COUNTRY HYDROMET DIAGNOSTICS

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ZAMG, Austrian Meteorological Service

Alliance for Hydromet Development

WORLD BANK GROUP

Report

Assessment of Kazakhstan's Capacity to Monitor, Forecast, Project and Warn on Climate-related Hazards.

Prepared for
World Bank Group

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1. Introduction

This report is the result of a much wider-scope project, performed by The World Bank, which aims at preparing the Kazakhstan Country Climate and Development Report (CCDR) to improve the understanding of the linkages between climate change and development, and to inform the Government's policy choices when acting to reduce emissions and build resilience. CCDRs are a critical input to achieve the commitments of the World Bank's Climate Change Action Plan 2021- 2025, which highlights the need to better integrate climate and development. To support this, the Zentralanstalt für Meteorologie und Geodynamik (ZAMG – Austrian Weather and Geophysics Service) of the Republic of Austria, was engaged to perform an assessment of the National Hydrometeorological Service of the Republic of Kazakhstan's (Kazhydromet) monitoring, forecasting, projection and warning systems for climate-related hazards, across timescales (from nowcasting for rapid onset hazards to downscaling for long-term climate projects).

To achieve the above objective, ZAMG has performed a remote-based assessment of relevant systems and capacities. The assessment was informed by the updated approach suggested for Country Hydromet Diagnostics (CHD) under the Alliance for Hydromet Development (of which, the World Bank is a member) and coordinated by the World Meteorological Organization (WMO). Though this report did not need to adhere to all CHD requirements, the authors of this report found almost all of the CHD components to be relevant for the objectives of the CCDR.

The Country Hydromet Diagnostics (CHD) provides a high-level strategic assessment of National Meteorological and Hydrological Services (NMHS), their operating environment, and their contribution to high-quality weather, climate, hydrological and environmental services and warnings. It integrates existing approaches, standards and data provided by WMO and partners, using a peer review approach. The CHD has been developed under WMO leadership and with guidance of a multi-party Working Group. The CHD aims at informing policy and investment decision-making, in particular guiding investments of the members of the Alliance for Hydromet Development. The Alliance brings together major development and climate finance partners behind a joint commitment to strengthen developing country hydromet capacity. Through the Diagnostics, developing countries are expected to benefit from better targeted and aligned financial and technical support.

The CHD is based on the ten most critical elements of the hydro-met value cycle, grouped under four categories – (i) enablers, (ii) observation and data processing system, (iii) service and product production and dissemination, and (iv) user and stakeholder interaction.

The 10 elements of the Diagnostic are defined as follows:

A. Enablers

1. Governance and institutional setting - The formalization of the NMS mandate and its implementation, oversight, and resourcing.

2. Effective partnership to improve service delivery - Effectiveness of the NMS in bringing together national and international partners therefore improving the service offering. This includes the academic, research, private sector and climate and development finance institutions.

B. Observation and data processing system

3. Observational infrastructure - The level of compliance of the observational infrastructure and its data quality with prescribed standards.

4. **Data and product management, sharing, and policies -** The nature of data and product sharing on a national, regional, and global level.

5. **Numerical model and forecasting tool application -** The role of numerical model output and forecasting aids such as remotely sensed products in product generation; whether models are run internally and if the value-added compared to global models is determined.

C. Service and product production and dissemination

6. **Warning and advisory services -** NMS role as the authoritative voice for weather-related warnings and its operational relationship with disaster and water management structures.

7. **Contribution to climate services -** NMS role in and /or contribution to a national climate framework according to the established climate services provision capacity. The assessment on this point will be based on, and complement the recently completed work on, the capacity assessment of climate information services in North Macedonia.

8. **Contribution to hydrology -** NMS role in and contribution to hydrological services according to mandate and country requirements.

9. **Product dissemination and outreach** - Effectiveness of the NMS in reaching all public and private sector users and stakeholders.

D. User and stakeholder interaction

10. **Use and national value of products and services -** Accommodation of public and private sector users and stakeholders in the service offering and its continuous improvement.

For each value cycle element, a limited number of standardized indicators is used, and each indicator uses explicitly defined data sources. The assessment of these critical elements of the National Meteorological Service should lead to their maturity level. Note that Level 5 is the highest attainable maturity level in the CHD assessment.

This report is presented along the ten most critical elements of the hydromet value cycles with an indication of their respective maturity level and some high-level recommendations to help lift up that maturity level, and as abovementioned, with a special emphasize monitoring, forecasting, projection and warning systems for climate-related hazards, across timescales.

The Republic of Kazakhstan

The Republic of Kazakhstan is located in northern and central Eurasia and stretches for 3,000 kilometres from the lower reaches of the Volga River in the west to the West Siberian lowland and the foothills of Altai in the east, and for 2,000 kilometres from the West Siberian plain in the north to the Kyzyl Kum desert and the Tien Shan mountains in south. The area of the republic is 2,724,900 km2 and in terms of territory it is the ninth largest in the world after the Russian Federation, China, USA, Argentina, Brazil, Canada, India and Australia.

The topography of the country is complex and varied. The south-west, north and central regions of Kazakhstan are characterized by a flat topography with low altitudes within 200-300 m above sea level. About 10% of the territory is occupied by highlands. In the south-east of the country there are mountains, the peaks of which reach up to 5-6 thousand meters above sea level. Here, in the Tien-Shan mountain Range (Saryzhaz ridge), the highest point of Kazakhstan is located – the Khan-Tengri peak (7010 m).

The remoteness from the oceans and the size of the territory determine the sharply continental nature of the climate of Kazakhstan, its zonality and lack of precipitation. The plain territory of Kazakhstan is located in four climatic zones - forest-steppe, steppe, semi-desert and desert. Mountainous and foothill areas have a clearly expressed vertical climatic zonality. The change of vertical climatic zones occurs similarly to horizontal zones.

The forest-steppe zone includes the most moisture-provided flat areas in the north of the republic. The shortest season is spring - 1.5 months, summer lasts 3 months, winter - from October to April.

The steppe zone occupies a vast territory in the north of the republic. It is distinguished by high wind speeds. Compared to the forest-steppe zone, the duration of the winter period is shorter, and the summer period is longer. Spring is short and autumn lasts less than two months. It arrives at the beginning of September.

The central part of Kazakhstan is occupied by a semi-desert, zone of dry steppes, with severe winters and hot summers.

The desert zone occupies most of the flat Kazakhstan. The climate of the desert is characterized by long hot summers, cold winters, and great dryness of the air.

In the foothills and mountainous regions, a precipitation amount of 500 to 1500 mm and more is measured annually, in the steppe - 200-500 mm, in the desert - 100-200 mm. The average January temperature ranges from minus 18°C in the north to minus 3°C in the south; the average temperature in July is from 19°C in the north to 29°C in the south. Winter in the north is long and cold. In some years, in the northern regions of the country, frosts reached minus 52°C (Nursultan), but sometimes also a warming is possible - up to 5°C. The highest surface air temperature in July in the north does not exceed 41°C, and in the south 47°C (the Kyzyl Kum desert).

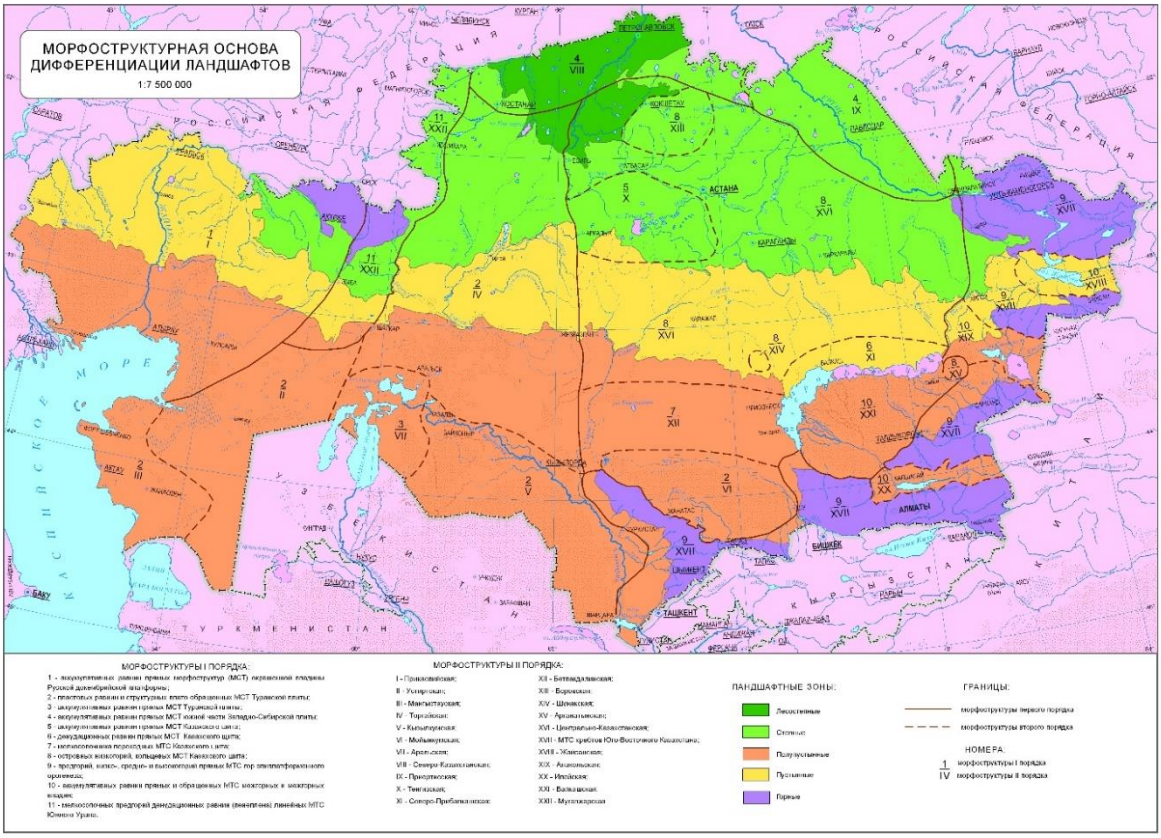

Image 1 (Source: Kazhydromet) : the geoclimatic division of Kazakhstan to: Forests (deep green), Steps (light green), Semi-arid (yellow), arid (brown) and mountainous (blue)

2. Governance and Institutional Setting

In the Republic of Kazakhstan, both meteorological and hydrological services are provided by a single entity: The National Hydrometeorological Service of the Republic of Kazakhstan (Kazhydromet). The Service is under the Ministry of Ecology, Geology and Natural Resources.
The Service was granted the status of a state enterprise following a governmental decree on the 2nd March 1999 and acts according to different legal regulations (a summarised list can be found in annex 3), mostly considerably revised last year (2021) and consists of a main headquarters in Nur-Sultan, some units at Almaty as well as 15 regional branches. However, it should be mentioned here, that the meteorological services for aviation are not provided by Kazhydromet, but by a different entity – the Kazaeronavigatsia division under the Ministry of Transport. It seems, that the Permanent Representative nominate experts for some WMO relevant work groups, but not for the Technical Commission for Aeronautical Meteorology with WMO. Other than that, the working relations include only data sharing (Surface and upper air observations as well Radar Data in the future). Certain roles of the Kazhydromet are also described in other laws, such as the law of ecological CODEXWaters and the law of Environment. However, the official mandate of the Kazhydromet is considered to be of a body entitled for monitoring, forecasts and warnings, but not as an advisory and scientific entity. Such is the case also with the choice of the focal point for IPCC in Kazakhstan – in most countries, it should be the PR of the country with WMO, but in Kazakhstan, it is to be found in the academia. Although Kazhydromet provides much climatological data and information, but it is not considered to be the main advisory body on climate and climate change issues for the government, though it is a major part of the core activities of any NMHS in the world.
Kazhydromet has a long-term strategic plan, prepared by the management of Kazhydromet and confirmed by the Minister in charge.
Until last year (2021), part of Kazhydromet's budget was income-based (Kazhydromet was selling some of its data and products). This situation has changed completely with the revised financial regulations entering into force on 2021, since then, all of Kazhydromet's data and products are provided free of charge. Thus, Kazhydromet's budget is now fully provided by the government.
As for Kazhydromet's staff, it includes a very large number of employees (almost 3000). A very large part of this population is conceived from observers since most of the meteorological and all of the hydrological stations are still manual. Also, a large number of technicians in the regional branches, due to sheer size of this very large country, the remoteness of many stations.
The staff is very varied in terms of age and surprisingly, consists of a very large percentage of young people (below 40). However, the number of holders of PhD (or higher, according to the Kazakh higher education system) is only 10, a very low number compared with the very large staff. As the future of the NMHSs looks now, it seems that NMHSs will have to have more people, who are able to perform practical research in an academical level, especially with adaptation of new tools for forecasters, hydrologists, etc, but also with the developing of new weather and climate-related products and services. As in many other countries, there is a problem to keep IT personnel at Kazhydromet due to an ever-increasing competition with the private market. At the same time, most IT personnel have no background in meteorology, which makes it more difficult to find "a common language" between them and their users.
Kazhydromet has a very is quite a large experience in the implementation of internationally funded hydromet projects and research and development projects in general (World Bank, USAID, WMO, etc.), but since Kazakhstan is considered to be an economy in transition, it is not considered to be eligible for additional support, other than training, software, etc. and mostly through regional or multinational projects. It should be added here, that Kazhydromet is considered to be the more advanced and able NMHS in the region and therefore is considered to be the "stronger chain" in most international regional cooperation projects. All these projects are coordinated professionally by the directors of the relevant departments, with a supervision of the General Director and through the coordination of international relations department.
The maturity level for the Governance and Institutional Setting is assed to be to be at **Level 4**.

3. Effective Partnerships to Improve Service Delivery

Kazhydromet has working relations with many governmental and private entities, as well as with different NGOs and the Academia. One important example, where Kazhydromet enjoys directly from these relations is the field of observations – according to different agreements, Kazhydromet receives all the data from the Kazakh Air Authority (Kazairnavigatsia), especially their radar data, and in addition, there is a series of agreements with private entities measuring air quality in the big cities, according to which, the latter's data is flowing into Kazhydromet's data centre and used by its employees as well as the general public. Another good example is the agreement Kazhydromet has with the Kazakh Research Institute of Soil Science and Agrochemistry. U.Uspanov, allowing Kazhydromet obtaining data on soil composition (necessary for the growth and development of crops).

Kazhydromet, as mentioned in the previous section, has working relations with Kazairnavigatsia, but as it seems, these working relations include only sharing surface and upper-air observations, whereas both organizations have much more relevant data to share (radar imagery, automated precipitation measurements, climatological statistics, regional model results) and potential joined research ventures (nowcasting models, climatological characteristics of extreme events, developing products based on remote sensing).Kazhydromet also provides data and services for different governmental and state enterprises. There are several good examples of cooperation between Kazhydromet and other entities: with the CESDRR (Centre for Emergency Situations and Disaster Risk Reduction) as well as other emergency response entities, the Ministry of Agriculture (extension service, agricultural insurance services, research and development), the ministry of transportation and the national railroad company, the ministry of tourism, the water authority, local governmental offices (as Kazakhstan is divided into different provinces, each having its own local governing services), municipalities of the larger cities, etc. In addition, Kazhydromet also has strong ties with the mining and oil industry, local farms as well as different NGOs. Different experts of Kazhydromet are regular participants in different governmental committees regarding assessment of damages from weather disasters, water management, climate change, agricultural planning, energy, construction, etc.

However, it should be mentioned that most of provided abovementioned services of Kazhydromet are mostly limited to Observation data and different kinds of short-term to seasonal forecasting and much less related to climate services, which are mostly limited to general publications, supporting the government's decisions, as Kazakhstan is a party of the UNFCCC. Another issue is that it seems that the interaction goes in one direction – the different entities get what they were used to get for years and there exists almost no two-sided interaction, no official platform for feedbacks. Kazhydromet is reacting to requests, but not being pro-active with targeting new potential users, but also not with offering upgraded and noval services and products to its already existing users. In many cases, the users of Kazhydromet's services and products are even not aware of the fact, they can get much more and on the other hand, Kazhydromet is not always aware of the changing and newly-emerging actual needs of its users.

As for the relations with Academia, there is an agreement between Kazhydromet and the "Kazakhstan National University. Al-Farabi" on the training of hydrologists and meteorologists, on the conduct of educational and professional practices for students and undergraduates in the specialty Agreement on the training of hydrologists and meteorologists, on the conduct of educational and professional practices for students and undergraduates in specialties " Hydrology" and "Meteorology". In addition, there are also agreements and MOUs with a number of, research centers and universities. Some of Kazhydromet's experts were used to provide lectures at the universities, but this quite important habit is disappearing slowly.

Kazhydromet is quite active in terms of cooperation with different international organisations: 1. Kazhydromet is part of WMO's Flash Floods Guidance System (FFGS) for Central Asia, with the support of US Hydrological Research Centre (HRC) and USAID. Under the same umbrella, the Turkish Meteorological Service (TSMS) has helped to upgrade the forecasters' working environment. 2. Different cooperation schemes regarding transboundary water bodies – rivers (through bilateral agreements with the Russian Federation, Uzbekistan and Kyrgyzstan), the Aral Sea (with Uzbekistan), the Caspian Sea (through the

Teheran agreement regarding the use of the Caspian Sea). 3. Different agreements with ECMWF (for observation and model), EUMETSAT, etc. 4.Different projects with the World Bank Group (such as establishing a distance learning system (LMS) for the Central Asian countries or the CMIP5 global climate models downscaling project).
Nevertheless, it should be pointed out, that in many of these cooperation schemes, Kazhydromet is only being provided with different data and software, but quite often, in a minor role, so that though the projects themselves might be sustainable, but Kazhydromet does not always use the opportunity to upgrade the abilities of its own professional staff. Kazhydromet seems to be an organization, which is very good at adapting new possibilities from the outside, but still needs to improve on creating new possibilities from the within.
The maturity level of the Effective Partnerships is assessed to be at **Level 3.**

4. Observational Infrastructure

Kazhydromet's stations network includes:

a. 347 surface stations (228 manual + 119 AWS), out of which data from 242 stations is shared internationally. In addition, there are dozens of other stations belonging to other governmental entities in Kazakhstan, which data is also shared with Kazhydromet. (however, it should be mentioned that some of the parameters from the AWSs are received on a hourly base, rather than a 10 minutes base)
b. 9 upper-air stations
c. 4 Doppler radars (and in addition, Kazhydromet will have access to the data from the 13 radars of KazNavigation – the Kazakh airports authority) . Kazakhstan, the Russian Federation and Belarus are planning to create composite radar map of the three countries through the framework of the Euroasian Economic Union (EAEU).
d. Agrometeorological measurements are performed in 128 surface stations and 88 agrometeorological posts (out of which 25 are manual and the rest AWS).
e. 170 air quality stations, out of which 47 manual and 123 automated.
f. And hydrological as well as water quality measurement stations (to be elaborated in the Hydrology section).

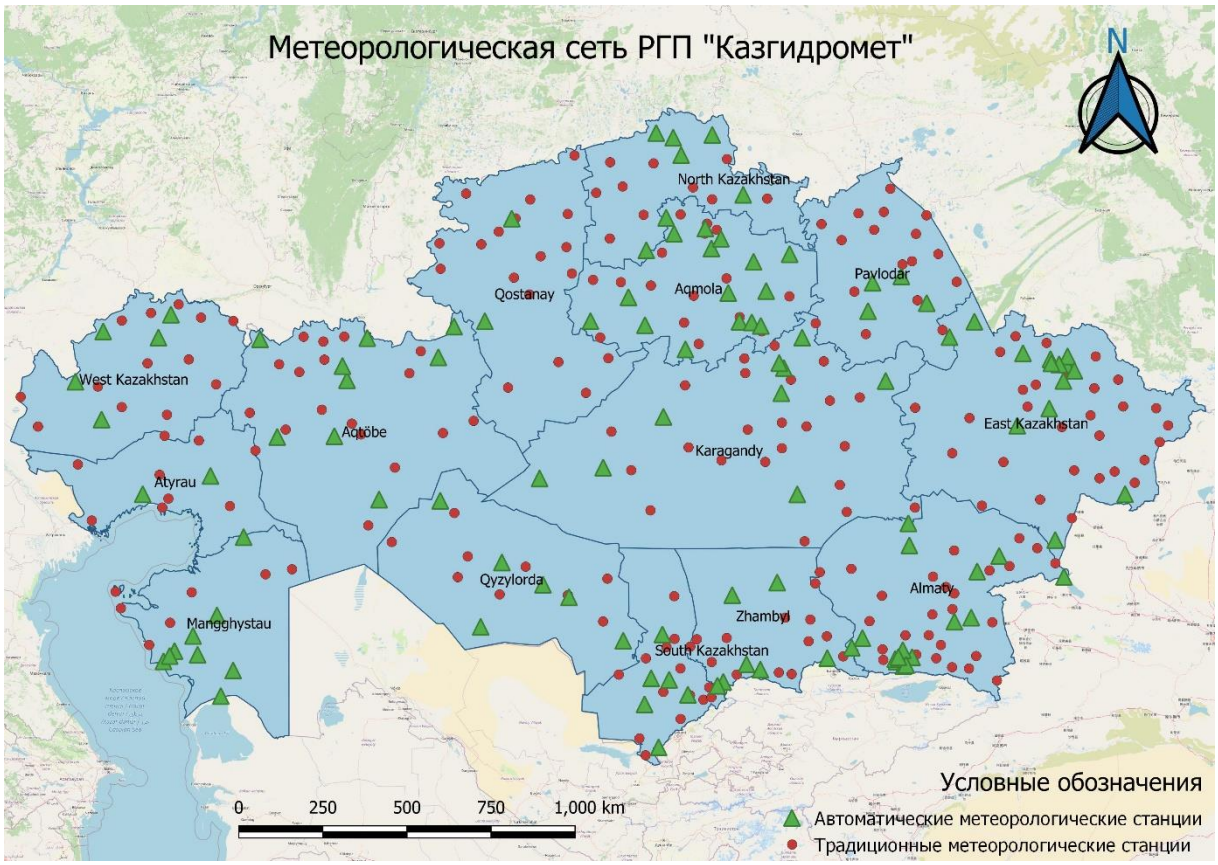

Image 2 (Source: Kazhydromet): Location of the manual stations (noted by red points) and AWSs (noted by green triangles) of Kazhydromet in the Republic of Kazakhstan

The network is largely homogenous, but one should consider that most of the stations are located in the more populated areas and due to the size of the country, from the one hand and the fact it has very large areas, which have very little population, if at all, causes some gaps in these areas. Historically, manual stations were installed in places, where there was a possibility to hire observers, but at the same time, different unpopulated areas are also quite difficult to access in different periods of the year, for maintenance. Two factors, which have a major impact on a possible future expansion of the network.

The Global Basic Observing Network (GBON) criteria[1] regarding Kazakhstan is generally fulfilled as for surface stations, but as for upper-air ones, their required number should be almost doubled. In addition, with the future requirements of GBON regarding hourly measurements, only AWSs could be considered as completely fulfilling GBON's requirements. Nevertheless, the existing number of Surface AWSs in Kazakhstan fulfils GBON's requirements.

Kazhydroment has quite a well-functioning maintenance Standard Operating Procedure (SOP), including also instruments laboratories (around 2 thirds of the instruments are fixed in Kazhydromet's labs, and the rest is sent to other labs, mostly out of Kazakhstan). Nevertheless, there are many stations, especially the manual ones, who continue making use of older instruments, with an approaching end-of-life cycle and/or without suitable spare parts. As mentioned beforehand, Kazhydromet faces a formidable challenge in the form of very remote and difficult-to-access stations, which also might create some delays with the maintenance of these stations. In addition, due to limited range of the cellular networks in many areas, there are sometimes gaps or delays with the data flow and therefore, on average, the temporal availability of data is around 92%.

Outside of the internal quality check system, there is always an external one, performed by some of the centres running global models (such as ECMWF, GFS, DWD, etc.), but due to issues related to registration of Kazhydromet's stations in OSCAR (to be elaborated in the section), the quality check performed is only partial.

[1] See https://ane4bf-datap1.s3.eu-west-1.amazonaws.com/wmod8_gcos/s3fs-public/3a_aopc-24-gbon_icgwigos_jan_2019.pdf?tSO_Ga.kZK2ydXHMVMTctsfbQAjags1i for more

As for the radar system of Kazhydromet, it includes mostly new radars and the staff of Kazhydroment is in the process of learning how to use and maintain of these newly installed radars. An important issue is the lack of an official data policy, telling which radar data should be saved, where and how. And due to the relatively limited data storage capabilities of Kazhydromet, it might become a burning issue soon enough. In addition, though Kazhydromet and Kazairnavigatsia had expressed the desire to create a composite map of both organisations' radars, since the radars of both organisations are from different producers and use different softawares, it still remains an unsolved issue.

- A personal remark of the authors: due to the sheer size of the country and its geographic and climatological location, any improvement of the observation system might lead to significant results, much beyond Kazakhstan's borders.

The maturity level of the observational infrastructure is assessed to be at **Level 3.**

5. Data and Products Sharing and Policies

Kazakhstan, as a Member of the World Meteorological Service (WMO), is obliged, according to resolution 40 of the XII congress of WMO, to "provide on a free and unrestricted basis essential data and products which are necessary for the provision of services in support of the protection of life and property and the well-being of all nations, particularly those basic data and products, as, at a minimum, described in Annex 1 to this resolution, required to describe and forecast accurately weather and climate, and support WMO Programmes". Actually, Kazhydromet shares most the data of most its surface stations and all of its upper-air stations (via the website of WMO as well as the WMO OSCAR system - https://www.wmo-sat.info/oscar/), through the GISC in Moscow, Russian Federation as well as the Regional Centre in Toshkent, Uzbekistan. However, the question is not only how much data a curtain NMHS shares internationally, but also how much of it is really used.
A thorough check of the OSCAR Registry has shown that the registry of the internationally shared stations of Kazakhstan is incomplete and, in many cases, even erroneous. This is the case, especially, with most of the upper-air stations as well as with many surface stations. Such a state might cause that the global models seem to neglect many of the Kazhydromet's stations or even worse, might use incorrectly. This might lead in its turn to three major issues: a. a substantial decrease of the quality of the prediction abilities of these models above Kazakhstan in real-time. b. the data in OSCAR regarding the availability and moreover the quality of Kazhydromet's stations is only partial. c. When the global centers come to verify their own models above Kazakhstan, they have much less "assured" stations to use. Thus, the verification is poorer and henceforth, also any future improvement is also limited.
As for the national data policy, generally speaking, since last year (2021), according to the plan adopted by the Government of the Kazakhstan, any data measured, gathered or analyzed by Kazhydromet is freely available. The real-time data is easily accessible via the Kazhydromet's website. As for historical data, the access has to be done through a request (that can be sent by any interested party). If the historical data exists digitally, the interested side receives it in the form of files, otherwise, it is invited to visit the central archive of Kazhydromet.
Kazhydromet receives internationally shared data from WMO's GISC in Moscow and Toshkent, as well products from EUMETSAT, ECMWF, DWD etc. Among others, it receives:
1. Satellite images: Meteosat 8 of (within the framework of the SADCA project, the Turkish Meteorological Service developed the TMet software package (Application of meteorological satellite data for the territory of Central Asia). Also, satellite imagery from: CMA Cast FY-2H every hour, FY-4A every 15 minutes, "Planet" every hour.
2. ECMWF products (within the framework of the World Bank project "Central Asia Hydrometeorological Services Modernization Project", a web license of the European Centre for Medium-Range Weather Forecasts (ECMWF) for the Central Asian countries was acquired in 2018 and was updated in 2021).
3. The products of the global models: GFS, DWD, as well as the Regional Model Cosmo-ru (within the framework of the WMO project "Severe weather forecasting in Central Asia)".

4. Model of the Finnish Meteorological Institute for the forecast of air pollution SILAM: http://silam.fmi.fi/roux/KAZ/.
The maturity level of the Data and Products Sharing and Policies is, therefore, assessed to be at **Level 3.**

6. Numerical Model and Forecasting Tool Application

The Kazhydromet has an access to Global models (as abovementioned in the previous section: ECMWF, GFS, DWD) as well as to the regional model COSMO-ru run at the WMO Regional Specialized Meteorological Centre (RSMC) hosted by (it should be mentioned, however, that the current resolution of this model is 13 kms, which is worse than most of the global models. Already in 2020, it was promised to improve the resolution to 6.6 km by the WMO Regional Specialized Meteorological Center (RSMC) hosted by Uzbekistan, but still did not happen), through their internet sites as well as through GIS-Meteo and Metcap+ software. In addition, Kazhydromet runs its own regional model, based on the American WRF for different time scales (48-164 hours) and spatial resolutions (2, 4, 13 and 18 kms). However, no systematic automated verification and validation of the results of these models exists versus the stations of Kazhydromet, so that the forecasters have to base their decisions according to their personal subjective experience. The forecasters are also using the Ensemble forecasts produced by ECMWF to a high degree. As for the Kazakh regional model, it is run without any data assimilation and moreover without a sufficient scientific base, researching for the optimal model configuration for the conditions of Kazakhstan.
No model or special additional measurements for nowcasting are available (except the newly installed radars) and generally, the idea of nowcasting is only making its first steps in Kazhydromet. The relative lack of nowcasting tools (use of nowcasting NWP, radar composite imagery, 10 min observations from AWSs, etc.) limits Kazhydromet's abilities to "recognize" in real-time development of these phenomena and hence also to warn them in near-real-time mode. Also, the little use of Ensemble products is rather decreasing the chances "to catch" these extreme cases, that very often can be forecasted only by several of the ensemble members, but not by the deterministic model, despite being in a higher resolution. Naturally, the longer-term weather/climate events (such as heat/cold waves, large-scale storm systems, major river floods) are easier to forecast, using the more traditional deterministic model's results. However, also here, a more advanced use of the ensemble products might strengthen the ability to define the probabilities for such events.
The forecasters enjoy an access to the different sources of data (stations, radar, satellite imagery and models) via METCAP+.

The maturity level for numerical model and forecasting tool application is assessed at **Level 3**.

7. Warning and Advisory Services

Kazhydromet produces all kinds of warnings: extreme weather, hydrological and air/water quality warnings.
However, each such type of warning is issued by a different department inside of Kazhydromet, according to the specification (forecasting, hydrological and ecology), which may lead to a feeling of a lack of "a single issuing service".
As for weather early warnings and warnings, the forecasting centre provides purely weather warnings ("in such and such area, a snow storm is expected between X and Y"), without any notice of possible impact-based information and data. It does not lay under the official mandate of Kazhydromet, which is entitled only to provide solely weather information (the official mandate for these services is entitled to the different emergency entities) . Therefore, there is no use of the Common Alerting Protocol (CAP) in Kazhydromet.
As mentioned in the previous section, Kazhydromet is issuing early warnings and/or warnings for regions, where potentially different local severe weather events (such as flash floods, avalanches, landslides, snow

blizzards, hail, wide-spread fog, etc.) might develop, but it is a true challenge to predict them (and hence warn against them), as they are truly beginning to develop. Moreover, a more systematic use of ensemble products might lead to probability-based forecasts and warnings, which can serve as additional information for relevant stakeholders.
There is a very good formal cooperation with the different emergency entities, receiving their warnings by email as well as sms and having the possibility of consulting the relevant Kazhydromet staff by phone, in case of a need. The warnings are used for preparatory steps as well coping in real time with extreme events. The different stakeholders quite frequently contact the forecaster on duty for consultation and advisory.All the warnings are also published immediately via all of the new-media channels of Kazhydromet and sent to all of the media representatives, Kazhydromet working with.
There is a systematic internal verification and validation process of the issued warnings. However, due to the local mentality, there is a lack of a "complaining" culture from the end users, thus there is no systematic feedback process.
Last, but not least, Kazhydromet also issues forecasts and warnings regarding its part of the Caspian Sea, with the support of Kazhydromet's Research Centre.
Kazhydromet contributes to the Meteo-Alert System, coordinated by Rushydromet.The maturity level for warning and advisory services assessed at **Level 3.**

8. Contribution to Climate Services

The first and arguably the most important climate service, any NMHS has to provide is simply climate data - observations and related statistics. Kazhydromet is providing climatic data of all sorts, but most of the historical data is still found only in a paper form. Kazhydromet has a very long series of measurements, some of which extend back deeply into the 19th century, a possible treasure box for climatologists, interested longer-term climatic processes in Asia. In the recent years, Kazhydromet is dealing with saving this data for posterity, by scanning the data as images. Currently, digitation of this data is still under consideration, due to the high costs involved. Basic metadata is provided for users, but Kazhydromet possesses a well-documented metadata archive for its stations.
Kazhydromet also participates in various national working groups and provides information related to climate and related issues, such as water, transportation, air quality, agriculture, DRR, etc. However, due to a limited legal scope, Kazhydromet is considered to be more of a provider of pure observational data, forecasts and quite basic statistical data (maps, averages, norms, etc.). Nevertheless, since 2010, the Climatic Research Department of the Research Center has been publishing an annual bulletin for monitoring the state and climate change in Kazakhstan. The bulletin provides an assessment of current climatic conditions based on anomalies relative to the period 1961-1991, an assessment of WMO climate indices (using the ClimPact software product), as well as an assessment of trends in various characteristics of the air temperature and precipitation regime, including trends in the values of climate indices WMO. The WMO climate indices include a range of sectoral indices that can be used for agriculture (e.g. length of growing season, length of rainy and dry periods) and water (precipitation), energy sector (cold deficit in warm season, heat deficit in cold period, duration of the frost-free period), public health (recurrence of heat and cold waves, recurrence of extreme temperatures), for emergency management (recurrence of extreme precipitation, temperatures).
However, due to the limited capacity of its scientific department, Kazhydromet is unable also to conduct larger climatological research and added-value products. If such research occurs, it is always conducted with the support of an external entity (mostly international agencies). As an example, a few years ago, through an international project, new atlases for renewable energy (wind and solar) were developed for Kazakhstan. Kazhydromet has provided some consultancy, but did not play the main role in this process.
A similar situation also exists in the field of climate prediction, an internationally funded project was conducted in 2017 (through a World Bank) to downscale the predictions of global climate models (21 CMIP5 generation models) to a higher resolution (0.5 to 0.25 degs), and calculation of the different climatic indicators). KazHydromet was not able to downscale higher-resolution model runs from the CORDEX project, since the latter does not include any domain which is relevant for Central Asia. The

project was performed with the assistance of experts from Kazhydromet, but again not in a leading role. This project was part of the national adaptation program, but with the emergence of the CMIP6 generation and more accurate downscaling methods (such as CDF-t), the previous results become more and more obsolete. The main problem with such projects is that their results become obsolete with time, but the knowledge of how to perform them again is not accumulated in house and hence, Kazhydromet would find it difficult to remake this assignment with the support of external experts. Naturally, without such a sustainable capacity, Kazhydromet would not be to provide the government with updated data regarding the impact of the predicted climate change on the water availability, agriculture and associated trends related to desertification.
Monthly and Seasonal forecasting also being performed at Kazhydromet twice a year (currently, Kazhydromet is performing an experiment, in which a seasonal forecast is provided four times a year). The seasonal forecasts is based on ensemble predictions, developed on the base of the CFSv2 of the northern Euroasian Climate Centre of ECMWF, according to the "analogous year" method. The main goal of these seasonal forecasts is to provide information regarding possible droughts and hotter/colder than average seasons.
The maturity level for contribution to climate services is assessed at **Level 2**.

9. Contribution to Hydrology

Kazakhstan, despite having very large arid and semi-arid regions, is also a country with countless water bodies. The traditional hydrological network includes 377 stations, whereas water quality is measured in 372 stations, located in 134 water bodies: 88 rivers, 29 lakes, 13 water reservoirs, 3 channels and on the Caspian Sea (Kazakhstan's only international marine border). In addition, as from the one hand, Kazakhstan is an agrarian country, but on the other hand, many of these water bodies might cause large-scale floods, hydrology plays a very important role in Kazakhstan.
Thanks to the fact, that Kazhydromet is a hydrometeorological service, hydrology and meteorology sit under the same umbrella. Therefore, the Hydrology department receives all the meteorological data from the Meteorological observation network (including Surface observations, radars data as well as satellite imagery).
Back in the Soviet period, the hydrological observation network had more than 500 hydrological stations. Kazhydromet has a strategic plan to recover most of the previous, currently non-functioning stations, so that eventually, the network will encompass all the main water bodies of the country. It should be mentioned here, that many of these stations and posts are found in scarcely populated (if at all), remote and difficult-to-access regions (even to a higher degree than the meteorological stations), which makes a big challenge as for their maintenance. Moreover, due to the hydroclimatic conditions in many of these regions, many of the instruments have to withstand very harsh and severe conditions. Currently, all of the hydrological stations of Kazhydromet are manual, with only a few with AWSs (that tend to be more sensitive to harsh hydroclimatic conditions). The hydrology department works hand in hand with the Forecasting Department in issuing forecasts and warnings for the main water bodies of the country. However, one obstacle might be that the shifts are conceived only from forecasters, though the hydrologists are also available by phone during night-time and holidays.
In addition to forecasts and warnings, the Department publishes hydroclimatological publications, such as "Annual data on the regime and resources of land surface waters", "evaporation observations from the water surface", etc. In cooperation with the scientific centre, other publications are prepared as well, such as "Water resources by main river basins and their sections" and "River runoff resources throughout Kazakhstan". However, due to the abovementioned limited abilities related to climate models downscaling and analysing, it seems that an additional research into the impact of the predicted climate change on the water availability of the country is still lacking.
Kazhydromet has implemented a Flash Flood Warning System (CARFFG), the regional center of which is located in Kazakhstan. Hydrological models are also used that have shown their effectiveness in predicting river flow. These are well-known models HBV, SWIM, there is a potential to use hydrodynamic model MIKE 11 from DHI in the near future.

In 2021, Kazakhstan has joined the WMO Water and Climate Coalition. Kazhydromet also acts as the regional centre for Central Asia for the Flash Flood Warning System (CARFFG). The enterprise cooperates with all neighboring countries on the exchange of hydrometeorological and environmental products, including cooperation on transboundary water objects. As part of this work, at the level of the Governments of the countries there are working commissions, expert groups to discuss methods, standardize observations, and discuss joint work. However, one should note, that the cooperation is especially good with Kyrgyzstan, Uzbekistan and the Russian Federation, but seems to be less effective with China and Turkmenistan.
Kazhydromet makes a use of the hydrological models HBV and SWIM and considers the use of Mike11 as well. These models are used for some of the larger rivers and other water bodies and their results are being verificated and validated against observations. However, due to the fact, that almost the entire observation network is manual, puts limitations with: no real-time data for assimilation in the Hydro models used by Kazhydromet as well as much less available data for a better verification and validation of the forecasts and warnings. Moreover, without AWSs, also the nowcasting abilities of Kazhydromet, as was already mentioned, are much decreased, especially in cases of flash floods or even sudden and pronounced changes of the rivers' flow.
The maturity level for contribution for hydrology assessed at **Level 3.**

10. Product Dissemination and Outreach

The dissemination of information is made through Kazhydromet's official internet site (www.kazhydromet.kz) as well as different new-media channels (facebook, twitter, Instagram and youtube). The website itself is available in three languages (Kazakh, Russian and English, though for obvious reasons, there is much less information in the latter). In addition, Kazhydromet utilizes special applications developed especially for farmers (agrodata.kz) and air quality for the general public (Airkz). The Website is responsive and provides much information in a very clear and friendly way. As for the New-Media channels, Kazhydromet has a strategic plan headed by the Department for International Affairs and Public Relations. Currently, Kazhydromet has a main Instagram channel (with more than 10,000 followers) and two more channels of regional centers (with around 3,000 followers), a telegram channel (with more than 600 subscribers), an youtube channel (more than 700 subscribers) and a facebook page (actually not a page, but a profile with 700 friends) and a special virtual blog of the General Director. However, it seems that exposure of most of these channels is still quite limited, but mostly they are still quite new.
Product dissemination is also made through Radio, TV, emails, SMSs and Telegram. Kazhydromet can be contacted by multiple ways. The Kazhydromet organized press releases quite often, its' experts are interviewed on TV and Radio. Despite having no Recording Studio, Kahzhydromet is producing, throughout sourcing, short films for youtube about its different activities and interviews with its staff.
Before the COVID-19 pandemic, the Kazhydromet was hosting groups of different populations (Children, Students, Farmers) or participating in local meetings. Now, the situation is improving and Kazhydromet is returning to this important practice. Actually, in curtain populations (elderly, farmers, populations in remote areas, professionally related), it might be of a high importance to increase such visits and meetings, as these populations might be much less exposed to Media and New-Media.
In addition, the Kazhydromet might play a more leading role in Meteorological and Hydrological Education, whether it is on the level of high school education or higher education, through a cooperation with academia, the ministry for education and different interested institutes. Proper resources should be provided for these highly important outreach and education activities.
The maturity level for product dissemination and outreach assessed at **Level 4.**

11. Use and National Value of Products and Services

In the past, Kazhydromet had a partial formal process for conducting surveys with a platform for co-designing services with users. But nowadays, there is only an informal feedback and input from some of

the central stake holders, but more on a departmental level, rather than on the organisational one. One of the issues raised in the different interviews with some of the users of Kazhydromet's services (and also some of its own staff), is the "you shall not complain" mentality. In many cases, so it seems, the users themselves do not know that they are able to get much more information from Kazhydromet and sometimes, Kazhydromet is not aware that some of the services provided are partially irrelevant. Generally, the users sound to be satisfied, but when going into more details, it feelds that they would have had preferred to have more tailored products for their own specific needs. The same behaviour also applies for the search for new potential users. Kazhydromet is not pro-active enough with trying outreaching to new possible fields of activity.

The authors of this report strongly believe that is quite an abundance of potential users all around the country, with a high need and interest with the data and products of Kazhydromet A proper organisational policy should be consolidated for this purpose.

The maturity level for use and national value of products and services assessed at **Level 4.**

12. Summary of the Assessment and Key Recommendations to lift up the Maturity Levels

Maturity Level	Element of the Value Cycle	Key Recommendations to lift up the Maturity level
4	Governance and Institutional setting	• Revise the existing laws regarding Meteorological Services, especially with a stronger mandate in advisory related to climate and climate change issues. • Consider delivering the position of the focal point for IPCC to Kazhydromet. • Enhance the capabilities of the scientific research Department (by adding vacancies and required IT equipment) • Consider providing the IT personnel basic background training in meteorology and hydrology • Providing possibilities for Kazhydromet's employees to upgrade their education level (especially for these interested in a more scientific career) • Assign in every department at least one person (or more, with high level of English) to be responsible for the professional international activities of the department (communication with WMO and other professional international entities, but also as the "ears" and the "eyes" of the department for new developments in the specific field in the international arena • Conduct functional analysis of organizational units/ assignment of staff/ protocols of workflow. • Create a standing committee with the Kazairnavigatsia and to nominate experts from there for relevant WMO workgroups
3	Effective partnerships to improve service delivery	• Establish stakeholder group with partners in government, academia and the private sector to identify fields of common interest and needs • Engage users with requests for feedbacks, complains and ideas for improvements and new or upgraded services and products • Seek for opportunities with private sector (energy, construction and agriculture), both in the form of new

		business opportunities as well in the form of joined research and a two-sided data and info flow • Strengthen the bond with the Academia, by increasing the number of lectures and courses provided by Kazhydromet's relevant staff • Strengthen the Scientific Research Centre, so that it would be to develop new services and products, especially in the fields of Climate and Climate Change. Otherwise, Kazhydromet will be always dependent on international projects for receiving, rather than developing services and products • Create a working environment of a flow of "new ideas and suggestions"
3	Observational infrastructure	• Currently, not investing in expanding the observation system, but rather investing in a further automatization of the existing stations. • Search for ways to improve the data delivery from the stations to the central system. • Establish an experiment field lab for new instruments. • Establish a formal data policy. And adapting the data storage capabilities to this policy. • In the more remote future, the first priority for the station network expansion should be the upper-air system. • Consider increasing the data delivery from the automated raingauges to once in ten minutes (highly relevant for nowcasting, data assimilation, hydrology and more)
3	Data and product sharing and policies	• A major revision and update of the OSCAR stations registery as well as a thorough of the stations' registery at the centers running global models (ECMWF, GFS, DWD, Rushydromet). • Consider searching for alternatives for the regular internet data exchange communication with GISC (such as RMDCN and alike) • Expand the MoU with Kazairnavigatsia, to a much wider data sharing policy and potential research ventures • Consider creating an easier access, via Kazhydromet's website, to historical data. • Consider sharing some products and data of the Kazhydromet's regional model as well as its radars.
3	Numerical model and forecasting tool application	• Assign a person/personal in the research department (together with the IT department) to work on NWP models: a. optimising the regional model's configuration. b. Creating an automated verification system for the different models used by Kazhydromet. c. adding data assimilation to the Kazakh regional model. • Assign a person\personal in the research department to explore ways to make a better use of the existing data sources (radar, stations, satellite imagery) for nowcasting. In addition, considering adapting a model for nowcasting, especially for areas with complex topography.

		• Learn how to make a full use of the available data and products of the radars (including the data from the Airports authority), creating a unified radar-rain gauges map of Kazakhstan and consider the Opera Project of EUMETNET.
3	Warning and advisory services	• Create a "single voice" warning policy of the different relevant departments of Kazhydromet • Strengthen the interaction between the different relevant departments of Kazhydromet, so that representatives of these departments will participate in the daily synoptic discussion and add their added value in their respective fields of expertise (forecasting, hydrology, ecology and agrometeorology). • Create a daily "synoptic summary" to be written by the senior forecasters and to be shared internally between all the departments as well as in between relevant partners (Kazairnavigatsia, the army, Ministry of Agriculture, etc.) • Consider providing warnings for sub-areas, especially in the populated areas, where there might be considerable differences between different sub-areas. • Designate an experienced forecaster for warning verification and validation for severe weather events. Together with the IT department and the Research Centre, improve the existing a automated verification procedure. • The Marketing Department, together with the Forecasting Centre, should pro-actively contact periodically the end users of the forecasts and warnings, with surveys as well as unofficial talks, getting the end-users' feedback • Consider periodical meetings of the forecasters as well as other interested parties, where "forecasting failures" will be presented and discussed, as part of a continuous improvement cycle. Representatives of relative external users might be also invited to provide their feedback, as for the impact of these "failures" • Consider a change in the legal mandate of Kazhydromet, so that it would also include additional advisory services, through a formal agreement with the different relevant governmental entities.
2	Contribution to climate services	• Consider reinitiating the digitation project of the historical data of Kazhydromet • Perform a homogenization of the historical data (perhaps through partnership with academia). • Increase resources allocated to climate-related research • Assign researchers and climatologists, who will be able to lead projects in the fields of homogenization, mapping of different parameters (topoclimatic, wind, solar, etc. atlases, extreme values), climate models downscaling and climate change indicators calculation • Create a survey of historical extreme severe events, for the use of the Kazakh Emergency Entities

3	Contribution to hydrology	• Consider an automatization of the observation network. • With such an automatization, and together with the research centre, adding data assimilation to the existing hydrological models and creating a new automated verification and validation system • Consider having a representative of the hydrology department at any synoptic discussion, to improve the communication between the departments • To assign a person at the Research Centre to work on everything related to the Caspian Sea (wave and surge models, icing forecasts, etc.)
4	Product dissemination and outreach	• Create a facebook page (rather than a profile) • Consider maintaining only a single Instagram page • Create different Telegram channels, according to interest and region • Consider installing a TV Studio • Consider special training for relevant Kazhydromet's employees for "performing in front of the camera", "public talking", etc. • Provide as much as possible online/physical webinars/lectures for the general public as well as at the Academia • Develop partnership with the Ministry of Education to foster hydrometeorological education at high schools, with a focus on "out of the main cities" policy (as one of the scientific fields in the Curricula, chosen high-schools to be "adopted" by Kazhydromet, considering establishing in different schools, servers with screens, showing Meteorological Data, local and national as well)
3	Use and national value of products and services	• Designate a focal point for communication with the users • Organize as many as possible periodical specialized users' groups meetings with relevant representatives of Kazhydromet, presenting them new updates, encouraging the users "to demand more" and reflect to them Kazhydromet's possibilities (as well as what is not possible) • Develop and implement regular users' satisfaction surveys • Establish action plans for continuous improvement based on user feedback • Invite new potential users for meetings and suggesting them relevant tailored products

Annex 1: List of Interviewed Persons (Kazhydromet)

Name	Department	Position
Makatov Olzhas Orkinovich	Marketing and Price Monitoring Unit	Senior Accountant
Kamshibaeva Nazgul Zhaskayratovna	Marketing and Price Monitoring Unit	Head
Shingisova Aygul Turuspekovna	Marketing and Price Monitoring Unit	Senior Specialist
Bolatov Kaynar Merkeevich	Hydrology Department	Director
Tulubaeva Gulzhan Muratkizy	Department for External Affairs and Public Relations	Director
Kornyuchova Olga Vladimirovna	Department for Ecological Monitoring	Director
Abeav Nurlan Nusipbaevich	Scientific Research Centre	Director
Schmidt Marina Edvardovna	Hydrometeorological Centre	Director
Shabdanov Almaz Kaziachmetovich	Meteorology Department	Director
Loenko Nonna Michailovna	Department for Agrometeorological Monitoring and Forecasts	Director
Saylybaev Bakytzhan Ibaydullauly	IT Department	Director
Baymuratov Arman Cerikbaevich	Governmental Purchases, Legal Matters and Property Maintenance	Director
Zhabbarov Asylbek Amankeldievich	Maintenance Lab for Meteorological and Hydrological Measurement Instruments	Head
Balchieva Dzhazira Dzhaaomirovna	Republic’s foundation’s Archive	Head
Alimbaeva Danara Kizatonova	Management	General Director

Annex 2: List of Interviewed Persons (Other Entities)

Name	Entity	Position
Malikova Laura	The Association of Ecologists	Chairman
Shishanova Olga Vladimirovna	Journal “the new generation”	Journalist
Zhanar Mahanova	Ministry of Agriculture of Kazakhstan	Head of the financial

		department of the
Aubakirov Serik Gabdulovich	Centre for Emergency Situations and Disaster Risk Reduction (CESDRR) of Central Asia	Senior Deputy Director
Novikov Viktor	ZOI environmental network	Project Development and Management for Central Asia
Kaya Fatih	WMO	Project Manager at WMO
Gafurov Arbor	GFZ-Potsdam	Hydrologist
Balagambetov Alibek	The National Company of Kazakhstan Temir Zholy (National Railway company)	Chief Specialist at the Department of Meteorological Support ns of the "Central Track Laboratory"
Sazanova Bayan Aydarhanova	Kazairnavigatsia	Head of Department for Meteorological Support and Information
Kostikova Vasilina Alexandrovna	Kazairnavigatsia	Senior Engineer at the Department for Meteorological Support and Information

Annex 3: List of Reviewed Documents

Name	Date	Language	Status
Charter of the Republican State Enterprise on the financial regulations of Kazhydromet	01.10.2021	Russian	Law
Regulations of maintaining the state climate Registry, as well as determining the composition of the data of the state climate Registry and the procedure for submitting its data to state bodies, other organizations and individuals	05.08.2021	Russian	Law
Regulations of the maintenance of the state registry of producers of meteorological data	1.07.2021	Russian	Law
Regulations of stationary observation points and observation points for the state of atmospheric pollution of the state observation network	02.08.2021	Russian	Law
Regulations of data provision of the National Meteorological Service	2.01.2021	Russian	Law
Regulations on the management of the hydrometeorological Foundation	07.01.2021	Russian	Law
Regulations for the provision of information on severe meteorological conditions, requirements for the composition and content of such information, the procedure for its publication and provision to interested parties	09.07.2021	Russian	Law
Kazhydromet's reply to the authors' questionnaire	23.02.2022	Russian	Questionnaire
Dataset for Kazakhstan (by WMO)	28.03.2022	English	Summary Report
Different forecasts and warnings	24.03.2022	Russian	Products
The Ecological Codex of the Republic of Kazakhstan, Section 11	02.01.2021	Russian	Law