weather, climate, water and environmental-related)

PMD has 13 observing sites (8 automatic Weather Stations and 5 manual) and 150 manual rain gauges. Some rain gauges have been distributed in schools, local councils or volunteer houses. In cities, observing stations are placed on the roofs of buildings to avoid vandalism and theft. However, this practice does not meet WMO standards.

There are 8 synoptic reports per 24h. Because of restrictions, radar is not permitted. This is also valid for upper air observations (Note that the Israel Meteorological Service has one radar that covers West Bank and Gaza, and upper air stations that could be accessed if there is a bilateral agreement to exchange such information).

Information and communications technology (ICT)

There is no information available on PMD's communication system. However, there may be a telecommunication system in place to collect local meteorological data from the Automatic Weather Stations.

The power grid is unstable and the PMD lacks backup power (Generator). The probability of losing equipment to power surges is very high.

Data-processing and forecasting systems

A Satellite Distribution System (supported by ICAO) – SADIS – has been acquired by PMD; however, it stopped working some years ago and is unlikely to be repaired. Subsequently, the SADIS system was upgraded, but PMD could not afford it.

Two main servers are available: one for the database which is being upgraded through Germany funding and one to support the PMD website. The collection and archiving of data from observing stations complies with WMO standards.

The PMD has 6 observers/forecasters covering one meteorological desk on a 24/7 basis. The main forecasting tool is a personal computer with a small monitor (14”) connected to the Internet. Forecasters gather (both reliable and non-reliable) information from various sources to develop forecasts. The PMD has no forecaster workstations to visualize and overlay weather parameters to improve forecasts, products and services.

Public weather services

The PMD is responsible for issuing meteorological bulletins, weather forecasts, and warnings. Overall, PMD has many sources to disseminate forecasts and warnings: media, email, radio and TV, and social media. Over 60 radio and TV stations are provided with phone briefings and bulletins between 6 AM and 2 PM each day. Since the forecasters operate 24/7, they are also available to answer phone calls from users.

The PMD also operates a website to disseminate forecasts and warnings, and runs an outreach program to raise awareness of the importance of meteorology and the work they do.

Climate services

The PMD are attempting to repatriate climate data:

- For the period 1948-1967 for Gaza, data were received from the Egypt Meteorological Authority;
- For the period 1948-1967 for the West Bank, discussions are underway with the Jordan Meteorological Department; and,
- For 1967-1997, data were received from the Israel Meteorological Service.

Agricultural meteorological services

The PMD provides services to agriculture in the form of rainfall statistics. No further information is available.

Aeronautical meteorological services

In addition to public weather services, the PMD provides aeronautical meteorological forecasts in accordance with instructions from WMO and ICAO. There is no reference to PMD being the designated aeronautical meteorological service provider in West Bank and Gaza.

Marine meteorological and/or oceanographic services

The PMD provides forecasts for sea navigation in the Palestinian Economic Exclusive Zone.

Hydrological forecasts and assessments

Hydrology falls under the Palestinian Water Authority (PWA), which was established by Presidential Decree No. 90 of 1995. The PWA is a public institution working to manage, develop, and protect water resources through integrated and sustainable water supply, protection of the environment, and sustainable development. No information is available on the hydrological network or the relationship with PMD.

Other related aspects, partnerships, and investments

The PMD does not contribute operational weather forecasts or climate information to the WMO's World Weather Information Service.

Early Warning Systems

The PMD has a very rudimentary observing system to monitor hazardous weather which does not follow WMO standards. Severe weather forecasts and warnings are issued by PMD.

The PMD is a member of the National Council of Civil Defense, and has a high profile in this regard, as the Prime Minister chairs the Council when dealing with emerging disasters. The PMD's Director features prominently on TV when severe weather threatens.

Summary of NMHS status and challenges

Political uncertainties are a serious threat to PMD development. The budget for the PMD is extremely limited. However, PMD staff are very dedicated, wish to improve their operational situation, and are eager to provide better services to users, despite the fact that all posts have been frozen by the Palestinian Authority. Many PMD staff lack degrees in Maths and Physics, and are unable to upgrade their skills as forecasters. Nevertheless, the PMD has MoUs with universities in Palestine for research purposes.

Important operational tools are not available. There are no Forecaster Workstations to visualize model outputs and to overlay fields to assist with forecasting. The forecaster works with a desktop linked to the Internet, with a small monitor (14") which is not adequate for charts, model outputs, and satellite images. The power grid is unstable, which increases the probability of losing equipment. The PMD disseminates forecasts and warnings widely within West Bank and Gaza, and also through media in Israel. EWS is very rudimentary.

Chapter 4 – Socio-economic Benefits of Improved Hydrometeorological Services and Early Warning Systems in the MENA Region

For a potential public investment to be justified, the socioeconomic benefits it will produce should be compared to the costs involved. The application of cost-benefit analysis to modernizing hydrometeorological services was explored in WMO et al. (2015), which also outlined different methodologies (and challenges) for quantifying benefits and costs related to weather, climate, and water-related information and services. This study found that in general, investing US$1 in hydrometeorological services and EWS generates at least US$3 in socioeconomic benefits (defined as a 3:1 benefit/cost ratio), and often far more. This chapter presents the cost-benefit analysis specific to the MENA region.

CONSERVATIVE APPROACH

Cost-benefit analysis for disaster and climate risk management is often difficult due to a lack of data and information. In addition, the complexities and uncertainties inherent in quantifying disaster risk are compounded by climate change.[83] Cost-benefit analysis also deals in intangibles, and—of particular importance for extreme events—in discounting future impacts (WB 2019). Therefore, a robust cost-benefit analysis of hydromet services requires a transparent and conservative approach (Kull, Mechler, and Hochrainer 2013). All assumptions and their supporting analyses are described below. Input values are conservative i.e. for a range of potential benefits the lowest value is used; resulting in net present values and benefit/cost ratios for the lowest expected economic effectiveness. Thus, these values and benefit/costs are likely to be lower than those realized.

The three key conservative assumptions taken in this study are:

1. The analysis does not consider future population growth and development that will be protected by a potential investment; the economy at risk is considered the same as the most recent World Bank data on GDPs (mostly 2020, see **Table 5**).

2. Only reductions in the short-term direct impacts of weather and climate-related hazardous events are considered; long-term indirect impacts (such as in health) are not included.

3. Disaster risk assessment is based on past experience and therefore does not consider the potential impacts of climate change.

As indicated above, these assumptions contribute to a conservative estimate of the investment's economic effectiveness.

[83]IPCC's (2012) SREX report

Table 5. GDPs of MENA Countries[84]

Country	GDP (current US$; billion)	Reference year
Morocco	112,871	2020
Algeria	145,164	2020
Tunisia	39,236	2020
Malta	14,647	2020
Libya	25,418	2020
Egypt	363,069	2020
West Bank and Gaza	15,561	2020
Israel	401,954	2020
Lebanon	33,383	2020
Jordan	43,698	2020
Syria	40,405	2007
Saudi Arabia	700,118	2020
Iraq	167,224	2020
Djibouti	3,384	2020
Yemen	23,485	2018
Kuwait	136,197	2019
Iran	191,718	2020
Bahrain	38,475	2019
Qatar	146,374	2020
United Arab Emirates	421,142	2019
Oman	76,332	2019
Total MENA	**3,098,531**	**2020**

Benefits from Avoided Disaster Losses

Considering the stochastic nature of disasters, a common practice for cost-benefit analysis of disaster risk management is to determine average annual losses due to disasters (Kull, Mechler, and Hochrainer 2013) i.e. to average potential yearly losses in order to arrive at an expected annual economic burden. When sufficient data are available, the average annual loss is calculated as the area under a loss frequency curve, which is a common metric indicating the exceedance probability of the full potential range of losses per year (for example from the yearly flood to the 100- or 200-year flood).

Tables 6 and 7 provide, respectively, the total loss and the average annual loss (AAL) in US$ for the main hydrometeorological (weather-, climate- and water-related) hazards in MENA countries during the period 1950-2020. While noting that forest fires are a major hazard in the MENA region, and can be induced by hydromet conditions, these have not been considered in this study due to the lack of reliable data.

Table 6. Total Loss in US$ Thousand for the Main Hydromet Hazards in MENA Countries, 1950-2020[85]

Country	Extreme temperatures	Droughts	Floods	Storm	Forest fires	TOTAL

[84] Source: World Bank database
[85] Source: EM DAT database

Morocco	809 (heatwave)	900,100	330,200	300,050 (cyclone and convective storm)	6,490	1,537,649
Algeria	Unknown	Unknown	1,543,917	Unknown	Unknown	1,543,917
Tunisia		46,502	476,800		2,450	525,752
Malta[86]						0
Libya			49,300			49,300
Egypt	Unknown		231,000	126,000 (sand storm and thunderstorms)		357,000
West Bank and Gaza	25 (frost)			7,100		7,125
Israel	550,000 (cold wave)	75,000	620,000	2,750	835,000	2,082,750
Lebanon			10,000	155,000 (winter storm)	500	165,500
Jordan	400,000 (cold wave)	Unknown	3,400	Unknown		403,400
Syria		Unknown	44,000	Unknown	Unknown	44,000
Saudi Arabia			1,652,000	50,000 (winter storm)		1,702,000
Iraq		2,000	159,300			161,300
Djibouti		157,058[87]	11,100[88]			168,158
Yemen		10,000	2,684,400	200,000		2,894,400
Kuwait			328,000[89]			328,000
Iran	Unknown	3,300,000	13,829,528	28,540	Unknown	17,158,068
Bahrain						0
Qatar			10,000			10,000
United Arab Emirates			Unknown			Unknown
Oman			Unknown	5,172,000 (cyclones and severe storm)		5,172,000
Total MENA	**950,834**	**4,490,660**	**21,982,945**	**6,041,440**	**844,440**	**34,310,319**

Table 7. Average Annual Loss (AAL) in US$ Thousands Per Hydrometeorological Hazard, 1950-2020[90]

Country	Extreme temperatures	Droughts	Floods	Storm	Forest fires	TOTAL

[86] Malta has not reported a disaster between 1980–2010. Source: "Natural Disasters in the Middle East and North Africa: A Regional Overview", The World Bank, 2014.
[87] Source: Djibouti PDNA, 2011
[88] Source: "Natural Disasters in the Middle East and North Africa: A Regional Overview", The World Bank, 2014.
[89] Development of National Hazard Profile for the State of Kuwait and Identification of Existing Data and Gaps for Exposure and Vulnerability Assessment, RMSI Private Limited India, January 2020.
[90] Source: EM DAT database

Morocco	12	298,017[91]	461,096[92]	4,286	93	763,504
Algeria			22,056			22,056
Tunisia		664	42,300[93]		35	42,999
Malta				0[94]		0
Libya			704			704
Egypt			3,300	1,800		5,100
West Bank and Gaza	0,357			101		101
Israel	7,857	1,071	8,857	32	11,929	29,746
Lebanon			143	2,214	7	2,364
Jordan	5,714		49			5,763
Syria			629			629
Saudi Arabia			23,600	714		24,314
Iraq		28	2,276			2,304
Djibouti		2,244[95]	19[96]			2,263
Yemen		143	38,349	2,857		41,349
Kuwait			4,686			4,686
Iran		47,143	197,565	408		245,116
Bahrain			0[97]			0
Qatar		0[98]	143	0[99]		143
United Arab Emirates				32[100]		32
Oman				73,886		73,886
Total MENA	**13,583**	**349,310**	**805,772**	**86,330**	**12,064**	**1,267,059**
% GDP						0,041

91 Results from the "Morocco natural hazards Probabilistic Risk Analysis" can be found in: World Bank (2013). Building Morocco's Resilience: Inputs for an Integrated Risk Management Strategy. Washington, DC. MAD/USD: 0.11 (10/11/2021).
92 Ibid.
93 Tunisia Risk Profile, World Bank 2020
94 Source: Global Assessment Report on Disaster Risk Reduction, 2015 (GAR) https://www.preventionweb.net/english/hyogo/gar/2015/en/home/data.html
95 Based on the data from Djibouti PDNA 2011
96 Source: Global Assessment Report on Disaster Risk Reduction, 2015 (GAR) https://www.preventionweb.net/english/hyogo/gar/2015/en/home/data.html
97 GAR, 2015
98 GAR, 2015
99 Ibid.
100 GAR, 2015

Benefit Analysis

Benefits from Reduced Disaster Losses

Subbiah, Bildan, and Narasimhan (2009) discuss damage reduction that can be achieved through early warning, which ranges from 5 percent to 90 percent, depending on the items at risk and provided lead times. While a 20 percent reduction in losses through EWS is often cited as an average, case studies suggest that a more conservative range of 5–10 percent is more appropriate; for example 5 percent in Georgia (World Bank 2018), 8.5 percent in Russia (World Bank 2005) and 10 percent for floods in southeastern Europe (World Bank 2008). In line with the conservative approach set out for this analysis, the lower end of the range of global experience (5 percent) is applied. Out of total annual damages due to hydrometeorological hazards of US$1,267,059 million, improved forecasting and early warning can potentially eliminate some US$63,353 million.

Considering the lack of data, a benchmarking methodology is here employed to verify the results, following Hallegatte (2012) and based on a country's GDP. Hallegatte (2012) found that on average, well-functioning, modern EWS reduce disaster-related asset damages by between 0.003 percent and 0.017 percent of GDP. The study concludes that the potential benefit of an investment in EWS is the difference between asset damage costs under the country's existing systems and the potentially reduced costs if those systems are modernized.

Under this benchmarking methodology, MENA region countries would be considered as lower-middle-income countries with relatively modest systems and would therefore be assumed to currently capture only 20 percent of the potential damage reduction benefits of hydromet early warning. Potential benefits would thus be calculated as the difference between the potential reduced losses—between 0.003 percent and 0.017 percent of GDP, assuming MENA corresponds to the global benchmark—and the actual reduced losses, which in this case would be 20 percent of that value. The results for MENA range up to US$105,350 million in average annual reduced losses.

The benchmarking methodology indicates that estimates of annual benefits from reduced flood losses are of a similar order of magnitude to the lower value. Recognizing some discrepancies, likely due to MENA countries being less or more exposed to hydrometeorological hazards than the global average, a sensitivity analysis is also pursued to identify the impact of reduced benefits on the overall economic assessment.

Benefits from Increased Production

In addition to lessening disaster losses, modernized hydromet systems can significantly enhance economic productivity. Because information is lacking, a benchmarking approach is used to estimate potential benefits to the economy from modernized hydromet services in MENA countries.

Hallegatte (2012) found that about 25 percent of global GDP is generated in weather- and climate-sensitive sectors i.e. agriculture, mining and energy, construction, and transport.

Modernized hydromet and warning systems can benefit these sectors in many ways, ranging from immediate warnings and seasonal advisories to infrastructure design and spatial planning. A conservative global benchmark is that modern forecasts add values of 0.1 percent to 1 percent in weather- and climate-sensitive sectors, which would translate into gains of approximately 0.025 percent and 0.25 percent of global GDP.

In MENA countries, weather- and climate-sensitive sectors represent at least 25 percent of the regional economy for agriculture, transport, energy, construction, and tourism; but this may be even higher as there are other sectors of society that are also weather- and climate-sensitive. Applying the Hallegatte (2012) benchmarking approach results in annual benefits in production of US$774,633–7,746,328 million per year. To avoid double-counting and again pursuing a conservative approach, the lower end of the range (i.e. US$774,633 million) is used in this analysis. However, considering the frequency of droughts, floods, and storms in the region, this must be considered extremely conservative.

Total Annual Benefits

As indicated above, the benefits attributed to improved hydrometeorological services for this analysis are based on the lower end of the range i.e. US$18,592 million for reduced disaster losses due to hydromet hazards, and US$774,633 million for increased productivity, out of a total of US$793,225 million.

Cost-Benefit Analysis

For this study, a proposed average investment of US$25 million per MENA country has been considered; but some countries would require more investments than others in order to fully modernize and gain the 5 percent loss reduction possible through early warning. It must again be noted that this is already a conservative estimate. Benefits in terms of reduced disaster damages and increased production are assumed to increase linearly after the first project year, reaching full benefits the year after program completion.

Comparing the costs and benefits of the program over time can show the relative value of the planned investments. While cost-benefit analysis provides a useful process and resultant metrics to help steer investment decision making, however, it should not be the only factor considered.

While implementation typically spans 5 years, this analysis assumes that the project impact is 20 years, and is based on the average life cycle of the infrastructure (meteorological and hydrological equipment). Investment disbursements are assumed to occur equally across each year of the project. Additional O&M costs attending modernization thus increase linearly as cumulative project investments are made, reaching a constant maximum after the fifth year of project investments. Benefits of reduced disaster damages and increased production are also assumed to increase linearly; they start to be realized from the second year and reach a constant maximum after the fifth year of project investments.

Cost-benefit analysis uses a discount rate to represent societal preference for consuming in the present as opposed to saving, and consuming in the future. A discount rate of 0% indicates no preference between now and in the future, while a discount rate of 15% represents a high preference for spending now. In this analysis a discount rate of 5% is applied, representing an understanding that future costs and benefits are relatively important in comparison to the current situation (in keeping with concerns regarding climate change). However, 0% to 15% discount rates are also applied for sensitivity analysis. **Table 8** shows the results of the analysis for the following cost-benefit metrics:

- **Net present value:** Present benefits minus present costs. If the net present value is greater than 0.0, then the investment is considered economically effective.

- **Benefit/cost ratio:** Present benefits divided by present costs. If the benefit/cost ratio is greater than 1.0, then the investment is considered economically effective.

Table 8. Cost-benefit Analysis Results

	Net present value (US$ million)				**Benefit/cost ratio**			
Discount rate	*0%*	*5%*	*10%*	*15%*	*0%*	*5%*	*10%*	*15%*
"Realistic" benefits	12,553	7,467	4,787	3,270	13.9	11.5	9.6	8.1

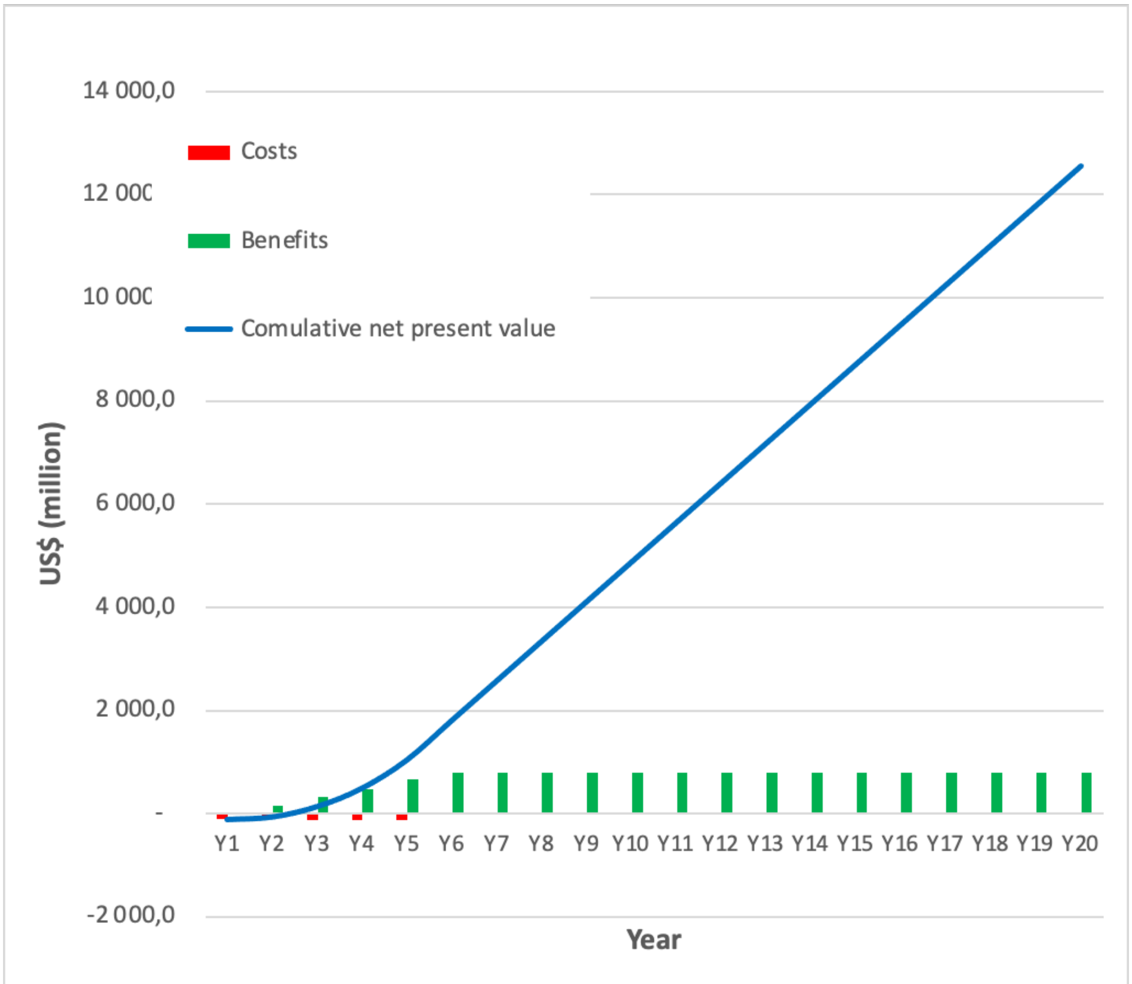
To further test the sensitivity of the analysis, the "realistic benefit" (i.e. the lower end of the range) is calculated using an assumption that the costs are 30% higher than estimated. The results are shown in **Table 9**.

Table 9. Cost-benefit Analysis Results: Realistic Benefits and 30% Cost Overruns

	Net present value (US$ million)				**Benefit/cost ratio**			
Discount rate	*0%*	*5%*	*10%*	*15%*	*0%*	*5%*	*10%*	*15%*
"Realistic" benefits	12,262	7,254	4,620	3,132	10.7	8.8	7.4	6.3

The importance of reliable long-term budget availability is reflected in ***Figure 30***, which shows the first 10 years of financial and economic flows, assuming "realistic" benefits and a discount rate of 5%. The first year of investment results in a nearly constant reduced net present value, but as more and more investments accrue, the net present value increases, despite increased operations and maintenance costs. Once the program is completed (in year 5), the annual costs and benefits remain constant, and the cumulative net present value significantly increases year-on-year. The relatively small operations and maintenance costs leverage the investment to deliver significant benefits far into the future.

Figure 30. Annual Financial and Economic Flows of Investment with "Realistic" Benefits and 5% Assumed Discount Rate



14 000,0
12 000
10 000
8 000,0
6 000,0
4 000,0
2 000,0
-
-2 000,0
US$ (million)
Costs
Benefits
Comulative net present value
Y1 Y2 Y3 Y4 Y5 Y6 Y7 Y8 Y9 Y10 Y11 Y12 Y13 Y14 Y15 Y16 Y17 Y18 Y19 Y20
Year

Chapter 5 – Conclusions and Recommendations to Strengthen Hydrometeorological Services in MENA: Regional and National Contexts

A close look at hydromet services in the MENA countries featured in this review reveals different governance, organization, and capacities among the National Meteorological and Hydrological Services (NMHSs) of Morocco, Algeria, Tunisia, Libya, Malta, Lebanon, Jordan, Syria, Iraq, Iran, Saudi Arabia, Kuwait, Bahrain, Qatar, United Arab Emirates, Oman, Egypt, Djibouti, Yemen, and West Bank and Gaza, *as highlighted in* ***Tables 10 and 11, and Figures 31 and 38****. This chapter presents conclusions and recommendations for further study of the capacities of these NMHSs, and recommendations to strengthen their hydromet services.*

SUMMARY OF GOVERNANCE, ORGANIZATION, AND FUNCTIONAL CAPACITIES OF NMHSS IN MENA COUNTRIES

The services provided by NMHSs rely on a complex and dynamic system of subsystems—monitoring and observing, modeling, forecasting, service delivery, information and communication technology, research, and quality management—all of which are supported by institutional capacity building, technical training, and outreach to stakeholders and recipients of information. A summary of the governance, organization, and management of the NMHSs of Morocco, Algeria, Tunisia, Libya, Malta, Lebanon, Jordan, Syria, Iraq, Iran, Saudi Arabia, Kuwait, Bahrain, Qatar, United Arab Emirates, Oman, Egypt, Djibouti, Yemen, and West Bank and Gaza is included in ***Table 4***; and a summary of their hydromet functional capacities is included in ***Table 5***.

Except for the NMHS of Morocco (which is under the Ministry of Energy, Mines, Water, and Environment), Syria (which is under the Ministry of Defense), Iran (which is under the Ministry of Roads & Urban Development), and UAE (which is under the Ministry of Presidential Affairs), all other NMHSs of MENA countries are under the supervision of Ministries of Transport, mostly because of their primary role to support aviation sector. All NMHSs, except those of Lebanon, Yemen, and Syria (lack of information), have a legal basis to provide meteorological services. Specifically, their primary role is to provide aeronautical meteorological services for air navigation, but they are also the authority for issuing warnings for the safety of life and property in their countries. All NMHSs, except those of Lebanon (that does not have a plan), Syria, and West Bank and Gaza (where there is a lack of information), have a strategy for the next 3 to 5 years, highlighting their increasing role in climate change and in disaster risk reduction, and the importance of close relationship with stakeholders and end users in order to better address their requirements. In particular, disaster risk reduction and early warning systems require that NMHSs run a 24/7/365 monitoring and forecast operations, which are not always feasible due to the lack of human and financial resources, as in the case of Djibouti; no information is available for Lebanon, Jordan, and Syria.

Table 10 - Summary of Governance, Organization, and Management of MENA NMHSs

Governance, organization and management	Maghreb and Malta					Mashreq					GCC c		
	Morocco	Algeria	Tunisia	Libya	Malta	Lebanon	Jordan	Syria	Iraq	Iran	Saudi Arabia	Kuwait	Bahrain
Ministry	Ministry of Energy, Mines, Water and Environment	Ministry of Public Works and Transport	Ministry of Transport	Ministry of Transportation	Civil Aviation	Directorate General of Civil Aviation	Ministry of Transport	Ministry of Defense	Ministry of Transportation	Ministry of Roads & Urban Development	Ministry of Environment, Water and Agriculture	Directorate General of Civil Aviation	Ministry of Transport and Communications
Legal framework	Y	Y	Y	Y	N	N	Y	LI	Y	Y	Y	Y	Y
Strategy	Y	Y	Y	Y	Y	N	Y	LI	Y	Y	Y	Y	Y
Staff	S	D	D	D	D	LI	D	LI	I	D	S	D	D
Budget	I	S	S	I	LI	LI	S	LI	S	I	S	S	I
Business model	Y	Y	Y	N	N	N	N	LI	N	N	N	N	N
Run 24/7/365	Y	Y	Y	Y	Y	LI	LI	LI	Y	Y	S	Y	Y
Well-established link with stakeholders	Y	Y	Y	Y	LI	N	N	LI	Y	Y	N	Y	Y
NMS and NHS associated / if not, they have close working relationship	N / Y	N / LI	N / Y	N / LI	N / LI	N / LI	N / LI	LI / LI	N / LI	N / LI	N / LI	N / LI	N / L

Source: Based on recent reviews conducted on behalf of the World Meteorological Organization (WMO) and on existing literature, WMO Country Profile Database, NMHSs' individual websites.

Notes:

Red	N = no or NS = not stable
Orange	D = decreasing
Yellow	I = increasing
Green	Y = Yes or S = Stable
White	NA = not applicable
Grey	LI = lack of information

Table 11 - Summary of Hydromet Capacities of MENA NMHSs

System Categories	Functions and/or Capacities	Maghreb and Malta					Mashreq					GCC cou		
		Morocco	Algeria	Tunisia	Libya	Malta	Lebanon	Jordan	Syria	Iraq	Iran	Saudi Arabia	Kuwait	Bahrain
	Weather monitoring	F	E	B	F	F	E	E	B	B	F	E	A	A

Monitoring and Observing System	Climate monitoring	F	E	E	F	F	E	E	B	B	F	E	F	F
	Hydrological monitoring	F	E	F	LI	LI	LI	LI	LI	LI	LI	LI	LI	LI
	Quality assurance/quality control of observations	F	LI	LI	LI	LI	LI	LI	LI	LI	LI	LI	F	LI
Modeling System	Numerical Weather Prediction	A	F	E	E	LI	E	E	LI	E	E	E	F	E
	Ensemble Prediction Systems (use of probabilistic forecasts)	E	E	B	B	LI	B	LI	LI	B	B	B	LI	E
	Hydrological forecasting and assessments	LI	LI	LI	LI	E	LI	LI	LI	LI	LI	LI	LI	LI
Forecasting and Warning System	Nowcasting	F	E	B	E	F	E	E	B	B	F	F	A	F
	Short- to medium-range weather forecasting	F	F	E	E	E	E	E	B	F	F	E	F	F
	Seasonal forecasting, including climate outlooks	A	E	F	F	LI	E	E	LI	LI	F	E	LI	LI
	Forecast verification	LI	LI	LI	LI	LI	LI	LI	LI	LI	E	LI	LI	LI
Management and information Systems	ICT and computing facilities	F	F	E	E	LI	E	E	LI	E	E	F	F	LI
	Connection to WIS/GTS	A	F	E	F	F	F	E	LI	F	F	F	F	F
	Quality management systems	A	F	F	F	LI	LI	E	LI	F	LI	F	F	A
Service Delivery Systems	Public weather services, including early warning systems	A	F	F	F	F	B	F	E	F	F	E	A	F
	Climate services, including climatological normals, maps, etc.	F	E	F	F	LI	E	E	B	B	E	E	F	F
	Agromet services, including yield information	E	E	E	E	LI	B	B	LI	E	E	LI	LI	LI
	Marine forecasting	F	F	E	F	F	E	E	LI	LI	F	F	A	E
	Aviation forecasting	F	E	E	F	F	F	E	LI	F	F	F	F	F

Source: Based on recent reviews conducted on behalf of the World Meteorological Organization (WMO) and on existing literature, WMO Country Profile Database, NMHSs' websites. Functions are described according to the World Meteorological Organization's terminology database METEOTERM, https://www.wmo.int/pages/prog/lsp/meteoterm_wmo_en.html; and capabilities/levels of service are identified based on the WMO Categorization of NMHSs, https://library.wmo.int/doc_num.php?explnum_id=7871 (Table 4).

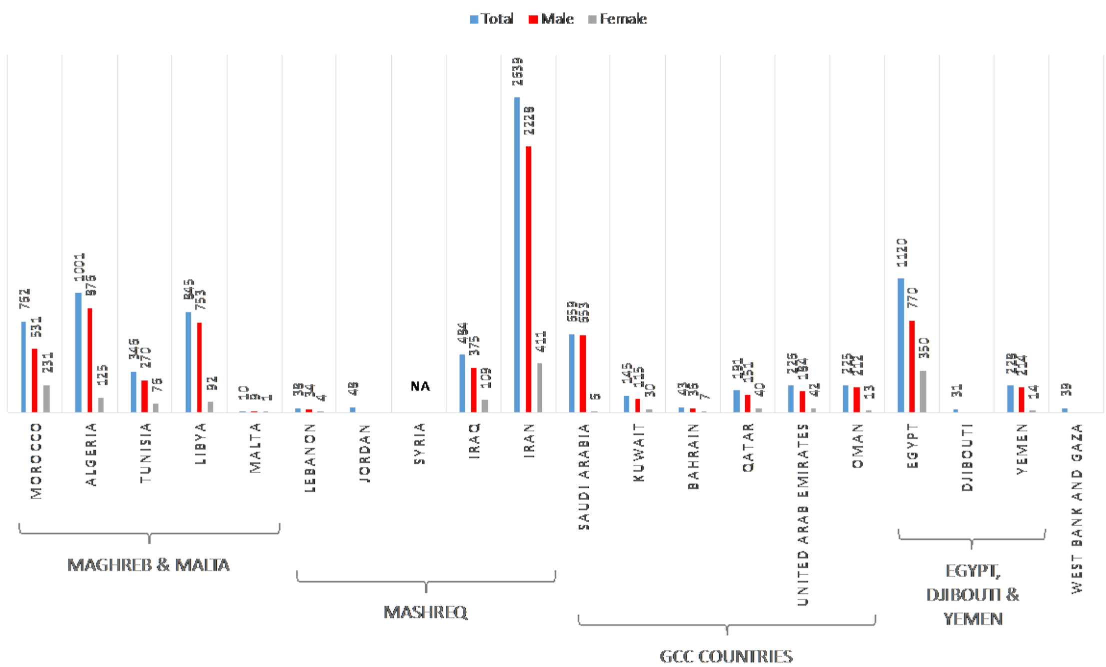
Notes:

(grey)	<B = Less than Basic or no capacity
(red)	B = Basic
(orange)	E = Essential
(yellow)	F = Full
(green)	A = Advanced

(white box)	NA = not applicable
(grey box)	LI = lack of information

While noting their growing involvement in addressing the requirements of stakeholders and increasing demands by user communities in various socio-economic sectors, most of the NMHSs of MENA countries are facing a steady decrease of staff, except in Iraq, Qatar, UAE, and Oman. ***Figure 31*** shows the number of staff (total; male; and female) per country. The country with the highest number of NMHS staff is Iran, followed by Egypt, Algeria, Libya, Morocco, and Saudi Arabia (all over 500 staff). All countries show a gender imbalance, with more male than female. The number of staff tend to be associated with the size of the country, number of observing stations and systems (due to the staff required for operating and maintenance), and capacity of the Service in all aspects of the end-to-end system (from observation, forecasting, to service delivery and warning systems). However, the analysis is not linear, as small countries may have nearly full capacity, with a small number of staff (e.g. Kuwait and Bahrain); the opposite can also happen, i.e. a big country with limited capacities, with a high number of staff. Some of the NMHSs of MENA countries are currently inviting applications for the *Basic Instructions Packages for Meteorologists and for Meteorological Technicians* required for NMHS staff (e.g. Jordan).

Figure 31 – Number of Staff (total; male; and female) Per Country



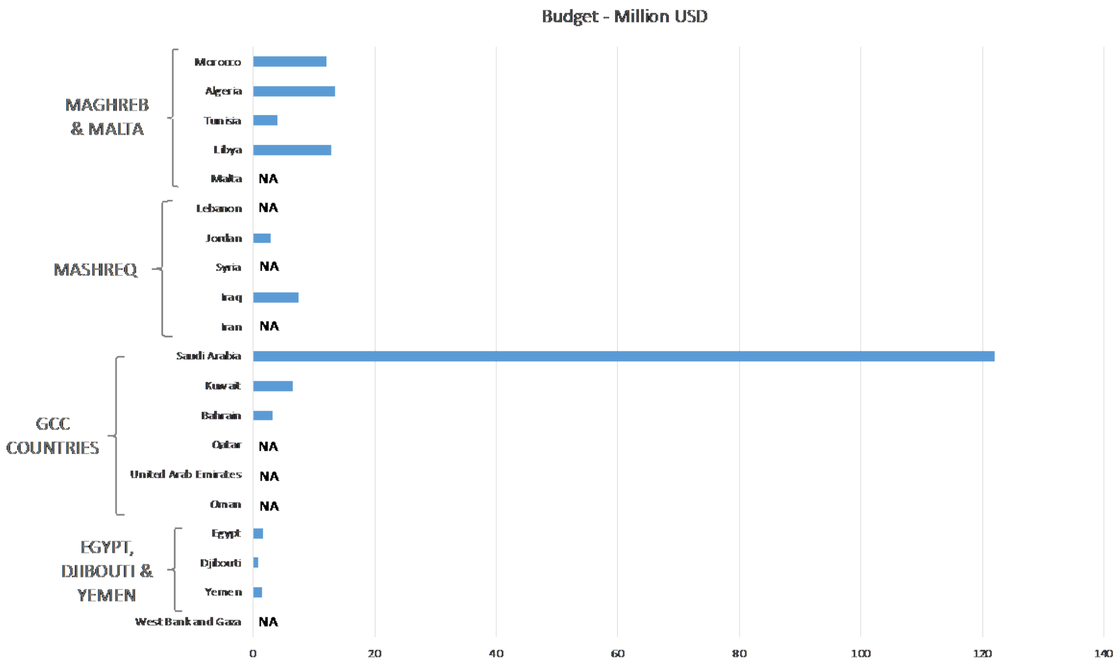
Source: Based on recent reviews conducted on behalf of the World Meteorological Organization (WMO) and on existing literature, WMO Country Profile Database, NMHSs' websites.

Notes: NA – Not Available

In the last 3 to 5 years, NMHS budgets from MENA country governments have decreased, except in Bahrain, Iran, Libya, Morocco and Oman where they have increased slightly, and in Lebanon, West Bank & Gaza, and Yemen where there is no information available. Only the NMHSs of Algeria, Morocco, and Tunisia have introduced a business model – they are

Government services with a commercial arm. Other NMHSs are fully public services with budget provided by the Government and no commercial activity except for basic cost recovery for production and communication services, mostly for aviation. ***Figure 32*** compares the government budgets of MENA country NMHSs. Similarly to the number of staff, the budget also depends on the size of the country, number of observation stations and systems (due to operating and maintenance costs), and capacity of the Service in all aspects of the end-to-end system (from observation, forecasting, to service delivery and warning systems).

Figure 32 – Government budgets for MENA NMHSs Per Country and Per Sub-region



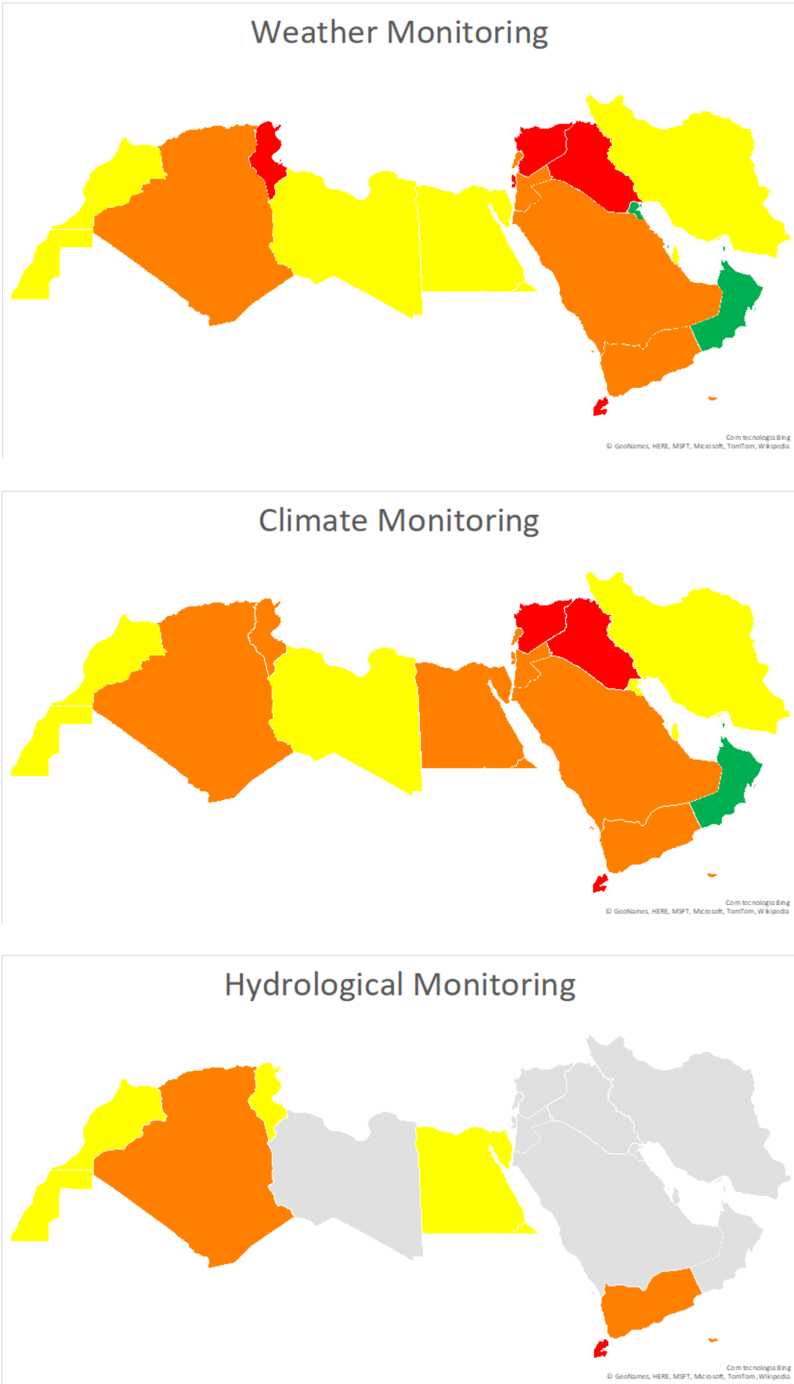
Source: Based on recent reviews conducted on behalf of the World Meteorological Organization (WMO) and on existing literature, WMO Country Profile Database, NMHSs' websites.

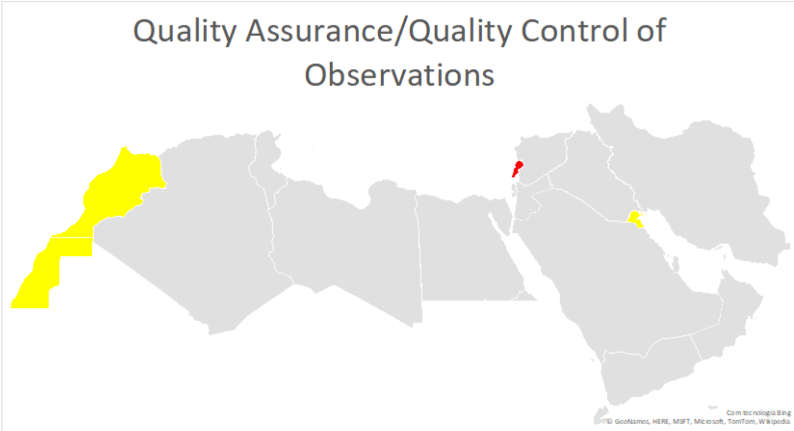
Note: NA = Not Available

In all MENA countries, the National Meteorological Service (NMS) is not associated with the National Hydrological Service (NHS), and in most cases, the hydrological services are dispersed across multiple government departments or agencies, which makes working relationships more challenging. However, in Morocco and Tunisia, NMSs and NHSs have a close working relationship. This collaboration is important given the current and expected future impacts of hydromet-related hazards (such as droughts and floods) on countries of the MENA region.

In terms of observing systems (***Figure 33***), there are significant differences between NMHSs of MENA countries, with those with very high capacity such as Kuwait, Bahrain, UAE, and Oman (in both quantity and diversity of observations; and therefore at the Advanced level), and others with very low capacity such as Djibouti and Syria (less than the Basic level) where there is a noteworthy lack of observations, and Iraq where observations are mostly manual. Most likely due to restrictions, the NMHSs of Algeria, Tunisia, Iraq, Syria, Djibouti, West Bank and Gaza, and Yemen (which are either at Basic or Essential levels) have no weather radar. Those with high and very high capacity typically have a program of regular maintenance and calibration of observation instruments. In the region, there are WMO Regional Instrument Centres (RICs), and those NMHSs with less capacity should make use of these facilities. There is a lack of information related to quality assurance/quality control of observations, except for the NMHSs of Morocco and Kuwait which are at Full capacity; and the NMHS of Djibouti which is at less than Basic level.

Figure 33 – Monitoring and Observing Systems

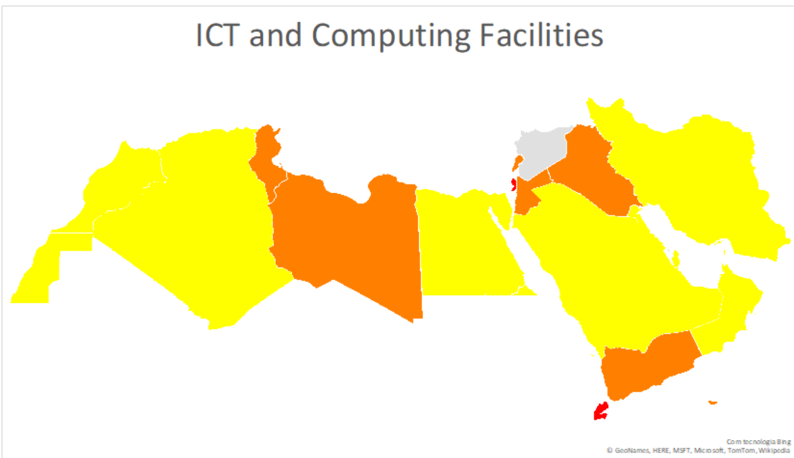


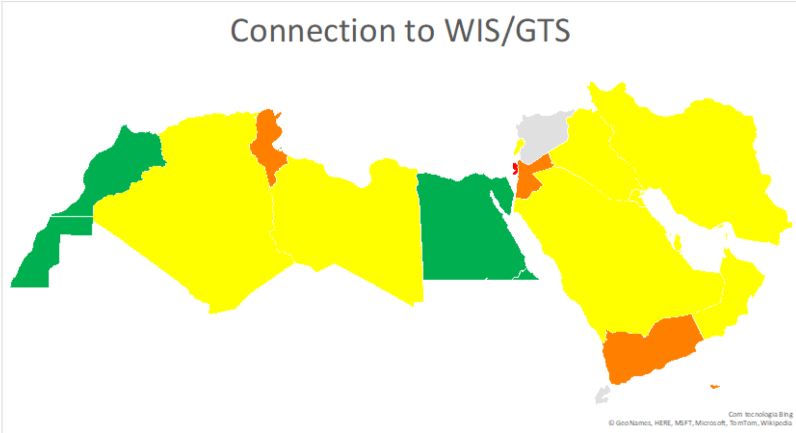


Source: Based on recent reviews conducted on behalf of the World Meteorological Organization (WMO) and on existing literature, WMO Country Profile Database, NMHSs' websites.

Similarly, capacities vary in terms of information, communications and technology (***Figure 34***), and computing facilities for communication at the national level and with the "outside world." Better communications would allow NMHSs to benefit from data and products being made available through the Global Telecommunication System. It would also allow them to make their own data available for improved monitoring and numerical forecasting, which would be beneficial to the worldwide meteorological community and a step toward full compliance with WMO data-sharing policies. NMHSs of Morocco and Egypt are at the Advanced level in terms of connection to the WIS/GTS; while most of the region is at the Full level. In terms of ICT and Computing Facilities, NMHSs of Djibouti and West Bank and Gaza are at the Basic level; and NMHSs of Tunisia, Libya, Lebanon, Jordan, Iraq, Iran, and Yemen are at the Essential level. The remaining NMHSs have Full capacity.

Figure 34 – Information Systems

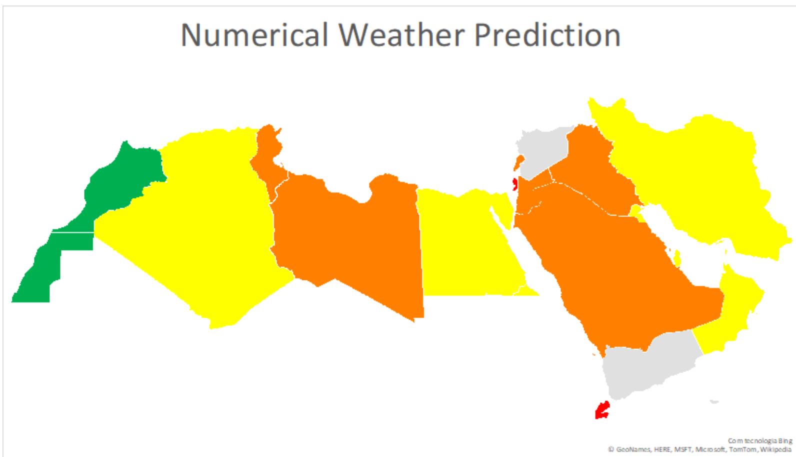


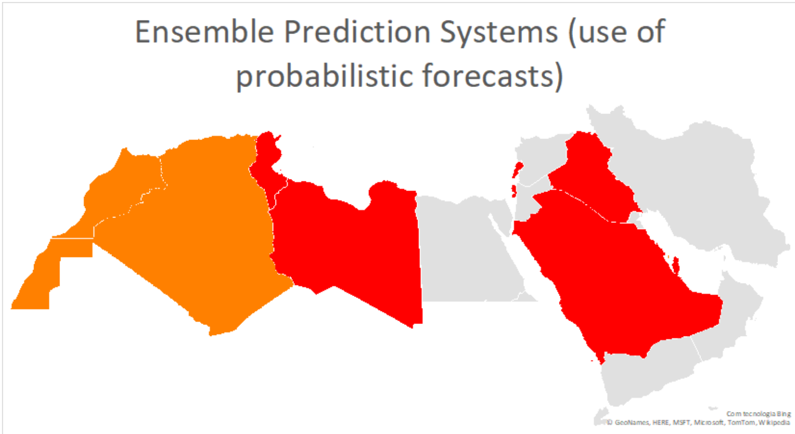


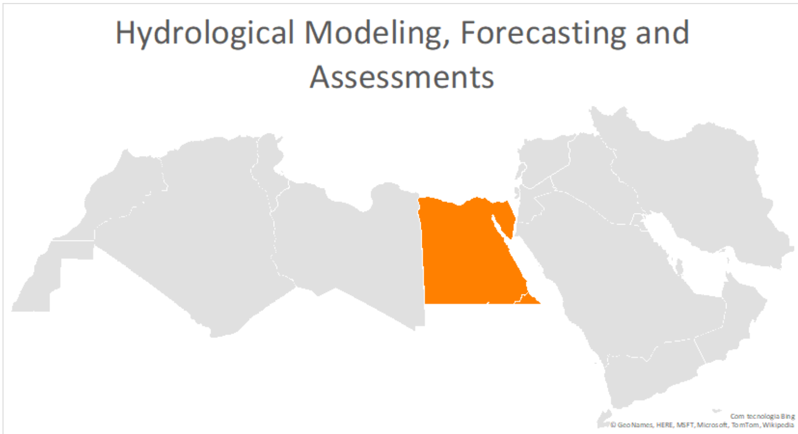
Source: Based on recent reviews conducted on behalf of the World Meteorological Organization (WMO) and on existing literature, WMO Country Profile Database, NMHSs' websites.

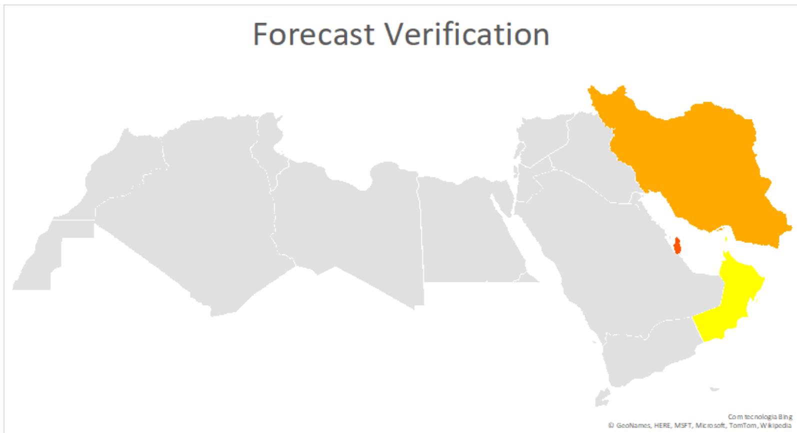
All countries make use of the limited set of global numerical weather prediction outputs made available through the WIS/GTS, and/or the Internet. The NMHS of Morocco (which has Advanced capabilities) is the only one that makes use of the full set of products from the European Centre for Medium-range Weather Forecasts through a license agreement. Most of the NMHSs of MENA countries (***Figure 35***) run their own limited area models; except the NMHSs of West Bank and Gaza, and Djibouti (which are at the Basic level); while Bahrain (Essential level) plans to implement its own model; there is lack of information for the NMHSs of Malta, Syria and Yemen. It is not clear whether these limited area models provide an added-value to the forecasts obtained from global models, as either verification activities are not in place or if they are, the results are not publicly available. In addition, in most of the countries, limited area models are implemented in a research context or for capacity building, as significant human resources, network infrastructure, and computational capacities are required to keep these models running. Overall, there is very limited use of ensemble prediction systems, including probabilistic forecasts, as most of the countries have Basic capabilities, with the exception of the NMHSs of Morocco, Algeria and Bahrain which are at the Essential level. There is lack of information on hydrological forecasting capabilities in these countries.

Figure 35 – Modelling Systems





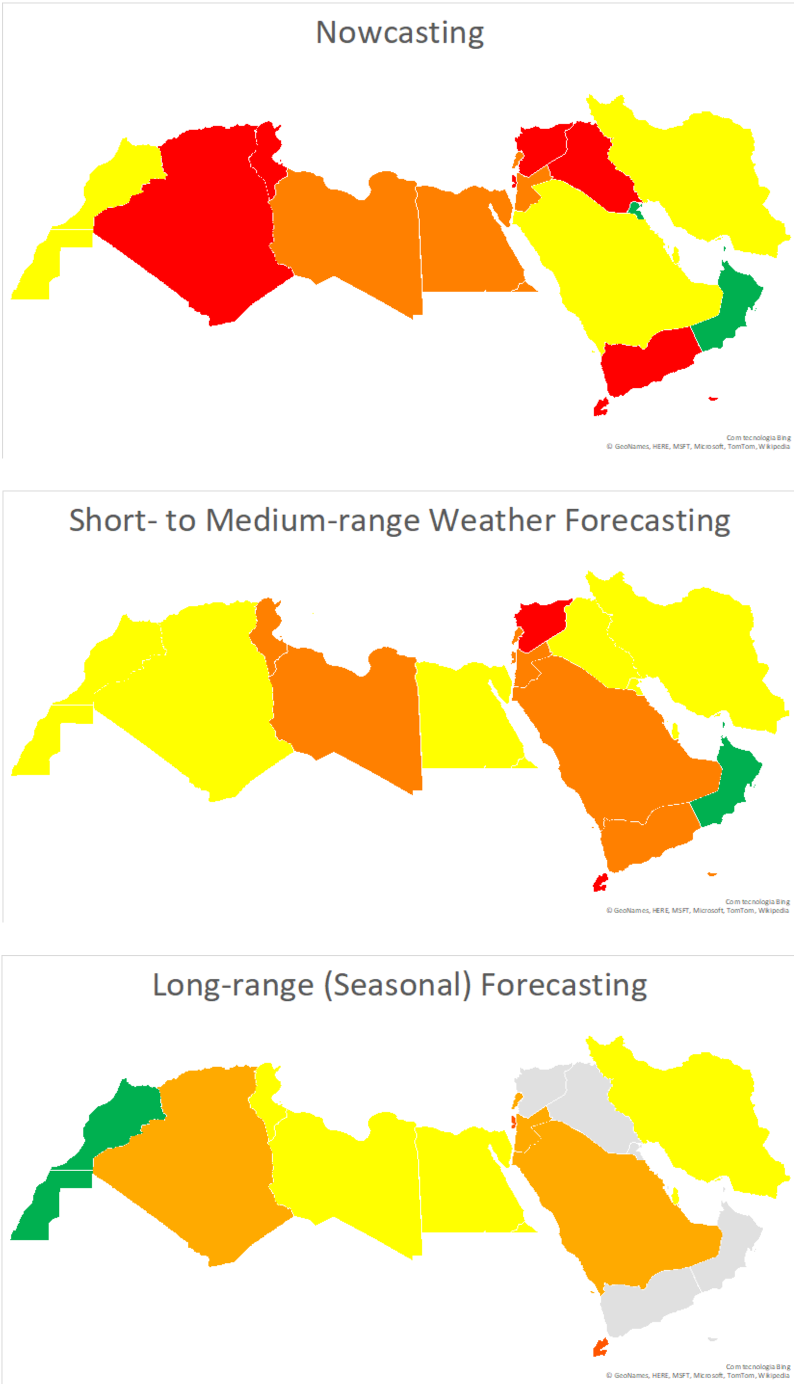




Source: Based on recent reviews conducted on behalf of the World Meteorological Organization (WMO) and on existing literature, WMO Country Profile Database, NMHSs' websites.

Capacity varies from nowcasting to long-range forecasting (***Figure 36***). NMHSs that operate weather radar systems tend to have a nowcasting system in place (such as the NMHSs of Kuwait, UAE and Oman; which are at the Advanced level). NMHSs of Tunisia, Syria, Iraq, Djibouti, Yemen, and West Bank and Gaza are at the Basic level; while the remaining NMHSs are at either Essential or Full levels. Nearly all NMHSs are able to generate short- to medium-range weather forecasts, except Syria and Djibouti that are at the Basic level. Seasonal forecasts are generated by the NMHS of Morocco (Advanced level), while the other NMHSs make use of seasonal outlooks prepared at the RCOFs. The NMHSs of Djibouti, and West Bank and Gaza don't have the capacity to issue seasonal forecasts (less than Basic level).

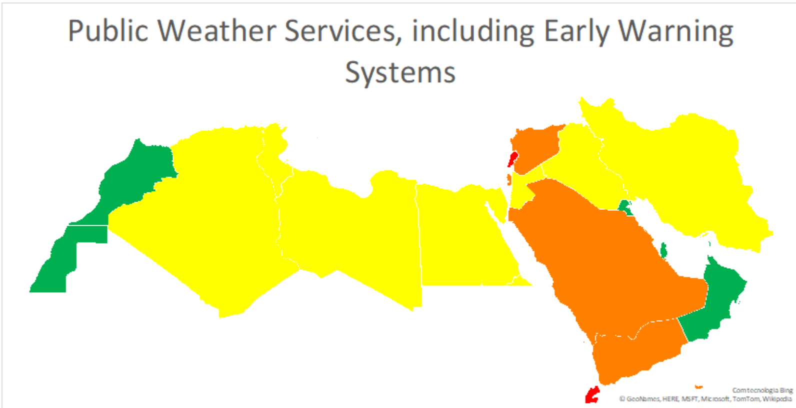
Figure 36 – Forecasting and Warning Systems

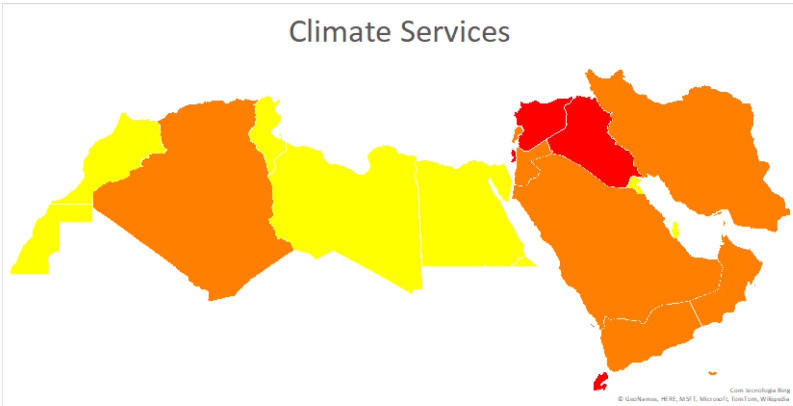


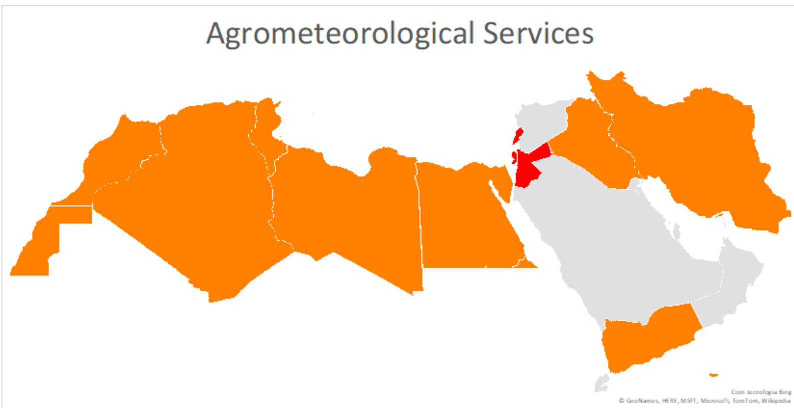
Source: Based on recent reviews conducted on behalf of the World Meteorological Organization (WMO) and on existing literature, WMO Country Profile Database, NMHSs' websites.

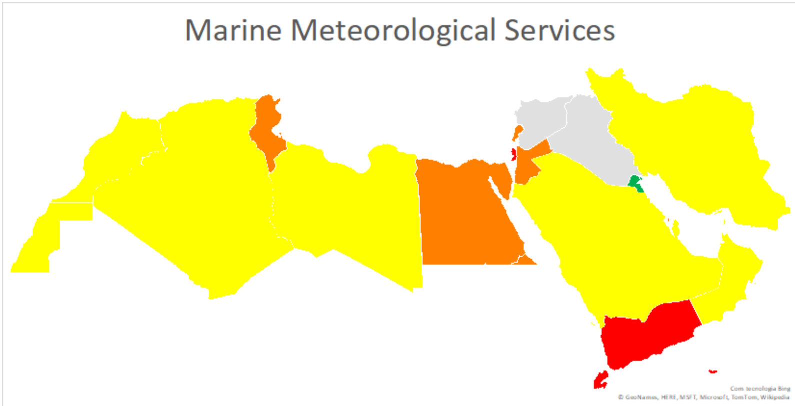
Capacities of service delivery systems tend to be aligned with the main functions of NMHSs in MENA countries, i.e. aviation forecasting. Aeronautical meteorological services for air navigation, public weather services, and marine meteorological services (***Figure 37***) seem to be the most developed services (they range from Essential to Advanced levels). These are the historical and foundational areas of most NMHSs in the region. Generally, climate and agrometeorological services are still to be further developed in these countries (most are at either Basic or Essential levels).

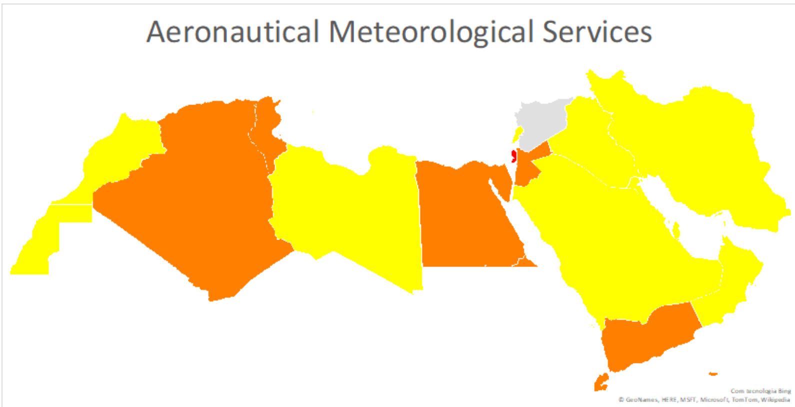
Figure 37 – Service Delivery Systems







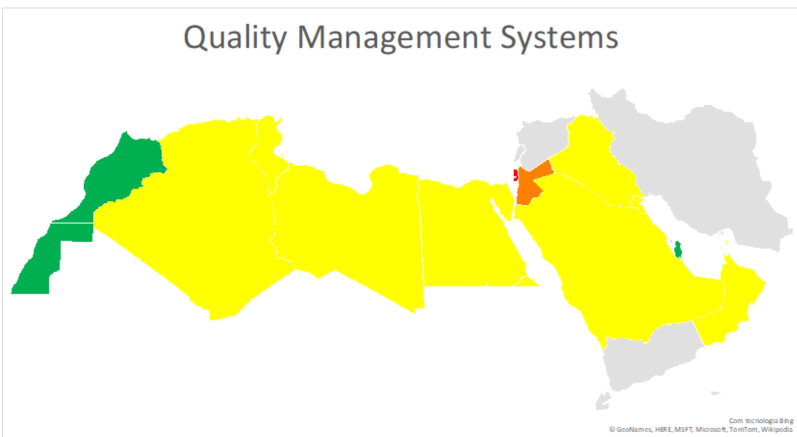




Source: Based on recent reviews conducted on behalf of the World Meteorological Organization (WMO) and on existing literature, WMO Country Profile Database, NMHSs' websites.

Quality management systems (QMS) have been implemented by most of the NMHSs focused on aviation services (***Figure 38***), with the exception of Djibouti and West Bank and Gaza; there is no information for the NMHSs of Malta, Lebanon, Syria, Yemen, Iran, and UAE. NMHSs of Morocco, Bahrain and Qatar are at the Advanced level, with full QMS and ISO certification.

Figure 38 – Quality Management Systems



Source: Based on recent reviews conducted on behalf of the World Meteorological Organization (WMO) and on existing literature, WMO Country Profile Database, NMHSs' websites.

SUMMARY OF THE SOCIOECONOMIC BENEFITS ANALYSIS

The cost-benefit analysis indicates that the investments are economically efficient, meaning they will produce socioeconomic benefits greater than their costs. In all cases the generated benefits are significantly greater than the costs; for example, in the worst-case scenario, with realistic assumed benefits and 30 percent cost overruns the benefit/cost ratios for the investment are over 6.3. For what are considered the most realistic assumptions, the benefit/cost ratio ranges between 8.1 and 13.9.

Considering the very conservative approach and assumptions applied throughout the analysis, the results are considered robust. Hallegatte et al. (2017) found that globally, universal access to EWS would almost double the benefits of reduced asset loss by also reducing "well-being" losses. These less tangible well-being benefits—for example, contributions to poverty reduction—are not considered in this analysis, further suggesting that the analysis underestimates the benefits of the proposed investments. In addition, the saving of lives, which is a primary benefit of EWS, is not considered in the analysis. It has been omitted due to the moral implications and sensitivities of assigning economic values to human lives, even with "neutral" approaches such as value of a statistical life (VSOL). This omission further contributes to the conservative nature of the analysis.

As weather and climate impacts worsen, the net present value and benefit/cost ratio of the proposed investments will increase. This is because early warning provides benefits that are not limited by thresholds; whether a flood is a 25-year or a 50-year event, early warning still reduces impacts similarly (as opposed for example to levees or other structural measures, whose design thresholds are at some point exceeded).

As the MENA region's population and economic productivity grows, EWS will continue to provide benefits. New developments and investments will also benefit from improved forecasting and early warning, as opposed (again) to structural measures such as levees, which may be built to protect new developments. The fact that these two factors (climate change and population/economic growth) were not incorporated in the analysis again points to an underestimation of the actual program benefits.

The investment is economically efficient i.e. it has a net present value greater than 0.0 and a benefit/cost ratio greater than 1.0. Considering that such higher-level investments are relatively low in cost, are economically efficient, protect lives and property, and contribute to economic development and resilience, they should be considered for priority financing.

RECOMMENDATIONS

A common desire is to direct investments toward the modernization of all subsystems at the national level, for example, by installing comprehensive observing networks and developing the ability to run sophisticated local limited area models (LAMs). However, these are technological goals rather than activities designed to achieve the expected socioeconomic outcomes that drive the hydromet investment in the first place. In any case, technological constraints are not the only limitations that NMHSs' face; in many cases, there are limited human and financial resources to operate and maintain the subsystems.

International good practice suggests that a regional approach to countries facing common hydromet conditions has advantages: it enables enhanced networking; ensures robust interoperability, efficiencies, and optimization of infrastructure costs; and results in greater harmonization, integration, and complementarity within the region. Regional frameworks and initiatives may help to address major challenges that national hydrometeorological service providers face. For example, very costly functions could be handled at the regional level by the most advanced NMHSs in the region. In this context, at the regional level, it is recommended that:

1. Introduce the agenda for hydromet modernization and NMHS strengthening in a regional forum for knowledge sharing, and for pursuing regional hydromet strategies, including effective regional cooperation, collaboration (within and outside the region), and cross-boundary coordination and data sharing for monitoring and nowcasting (that is, monitoring and extrapolation of weather conditions in the present and immediate future), transboundary hazardous events and harmonization of warning criteria. This approach, in turn, will help to enhance networking and interoperability, creating efficiencies and economies of scale, and optimizing infrastructure costs (e.g. through more advanced providers managing more sophisticated local operations) which may lead to overall savings on the cost of capital infrastructure, and sustainable operations and maintenance. In addition, both twinning arrangements and south-south collaboration would be explored to support hydromet services in FCV (post-conflict) countries establishing EWS mechanisms.
2. NMHSs in the MENA region make use of regional frameworks and initiatives, including products and facilities from regional centers e.g. Regional Climate Centre products for improving climate services, calibration of their instruments at Regional Instrument Centres etc.
3. Advanced NMHSs in the MENA region to make their numerical products available to neighboring countries.
4. Establish twinning arrangements between advanced NMHSs in the MENA region and those requiring support in capacity building and technology transfer.

In general, at the national level, there is a need to:

a. Confirm/validate the information gathered in this Report through consultations with individual countries, as some of these countries had few resources with which to participate, and/or outdated information. Nevertheless, the information provided in this Report is believed to fairly represent the hydromet capacities in the targeted MENA countries.
b. Assess stakeholder and user requirements as drivers for hydromet modernization. The NMHSs of target countries have developed their own strategic plans, which lay out the goals and objectives of their organizations. The means to achieve these is through business plans and models (which involve socioeconomic benefit studies), a roadmap, and the implementation of the strategy within an operating plan (a Concept of Operations – CONOPS). The aim of the CONOPS is to explore the entire operational system (of subsystems) from the perspective of users and stakeholders, which will

determine the scope and direction of the modernization project. It enables many different options (including potential opportunities for engagement with the private sector) to be assessed theoretically to determine their importance for mission objectives. This is a living document that guides the implementation and ongoing operation of the system, and should evolve with it.

c. Introduce the agenda for hydromet modernization and NMHS strengthening in country assistance strategies and country partnership strategies, usually through disaster risk management, climate adaptation, food security, water resource management, and other significant sectoral programs and projects. This would also contribute to: (i) the establishment of partnerships, (ii) the development of a business plan based on the socioeconomic benefits of the new services, and (iii) the engagement of the Government to consider financing of additional operations and maintenance costs associated with modernization.
d. Strengthen relationships between National Meteorological Services (NMSs) and National Hydrological Services (NHSs).

In addition, especially for FCV (post-conflict) countries, it is important to develop a roadmap which lays out a technical strategic framework with milestones to bridge gaps between current hydromet and early warning services and those which may be provided following investment. It should model three investment scenarios (i.e. advanced modernization, intermediate modernization, and technical assistance for high priority and immediate needs) based on realistic fiscal and sociopolitical possibilities to better deliver hydromet and early warning services.

In particular, the conflicts of the past decades, and limited training opportunities, coupled with rapid advances in hydrology, meteorology, information technology, and meteorological and hydrological modeling, have left many MENA NMHS staff behind. Many university graduates - meteorologists, hydrologists, engineers, and related specialists, are needed to replace retiring staff. It is essential to establish twinning arrangements with more advanced NMHSs, and to provide in-house courses, and regional/international training, to familiarize staff with new meteorological and hydrological tools and software.

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Annex – The WMO Global and Regional Network of Designated Centers Relevant to the MENA Region

To predict the weather, modern meteorology depends upon the near instantaneous exchange of weather information across the entire globe. Established in 1963, World Weather Watch (WWW)[101] is a unique international cooperation program that combines observing systems, telecommunication facilities, and data-processing and forecasting centers, all operated by WMO members, to make available the meteorological and related environmental information needed to provide efficient services in all countries. Originally

[101] See WMO, "World Weather Watch (WWW)", http://www.wmo.int/pages/prog/www/index_en.html.

focused on weather, the current WWW has been expanded to address climate and hydrological aspects. In doing so, it respects data-sharing policies[102] and helps maintain high data-quality standards and benefits. Soares (2018) summarizes the infrastructure underpinning the WWW, describing how within the framework of the expanded WMO's World Weather Watch and related programs, a number of global and regional centers coordinate global and regional activities, act as central or regional hubs, and/or provide products for the various regions. The main users are staff of the National Meteorological and Hydrological Services (NMHSs). The list of WMO centers relevant to the MENA region (including descriptions of their roles, responsibilities, and activities by thematic area) is presented below.

Observing systems

Regional Instrument Centres (RICs) are in Algiers, Cairo and Casablanca, and are hosted by the National Meteorological and Hydrological Services (NMHSs) of Algeria, Egypt and Morocco, respectively. These centers are regional hubs to assist WMO members in their regions to calibrate their national meteorological standards and related environmental monitoring instruments for one (or more) of the following variables: temperature, humidity, pressure and possibly others. Mandatory functions include: (a) assist members of the region to calibrate national meteorological standards and related environmental monitoring instruments; (b) participate in, or organize, WMO and/or regional instrument intercomparisons, following recommendations by the *WMO Technical Commission for Instruments and Methods of Observation (CIMO)*; (c) according to recommendations from the WMO Quality Management Framework, contribute to the quality of measurements; (d) advise members on instrument performance, maintenance, and the availability of relevant guidance materials; (e) help to organize regional workshops on meteorological and related environmental instruments; (f) cooperate with other RICs to standardize meteorological and related environmental measurements; and (g) regularly inform members, and report annually to the president of the regional association concerned and to the WMO Secretariat on services offered to members and activities carried out.

Regional Radiation Centres (RRCs) are in Cairo, Tamanrasset and Tunis, and are hosted by the NMHSs of Egypt, Algeria, and Tunisia, respectively. They are centers for interregional comparisons of radiation instruments within their regions and to maintain the standard instruments necessary for this purpose. Mandatory functions include: (a) maintain a standard set of at least three stable pyrheliometers, with a traceable 95% uncertainty of less than 1 Wm^{-2} to the World Standard Group, and in stable clear sun conditions with direct irradiances above 700 Wm^{-2}, 95% of any single measurement of direct solar irradiance will be expected to be within 6 Wm^{-2} of the irradiance; (b) one of the radiometers to be compared through a CIMO sanctioned comparison, or calibrated, at least once every five years against the World Standard Group; (c) standard radiometers be intercompared at least once a year to check the stability of each instrument; (d) have, or have access to, the facilities and laboratory equipment to check and maintain the accuracy of the auxiliary measuring equipment; (e)

[102] Data sharing in WMO has been articulated specifically over the last 20 years—in WMO Resolution 40, adopted at the 12th World Meteorological Congress (Cg-XII) for weather, Resolution 25 (Cg-XIII) for water, and Resolution 60 (Cg-17) for climate. These resolutions were adopted with the intent to establish a system for free and unrestricted exchange of data and products, which is a unique international hallmark of WMO. Many commercial operators also rely on this capability which is built on top of global data-sharing arrangements.

provide outdoor facilities for simultaneous comparison of national standard radiometers from the region; and (f) be assessed by a national or international agency, or CIMO experts, at least every 5 years to verify traceability of direct solar radiation measurements. In addition, RDCs should have stable staff and should include a qualified scientist with wide experience in radiation.

Information systems

Global Information System Centres (GISCs) are in Casablanca, Jeddah and Tehran, and are hosted by the NMHSs of Morocco[103], Saudi Arabia[104] and Iran[105], respectively. These centers are regional coordinators for the real-time operations of the WMO Information System (WIS) network, and provide entry points to WIS through (a) the *GISC Cache Services* function, which relates to the exchange of data and products (including weather bulletins and warnings) intended for global distribution; and (b) the Discovery, Access and Retrieval (DAR) Catalog, consisting of metadata to be collected from the entire WIS.

Connected to the *GISC Casablanca* and hosted by the Egyptian Meteorological Authority (EMA)[106], the ***Data Collection and Production Centre (DCPC) Cairo*** coordinates the area's meteorological telecommunication network—i.e. it is a *Regional Telecommunication Hub (RTH)* within the framework of the *WMO GTS*. Under defined transmission rates and protocols, *DCPC Cairo* collects and disseminates meteorological data and products within its geographical area of responsibility and exchanges these data and products with other RTHs and GISCs for their global distribution.

Data-processing and forecasting systems and services

WMO has eight designated ***World Meteorological Centres***: Beijing (hosted by CMA), Exeter (hosted by the UK Met Office), Melbourne (hosted by the Australian Bureau of Meteorology), Montreal (hosted by the Canadian Meteorological Centre of Environment Canada), Moscow (hosted by Roshydromet), Tokyo (hosted by JMA), Washington (hosted by the U.S. National Weather Service), and the European Centre for Medium-range Weather Forecasts. Through the WIS, these centers provide a limited range of forecast products (in digital form) based on their global models for both medium-range and seasonal ensemble forecasts, following the protocols described in the *WMO Manual on the Global Data-processing and Forecasting System* (WMO, 2017a). They also provide documentation and verification to demonstrate the quality of their forecasts. In addition, the ***European Centre for Medium-range Weather Forecasts (ECMWF)*** also provides WMO members with access to its catalog of ECMWF forecast data and products (in digital and graphic forms) with a non-commercial license.[107] *ECWMF* also operates the *Global Flood Awareness System (GloFAS)*[108]*,* which provides large-

[103] See the WIS Portal–GISC Casablanca site at http://gisc.marocmeteo.ma/openwis-user-portal/srv/en/main.home.
[104] See the WIS Portal–GISC Jeddah site at http://wis.pme.gov.sa/MessirWIS/srv/en/main.home.
[105] See the WIS Portal–GISC Tehran site at http://gisc.irimo.ir.
[106] See the RTH Cairo–DCPC WIS portal at http://212.103.189.107:8080/MessirWIS/srv/en/main.home.
[107] See ECMWF, "Licences Available,"https://www.ecmwf.int/en/forecasts/accessing-forecasts/licences-available.
[108]See the GloFAS website at http://www.globalfloods.eu.

scale flood forecasts, and the Copernicus Climate Change Services[109], which provide information for monitoring and predicting climate change.

The ***Regional Specialized Meteorological Centre New Delhi*** is hosted by the India Meteorological Department (IMD)[110] and monitors tropical cyclones generated in the Bay of Bengal and Arabian Sea, from their early stages of formation and throughout their lifetime. It provides forecasts on the behavior of tropical cyclones, including their movement, intensity, and associated phenomena, including storm surges and flash floods; these are disseminated to National Meteorological Centres (including those in the MENA region that are affected by tropical cyclones: Oman and Yemen) in agreed formats for operational processing, as described in the WMO/ESCAP Panel on Tropical Cyclones (PTC) Operational Manual (PTC, 2017; see section below). The RSMC New Delhi also supports training

The ***WMO Global Data-processing and Forecasting System*** **(GDPFS)** infrastructure has been extended to strengthen NMHS capabilities to generate and deliver up-to-date climate information and prediction products for climate services, especially in support of climate adaptation and risk management. Accordingly, 13 WMO-designated ***Global Producing Centres for Long-range Forecasts (GPC-LRF)*** (Beijing, Centro de Previsão do Tempo e Estudos Climáticos, Exeter, Melbourne, Montreal, Moscow, Offenbach, Pretoria, Seoul, Tokyo, Toulouse, Washington, and the ECMWF) provide a range of global long-range forecasting products. A ***Lead Centre for Long-range Forecast Multi-model Ensemble (LC-LRFMME)***, jointly hosted by the KMA and National Oceanic and Atmospheric Administration/National Centers for Environmental Prediction (NOAA/NCEP), consolidates all information from the GPC-LRF and prepares and verifies multi-model ensemble products, which are available from the password-protected LC-LRFMME website.[111] In addition, WMO-designated Regional Climate Centres (RCCs) are being established to generate and deliver more regionally focused high-resolution data and products and to provide training and capacity building. In particular, for the North Africa region, the ***North Africa (NA) RCC-Network***[112] has been established to create regional products that support climate services at regional and national levels. In the NA RCC-Network, there are four nodes: (1) Casablanca Node on Long-Range Forecasting led by the *Direction de la Météorologie Nationale (DMN)*, Morocco, which also provides overall coordination of the NA RCC-Network; (2) Tunis Node on Climate Monitoring led by the *Institut National de la Météorologie (INM)*, Tunisia; (3) Algiers Node on Data Services led by the *National Meteorological Office (ONM)*, Algeria; and (4) Cairo and Tripoli Node on Training led jointly by the *Egyptian Meteorological Authority (EMA)*, Egypt and the *National Meteorological Centre (NMC)*, Libya.

As part of the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS), the ***Regional Specialized Meteorological Centres for Atmospheric Sand- and Dust-storm Forecasts (RSMC-ASDF) in Barcelona***[113] for the Northern Africa, Middle East and Europe (jointly managed by the Spanish State Meteorological Agency, AEMET, and the Barcelona

[109] See the Copernicus Climate Change Services website at https://climate.copernicus.eu.
[110]See IMD, “RSMC New Delhi”, http://www.rsmcnewdelhi.imd.gov.in/index.php?lang=en.
[111] See the WMO Lead Centre for Long-range Forecast Multi-model Ensemble website at https://www.wmolc.org.
[112] See the “WMO RA I North Africa (NA) RCC-Network” website at http://rccnara1.marocmeteo.ma.
[113] See the “RSMC-ASDF Barcelona” website at http://sds-was.aemet.es.

Supercomputing Center, BSC) and ***in Beijing***[114] for Asia (hosted by the China Meteorological Administration, CMA) provide the following: (a) operate a numerical weather prediction model incorporating parameterizations of all the major phases of the atmospheric dust cycle; (b) prepare limited area analyses of variables relevant to atmospheric sand and dust storms; (c) prepare limited area forecasts of variables relevant to atmospheric sand and dust storms; and (d) make these products available on the WIS and a web portal.

Public weather services

The ***WMO World Weather Information Service (WWIS)*** [115] is a website which allows the media to obtain official weather information issued by NMHSs. The WWIS website is developed and maintained by the Hong Kong Observatory (HKO). This global website presents official weather observations, weather forecasts, and climate information for selected cities, as supplied by NMHSs worldwide. These NMHSs make official weather observations in their respective countries, including those from the MENA region. Links to their official weather service websites and tourism boards/organizations are also provided if available. Weather icons are shown alongside written forecasts to aid interpretation.

Training

WMO supports a network of ***Regional Training Centres (RTCs)***[116], which are national education and training institutions, or groups of institutions, recognized by WMO as (a) providing education and technical training in management and operations to WMO members in the region, particularly staff of NMHSs; (b) providing advice and assistance on education and training to WMO members; and (c) promoting education and training opportunities in weather, water, and climate for WMO members. There are 26 RTCs, which provide a diverse portfolio of education and training opportunities through in-residence classes, distance-learning, and blended learning. In the MENA region, there are five RTCs:

(1) The ***RTC Algeria***[117], which provides the Basic Instruction Package for Meteorologists (BIP-M) for African NMHSs;

(2) The ***RTC Egypt***[118], which provides training in numerical weather prediction (NWP), seasonal forecasting, air pollution, and in agrometeorology;

(3) The ***RTC Iran***[119], which provides training in meteorology and atmospheric sciences;

(4) The ***RTC Iraq***[120], which provides training courses on aeronautical meteorology for aviation;

[114] See the "RSMC-ASDF Barcelona" website at http://www.sds.cma.gov.cn.

[115] See WMO, "World Weather Information Service", http://worldweather.wmo.int/en/home.html.

[116] See WMO, "Regional Training Centres", https://public.wmo.int/en/resources/training/regional-training-centres.

[117] See the *Institut Hydrométéorologique de Formation et de Recherches (IHFR) Oran* - RTC Algeria website at http://www.ihfr.edu.dz.

[118] See the Egyptian Meteorological Authority (EMA) Cairo - RTC Egypt website at http://nwp.gov.eg.

[119] See the Islamic Republic of Iran Meteorological Organization (IRIMO) Tehran - RTC Iran website at http://www.irimo.ir/eng/index.php.

[120] See the Iraqi Meteorological Organization (IMO) Baghdad - RTC Iraq website at http://www.iraqcaa.com/index.html.

(5) The ***RTC Qatar***[121], which provides BIP-M and training courses on aeronautical meteorology for aviation.

[121] See the Qatar Aeronautical College (QAC) Doha -RTC Qatar website at http://www.qac.edu.qa.