SEAMLESS GDPFS IMPLEMENTATION PLAN

1. Background

The Resolution 11 (Cg-17) decided to move – Towards a future enhanced integrated and seamless WMO Data-processing and Forecasting System and requested the Executive Council to formulate Terms of Reference for this process, and a description of the set of products the system should produce for consideration by Cg-18. The Executive Council established a Steering Group on Seamless GDPFS to be co-chaired by the President of CBS and President of CAS to address the implementation of the Resolution 11 (Cg-17). The Steering Group was to be composed of representatives of TCs and RAs.

The Steering Group met twice in 2016, in particular in November 2016 to bring their progress to the attention of 16th Session of CBS. This included a white paper and an outlines of the S/GDPFS IP. The Vision was approved at EC-68.

Subsequently, the Co-chairs decided to establish a Drafting Team for the Implementation Plan which met in December 2017 to tackle the development of the IP. Their results of their work was presented successfully to PTC/PRA in January 2018 and at TECO and CBS MG at the end of March 2018. The draft IP was developed further, integrating comments and suggestions from SG S/GDPFS, TECO and CBS MG, CAS MG and WWRP Science Steering Committee (March 2018). The draft IP available in Annex 1 will continue to be fine-tuned with specific activities and inputs from all stakeholders. Use-cases examples are also provided in Annex 2 to help understand the functions of the future S/GDPFS.

2. Collaboration

The implementation of the Revised Manual on GDPFS (WMO-No. 485) combined with the implementation of the seamless GDPFS, offer new opportunities for collaboration across WMO. In particular, CBS-MG endorsed the effort between CBS and CCl to integrate operational functions of the Climate Services Information System (CSIS) into GDPFS. This includes plans to expand the Global Producing Centre (GPC) portfolio to cover sub-seasonal forecasts on the global scale. The plan is to integrate with the core functions of CSIS encompassing climate data, climate monitoring, climate prediction and climate projection; and to evolve GDPFS to include a new class of RSMCs to include (i) centres that maintain Climate Reanalysis, and (ii) centres that provide Climate Monitoring on global scale.

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Annexes: 2

Annex 1

Future Global Data Processing and Forecasting System Implementation Plan

This Implementation Plan is built on the current GDPFS structure, considered as a baseline. It identifies the core elements that represent the main directions to improve the present GDPFS. Progress will be made through pilot projects that act as benchmarks to explore new services, their delivery and the underpinning science.

1. Introduction / Motivation

Accurate weather, ocean, water, climate and other related environmental information is critical to enable society to prepare for and protect itself against natural disasters as well as in ensuring the safety and efficiency of not only day-to-day socio-economic activities but sustainable long-term planning and decision-making as well. On the scale of minutes to days, knowledge of the current and forecast location and structure of weather systems, current and forecast river discharges and water levels, temperature, wind, precipitation, ocean variables (e.g. waves, currents, temperature, salinity) and air quality conditions can inform a variety of decisions, from emergency managers responding to disasters, to airlines in flight planning, to an individual deciding what to do and what clothes to wear on a given day. On scales of weeks to months, environmental predictions can help inform farmers as to the best crops to plant for the coming season, water managers to effectively manage reservoir levels and flows of waterways, tourism-related industries to plan for the most appropriate and profitable activities, maritime transport companies to plan safe and optimal routes, and coastal managers to get alerts and better plan coastal protection. Longer term climate reanalyses for the past and projections in the future related to the expected return periods of extreme weather, water, ocean and environmental conditions inform building codes, renewable energy emplacements and infrastructure investments. Furthermore, expected long-term changes in ocean levels, temperature, salinity and currents can inform coastal communities in future planning and fisheries in sustainable operations.

These are but a few examples of how environmental information is necessary and useful but, in fact, the data by itself can only take one so far. Only when combined with other data related to exposure and vulnerability, economics and society, can the true power of the information be exploited for enhanced understanding of the expected *impacts* of the environmental conditions and then used to improve the safety, security and competitiveness of citizens and economies in a sustainable way.

The effect of environmental conditions on society is demonstrably increasing as the climate changes, as populations move to mega-cities, as populations increasingly encroach onto flood plains, as reliance on infrastructure grows, and as the connectivity of the modern world becomes essential to food production, water supply protection and overall quality of life.

The damage to lives and property has increased in absolute terms as a result of extreme weather and increasing drought, rising sea level, and other climate change effects. This is compounded by a growth in population living in vulnerable areas such as the coastal zone and an increasing complexity of infrastructure.
Recent scientific and technological advances bring new opportunities for the provision of environmental information; but also present new challenges. While advanced observing systems provide a wealth of data (that is a challenge to utilise); there are still many crucial aspects of the Earth System that are inadequately observed. Social media provides access to contextual information and dissemination mechanisms but can be a challenge to keep up

with given its explosive growth and innovation. High performance computing platforms allow us to tackle previously unsolvable problems but present new challenges for software infrastructure of numerical models themselves and for the accessibility and dissemination of the resulting information. Probabilistic prediction systems produce a vast amount of data requiring new technologies and methodologies for analysis and applications. These technologies are resulting in automation of routine tasks and motivating the development of human-machine interaction interfaces based on artificial intelligence. It is only a matter of time before the fusion of weather, climate, water and environmental information, big data technologies and business applications will change the way people and businesses utilise these data. This is fundamentally impacting the way meteorology and hydrology is conducted and information is delivered globally, thus forcing WMO Members and partners to rethink the business models, recruitment and training strategies and partnerships at the global, regional and national level.

Meanwhile, citizens have an expectation that governments will provide services to protect them; utilities maintain reliable essential services; and transportation remains safe and timely. The assessment and management of risks requires the best available weather and environmental information and predictions.

2. Background

Fifty-five years ago, the World Meteorological Organization (WMO), recognizing the global nature of the environment, conceived and implemented three components of a World Weather Watch (WWW) to monitor and predict the state of the atmosphere and enable the provision of weather services around the world: the Global Observing System (GOS) was established to provide detailed current conditions through real-time observation and monitoring of the atmosphere; the Global Data Processing and Forecasting System (GDPFS) brought a network of operational centres operated by WMO Members together to make defined weather products and services operationally available to WMO Members and relevant operational organizations; and the Global Telecommunications System (GTS) was the “wiring” that provided the means to manage, exchange and share data and information, thus enabling the global nature of the WWW.

The three components of the WWW are evolving, utilising advances in science and technology to meet the needs of an increasingly vulnerable society. The GOS has evolved into the WMO Integrated GOS (WIGOS) and the GTS into the WMO Information System (which is itself evolving to a WIS 2.0). The GDPFS also needs to evolve, enabled by WIS and WIGOS, into a modernized service delivery model (Figure 1) that considers the following context:

- the need to move beyond the World Weather Watch in order to address societal needs for relevant, coherent and authoritative weather, water climate and other related environmental information;
- the trend toward coupled Earth system modelling to provide prediction and analysis products at all time and space scales and to all sectors and applications that require such information;
- the recent unprecedented improvement in the availability of computing power, contributing to the improved accuracy at all time-scales and forecast lead-time of numerical predictions, and allowing the generation of ensemble systems that enable a probabilistic approach;
- the strengthened involvement of social scientists enabling improved understanding of human behaviour and response;
- the need to consider the increasing role of the private sector in the global weather enterprise;
- the need to further develop engagement with partners (e.g. UN Environment Programme, International Civil Aviation Organization, WHO, IEA, IAEA etc.); and

- the need for increased effectiveness and efficiency in delivering on the core purpose of WMO.

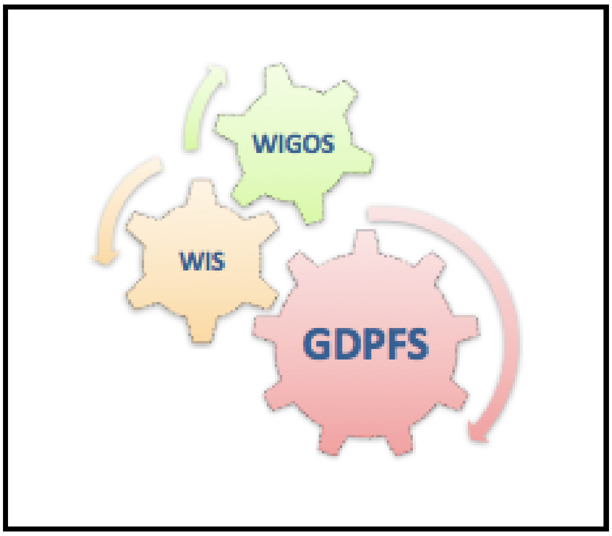


Figure 1: WIGOS, WIS and GDPFS – the "mechanisms" within the WMO Operational System that enable service delivery.

3. Present status of the GDPFS

The GDPFS is an international mechanism that coordinates Member capacities to prepare and make meteorological analyses and forecast products available to all Members. It enables delivery of harmonized services and is currently organized as a network of Global, Regional and National Centres (illustrated in Figure 2) that produce a variety of defined outputs primarily related to weather, water and climate but also for specialized applications such as emergency response to nuclear accidents and space weather forecasts during solar events. This network, as of August 2018, consists of:

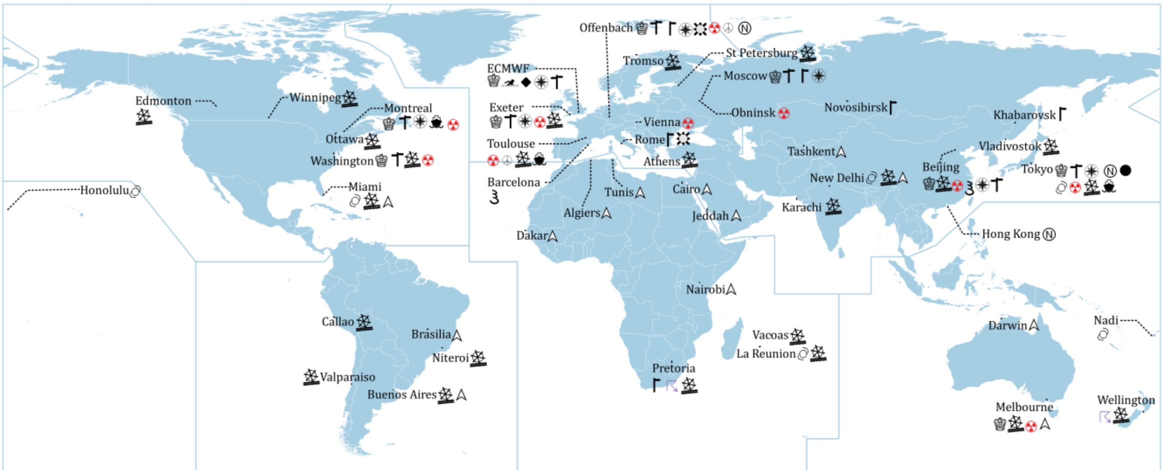
(a) 9 World Meteorological Centres (WMC);
(b) 13 Regional Specialized Meteorological Centres (RSMC) with Geographical Specialization, 29 with General Purpose Activity and 49 for Specialized Activity;
(c) 43 Centres with General Purpose Activity (26 RSMCs, 13 Global Producing Centres (GPC) for long-range prediction, and 4 GPC for Annual to Decadal Climate Prediction);
(d) 49 RSMCs for specialized activities;
(e) 8 Regional Climate Centres (RCC) and 3 Regional Climate Centre-Networks, and
(f) 6 Lead Centres (LC) for non-real-time coordination activities: one Centre each for coordination of Long-Range Forecast (LRF) verification, Multi-model Ensemble verification, Deterministic NWP verification (DNV), EPS verification and Annual to Decadal Climate Prediction (ADCP), and wave forecast verification.

Notes:
1. A distinction is made between general-purpose and specialized activities: general-purpose activities are those that encompass essential data processing required for a wide range of end use, while specialized activities are those that make forecasting products, which may include guidance based on human interpretation, tailored for a specific type of application or user community. In addition to these activities conducted in real time, non-real-time operational coordination activities are also part of GDPFS;
2. Some centres serve more than one role.

WMO Designated Global Data-processing and Forecasting System Centres

- Nowcasting and Weather Forecasting (upto 30 days)

Updated on 12 March 2019



Legend

- World Meteorological Centres (WMCs)* (9)
- RSMCs Geographic (13)
- RSMCs(NRT***) Lead Centre for Coordination of Wave Forecast (1)
- RSMCs(NRT***) Lead Centre for Coordination of EPS Verification (1)
- RSMCs(NRT***) Lead Centre for Coordination of DNV (1)
- RSMCs Numerical Ocean Wave Prediction (3)
- RSMCs TC (6)
- RSMCs Severe Weather Forecasting (2)
- RSMCs Marine Meteorological Services (24)
- RSMCs Nuclear Emergency Response** (10)
- RSMCs Non-Nuclear Emergency Response** (2)
- RSMCs Sand Dust (2)
- RSMCs Nowcasting (3)
- RSMCs Limited Area Ensemble NWP (2)
- RSMCs Global Ensemble NWP (7)
- RSMCs Limited Area Deterministic NWP (6)
- RSMCs Global Deterministic NWP (8)

* World Meteorological Centres are also Global Producing Centres for a) Deterministic Numerical Weather Prediction, b) Ensemble Numerical Weather Prediction, and c) Long-Range Forecasts.
** RSMC for nuclear and non-nuclear emergency response have Atmospheric Transport and Dispersion Modelling (ATDM) capabilities.
*** NRT stands for Non-Real-Time
DESIGNATIONS USED
The depiction and use of boundaries, geographic names and related data shown on maps and included in lists, tables, documents, and databases on this web site are not warranted to be error free nor do they necessarily imply official endorsement or acceptance by the WMO.

WMO Designated Global Data-processing and Forecasting System Centres

- Long-range and Climate Forecasting (over 30 days)

Updated on 26 September 2018

Legend

- World Meteorological Centres (WMCs)* (9)
- RSMCs(NRT**) Lead Centre for coordination of ADCP*** (1)
- RSMCs(NRT**) Lead Centre for coordination of LRFMME**** (2)
- RSMCs(NRT**) Lead Centre for coordination of LRF verification (2)
- RCC - Networks Regional Climate Prediction and Monitoring NODEs (11)
- RCCs Regional Climate Prediction and Monitoring (8)
- GPC for ADCP*** (4)
- GPC for Long-Range Forecasting (13)

* World Meteorological Centres are also Global Producing Centres for a) Deterministic Numerical Weather Prediction, b) Ensemble Numerical Weather Prediction, and c) Long-Range Forecasts.
**NRT stands for Non-Real-Time
***ADCP stands for Annual to Decadal Climate Prediction
****LRFMME stands for Long-Range Forecast Multi-Model Ensemble

DESIGNATIONS USED
The depiction and use of boundaries, geographic names and related data shown on maps and included in lists, tables, documents, and databases on this web site are not warranted to be error free nor do they necessarily imply official endorsement or acceptance by the WMO.

Figure 2: The GDPFS is organized as a three-level system to carry out functions at global, regional and national levels: World Meteorological Centre (WMC), Regional Specialized Meteorological Centre / Regional Climate Centre (RSMC / RCC) and National Meteorological Centre (NMC)

upper chart: Nowcasting and Weather Forecasting Centres
lower chart: Long-Range and Climate Forecasting Centres

The GDPFS has proven to be an effective mechanism to make these modeling and prediction capabilities available to countries that do not have them, so that they can provide better meteorological services to their populations. This is achieved, in most cases, by taking relevant information from advanced centres and passing it on to less advanced countries through Regional Centres, tailored to their needs and capabilities. However, more and more, the private sector is becoming active in the delivery of value-added meteorological and related services around the world, requiring new partnership approaches to be developed. The growth of “the Cloud”, the development of Artificial Intelligence (AI), the growing application of machine-learning techniques to weather, climate and ocean data and the explosion of data availability from the Internet of Things (IoT), crowdsourcing, and new space-borne platforms (both traditional public-funded missions and private-funded missions and micro-sat constellations), as well as the rapid growth of social and other media as innovative ways of disseminating and accessing information, is leading to many non-traditional ways of generating and delivering weather, water and climate data and services. There are also growing capabilities outside of the current GDPFS that develop environmental-oriented services, such as atmospheric composition forecasting (e.g. Copernicus Atmospheric Monitoring Services). Moreover, many forecast products are becoming available from the academic sector, research institutions and NGOs, calling for linkages and integration in order to guarantee better services to Members. The design of the future GDPFS recognizes the importance of partnerships to enable this integration.

4. Vision for a future integrated, seamless GDPFS

The Seventeenth World Meteorological Congress (Cg-17, 2015 - Resolution 11) decided “to initiate a process for the gradual establishment of a future enhanced integrated and seamless WMO Data-processing and Forecasting System” and, among other things, requested Executive Council to “submit a comprehensive report on the integrated and seamless WMO Data-processing and Forecasting System to Eighteenth Congress”. Subsequently, the sixty-eighth Session of WMO Executive Council (EC-68, 2016) – Decision 55) decided to establish a Steering Group to address Resolution 11 (Cg-17) and EC-69 (2017) requested that it “Complete the Implementation Plan of the seamless Data-Processing and Forecasting System for consideration by the Executive Council at its seventeenth session (2018)”.

EC-68 endorsed a Vision for a future Seamless Global Data-processing and Forecasting System (S/GDPFS) with the following characteristics.

(a) Building on the existing architecture, the future S/GDPFS will become a flexible and adaptable ecosystem of independent centres that will expand and strengthen prediction of the environment, making impact-based forecasts and risk-based warnings accessible, thus enabling Members and partners to make better-informed decisions.

(b) The S/GDPFS will provide standardized state-of-the-art interfaces to facilitate partnerships and collaboration globally and regionally among jurisdictions, academia and the private sector to access and make available related information of relevance to the mandate of WMO across all timescales and domains of the Earth system.

(c) The S/GDPFS will, as much as possible, share authoritative weather, water, climate and related environmental data, products and services freely and openly and in a viable and sustainable way, ensuring no Members are left behind.

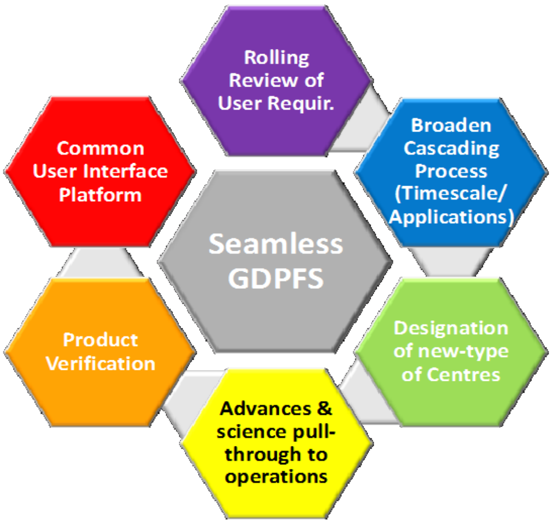


Figure 3: Process that enables the sharing of relevant weather, water, climate and related environmental data, products and services to Members within a Seamless GDPFS. The arrows indicate the pathway from identifying requirements to providing new information.

As stated in the draft WMO strategic plan for 2020-2023, the fundamental responsibility of GDPFS (Strategic Objective 2.3) will be to enable access to, and use of, the state-of-the-art numerical analysis and prediction products at all temporal and spatial scales. It is a high priority that the Seamless GDPFS will assist Developing and Least Developed Countries to make significant progress towards community resilience and reaching Sustainable Development Goals.

Figure 3 illustrates some key components of a Seamless GDPFS to meet this objective:

- In order the ensure the relevance of a S/GDPFS, a Rolling Review must collect, vet, and record user requirements, and match them with the advancing capabilities of technology and techniques within Earth system prediction. The Cascading Process, and the composition of a collaborative network of Centres within a S/GDPFS, will therefore need to be broadened and optimally designed.
- Roles for meteorologists and hydrologists will also broaden, and the "human/machine mix" will be optimized to extract insight and value from the wealth of model and observational data. An interactive model linking science and services will facilitate training and development of operational staff. It will also enable the pull-through of new observational and predictive capabilities into operations and to feed the needs of users back into research (the so called R2O and O2R functions). Establishment of new partnerships with other relevant disciplines (within government, academia and the private sector) will enable this "earth system enterprise" to better serve the needs of their customers and a broader cadre of key stakeholders.
- The Quality Management System will also broaden to verify the added-value of this seamless approach to meet societal needs. Furthermore, the delivery of the data and tools needs to be accessible by all users through a common interface.

One may imagine a S/GDPFS in 2035, where Members will have access to the environmental information they need for sustainable development and resilient communities. S/GDPFS will be facilitating the attainment of sustainable development goals (e.g. UN Agenda 2030) related to water resource management, food and energy security, and ecosystem function.

Some of the attributes to enable this include:

- There is a greater emphasis on probabilistic forecasting and coupled Earth system modelling to improve predictions over longer-time scales and climate simulations and sub-seasonal and seasonal time scales are skillful enough to support more of societal needs than ever before.

- The overall accuracy of state of the art global weather prediction models has improved enough to add 1.5 days of overall predictability. Global models have resolutions below 5km, and regional models significantly below 1km, down to a few tens of meters in urban areas for example.
- Real-time observations, nowcasting simulations, and the output of numerical weather and Earth system models are integrated in continuous manner. This will enable a seamless probabilistic approach to warning of severe weather and environmental events from minutes to hours.
- The system enables not only prediction, but historic and contemporary analyses as well.
- The system will support highly informed decision-making in many areas, including water management (dams, transboundary), water scarcity, water related disasters (flood, drought), and sanitation; therefore contributing to the UN water agenda.
- The system has evolved through partnership agreements that allow it to absorb or carry information produced either by the private sector, or by other organizations related to the traditional NMHSs.
- Embedded in the design of the system is a direct feedback capacity between the providers and the receivers of the data and products that feeds into the rolling review of user requirements that informs research directions and product development.
- Most, or even all, of this information is accessible as a public good product to all WMO members and their partners, and most of this information is available either in native format as input to Decision Support Systems, or directly as impact information. It is disseminated and presented in accordance with users' formats using point to point, or increasingly, cloud to point communication broadband technologies. It is quality controlled, validated and has metadata information associated. In the case of forecast information, it is verified. All this requires a strong coordination with other WMO initiatives.
- Models will consider human behaviour, social and economic response, and human interactions with other biotic and abiotic components of the Earth system.

Earth System Prediction: the seamless vision

The grand challenge of accelerating advances in Earth system observation, analysis, and prediction capabilities was postulated by Shapiro et al. (2010). In this context seamless prediction was introduced for sub-seasonal to seasonal prediction to span the boundary between weather and climate (Brunet et al. 2010). These authors extended the use of seamless beyond the realm of atmospheric predictions to include the consideration of biophysical, medical, and socioeconomic factors pertinent to successful decision making.

At the World Weather Open Science Conference (2014) seamless prediction was used more generally to cover timescales from minutes to months, considering all compartments of the Earth System including hydrology and atmospheric composition, and linking to users, applications and social sciences

Seamlessness is now viewed as a useful concept to express the need for information for users, stakeholders, decision makers that is smooth and consistent across the artificial barriers that exist because the information comes from different observing systems, models, time and space scales, or compartments of the earth system. Thus, in the context of WMO, seamless prediction considers not only all compartments of the Earth system, but also all disciplines of the weather–climate–water–environment value cycle (monitoring and observation, models, forecasting, end-user products, dissemination and communication, perception and interpretation, decision-making) to deliver tailor-made weather, climate, water and environmental information covering minutes to centuries and local to global scales.

The importance of cooperation within the “Weather Enterprise” (government, non-government organizations and societies, private-sector and academia) was another conclusion of the World Weather Open Science Conference (2014). A seamless vision needs to expand this into the concept of an “Earth System Enterprise”, where the partnerships expand into a number of other disciplines in order to address the broad needs of society.

5. Benefits of S/GDPFS

A GDPFS evolution will allow the generation of products and delivery of services in environmental areas beyond the original paradigm of weather delivery system. It will take advantage of technological and social developments in order to increase its usefulness and maintain its relevance to Members by taking a verifiable Earth system approach. Most important, it will provide critical data to Developing and Least Developed Countries. Building on the existing architecture of the GDPFS, a future S/GDPFS will become an ecosystem of independent numerical predictive systems that will further strengthen the ability to predict changes to the state of the environment. It will facilitate the sharing of this predictive environmental data and re-usable content for the benefit of all our Members; so no Member is left behind.

Members will be better able to harness the increasing power and scope of environmental prediction infrastructure in order that;

- enhanced information is available to make quicker and better decisions;
- improved access to information and data by NMHS saves time and resources, allowing them to add more value to their services.
- Members have the tools and skills to handle the growing and complex data and information;
- NMHSs have more time to apply skills and expertise through further automation of routine tasks;

- new observations, new science and new technologies are pulled through into operational services; and
- by 2025, in line with WIS 2.0 implementation plan milestones, the further development of S/GDPFS will result in substantial benefits for developing NMHSs.

The Future S/GDPFS will also bring benefits to broader user communities including:

- stakeholders responsible for preparedness for a wider variety of high-impact events;
- sectors impacted by weather and climate (e.g. energy, agriculture, health, integrated water resource management); and
- urban stakeholders and city planners.
- United Nations and other humanitarian agencies, including NGO's.

It is also important to note that products based on outputs from multiple WMCs are routinely being used even in countries with advanced centres. Operational multi-model products and services combining outputs from more than one WMC are in place, such as the North American Ensemble Forecasting System (NAEFS). Furthermore, even in countries having access to a WMC, forecasters routinely consider forecasts from multiple WMCs in order to improve the guidance. Although the data sharing mechanisms are not perfect, the value of this exchange of information is already clear to forecasters and some end-users

The evolution to a S/GDPFS also needs to support the Overarching Priorities being recommended related to the WMO Strategic Plan:

- Reducing losses of life and property from hydro-meteorological hazards.
- Supporting climate action to build resilience and adaptation to climate risk.
- Enhancing socioeconomic value from hydro-meteorological and climate services.

All of the Goals, and a substantial number of Strategic Objectives, will be supported by the S/GDPFS.

The WMO serves the interests of its Members. It seeks to support them in achieving their goals in the most efficient and cost-effective manner possible. In particular, WMO Members are committed to delivering high-quality weather, climate and water information and services that will assist decision-makers at all levels of society. S/GDPFS will be critical to achieving this mandate.

6. Implementation Pathway

An important objective of this Implementation Plan (IP) is to lay out, at a high level, some of the challenges, opportunities, and actions that must be considered. It is ultimately a priority to identify the desired outcomes of the IP: effective decision-making that results in minimized impacts to society, enabled by highly qualified professionals.

To ensure these outcomes are achieved, an appropriate design must include sound governance, strategic partnerships, and a quality management system (QMS) that sets targets and measures performance in achieving the outcomes. In addition, three core elements have been identified to enable effective implementation: the development of the S/GDPFS system; the delivery of necessary research and innovation; and the enhancement of the accessibility of the information. Finally, in order to close the gap between science and services, we need to develop a new interactive model linking science and services.

Figure 4 illustrates this pathway to implementation, including design and core elements to achieve the priority outcomes of a S/GDPFS. This section will highlight each of the components described in the pathway, and conclude with a summary of some of the challenges requiring consideration. This is followed by Section 7, which identifies a number of specific recommended actions.

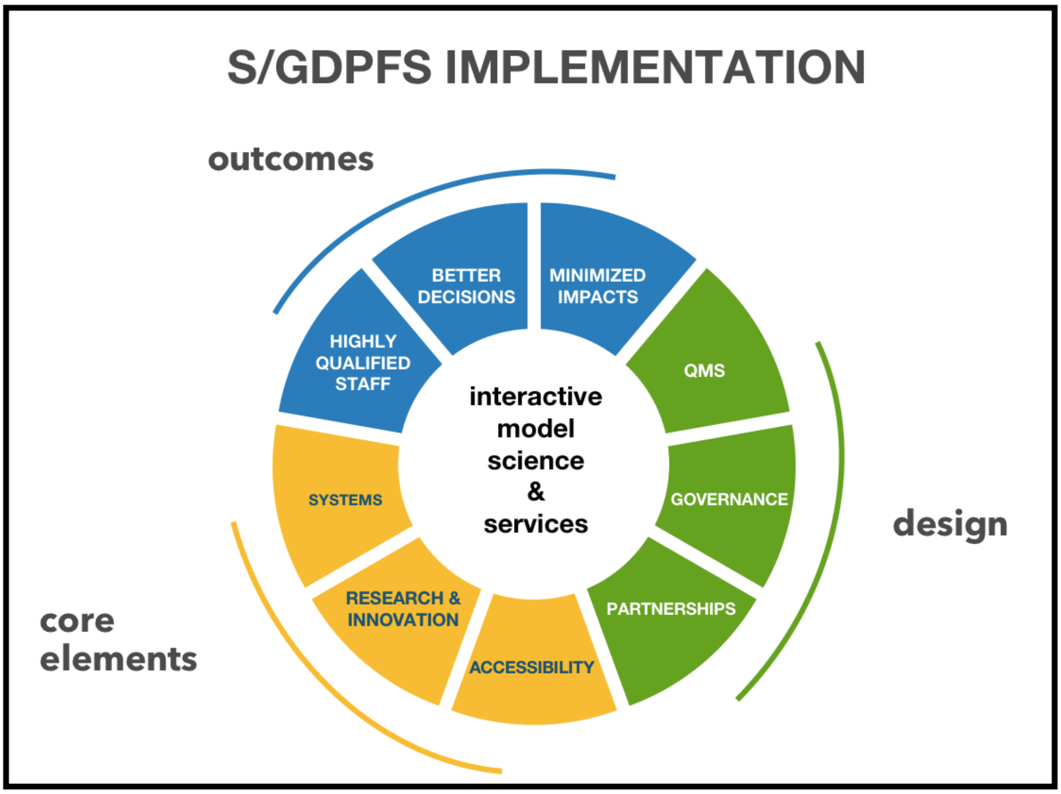


Figure 4. Illustration of key components of the S/GDPFS Implementation Plan.

There will be specific well-defined projects over four-year increments (including a look-ahead to the subsequent four years) to align with the WMO planning schedule. A key part of the implementation of the future S/GDPFS will be the definition and carrying out of benchmarks, pilot projects and test beds. These can, for example, allow some of the more challenging aspects to be tested in a research or quasi-operational setting. Some of these will address overarching challenges or be associated directly with the recommended priority actions within the core elements (System, Research and Innovation or Accessibility). Others will be cross-cutting in nature. Many projects currently underway are implicitly linked with the implementation of a S/GDPFS and will be highlighted in text boxes throughout this plan along with other proposed pilots. These projects can serve to demonstrate that we are already headed down a path of implementation and can represent "early wins" following formal approval of this IP by Congress.

6.1 Overall Design of S/GDPFS

6.1.1 Business Model and Governance

The business model and governance for the future S/GDPFS will need to facilitate the development of flexible and timely services, and open new perspectives for win-win solutions between regional, global, national and transnational partners. Ideally, it will demonstrate how a broad spectrum of users will concretely benefit from interoperability, coordination, and integration.

Governance mechanisms will be improved to identify and fill internal gaps in capabilities, avoid proliferation of centres to avoid duplication of effort, and sharpen

> A Steering Group for implementation of the S/GDPFS has already been established and has sought the necessary EC approvals along the way. EC 70 endorsed the approach for the development of Plan and requested consultations with Members to finalize the Plan for approval at Cg-18.
>
> The Manual on GDPFS has been updated to include designation of new types of Centres. The revised version has been published in Feb 2018

Project 1: Establishing the governance the WMO centre designation process while allowing it to broaden coverage to include Earth system compartments.

Governance will be challenged by the breadth of partnerships required within a seamless and impact-based service delivery system. In particular, partnerships with the private-sector and other agencies within the context of the authoritative status of NMHS to issue warnings, will need to consider the fact that some environmental threats (e.g. flooding or air quality) may be outside of the mandate of the NMHS. In addition, some public-good utilities use private sector weather services to provide forecast and warning advice.

6.1.2 Quality Management System

All facilities of the future S/GDPFS platform will need to adhere to a Quality Management System (QMS) and will be regularly audited by the WMO secretariat for compliance with designation criteria so as to best meet the requirements of users. Verification procedures will be established with reporting and tracking of data and product qualities.

There is an opportunity to identify and partner with end users to obtain their feedback and initiate activities to provide the necessary improvements in products and services. This feedback will also assist in identifying research and technological improvements. Ultimately, these mechanisms and the involvement of the operational forecast desk in evaluating S/GDPFS products will ensure continuous improvement of services and assist Members to achieve the standards that will be developed within the QMS.

> The revised Manual on GDPFS (WMO-No.485) clearly regulates the functions of GDPFS Centres. The general requirements of all GDPFS Centres include documentation of systems and products, product verification and reporting on compliance. A regular audit of GDPFS Centres will be conducted to ensure the quality and the sustainability of their products and services. OPAG-DPFS is developing a common audit process that is applicable to all type of GDPFS Centres.

Project 2: Establishing a Quality Management System

It is recognized that there will be challenges to design an effective QMS where relevance is measured (including that related to reduction in impacts), and includes products and systems being provided by partners. Furthermore, a QMS that facilitates cost-benefit analyses would be of significant value to all partners.

6.1.3 Partnerships and Resources

Facing the challenges for developing the future S/GDPFS necessitates a move away from an isolated view on each major component, both of the Earth system and of the weather enterprise. Substantial work is required to better connect different elements, especially those addressing exchange processes at various interfaces and complex feedbacks. Key sectors of an “Earth system” enterprise (i.e. public, private, academia, and non-government organizations) and their interfaces have to be identified, and ideas that enable a smooth interaction across the interfaces have to be developed jointly by all players involved.

Examples of this with private sector interests include, among others, the interaction between the Earth system science community and the reinsurance, energy, water utility or transportation sectors; or between satellite developers and users of advanced satellite data. It is important to recognize that many “non-weather enterprise” activities contribute to shared societal benefits, including public safety and resilient communities. It is recognized that there may be issues arising from these new relationships, including those related to the free and open access to data.

> Pilot projects in the field of big data and analytics currently underway could be used to demonstrate the potential of bringing these private sector applications to the data.

Project 3: Develop Public-Private Partnerships

Such a co-designed process that connects all relevant components of research and applications, and the key contributors, can be of mutual benefit to all parties involved; but some efforts might be required to move toward such an approach. Ways have to be sought to get all key value-cycle contributors involved to create a culture of co-designing a common vision for achieving sustainable development goals. This includes clearly defining the responsibilities in implementation, as well as its availability, usage and dissemination, and could leverage access to additional financial resources. For example, opportunities exist within the societal sectors where effective user engagement is already taking place, or from international funding structures (World Bank, Green Climate Fund, Global Environmental Fund, regional banks, national authorities).

This co-designed process needs to work not only at the global level but also at the regional, national and local levels

Implementation will need to take advantage of existing, or creation of new networks or communities of practice. These will allow stakeholders with different kinds of knowledge and ways of tackling problems to cross-fertilize ideas which in turn drives innovations. To implement the future S/GDPFS, this networking must be leveraged to promote innovation in the Earth system sciences and a better link be established between WMO activities and related existing or new initiatives.

The objective for S/GDPFS is for a nimble, responsive and efficient program. Given that many if not all Members are challenged with dealing with increased public expectations within a tight fiscal environment, as well as the growing costs of High Performance Computing and Data Transfer systems, it is recognized that the implementation to a Seamless GDPFS is likely to be a gradual evolution. This implementation will require building on existing initiatives, and the development of new innovative partnerships.

6.1.4 Training and Education

A strategy to develop a skilled, trained, knowledgeable, innovative and diverse workforce will be implemented. The recognition of the critical need for skilled personnel in key components of seamless prediction from research to operations and services will result in a stronger emphasis on entraining early career scientists into WMO activities and providing them with attractive career paths to meet needs and requirements for the future. The development of the S/GDPFS will be accompanied by training methodologies, with support from regional partnerships (e.g. RMSC's and SWFDP's) and pilot activities, to increase the capacity within NMHSs and other end users to use platforms, information and tools at all levels from global to local. Particular focus will be on novel web-based E-Learning modules, apps and a range of other tools reflecting best practice. Coordination with other technical programs (e.g. Public Weather services (PWS) for competencies and service delivery, Education and Training (ETR)) will be required for success.

A close relationship between research and operations will facilitate training and development. The research community is well-positioned to have an important role in the transfer the knowledge from advances in science and technology to the operational communities. Furthermore, a close relationship with operations will enable them to concentrate on innovations that address the priorities for improved products and services. The interactive model, discussed in 6.3.2, is an important enabler for effecting training and development.

6.2 Core Elements for Implementation

The foundation of the S/GDPFS comprises the integrated and seamless Earth analysis and prediction system; the research and innovation to enable the generation of high quality and relevant products and services; and the platform to ensure users and stakeholders have reliable access.

Figure 5 illustrates the value chain where these core elements form a feedback loop whereby the joint effort of the science and user communities results in the generation of information to meet the needs of an increasingly vulnerable society.

6.2.1 An Integrated and Customized S/GDPFS System

The operational predictive capability of the future S/GDPFS will be integrated across multiple time and space scales from weather to climate and address a broader spectrum of user needs, recognizing that this requires an Earth System modelling approach (Atmosphere, Land (vegetation, soil, cities, etc.), Ocean, Rivers, Lakes , Ice, Atmospheric Composition and Chemistry) including an effective representation of uncertainties and interfaces through the exploitation of a diverse set of observations. It will provide the data, information and re-usable content needed to analyze and predict the environment in a consistent and harmonized way. The flexibility to provide different options such as generation of tailored products from large ensemble datasets for specific user needs or providing Earth System Service requirements on demand will be explored.

> Use the Flagship Polar Prediction Project to look at the stakeholder requirements with the aim of identifying how the future requirements might develop across a range of time and space scales.

Project 4: Assessing future multiscale requirements:

6.2.1.1 Interoperability: The future S/GDPFS will be able to exchange and use data from a variety of sources, including vulnerability and exposure data to facilitate impact-based forecasting and risk-based warnings across different disciplines. Interoperability will also require the development of common data formats for new technologies such as data from cars, home weather stations, smartphones, allowing users to combine numerical environmental prediction data, information and content with other third-party data as well as the latest science to develop authoritative, quality assured advice of the future state of the environment in a cloud environment.

6.2.1.2 Coordination and Regulations: The future S/GDPFS will benefit from a higher level of coordination internally (for the integration and interaction of individual components - WMC, RSMC, NMC), other WMO systems (e.g. the GFCS – Climate Services Information System) and with external agencies and organizations. The introduction of a revised and evolving Manual on GDPFS will continue to promote the exchange of information and expertise and guarantee balanced coordination including extension over other disciplines and services**.**

6.2.2 Research and Innovation

The Research and Innovation component of S/GDFPS will strengthen the science linkages among compartments of the Earth system to allow the spawning the development of novel operational products, exploit predictability on all time-space scales, adapt to emerging technologies, and promote socio-economic research within the Earth System enterprise value cycle (see definition of seamless prediction and the Earth System Enterprise in section 4 above). Key elements are modularity and operational-oriented development of modeling and data tools, open-source strategy together with a specific data-policy for science, and the availability of tailored observations for advancing earth system models. Reliable access to quality-controlled global data and models for research purposes are essential, through a 2-way approach where research can contribute and beta-test new modeling capabilities. A well-established rolling review to understand user requirements in all socioeconomic sectors that also collects requirements outside of the WMO domain acts as a key input to research in support of the development of impact-based, user-focused services.

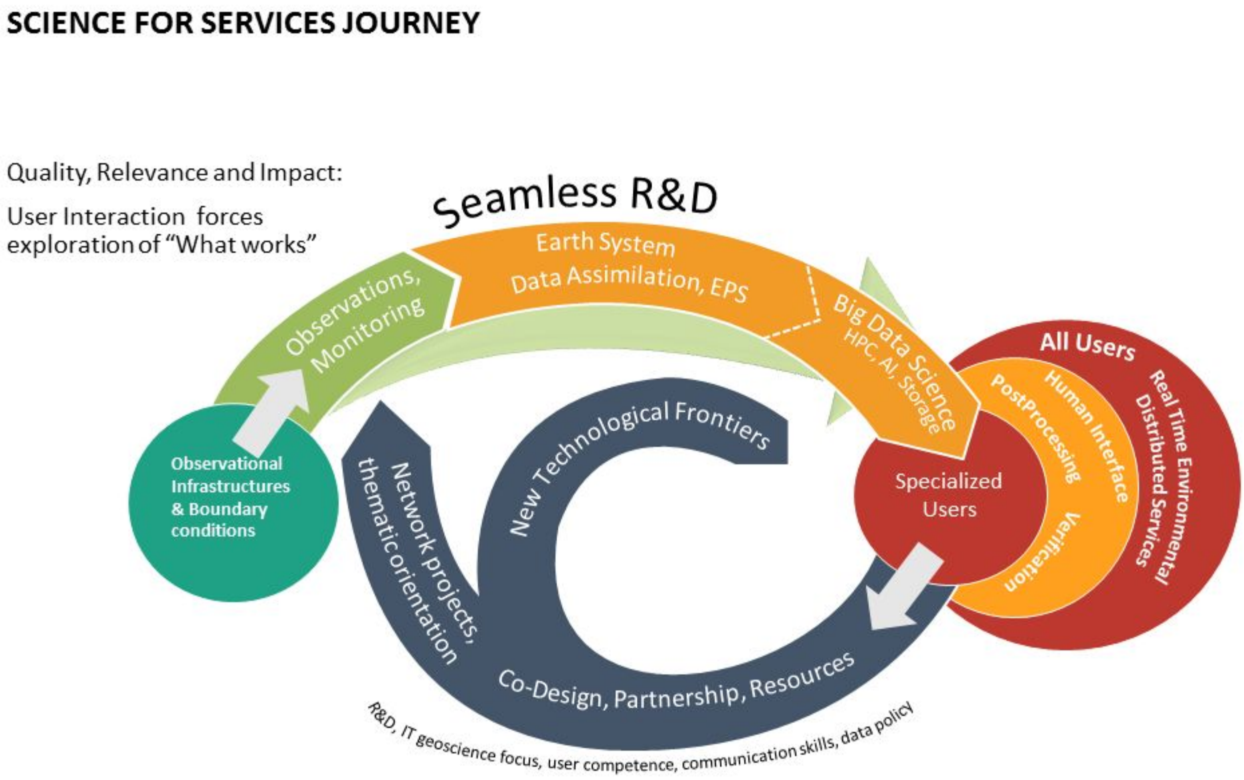


Figure 5. A value cycle approach encompasses the whole value chain from observations (green components), through production of forecasts and products (orange component), to the engagement of users (red components) and calls for a co-designed approach, featured through a feedback loop (grey components) to achieve scientific breakthroughs that serve society. From Ruti et al. (BAMS, 2019).

6.2.2.1 Science for Services

The Research and Innovation component will be focused on delivering the required scientific advances through the following actions:

- Implement a value cycle approach to set research priorities, using knowledge of predictability to focus research efforts in areas where success is expected.
- Co-design operational projects that rely on research advances.
- Develop an integrated approach for research programs spanning weather, climate, water and environment.
- Engage with research funding agencies.
- Ensure availability of data/models/tools for research purposes.

6.2.2.2 Seamless Prediction

Research in all relevant disciplines will facilitate delivery of tailor-made information from minutes to decades, from global to local and for different domains of the Earth System through the following actions:

- deliver the underpinning science necessary to advance earth system prediction through international coordination;
- facilitate research across relevant disciplines to provide seamless information to users, stakeholders, decision makers;
- contribute to development of the observing system; and
- conduct research to demonstrate the benefit of advances in seamless prediction.

6.2.3 Accessibility and Web Platform

The accessibility of data, products and services from the S/GDPFS will be complemented and facilitated by the future plans for the federated WMO Information System (WIS 2.0).

WIS 2.0 acknowledges that the constant increase, in the flow of data and information to be disseminated to various users, means that it is necessary to re-think how data is processed, managed and shared. In particular, data volumes created by earth observing and numerical prediction systems continue to grow considerably faster than the performance of telecommunications networks. Furthermore, other sources of information are becoming available that may have data volumes that exceed those of traditional data sources.

Meanwhile, users expect to access weather, water and climate information and services through the same mechanisms that they use for other types of information, using familiar interfaces and applications. They also wish to combine mobile, cloud and social technologies to access a wider range of information sources and to collaborate in new and different ways.

Common data sharing platforms and technology are a prerequisite. However, this is a challenge. For example, risk reduction and emergency response requires collaboration with multiple agencies. As well, assessing the impact of environmental hazards requires meteorological data to be combined with other socio-economic data. At the same time, changes in technology present new opportunities, such as the increasing use of the Web as a data sharing platform.

6.2.3.1 Availability and Visibility

The system will provide access to data, models, products and software packages in a user-friendly manner, ensuring interoperability and integration with other systems, geospatial reference data, metadata and advanced standards and documentation. Technological aspects such as federated nodes and bandwidth issues will be considered and linked to WIS development, while S/GDPFS will implement those parts not implemented by other WMO initiatives. The whole S/GDPFS infrastructure will be visible and easy to identify. Use cases and success stories will be at the forefront, making clear the benefit of the S/GDPFS integrated value cycle.

6.2.3.2 Usability: Monitoring Software and user-oriented tools

A dedicated effort and investment in software infrastructure will produce web-tools for handling data and creating on-demand products based on core requirements; the maintenance of metadata and infrastructure will be clarified in collaboration with WIS and WIGOS. The usability of the future S/GDPFS will be enhanced significantly, considering aspects such as authenticity of the source, quality of access and cost effectiveness. Focus areas are providing tools/documentation on how to combine / interpret multiple datasets, providing guidance on seamless products (Help desk services), developing integrated web-tools for tailoring information, ensuring local ownership and developing downstream statistics.

6.3 Cross-Cutting Components

The success of the S/GDPFS will be measured by its ability meet the needs of Members and key partners, with a strong emphasis on developing and Least Developed Countries. Ultimately, more effective decision-making will result in minimized impacts from environmental change and extreme events.

There are two key cross-cutting considerations that will greatly facilitate the achievement of the outcomes:

- the development of impact-based forecasts by highly qualified forecasters; and
- an interactive approach that will enable the important link between science and services

6.3.1 Impact-Based forecasts and the Role of the Forecaster

To close the gap in the understanding of potential impacts, an all-encompassing seamless approach to observing, modelling and predicting severe hydro-meteorological events, and the consequent cascade of hazards through to impacts, needs to be developed. This will require a multidisciplinary, highly integrated and directed scientific endeavor within a S/GDPFS to translate natural hazard risk into impact services, and a validation process to assess service benefits and performance bespoke to users.

> A pilot project linking the Coupled Hydrologic, Hydrodynamic, and Atmospheric Modelling Program (CHAMP) project with Global Flood Awareness System (GLOFAS) coordinated with the Global Hydrological Status and Outlook System (HydroSOS) to develop experimental hydrological products such as ensemble streamflow forecasts, flood warnings, and net basin supply prediction.

Project 5: Developing probabilistic hydro-meteorological products

Data processing strategies will also need to be revisited in order to capture, exchange and integrate information on vulnerability and exposure, as well as impact observations, into seamless prediction systems.

Furthermore, the evolution towards impact-based forecasting combined with the increased automation of products and warnings will require a transition of the role of the forecaster. This will require the forecasters to develop additional skills and experience with a variety of other disciplines as well as increasingly taking on an advisory function. There will be mutual benefit from relationships with existing and new users, stakeholders and partners from both the private and public sectors.

Forecasters and product developers will be working collaboratively with researchers to develop new tools and approaches, applying analytical and artificial intelligence techniques on the enormous amounts of available data.

This shift requires the implementation plan to acknowledge the critical value of training, as well as an interactive model linking science and services.

6.3.2 Interactive model linking science and services

Achieving the ambitious vision of the future S/GDPFS requires a new interactive model for integrating science and services. This interactive model will increase the effectiveness of the planning of research activities and the knowledge transfer between research and operations to provide improved weather, climate, water and environmental services to Members. Such a model will include multiple interactions between the research and operational communities to address the needs of users, stakeholders and decision-makers.

> A joint activity of the Lead centre for long-range forecasting and the Seasonal-to-subseasonal Prediction Project to enhance visibility of the lead centre, improve access to data and quantify its usage, define and implement an interactive science-to-services approach based on the value cycle for selected applications.

Project 6: Advance seamless prediction at the weather-climate interface:

During this process stakeholders, assess and articulate their future needs, researchers work in dialogue with stakeholders to define and implement appropriate research programmes, the research results are transferred into operations at appropriate intervals, and the stakeholder needs and research programmes are refined taking into account the knowledge and experience gained through the use of operational products and services. Success will depend on bringing together people working at interfaces of forecasting – product development – research who are open to new ideas and different ways of working.

This interactive model must coordinated as a high-level activity encompassing different WMO initiatives with operational and research components. It would provide a mechanism for coordination across the WMO working structures, rather than being part of the S/GDPFS structure, but would contribute strongly to the S/GDPFS implementation.

A particular challenge for such a model in the context of the S/GDPFS is that we are not working in the context of a single organisation with well-defined line management structures. The operational system is currently founded on contributions from many different NMHSs. The research and innovation relies on international partnerships between NMHSs, public research institutions and the academic research community. Thus, traditional models for linking research and operations (often referred to as R2O and O2R functions) that work for a single organisation will not be sufficient here. Future development of the S/GDPFS relies on strengthening the operational and research partnerships to the mutual benefit of the organisations involved as well as exploring the role of the private sector. If this model is well-conceived and implemented, the research capabilities relevant for the GDPFS within NMHSs and in the broader research community will be strengthened, the linkage between science and services enhanced.

Some of the key features of a new interactive model are:

- co-design by attempting to actively involve all stakeholders in the design process to help ensure the result meets their needs and is usable for all activities that require research and innovation;
- identifying user needs based on specific sectors / applications as well as across sectors and applications;
- enabling the co-existence of long-term strategic research projects and short-term tactical innovation responding to stakeholder needs;
- cooperation with partners in other components of the Earth System (e.g. the Intergovernmental Oceanographic Commission and the International Hydrological Program in UNESCO, the International Association of Hydrological Sciences); and
- Engaging with social scientists, impact researchers, relevant communities of practice, the private sector and economists to identify the main user requirements and deliver the necessary innovation.

Some of the considerations and questions that can help in developing this model are:

- Using a value-cycle approach, a clear articulation of research priorities and needs at the global and regional levels is one mechanism to boost innovation. One of the reasons that science coordinated by WMO and its Members is at the global forefront, is because of the established vision in developing long-term projects to pursue fundamental research questions. What are the future priorities for long-term projects that could attract strong interest from donors and key stakeholders? What mechanisms exist or must be developed to translate this interest into concrete research programs? What are the measures of success to judge the achievements of such programs?
- There is a need to complement a long-term perspective, challenging the research community with short-term ad hoc projects as accelerators for technological development and networking capacity. What mechanisms can be developed for this purpose?
- Currently, the involvement of the private sector in all aspects of weather, climate, water and related environmental topics and the development of new technologies is increasing. What are the opportunities and risks related to research and innovation in this context?

Effective links between science and service will evolve based on lessons learned and best practices from existing approaches in a number of NMHS's, as well as the success of pilots and demonstration projects.

Ultimately, effective service delivery will require this linkage to extend into the user community, benefitting from an understanding of vulnerabilities and decision-making approaches.

7. Action Plan

A fundamental premise of the implementation plan is to improve and build on the solid foundation of the current GDPFS system whilst extending it to allow for new capabilities and deliver seamless Earth System services. This implementation plan will be further developed and refined in preparation for submission to Cg-18, responding to the decisions of EC-70, in close consultation with the WMCs and RSMCs, and taking input from all relevant WMO programmes, from the WMO Technical Commissions and Regional Associations and from associated programmes and external partners. This initial consultation process will also help develop a process for continued collaboration during the implementation phase.

Priorities for the implementation will be set based on some key criteria including:

- responding to specific geographical needs and the needs of developing countries;
- building on existing and emerging data platforms and activities;
- providing information urgently needed for decision making;
- ensuring the relevance of services provided by WMO members (e.g. impact-based forecasting);
- making global infrastructure available regionally and locally combined with local-regional input feeding back to improve the system; and
- enabling WMO and its Members as a whole to support United Nations and other humanitarian agencies.

This section includes a series of priority actions. However, it is recommended that these be used as context to explore existing and potential projects that can be used as benchmarks, test-beds or pilots.

Current initiatives that meet many of the above criteria should be examined in order to provide a potential framework for implementation. For example, the Polar Prediction Project/Year of Polar Prediction has a well-developed Implementation Plan. The Severe Weather Forecast Demonstration Project is another example.

The Climate Risk and Early Warning Systems (CREWS) initiative provides a framework for an initiative involving important external partnerships. CREWS aims to significantly increase the capacity of Least Developed Countries (LDCs) and Small Island Developing States (SIDS) to generate and communicate effective, impact-based, multi-hazard, gender-informed early warnings and risk information.

In the medium-term, there are a number of actions identified related to the three key strategies: Systems, Research & Innovation, and Accessibility.

Furthermore, given the fact that the identified issues and opportunities will benefit from a strong relationship between research and services, the development of an innovative interactive model for two-way technological and knowledge transfer knowledge transfer is a fundamental component of S/GDPFS implementation.

7.1 S/GDPFS: Evolution through Pilot Activities

A key part of the ongoing implementation of the S/GDPFS will be the definition and carrying out of pilot projects and test beds. These will be designed and prioritized in order to evaluate the outcomes achieved, as well as the identification of strategies and options to address the challenges within the Design and Core Elements of this Implementation Plan.

This will include the exploration of innovative approaches to link science with services and the opportunity to empower partnerships (e.g. neighboring countries could work together on specific areas of mutual interest; NMHS's could work with the private-sector to improve services; or researchers and forecasters could join forces in an impact-based forecasting initiative).

A pilot activity envisaged under the auspices of Global Atmosphere Watch to develop monitoring, analysis and forecasting systems from Pan-African to Urban scale to inform populations of expected acute pollution events.

Project 7: Develop Integrated Air Quality Prediction and Forecast Systems in Africa:

Currently a number of existing and potential future activities have been identified, examples of which are given below. These will be explored further at the meeting of World Meteorological Centres (WMC) in Beijing, China in late March, 2019. In addition, Use Cases have been created (Annex 2) to illustrate some operational outcomes of a S/GDPFS. The WMC meeting will also be an opportunity to review and refine these examples.

- **Advance seamless prediction at the weather-climate interface:** a joint activity of the Lead Centre for long-range forecasting and the Seasonal-to-Sub-seasonal Prediction Project to enhance its visibility, improve access to data and quantify its usage, and define and implement an interactive science-to-services approach based on the value cycle for selected applications.
- **Advance Seamless Prediction from minutes to hours:** enabling a seamless transition from nowcasting to numerical weather prediction in a probabilistic framework; a pilot project led by the RSMCs for nowcasting, limited-area deterministic weather prediction, and limited-area ensemble numerical prediction working together with providers of global deterministic and probabilistic predictions.

Pilot projects would empower neighbouring countries to work together on specific areas of mutual interest. Partnerships could be built around the new RSMC's for nowcasting in Tokyo and Hong Kong, and the existing SWFDP to co-design activities, develop products of mutual benefit and work together on verification. Such projects can draw on experience from existing activities such as the SWFDPs and Regional Climate Outlook Forums.

Project 8: Developing and strengthening regional partnerships

- **Develop Public-Private Partnerships:** Pilot projects in the field of big data and analytics could be used to demonstrate the potential of bringing the applications to the data to address relevant societal needs. One example could be a "smart city" initiative such as being undertaken for a number of cities in China.
- **Develop Integrated Air Quality Prediction and Forecast Systems in Africa:** a pilot activity envisaged under the auspices of Global Atmosphere Watch to develop monitoring, analysis and forecasting systems from Pan-African to Urban scale to inform populations of expected acute pollution events.
- **Develop seamless probabilistic hydro-meteorological products:** a pilot project linking the CHAMP[1] project with GLOFAS[2] and the Copernicus Climate Change Service (Sectoral Information System: Water) to develop experimental hydrological products such as ensemble streamflow forecasts, flood warnings, water quality and

[1] Coupled *Hydrologic*, Hydrodynamic, and. Atmospheric Modelling Project

[2] http://www.globalfloods.eu/

net basin supply set within a strong community of practice such as HEPEX[3]. This project would be coordinated with the HydroSOS initiative, with global and regional pilot effort so as to give guidance for the development of operational systems in this context.

- **Assess future multiscale requirements:** use an existing Flagship such as the Polar Prediction Project to look at the stakeholder requirements with the aim of identifying how the future requirements might develop across a range of time and space scales.

7.2 Priority Actions to enable Implementation

7.2.1 Systems

- Model/components Interfaces: developing a framework that allows integration of different models and model components across weather, climate, water, ocean and other environmental components while ensuring that these are well configured and compatible; (e.g. improving meteorological-ocean modeling capability and forecasting capacity using fully integrated met-hydro-ocean systems for coastal management).
- Seamless Verification and Quality Management - protocols and layers: establish consolidated seamless methods for weather, climate, water, ocean, atmospheric composition models to enter the operational cycles, and pre-operational phase of verification system.
- Data Store, Infrastructures and Analytics: consolidated solution at global and regional and basin scale; integration of all WIGOS observations; integration of available analysis tools (ex. existing libraries); web services applications for the development of weather, climate, water and environmental information.
- Customization: Extension to hydrological prediction of higher resolution capability that can be deployed at the basin scale by a number of countries with support from regional centres. Extension to atmospheric composition of a relocatable higher resolution capability that can be deployed by a number of countries with support from regional centres.

7.2.2 Research and Innovation

- Interact with users, stakeholders, other research partners and decision makers to determine the value cycle for the key services required by WMO members and identify the corresponding research priorities; have to consolidate requirements by looking at technical, research, application, and service aspects.
- Establish a culture of co-design that includes a path to impacts from the early stages of project design (as illustrated in figure 5), taking into account the research spectrum from fundamental to applied. Work with partners outside the WMO to establish new programmes and strengthen existing programmes so as to fill the gaps in research capability
- Identify areas where access to observations, predictions and projections is not available for research purposes and work with WMO members to remove these restrictions.
- Advance understanding of the coupling between physical processes, society and the ecosystem and the impact on predictability and establish flagship projects to advance further coupling of earth system components, including propagation of uncertainty and changes in vulnerability.
- Advance seamless prediction across significant boundaries in time/space, e.g. minutes to hours, months to years and across domains.

[3] www.hepex.org

- Develop and use integrated Earth System prediction systems to represent the physical, chemical, and biological characteristics of terrestrial and aquatic environments.
- Invest in computing and software development to handle larger and more diverse observational datasets and forecasts with high-resolution coupled ensembles, to deal with the model output, and integrate the value cycle - ideally all of this in an interactive manner.
- Address the challenges posed by merging spatial and time information across scales from different forecast systems in terms of communication and usability of the weather, water climate and environmental information.

7.2.3 Accessibility

- Federate existing web-interfaces and data standards for different communities' needs: International open data policies are a vital component here building on the long-standing sharing of observations (link to WIS and others). Many countries are moving to this open data paradigm which is a key capability and differentiator with commercial interests. Develop real-time verification engine for "simple" use (e.g., hourly/daily precipitations, and max/min temperature) and for extreme events in support of impact-based forecasting (e.g. extreme heat/cold, flooding and high winds). Clarify the governance of the metadata and provenance solutions to merge as many standards as possible and reduce the current confusion between practices to document weather and climate data.
- Develop easy-to-use documentation for all informative contents. Agree on common vocabularies and strategies to document nowcasting systems, prediction models (especially as their complexity increases) and data; ensure that there is a mapping for the different data formats.
- Develop a multiple-tiered approach featuring an uppermost open layer of freely accessible information, and a well-defined data-policy for the other layers, considering a research stream, and ensuring interoperability across the layers; promote the use of Open Geospatial Consortium (OGC) standards for interoperability. Design strategies that explain the different policies applied to each dataset to address questions such as the free access to all to climate data and the mix of open and restricted access to weather and atmospheric composition forecast data. As the service is developed in more instances, advertise the seamless products among weather- and climate-sensitive communities, partnering with sister initiatives like GFCS; work on data policies and documentation with communities who are familiar with the problems of open access and reproducibility.

8. Next Steps: Steering Group and Project Office

While this IP can be considered somewhat of a "roadmap", it is by no means includes the detailed work plans that are needed to identify specific deliverables, their inter-dependencies, the resources required and identification of responsible persons or working groups in carrying them out. Once the Steering Group has established the governance of S/GDPFS, it will be important to task development of detailed plans for implementation to the various Constituent Bodies and their working structures as soon as possible.

The Steering Group must be vigilant in terms of overarching policy concerns and from time to time review and consider the following issues to seek guidance from Congress/EC where appropriate:

- Clarity of the role between the Climate Services Information System (CSIS), the Public Weather Service (PWS) and GDPFS and the integration of activities.

- Clarity on the role of WMCs and RSMC's and their interaction with Members, as well as evolution to a new class or groupings of RSMCs. For example: (i) centres that maintain climate reanalysis, and (ii) centres that provide climate monitoring on global scale.
- Open data/Open source considerations: The default policy should be to respect the principles of Resolutions 40, 25 and 60. The S/GDPFS steering group should stay very vigilant for any issues that come up related to the free and open exchange of data and information that could compromise the effectiveness of the system and raise to EC and/or Congress if necessary for resolution.
- Mandates and legal aspects of NMHSs and partners (e.g. civil protection): in many countries, all applications and sectors that the S/GDPFS wishes to serve may not fall under the jurisdiction of the NMHS or might bring conflicts of responsibilities at different temporal and spatial scales (subnational to national to regional to global). This could limit a Member's desire to become a Centre within the system. The steering group should continually monitor the implementation to deal with these possible conflicts before recommending designation of Centres and in fact this should be built in to the designation process.
- Role of the private sector: the private sector is deepening its reach into the weather forecasting business (e.g. IBM/TWC, Panasonic) and there is an increasing move towards commercialization of data (e.g. space-based EO data services for sale). Congress and EC have noted this and are developing policies and approaches to deal with the situation. The steering group will need to keep apprised as to how this evolves and adjust its plans accordingly to be able to leverage the capabilities of the private sector in implementing an effective S/GDPFS.
- Adaptable governance model: To start, it will be necessary to engage and involve all Technical Commissions and Regional Associations in the implementation of the S/GDPFS. However, it must be recognized that Cg-17 directed the Executive Council to conduct a review of the constituent bodies of the WMO to ensure that it is operating as effectively and efficiently as possible. This could result in a restructuring of the constituent bodies, and this plan needs to be flexible enough to adapt to whatever changes may come.
- Linkages with GFCS, UNISDR (Sendai Framework for DRR), the UNFCC Paris Agreement and the UN Sustainable Development Goals.
- Linkages with stakeholder and industry groups that represent the interests of important users and potential partners (e.g. Geneva Association, International Air Transport Association, International Energy Agency).

The design and development phase will continue until at least the end of 2019 in order to consolidate project participants and contributing stakeholders. Following approval of the implementation plan by Cg-18 (2019), initial implementation activities will start in mid-2019 and by 2025, the core services required for the operation of S/GDPFS will be fully operational, also considering time lines of other WMO initiatives such as WIS etc. At this time, consistent with WIS 2.0, legacy message switching operations will be decommissioned and the GTS as it works today will be phased out. It will be important that S/GDPFS implementation aligns to this key milestone. Beyond that, the S/GDPFS will continue to advance improvements in environmental predictions and service delivery.

The S/GDPFS implementation plan will help Members understand when the transition to S/GDPFS begins, when services and capability are available for use and when the transition period is expected to be complete. The S/GDPFS implementation program will adopt an industry-recognized approach to project, program and portfolio management (P3M), establishing the necessary structures and accountabilities to ensure effective governance of the implementation.

Building on experience from the Severe Weather Forecasting Demonstration Project (SWFDP), a Project Office with a full-time program manager will be established within the Secretariat to coordinate the implementation and support of all implementation activities (See Annex to Recommendation 15, EC-70).

The Project Office will:

- Ensure that S/GDPFS is aligned with the long-term goals and strategic objectives outlines in the WMO Strategic Plan;
- Have responsibility for developing and monitoring S/GDPFS benefits framework;
- Support all implementation activities, including coordination with a future stakeholder group, participants to the program and contributing Members;
- Ensure that the resource requirements to support the implementation are understood by Members, and considered in the WMO budgeting and planning process; and
- Coordinate implementation with the different WMO Programs and the WMO Secretariat.

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Annex 2

POTENTIAL USE-CASES IN THE CONTEXT OF OPERATIONAL Seamless GDPFS

Use Case 1

A centre wants to run its own model remotely – access to infrastructure without having to maintain in hardware

Assumptions: the centre has internet access, either 3G /4G, the data is correctly described in metadata, any stations are listed in OSCAR.

- A future GDPFS portal and Data Store– machine to machine or observer to machine mechanisms.
  - WIPS portal accessible from internet.
  - Security Authentication/Authorisation/Access functionalities. (Google/FB etc. technology)
  - Data formatting and validation functionality to agreed standards (intelligent platform).
  - Training and documentation of system
- Running the model
  - Provision of a virtual machine on a remote platform (IAAS) using the WIPS toolkit function.
  - Accounting system for user costs.
  - Require the underlying model for boundary conditions from any global centre.
  - Service offered by global NWP centres – supply the underlying model for boundary conditions.
  - Training and documentation of system

Use Case 2

Centre wants to run someone else's model on a defined area – access to infrastructure without having to maintain in hardware

Assumptions: the centre has internet access, either 3G /4G, the data is correctly described in metadata, any stations are listed in OSCAR.

- The portal and Data Store– machine to machine or observer to machine mechanisms.
  - WIPS portal accessible from internet.
  - Security Authentication/Authorisation/Access functionalities. (Google/FB etc. technology)
  - Data formatting and validation functionality to agreed standards (intelligent platform).
  - Training and documentation of system
- Running the model
  - Provision of a model machine on a remote platform (SAAS) using toolkit function.
  - Accounting system to ensure NMHS stays within agreed computer resourcing.

- Require the underlying model for boundary conditions from any global centre.
- Service offered by global NWP centres – supply the underlying model for boundary conditions.
- Training and documentation of system

- Using Global Model to prepare new services using WIPS Data Store and toolkit.
  - Access to visualisation tools for view model products.
  - Authentication/Authorisation/Access functionalities required for such a service.
  - Delivery service to send products/service to ‘end user’.

Use Case 3

Centre wants to run a High Res Global Model with a grid less than 5km and use a toolkit containing data applicators and product generation algorithms

Assumptions: Need to get all in-situ observation in real time (5’ or 1’ temporal resolution), need to get all radar data in real time; getting all raw data is too big, provide services on NWP output.

- In-situ observation acquisition.
  - System to subscribe to all Observations within WIS 2.0, in a ‘twitter-like’ manner.
  - System needs Authorisation, Access, Authentication for the publisher and accounting system, so the publishers know who is consuming their data.

- Radar data acquisition.
  - The radar data owner to run pre-defined extraction service for NWP centre.
  - The Radar data consumer to run pre-defined service within the radar data centre environment, and export the subset of data required for modelling.
  - Requires notification, distribution, accounting, authentication services.
  - Change management for new/ closed observation sites (OSCAR).

- Provide services on NWP output.
  - Post-processing toolbox: Sub-setting of data – extraction, slicing and dicing of model data. Data cubes. Downscaling and interpolation. (includes Boundary data for LAM centres).
  - Workflow management system and notification service.
  - Classic set of web services (WCS, WFS etc.) for machine and human consumers.
  - Visualisation tools for human consumption.
  - Data repository for model users to retrieve model.

Use Case 4

A Met Service wants to know the likelihood of an extreme rainfall event for an area in their country

Assumptions: the centre has internet access, either 3G /4G.

- S/GDPFS Common Interface and Data Store– machine to machine or observer to machine mechanisms.
  - S/GDPFS Common Interface accessible from internet.
  - Security Authentication/Authorisation/Access functionalities. (Google/FB etc. technology)
  - Data formatting and validation functionality to agreed standards (intelligent platform).
  - Training and documentation of system
- Creating the forecast
  - Post-processing toolbox used to run multiple calculations from a selection of WMC models data available from the Data Store
  - Using a post processing application available from the toolkit the likelihood of rainfall exceeding an user defined extreme threshold is determined from each WMC model runs
  - Aggregator application tool which applies a weighting scheme to produce one product that answers the question raised, This could be complement with a service that overlay outputs into one fully integrated solution and present output using a WBS visualisation application available in the toolkit
  - Re-useable content produced for downstream production
  - Assessment of forecast quality is achieved by using the QMS services
  - Known strengths and limitations of each WMC model used is available from the O2R function service
- Provide services based on above, which includes web-based visualization services and product creation for end-us

Use Case 5

A coastal city wishes assistance from an NMHS to evaluate present and future risks and impacts from of flooding due to storm surges:

Assumption: the S/GDPFS has enabled access to storm surge hindcast and prediction capability

- Creating flood risk and impact based scenarios
  - Historical risk assessment from historical water level data from nearby tide gauges
  - Creation of hindcast storm surge risk assessment using Historical Forecast coupled atmospheric-oceanographic model output.
  - Creation of coastal flooding return periods
  - Project changes in flood risk based on 50 and 100year sea level rise scenarios.
  - Project changes in flood risk based on changes in storm intensity
  - Provision of flood risk maps in GIS for present storm surge flood risk and projected risk for 50 and 100 years.
- Provide services based on above, (possibly in partnership with private sector, other levels of government etc.) which includes web-based visualization services to provide advice:
  - To city planners on areas of highest coastal flood risk (present and future)
  - To city engineers responsible for asset management to assess risk on critical infrastructure
  - To city emergency managers to assess risk and develop response plans considering vulnerable populations
  - To all of the above to assess areas of environmental threat for contamination as a result of flooding (water supply, water treatment facilities, contaminated sites etc.)
  - Development of a local real-time storm surge prediction and warning program

Use Case 6

A national hydrological service wants to analyze GCM data with respect to circulation patterns that are potentially related to extreme hydrological situations (droughts, river floods, flash floods) in a specific region or country.

Assumptions: The national hydrological service has high speed internet access and is registered at relevant global climate simulation (projections and reanalyses) data stores such as CMIP/ESGF and COPERNICUS/C3S. The GDPFS has implemented weather type classification schemes (e.g. COST 733) that can be applied to standard global model outputs. All climate model data are compliant to standards such as CMOR.

- **Access to GDPFS**: S/GDPFS Common Interface and Data Store - machine to machine or observer to machine mechanisms.
  - S/GDPFS Common Interface accessible from internet.
  - Security Authentication/Authorization/Access functionalities.

  - Training and documentation of system

- **Configuration**: S/GDPFS Common Interface and Data Store - machine to machine or observer to machine mechanisms.
  - Selection of weather type classification scheme
  - Selection of relevant weather type(s)
  - Selection of Region
  - Selection of Period(s): Evaluation (simulated past) of Climate Change analyses (simulated past and future)
  - Selection of climate simulation(s)
  - Selection of reference simulation (reanalyses)
  - The settings can be stored on user account.

- **Processing / Output**:
  - The system processes data according to the configuration settings.
  - Output 1: Time series data of weather patterns for selected region, periods
  - Output 2: Plots showing number of days when relevant weather types occurred or will occur.
  - All data and plots can be downloaded by user.

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