Ministry of Climate Change and Environmental Coordination

BUILDING CAPACITY TO ADVANCE THE NATIONAL ADAPTATION PLAN PROCESS IN PAKISTAN

Develop a model for the operation and maintenance of the climate information system in the long term in Pakistan

National Adaptation Plan for Pakistan

"Adapting Today for Sustainable Tomorrow"

November 2024

Main Contributors:
Mike Harrison, CCRM
Diar Hassan, WSP

This report was commissioned by the GCF PAK-RS-003 Project “Building capacity to advance National Adaptation Plan Process in Pakistan” which aims to support the Federal Ministry of Climate Change and Environmental Coordination (MOCC&EC) and its partners at Federal and Province levels to implement the National Adaptation Plan (2023). The Delivery Partner is the United Nations Environment Programme (UNEP).

EXECUTIVE SUMMARY

Pakistan has experienced several extreme weather events in recent decades, including extreme temperatures, heavy rainfall, flooding, and earthquakes. One of the most recent devastating events was the July 2022 flooding, which affected around 9% to 10% of the country, resulting in over 1,700 deaths (including 639 children), nearly 1,300 injuries, and over 1.1 million livestock deaths. The flooding caused significant damage to infrastructure and the economy.

Pakistan, being the world's sixth most populous country with an estimated population of over 207 million, is highly vulnerable to these extreme weather events. To mitigate the impact of such events, Pakistan needs to develop a robust observational network and modeling predictive ability to effectively disseminate and communicate warnings to local governments, emergency relief entities, and residents.

This report provides an overview of the Pakistani government's current abilities and needs to save lives and reduce the impact of extreme events. It emphasizes the importance of advancing the Pakistan Meteorological Department (PMD), which provides early warnings to multi-level stakeholders and decision-makers across the country. The PMD's main goals include providing meteorological services for aviation, public weather, early warning, climate, geophysical, seismic, marine meteorology, agro-meteorological, glacier monitoring, and glacial lakes outburst flood warnings.

The subsequent sections of the report discuss the deliverables established in the UNEP Provision of Consultancy Services to Synthesize Available Information on Adverse Effects of Climate Change and Producing Climate Change Scenarios and Risk Assessments for Pakistan.

Please note that this report was constructed based on publicly available information. Despite our numerous attempts, we were unable to receive information from Pakistani stakeholders. Nevertheless, this report serves as a valuable source of information on the current status of the country.

Contents

1 INTRODUCTION

Pakistan has experienced dangerous natural and weather events in the last decades from extreme temperatures to heavy rainfall, flooding, and earthquakes. One of the most recent devastating events was the July 2022 flooding that affected (and is still affecting) around 9% to 10% of the country with over 1,700 people killed (including 639 children), nearly 1,300 injured, and over 1.1 million livestock killed; needless to mention the damage to infrastructure and economy this event has caused. The event occurred after an extreme heat wave was followed by an unusually heavier monsoon rainfall that coincide with the melting glaciers.[1]

Pakistan is the world's sixth most populous country in the world with an estimated population of over 250 million.[2] Extreme weather events can easily affect a large number of lives. Since these extreme weather events are inevitable, Pakistan needs to develop a strong observational network and a modelling predictive ability to effectively disseminate and communicate different warnings to local governments, emergency relief entities, and residents.

This report provides an overview of the Pakistani government's current abilities and needs to save lives and reduce the impact of such extreme events.

The Pakistani Ministry of Climate Change consists of multiple wings, namely: the Administrative Wing, Climate Finance Unit, Development Wing, Environment Wing, Forestry Wing, and International Cooperation (IC) Wing. The Pakistan Meteorological Department (PMD) is the governmental body that provides early warnings to multi-level stakeholders and decision-makers across the country. PMD's main goals are providing meteorological services for aviation, public weather, early warning, climatological, geophysical, seismic, marine meteorology, agro-meteorological, glacier monitoring, and glacial lakes outburst flood warnings. Advancing the PMD will reflect positively at the national and local levels.

As a Member of World Meteorological Organization (WMO) since 1950, the PMD has been designated as a National Meteorological Communication Center (NMCC)

[1] British Red Cross (2025). Flooding in Pakistan: the latest news. Available at: https://www.redcross.org.uk/stories/disasters-and-emergencies/world/climate-change-and-pakistan-flooding-affecting-millions#:~:text=100%2C000%20people%20have%20been%20evacuated,and%20almost%2013%2C000%20were%20injured.

[2] Worldometer (2025). Pakistan Population. Available at: https://www.worldometers.info/world-population/pakistan-population/.

in Karachi,[3] and acts as the country's National Meteorological and Hydrological Service (NMHS) with headquarters in Islamabad.[4] The web pages that collate all aspects of the PMD role within the national and international structure organised by WMO, referenced in the previous sentence, provide few details to inform this report. Reference below will be made as possible to both the WMO and the PMD web pages just listed, but most information that forms the backbone of this report has been obtained indirectly from other sources, including additional pages on the WMO website.

The PMD is an Attached Department under the Ministry of Aviation of Pakistan, which lies under the Cabinet Secretariat.[5] There is also a Ministry of Climate Change and a Ministry of Water Resources. The Global Change Impacts Studies Centre lies under the former Ministry.

This report will discuss the denoted deliverables established in the UNEP Provision of Consultancy Services to Synthesis Available Information on Adverse Effects of Climate Change and Producing Climate Change Scenarios and Risk Assessments for Pakistan.

All data sources cited were last accessed and information accurately reported as of June 2024 to August 2024, unless otherwise specified.

[3] WMO (2020). Pakistan. Available at: https://community.wmo.int/en/members/pak

[4] Pakistan Meteorological Department (2023). About Us. Available at: https://www.pmd.gov.pk/en/about.php

[5] List of Ministries / Divisions. Available at: https://cabinet.gov.pk/SiteImage/Downloads/List-of-Ministries-Divisions-2021.pdf

2 OBSERVATIONS AND THEIR MANAGEMENT

2.1 METEOROLOGICAL SURFACE, INCLUDING CLIMATE

2.1.1 OBSERVING SYSTEMS

Meteorological observations form the bedrock of all aspects of weather and climate knowledge and provide the basis for development of climate services of all types. At the national level, they inform three major societal building blocks – water, food and health – as well as multiple other facets of socio-economic development. At the international level, they are vital in the production of forecasts and in the understanding of climate change, amongst other environmental issues.

It was the recognition of the need for cooperation and exchange of meteorological observational data if weather forecasts were to be produced that led to the formation of the International Meteorological Organisation in 1873 (now the World Meteorological Organisation – WMO), the first intergovernmental structure that subsequently developed alongside others into the United Nations. The data, methodologies and observations needed to be standardised in terms of instrumentation, observation times, quality control, and archiving, and in terms of the methods of exchange, exchange that required rapid transmission to retain value for short-range forecasts. That basis of exchange is still maintained by WMO, as discussed further in this report.

Observations can be separated into various categories. At the national level, there are the networks established and maintained by the government, in general the National Meteorological and Hydrological Service (NMHS), although in some cases other organisations contribute. Beyond that, there may be several networks set up for specific purposes, such as a research project. Whereas the former are normally exchanged internationally through WMO systems, the latter tend not to be. In this report, we are focused on only observations under the WMO system.

Until the mid-1990s, there were no restrictions on data exchanges between NMHSs and WMO, but that changed with the coming of commercialisation of services and the recognition by governments that cost recovery could reduce the burden on the exchequer. The process started in 1995 with Resolution 40, that limited free exchange of atmospheric data to those observations required for global weather forecasts and permitted NMHSs to place restrictions and/or costs on access to other types of observations. Resolution 40 was followed in 1999 by the similar Resolution

25 that covered hydrological observations, and in 2015 by Resolution 60 that covered climate products. All three Resolutions have since been combined and updated into the WMO Unified Data Policy[6], introduced in 2021.

The information reviewed in this report on Pakistan, in all respects, is restricted to information that is publicly accessible on the internet and may thus omit anything withheld by the Pakistan Meteorological Department (PMD) under the WMO Unified Data Policy, and any managed other than by PMD.

It is known to the authors that there is a current project to update multiple aspects of the PMD network, including international exchange, but no details have been received. A project started in 2018 with World Bank (WB) sponsorship[7], entitled "Pakistan Hydromet and Climate Services Project (PHCSP)." The agreed objective of this project was:

> *The development objective of the Hydromet and Disaster Risk Management Services Project [note the difference in project name] for Pakistan is to strengthen Pakistan's public sector delivery of reliable and timely hydro-meteorological and disaster risk management services. It has three main components. 1) First component, Hydro-meteorological and Climate Services. This component will include four sub-components. (i) Institutional Strengthening and Capacity Building; (ii) Modernization of the Observation Infrastructure, Data Management, and Forecasting Systems; (iii) Enhancing Pakistan Meteorological Department (PMD) Service Delivery and Building Partnerships with the Private Sector; and (iv) Project Management, Systems Integration, and Monitoring and Implementation Support of PMD; 2) Second component, Disaster Risk Management will consist of three subcomponents. (i) Legal Policy and Institutional Strengthening; (ii) Infrastructure for Resilience; and (iii) Project Management, Monitoring, and Implementation Support of NDMA; 3) Third component, Contingent Emergency Response Component (CERC) will support preparedness for and rapid response to climate and natural disasters, emergency, and/or catastrophic event as needed.*

[6] WMO (2025). WMO Unified Data Policy Resolution (Res.1). Available at: https://wmo.int/wmo-unified-data-policy-resolution-res1

[7] World Bank (2024). Pakistan Hydromet and Climate Services Project (PHCSP). Available at: https://projects.worldbank.org/en/projects-operations/project-detail/P163924

As far as can be analysed from the public documents on the WB site, initial spend on this project was minimal until Q4 2022, and on 24/5/23 a project amendment was issued that read:

> *The objective of the Project in Schedule 1 to the Financing Agreement is amended to read as follows: "The objective of the Project is to restore ecosystems in selected areas and provide immediate and effective response to an Eligible Crisis or Emergency."*

No reasons for this change are stated on the web site, but concurrently, spending increased substantially, on projects such as forest restoration. The project has retained its original name, if not its purpose, and clearly is no longer contributing to the upgrade of the PMD network.

There is a management note that establishes the Project Management Unit (PMU) of "Modernisation of Hydromet Services of PMD in Pakistan (MHSP)"[8]. No further documentation on this project has been located.

A similarly named project, "Modernization of Pakistan Meteorological Department Hydrologic Forecast Capacity", is mentioned on the Hydrological Research Centre (HRC) site[9] with statements that the sponsor is WMO in collaboration with the UN Economic and Social Commission for Asia and the Pacific (ESCAP) and the PMD. Gaps in the international network of observations have been a multi-decadal issue for WMO. In order to address this, WMO has set up the System Observations Financing Facility (SOFF)[10], in which advanced NMHSs provide support to those needing to upgrade their facilities. As of August 2024, there is no mention of any Pakistan project under SOFF, nor in any other part of the WMO site. The current status of the project mentioned by HRC is unknown to the authors.

The Green Climate Fund (GCF) project SAP039 – "Integrated climate risk management for strengthened resilience to climate change in Buner and Shangla Districts of Khyber Pakhtunkhwa Province, Pakistan"[11], includes as its objectives:

> *To address these challenges, the project aims to enhance flood early warning and anticipatory action by strengthening the value chain and dissemination of climate information services and early-warning systems.*

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[8] https://circular.pmd.gov.pk/index.php/2024/01/12/project-management-unit-pmu-of-the-project-titled-modernization-of-hydromet-services-of-pmd-in-pakistan-mhsp/

[9] https://www.hrcwater.org/projects/modernization-of-pakistan-meteorological-department-hydrologic-forecast-capacity/

[10] https://un-soff.org/

[11] https://www.greenclimate.fund/project/sap039

This includes the installation of automatic weather stations, automatic river gauges, and automatic water level stations. The project will also improve climate-sensitive anticipatory action through better protocols and simulation exercises. Additionally, the project will enhance local adaptation plans, support livelihood diversification, and improve knowledge management and learning.

This project was approved in July 2024 and is scheduled to run until April 2028. The project aims to enhance the capacity for flood early warning systems and anticipatory action, boost climate resilience through local adaptation plans and diversified livelihoods, and advance knowledge management and learning. However, this project is limited to the districts of Buner and Shangla in Khyber Pakhtunkhwa (KP) province.

Although the details of the currently planned upgrades to the PMD system are unknown to the authors, there is evidence from visits over time to the WMO OSCAR site (discussed below) that progress has been made, at least in terms of international exchange of data and implementation of new facilities. The project under which these improvements have been made is unknown.

The current overarching WMO structure for observations is the WMO Integrated Global Observing System (WIGOS) which oversees environmental observing systems, ensuring the provision of relevant data for all WMO applications. WIGOS comprises of:

- **Global Observing System (GOS)** – according to WMO "It consists of a multitude of individual surface- and space-based observing systems owned and operated by a plethora of national and international agencies with different funding lines, allegiances, overall priorities and management processes".
- **Global Atmosphere Watch Programme (GAW)** – "develops a single coordinated global understanding of atmospheric composition, its change, and helps to improve the understanding of interactions between the atmosphere, the oceans and the biosphere. It coordinates high-quality atmospheric composition observations across global to local scales to drive high-quality and impact science while co-producing a new generation of research enabled products and services".
- **Global Cryosphere Watch (GCW)** – "produces authoritative, actionable, and accessible science-based information on the state of the cryosphere as a key component of Earth system".
- **WMO Hydrological Observing System (WHOS)** – with the objective of "collecting reliable data for use in water resources planning and decision-

making, including for managing flood and drought conditions, integration into hydrological and climate applications and services, and for research".

- **Global Basic Observing Network (GBON)** – the basic, modernised network of WIGOS, including information exchange.
- **Regional Basic Observing Network (RBON)** - RBON consists of surface-based observing stations, typically used in combination with space-based and other surface-based observing components of WIGOS. The network capabilities respond to "observational user requirements at the national, regional and global levels".

In addition, a subset of sites with more complex requirements reflecting the meticulous requirements in assessment of climate change are being established under the Global Climate Observing System[12]. GCOS regularly assesses the status of global climate environmental observations and produces guidance for its improvement. GCOS covers both the atmosphere and climate-relevant surface measurements. In the atmosphere there are three components:

- **GCOS Surface Network (GSN)** – based on selected GOS and GBON stations, but with the more stringent observational requirements indicated previously;
- **GCOS Reference Upper-Air Network (GRUAN)** – designed "to fill an important gap in the current global observing system" but, as of August 2024, with no stations within several thousand km of Pakistan[13]; and
- **GCOS Upper-Air Network (GUAN)** – as GSN based on selected GOS and GBON stations.

Terrestrial observations fall into several areas, all with an overarching name of Global Terrestrial Network (GTN)[14]. These include:

- GTN-G for glaciers[15]
- GTN-H for hydrology[16] – deals with all aspects of the global water cycle

[12] https://gcos.wmo.int/en/networks/gcos-surface-reference-network

[13] https://www.gruan.org/

[14] https://gcos.wmo.int/en/networks/terrestrial.

[15] https://www.gtn-g.ch

[16] https://www.gtn-h.info/

- GTN-L for Lakes[17]
- GTN- P for Permafrost[18]
- GTN-R for River Discharge[19]

PMD has responsibilities in all of the WIGOS components listed above, plus GCOS, but it is thought that observing systems other than those run by PMD exist. WHOS and GCW systems are considered in later sections, and GAW is included in the climate section. No information on the national structure for RBON has been located, and so this limits discussion to GBON.

GOS is the original global network of sites set up over many years to provide standardised observations for all meteorological purposes, including forecasting and climate applications. A complete list of current Pakistan stations and their statuses can be found on the WMO site.[20] In recognition of changing requirements, not least for Numerical Weather Prediction (NWP), a revised network, GBON, is in the process of establishment to provide international data exchanges; development of GOS in some parts of the world has not achieved WMO regulatory requirements and thus countries developing GBON observations may be supported by SOFF which is a UN fund co-created by WMO, UNDP, and UNEP to address observation gaps in climate and weather data, with a focus on least developed countries and small island developing states. As noted above, there does not appear to be SOFF funding to PMD at present.

Under WIGOS there are two reporting structures from which many of the following details have been extracted:

- The Observing System Capability Analysis and Review (OSCAR), the repository of WIGOS metadata[21]
- The WGOS Data Quality Monitoring System (WDQMS), the monitor of availability, quality and timeliness, that covers also GCOS[22]

Both OSCAR and WDQMS are dynamic sites, with information changing frequently to reflect latest conditions. The information illustrated has been obtained during the

[17] No web site

[18] https://gtnp.arcticportal.org/

[19] https://grdc.bafg.de/GRDC/EN/04_spcldtbss/44_GTNR/gtnr_node.html

[20] https://oscar.wmo.int/oscar/vola/vola_legacy_report.txt

[21] https://oscar.wmo.int/surface/#/

[22] https://community.wmo.int/en/activity-areas/WIGOS/implementation-WIGOS/WDQMS

week starting 1 July 2024. According to the OSCAR classification system, there are no registered observational stations in Pakistan for:

- Land/River (fixed)
- Agricultural meteorological station
- Aircraft meteorological station
- Automatic Weather Station (AWS)
- GBON upper air Station
- Radar wind profiler Station
- Sea profiling Station
- Space weather Station
- Surface marine meteorological stations
- Upper Air/Pilot stations

OSCAR provided the following details for other station types:

- GBON surface stations: 38 stations but OSCAR did not produce a map (status unknown)
- Radiation stations: 1 station but OSCAR did not produce a map (status unknown)
- Surface land meteorological stations: 88 stations but OSCAR did not produce a map (status unknown)

In addition, there appear to be 5 GCOS stations in Pakistan. There seem to be small differences between the station distributions according to the PMD (Figure 1) and according to OSCAR (Figure 2).

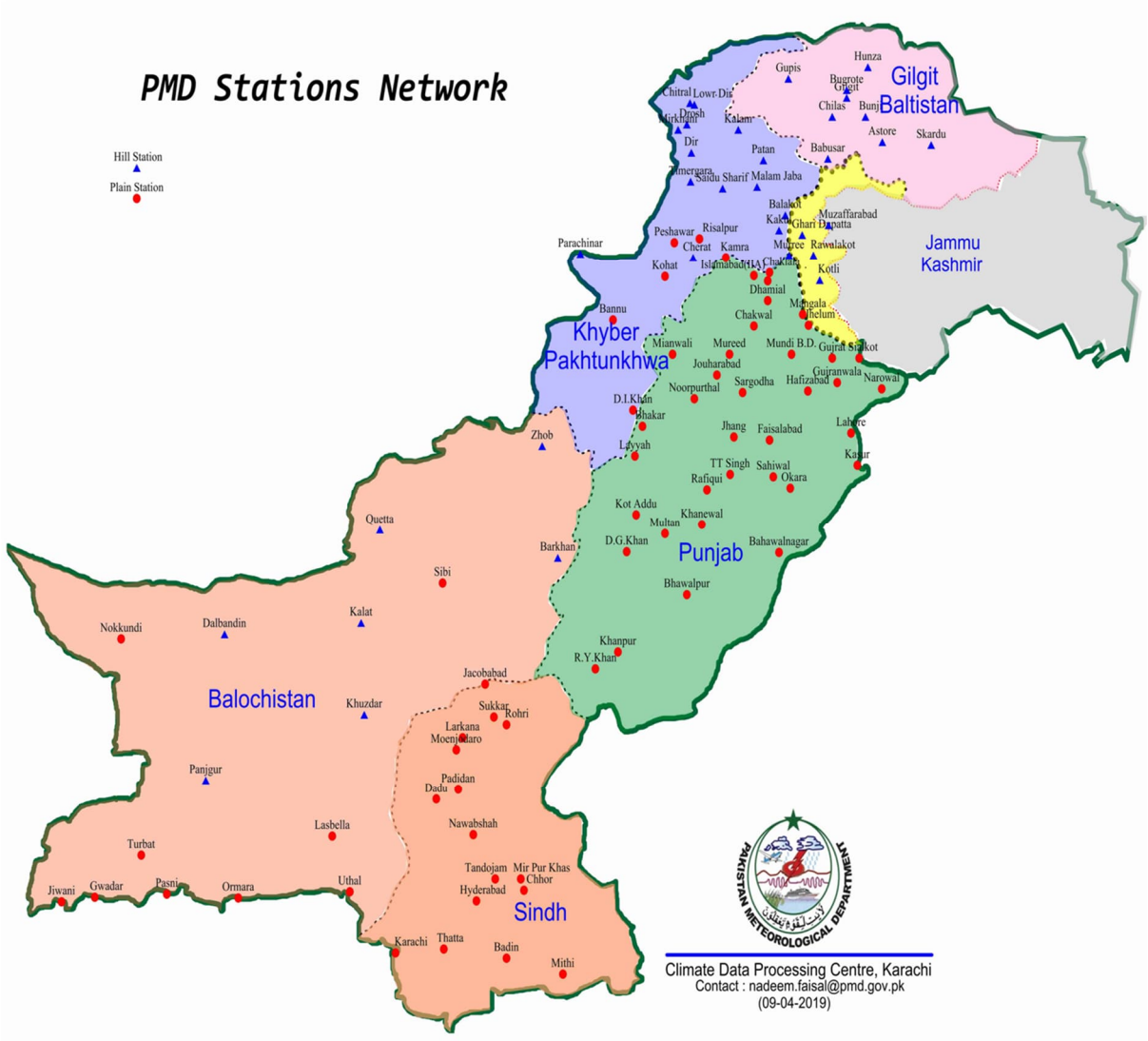


Figure 1. PMD Stations Network created by the Karachi Climate Data Processing Center (accessed on 3/7/2024 from https://cdpc.pmd.gov.pk/Stations%20Network.jpg)

According to OSCAR, there were 96 Land (fixed) stations as of July 2024, all declared operational by PMD (Figure 2). OSCAR reports 88 Land Surface Meteorological Stations; earlier discussions with PMD representatives suggested that the 88 are owned by PMD, the remaining 8 are owned by a different organisation and are thought not to have information distributed through WMO. OSCAR also provides a map of GOS stations, but this appears almost, if not completely, identical to Figure 2 and so has not been reproduced here. Additionally, there were 25 operational climatology stations (Figure 3), all likely collocated with the Land Surface Stations; climatology stations record more variables and all variables to higher standards than meteorological stations.

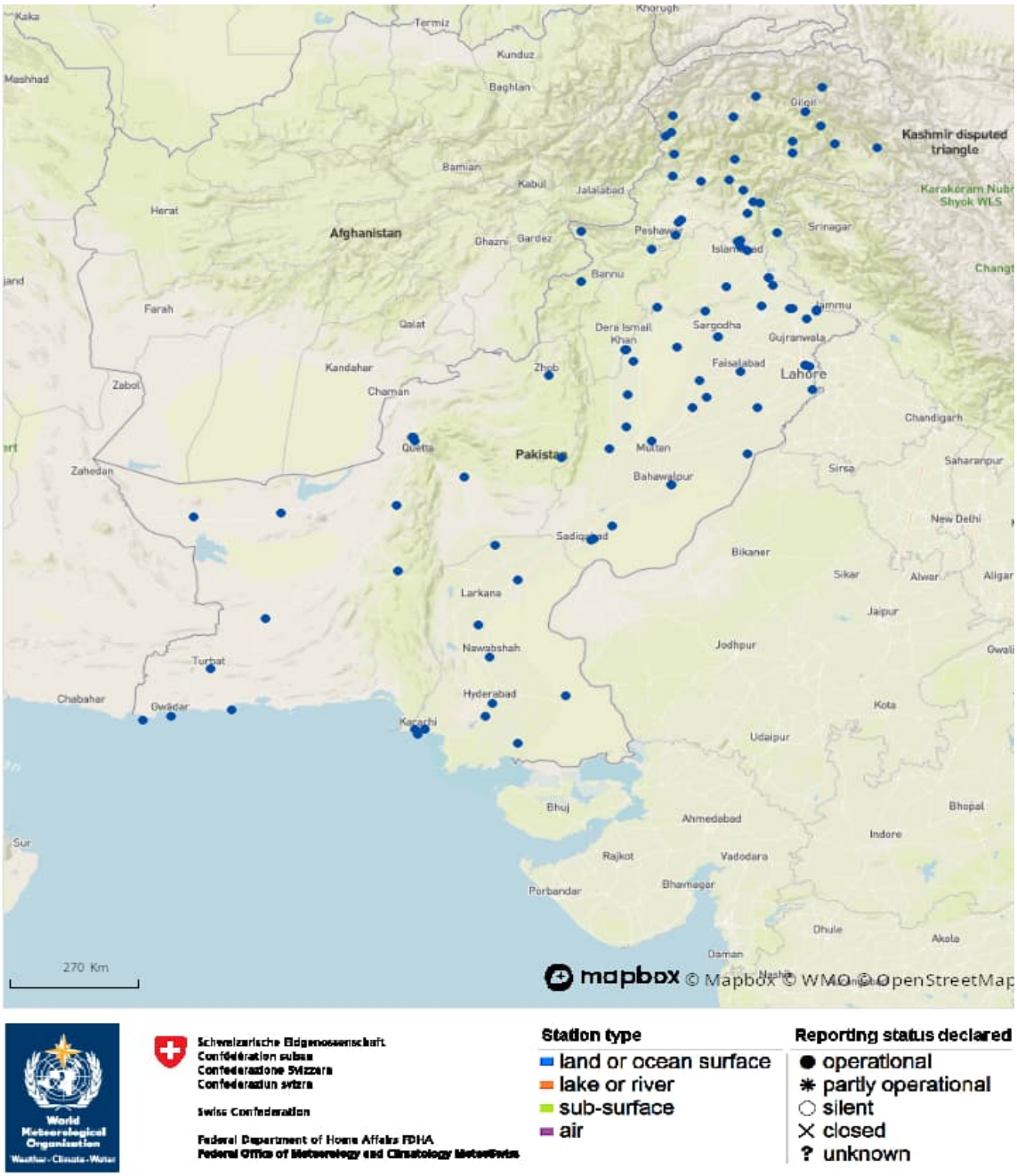


Figure 2. Land (fixed): 96 stations (OSCAR-Accessed 1/7/2024) all declared operational by PMD

Figure 3. Climatological stations: 25 stations (OSCAR-Accessed 1/7/2024): all declared operational by PMD

OSCAR additionally lists 7 operational precipitation stations (Figure 4), all of which appear to be collocated with climatological stations and with weather radar sites in Pakistan. In some countries, there are networks of volunteer sites, often run by farmers, at which rainfall is recorded, but typically those data do not reach operational international data sets.

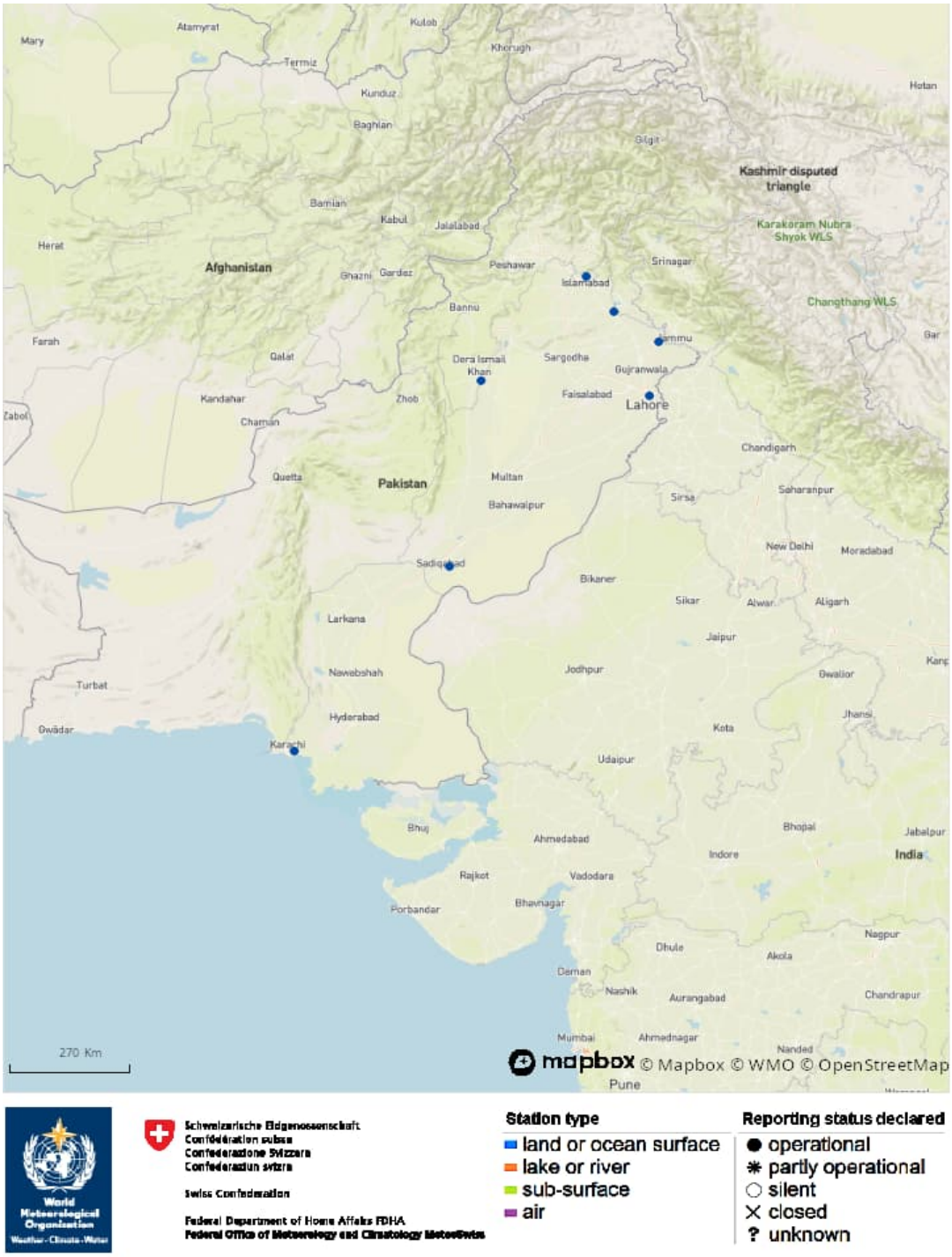


Figure 4. Precipitation stations: 7 stations (OSCAR-Accessed 1/7/2024): all declared operational by PMD

The seven radar stations (located at the precipitation stations), stated as operational by PMD, that are used to observe rainfall are shown in Figure 5.

Figure 5. Weather radar stations: 7 stations (OSCAR-Accessed 1/7/2024): all declared operational by PMD

Some of the surface climatology stations have been designated also as GCOS stations, which are part of the global climate change observing network requiring multiple observations of high quality (Figure 6); the OSCAR presentation is dissimilar to those in the earlier Figures, includes sites in neighbouring countries, and does not provide declared status. The Figure 6 caption notes that OSCAR indicates there are no GTOS stations in Pakistan – GTOS, the Global Terrestrial Observing System, is a component of GCOS run by FAO.

Figure 6. GCOS Stations - screenshot, could not download OSCAR map (GTOS – no stations)

Figure 7 presents an alternate view of the surface network obtained from the PMD website, indicating whether sites have Automatic Weather Stations (AWS) only or are hybrid, which presumably means a combination of AWS and manual observations, and whether the stations are on- or off-line.

The coverage is not quite as extensive as indicated by OSCAR (Figure 2), and includes AWSs, (according to OSCAR there are none). Not all stations are on-line (operational) according to Figure 6. Overall, the contrasts between the information in Figures 2 and 6 suggests that the OSCAR details might not be fully up to date (assuming the PMD site is maintained in real time).

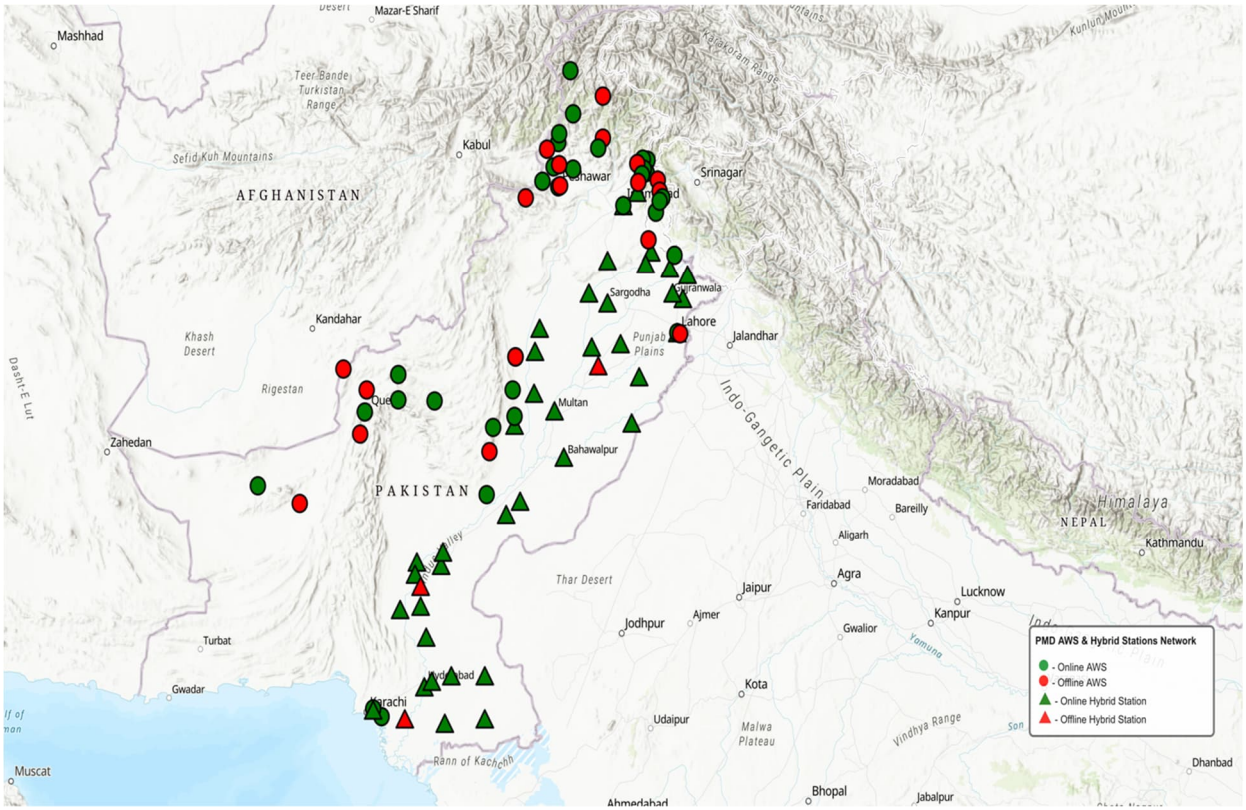


Figure 7. PMD network map accessed 1/7/2024 from PMD site

2.1.2 ADHERENCE TO WMO STANDARDS

WMO standards cover many areas, including instrumental and observational details, quality control, archiving, data transfer and exchange, and staff training. Many of these aspects cannot be judged from only a web-based assessment, and so indirect measures have been sought.

The 2022 Multi-Hazard Early Warning Systems (MHEWS) Report from the United Nation Office of Disaster Risk Reduction (UNDRR)[23] (page 25) says that the Pakistan surface network achieved 120-150% of GBON target compliance by reporting more than 30% of requirements at least 60% of the time in January 2022. Alternatively, the 2023 MHEWS report[24] (page 50) indicates a less than 50% compliance of reporting 80% or requirements at least 80% of the time. It is not immediately clear from these values whether the change indicates an improvement.

[23] https://www.undrr.org/publication/global-status-multi-hazard-early-warning-systems-target-g

[24] https://www.undrr.org/media/91954/download?startDownload=20240828

A basic view of the January 2024 GBON member compliance for surface observations is provided in Figure 8 from the 2024 Hydromet Gap Report[25]. These data indicate a need for further stations and an increased frequency of reported observations in Pakistan to meet GBON requirements.

In summary, as far as can be determined, the Pakistan GBON network requires enlargement and an improvement in the frequency of international information exchange. It is likely that the projects discussed earlier, whichever are implemented, will contribute to addressing these issues.

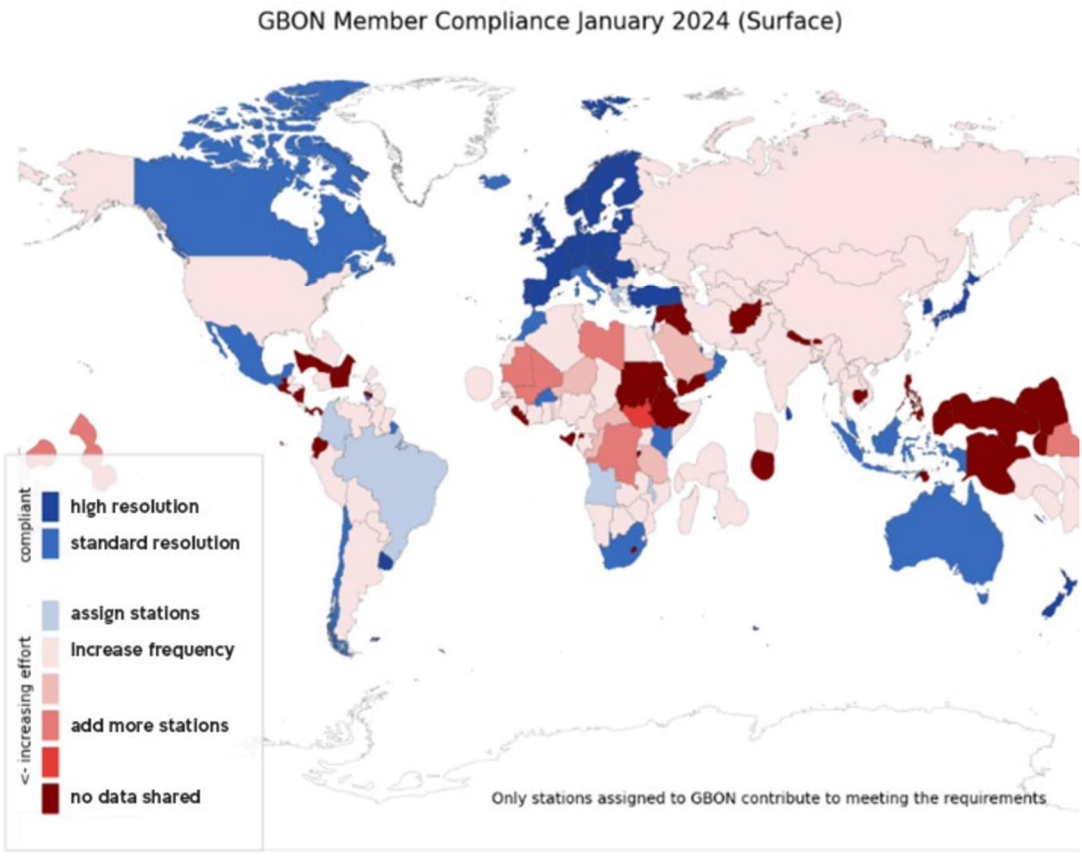


Figure 8. GBON Surface Observations Compliance January 2024, from 2024 Hydromet Gap Report[26]

[25] https://alliancehydromet.org/gap-report-2/

[26] https://library.wmo.int/viewer/68926/download?file=Hydromet-Alliance-Gap-Report-2024_en.pdf&type=pdf&navigator=1

2.1.3 DATA CAPTURE, QUALITY CONTROL, ARCHIVING, DISTRIBUTION

WDQMS, the WIGOS Data Quality Monitoring System[27], is a developing online system, managed by the European Centre for Medium-Range Weather Forecasts (ECMWF), that monitors the performance of all WIGOS components. At the time of writing (July 2024), results are available for:

- GOS land stations:
    - Surface land stations (SYNOP reports)
    - Upper-air (radiosonde) land stations (TEMP and PILOT reports) – see later section
    - An “alert” status to assist WMO members in rapid identification of issues with data collection and/or transmission
- GBON surface stations.
- GCOS land stations:
    - Surface stations (GCOS Surface Network - GSN)
    - Upper-air stations (GCOS Upper-Air Network - GUAN) – see later section

Similar to OSCAR, the information presented by WDQMS is dynamic (examples provided below were accessed in July 2024). There are too many options on WDQMS to illustrate all, so the priority has been given to monthly summaries for June 2024. The selected variable in Figure 8 is for the 2-meter temperature reports, but results for other parameters assessed in WDQMS are similar.

Availability of GOS data from the Pakistan surface stations through the month of June 2024 was inconsistent (Figure 9); several stations supplied 80% or more of expected observations, whereas at the other end of the spectrum, a number of stations were silent.

[27] https://community.wmo.int/en/activity-areas/WIGOS/implementation-WIGOS/WDQMS

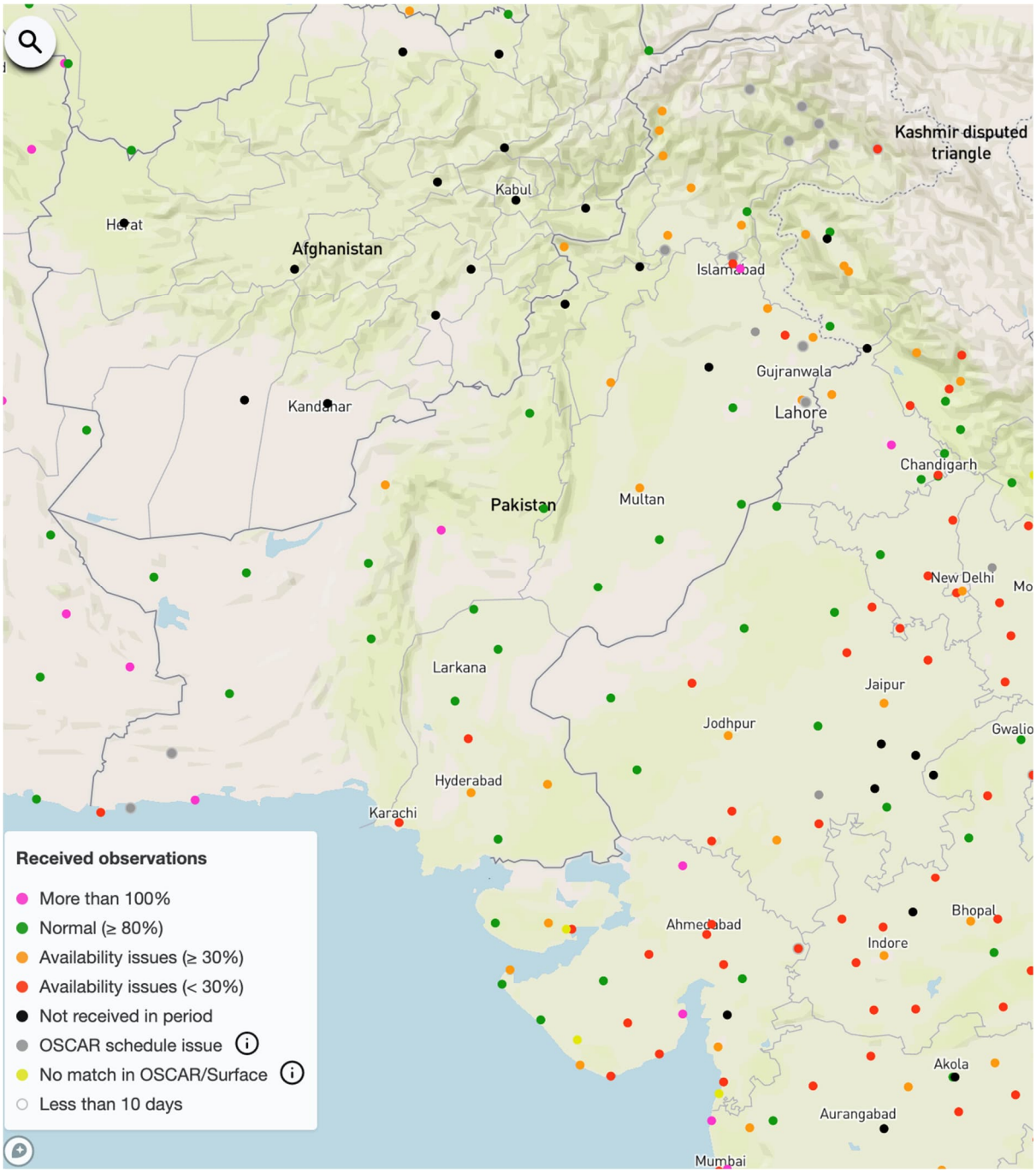


Figure 9. Availability of GOS data (2m temperature) in June 2024

A further issue covered by WDQMS is quality, which is measured by differences between observed values supplied and those calculated in global assessments by leading NWP centres (Figure 10).

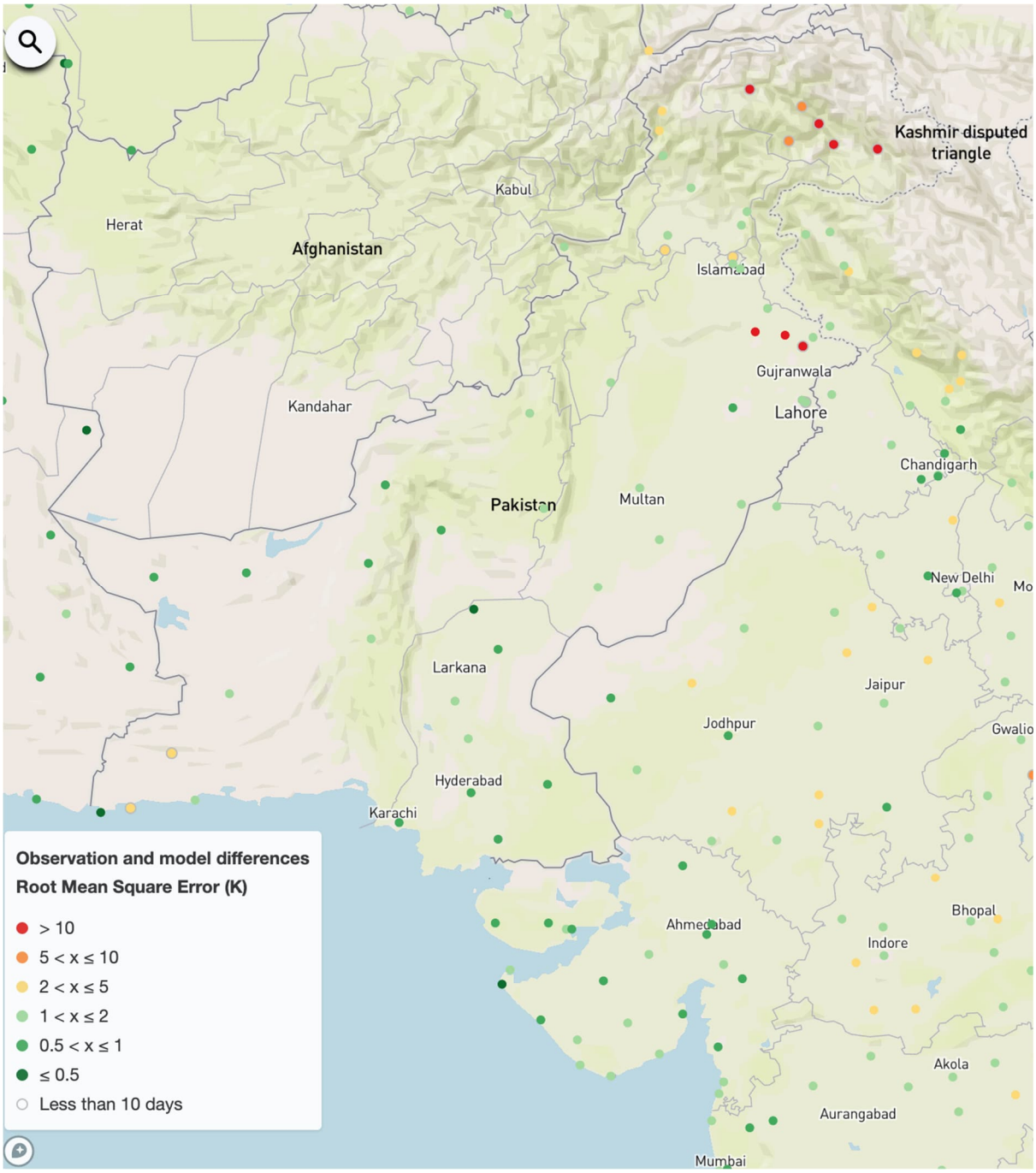


Figure 10. Quality of GOS data (2m temperature) in June 2024

For Pakistan, the root-mean square errors provided by on WDQMS were typically no more than 2ºK, but at a number of stations in the north, errors exceeded 10ºK. Ideally, errors by this measure should be less than 1ºC, even 0.5ºC, while errors in excess of 10ºK are of concern. A similar picture to that in Figure 10 is given by the alert information available only as quality for individual days (Figure 11). These issues should have been brought to the attention of PMD through the alert section of WDQMS.

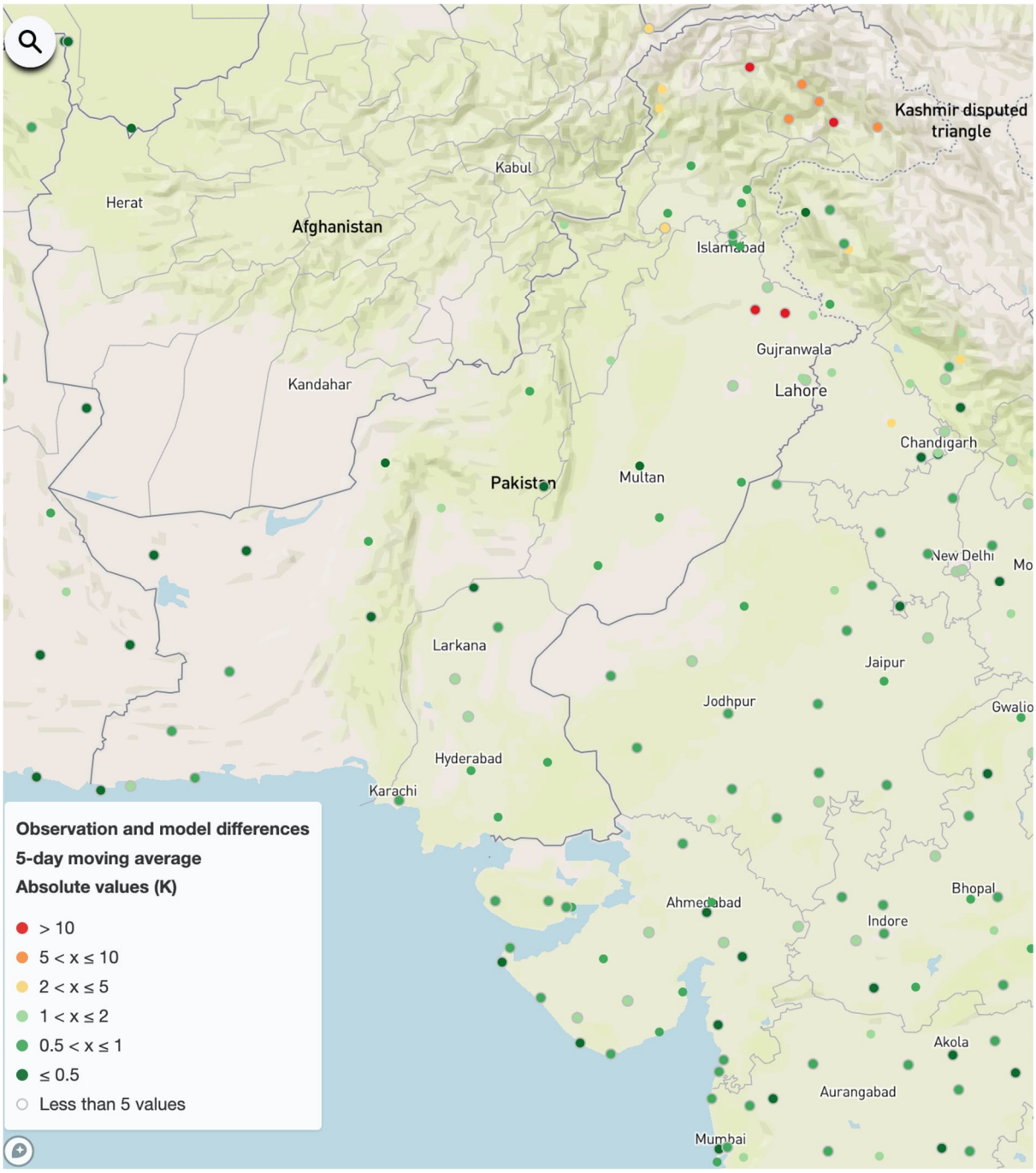


Figure 11. Alert quality (2m temperature) for 1 July 2024

Despite the GOS data availability for June 2024 being reasonable for Pakistan as was shown in Figure 9, the GBON surface network (Figure 12) is showing data availability as between 30% and 80%. A comparison between Figures 9 and 12 indicates similar number of station availability for GOS and GBON, but for an unknown reason, at some stations more GOS data than GBON data were delivered.

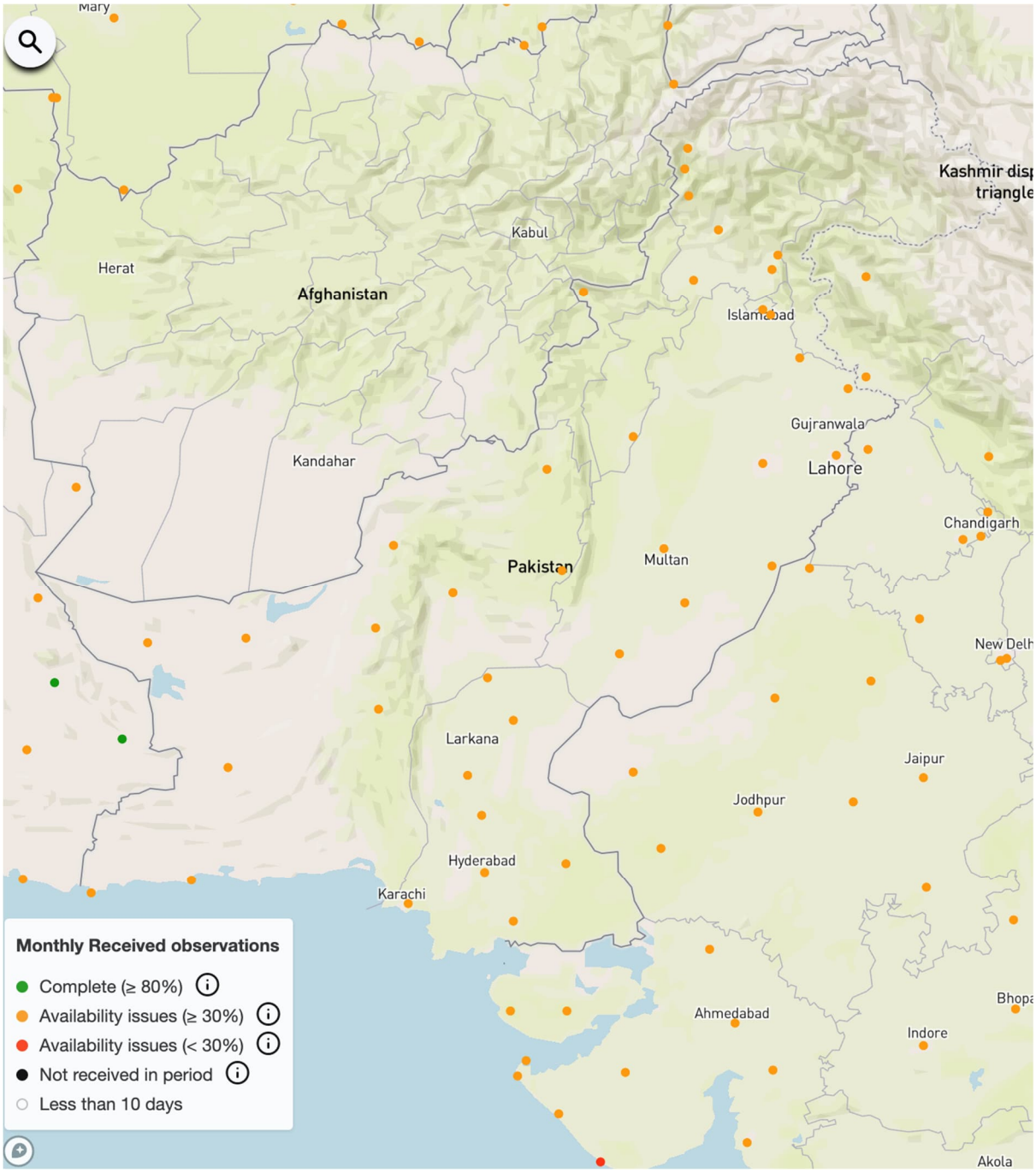


Figure 12. GBON availability (2m temperature) for June 2024

For GCOS surface information on WDGMS, the most recent monthly data reviewed are for May 2024 rather than for June 2024 as for GOS and GBON. Figures 13 and 14 indicate that all stations in Pakistan reported fully during May 2024.

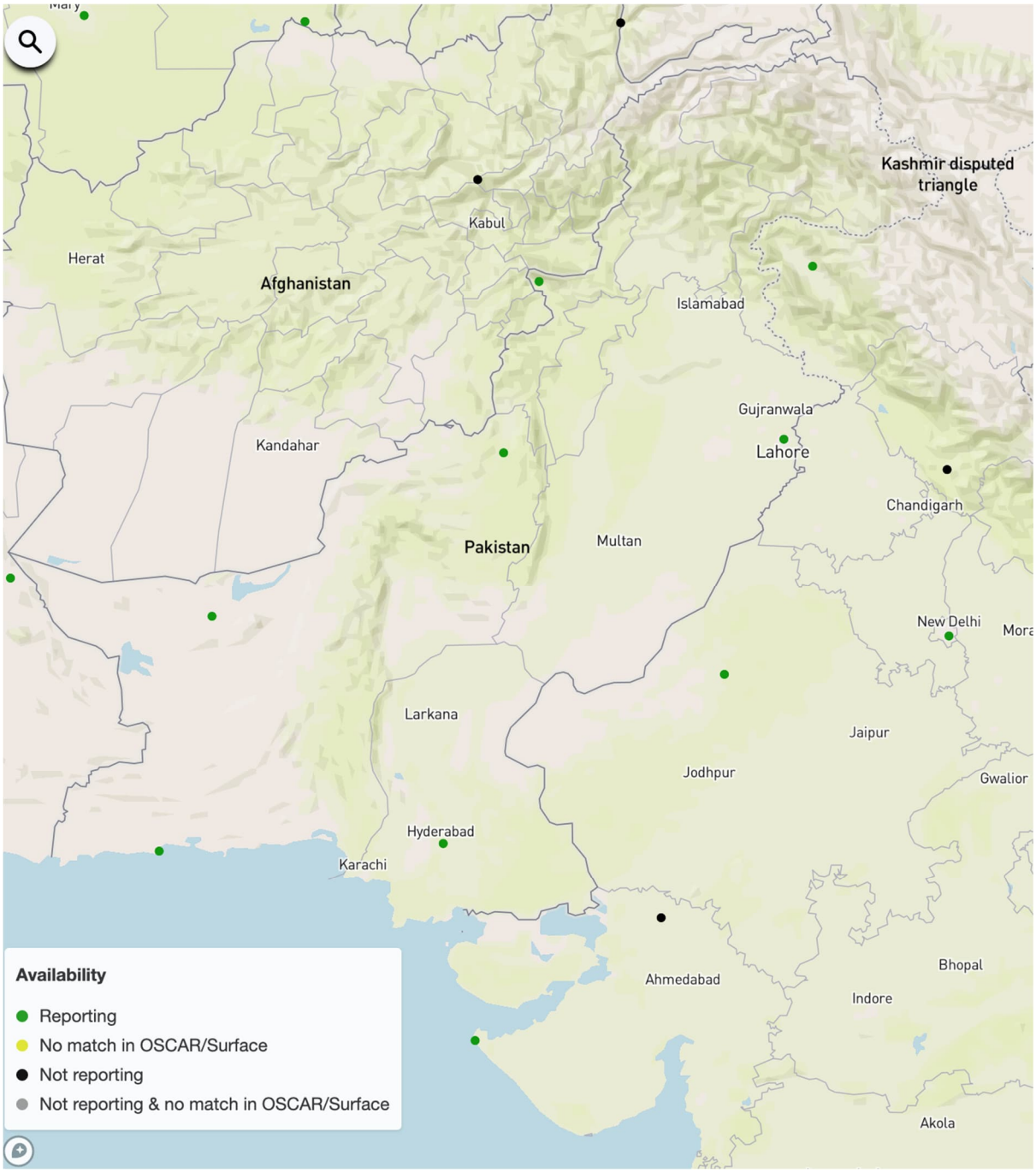


Figure 13. GCOS surface data availability (all parameters) for May 2024

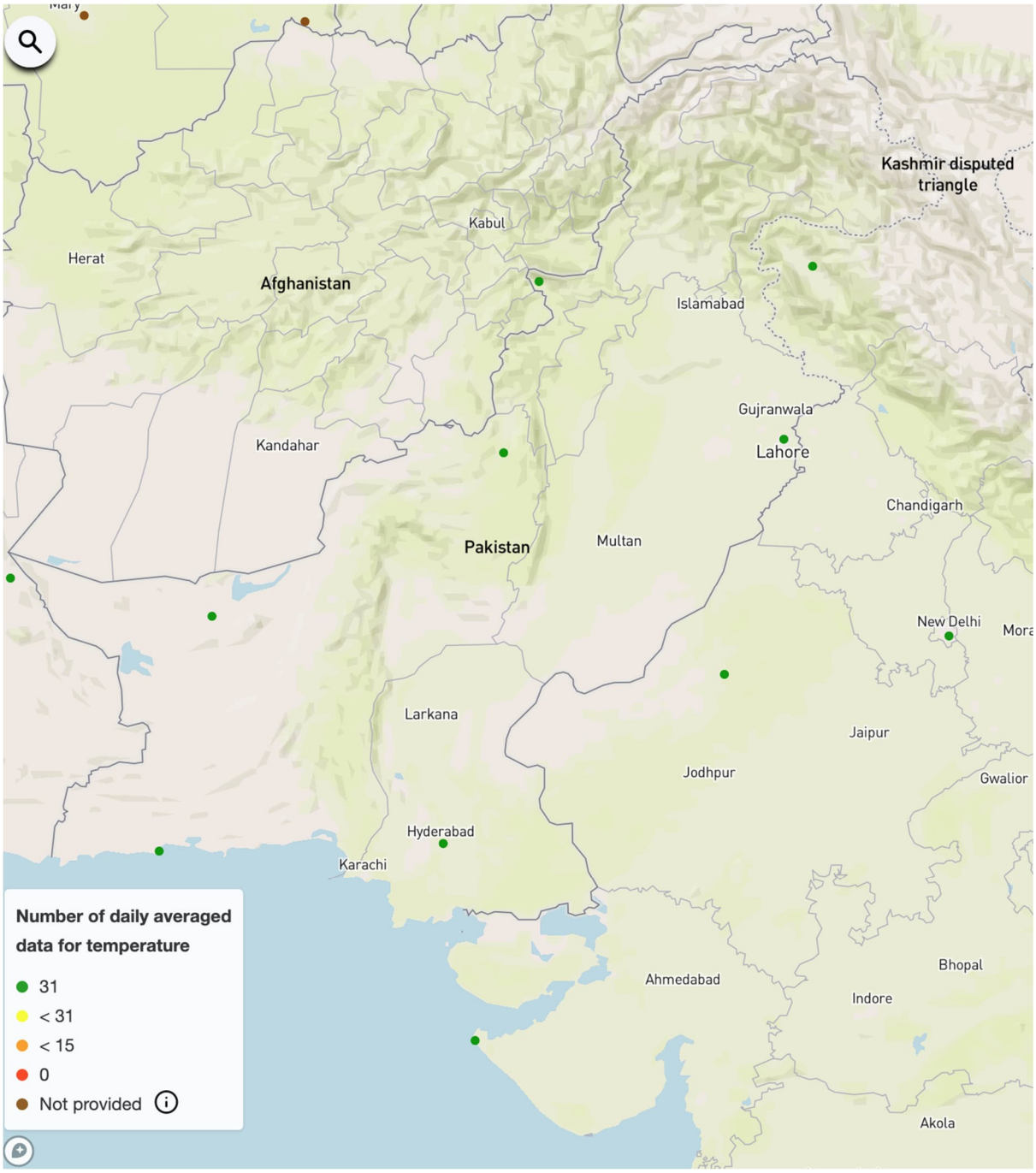


Figure 14. GCOS surface data availability (temperature) in May 2024

2.2 METEOROLOGICAL UPPER AIR, INCLUDING CLIMATE

The 2022 MEWS Report (p. 25) mentions that the Pakistani upper-air network achieved 0-50% of GBON target compliance by not reporting at least 1 daily report at least 60% of the time in January 2022. According to the 2023 report (p. 50), 2 daily radiosonde ascents were not provided over 80% of the time, less than a 50% compliance with GBON requirements. Upper-air data are collected by PMD either by

pilot balloons or radiosondes. Pilot balloons only provide wind data while radiosondes provide wind data in addition to air temperature, humidity, and pressure; some sondes provide additional data on the chemical composition of the air. According to OSCAR, there are six operational radiosonde stations in Pakistan (Figure 15).

Figure 15. Radiosonde stations: 6 stations: all declared operational by PMD

In addition, there is a single GAW station that appears collocated with one of the radiosonde stations (Figure 16).

Figure 16. GAW Stations - screenshot, could not download OSCAR map

Despite all radiosonde stations having been declared operational (Figure 15), no data were received internationally from any of these stations according to WDQMS during June 2024 (Figure 17). Similarly, no GBON data were shared in January 2024 (Figure 18). According to WDGMS, for June 2024, there were no GBON upper-air stations in Pakistan and just one GCOS station, at Karachi, from which no (BUFR – a WMO data transmission format) data were shared (not illustrated).

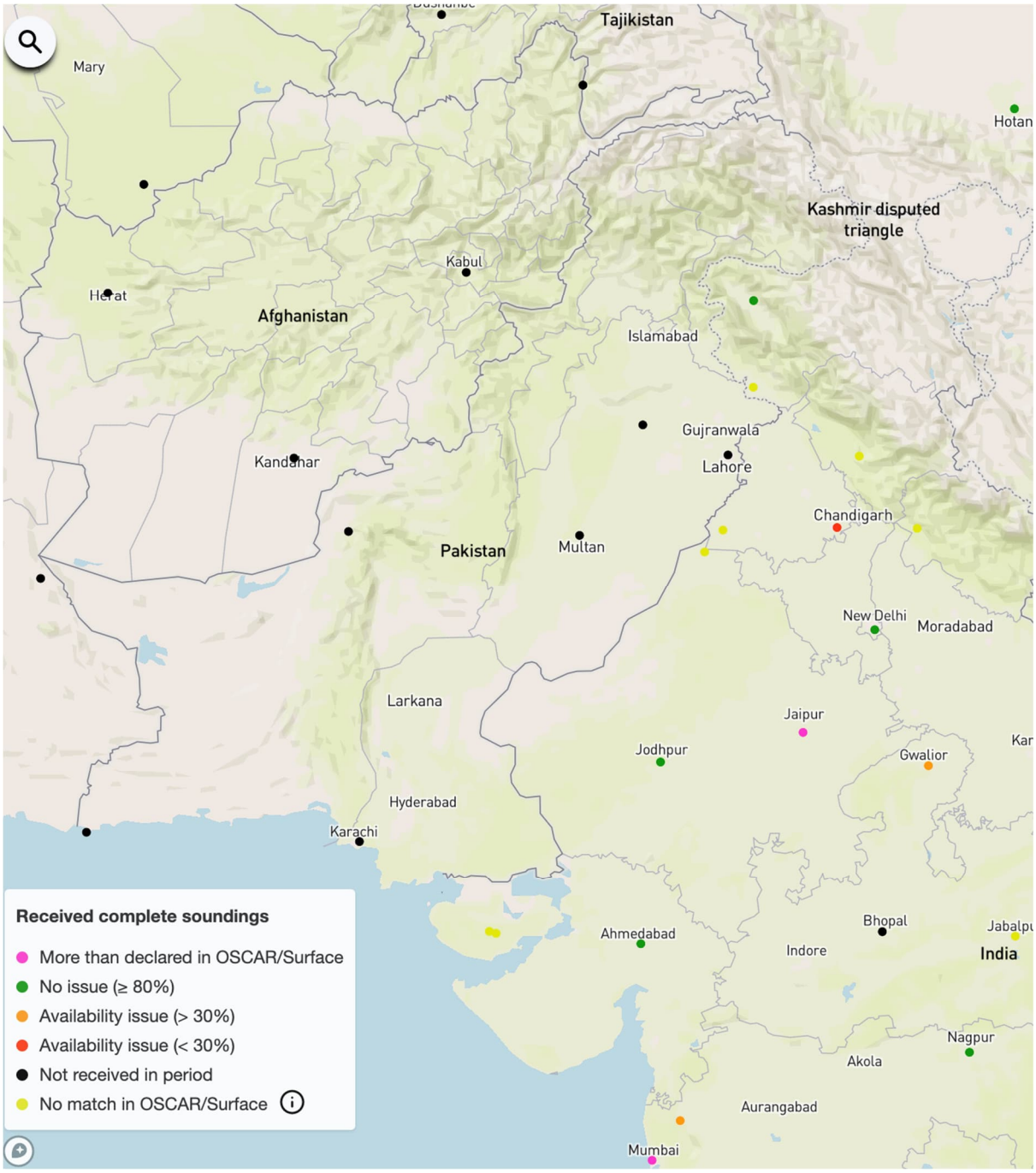


Figure 17. Data availability from upper-air measurements (temperature) in June 2024

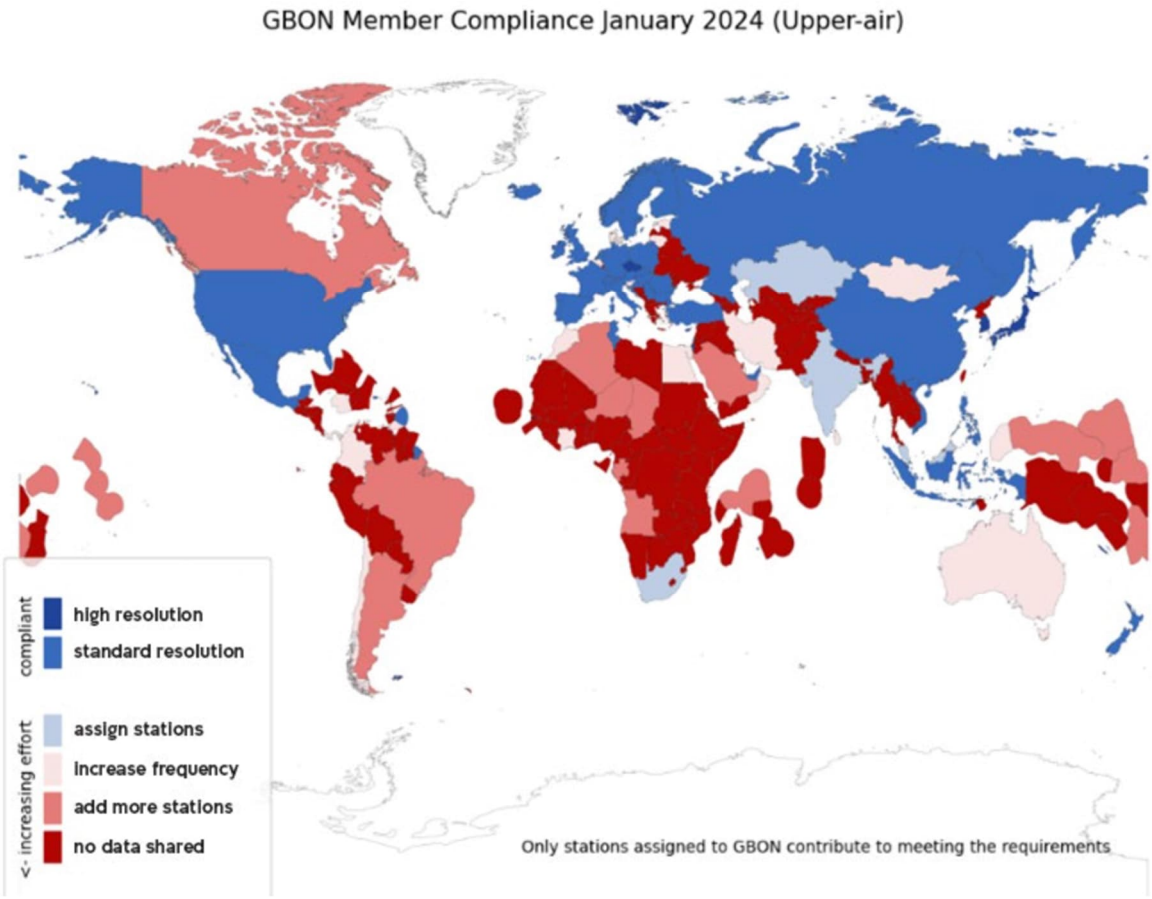


Figure 18. GBON upper-air compliance January 2024[28]

Upper-air data are vital in terms of producing weather forecasts, assessing climate change, and also for calibration of remote satellite sensor measurements with those corrected satellite data ingested into the weather forecasting processes. It is understood by the authors that the PMD has made efforts to improve the quality and quantity of these measurements; results outlined above indicate that progress has been made but that perhaps more still needs to be done.

[28] https://alliancehydromet.org/wp-content/uploads/2023/01/Country-Hydromet-Diagnostics-2022.pdf

2.3 HYDROLOGICAL

According to OSCAR, there are no WHOS stations in Pakistan. As of 1/5/2024 the status of progress of the County Hydromet Diagnostics (CHD) for Pakistan was not recorded nor was Pakistan listed as a SOFF beneficiary[2].

The Alliance for Hydromet Development together with WMO have developed CHD as a standardised process globally; its structure (copied from the Hydromet Gap Report 2021[29]) is illustrated in Figure 19. The CHD is intended to provide an overarching structure for hydrometeorology under the AHD with the objective of bringing "together major international development, humanitarian and climate finance institutions, collectively committed to scale up and unite efforts to close the hydromet capacity gap by 2030", following UN principles including the SDGs, the UNFCCC Paris Agreement and the Sendai Framework for DRR. [30] Assistance to NMHSs to upgrade a country's hydromet system is through SOFF. According to the SOFF site, there are no current activities in Pakistan.[31]

[29] https://allianceforhydromet.org/wp-content/uploads/2021/07/Hydromet_Alliance_Gap_Report_v7_LOW_RES.pdf

[30] https://allianceforhydromet.org/about/ - accessed 29/8/24

[31] https://www.un-soff.org/operations/countries/ - accessed 29/8/24

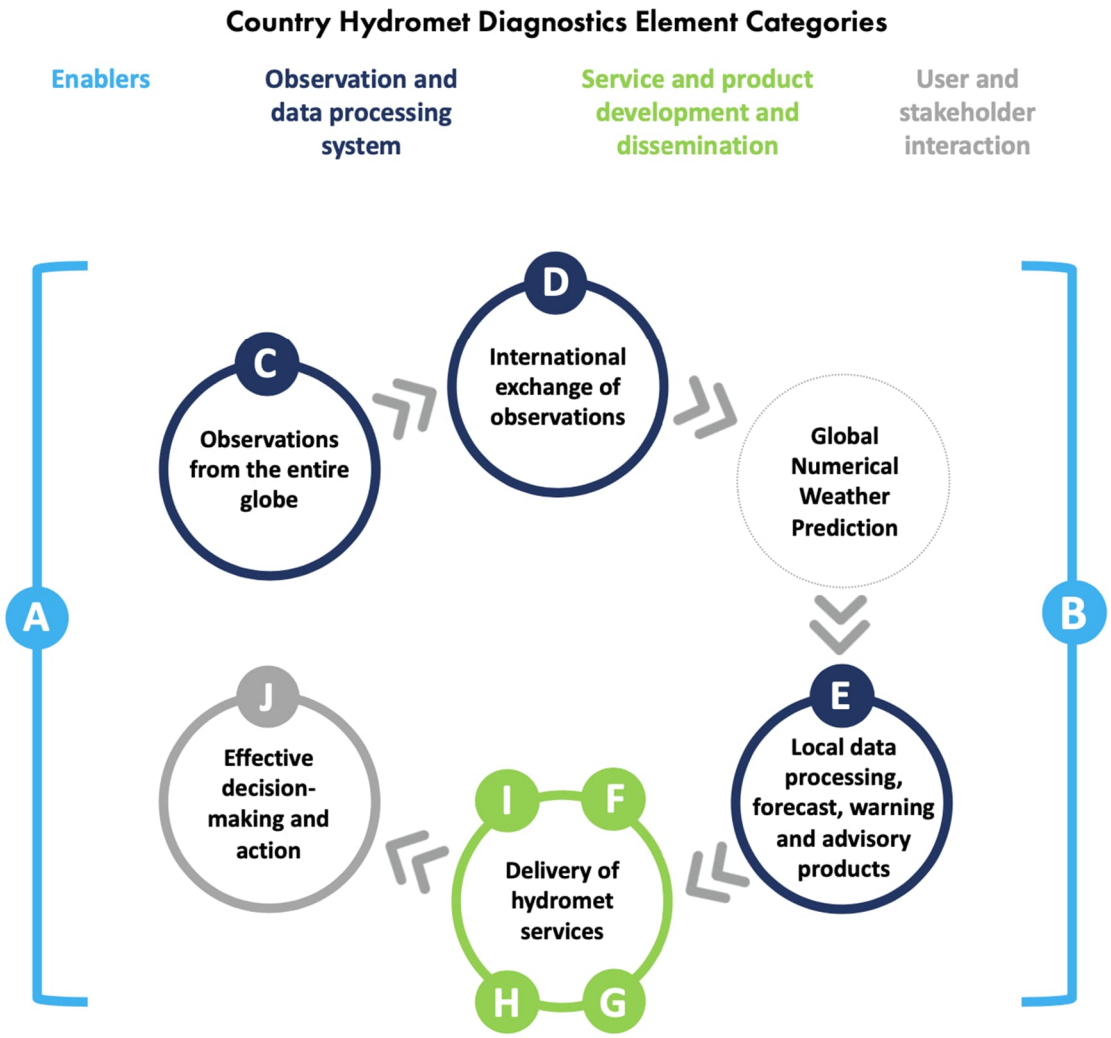


Figure 19. Structure of the Climate Hydromet Diagnostics system of AHD

The GTN-H, to which the CHD contributes, is a multifaceted structure which is not wholly relevant to this report (Figure 20 – note that not all abbreviations are expanded in the Appendix).

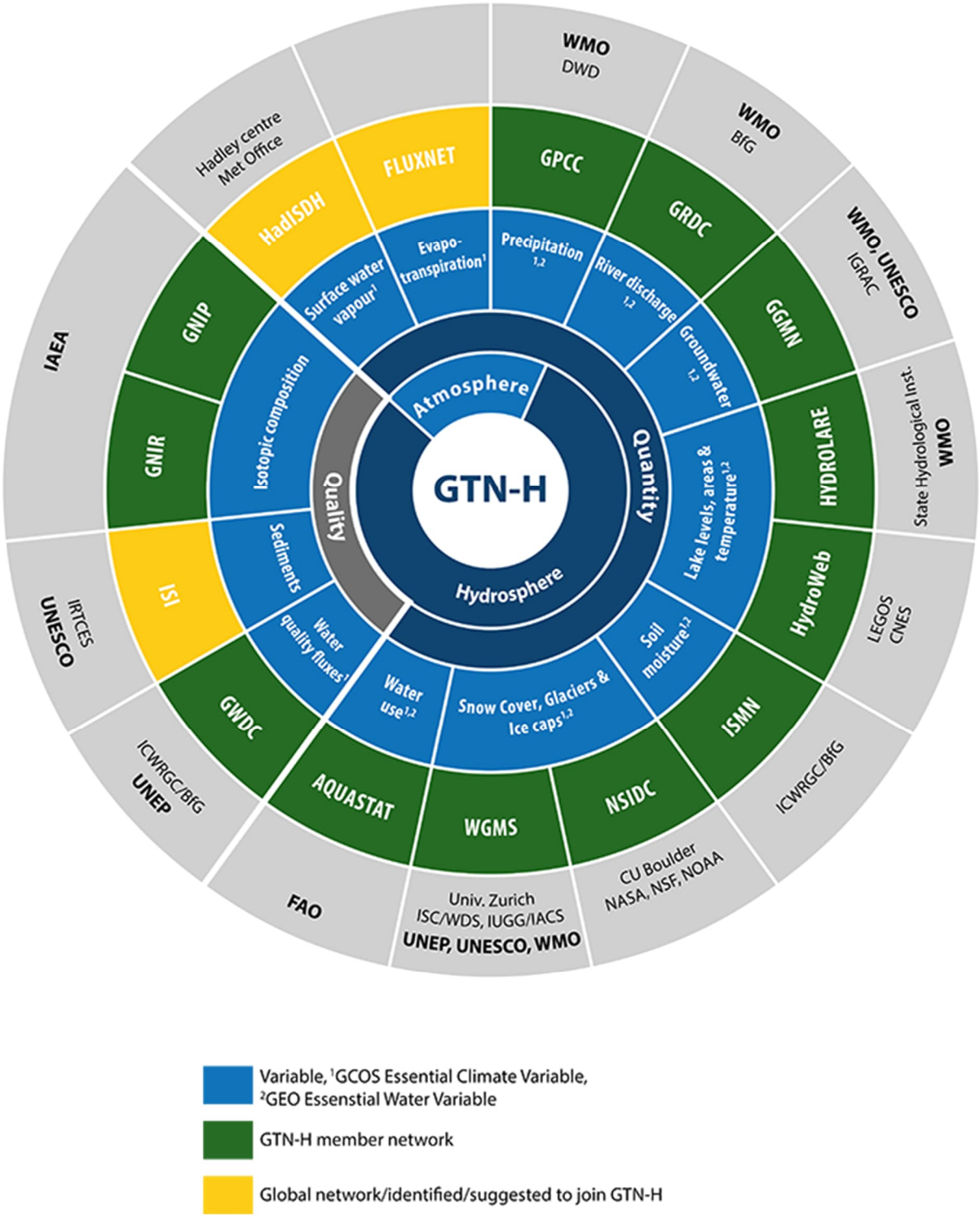


Figure 20. The structure of GTN-H as of 29/8/24

In terms of observation data capture as opposed to data archiving and analysis, the relevant GTN-H areas to this section of the report are the Global Groundwater Monitoring Network (GGMN) and the International Soil Moisture Network (ISNM).

Pakistan has one network registered in the ISNM (accessed August 2024) – Water Informatics and Technology (WIT) – for which there are two stations as of August 2024 recording soil temperature and moisture (Figure 21); it is run under the Lahore University of Management Sciences. There is no direct mention of links with PMD on the website.

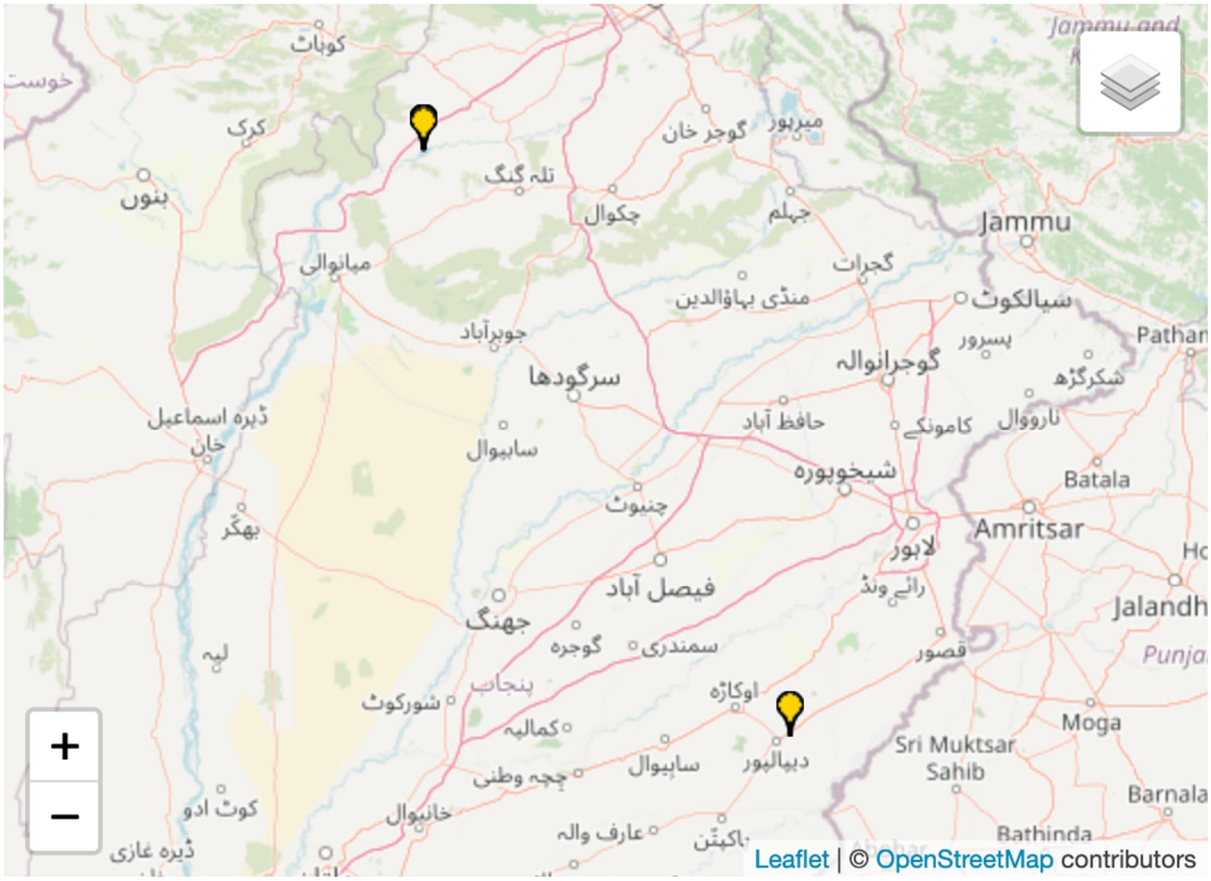


Figure 21. The stations in the WT Network - https://ismn.earth/en/networks/?id=WIT-Network

Under GGMN[32], Pakistan has a substantial network of observation sites including 9000 wells in Punjab and 3000 in Sindh[33] – Figure 22. This network is run by the Ministry of Water Resources. There is no mention of links to PMD in the information viewed by the consultants, nor has information been found on the situations in provinces other than Punjab and Sindh.

[32] https://www.un-igrac.org/special-project/ggmn-global-groundwater-monitoring-network

[33] https://www.un-igrac.org/sites/default/files/resources/files/Monitoring%20overview%20-%20Pakistan.pdf

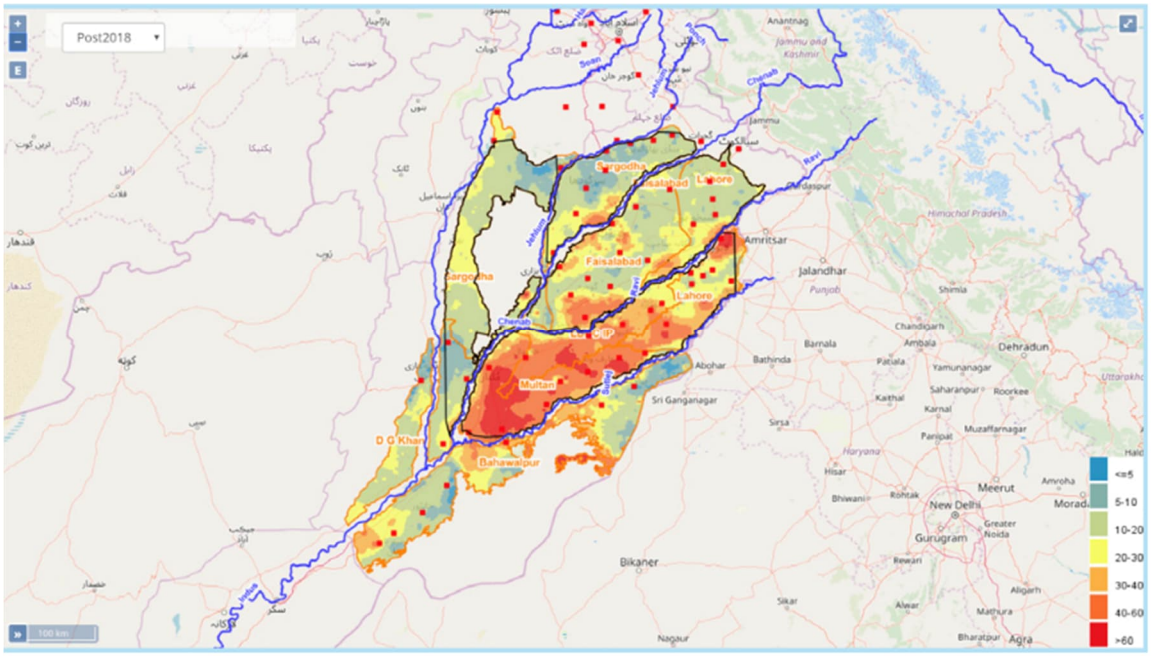


Figure 22. Ground water monitoring in Punjab post 2018 from https://www.un-igrac.org/sites/default/files/resources/files/Monitoring%20overview%20-%20Pakistan.pdf.

According to the PMD website, the organisation offers “Hydro-Meteorological Services and flood forecasting”. No indication of gauging stations has been found except for a list on the Flood Forecasting Division (FFD) site[34]; this list covers gauges on 6 rivers (all part of the Indus system) with a total of 22 gauging stations as seen in Figure 23. The earliest date with records noted in the list is 1928, but there is no detail of length of record at any of the sites. As far as can be determined, none of the gauging data are transmitted internationally, including to WHOS. Note that there are more than 22 gauging stations indicated on Figure 23.

[34] https://ffd.pmd.gov.pk/home

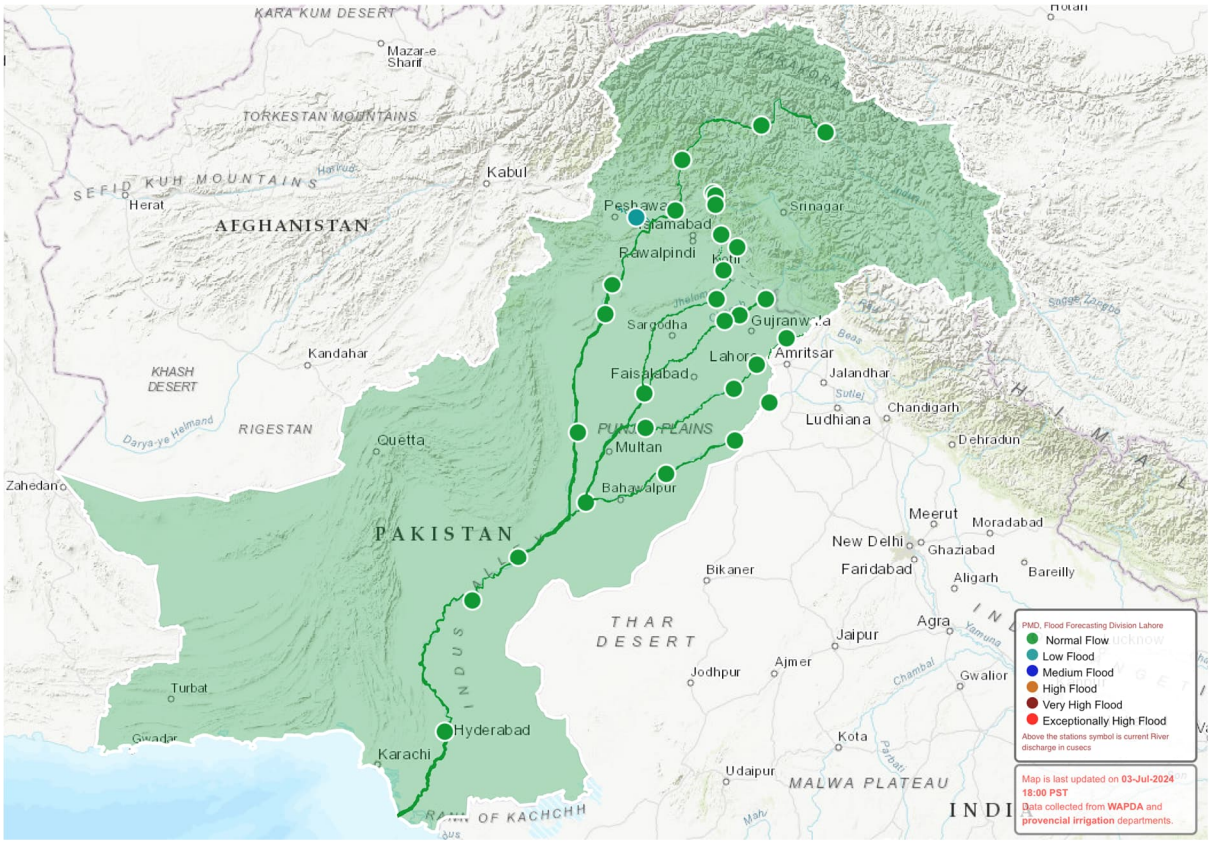


Figure 23. PMD Flood Forecasting Division (FFD) stream flow gauges (Link accessed on 3/7/2024),

2.4 GLACIOLOGICAL

The Pakistani glacier monitoring system[35] is under the PMD, but the linked website is blank (as of July 2024). The Research and Development Division (RDD) within the PMD website mentions the involvement of the PMD in in-situ measurement of glaciers characteristics, including melting rates, depth, debris cover, velocities of different glaciers and their mass balance. The site indicates that the in-situ measurements stem from AWS observations and scientific expeditions.

The WGMS holds lists of references (with more than 30 years of ongoing glaciological mass-balance measurements) and of benchmark (with more than 10 but less than 30 years of on-going glaciological mass-balance measurements) glaciers, but none are within Pakistan.[36]

[35] https://rnd.pmd.gov.pk/glaciers/

[36] https://wgms.ch/products_ref_glaciers/

According to the PMD website[37], there is a service for warning of GLOFs that is placed under RDD. Under Services → Weather Forecasting Centre → Disaster Watch is the page in Figure 24 which is maintained by the Pakistan Space and Upper Atmosphere Research Commission (SUPARCO).

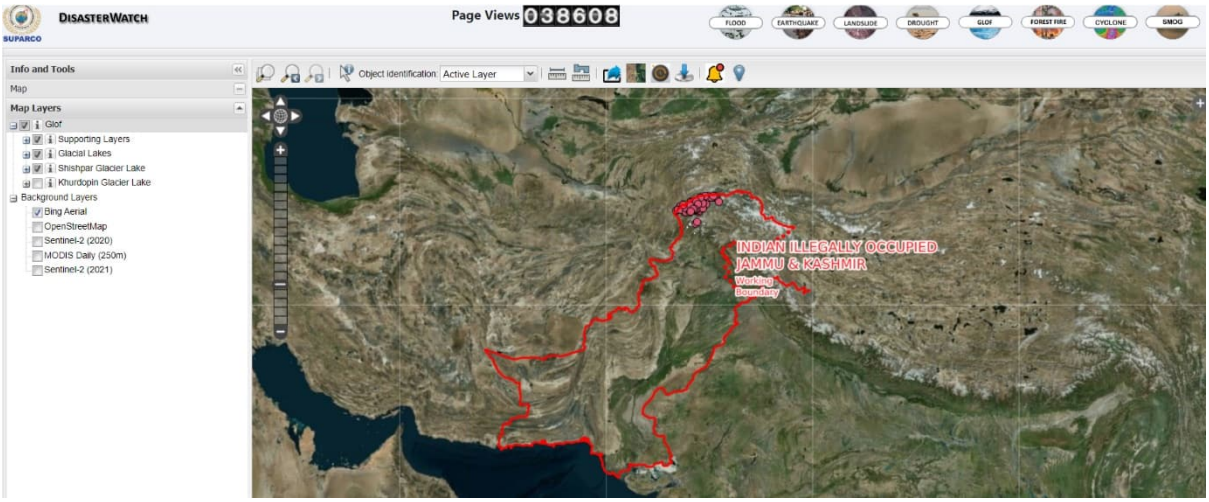


Figure 24. Disaster Watch (http://disasterwatch.sgs-suparco.gov.pk/?map=glof)

The top right corner in Figure 23 is a list of disasters accessible through the site – flood, earthquake, landslide, drought, GLOF, forest fire, cyclone and smog; the example shown is for GLOF. Clicking on one the red dots over the northwest of the country with the "object identification arrow" produces a list of monitoring points with comments such as "No Lake found" or "Lake Area has increased"; where lakes exist, there are some links to graphics indicating time series of lake sizes, but in all cases examined, only a single value was provided, presumably given the earliness of the season for major glacial melt when access was made (accessed July 2024).

2.5 SPACE-BASED

The details in Figure 23 are from the SACRED programme of SUPARCO, obtained from PAKISTANI satellites, as part of UN-SPIDER. As noted above, there is a single link from the PMD WFC site to the Disaster Watch page of SUPARCO, but there is no return link found from any SUPARCO page to PMD. The **Satellite Data**

[37] http://disasterwatch.sgs-suparco.gov.pk/?map=glof

Receiving and Processing Centre works with a number of internationally managed satellites to develop information on:

- Aerosol and Gaseous Components (AOD, BC, Hg, O3, SOx, NOx, CO2 etc)
- Atmospheric Profiles (Total-ozone burden in tropospheric and stratospheric ozone content)
- Water Quality (DO, Alpha Chlorophyll, Phosphorus, Turbidity etc.)
- Glacier and Climate Change (snow cover, glacial extent, glacial hazards)
- Marine and Coastal Studies, Droughts
- Biomass assessment (surface biomass)

Within the cryosphere modelling work, SUPARCO works with:

- Development of regional glacier database
- Monitoring of glaciers
- Glacial hazard mapping and modelling
- Glacier depletion monitoring
- Estimation of snow cover
- Snow melt and runoff modelling
- Study atmospheric conditions of the cryosphere

Within the water resources work, SUPARCO works with:

- Surface energy balance and evapotranspiration
- Hydrological modelling
- Mapping of Surface water resources and irrigation networks
- Watershed modelling and integrated watershed management
- Ground water prospection
- Wetland ecosystem modelling
- Dam site selection
- Soil moisture estimation

Within the disaster management work, SUPARCO works with:

- Monitor, forecast and map various hazards
- Damage assessment in affected areas
- Integrated Flood Analysis System
- Disaster vulnerability assessment (earthquake, landslide, flood, cyclone, tsunami, drought, heat)
- Risk modelling
- Rehabilitation and mitigation support

In the above regard, SACRED works with:

- Provision of the space-based information to NDMA and PDMAs in the event of the natural disasters (Flood, Drought, Earthquake, and Landslide) for mitigation, preparedness, response and recovery
- Activation of the International Charter Space and Major Disasters in the event of the major calamity
- Technical support to the NDMA and PDMA for the conduct of the Multi Hazard Vulnerability and Risk Assessment (MHVRA) Studies
- Capacity building of the NDMA and PDMAs in the field of space-based disaster management
- Technical support to the NDMA for the realization of the long-term agenda including NDMP 2015-30, Sendai Framework 2015-30, Paris Climate Change Agreement COP21 and SDGs 2015-30
- Provision of space-based information/support to the regional countries in the event of the natural disasters

SUPARCO is also host to the Pakistan Space Weather Centre which undertakes monitoring duties.

3 SERVICE PRODUCTION

3.1 NATIONAL PRODUCTION OF WEATHER FORECASTS, SHORT-TERM CLIMATE OUTLOOKS AND CLIMATE PROJECTIONS

The PMD website provides few direct details of approaches used to produce forecasts of any time ranges, whether locally or through access to international products. For local production, the basic process is:

1. Develop or obtain a forecast model, install and commission
2. Establish a data assimilation system:
    a. Data assimilation is a vital, but complex, step that produces the initial fields from which a forecast model is run
    b. The simplest approach is to obtain appropriate assimilated fields from one of the international forecast centres
    c. For in-house assimilation, there is need not only for the appropriate software but also for rapid ingest of all observation data required for the process
3. Run the model from assimilated fields
4. Provide appropriate outputs from model runs
5. Process model outputs into services

In this section of the report, the focus is on steps 1 to 3; step 4 will be discussed under “Service Delivery” while no information on step 5 has been located for Pakistan.

According to the PMD site, two sections have responsibilities in modelling, although it is not clear whether their work is collaborative or independent (see Appendix 2 for details). There is the Specialised Medium Range Forecasting Centre (SMRFC)[38] and the Research and Development Division (RDD)[39]; both web pages list models that are being or have been used to produce forecasts for the WFC; no indication of

[38] https://smrfc.pmd.gov.pk/

[39] https://www.pmd.gov.pk/rnd/rndweb/rnd_new/index.php

model statuses is provided and so it is unclear which are in use for operations under what divisional responsibilities. Some models are common to both lists, some not.

The following two models are common to both lists:

- The Global Spectral Model (GSM), provided by JMA (Japan), has a resolution of about 20km and is/will be run for 72 hours to provide short-range forecasts. Forecast fields are provided on the SMRFC web site.
- The Global Forecasting System (GFS) is the main NOAA model and is used for medium-range forecasts over 3 to 7 days with a 25km resolution. The site does not make clear whether these products are created locally or are obtained remotely.

Other models mentioned on the SMRFC list are:

- The Weather Forecasting and Research model (WRF) developed at NCAR through a collaboration of US universities that provides forecasts to 72 hours with a resolution of 5km. Its uses are for short-range, flood and marine (including GMDSS) forecasting, with hourly products for the latter. It includes a data assimilation component, but no details are provided of data sources for the assimilation process. Forecasts are provided on the SMRFC web site.
- The ICOsahedral Nonhydrostatic model, provided by DWD, has been operational since 20/1/15 (although the web site does not make it clear whether this date refers to DWD or to PMD). It is/will be run over 72 hours at 13km resolution for short-range forecasting. No other details, including of assimilation processes, are provided. Forecast fields are provided on the SMRFC web site.
- The Global Environmental Multiscale model (GEM), developed by the Canadian service, includes an assimilation component and provides medium-range forecasts with 1º resolution to 7 days. It seems likely these products are obtained remotely.

Other models mentioned on the RDD list are:

- It is possible, but not clear, that GCM20 is used at PMD, in which case most likely for climate change projections but possibly also for downscaling with at least one of the ICTP RegCM4 and the UKMO PRECIS models
- The DWD HRM (High Resolution Model) is run with 11km resolution, but according to SMRFC the DWD model used is the 13km resolution ICON model; the section clarifies that assimilated initial conditions are provided by DWD
- The CMA GSM with a resolution of 30km providing information to one week

No details are provided to indicate local production or international access for any of these models, although given their appearance on the SMRFC web site it is assumed that the current operational models are WRF, ICON and JMA. In a few cases, there are statements that a model includes assimilation capabilities, but it is not clear whether this is run locally by PMD or is imported from the specific modelling centre.

All of the above provide deterministic solutions (and only deterministic products have been noted on all PMD sites). In addition, the SMRFC lists the Global Ensemble Prediction Suite (GEPS), presumably accessed remotely, that provides an ensemble of 63 global models from three international centres running out to 7 days for the medium range. In principle, this would provide an extensive resource for producing probabilistic products and, to an extent, estimating the confidence that might be placed in the deterministic products. No indication of any production as opposed to research use of the GEPS has been located.

3.1.1 ADHERENCE TO WMO STANDARDS AND GUIDELINES

Cannot be assessed through this assignment.

3.2 INTERNATIONAL COOPERATION IN THE PRODUCTION OF WEATHER FORECASTS, SHORT-TERM CLIMATE OUTLOOKS AND CLIMATE PROJECTIONS

All of the models used have been obtained from international modelling centres.

3.3 NATIONAL PRODUCTION OF HYDROLOGICAL FORECASTS

Cannot be assessed through this assignment.

3.3.1 ADHERENCE TO WMO STANDARDS AND GUIDELINES

Cannot be assessed through this assignment.

3.4 INTERNATIONAL COOPERATION IN THE PRODUCTION OF HYDROLOGICAL FORECASTS

Cannot be assessed through this assignment.

3.4.1 ADHERENCE TO WMO STANDARDS AND GUIDELINES

Cannot be assessed through this assignment.

3.5 PRODUCTION OF GLACIER MONITORING

Cannot be assessed through this assignment.

4 SERVICE DELIVERY

4.1 INTRODUCTION

Services are provided from a number of sources, of which the two considered here are those from PMD and from SUPARCO. Services such as the National Food Security and Research and the Water Resources Divisions of the relevant GoP departments have not been considered. The following section headings are used to differentiate services from PMD (see a full list in Appendix 2), with comment added regarding services from SUPARCO. In summary, the relevant areas in which SUPARCO proves services are (see also Appendix 3):

- Agricultures
- Forestry
- Disaster management
- Water resources
- Environment
- Cryosphere modelling
- Coastal and marine resources

There appears to be a single link to the SUPARCO site from the PMD site, pointing to SUPARCO's disaster watch pages; there is no link from SUPARCO to PMD.

Apart from services supplied via the website, the PMD offers public services via television, printed media, and also PMD website videos (which all appear to be in Urdu) for tourists, daily weather, Pothohar, farmers, Sindh and Punjab, as well as a monthly climate outlook. There are also regional forecasts for Balochistan, Sindh and Punjab/Kasmir, although the format of these varies – see Appendix 2 for details.

4.2 SHORT-RANGE WEATHER FORECASTING SERVICES

According to the PMD website[40], the short-range weather forecast services for which the organisation is responsible are:

[40] https://www.pmd.gov.pk/en/about.php (accessed 23/8/24)

- Aviation meteorological Services
- Hydro-meteorological Services and Flood Forecasting
- Agro-meteorological Services
- Weather Forecasting Services to the Public through electronic and print news media
- Met-forecast for mountaineering expeditions
- Marine Meteorological Services
- Safety of civil and armed forces aviation operations, WIP flights and marine activities
- Early warning of Natural Hazards such as tropical cyclones, heavy rains, heat waves, floods

Naturally some of these services extend across longer time scales, as discussed below. Further, some services are covered under additional headings.

AVIATION METEOROLOGICAL SERVICES

Although listed independently on the PMD site, it is assumed here that "Safety of civil and armed forces aviation operations and WIP flights" is handled as part of "Aviation Meteorological Services". The PMD aviation services page[41] provides a number of links to pages in general accessible from the WFC pages, although with additional charts at various flight levels locally, over the Middle and Far East and over Europe. There are also maps, but that for the "World" did not work when visited, nor did any of the links from METARs or TAFs. Further links include:

- daily forecasts from WFC (inaccessible link on 27/8/24); and
- the weekly forecast provided for National linked to the NWFC page, while the Cities Weekly Forecast connected to a NOAA product.

Presumably these data are provided directly to airports and to airlines in some form, but there is no indication on the PMD site of this.

HYDRO-METEOROLOGICAL AND FLOOD FORECASTING SERVICES

These services are the responsibility of the FFD that provide graphics of the current state of river flows, a set of rolling forecasts, and downloadable text only-documents that cover: the current river situation and a qualitative flood forecast; a quantitative flood forecast for existing gauging stations; a significant weather outlook; and

[41] https://aviation.pmd.gov.pk/products.php

significant flood warnings. There appear to be no details on the website of the processes for producing the qualitative and quantitative flood forecasts.

Additionally, the NDMC provides pertinent short-range services including flash drought alerts, and daily graphics of levels and inflows/outflows for 5 reservoirs.

AGRO-METEOROLOGICAL SERVICES

The NAMC provides mainly longer-range services but does offer some daily data.

WEATHER FORECASTING SERVICES TO THE PUBLIC THROUGH ELECTRONIC AND PRINT NEWS MEDIA

The authors are aware of these services but have made no surveys.

MET-FORECAST FOR MOUNTAINEERING EXPEDITIONS

The only information detected for this service is under the RDD pages that included graphical and up-to-date forecasts for the mountains and higher plains of surface temperature and rainfall from the WRF and ICON models (although when visited, no information was available from ICON). No interpretation for mountaineers was found, nor is it clear how mountaineers might access this information.

MARINE METEOROLOGICAL SERVICES

The only reference found to marine services are an English document[42] (not downloadable), plus a mention on the SMRFC site of a project entitled "Establishment of Specialized Medium Range Weather Forecasting Centre (SMRFC) and Strengthening of Weather Forecasting System in the Islamic Republic of Pakistan", being undertaken with sponsorship from Japan, also including installation of a weather radar and a wind profiler system. The objectives are to provide short and medium-term flood and marine forecasts. Otherwise, no details have been located.

4.2.1 ADHERENCE TO WMO GUIDELINES

Cannot be assessed in this assignment.

[42] https://www.pmd.gov.pk/marine/marine_forecast.htm

4.3 MEDIUM-RANGE WEATHER FORECASTING SERVICES

According to the PMD website[43], the medium-range weather forecast services for which the organisation is responsible cover:

- Hydro-meteorological Services and Flood Forecasting
- Early warning of Natural Hazards such as tropical cyclones, heavy rains, heat waves, floods
- Glacier Lakes Outburst Floods (GLOFs) warnings

Medium-range is typically understood as the 3 to 10 day period, a definition used here. All information on the main PMD site is for the short-range, although two of the regional meteorological centres provide some information:

- Balochistan – no medium-range information
- Sindh – 3-day forecasts as weather symbols for selected locations
- Punjab/Kashmir – city forecasts in writing and as symbols out to 7 days for selected cities

The medium-range is covered in the monthly climate outlook delivered as a video in Urdu.

No direct services appear to be provided by the SMRFC; the site listing models used operationally either currently or in the past (there is no indication of which), with most run to 3 days, but three (GFS, GEPS and GEM) appear to be used to 7 days. The GFS and GEM provide deterministic forecasts whereas GEPS is an ensemble system that potentially would provide probabilistic forecasts, or, to an extent, confidence estimates for deterministic forecasts. In the view of the authors, ensembles are the most appropriate for providing forecasts on all time scales, but there appears to be no information on any site indicating any operational use of the ensembles.

The source of the 7-day forecasts, provided for 15 locations in a mixture of symbols for the first three days followed by Urdu text, given on the NAMC site is not stated. These forecasts are produced jointly with the MNS-University of Agriculture, Multan, but a brief search of the University's site[44] revealed no information on the collaboration.

[43] https://www.pmd.gov.pk/en/about.php (accessed 23/8/24)

[44] https://mnsuam.edu.pk/

Similarly, there is no information on the source of forecasts provided on the FFD site. These include a 72-hour forecast plus a worded outlook for a week, focused on potential flooding issues, and a further set of warnings for a week.

The RDD website carries graphical forecast fields out to 6 days from the ETA model but offers no interpretation of these.

4.3.1 ADHERENCE TO WMO GUIDELINES

Cannot be assessed in this assignment.

4.4 CLIMATOLOGICAL SERVICES, INCLUDING SEASONAL OUTLOOKS, DROUGHT MONITORING, AND CLIMATE CHANGE PROJECTIONS

According to the PMD website[45], the climatological services for which the organisation is responsible cover:

- Climatological Services
- Climatological data processing for scrutinising, comparing and publishing
- Glacier monitoring and research

There is substantial information in this area across the linked sites, especially information on recent conditions offered on the PMD, Punjab/Kashmir regional centre, NAMC, NDMC and CDPC sites. The NDMC site in particular includes extensive information covering droughts, reservoir levels, and numerous rainfall and other statistics, not least including a number of satellite indices, such as the NDVI. In parallel, the NAMC site offers a seasonal agroclimatic outlook, together with a monthly agroclimatic advisory, the latter in Urdu only. CDPC is responsible for archiving, assessing and delivering climate information.

There is a reference to an “Experimental Seasonal Forecast” on the RDD site, for which ensembles from 13 international modelling houses, each with differing numbers of ensemble members, are used to create the forecasts in the final week of each month. Neither the process employed not any operational uses are covered on the site, but there are links to English text and graphics on monthly rainfall outlook

[45] https://www.pmd.gov.pk/en/about.php (accessed 23/8/24)

(for August 2024 when accessed) and to a seasonal outlook that additionally includes temperature (August to October 2024 when accessed).

The RDD site also includes downscaled information from some climate change projections; only data are provided without interpretation. There are two sets, both covering the period from 2010 to the end of the century, and mostly at both 25km and 50km downscaled resolution. At most, data for two global models downscaled using two regional models are provided.

4.4.1 ADHERENCE TO WMO GUIDELINES

Cannot be assessed in this assignment.

4.5 AGRO-METEOROLOGICAL SERVICES INCLUDING SEASONAL OUTLOOKS

According to the PMD website[46], the agro-meteorological services for which the organisation is responsible cover:

- Agro-meteorological Services [presumably a catch-all indication]
- Climatological services
- Climatological data processing for scrutinising, comparing and publishing
- Early warning of Natural Hazards such as tropical cyclones, heavy rains, heat waves, floods

Additional detail on these services is provided in section 5.4.

4.5.1 ADHERENCE TO WMO GUIDELINES

Cannot be assessed in this assignment.

[46] https://www.pmd.gov.pk/en/about.php (accessed 23/8/24)

4.6 HYDRO-METEOROLOGICAL SERVICES AND FLOODING FORECASTING

According to the PMD website[47], the hydro-meteorological services and flood forecasting for which the organisation is responsible cover:

- Hydro-meteorological Services and Flood Forecasting
- Climatological services
- Climatological data processing for scrutinising, comparing and publishing
- Early warning of Natural Hazards such as tropical cyclones, heavy rains, heat waves, floods

The three sites with greatest responsibility are the NAMC, the NDMC and the FFD sites. Flood forecasting comes mainly under the FDD, which provides advisories, mainly in text and in tables, covering the current situation and weather plus flood warnings and outlooks. The NDMC provides details on river levels plus inflows/outflows at 5 reservoirs and information that might assist flood forecasts under appropriate circumstances, but the main service is provision of drought alerts. Information on the NAMC site is indirectly related to flooding and drought. Regional information is provided on each of the sites for the regional meteorological centres, while national warnings are carried on a rolling display on the main PMD site. The PMD site includes also a major heading “Alerts/Advisories”, that links to WFC text forecasts in Urdu and English, drought alerts, the TCWC, Farmer Advisories, and Lai Nullah Flood Forecasts. A further link points to a Heat Wave Early Warning Centre for Karachi, that includes also a monsoon alert.

4.6.1 ADHERENCE TO WMO GUIDELINES

Cannot be assessed in this assignment.

[47] https://www.pmd.gov.pk/en/about.php (accessed 23/8/24)

4.7 MULTI-HAZARD EARLY WARNING SYSTEM (MHEWS), INCLUDING TROPICAL CYCLONES, HEAVY RAINS, HEAT WAVES, GLOFS, WFP PROJECT

According to the PMD website[48], the hydro-meteorological services and flood forecasting for which the organisation is responsible cover:

- Early warning of Natural Hazards such as tropical cyclones, heavy rains, heat waves, floods
- Glacier Lakes Outburst Floods (GLOFs) warnings

Early Warning Systems (EWS) are an effective climate adaptation measure to reduce the risk and impact of natural disasters and hazards associated with climate change and extreme weather. The Sendai Framework for Disaster Risk Reduction 2015 – 2030[49] emphasises that the focus for adaptation should be on disaster risk reduction, in contrast to disaster management, where one of the seven goals (Target G) is to:

> *"Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030'.*

The UN Global Early Warning Initiative, 'Early Warnings for All', builds on the Sendai Framework to create the Multi-Hazard Early Warning Systems checklist[50], which is structured around the four components of EWS, as shown in Figure 25**,** applicable to activities from national governments and institutions to community organisations.

[48] https://www.pmd.gov.pk/en/about.php (accessed 23/8/24)

[49] United Nations (2015). Sendai Framework for Disaster Risk Reduction 2015 – 2030 (Online). Available from: https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030 (Accessed 01/12/2022).

[50] World Meteorological Organisation (2018). Multi-hazard Early Warning Systems: A Checklist (Online). Available from: https://library.wmo.int/doc_num.php?explnum_id=4463 (Accessed 01/12/2022).

Figure 25. The four components of EWS, adapted from WMO, 2018

According to WMO[51], the top hazard for both deaths and economic losses is flooding (based on data across 1970-2019 from CRED); other disasters considered that do not feature amongst the major life-threatening and economic issues for the assessed time period include extreme temperatures, wildfires, drought, storms and landslides, although in some cases this situation might alter under climate change. The recurrence of natural disasters in Pakistan led to the formation of a disaster management system, organised as shown on Figure 26. The Pakistan National Disaster Management Authority (NDMA) identified the importance of a multi-hazard EWS to reduce economic losses and loss of lives resulting from natural disasters through the implementation of the National Disaster Management Plan (NDMP), part of which involves the Multi-Hazard Early Warning System Plan (MH-EWS-P)**Error! Bookmark not defined.**. The NDMA, alongside accompanying institutional organisations such as the Pakistan Meteorological Department (PMD), have been lauded in the success of the EWS in the reduction of loss of lives during the 2022

[51] World Meteorological Organisation (2020). State of Climate Services: Risk Information and Early Warning Systems. Available from https://library.wmo.int/idurl/4/57191?offset=4 (Accessed 25/6/24)

flooding disaster events experienced in Pakistan[52]. Ironically, the same report indicates that there is no MHEWS system in Pakistan advised to UNDRR.

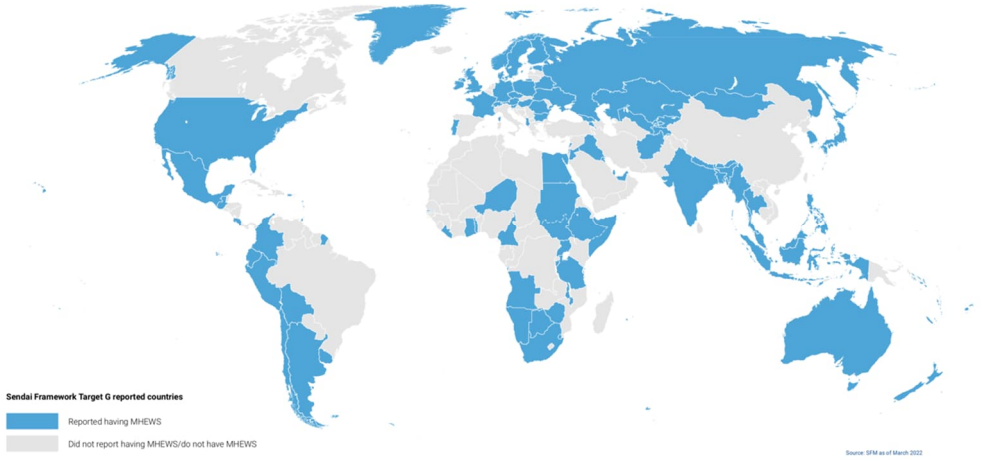


Figure 26. Reported position of MHEWS

The MHEWS link on the PMD site points to a document: Government of Pakistan, Cabinet Division, National Plan: Strengthening National Capacities for Multi Hazard Early Warning and Response System Phase: I (May 2006).

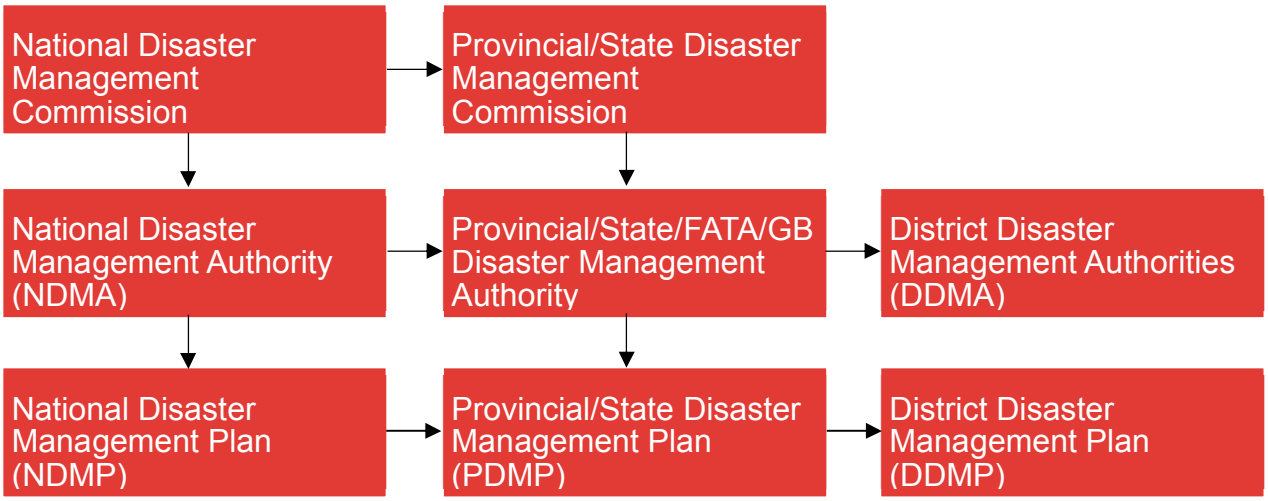


Figure 27 Disaster Management System in Pakistan, adapted from the National Disaster Management Plan[53]

[52] UNDRR and WMO (2022). Global status of multi-hazard early warning systems: Target G, United Nations Office for Disaster Risk Reduction (Online). Available from: https://www.undrr.org/publication/global-status-multi-hazard-early-warning-systems-target-g (Accessed 02/12/2022).

[53] NDMA (2012). National Disaster Management Plan (Online). Available from: https://cms.ndma.gov.pk/storage/app/public/plans/October2020/eUvDKZR0Qa0f2eA966um.pdf. (Accessed 01/12/2022).

The following section describes the current EWS in place in Pakistan with reference to the four key components of EWS to enable disaster risk reduction.

As of June 2024, Pakistan is not involved in CREWS[54] nor is it involved the SOFF[55] to finance observations systems. Not yet assessed for the CHD[56].

4.7.1 OBSERVATIONAL NETWORK INVENTORY

Section 2 describes the role of the Pakistan Meteorological Department (PMD) in the monitoring, observations and data collection of the hazards associated with extreme weather and disasters. The PMD play an important role in the second element of EWS: detection, observation, monitoring, analysis and forecasting of hazards. The NDMP describes their key responsibility to develop a communication strategy for early warnings, centred around the community. The PMD observe the geological and meteorological hazards, analyse the data and are committed to issuing weather forecast data at regular periods to the public, e.g., warnings and advice notes for the agricultural sector to take pre-emptive mitigation measures in light of worsening drought conditions.[57] The PMD must analyse both the short term and long-term trends, for effective dissemination of warnings as part of the EWS.

Despite the increasing capacity of the observational network, gaps remain, particularly in rural or mountainous areas. For example, the rapid melting of glaciers has led to glacial lakes forming in Northern Pakistan, of which several are prone to glacial lake outburst flooding (GLOF) where millions of cubic metres of water are released, alongside debris, triggering flash floods. The Minister for Climate Change warned the PDMA of unprecedented high temperatures in the areas that could trigger GLOF, however, in these mountainous areas the PMD do not have observatories or weather stations to monitor levels or issue warnings. The installation of equipment in these areas is a crucial element of disaster risk reduction, as currently, local knowledge and unstructured dissemination of information is relied

[54] https://crews-initiative.org/

[55] https://un-soff.org/operations/countries/

[56] AHD and WMO, Hydromet Gap Report 2024, Available from https://library.wmo.int/viewer/68926/download?file=Hydromet-Alliance-Gap-Report-2024_en.pdf&type=pdf&navigator=1 (Accessed 26/6/24)

[57] PMD National Drought Monitoring Centre, Islamabad Advisories (Online). Available from: https://ndmc.pmd.gov.pk/new/advisories.php (Accessed: 01/12/2022).

upon in these critical events.[58] In response to this gap in the observational network, GLOF-II is a risk reduction project where the anticipated outcomes include the installation of 50 weather monitoring stations, 408 river discharge sensors, and at least 250 minor engineering structures to reduce the impacts in GLOF events. The data will feed into hydrological modelling. There is a target that 95% of households in these vulnerable areas will receive communications through the EWS to take appropriate action.[59]

Analysis within Muktar (2018) shows that 90% of the budget for the Strategy for National Multi-Hazard Early Warning System has been allocated to the component of EWS associated with forecasting through expansion of the observational network.[60] Although this is beneficial, there remains a lack of synergies between monitoring centres and communication, particularly the improvement of a people-centred EWS.

4.7.2 SOFTWARE AND DATA STRUCTURE

The Pakistan NDMP, launched in 2012, highlighted a lack of existing technological infrastructure to facilitate the sharing of technical information amongst multiple stakeholders within the EWS process.

As part of the NMH-EWS-P, the early warning communication utilises media and the internet. For example, the PMD will issue warnings to government agencies (PDMA and NDMA) whilst updating the PMD webpage and social media. The DDMA communicates at a community level through telephone, social media, word of mouth, and utilising loudspeakers associated with mosques.[61] The use of technology to implement EWS, for example through mobile phones or social media is noted in the IPCC AR6 as increasing the effectiveness of disaster management particularly within urban areas in Asia[62]. However, there is still a proportion of the population,

[58] Bhatti, M. W., (2022). Over 30 GLOF incidents reported in northern Pakistan: officials. The News (Online).

[59] United National Development Programme (UNDP) Pakistan (2021) Project Brief: Scaling-up of Glacial Lake Outburst Flood (GLOF) Risk Reduction in Northern Pakistan (Online). Available from: https://www.undp.org/sites/g/files/zskgke326/files/2022-11/project_brief_-_glof_ii_project_updated_25_jan_2022-mb.docx (Accessed 02/12/2022).

[60] Mukhtar, R (2018). Review of National Multi-Hazard Early Warning System Plan of Pakistan in context with Sendai Framework for Disaster Risk Reduction. (Online). Procedia Engineering 212(2018) pp. 206 – 213.

[61] Mukhtar, R (2018). Review of National Multi-Hazard Early Warning System Plan of Pakistan in context with Sendai Framework for Disaster Risk Reduction. (Online). Procedia Engineering 212(2018) pp. 206 – 213.

[62] IPCC, (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Available from: https://report.ipcc.ch/ar6/wg2/IPCC_AR6_WGII_FullReport.pdf (Accessed 02/12/2022)

especially in rural locations, that do not have access to technology, with little alternatives available to ensure the success of the EWS.

Institution/Organization

A national plan for Strengthening National Capacities for MH-EWS produced by the PMD in 2006 highlighted that there is no *'long-term, inclusive and coherent institutional arrangements to address disaster issues with a long-term vision'*. The success of an EWS is dependent on strong collaboration amongst institutions and governmental departments, requires strong policy, an optimum use of technology, amongst other factors. Since this initial report, the National Disaster Management (NDM) Act (2010) has become the legislative vehicle which established a disaster risk management approach into the three tiers shown on Figure 28Error! Reference source not found., which requires institutional organisation from the National level through Provincial level to District level action. The roles and responsibilities of the various levels of institutions and organisations are detailed in the NDMP.

The IPCC AR6 suggests that there are several institutional challenges associated with the implementation of EWS such as a lack of coordination and community involvement, alongside policy gaps. Alongside the role of the PMD, there are several early warning centres in Pakistan which are set up to deal with specific hazards such as the Tsunami Early Warning Centre, however a lack of effective coordination has been reported between the organisations responsible for forecasting and those issuing the warnings as part of EWS, coupled with a linear connection, the dissemination and communication of early warnings can be ineffective. There is also a lack of formal linkages between the tiers shown in Figure 28Error! Reference source not found..

As part of the GLOF programme, the mitigation was included in the NDM Act and into a Disaster Risk Reduction Plan[63] where existing DRM guidelines were integrated into long-term climate risk planning.

[63] WMO (2020). 2020 State of Climate Services Report – Risk Information and Early Warning Systems (Online). Available from: https://public.wmo.int/en/resources/library/2020-state-of-climate-services-report. (Accessed 01/12/2022 and 25/6/24).

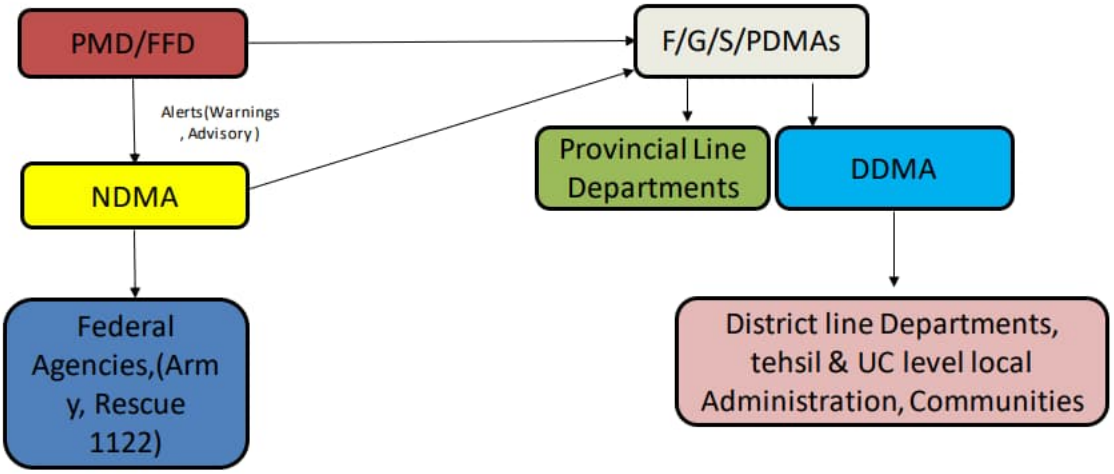


Figure 28. Reported position of MHEWS

4.7.3 HUMAN RESOURCE CAPACITY

Although focus has remained on improving the institutional capacity of implementing EWS, to be effective, they need to be person-centred and involve the community, benefitting from local knowledge and ensuring suitable livelihood protection. The roles and responsibilities of stakeholders involved in the dissemination and communication of early warnings are detailed within the NDMP.

For example, the NDMA annual report (2021) reported effective disaster risk management associated with the Shishper Glacier melting due to high temperatures in May 2021. All stakeholders were given the timely opportunity to implement preparedness measures which included the support of local community.[64] During the 2021 monsoon season, four coordination conferences were held for all relevant stakeholders involved in the disaster risk management associated with monsoon season including hazards such as: GLOF, landslides, urban flooding, cyclones. Nationally, the National Emergency Operation Centre and Army Flood Control Centres were engaged and reporting daily SITREPs and the PMD were continuously monitoring the hydrometeorological conditions, whereas locally, the deployment of machinery was able to quickly clear roads affected by landslides.

Historically, Pakistan has been improving its resource capacity, for example in 2007 the Japan International Cooperation Agency (JICA) helped improve technical

[64] NDMA (2021). Annual Report 2021: Striving for a disaster resilience Pakistan (Online). Available from: https://cms.ndma.gov.pk/storage/app/public/publications/September2022/P1XxBlfytliNoKoYut5h.pdf (Accessed 02/12/2022).

cooperation between institutions and stakeholders through the programme for Project for Strengthening of Flood Risk Management in Lai Nullah Basin.[65] The output of the project was to improve the capacity of PMD to utilise flooding EWS effectively. The project also developed the capacity of the local authorities to promote community awareness and preparedness for flood events and improved other organisational capacity to mitigate damage. They held workshops and trainings for awareness and evacuation drills.

The GLOF-I project (2011 – 2016) saw 1,000 people located in areas vulnerable to GLOF-related risks educated on GLOF preparedness and a number participated in strategies and techniques for risk mitigation, including training Community Based Organisations in the operation of the EWS.

In 2021, the Pakistan Resilience Partnership (PRP) conducted a series of webinars to build technical and operation capacity and also School Safety Preparedness was integrated into the school curriculum. The NDMA has organised consultation sessions at the provincial level around disaster risk reduction and Emergency Preparedness and Response training and the National Institute of Disaster Management held 19 training events for government, academia, media and humanitarian organisations.

The Pakistan Army holds responsibilities to respond to flood risk management by providing emergency relief and rescue services.[66]

4.7.4 ADHERENCE TO WMO GUIDELINES (OTHER?)

Pakistan's labour law mandates adherence to 30 International Labor Organization (ILO) conventions, guaranteeing basic employee rights, including:

- Minimum legal wage (approximately $114 as of July 1, 2022)
- Up to 14 calendar days of annual vacation leave
- Variable maternity leave (ranging from 180 to 90 days)
- Capped working hours (six hours per day during Ramadan)

[65] PMD Project for Strengthening Flood Risk Management in the Lai Nullah Basin. Available from: https://ffws.pmd.gov.pk/index.html. (Accessed: 01/12/2022).

[66] Dr Chaudhry, Q. (2006) National Plan: Strengthening National Capacities for Multi Hazard Early Warning Systems. Phase: 1 (Online). Available from: http://www.pmd.gov.pk/Establishment%20of%20Early%20Warning%20System.pdf (Accessed 01/12/2022).

In addition to the services noted above, mention should also be made of the Third Pole Regional Climate Centre Network (TPRCC), under WMO with partners GCW, TPE, ICIMOD, GEWEX, MRI and ESCAP. This is a relatively new (since 2018) project focussed on providing an equivalent to the WMO Regional Climate Centres for the so-called third pole, the high mountain area of the Himalayas and the Nepal Plateau. Products under TPRCC do not cover specifically the lowland area of Pakistan as such but the graphics provided do include the vast majority of the country.

From the main page[67], various products of relevance here are provided graphically for temperatures and rainfall with selection of monthly, seasonal or annual climate monitoring plus monthly or seasonal numerical forecasts. The source of these forecasts, all deterministic, does not appear to be stated on the site (the page on verification is under construction as of 9/9/24). Additionally, there is a page on glacier mass balances, but no glaciers in Pakistan are included.

Of more immediate concern, the TPRCC is split into three nodes, Northern Southern and Western. The PMD leads the Western node, which includes China, Afghanistan, Tajikistan and Uzbekistan[68] (links are provided to the home pages of each national service). Several links are provided from the node page to PMD pages (as of 9/9/24):

- Weather forecast – goes to the RDD seasonal forecast page
- Seasonal forecast – goes to the RDD experimental forecast page
- Glacier monitoring – goes to a blank page
- Monthly outlook – goes to the NWFC outlook page (last updated in 2019)
- GLOF monitoring – goes to the RDD home page (from which the same blank page can be accessed as noted above)
- Seismic monitoring – goes to the National Seismic Monitoring Centre in Islamabad's page, but not relevant here.

[67] http://www.rccra2.org/tp-rcc/

[68] https://ffd.pmd.gov.pk/cp/tprcc-network/tprccn-new.html

5 INSTITUTIONAL STRUCTURE, HUMAN CAPACITY AND RESEARCH TO PROVIDE SERVICES

5.1 INSTITUTIONAL STRUCTURE OF SERVICES

The WMO 2023 State of Climate Services – Health (Accessed 23 June 2024) indicates:

- In relative terms, Pakistan human vulnerability to climate change is “high” (5-point scale very low to very high);
- Emissions are low in terms of fair share; climate change will increase attributable mortality from diarrhea, malaria, heat and undernutrition;
- Health engagement score in NDCs: 2 - Specific health impacts, adaptation needs, or co-benefits, such as concerning diseases or heat-related illness;
- Overview of generalised climate services capacities (not sector specific) - “essential”; and
- WMO Member weather services capacities calculated as a percentage of functions satisfied of NMHSs providing data, categorized as “less than basic (0‑33%), “basic/essential” (34‑66%) and “full/advanced” categories (67‑100%) of functions satisfied, respectively (not sector specific) ‑ “less than basic.”

Pakistan did not participate in the 2021 WHO Health and Climate Change Survey.

There is no specific mention of health on the PMD site (accessed July 2024).

The WMO 2022 State of Climate Services – Energy” (accessed 23 June 2024) provides the following:

- According to RISE (World Bank’s Regulatory Indicators for Sustainable Energy) in June 2022, Pakistan classified as weak; and
- Nine maps with Pakistan potential of energy generation by solar, wind and hydro.

There is no specific mention of energy on the PMD site (accessed July 2024).

The “WMO 2021 State of Climate Services – Water” (accessed 23 June 2024) provides a map suggesting 2002-2021 major loss of terrestrial water storage in much of Pakistan and a map includes Pakistan in a “Global Water Stress Hotspot” as shown in Figure 29.

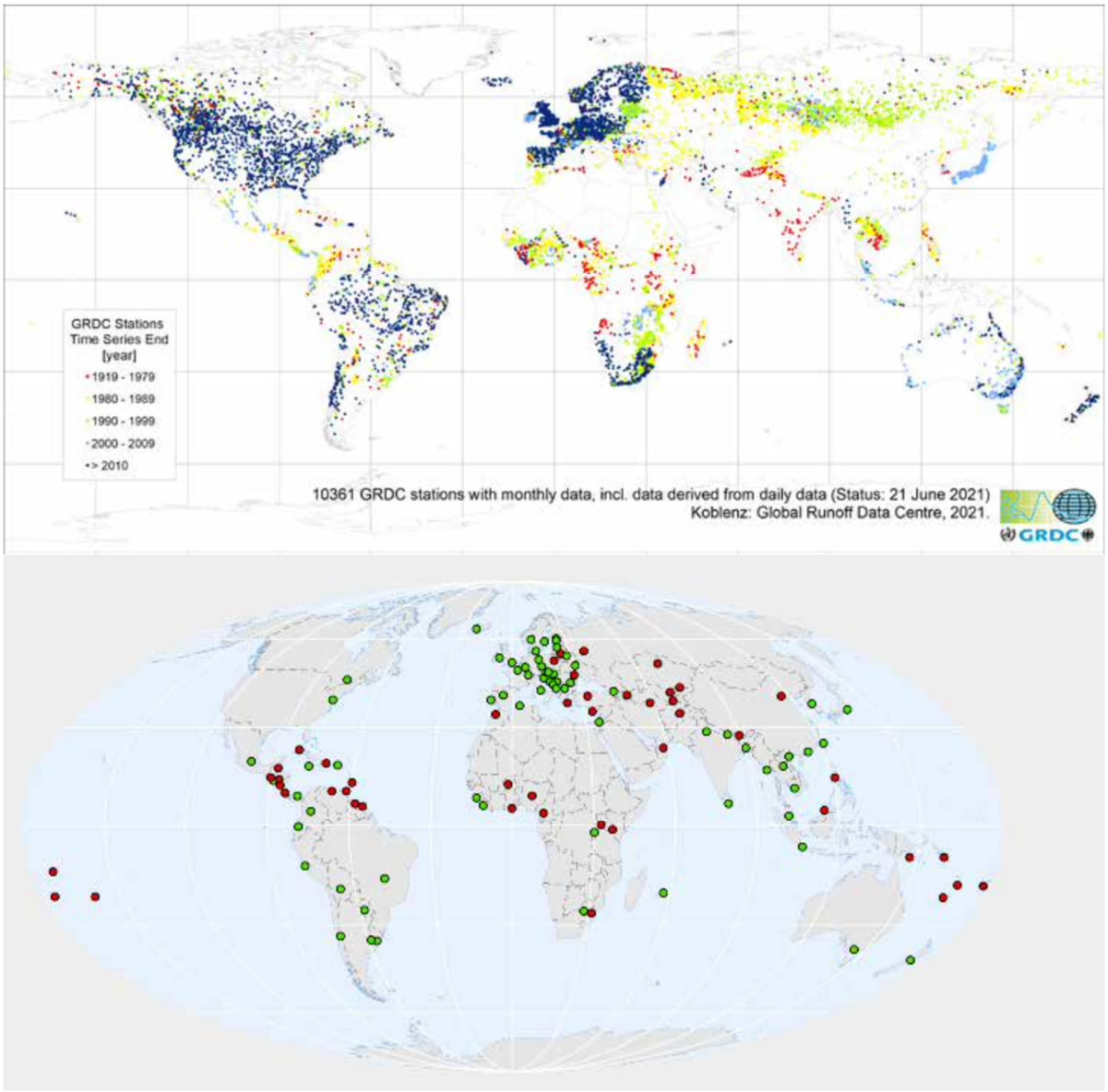


Figure 29. Reported position of MHEWS Area of Pakistan last reported in 1979 (top): Bottom: Organizations/institutions providing links to data (green) and organizations/institutions collecting data without providing links (red). The most recent report from Pakistan to the GRDC was no more recent than 1979 (top which illustrates the monthly hydrological runoff data delivered to the WMO Global Runoff Data Centre status as of February 2021; the map shows the stations that last reported in 2020 (blue), in 2009 (light blue), in 1999 (green), in 1989 (yellow), and in 1979 (red). In the bottom diagram: organisations/institutions providing links to data (green) and organizations/institutions collecting data without providing links (red); according to this there are no external links to Pakistan data.

The PMD site has the following hydro-related services:

- Hydro-Meteorological Services and flood forecasting.
- Agro-meteorological services
- Climatological Services
- Weather forecasting Services to public through electronic and print news media
- Early Warning of natural hazards such as Tropical Cyclones, Heavy Rains, Heat Waves, Flood & Earthquakes etc
- Glacier Monitoring and Research
- Glacier Lakes Outburst Flood (GLOF) warnings

“WMO 2020 State of Climate Services – Risk Information and Early Warning Systems” includes:

- Top Pakistan hazards for both deaths and economic losses – floods

PMD site has the following MHEWS services:

- Glacier Lakes Outburst Flood (GLOF) warnings
- Disaster Watch page
- Drought alerts
- Tsunami Early Warnings
- Flood alerts/warnings
- Tropical cyclone warnings

“WMO 2019 State of Climate Services – Agriculture and Food Security” includes:

- Nothing directly relevant to Pakistan

5.1.1 ADHERENCE TO WMO GUIDELINES

Cannot be assessed in this assignment.

5.2 HUMAN CAPACITY TO PROVIDE SERVICES

Cannot be assessed in this assignment.

5.2.1 ADHERENCE TO WMO GUIDELINES

Cannot be assessed in this assignment.

5.3 TRAINING PROTOCOLS AND PROCESSES

Cannot be assessed in this assignment.

5.3.1 ADHERENCE TO WMO GUIDELINES

Cannot be assessed in this assignment.

5.4 RESEARCH SUPPORTING SERVICES

As far as PMD is concerned, the main research arm is the RDD as discussed previously, with stated areas as:

- Seasonal Prediction
- Climate Change & Modelling
- Crop Modelling & Pollen Monitoring
- Numerical Modelling
- Glacier Monitoring and Snow Research.

The latest publication listed on the site is in 2016, so the current level of activity in the division is not clear. Products displayed on the RDD site have been discussed above. It is reasonable to conclude that some research is conducted in other divisions of PMD, not least in the development of services, but there are limited specifics supplied on any of the sites.

In a separate but parallel project for Pakistan the consultants have undertaken a partial examination of research for the country, with sole focus on climate change. Numerous peer-reviewed papers and grey literature documents have been obtained, but if it is assumed that these are representative then most have been produced by university researchers, often based outside Pakistan. Some of these papers include Pakistan-based experts, while some do not; as far as can be assessed, none of the authors are from PMD. As noted above, the RDD has provided some downscaled projected fields for open use, with a request to mention the source in any study but does not provide details of any in-house nor external research using these.

Separately from PMD and SUPARCO (there appear to be no cross-links between the web sites), and acting as a national entity now established in law, is the

Islamabad-based Global Climate Change Impacts Studies Centre (GCISC)[69], with the following mandate:

> *Global Climate-Change Impact Studies Centre is a dedicated research institute for climate change studies in Pakistan. The Centre is mandated for national level R&D effort, capacity building, policy analysis, information dissemination and assistance to national planners and policymakers on issues related to past and projected future climatic changes in the country, their likely impacts on the key socio-economic sectors of the country such as water, food, agriculture, energy, forestry, health, and ecology, and appropriate adaptation and mitigation measures.*

There are three main areas (and sub-areas) of research:

- Physical Science Basis
    - Climatology
    - Future climate projections
    - Climate projections for the Hindu Kush Himalayan region
    - Monsoon variability and predictability
    - Climatic extremes and heatwaves
- Impacts, adaptation and vulnerability
    - Water
    - Future hydrological projections
    - Glaciology
    - Agriculture
    - Food security
    - Health
    - Forestry
- Mitigation and climate change policy
    - Climate change policy

[69] https://www.gcisc.org.pk/index.php

- Framework for the implementation of climate change policy
- Taskforce on climate change
- NDCs
- National Communications
- Energy systems

The responsibilities for mitigation and climate change policy are not pertinent to this report but do appear to be parallel to responsibilities of the GoP Ministry and Climate Change; the consultants have not examined this further. For the other two areas of responsibility, there appear to be overlaps with PMD and/or SUPARCO but no information regarding collaborations has been located.

The GCISC is active at the present time, but the current status of activity is difficult to define as it appears the website has not been updated recently; the latest “Major Contribution and Recognition” listed is for 2014 while the latest listed international publication is in 2020, and national publication is in 2017; for in-house research reports it is 2016. International publications have been co-authored frequently with university researchers, both national and international. The links to individual research areas provide brief overviews of the area plus, in some cases, lists of relevant publications; three of these links did not work. A number of international projects are referenced, the latest dated 2023.

There is no doubt that the GCISC has produced a valuable body of work, including in assessing climate change projections and linking these to national policies. It is a research centre and thus is not expected to provide direct services. Research results are clearly of relevance to PMD, to SUPARCO and to the Ministry of Climate Change, as well as to other GoP ministries, but the consultants are not aware of how any such links are organised with a dearth of on-line information and within that context, there is the possibility of duplication.

6 SERVICE PROVISION IN TERMS OF DEVELOPMENT PLANNING

6.1 REVIEW OF RELEVANT SERVICES, SDGS AND NATIONAL PROGRESS

As part of the project to which the current report is a contribution, the Walker Institute at the University of Reading, England, has produced a document entitled “Pakistan Climate Change Impact Storylines Based on Existing Vulnerability Literature” from which several of the following diagrams are reproduced.

According to Figure 30, indicating the enabling environment as determined by the Walker Institute, the PMD links only to the provincial meteorological departments which in turn link only to the PDMAs. In this diagram, there is no direct link to the NDMA or to any of the other government departments, including disaster management and climate change. It is effectively certain that these links exist, but this web search has not provided any details. Brief visits to the Ministries of Agriculture (National Food Security and Research) and of Water Resources revealed no onward or internal use/production of meteorological/hydrological information/warnings.

As far as the general population of Pakistan is concerned, it appears that the main medium of information provision is through the media, television, radio and newspapers – no evidence for direct services using electronic media such as mobile telephones has been found. The authors are not in a position to judge how successful these media channels are. Other services are provided through the website, often without interpretation, typically requiring expert understanding, and on occasion leading to blank or out-of-date pages. In addition, there appear to be parallel services provided by PMD and by SUPARCO, with only one difficult-to-find link from PMD to SUPARCO and none in the other direction; note that there is no interpretation of the products on the SUPARCO site. Research overlaps may be present between PMD, SUPARCO and GCISC. The consultants assume that decision-makers at all levels within Pakistan are aware of these services and are capable of using them, but no evidence for such has been determined.

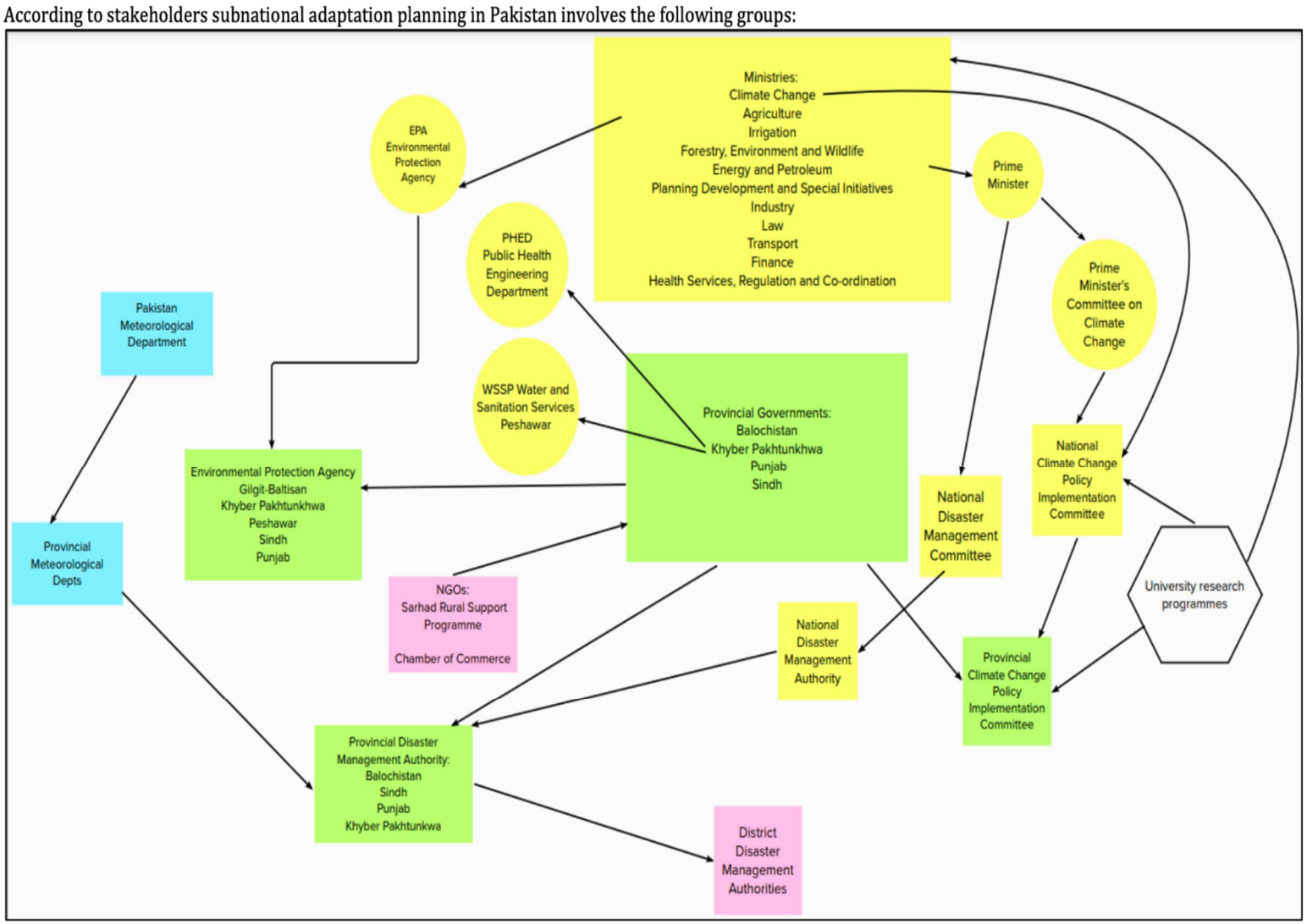


Figure 30. Key stakeholders in the enabling environment

The Walker Institute report provides further details of the enabling environments for five activity areas within six specifics of which only “Data and Technology” and “Science” are considered in the following. The lists below summarise outcomes of the review of services given above within each of these areas/specifics; only activities relevant to this report are listed.

6.1.1 AGRICULTURE AND LAND USE

DATA AND TECHNOLOGY

- Digital simulations to model climate impacts on agriculture
    - There is nothing in this area under PMD, but SUPARCO lists “drought and crop yield monitoring and forecasting” amongst its responsibilities although no details are provided on the web site; the Ministry of National Food Security and Research may run relevant work, as may the Agricultural Research Council. GCISC has projects according to the website looking at climate change impacts on agricultural productivity, land degradation, insect infestation, food security, supply of water for irrigation, livestock, the nexus of water, food and energy security, and on related emissions.
- Publicly available data on long-term climate projections
    - The RDD site offers access to a few climate change projections, requesting any research acknowledge the source, but provides no information otherwise nor are any details available elsewhere on the PMD site; additional work might be underway in the Ministry of Climate Change, but the site was deemed unsafe by the browser and so was not visited. Projection results obtained by GCISC appear to be available only through publications.

SCIENCE

- Identify resilient crops for local weather and soils
    - There is copious information on the climate of Pakistan and on observed weather across several PMD sites, not least the NAMC site, but determining resilient crops does not fall under the remit of PMD. GCISC works in this area also.
- Climate change assessment on farming practices
    - This is an area often taken by universities (it is likely not considered by PMD), but it might be worth noting that the latest IPCC AR6, in Chapter

5 of WGII which handles this area, does not reference any research from Pakistan. GCISC works in this area also.

- Research into the seafood sector under climate change
    - There are marine services under PMD and SUPARCO, but no pertinent information has been found.
- Research into climate impacts on local flora and fauna
    - No pertinent information has been found but there is ample observational information available from PMD.

6.1.2 Water Resources

DATA AND TECHNOLOGY

- River flow rate monitoring to warn of floods and droughts
    - Monitoring does take place at about 30 locations according to the FFD site, with warns of floods provided by FFD and of droughts by the NDMC; services are provided also by SUPARCO. It appears that the media are the main channel for warnings to the general public. Research at GCISC includes climate change impacts on high elevations, river flows and groundwater (see next bullet).
- Regularly updated data base of soil moisture
    - While in a separate project for Pakistan, the consultants have been advised that an archive of soil moisture measurements does exist. However, none appears on any of the GTN-H-related web pages.
- Better GLOF statistics
    - The SUPARCO GLOF DisasterWatch page does include a number of red dots in northern Pakistan that *presumably* (there is no legend) mark glacial lakes that possibly might produce GLOFs. However, there are no statistics provided; all of the relevant PMD site pages are blank. It is possible there might be additional information held by the Ministry of Climate Change and/or by the Ministry of Water Resources. No monitoring of GLOFs in Pakistan is recorded on any of the GTN-G-related web pages.

SCIENCE

- Predicting streamflow from weather indices

- The river flow monitoring by FDD plus the extensive weather statistics available should facilitate this activity, but the authors are not aware of activity in this area.

- Quantification of glacier/snow-melt run-off effect
  - As noted above, both PMD and SUPARCO have responsibilities in this area, but the authors are not aware of any relevant activities; also a GCISC activity.

6.1.3 HEALTH

DATA AND TECHNOLOGY

- Better records on climate-sensitive diseases
  - The authors cannot comment on the disease aspects but note that plentiful weather and climate information is available for this activity.
- Heatwave/coldwave EWS
  - These services are provided by PMD with information supplied through the media; the authors are not in a position to judge the effectiveness of these services.
- Disease outbreak EWS
  - The authors are not aware of any service based on weather/climate.

SCIENCE

- Research into the effect of climate migration on health
  - The authors are not able to comment on this issue.
- Assessment of the impact of climate change on water borne, vector borne and nutritional diseases
  - The background observations required for this work from the weather/climate side exist.
  - The GCISC site indicates research responsibilities in health, but no details are provided.

6.1.4 DISASTER PREPAREDNESS

DATA AND TECHNOLOGY

- Localised risk mapping integrating local threats to livelihoods

    - This area covers fluvial and coastal flooding, droughts, GLOFs, heatwaves, landsides, etc.; substantial data are available from PMD and from SUPARCO but the consultants cannot judge whether this is sufficient for the localised risk mapping suggested.

- Hydrometeorological stations in the north
    - The limitations of the current network across the country, including the north, were provided above from the point-of-view of international data reception and access; the consultants are aware of intention to improve the network and information delivery but have not been able to determine any details.
- Clarification of EWS cascades for alerts
    - As far as can be determined, all alerts covered in this document are for individual events and do not cover cascades, although there might be work elsewhere dealing with cascades in terms of health, infrastructure, etc.
- Monitoring of risk and vulnerability
    - Without assessment of the impacts of climate change, it is not possible to estimate any changes in risks this might impose; possible related changes in vulnerability might also occur.
- Improved rainwater monitoring
    - As above, there are projects in process to improve the observational network, but no details have been obtained.
- Loss and damage database
    - Presumably, this refers to the loss and damage discussions under the UNFCCC; it is not known to the authors if a national database exists, but details are available where recorded on the EM-DAT site[70].

[70] https://www.emdat.be/

SCIENCE

- This area refers to drought and flood zone mapping and to compound disasters, disaster planning, reducing levels of glacial lakes to prevent/ mitigate GLOFs, environmental assessments.
    - The main responsibilities of PMD and SUPARCO in this area are in the provision of information, and in many cases, it appears that sufficient data may exist, although this may not be the case for GLOFs, for example.

6.1.5 CLIMATE CHANGE PREPAREDNESS

DATA AND TECHNOLOGY

- Improvements to flood, heatwave and drought EWSs
    - The position with EWS has been provided above; one evident improvement for which the consultants have not seen any evidence is in the broadcasting of the information, both to expedite receipt and enhance reach.
- Better management of weather station data feeds
    - One issue facing development projects is that not all data are reaching the international community within the required timescales, and no details have been obtained about these projects; it is likely that additional data are available that do not reach the international community, but the consultants have not been able to determine the extent and the archiving of these.
- Improve access to high-resolution satellite data
    - This area appears to be mainly, if not completely, in the purview of SUPARCO, with information presented graphically without explanation on the web site. It is assumed that SUPARCO provide feeds with greater detail to interested bodies but no information on this has been located by the authors.
- More data to justify policy implementation
    - This is a very wide field indeed and requires more consideration than possible in this report.
- Better monitoring of GLOFs and snowmelt
    - The blank relevant pages on the PMD website and the lack of representation of Pakistan within GTN-G at this stage are issues

of concern that suggest improvements in this area can, and perhaps should, be made.

- Better availability of stored data
    - From a meteorological perspective, data access from PMD is governed by WMO resolutions 40, 25 and 60 as discussed earlier; all three resolutions permit national flexibility in their interpretation, but it is not known to the authors any details of policies within Pakistan.

SCIENCE

- Coordination between institutions/collaboration
    - The authors are not able fully to comment on this from this assignment, but the impression has been gained that more collaboration might be beneficial, such as between PMD and SUPARCO.
- More GCM-based studies of Pakistan
    - The authors are aware of a body of research published in the reviewed literature and in reports, but it appears that much of this has not been published in recent years. Whether this is correct cannot be determined, but it is noted that the RDD page lists papers only up to 2016 (although this might be because of lack of webpage maintenance); a few sets of downscaled projected fields are available for use from the RDD site but no evidence has been found of their use; from the technical perspective these are limited as they do not utilise the full information available to the IPCC, although further discussion on this point is beyond the bounds of this report. The header in the Walker Institute report also mentions the inclusion of uncertainty, a vital aspect for which no evidence of consideration has been found for climate change studies, nor indeed for forecasts and outlooks at shorter time scales.
- GCISC research inputs into several of the above areas, not least GCM studies

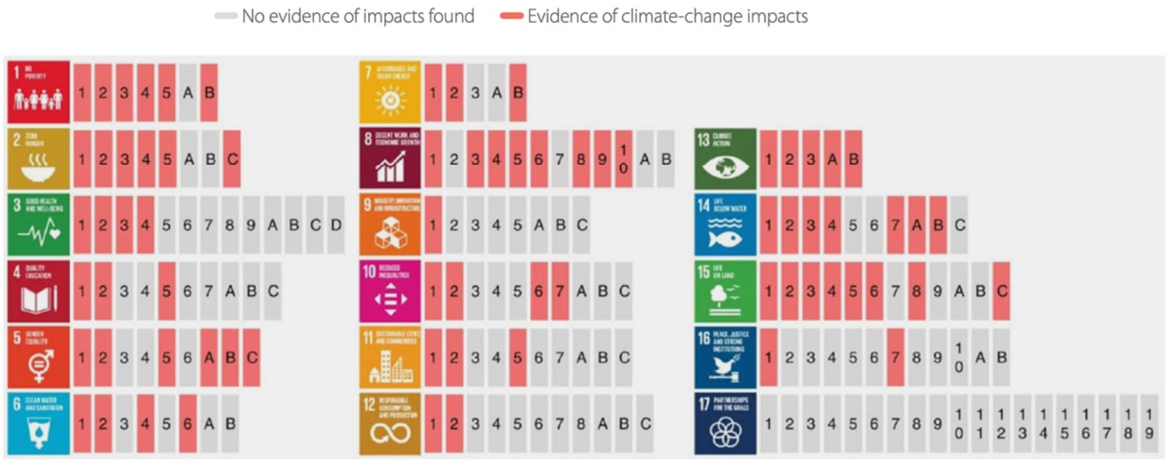
6.2 ASSESSMENT OF SERVICES IN TERMS OF SDG TARGETS

6.2.1 SUSTAINABLE DEVELOPMENT REPORT (SDG)

According to the SDG dashboard[71], Pakistan has improved its standing in terms of its overall score across all Goals, from 51.46% in 2000 to 57.02% in 2024, but it nonetheless stands in the 137th position out of 166 countries. The only Goal for which the country has been determined as having been achieved is Goal 13, Climate Action, but progress on this has stagnated. Major challenges remain for 12 of the 17 Goals.

Reproduced below is “Figure 4” from the recent UN-SDG report[72] on the synergies between climate change and the SDGs.

FIGURE 4. Impacts of climate change on the achievement of the SDGs. Each rectangle to the right of the relevant SDG represents a Target. Targets highlighted in red denote the presence of published evidence of impacts. The absence of highlighting indicates the absence of identified evidence, although it does not necessarily mean the absence of an impact.



Source: Fuso Nerini *et al.*, 2019.

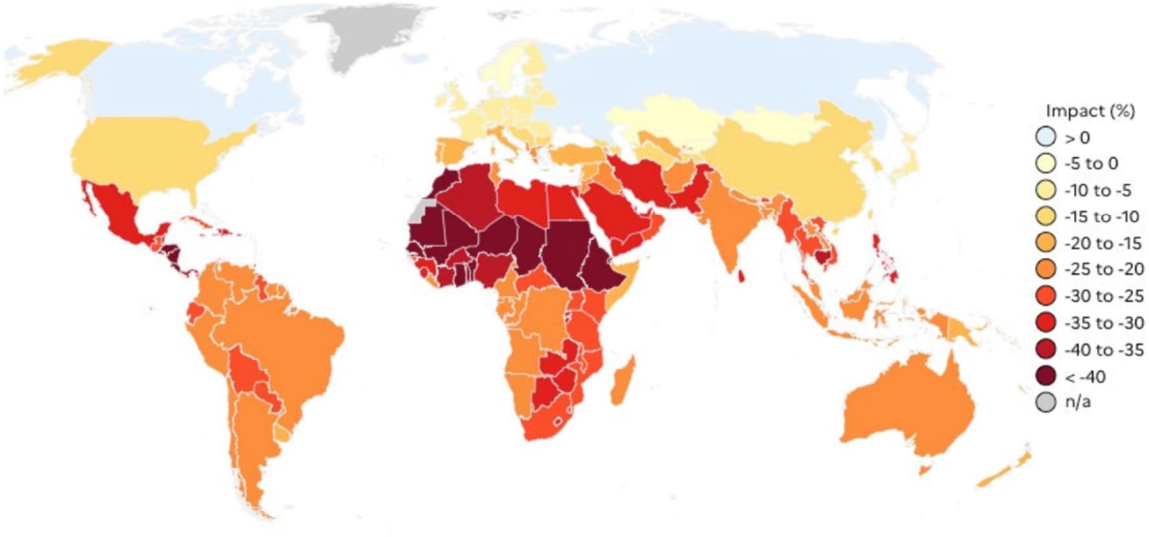
Each of the 17 SDGs are listed alongside the target indicators (that vary in number by Goal) used for assessment of progress, with red shading indicating evidence that that target is impacted by climate and/or climate change. Naturally, all five indicators for Goal 13 – Climate Action – are shaded red, but otherwise climate impacts every

[71] https://dashboards.sdgindex.org/rankings

[72] https://sdgs.un.org/sites/default/files/2024-08/UN%20Synergy%20Solutions%20for%20Climate%20and%20SDG%20Action-4_0.pdf

Goal to greater or lesser extents other than Goal 17 (Partnerships for the Goals). An example is provided in the reproduced "Figure 5" from the same report that illustrates the impact of climate change on agricultural productivity from 1961 to 2015; for Pakistan, that impact has been for a reduction in productivity in excess of 30%. [Note that a national overview of progress on the SDGs was published in 2021].

FIGURE 5. Observed regional effects of climate change on agricultural productivity across the world (1961–2015)



In the Task 3 report is the statement "*Agriculture is highly dependent on atmospheric conditions and as Pakistan's climate changes, it is likely that productivity will be reduced, bringing food shortages and additional suffering to many, but particularly to those already enduring poverty, malnutrition and loss of livelihood*", suggesting that the observed reduction in productivity over several decades is likely to continue with climate change.

At the time of preparation of this report the 5th UN Conference on Climate and SDG Synergies has closed (September 2024) in Rio de Janeiro. In the IISD report[73] on the conference, the co-chairs summarised that:

- Evidence indicates that pursuing the goals of the Paris Agreement in conjunction with the SDGs will lead to greater co-benefits than trade-offs;
- Unlocking barriers to synergistic solutions should be a primary focus; and

[73] https://enb.iisd.org/global-climate-sdg-synergy-conference-5-summary?utm_medium=email&utm_campaign=ENB%20Update%20-%2010%20September%202024&utm_content=ENB%20Update%20-%2010%20September%202024+CID_bffccc1bd28ac7e89c508f29ce071f56&utm_source=cm&utm_term=Read%20the%20summary

- Adaptation and mitigation should be driven by inclusive processes by taking into account the most vulnerable.

Disasters are a further area linked to climate and climate change, as summarised in the 2023 publication from the UNDRR "Closing Climate and Disaster Data Gaps: New challenges, new thing"[74]. The main conclusions from this report [75] include:

- A fundamental, long-term goal of the data community should be to collect comprehensive, standardized and peer reviewed and/or validated data from as near as possible to the time and place of climate-related disasters.
- Together with innovative methods to capture the impacts of smaller-scale events, disaggregated local records are also needed to contribute to a more comprehensive picture of localized events that can cumulatively cause greater losses and damages to affected communities than single catastrophic events.
- Data managers should review historical disaster impact records for missing data. When gaps are found, these should be flagged to data users so that account can be taken of potential bias within these data sets. Where reviews identify and diagnose patterns of missing data, advanced statistical methods should be used to address these gaps if possible. All analyses based on historical data sets should take account of data gaps and make clear to recipients how missing data was considered.
- Collectively, as data generators, processors and users, we need to increase our understanding of the cyclical nature of data, information and action. To do so, we need to know what data we have; what data we need; the ecosystems in which these data exist; the analytical processes needed to transform data into information; and the information decision makers need to take meaningful action.

PMD, SUPARCO and GCISC are three of the information providers that facilitate achievement of the SDGs and of the Sendai Framework, alongside other government departments and institutes not reviewed in detail in this report, including the Ministry of Climate Change whose web site has not been visited as it was flagged as unsafe. The authors are unable, therefore, to take an overarching view of the collection and provision of data for these two objectives, SGDs and Sendai, and of their use in achieving these objectives. Nevertheless, the impression, clearly subject to correction, has been gained (partly through working on a second unrelated

[74] https://www.undrr.org/media/91937/download

[75] https://undrr.org

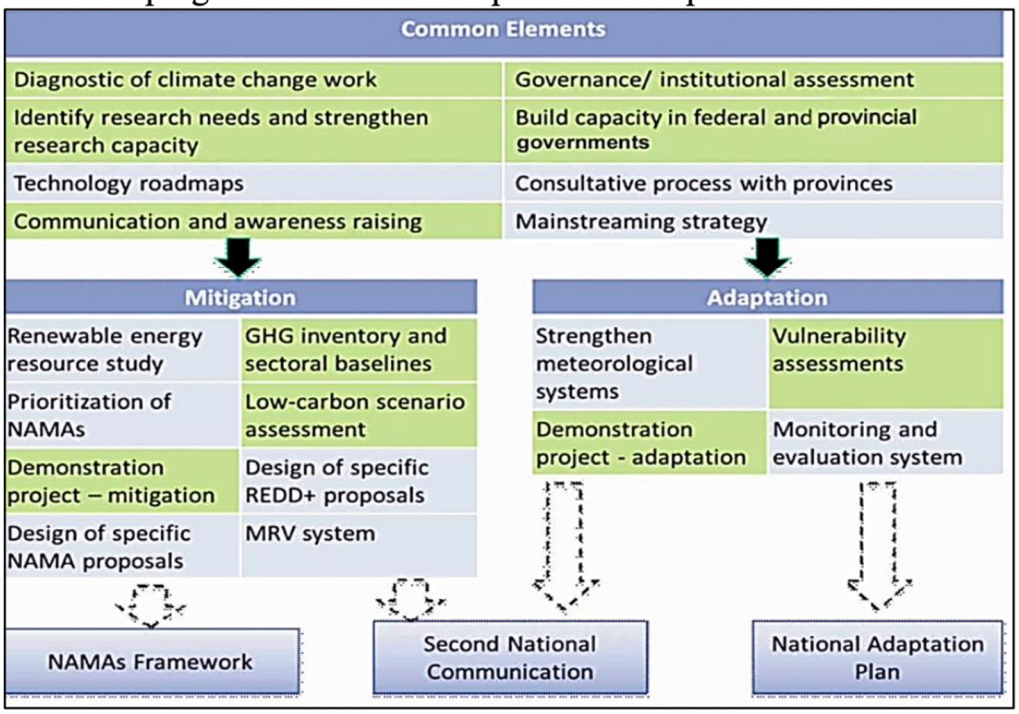
project in Pakistan) that much of the research related to climate change has been undertaken in universities, and in particular in universities outside Pakistan but often in collaboration with some in Pakistan. The extent to which this university-generated knowledge on national climate change and its impacts has been considered by the government is unknown to the consultants. Within the climate change literature, much is based on older projection techniques and certainly takes only limited cognisance of the uncertainties involved. Overall, it seems reasonable to state that more detailed attention needs to be given to understanding and developing the role of the weather and climate sciences in their integration into progress towards the SDGs and the Sendai Framework.

7 GAPS AND BARRIERS – AN OVERALL ASSESSMENT

Within the limited time available to produce this survey, and given the constraints imposed by a fully web-based investigation without direct contact with experts in Pakistan, it is clear that Pakistan has advanced resources in the areas covered and that there are plans to upgrade these resources. That stated, there appear to be a number of gaps in the systems and areas to which attention might be offered; this statement is made with the critical caveat that many of the issues outlined below are the perceptions of the authors that could be clarified through direct discussion.

The diagram below is a reproduction of Figure 1.2 from the 2016 Technology Needs Assessment for Climate Change Adaptation[76].

Figure 1.2: Work program for climate compatible development in Pakistan



GHG = greenhouse gas, MRV = monitoring, reporting and verification, NAMA =national appropriate mitigation actions, REDD = Reducing Emissions from Deforestation and Forest Degradation

Note: Priority actions in green.

Source: Government of Pakistan, Ministry of Climate Change. 2014.

[76] https://tech-action.unepccc.org/country/pakistan/

Much of the work identified in the diagram is not relevant to the current report, but the one that stands out is “Strengthen meteorological systems”, with a lead to the Second National Communication to the UNFCCC (NC2). NC2 itself was dated 2018 (the most recent completed) and much of the content of the relevant chapter (6 – Research and Systematic Observations) has been covered in this report, with minimal additional information supplied. There is a list however of organisations involved in climate-related research:

- Global Change Impact Studies Centre
- Pakistan Meteorological Department (PMD)
- Pakistan Council for Research in Water Resources
- Space and Upper Atmosphere Research Commission
- Pakistan Agricultural Research Council
- Ministry of Climate Change
- Ministry of Science and Technology
- Ministry of Food Security and Research
- Ministry of Water Resources
- Ministry of Energy
- Ministry of Defence
- Ministry of National Health Services, Regulation and Coordination

The work of many of the above have not been considered in this report and it might address some of the gaps discussed below.

Regarding observations, it is recommended to upgrade the current system and acknowledge the need for improvements. These improvements should address the number of sites, the quality of the observations produced, and potentially the archiving and quality control facilities. However, the international transmission of the data is certainly a priority. Southern Asia is an area with relatively limited observational data available, and data from Pakistan is important for all forms of weather/climate services/research in the region and globally. From the meteorological perspective, the lack of data provided internationally by the upper-air network is critical, although it is known that steps are being taken to address this. From the climate perspective, there appear to be a number of issues beyond those of the atmospheric observations, perhaps the most important being monitoring of glaciers. A number of organisations appear to share responsibilities for aspects of glacier monitoring, but few details of observations or of results have been located.

In the area of services provision, there are a number of details that the consultants have been unable to adequately clarify. It appears that the main channels for information to the general public are through the media, television, radio, and newspapers. This includes alerts, some of which are of necessity provided with only short notice, and in that regard, it is unclear whether these channels are adequate. It is possible that the NDMA and RDMAs might have improved facilities for broadcasting alerts.

It is in the broader sense of providing services to specific bodies that the consultants have been able to obtain relatively few details. Many of the services on the PMD and SUPARCO websites, such as for agriculture or water resources, appear to be provided through webpages that some might be unable to access or interpret. There may, of course, be supplementary services that assist in this regard; for example, extension services might take the information from PMD and convert it into a form accessible to farmers. It could be helpful to undertake a review of service provision in all respects to examine any gaps in greater detail and to indicate possible improvements.

The service production processes have not been fully clarified by the authors. For short-range weather forecasting, the responsibilities lie fully under PMD. There is no mention on the PMD site of an operational centre with responsibility for running the prediction models, but rather the task appears to be undertaken by two divisions, SMRFC and RDD, that give priority to research rather than to operations. Both sites list models that are being, or have been, used, all developed elsewhere, but the lists are inconsistent to an extent and in some cases appear to be out of date. A similar situation appears to be present in climate change projection research and use, with several centres undertaking work but with limited clarity on collaboration and on the onward use of their results.

Currently, it is easy to obtain time-critical global weather forecasts through the WMO telecommunications systems or just directly through web pages of the producers, and this approach appears to have been taken in Pakistan, but many developing nation NMHSs, in the experience of the authors, have visions of producing forecasts locally. Similarly, there is often the desire to develop climate change projections locally despite ready access online to large projection sets from many models. It is plausible these visions exist in Pakistan, and certainly in the case of producing downscaled projections, and perhaps forecasts, this has been achieved already.

Weather in the sub-tropical zone, in which Pakistan sits, is more difficult for models to simulate than weather in the mid-latitudes, for technical reasons beyond the scope of this report. This is just one of the reasons why the use of ensembles and the presentation of forecasts/projections in a probabilistic manner is preferable over deterministic presentations. All service provision seen from PMD is deterministic,

although there is mention of the use, perhaps research only, of GEPS. Admittedly, even in an advanced service such as the UK, the issue of presentation of probabilistic information to the general user has only been partly resolved, the main uses being retained for specialised services. For all forecasts in Pakistan, the use of ensembles is recommended strongly, not least for days 3 on but also earlier.

The most straightforward way in which services such as PMD can generate their own forecast/projection information is through the use of high-resolution regional models that take the necessary boundary conditions supplied from global models run at the major houses. There are indications that this approach has been taken in Pakistan for both weather forecasts and certainly for climate projections. The issue in this regard lies with the number of forecast/projections produced, the larger the number the more useful the details provided in both a probabilistic and a deterministic sense. In an ideal world, a number of global models would feed a number of regional models.

For weather forecasts, it appears the approach has been taken with only one or two models, with the exception of GEPS. Whether this is adequate for the short-range services provided cannot be assessed in this report, not least as no verification results have been obtained other than those from the WDQMS. The significant errors in observational data at some locations revealed by WDQMS require urgent attention.

Equally important is the approach to developing climate change projections, which has been undertaken by at least PMD and GCISC. Frequently, modelling houses have offered their regional models to developing nations to produce downscaled projections. This, undoubtedly, is an important step for capacity building, but it has the side disadvantage of wedding the developing nation to perhaps a single global model and a single regional model, with the risk of misleading projections being produced used later to guide national policies. There is no longer the necessity for doing this given the ready access to databases of both global and regional models, although the opportunity exists for developing nations such as Pakistan to contribute to the latter. No evidence has been located that any organisation in Pakistan has used these international model data bases except in limited form in the NC2. In the NC2, the projections presented are largely deterministic although there are tabulated temperature and rainfall change values from a number of models that provide some probabilistic oversight (values listed to an unrealistic 2 decimal places); no substantive interpretation in a probabilistic sense is provided.

The conclusions achievable in this report regarding the use of the climate information in tackling the SDGs and in achieving the Sendai Framework (amongst other international objectives) are limited through lack of accessible information. The latest Disaster Gaps Report (Sendai) makes no specific mention of any progress in

Pakistan, and while limited progress towards the SDGs has been made, the overall position in Pakistan remains unsatisfactory (137th out of 166 nations). Both the SDGs and the Sendai Framework have numerous drivers other than climate and the consultants have no process at present to disaggregate these, but it might help to examine all climate work in Pakistan through critical lenses focussed on the SDGs and the Sendai Framework.

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APPENDIX

APPENDIX A – GLOSSARY

AHD	Alliance for Hydromet Development - https://alliancehydromet.org/
AR*n*	Assessment Report No. *n* of the IPCC
AWS	Automatic Weather Station
BUFR	Binary Universal Form (WMO)
CAPPI	Constant Altitude Plan Position Indicator (a type of radar display)
CAS	Chinese Academy of Sciences
CDPC	Climate Data Processing Centre (PMD) - https://cdpc.pmd.gov.pk/
CHD	Country Hydromet Diagnostics (AHD and WMO)
CMA	China Meteorological Agency
CMC	Canadian Meteorological Centre
CMIP*n*	Coupled Model Intercomparison Project *n* (provides most of the models used in the IPCC ARs)
CRED	Centre for Research on the Epidemiology of Disasters
CREWS	Climate Risk and Early Warning Systems
CCSM	Community Climate System Model (UCAR)
DWD	Deutsche Wetter Diens
ECMWF	European Centre for Medium-Range Weather Forecasts - https://www.ecmwf.int/
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	UN Food and Agriculture Organisation
FFD	Flood Forecasting Division (PMD) - https://ffd.pmd.gov.pk/home
GAW	Global Atmosphere Watch - https://community.wmo.int/en/activity-areas/gaw

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GBON	Global Basic Observing Network - https://community.wmo.int/en/activity-areas/wigos/gbon
GCF	Green Climate Fund - https://www.greenclimate.fund/
GCISC	Global Climate Change Impacts Studies Centre (Islamabad - https://www.gcisc.org.pk/index.php)
GCOS	Global Climate Observing System - https://gcos.wmo.int/en/networks/gcos-surface-reference-network
GCW	Global Cryosphere Watch - https://globalcryospherewatch.org/
GDPFS	Global Data-Processing and Forecasting System
GEM	Global Environmental Multiscale Model (CMC)
GEPS	Global Ensemble Prediction Suite (W557 - USA)
GEWEX	Global Energy and Water Exchanges
GFS	Global Forecast System (NOAA)
GGIS	Global Groundwater Information System (GGMN)
GGMN	Global Groundwater Monitoring Network (Part of GTN-H) - https://www.un-igrac.org/special-project/ggmn-global-groundwater-monitoring-network
GLIMS	Global Land Ice Measurements from Space - https://www.glims.org/
GLOF	Glacial Lake Outburst Flood
GMAS	Global Multi-Hazard Alert System (WMO)
GMDSS	Global Maritime Distress and Safety System (WMO)
GOS	Global Observing System - https://community.wmo.int/en/activity-areas/global-observing-system-gos
GOOS	Global Ocean Observing System
GRDC	Global Runoff Data Centre (Part of GTN-H) - https://grdc.bafg.de/GRDC/EN/Home/homepage_node.html
GRSN	GCOS Surface Reference Network
GSM	Global Spectral Model (CMA)

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GRUAN	GCOS Reference Upper Air Network
GSM	Global Spectral Model (JMA)
GSN	GCOS Surface Network
GTN-G	Global Terrestrial Network – Glaciers (https://www.gtn-g.ch/))
GTN-H	Global Terrestrial Network – Hydrology (https://www.gtn-h.info/) – replaces GTOS
GTN-L	Global Terrestrial Network – Lakes
GTN-P	Global Terrestrial Network – Permafrost (https://gtnp.arcticportal.org/)
GTN-R	Global Terrestrial Network – River Discharge (https://grdc.bafg.de/GRDC/EN/04_spcldtbss/44_GTNR/gtnr_node.html)
GTOS	Global Terrestrial Observing System - http://gosic.org/ios/about-GTOS-observing-system.htm
GTS	Global Telecommunication System (WMO)
GUAN	GCOS Upper-Air Network
HEC	Hydrological Research Centre - https://www.hrcwater.org/about-hrc/
HydroSOS	Global Hydrological Status and Outlook System (WMO) - https://wmo.int/activities/hydrosos/global-hydrological-status-and-outlook-system-hydrosos
IBF	Impact-based Forecast (NAMC) - https://namc.pmd.gov.pk/new/ibf/
ICIMOD	International Centre for Integrated Mountain Development
ICON	ICOsahedral Nonhydrostatic model (DWD)
ICTP	International Centre for Theoretical Physics
IISD	International Institute for Sustainable Development
IPCC	Intergovernmental Panel for Climate Change
ISMN	International Soil Moisture Network (Part of GTN-H) - https://ismn.earth/en/
JMA	Japan Meteorological Agency

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METAR	Meteorological Aerodrome Report
MHEWS	Multi-Hazard Early Warning System
MRI	Mountain Research Initiative
NAMC	National Agromet Centre (PMD) - https://namc.pmd.gov.pk/
NC	National Communication (UNFCCC)
NCAR	National Centre for Atmospheric Research (USA)
NDC	National Determined Contributions (UNFCCC)
NDMA	National Disaster Management Authority (Pakistan)
NDMC	National Drought Monitoring and Early Warning Centre (PMD) - https://ndmc.pmd.gov.pk/new/
NDVI	Normalised Difference Vegetation Index
NMC	National Meteorological Centre
NMHS	National Meteorological and Hydrological Service
NOAA	National Oceanic and Atmospheric Administration (USA)
NSIDC	National Snow and Ice Data Center - https://nsidc.org/home
NWFC	National Weather Forecasting Centre (PMD) - https://nwfc.pmd.gov.pk/new/daily-forecast.php
NWP	Numerical Weather Prediction
OIS	Operational Information System (WMO)
OSCAR	Observing Systems Capability Analysis and Review Tool (WMO) - https://oscar.wmo.int/surface/#/
PDMA	Provincial Disaster Management Authority (Pakistan)
PMD	Pakistan Meteorological Department - https://www.pmd.gov.pk/en/
PMU	Project Management Unit
PRECIS	Providing Regional Climates for Impacts Studies (UKMO)

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RBON	Regional Basic Observing Network - https://community.wmo.int/en/activity-areas/WIGOS/RBON
RDD	Research and Development Division (PMD) - https://www.pmd.gov.pk/rnd/rndweb/rnd_new/index.php
REAP	Risk-informed Early Action Partnership (launched at UNCAS)
RegCM	Regional Climate Model (ICTP)
SACRED	Space Application Centre for Response in Emergency and Disaster (SUPARCO)
SDG	Sustainable Development Goal(s)
SMRFC	Specialised Medium Range Weather Forecasting Centre (PMD) - https://smrfc.pmd.gov.pk/
SOFF	System Observations Financing Facility - https://un-soff.org/
SPI	Standardised Precipitation Index
SPEI	Standardised Precipitation Evapotranspiration Index
SUPARCO	Pakistan Space and Upper Atmosphere Research Commission -
SYNOP	WMO coding system for surface synoptic observations
TCWC	Tropical Cyclone Warning Centre (PMD) - https://www.pmd.gov.pk/en/tropical-cyclone-warning-centre/advisories.php
TPE	Third Pole Environment
TPRCC-Network	Third Pole Regional Climate Centre Network (WMO) - http://www.rccra2.org/tp-rcc/
UCAR	University Corporation for Atmospheric Research (USA)
UKMO	United Kingdom Meteorological Office
UNCAS	United Nations Climate Action Summit (2019)
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction - https://www.undrr.org/

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UNEP	United Nations Environment Programme
UNESCAP	UN Economic and Social Commission for Asia and the Pacific
UN-SPIDER	United Nations Platform for Space-Based Information for Disaster Management and Emergency Response
WB	World Bank
WIT	Water Informatics and Technology, a Centre in the Lahore University of Management Sciences - https://wit.lums.edu.pk/overview
WDQMS	WIGOS Data Quality Monitoring System - https://community.wmo.int/en/activity-areas/WIGOS/implementation-WIGOS/WDQMS
WGMS	World Glacier Monitoring Service (GCOS)
WHOS	WMO Hydrological Observing System - https://community.wmo.int/en/activity-areas/wmo-hydrological-observing-system-whos
WIGOS	WMO Integrated Global Observing System - https://community.wmo.int/en/activity-areas/WIGOS
WMO	World Meteorological Organisation - https://wmo.int/
WRF	Weather Research and Forecasting model (NCAR)
W557	US Air Force's 557th Weather Wing

APPENDIX B – ASSESSMENT OF LINKS ON THE PMD WEBSITE

On the main PMD page - https://www.pmd.gov.pk/en/ (all PMD sites accessed re section 3 on 23 to 27/8/24 unless otherwise indicated) – are:

- Links to visualisations of the radar network
    - the two main facilities included are at Islamabad and Karachi with visualisations of latest surface rainfall and of 12-hour accumulations, plus additionally for reduced areas a CAPPI (constant altitude) graphic, supplied by the National Weather Forecasting Centre (NWFC)
    - there are also direct radar displays available for Mardan and Sailkot, with the latter under the Flood Forecasting Division
- Links to visualisations of meteorological satellite data, including visible and infra-red plus other visualisations (NWFC)
- Video weather forecasts, all in Urdu, for:
    - Tourists
    - Daily weather
    - Pothohar
    - Farmer's
    - Sindh
    - Monthly climate outlook
    - Punjab
- A rolling screen that includes weather warnings
- Links to NWFC, CDPC, FFD, NAMC, NDMC, TCWC

On the NWFC site (https://nwfc.pmd.gov.pk/new/daily-forecast.php) there is:

- A daily forecast in Urdu only, that includes recent maximum temperatures and 24-hour rainfall accumulations charts with English text
- Links to the satellite and radar (Islamabad and Karachi only) sites mentioned above
- Monthly weather reports (the latest being for December 2022 as of 23/8/24)
- Links to the regional meteorological centres for:
    - Balochistan (https://rmcbalochistan.pmd.gov.pk/)
    - Sindh (https://www.pmd.gov.pk/rmc/RMCK/RMCK.html)

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  - Punjab (https://rmcpunjab.pmd.gov.pk/)
  - Khyber Pakhtunhkwa (http://www.rmckpk.pmd.gov.pk/ - site not accessible on 23/8/24)
  - Gilgit Baltistan (http://www.rmcgb.pmd.gov.pk/ - site not accessible on 23/8/24)
  - and Kashmir (https://rmcpunjab.pmd.gov.pk/) – the same link as for Punjab
- The regional meteorological centres' sites do not have a consistent format but provide information not always available on the main sites:
  - Balochistan – includes forecasts for up to the following day (presumably with warnings if required) and a summary of the previous day's weather in English; also, recent summaries of maximum and minimum temperatures with concurrent relative humidities plus daily rainfall totals at (presumably) all manual and AWS locations in the Province (there are 9 AWS stations of which 3 do not appear to be working as of 23/8/24)
  - Sindh – also in English but includes a map indicating that the Karachi Centre is closed permanently; several of the links on the site appeared not to be working on 23/8/24; there is a provincial map with flashing inverted red triangles, presumably indicating forecasts of storms or even warnings, but no explanation is given; links that did work include:
    - A weather warning in English
    - Forecasts to 48 hours in English
    - 3-day forecasts for a number of locations, mainly in terms of weather symbols
    - Details, but no data, of observation sites
  - Punjab/Kashmir – the most complex of the regional sites; the extensive list of services is in English alongside maps with Urdu text, and a rolling display gives recent temperatures and rainfall at a number of locations, with also a flashing weather warnings summary; services provided include:
    - Weather forecasts, both in writing and in symbols, up to 7 days for cities
    - Current and recent weather at various sites
    - Specific weather warnings
    - Airports weather (but not in the detail required for aviation services); however, there is a separate link to "Aviation Products", some of which requires log-in but accessible pages include detailed coded airport information
    - Daily rainfall amounts at selected locations

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- "Extreme" past weather events under the link "Climatology"
- Daily rainfall records at numerous stations under the link "Rainfall (ORG)" that has a header "Daily Rainfall Sheet for Drought" but the interpretation in terms of drought is unclear
- Fog/snow, air quality, and heatwave updates
- Quarterly Bulletins of activities
- Other links not relevant here

On the Specialised Medium Range Weather Forecasting Centre website (https://smrfc.pmd.gov.pk/), there are details of a project to enhance forecasting capabilities with PMD through a "high performance computing cluster" installed at Islamabad. The project, entitled "Establishment of Specialized Medium Range Weather Forecasting Centre (SMRFC) and Strengthening of Weather Forecasting System in the Islamic Republic of Pakistan", being undertaken with sponsorship with Japan, includes also installation of a weather radar and a wind profiler system. The objectives are to provide short, medium, flood and marine forecasts; no details of current outputs are provided on the site. Models being, or intended to be, run on the system include:

- The Weather Forecasting and Research model (WRF) developed at NCAR through a collaboration of US universities that provides forecasts to 72 hours with a resolution of 5km. Its uses are for short-range, flood and marine (including GMDSS) forecasting, with hourly products for the latter. It includes a data assimilation component, but no details are provided of data sources for the assimilation process.
- The ICOsahedral Nonhydrostatic model, provided by DWD, has been operational since 20/1/15 (although the web site does not make it clear whether this date refers to DWD or to PMD). It is/will be run over 72 hours at 13km resolution for short-range forecasting. No other details, including of assimilation processes, are provided.
- The Global Spectral Model (GSM), provided by JMA, has a resolution of about 20km and is/will be run for 72 hours to provide short-range forecasts.
- Global Forecasting System (GFS) is the main NOAA model and is used for medium-range forecasts over 3 to 7 days with a 25km resolution. The site does not make clear whether these products are created locally or are obtained remotely.
- All above product sources provide deterministic predictions; the Global Ensemble Prediction Suite (GEPS), presumably accessed remotely, provides an ensemble of 63 global models from three international centres running out to 7 days for the medium range.

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- The Global Environmental Multiscale model (GEM), developed by the Canadian service, includes an assimilation component and provides medium-range forecasts with 1º resolution to 7 days. It seems likely these products are obtained remotely.

The PMD home page includes a link to a Lightning Monitoring System run in cooperation with the CAS, but the page is password protected so no details can be suppled here.

The National Agromet Centre (NAMC – PMD – https://namc.pmd.gov.pk/) provides the following services:

- Forecasts in URDU for 8 regional centres updated every Monday
- Decadal, weekly and monthly bulletins in a mixture of English and Urdu that include nationwide recent weather/climate conditions plus forecast and advisories for specific time periods
- A pilot impact-based forecast (IBF), currently for Pothohar only, in Urdu
- Crop reports, but when the links were visited there was no information available
- A 7-day forecast in Urdu with graphics for 15 locations in a joint project with the MNS-University of Agriculture, Multan
- A seasonal agroclimatic outlook in both English and Urdu produced monthly, including an advisory
- A monthly agroclimatic advisory apparently in Urdu only
- Graphics of temperatures and rainfall across each year, including anomalies, for 13 locations

The National Drought Monitoring Centre (NDMC - https://ndmc.pmd.gov.pk/new/) provides the following services:

- Flash drought alerts (including scrolling information) and advisories; for 2024 there have two advisories (in English) to date, in January and May, but it is worth noting that in September 2023 the site provided a dengue alert
- Weekly drought updates and monthly/quarterly drought bulletins in English
- Daily and annual graphics of levels and inflows/outflows for 5 reservoirs
- A page in English proving national graphics entitled: drought monitor, precipitation, standardised precipitation index, soil moisture outlook, rain percentage anomaly change, percentage departure of rainfall, cumulative precipitation anomaly, soil moisture anomaly, water availability forecast, rainfall analysis, length of dry period, drought hazard map, and drought frequency map
- A similar page to that above for satellite indices: land surface temperature, normalised difference vegetation index, and temperature vegetation dryness index

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- Two further similar pages to the above for the standardised precipitation (SPI) and standardised precipitation evapotranspiration (SPEI) indices, provided monthly accumulated over periods of 1, 3, 6, 9 and 12 months (although the web pages do not make that clear)
- A similar page offering intercomparisons between SPI and SPEI on the different time scales
- A map of agricultural land use
- A final similar page to those above providing maps of the climate classification based on a moisture index (undefined), annual normal rainfall amounts (although when the page was visited it displayed only rainfall anomalies compared to annual for January), and annual 33% and 66% exceedance probabilities for rainfall

There are links provided to the National Seismic Monitoring Centre, the main aspect of which from the perspective of this report is the Tsunami Early Warning Center (https://seismic.pmd.gov.pk/seismicnew/index.html); the latter has produced a 2010 report "Numerical Modeling of Tsunami Inundation for Potential Earthquake at Makran Subduction Zone" (https://www.pmd.gov.pk/tusanami.pdf)

The Flood Forecasting Division (FFD - https://ffd.pmd.gov.pk/home) web site includes:

- A home page with a national map of gauged locations colour-coded according to the latest information, with categories: normal flow, low flow, medium flood, high flood, very high flood, and exceptionally high flood (no definitions are provided on the web site); also scrolling graphic forecasts for a number of locations
- Three advisory bulletins plus a flood advisory, all in English text without graphics and that can be downloaded as pdfs; the bulletins are:
    - A – Current river situation and qualitative flood forecast (current situation, warnings, meteorological situation and 72 hour forecasts plus outlook, last 24 hours rainfall recorded in major catchments
    - B – Quantitative flood forecast of gauging stations (tabulated 24-hour forecasts for the major catchments; flow observations and forecasts for major dams)
    - C – Significant weather outlook (for river catchments) (warnings for the coming week)
    - Significant flood warning (for the following 3 days in English and Urdu)

The Research and Development Division (RDD) webpage (https://www.pmd.gov.pk/rnd/rndweb/rnd_new/index.php) has a number of links:

- An introductory page with links to, those relevant expanded in later bullets:
    - Numerical Weather Products

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- An Experimental Seasonal Forecast
- The Pakistan Journal of Meteorology
- Glacier monitoring (but both links provided pointed to a blank page - https://rnd.pmd.gov.pk/glaciers/)
- An English text page entitled “Numerical Modelling” which provides a layman’s overview of atmospheric modelling for various time scales; the page is not dated but maybe out of date, noting mention of the Japanese GCM20 as leading the modelling world since 2010; the list of models noted is dissimilar in some cases to that under the SMRFC page:
  - It is possible, but not clear, that GCM20 is used at PMD, in which case most likely for climate change projections but possibly also for downscaling with at least one of the ICTP RegCM4 and the UKMO PRECIS models
  - The DWD HRM (High Resolution Model) is run with 11km resolution, but according to SMRFC the DWD model used is the 13km resolution ICON model; the section clarifies that assimilated initial conditions are provided by DWD
  - The NOAA GFS, also mentioned by SMRFC
  - The CMA GSM with a resolution of 30km providing information to one week
  - The page provides also links to dust storm and thunderstorm climatologies, but none of the links worked
- A list of research publications, also possibly out of date as the latest listing is for 2016
- A section on pollen monitoring

- The main links on the home page are to:
  - A brief introduction to the division
  - The SMRFC page of forecast models discussed above
  - GLOF updates, with two parts:
    - A section in English text with alerts for various locations, the latest being for 2019 (which might indicate that the page is no longer updated or might indicate that the last possible GLOF was in 2019)
    - Graphical and up-to-date forecasts for the mountains and higher plains of surface temperature and rainfall from the WRF and ICON models (although when visited no information was available from ICON)

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- Modelling Activities that connect to the “Numerical Modelling” page discussed above
- Numerical Weather forecasts with 4 links:
  - Graphical outputs from both the ICON and GFS models, including temperatures and rainfall as well as some fields more of professional interest
  - Under “More Products” further graphical fields of professional interest
  - Finally, “ICON model output for NWFC”, which is password protected
- Seasonal Forecast: links to the “Experimental Seasonal Forecast” page noted above; indicates that ensembles from 13 international modelling houses, each with differing numbers of ensemble members, are used to create the forecasts in the final week of each month, although the process used is not outlined; also provides links to an English text and graphics monthly rainfall outlook (for August 2024 when visited) and to a seasonal outlook that additionally includes temperature (August to October 2024 when visited)
- Pollen monitoring: a link to the RDD page noted above
- Glacier monitoring: the page was blank on 27/8/24
- Links to the Pakistan Journal of Meteorology and to the publications list noted under the RDD above
- Climate Scenarios data: downscaled data as follows:
  - Based on AR4 25km and 50km resolution outputs 2010 to 2100 from RegCM4 and Precis using ECHAM4, both for the A1B scenario only; for the 50km version additional downscaling using ERA40; data as downloadable files
  - Based on AR5 again 25km and 50km resolution outputs 2010 to 2099 using the CCDM4 model for the RCP4.5 and RCP8.5 scenarios; data available as downloadable excel files
  - No interpretation of these data is provided
- Climate Services: provides links to services from the Tokyo Climate Centre, namely: El Niño monitoring; NWP model ensemble prediction; climate system monitoring; World climate

The Climate Data Processing Centre (CDPC) provides links on its web site to:

- A map of PMD stations
- Maps of annual average temperatures and rainfall totals 1981 to 2010

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- Monthly climate summaries as documents with English text, charts and tables
- Annual “State of Pakistan Climate” documents with English text, charts and tables
- A current year monsoon update plus reports for earlier seasons, in English with charts and tables
- Record temperatures and daily rainfall totals for 7 sites
- Additional information on eclipses, the lunar calendar, new moon sightings, and sun rise and set times

On the PMD main page is a link to a pilot flood risk management held in the Lai Nullah Basin prior to 2010.

The Aviation Products web page provides links to pages mentioned previously, such as satellite and radar images. The daily forecast link did not work on 27/8/24; the weekly forecast provided for National linked to the NWFC page mentioned earlier, while the Cities Weekly Forecast connected to a NOAA product. The most important link is for the METARs and TAFs, although in this case links to a map and to the “World” did not work. However significant weather and wind charts were provided for “local”, “Middle-East”, “Far-East” and Europe, although some visited appeared to be out of date. No METARs or TAFs were found.

The Marine Forecast link on the main PMD page provides an English standard format (for such forecasts) text web page product.

The link to the “Karachi Forecast (3 days)” points to a Heat Wave Early Warning Centre, http://www.pmdnmcc.net/KarachiHeatwaveAlert/Heatwavealert.html, that includes tabulated details for 3 days plus a Monsoon Alert section, but when viewed on 27/8/24, nothing specific to heat waves.

A major heading on the PMD home page, “Alerts/Advisories”, provides further links to WFC text forecasts in Urdu and English, drought alerts, the TCWC, Farmer Advisories, and Lai Nullah Flood Forecasting, all as discussed above.

The “Synoptic” major heading provided SYNOPS and METARS, with the latter at least perhaps better placed under the Aviation section.

APPENDIX C – ASSESSMENT OF LINKS ON THE SUPARCO WEBSITE

The SUPARCO web site, https://suparco.gov.pk/products-services/, provides details of a number of services, some not relevant here. Those relevant include:

- Agriculture. Applications listed include the following relevant to this report, but no further details are provided:
    - Drought monitoring
    - Other weather/climate related products that might be used in relation to PMD products, such as crop yield production forecasting
- Disaster Management. Applications listed include the following relevant to this report:
    - Monitor, forecast and map various hazards
    - Integrated flood analysis system
    - Disaster vulnerability assessment (earthquake, landslide, flood, cyclone tsunami, drought, heat)
    - The page covers also SACRED, the Space Application Centre for Response in Emergency and Disaster. The functions of SACRED are:
        - Provision of the space based information to NDMA and PDMAs in the event of the natural disasters (Flood, Drought, Earthquake, and Landslide) for mitigation, preparedness, response and recovery
        - Activation of the International Charter Space and Major Disasters in the event of the major calamity
        - Technical support to the NDMA and PDMA for the conduct of the Multi Hazard Vulnerability and Risk Assessment (MHVRA) Studies
        - Capacity building of the NDMA and PDMAs in the field of space based disaster management
        - Technical support to the NDMA for the realization of the long-term agenda including NDMP 2015-30, Sendai Framework 2015-30, Paris Climate Change Agreement COP21 and SDGs 2015-30
        - Provision of space based information/support to the regional countries in the event of the natural disasters
    - SUPERCO further hosts the UN-SPIDER regional support office in Pakistan
    - There is no mention of PMD on this page.

    - The page also has links to DisasterWatch, run by SUPARCO, that provides GIS maps covering Flood (e.g. http://disasterwatch.sgs-suparco.gov.pk/?map=floods), Earthquake, Landslide, Drought, GLOF, Forest Fire, Cyclone, and Smog
- Water Resources. Applications listed include the following relevant to this report, but no further details are provided:
    - Surface energy balance and evapotranspiration
    - Hydrological modelling
    - Soil moisture estimation
- Environment. Applications listed include the following relevant to this report, but no further details are provided:
    - Environmental monitoring (air, sea, land)
    - Fog and aerosol monitoring
    - Air pollution
    - Dispersion modelling
    - Also mentioned on the page is the Satellite Data Receiving and Processing Centre, which includes:
        - Glacier and Climate Change (snow cover, glacial extent, glacial hazards)
        - Droughts
- Cryosphere Modeling. Applications listed include the following relevant to this report, but no further details are provided:
    - Development of regional glacier database
    - Monitoring of glaciers
    - Glacial hazard mapping and modelling
    - Glacier depletion monitoring
    - Estimation of snow cover
    - Snow melt and runoff modelling
    - Study atmospheric conditions of the cryosphere
- Coastal and Marine Resources, which includes oceanography as an application, but gives no further details.