WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION

Open Consultative Platform

REPORT OF THE SECOND HIGH-LEVEL SESSION (OCP-HL-2) 26-27 MAY 2021

OPEN CONSULTATIVE PLATFORM

PARTNERSHIP & INNOVATION FOR THE NEXT GENERATION OF WEATHER & CLIMATE INTELLIGENCE

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FOREWORD

At the Eighteenth session of the World Meteorological Congress in 2019, WMO launched the Open Consultative Platform (OCP), which serves as an open, constructive and participatory framework, and together with a high-level policy, the Geneva Declaration – 2019, WMO opened the door to the private sector, academia, and other stakeholders to meet the unprecedented demand for more accurate and reliable weather, climate, water and related environmental information. In developing WMO's long-term vision, it is a clear anticipation that the private sector, academia and other stakeholders will play a growing role in WMO's business domain under the framework of policies and guidance for the Public-Private Engagement (PPE).

The Second High-Level Session of the OCP (OCP-HL-2) was held on 26 and 27 May 2021 and discussed progress in two of the five thematic areas identified as "grand challenges" at the High-Level Round Table for the Launch of OCP (OCP-HL-1) in 2019. Discussions and perspectives of the future of forecasting, together with the WMO OCP White Paper #1 on Future of weather and climate forecasting launched during the session, will provide a basis for decision-making by stakeholders in planning their activities related to numerical prediction and operational forecasting during the next decade and beyond. The discussions in the second thematic session looked at the diversity of the institutional arrangements related to the National Meteorological and Hydrological Services (NMHS) in the Members and provided perspectives for the whole community to understand the drivers and trends shaping the future evolution of NMHSs and stakeholders.

I am pleased to present this Summary of the OCP-HL-2 discussions, which will be a good reference to all the stakeholders to enhance, join in, or reaffirm the collaborative endeavour of all of us in weather, climate and water domains. I would like to express my appreciation to all the speakers and panellists contributing to the enlightening and fruitful discussions. I hope that we will continue to meet together on an annual basis to monitor progress and share foresight. I would like to reassure you that the WMO Secretariat will provide continued support to the Platform and future initiatives of dialogue and engagement.

Prof. Petteri Taalas
Secretary-General
World Meteorological Organization

EXECUTIVE SUMMARY

BACKGROUND

The Open Consultative Platform (OCP) – Partnership and Innovation for the Next Generation of Weather and Climate Intelligence – is a WMO-facilitated mechanism established in 2019 for inclusive consultation among all stakeholders. Its annual thematic session brings together the public, private and academic sectors on a High-Level Round Table to address common grand challenges before the global weather and climate community in an open, constructive and participatory way. The Second High-Level Session of the Open Consultative Platform (OCP-HL-2) was held on 26 and 27 May 2021 via Zoom as an online event. The session discussed progress in thematic areas identified as "grand challenges" at the High-Level Round Table for the Launch of the Open Consultative Platform (OCP-HL-1) in June 2019. The discussions support the building of a common vision of the weather and climate community on relevant thematic areas with horizon 2030 and beyond. The OCP-HL-2 was hosted by Prof. Petteri Taalas, Secretary-General of WMO, and Prof. Gerhard Adrian, President of WMO.

THEMES AND SESSIONS

Two 90 minute thematic sessions on 26 and 27 May 2021 were moderated by **Ms Erica Grow** (USA) and **Mr Gerald Fleming** (Ireland). The sessions focused respectively on two of the five themes of common concern for the stakeholders from all sectors identified at OCP-HL-1:

(1) Forecasting and forecasters, and

(2) Roles, responsibilities and partnerships for common actions.

The session on Day 1 was also marked by the launch of the first OCP White Paper on Future of weather and climate forecasting (vision 2030+). The session on Day 2 was a pre-discussion on the preparation of the second OCP White Paper on Evolving Roles and Responsibilities – Future of NMHSs (vision 2030+).

PARTICIPANTS

For each session, there were three invited speakers and a high-level panel with ten invited participants attending the event via Zoom, who contributed their views in the form of presentations and Q&A to delve further into the highly important themes and provide suggestions and visions on the way forward. The list of speakers and panellists is included in Appendix 1.

In addition, there were a total of 372 people registered for the OCP-HL-2 as audience on the meeting platform Swapcard. They are from multiple sectors, including NMHSs, government agencies, private companies, academic institutes and international organizations.

PROCEEDINGS

All information on the OCP-HL-2, including the video recordings of all presentations and panel discussions, documents, slides, etc. are available online at the website: https://ppe-openplatform.wmo.int/en/news-events/OCP2.

The summary transcription of invited speakers in their presentations and panellists' views in Q&A sessions of both thematic sessions are presented in Appendix 2.

KEY MESSAGES

Key messages from the OCP-HL-2 are summarized below, the details of which can be found in the following sections and appendices of the report.

Theme I: Launch of the first OCP White Paper on Future of Weather and Climate Forecasting (vision 2030+)

- The decade of 2021–2030 will be exciting times ahead in Earth System modelling with significant improvements of the forecasts of all times scale from minutes to seasons.
- These improvements will be a major contribution to the common goal of building stronger resilience at all levels – from planetary to local.
- The OCP White Paper #1, "Future of weather and climate forecasting" is offered as a tool to researchers, practitioners, planners and decision makers. Its key messages and recommendations could fit different sorts of national or business scenarios.
- Major developments of technology and research will be expected, including an improvement in HPC, Cloud, AI/ML, and explosion of observations from satellites, the private sector and IoT, accelerated research to operations and innovation, and aligned strategy for weather and climate model development.
- A common view of all speakers is that partnerships are essential. They should be strategic, built around a common goal. Motivational differences should not be an obstacle. It is important to build more collaborative opportunities so that all partners are really motivated in the same direction. It is also necessary to engage more with users to co-design, including users at the community level.
- Smart investments are needed. Sustainable, systematic and enhanced public investments in the backbone infrastructure should be advocated. Development assistance financing should take the current and expected NEWP advancements into account to raise effectiveness and sustainability. PPE investments should be leveraged in all elements of the NEWP systems (observations, HPC, etc.).
- Roles of stakeholders are evolving. It is necessary to rethink "Who Does What" to optimize and develop best scenarios for each stakeholder, considering the needed resources as against the existing resources, e.g. for many smaller organizations and NMHSs to focus on the best use of the resources they have, i.e. ample amount of high-resolution global ensemble data available to work with. It is necessary to open the door for more collaborative opportunities through PPE and other forms of engagement among the sectors.
- "No One Left Behind" should always be pursued. It is important to help less developed countries to maximize the benefits, including through PPE. Global data sharing should be enhanced to get better products from the NEWP systems. Capacity-building in downscaling is essential so that the benefits of those improvements in global model can be brought right down to the national and local level. Scientists from developing countries should be better engaged in the NEWP development.
- WMO has many important roles in the coming decade: continuing to lead the international cooperation and promoting multi-sector engagement through the OCP; planning and developing further the GDPFS supported by Global Basic Observing Network (GBON), WMO Integrated Global Observing System (WIGOS) and the WMO Information System (WIS) as a backbone for all stakeholders; and providing the needed guidance and methodology for quality assurance in the multi-stakeholder service delivery environment.

Theme II: Evolving Roles and Responsibilities – Future of National Meteorological and Hydrological Services (NMHSs) (Vision 2030+)

- In the decade of 2021–2030, significant changes are envisaged in the roles and operations of all stakeholders in the weather and climate enterprise including the NMHSs. The NMHS's role and responsibilities is a central question that should be discussed continuously.
- NMHSs need to become more society-oriented. The great diversity in the legal and institutional frameworks under which the NMHSs are set and operate in different countries will remain which means that there is no one-size-fits-all approach.
- A common challenge for NMHSs will be how to engage with other stakeholders in a multi-sector enterprise that will serve better the society and will better use available resources.
- The forthcoming OCP White Paper "Future of National Meteorological and Hydrological Services" (White Paper #2) will provide guiding scenarios for mid- to long-term planning by decision makers.
- White Paper #2 is going to cover many aspects related to the afore-mentioned issues: drivers for change, institutional changes, legal and regulatory changes, data policy, operational changes, funding and business model changes and partnerships with external stakeholders.
- White Paper #2 will also inform strategic choices, including: how to preserve the NMHSs as a core institution for any type of national system solution; how to stimulate and accelerate progress through partnerships including the PPE; how to plan early for the changing market demands and new human resource requirements; how to engage with civil society for reaching to most vulnerable communities in need of essential weather, climate and water services; and how to manage changes.

THE FIRST THEMATIC SESSION: LAUNCH OF THE FIRST OCP WHITE PAPER ON FUTURE OF WEATHER AND CLIMATE FORECASTING (VISION 2030+)

INTRODUCTION

The first thematic session on 26 May was opened by **Prof. Petteri Taalas**, WMO Secretary-General. In his opening remarks, Prof. Taalas noted that in developing WMO's long-term vision, it is a clear anticipation that the private sector and academia will play a growing role in WMO's business domain, including the forecasting business. He informed the high-level session participants that in addition to the newly established PPE Office, all departments within the Secretariat have been tasked to incorporate PPE in their core functions. The two Technical Commissions, Research Board and Regional Associations are also supposed to increase engagement with the private and academic sectors in their work. He highlighted the recent development towards a more open data policy by WMO, and a matching effort to fill the major gaps in global Earth observing system. He emphasized the importance of building a trust between the NMHSs and the private sector actors at national level.

In this thematic session, a total of three invited presentations were made by Dr Gilbert Brunet, Chair of the WMO Scientific Advisory Panel, Dr Florence Rabier, Director-General of European Centre for Medium-Range Weather Forecasts (ECMWF) and Dr Kevin Petty, Director of Science and Forecast Operations and Public-Private Partnerships, IBM Watson Advertising and Weather, The Weather Company, an IBM Business. As the first thematic session also marks the first WMO OCP White Paper on the Future of weather and climate forecasting (Vision 2030+), Dr Gilbert Brunet, who led the drafting of the Paper, gave an overview of the main conclusions of the white paper for the challenges and opportunities towards an improved forecasting system by 2030 and beyond. Dr Florence Rabier's presentation focused on partnerships to advance Earth System predictions from the point of view of a global numerical weather prediction centre. Dr Kevin Petty shared the experiences and insights of The Weather Company, an IBM Business, in leveraging partnerships to advance its numerical weather prediction.

In the Q&A session after the invited presentations, a total of 10 panellists plus the above three invited speakers provided their thoughts and comments by answering a series of questions concerning the future of weather and climate forecasting, especially as it related to public-private engagement, emerging technologies and the impacts.

KEY MESSAGE FROM SPEAKERS

Future of Weather and Climate Forecasting: Leverage by PPE

Dr Gilbert Brunet

Chair, WMO Scientific Advisory Panel

Chief Scientist, Bureau of Meteorology, Australia

The WMO OCP White Paper #1 – Future of weather and climate forecasting addresses an important question:
How do we see the future of global weather and climate prediction in 2030?

Key messages and recommendations of the paper are as follows:

(1) We will see notable shift in roles and performance requirements in the PPE.

(2) WMO should increase significantly its effort in international R&D coordination and promotion.

(3) At the national level, NMHSs need to engage more in community-based modelling and data initiatives, and R&D consortia.

(4) WMO should continue to be the backbone of capacity-building and to provide global and regional numerical forecast through its GDPFS.

(5) Governments need to sustain and ideally accelerate public investments in global observing system and supercomputing capability.

(6) With the increasing improvements of global ensemble prediction system, the role of NMHSs and the private sector could be focused on downscaling forecast data.

(7) Implementing NEWP systems with post-processing, production and visualization on the cloud may offer a unique advantage for NMHSs.

(8) WMO, with the help of public-private engagement could come to an agreed methodology for validating the quality of weather and climate forecasts by various providers.

(9) Investments in observational networks will need to be coordinated with those for NEWP systems development.

(10) The development/improvement of climate models needs to be in line with the strategy for weather prediction.

Partnerships to Advance Earth System Predictions

Dr Florence Rabier

Director-General of ECMWF

At the ECMWF, we just launched our new 10-year strategy at the beginning of this year, which summarizes the two main science and technology goals for the period 2021 to 2030: a seamless Ensemble Earth System and the use of advanced high-performance computing. There are a lot of opportunities there for partnership with the private sector, in particular for technology with HPC centres and vendors to run our models, develop machine learning and AI, test a prototype hardware platform and access state-of-the-art technologies. We also partner with observation providers to implement data from new types of observing systems or platforms.

Some key messages:

(1) It is very exciting times ahead in Earth system modelling that will require major technological development in HPC, cloud, AI, machine learning, and more observations from satellites, private company and Internet of Things.

(2) For step-change in such developments, we need enhanced partnerships. We already have, of course, a strong partnership with our Member States at ECMWF, but it has to go through WMO, academia and observation providers. Co-designing with industry is also a critical partnership that I would like to highlight.

The Global high-Resolution Atmospheric Forecast (GRAF) System: Advancing NWP through Strategic Partnerships

Dr Kevin Petty

Director of Science and Forecast Operations and PPP for The Weather Company, an IBM Business

When the IBM set out, about three years ago, to develop what we call the Global high-Resolution Atmospheric Forecast System, we realized that we really had to lean in and find trusted, capable partners that had well aligned objectives. While there was key alignment on our goal that we want to develop this new forecasting capability, different players had a slightly different motivation around being a partner here. That is not a problem as we were still centred on this common goal. For the global weather and climate enterprise, the protection of life and property and advancing economic vitality is a common goal for everybody. We might have slightly different motivations about how to get there. But that is where we want to go, and each one of these organizations, whether in the private sector or community-based organizations, brings something that is very valuable to the table. It could be data, it could be science, it could be infrastructure, and it could be thoughts about policy.

A couple of takeaway messages:

(1) Developing strategic partnerships is a very effective and efficient way of achieving your goals and objectives, particularly if you have compressed timescales that you are trying to meet.

(2) Engaging the right partners is also essential and we should not force fit something. If there is not a good partnership there, it is okay to walk away from the table and realize we might need to find another partner.

(3) Partnerships should be built around a common goal, recognizing that the motivation of each partner might be slightly different.

(4) Strong partnerships can open the door to other opportunities.

KEY MESSAGE FROM PANELLISTS

Dr Paolo Ruti

In the near future, we will see an unprecedented increase of our capacity to monitor the Earth system, including in the data sparse areas such as Africa and Arctic. It is important to build multi-disciplinary solutions across different measurements and strengthen coordination across different agencies because no one single instrument or no one single satellite is the answer to a complex user-requirement landscape today.

Mr Michel Jean

The infrastructure that we currently have has been designed essentially to deal with structured data. As we get into this new world, it will be a combination of additional structured data and far more unstructured data. The availability of these data relies a lot on public-private partnership and a lot on those new sensor technologies, so the partnership is fundamental. The review of the data policy is important because a lot of those data are not part of the traditional thinking in terms of what is supposed to be made available.

Prof. Celeste Saulo

One of our main goals should be trying to focus on the science-for-service paradigm. In addition to fundamental research, the need for social sciences on board should be highlighted. In the end, we are providing services which are really challenging because they are different from one place to another. We need to secure that new knowledge from research efforts is really taken up by the global society so that we can reach people.

Dr Veronique Bouchet

There are many efforts currently combining the best of the physical model and what AI has to offer. In the short term, I believe this is certainly where we can expect to see some interesting developments in the near future. The artificial intelligence really has the power to augment what forecasters have done. More than likely, it will be very useful in connection to forecasting hyperlocalized impact as they are really moving towards services that are more impact-based and customized. The question is how we can get ready to explore that richness and how that brings forecasters to the next level.

Dr Craig McLean

NOAA's Earth Prediction Innovation Center (EPIC) opens up with a unified forecast system that has all of the elements of the model available for academics or the commercial sector to come in and work through. Try to find the motivation, and then harvest from that suite of opportunities to properly motivated individuals to get the best possible product. There may be a profit motivation for a commercial company but that does not dissuade us. This is a very compatible methodology for us.

Prof. Pauline Dube

We need to aim for a self-reinforcing capacity-building process, so that the capacity can be built and maintained. It means the interest in capacity for weather, climate and hydrological and environmental services needs to come from within the societies themselves, through building a demand for and awareness to make a need of such services in all sectors of society. In that way, countries will actually begin to prioritize putting their own resources on the issues of building capacity for weather, climate, and environmental services. It is critically important that all regions of WMO are capacitated in the whole cycle of weather, climate and water science, technology and service delivery. For the sake of global security, we need to expand to make sure that the technologies are available across regions. The social science should be brought into the framework, linking with policy and also linking with communication skills to make people see the value of weather services in their everyday life.

Dr Arlene Laing

The partnerships that we are looking at are research partnerships that focus on operation-directed challenges, which are really critical to improving hurricane forecasts. Forecasts are successful when used to make better decisions through dialogues and partnerships among forecasters, decision makers and producers of a variety of data that are needed for impact-based forecasting. Model developers, operational forecasters, and users should work together to co-design products, services and information flows.

Mr Madhab Uprety

In coming years, we will be seeing a lot of demands in terms of the accurate and reliable forecasts with different lead times. How better we can also forecast the impacts is really crucial in terms of reducing the potential impacts by those hazards or disasters. The defining point for humanitarian agencies, such as IFRC, to save lives and livelihoods of the people, would be how we could better capacitate the national hydrometeorological agencies to offer impact-forecasting services. In coming years, we really expect to see a lot of partnership and collaboration particularly in relation to the development or the co-production of these impact-forecasting services in different countries, particularly in the developing world where the climate and weather risk is really high. It is important to ensure that the information of whatever forecast dimension will be delivered at the human scale, relevant to how people could better relate the information to their lives, livelihoods and economy.

Mr Jim Anderson

In a lot of cases where there are mutual benefits, it is absolutely win-win, and we can set up an institutional structure to make that possible. If we can set up a better framework for allowing more win-win public-private partnership in these areas, then the private sector will have the capacity to provide services to enable not just the deployment of observing systems but also the operation and maintenance of those systems over time, and do that in cooperation with local institutions to build capacity and expertise at local level, and ultimately create a sustainable business model for the maintenance and continued operation of those systems that provides observations for the modelling community over time.

Mr Ian Lisk

Verification and validation are fundamentally important to continuously improve, and to obviously challenge what we all do as well. What is really important, though, from a WMO perspective, is that in order to actually do verification and validation, you do actually have to have benchmarking and underpinning quality standards that we have all agreed to in the first place. Through the WMO Technical Regulations and working with all our partners in academia, the private sector and Members, we have got a big job to do here to improve those service quality standards within the Technical Regulations and provide the appropriate guidance, standards, the recommended practices, and also the guidance in how we actually engender this culture of compliance.

Dr Kevin Petty

Many times, we focus as a community on the technology side of how our forecast verify, and we apply certain metrics to verify that forecast. However, we really need to bring in the public and the end users' perspective into that from the social science dimension. While we move towards these higher resolutions and higher capability, we have to bring in that human element of not only accuracy, but perception of accuracy. I think that is something that we need to really account for moving forward.

Dr Florence Rabier

The global models going to reach 1–3 km in resolution does not mean that you do not need to refine it more. This better description of local processes may be supplemented by other observations, local observations that may not be available or usable for the global models. So maybe in the cloud, you can also run these limited-area models. And for the NMHSs who do not have the resources to run models on the cloud, new technologies like AI and machine learning can complement and can downscale the global models by using in particular reforecast of the global models, local information, and local observations. Then they can make the most of these global models by downscaling to the local scale for knowing what is available and what is interesting for their users.

Dr Gilbert Brunet

I think for the very short timescale, ensemble will eventually be very valuable. But still, you will need to increase more the space resolution for those timescales. But for longer timescales, we clearly need more and more ensemble systems, and it is having a lot of added value. And I would like to remind you that the World Meteorological Organization has guidelines on how to communicate forecast uncertainty. When it comes to ensemble prediction system, I do not think there is a one-size-fits-all there. It depends on the type of users, their cultural background and the type of activity that people are doing. That is a place where we need to have more user engagement on this.

CLOSING OF THE FIRST THEMATIC SESSION

The first thematic session was closed by **Dr Elena Manaenkova**, Deputy Secretary-General, WMO. She expressed thanks to Dr Gilbert Brunet, all contributors, writers, reviewers for putting together the extraordinary white paper with great innovative thinking. WMO is already looking at this paper to see how to incorporate the recommendations in its future strategy. She encouraged NMHSs and partner institutions to look at this paper and to start planning for the mid- and long-term in a way that all the opportunities and innovations will be embraced to accelerate science-to-operation cycle and improve the seamless Earth System forecast from minutes to season. This improvement will also make it necessary to rethink what should be done at regional and national levels so that WMO's cascading system will transform into something more meaningful and more flexible. In this whole endeavour, the role of the private sector and academia is extremely important.

THE SECOND THEMATIC SESSION: EVOLVING ROLES AND RESPONSIBILITIES – FUTURE OF NMHSs (VISION 2030+)

INTRODUCTION

The second thematic session on 27 May was opened by **Prof. Gerhard Adrian**, President of WMO. In the opening remarks, Prof. Adrian emphasized that collaboration between the public, private and academic sectors is absolutely necessary for the purpose of building a common vision for the global weather and climate enterprise and guiding the future in an informed and scientific way. He noted that the theme for the session of Day 2 is of great importance for the whole community. He emphasized that it is important to remember that the NMHSs are the core element of the global system built over the last 150 years. They are the agencies designated by the state governments to fulfil the requirements of the WMO Convention and to make possible the delivery of services to save lives, protect property, and support the well-being of people. By providing basic data for national and international use, NMHSs also facilitate the operations of private companies delivering weather and climate services. The President also emphasized the importance to acknowledge the great diversity of NMHSs across different countries. He pointed out that there has always been interaction between the public and private sector in many ways, but the last two decades really raised the level of public-private engagement. And this is one of the main trends shaping the future.

In this thematic session, a total of three invited presentations were made by Ms Marianne Thyrring, the Permanent Representative of Denmark with WMO, Prof. Mansur Bako Matazu, the Permanent Representative of Nigeria with WMO, and Mr Naoyuki Hasegawa, the Permanent Representative of Japan with WMO, along with Mr Masanori Obayashi, the Director-General of the Atmosphere and Ocean Department of the Japan Meteorological Agency (JMA).

The second thematic session was a pre-discussion on the preparation of the second white paper of OCP on the future of NMHSs.

Ms Marianne Thyrring's presentation explained how the Danish Meteorological Institute (DMI) took off from being a very product-oriented institute to becoming more society-oriented.

Prof. Mansur Bako Matazu shared the experience on the changes undertaken by NiMet to deal with the challenges and service requirements in achieving sustainable development and economic growth, including its public-private partnership initiatives to improve the services delivered to the public.

Mr Naoyuki Hasegawa and Mr Masanori Obayashi presented about how Japan's Meteorological Service Act supports the overall sound development of meteorological services provided by JMA and private companies, and JMA's recent efforts to improve its services in collaboration with academia and the commercial sector.

In the Q&A session after the invited presentations, a total of 10 panellists provided their perspectives on the evolving roles and responsibilities of NMHSs and other stakeholders, the related legal, institutional and technological changes, and the challenges and opportunities to engage with other stakeholders in a multi-sector enterprise.

KEY MESSAGE FROM SPEAKERS

From Product-oriented towards Society-oriented

Ms Marianne Thyrring

Permanent Representative of Denmark with WMO

The Danish Meteorological Institute (DMI) is almost 150 years old and has recently been transformed from a very product-oriented institute to much more society-oriented one. DMI is very keen on the core function of a national meteorological service: the single authoritative voice in weather, and we are building up our understanding of impact-based weather warnings, and our collaboration with other public bodies in order to serve the society the best we can. What we have also decided is that providing data to society should be a core part of our authority as well, which means that we want to make our data open and free for everybody to use. But it is not something that you make a decision and then it works. There is a financial issue. We had to work very hard towards our ministry and the parliament in order to persuade them to see that the societal value of having a meteorological institute in Denmark would grow enormously if we were allowed to open our data and if the parliament were to give us the budget not only to enable us to establish and run the relevant IT structure, databases, and APIs, but also to reimburse what we lost in our commercial business as well. And what we did was to have our stakeholders, private users, interest organizations, local municipalities, and everyone around us to be the voice and put pressure on government by explaining that they want this meteorological institute to have a new role as a pusher of climate and weather data. So, an important conclusion is that if one wants to define a new role and responsibility like what we did, you have to find someone outside your national meteorological institute to call for this and speak in favour of you. This whole exercise was in fact a test of the trust and confidence through the meteorological service. So, asking for new tasks and new responsibilities, e.g. open data, would give us the answer to the question whether we are relevant to the society in future. I think we still have a lot of challenges to work with, including the change of mindset. We have to do a lot of changes in how we work together with the outside world.

Public-Private Partnership for Weather and Climate Services: An Experience Sharing from NiMet

Prof. Mansur Bako Matazu

Permanent Representative of Nigeria with WMO

Africa faces very huge, difficult development challenges. In addition, our climate is the most dynamic and difficult to monitor. And the meteorological infrastructure is not well-developed in Africa. These three key challenges, therefore, require that African meteorological services like NiMet to be more effective in saving lives and property. We cannot do it alone as government. The private sector has a very huge potential in the region, like in Nigeria, and can also help in raising and deploying private venture capital for high-tech developments, especially in measurements, computing or data technology. From observation to tailor-made products, the private sector can really come and work together with meteorological services. The prospects are very high in terms of private sector engagement. But there are some challenges, including some misunderstanding and even mistrust between the private sector and meteorological services. Greater engagement is needed between the two to dispel the perceived obstacles. The mistrust arises due to lack of knowledge and clarity about individual roles and responsibilities of both meteorological services and the private sector as well as how they can best work together. The private sector engagement in public service delivery is well considered in Nigeria, and there is a governing law to guide partnership. Therefore, we are leveraging the use of the ICRC modules regarding funding and revenue sharing and benefits realization. This quickly leads to technical partnership for good service delivery in Nigeria. We have learned some lessons from this experience. Partnership is a two-way venture, requesting us as meteorological services to do a lot in terms of technical, financial and procedural as well as administrative frameworks. In Africa, government funding for provision of meteorological infrastructure is not sustainable. Therefore, we need this weather enterprise to meet up with the infrastructure deficiencies that are existing. And if we properly back this by legal and other frameworks, weather enterprise can bring substantial revenue streams in meteorological service.

Public-Private Engagement in Japan: Activities Based on the Meteorological Service Act

Mr Naoyuki Hasegawa

Permanent Representative of Japan with WMO

Mr Masanori Obayashi

Director-General, Atmosphere and Ocean Department
Japan Meteorological Agency (JMA)

The public-private collaboration has been quite good in Japan, and we are now trying to strengthen the ties even more to respond to the changing and increasing requirements. The Meteorological Service Act supports the overall sound development of meteorological services provided by not only JMA but also private companies and various other entities. JMA's roles under that Act are to establish and maintain infrastructure for observation, forecast and warnings, and communication networks. It stipulates that only JMA shall issue warnings, which ensures a single authoritative voice in DRR activities. Promoting public utilization of meteorological data is also part of JMA's mission. The Act is also intended to maximize private sector activity. It stipulates observation standards and an instrument certification system to ensure observation data quality. The Act also stipulates a forecasting licensing system to ensure the quality of private forecasting services. The Weather Business Consortium, or WXBC, was established four years ago with the participation of service providers, academia and potential data users and functions as an important platform for sharing knowledge and promoting mutual understanding through ongoing dialogue. JMA's advisory body has recently recommended more comprehensive public-private-academic engagement towards future development, in recognition of vital academic-sector roles in innovation with state-of-the-art technology and the private sector roles in enhancing data utilization in socio-economic activities. The advisory body also highlighted the importance of continuous dialogues and mutual understanding to create positive synergies for better services for public good.

KEY MESSAGE FROM PANELLISTS

Dr Kornélia Radics

As to what is the optimum funding model for meteorological services of a medium-sized country and economy, the appropriate business model varies from country to country, due to their difference in their legal frameworks, responsibilities, capabilities and human resources, and the rapidly expanding needs of society and economy. The most important thing is to find the right balance between the official duties which are funded by the government, and those roles and responsibilities which have to be financed independently or commercially, while we also serve the global initiatives and roles such as GBON, free and unrestricted data sharing and contribution to regional multi-hazard early warning system.

Mr Daouda Konate

To achieve the aim of well-developed meteorological agencies in Africa by 2030, key challenges include strengthened infrastructure and increased involvement in research and modelling to provide climate solutions. This will necessitate increased government funding to NMHSs, closer collaboration with the private sector to identify opportunities for greater technical capacities, and involvement of development agencies for efficient and tailored project. The Regional Associations and Members should take due account of the WMO Guidelines for Public-private Partnership to establish cooperation, collaboration, and partnership at the regional and national levels.

Mr Patrick Benichou

The main challenge for NMHSs in the next decade is to continuously adjust the technical infrastructure to their main objective, and to adapt the organization to turn to a user-centric organization or society-centric organization. They have to set priorities on how they implement the value chain, i.e. where they should put focus and energy and for which benefit. Public-private engagement can bring leverage for that as they cannot do everything by themselves. PPEs are meaningless if they do not come along with fitted long-term business models. Those business models should comply with the local legal framework and may involve not only NMHSs and the private sector, but also local Ministry of Finance, governments and even development partners.

Dr Louis Uccellini

The advanced techniques of the forecast, such as multi-model ensembles, post-processing, AI and machine learning are being extended. In spite of a lot of uncertainty associated with that, they're good enough to alert the forecasters to the likelihood, possibilities of extreme events 7, 8, 9 or 10 days in advance. This is important, because decision makers focused on public safety and mitigating property loss increasingly require this information for evacuations and pre-positioning assets to mitigate the impact of storms, which actually start 7–8 days in advance even in the face of that uncertainty. So, the role of the forecaster is changing. Their job doesn't end with just the forecast, but it increasingly goes beyond the forecast to connect with decision makers, understand their needs, and provide the decision-support services out to 7–11 days prior to an event. Users still have to make decisions based on the uncertainty. That represents a big challenge. There has to be a human factor being involved working with decision makers to allow them to get through that uncertainty because they still have to make a decision one way or the other. From a research perspective, we still have a major predictability issue. I would argue that we can only address this through an Earth system science approach, and it can only succeed with the public-private enterprise being fully engaged with those national services. It's not an either-or. We have to work in partnership.

Mr Stephen Hunt

Under the commercial model, a market will self-regulate. Oversupply will drive down prices and the viability of inefficient or low-quality competitors. If NMHSs go a commercial route, each will be less or more competitive due to their national economies, commercial capabilities, their cost structures and how they manage their data as well. So, entering commercial market is not something that you want to do quickly or lightly or easily. Commercial capabilities, such as brand value, market penetration, differentiated products, are all built over many years. And they will be governed by the legal framework of the country where you are. The final point really is striking that right balance between maintaining your services for the public good while also delivering official and efficient commercial activities is not an easy transition and always a very fine balance.

Dr Ken Takahashi

Current increasing demands from the users in terms of accuracy, quality and diversity of meteorological and hydrological products and services is forcing the two communities to come together within the framework of the Earth system approach, e.g. for producing the high-resolution forecast and for coordination on hydrological data sharing. There are some challenges for this closer collaboration between hydrology and meteorology. A government-level national regulation is necessary to establish roles for water-related institutions in warning and other operations. Another issue is that meteorologists and hydrologists follow traditionally separate careers. The Earth system approach again has to be strongly emphasized in the formal education and training in both disciplines so that they should be able to understand the limitations and the strengths of each other so as to have more effective collaboration.

Mr Xiaonong Shen

The private sector has flexible mechanisms and a strong innovation ability. Commercial entities should be encouraged to engage in the value chain of the meteorological service through such mechanisms as service purchase, joint development of operational systems and coordinated meteorological service delivery. Industry and business associations should play a role in promoting the dialogue, consultation, and coordination between the public and private sectors. There are also challenges faced by national meteorological services in developing PPE. Legal system needs to be further improved to clarify roles and responsibilities of an NMHS and the market entities. In addition, considering the increasing diversity of service providers, there is a need to establish an assessment system for service quality.

Mr Vladimir Tsirkunov

During the last 10 years, the World Bank's main portfolio of hydrometeorology has tripled. One of the main challenges to NMHSs in developing countries, besides traditional lack of government support and resources, is how to reorganize themselves in the transformational process from traditional manual data collection agencies, such as many NMHSs in developing countries which are underfunded and understaffed, to modern NMHSs which have high-tech ICT systems providing a broad range of specialized and integrated services. For developing countries, there is no well-established solution so far. Therefore, the capacity gap between many NMHSs in developing countries and the most advanced NMHSs is not reducing. Some people argue that this gap is increasing. Facilitating a more active partnership between the rapidly advancing private sector and traditional NMHS is a promising direction to mitigate this and other challenges. NMHSs and their governments should recognize the value of building mutually beneficial partnerships between their institutions and the private and academic sectors. In some countries, these, as well as allocation of additional government support for implementation of NMHS' public functions, will be critical for their survival in the future.

Dr Sue Barrell

The benefits of free and unrestricted data exchange far outweigh the fees that we often hear about. Effective future NMHSs will use the WMO data policy proactively to drive and deliver an integrated Earth system's approach from both operational and strategic design perspectives. The NMHSs can act as role models in open data and in building and sustaining national data partnerships through bringing together those institutions, research bodies and private entities that can and do contribute relevant data. NMHSs can act as designers and operators of national observational and data infrastructure through fully implementing WIGOS as an integrated approach to Earth system's data. NMHSs can empower and sustain the science-to-service value chain, through providing and advocating free access to all of the data required for research that support the future evolution of public services. The most successful NMHSs post 2030 will be those who understand the importance of data in partnering, designing, investing, and delivering across the science-to-service value chain.

Dr A.R. Subbiah

Unlike in earlier times, the demand on NMHSs is increasing from many aspects. There is going to be a kind of transition from a traditional forecast system to a modern system embracing the 2030-decade and on, which is going to be a major kind of change in the NMHS, both in social and technological terms. The transition is facilitated by regional institutions like RIMES. As long as the transition process is there, they need regional institutions for support. That is why it is a very symbiotic kind of support to the NMHSs. NMHSs will become more popular with the national systems and communities because they are going to provide value-added services which their user communities need. The strengthening of NMHSs is supported by regional cooperation and regional mechanisms. That is why this system is now working so well.

CLOSING OF THE SECOND THEMATIC SESSION

The second thematic session was closed by **Prof. Gerhard Adrian**, President, WMO. He emphasized the importance of trust between the partners and transparency between the private and the public sector, which is very much connected with the legislation. He pointed out that it is our common responsibility and challenge to enable the maximum use of the weather and climate information by the society. The proposed second OCP white paper is anticipated to inform important decisions on the future of NMHS at national level with potential scenarios and ideas for possible governance choices to mitigate the negative impacts. He indicated his personal support and invited a wide contribution to this white paper.

APPENDIX 1: LIST OF SPEAKERS AND PANELLISTS

EVENT HOSTS AND OPENING SPEAKERS	
Prof. Gerhard Adrian	President of WMO
Prof. Petteri Taalas	Secretary-General of WMO

EVENT MODERATORS	
Ms Erica Grow	Broadcast meteorologist
Mr Gerald Fleming	Broadcast meteorologist

DAY ONE – 26 MAY 2021

INVITED SPEAKERS	
Dr Florence Rabier	Director-General, European Centre for Medium-Range Weather Forecasts (ECMWF)
Dr Gilbert Brunet	Chair, WMO Scientific Advisory Panel (SAP); Chief Scientist, Australian Bureau of Meteorology
Dr Kevin Petty	Director, Science and Forecast Operations and Public-Private Partnerships, IBM Watson Advertising and Weather, The Weather Company, an IBM Business

PANELLISTS	
Dr Arlene Laing	Permanent Representative of the British Caribbean Territories with WMO
Prof. Celeste Saulo	First Vice-President, WMO; Permanent Representative of Argentina with WMO
Mr Craig McLean	Acting Chief Scientist, National Oceanic and Atmospheric Administration (NOAA); Assistant Administrator for Oceanic and Atmospheric Research
Mr Ian Lisk	President, WMO Services Commission
Mr Jim Anderson	Chair, Association of Hydro-Meteorological Equipment Industry (HMEI); Senior Vice-President, Global Sales, Earth Networks

Mr Madhab Uprety	Asia Regional Advisor, Red Cross Red Crescent Climate Centre
Mr Michel Jean	President, WMO Infrastructure Commission; Associate Emeritus, Environment and Climate Change Canada
Prof. Pauline Dube	Vice-Chair, WMO Scientific Advisory Panel (SAP); Environmental Scientist and Associate Professor, University of Botswana
Dr Paolo Ruti	Chief Scientist, European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)
Dr Veronique Bouchet	Director-General, Canadian Centre for Meteorological and Environmental Prediction (CCMEP), Environment and Climate Change Canada

DAY TWO – 27 MAY 2021

INVITED SPEAKERS	
Prof. Mansur Bako Matazu	Permanent Representative of Nigeria with WMO
Ms Marianne Thyrring	Permanent Representative of Denmark with WMO
Mr Naoyuki Hasegawa	Permanent Representative of Japan with WMO
Mr Masanori Obayashi	Director-General, Atmosphere and Ocean Department, Japan Meteorological Agency

PANELLISTS	
Dr A.R. Subbiah	Director, Regional Integrated Multi-hazard Early Warning System (RIMES) Programme Unit
Mr Daouda Konate	President, WMO Regional Association I; Permanent Representative of Côte d'Ivoire with WMO
Dr Ken Takahashi	Permanent Representative of Peru with WMO
Dr Kornélia Radics	Vice-president, WMO Regional Association VI; Permanent Representative of Hungary with WMO
Dr Louis Uccellini	Permanent Representative of USA with WMO
Mr Patrick Benichou	CEO, Météo France International
Mr Stephen Hunt	Chief Executive, New Zealand MetService

Dr Sue Barrell	Chair, WMO Study Group on Data Issues and Policies (SG-DIP)
Mr Vladimir Tsirkunov	Lead specialist, Hydromet Program, Global Facility for Disaster Reduction and Recovery (GFDRR), World Bank Group
Mr Xiaonong Shen	Deputy Administrator, China Meteorological Administration (CMA)

CLOSING SPEAKERS	
Prof. Gerhard Adrian	President of WMO
Dr Elena Manaenkova	Deputy Secretary-General of WMO

APPENDIX 2: SUMMARY TRANSCRIPTION OF PRESENTATIONS AND Q&A[1]

THE FIRST THEMATIC SESSION

I. OPENING

Prof. Petteri Taalas, WMO Secretary-General

This is our second OCP. The first one was launched by the Eighteenth World Meteorological Congress in 2019, which has made very important decisions. First of all, by signing the Geneva Declaration – 2019, WMO Members decided to open the door to the private sector, enhance cooperation with the academic sector and engage other stakeholders, e.g. hydrological organizations, more in our activities. Members also decided to reduce the number of Technical Commissions. Now we have one for Earth system infrastructure and the other one for all services which takes Earth system and multi-hazard approaches. Both commissions have started working and have seen record number of participants in their first sessions. Our Scientific Advisory Panel (SAP), the Chair of which is also present today, is preparing the long-term vision for WMO. There is a clear anticipation in the vision that the private sector and academia will play a growing role in WMO's business domain, including the forecasting and related infrastructures. We have established the PPE Office led by Mr Dimitar Ivanov, who is supposed to retire in the coming summer. We have just appointed a new Office Director, who has long been engaged in PPE activities. Besides, all departments within the Secretariat have been tasked to incorporate PPE in their core functions. The two Technical Commissions, Research Board and Regional Associations are also supposed to increase engagement with the private and academic sectors in their work. The Permanent Representatives of Members appear to bring private sector actors to the Congress and the Executive Council sessions. Here in the WMO building, we have brought the Secretariat office of the Association of Hydro-Meteorological Equipment Industry (HMEI) next to our Infrastructure Department. We have seen a growing amount of private sector engagement in infrastructure and also recently in services. I am confident that the PPE will be a success story from the citizens-of-the-planet side. Now we are heading towards an extraordinary session of Congress to be held in October. At the Extraordinary Congress, we are supposed to update and strengthen our data policy by establishing a new "Resolution 42", which will promote free exchange of more data and take an Earth system approach. As we have realized that there are major gaps in the observing systems, especially in Africa, Caribbean, and the Pacific islands, we are supposed to improve our new standards for the GBON and get more financing into increasing the observing system coverage, especially in Africa and island states. According to a recent survey, our Members believe that PPE should be emphasized much more in our regional business, which is good news. And from my perspective, the key issue is that we have to build trust so that the private sector can act in close cooperation with the NMHS in every single country.

[1] This appendix presents the primary content of the presentations and Q&A rather than a verbatim transcription.

II. PRESENTATIONS

Presentation 1 by Dr Gilbert Brunet

"The WMO OCP White Paper#1 – Future of weather and climate forecasting" addresses an important question:
How do we see the future of global weather and climate prediction in 2030?

There are two main goals for that paper.
The first is to provide a basis for informed decision-making by enterprise stakeholders in planning their activities and investment in numerical prediction, and operational forecasting during the next decade, often referred to as the decade of digital transformation.
The Second goal would be to help decision makers, researchers and end users in the rapidly changing landscape of the weather and climate enterprise by compelling views, knowledge and expertise of a group of prominent scientists and practitioners from the public, private and academic sectors.

Key messages and recommendations of the paper are as follows.

(1) The main structure of the forecasting enterprise will not change significantly in the coming decade, but we'll see notable shift in roles and performance requirements in the PPE probably.

(2) International cooperation at state level will continue to be a main factor. WMO should increase significantly its effort in international R&D coordination and promotion.

(3) At the national level, NMHSs need to engage more in community-based modelling and data initiatives, and R&D consortia. The importance of working closely with users and the opportunities for public-private engagement should be recognized and promoted.

(4) WMO should continue to be the backbone of capacity building and to provide numerical forecast for various global and regional service providers through its GDPFS.

(5) Governments need to sustain and ideally accelerate public investments in global observing system and supercomputing capability, which are fundamental to nurture public-private engagement.

(6) With the increasing improvements of global ensemble prediction system, there are strong views for just a few producing centres, and the role of NMHSs and the private sector could be focused on downscaling forecast data.

(7) Implementing NEWP systems with post-processing, production and visualization on the cloud may offer a unique advantage for NMHSs, especially in developing countries and make more effective public-private engagement.

(8) WMO with the help of public-private engagement could come to an agreed methodology for validation of quality and recognition and attribution of various providers of weather and climate forecasts. This is very important point. We need to do more with the private sector and the public sector to validate the quality of our system.

(9) Investments in observational networks will need to be coordinated with those for NEWP systems development, considering the cost/benefits impact of observations on forecasts' skill.

(10) The development/improvement of climate models needs to be in line with the strategy for weather prediction, and a unified single model system across a range of timescales and spatial scales is possible and desirable in this context.

Now, with the focus in the paper on progressing together with developing countries, we have two important points to say. One is that massive investment through various development assistance projects have often provided disappointing results. The failures are often due to the lack of attention to the needs of met service and planning for sustainable operations, and I am insisting on that one – sustainable operations. The other point is that a way forward could be building national sustainable expertise and computation infrastructure for accessing and utilizing available high-resolution global ensemble forecasts, which are more and more available. That is important for developing countries.

Presentation 2 by Dr Florence Rabier

I will talk about partnerships to advance Earth system predictions from the point of view of a global numerical weather prediction centre or Earth system weather prediction centre. At the ECMWF, we just launched our new 10-year strategy at the beginning of this year, and this is summarizing the two main science and technology goals for the period 2021 to 2030.
The first one is a seamless Ensemble Earth System, maximizing the use of current and upcoming observations through consistent and accurate modelling with realistic water, energy and carbon cycles.
The second one is use of advanced high-performance computing, big data and AI methodologies to create a Digital Twin of the Earth with a breakthrough in realism.

There are a lot of opportunities there to partner with the private sector, in particular for technology with HPC centres and vendors. I will highlight a couple of examples of collaboration.

(1) At ECMWF, on top of our own supercomputer, we have access sometimes to some of the largest computers in the world. And this is very beneficial to test our code on different architectures. We had access to a Piz Daint down here in Switzerland, one of the largest in Europe. We won an award and some computing time on the Summit supercomputer in Oak Ridge National Lab which was the largest supercomputer at the time, which was very beneficial to run a version of our model of 1.4-kilometre in resolution. Through the Destination Earth initiative that is going to be launched by the European Union, we will also have access to EUROHPC, which are several large supercomputers going to the exascale in Europe. And we also have a new partnership with RIKEN, the centre in Japan where now Fugaku, the largest supercomputer in the world, has been installed.

(2) We have collaborations with private sector companies for computing activities. We now have a partnership with Atos for our next supercomputer that we will install just this year, to be operational next year. We have just launched, last October in 2020, the Centre of Excellence in HPC, AI and Quantum Computing for weather and climate together with Atos supported by AMD, Mellanox, Nvidia and DDN. In this Centre of Excellence we put our people together so that they can contribute some expertise, we contribute through our scientists, and we decide on different projects to run together. The first two projects, which have been launched now, is one on machine learning, and the other is the development of a CPU/GPU-based version of our code, which is the IFS. We recently had a project with Maxar as well. We had a contract with them to run the IFS model on Amazon Web Services, cloud computing resources, to test the feasibility and scalability of our model and the performance because we didn't have really the resources to do it ourselves and learned a lot from them.

(3) There are also some research projects and in particular, we have contributed to a lot that have been launched by the European Union. We had a very successful one in NextGen IO, which was a successful project to test prototype hardware. So, the different partners in NextGen IO have been collaborating closely over four years to design, build and deliver and test a prototype hardware platform based around NV-Ram, a non-volatile memory. So this allowed us to have access to state-of-the-art technologies.

(4) We have also been partnered with Nvidia to visualize some simulations. This sort of visualization is quite interesting to engage a broader community.

I will also give a few examples of partnering with observation providers.

(1) As we all know, we've been quite badly hit with a COVID crisis. Aircraft observations are actually one of the largest sources of observations contributing to forecast quality. And we had a fall of something like 75% of aircraft data globally in the period from March to April and May 2020. We have some new observing system coming into play. The private company Spire actually provided free of charge some of their data, GNSS radio occultation data. In the matter of a few weeks, we were able to implement this Spire data in our system.

(2) Also, some more research type of missions can be done. There are some interesting prospects with more varied source of data. We've been partnering with a private company called Saildrone, which develops the sort of windsurfing boat style platforms. We decided to locate these sail drones along transects crossing the Gulf streams because this is an area in the ocean that is difficult to represent. It is difficult as it has interactions with the atmosphere, and it can lead to lower predictability over Europe in particular. There will also be collaboration with climate scientists to look at air-sea fluxes of carbon with the same sort of platform.

Some key messages:

(1) It is very exciting times ahead in Earth system modelling that will require major technological development in HPC, cloud, AI, machine learning, and more observations from satellites, private company and Internet of Things.

(2) For step-change in such developments, we need enhanced partnerships. We already have, of course, a strong partnership with our Member States at ECMWF, but it has to go through WMO, academia and observation providers. And co-design with industry is also a critical partnership that I would like to highlight.

Presentation 3 by Dr Kevin Petty

I want to share some experiences, as well as some insights that we glean as we focus on advancing numerical weather prediction. And what I'm really focused on are the strategic partnerships that were developed as a part of this process. When we set out about three years ago to develop what we call the Global high-Resolution, Atmospheric Forecast system, we were really focused on:

(1) how we stay at the forefront of weather forecasting science and technology;

(2) how we can develop a global-scale, rapidly-updating system that would provide high-resolution data and that would meet our needs for product development and for some of our customers;

(3) we were looking at a very compressed timescale here, something on the order of two years or less, to create a new NWP capability for overall forecasting stack;

(4) how we ensure a sustainable, long-term capability that we could use for a period of time and continuously improve and update the system. As we started to think through these goals and considerations, we quickly realized that in order for us to go from point A to point B, we really had to lean in and find trusted, capable partners that had well aligned objectives. It's important to have a common goal when you're developing these partnerships. However, the motivation of different players may be slightly different. And I want to emphasize that's okay.

There were some key players that allowed us to bring this Global high-Resolution Atmospheric Forecast system into play. Internally, there were some players that we really needed to partner with, such as IBM Research and IBM Systems. Then there's an external component as well. We reached out to NCAR at the core of our Global high-Resolution Atmospheric Forecast system – MPAS: Model for Prediction Across Scales. As NCAR was the lead in developing this MPAS system along with some other institutions, they definitely had a motivation to see MPAS be put into operations. Nvidia is very much a company focused on GPU technology, which has been used in the gaming industry. They wanted to see how well we can press the envelope of the use of GPU in other areas such as numerical weather prediction. While there was key alignment on our goal that we want to develop this new forecasting capability, they had a slightly different motivation around being a partner here. That's not a problem as we were still centred on this common goal. Same thing with the University of Washington, who was also a very important part of this overall structure of helping to port code and also looking at new novel data sources that we could use. Again, from a university standpoint, University of Washington really focused on how they can nurture students and how they can advance fundamental research, which is why they wanted to engage here, having maybe slightly different motivations. But at the same time, we're very much aligned with the core initiative that we had put on the table. Even when we look internally, IBM Systems is not leveraging the final product here of GRAF, but they really had this motivation to build a new type of HPC and develop experience that could be used later. It was a slightly different motivation, but very well-aligned with the core aspect of where this project was going.

You can look at the global weather and climate enterprise as public, private and academic. We typically stop there. But I want to highlight non-governmental organizations as well as community-based organization in order for us to build into end solutions that are going to have an impact on society. That impact on society is the protection of life and property and advancing economic vitality, which is a common goal for everybody. We might have slightly different motivations about how to get there. But that's where we want to go, and each one of these organizations, whether that be in the private sector or community-based organizations, brings something that's very valuable to the table. It could be data, it could be science, it could be infrastructure, and it could be thoughts about policy, or how to do policy. Bringing all that together will allow us to be successful, to reach and tackle some of the world's biggest problem, particularly as it relates to the protection of life and property.

A couple of takeaway messages:

(1) Developing strategic partnerships is a very effective and efficient way of achieving your goals and objectives, particularly if you have compressed timescales that you're trying to meet.

(2) Engaging the right partners is also essential and we should not force fit something. If there's not a good partnership there, it's okay to walk away from the table and realize we might need to find another partner.

(3) Partnerships should be built around a common goal, recognizing that the motivation of each partner might be slightly different. That is okay. The notion that we have to be so completely well-aligned is not necessarily true.

(4) Strong partnerships can open the door to other opportunities. We've seen new opportunities bubbling up through this partnership.

III. PANEL DISCUSSION

Question: The future vision will require more observations to help initialize global models to calibrate the output of those models for local use. But there are still many, many data sparse areas around the globe. How will the satellite operators and other data providers help?

Dr Paolo Ruti: In the near future, we will see an unprecedented increase of our capacity to monitor the Earth system. Let's make concrete example of Africa. We will launch our third-generation geostationary satellite at the end of next year, where we will have a lot of additional information from our imagery every 10 minutes over the Africa and Europe at very high-resolution (1 km or 0.5 km for infrared or visible channels). We will have lightning information in that area. And soon after one year, we will launch our hyperspectral sounder, so we will capture all the information from the structure of atmosphere. What does it mean for the people living in Africa? It means additional information for nowcasting, for short range prediction, and for disaster risk mitigation. The Arctic is another data-sparse area. With the Copernicus' high priority, Sentinels, and with the near future Arctic Weather Satellite of EUMETSAT, we will have a lot of additional information for sea-ice region, i.e. sea ice, ocean and atmosphere information in that area. Radio Occultation is an interesting example of public and private information coming together to improve our forecasting systems, which is part of the answer. Let me highlight two other points. One is building multi-disciplinary solutions across different measurements. Air quality is one example. The new polar system of the second generation that we will launch in 2023–2024 will have Copernicus' Sentinel instrument providing information on air quality over several parts of the world. And the greenhouse gas would be another target where European Commission, EUMETSAT, ESA and ECMWF are working together to provide a global information available for emissions. The other point is the coordination across different agencies. This is an important element because no one single instrument or no one single satellite is the answer to a complex user-requirement landscape today.

Question: How will the INFCOM effectively utilize the non-standard data coming from the Internet of Things? Will this new data help to fill the gaps and enable highly localized forecasts? And are these developments going to impact the Global Basic Observation Network and the Global Data Processing and Forecasting System?

Mr Michel Jean: The infrastructure that we currently have has been designed essentially to deal with structured data. As we get into this new world, it will be a combination of additional structured data and far more unstructured data that could be of use by this community than we are actually using. A number of NMHSs have already started to use non-traditional data such as soil temperature data from sensors in tires. The availability of these data relies a lot on public-private partnership and a lot on those new sensor technologies because the private sector is a lot nimbler and can work faster. And once there is a prototype, they can re-engineer that way faster than in public organization. So, to me, that partnership is fundamental. Last but not least is the review of the data policy. A lot of those data are not part of the traditional thinking in terms of what is supposed to be made available. And this is something that we are factoring right now.

Question: The white paper talks a lot about the need for research to reach anticipated improvements in NWP. What do you see as the main focus for future research and how should the science community work in a more coordinated way?

Prof. Celeste Saulo: One of our main goals should be trying to focus on the science-for-service paradigm. We need to put our research efforts at every portion of the value chain. We have heard many interesting views today. I think they are more biased towards infrastructure technology and models. I would like to highlight the need for social sciences on board. Why? Because in the end, we are providing services. This is really challenging. Because services are different from one place to another. We need to secure that this new knowledge is really taken up by the global society. Of course, this does not mean that we should not take into consideration fundamental research. We have to understand the system, we have to understand how we can predict it, and better find which are the processes that we have not yet captured with our observing system and with our physics or chemistry and carbon cycle processes. But in the end, what we need to do, if we want to succeed, is to reach people. And for that, we need a lot of social science, too. As for how to involve a wider community, I think that WMO, the private sector, and each country have to become an attractor for scientists to work on these problems. For example, in my country in Argentina, only 20% of what is being researched in Earth science community is actually taken up by the weather service. We have to worry about that. Because we have a lot of brilliant minds working, but we are not sure whether we are taking up that knowledge for the benefit of this global enterprise.

Question: How will AI and ML impact the research to operations pipeline? Can AI model downscaling and calibration techniques deal with extreme events that are not found in the historical record or even found in training data sets? And as AI and ML lead to more automation of forecast production? Are they going to eliminate the need for traditional forecasters?

Dr Veronique Bouchet: First of all, will AI be able to look at extreme weather, even if it's not in the training data set? From my perspective, it really will be the ultimate test for AI techniques to see whether it can overcome this particular and long-standing science challenge. And maybe even more important is whether the resulting system that it would arrive to would be less costly than physically based system. There are certainly efforts in this direction, and many of those efforts are currently combining the best of both technology of the physical model and what AI has to offer. Right now, there's a lot of evolution towards the physics and form machine-learning technology. And in the short term, I believe this is certainly where we can expect to see some interesting developments in the near future. Will it result in the death of the traditional forecasters? I think it's quite certain that it will transform drastically. The artificial intelligence really has the power to augment what forecasters have done. And we can easily think of automatic situational awareness tools that can help sharpen and focus the attention among the millions of data and information, something that has already arisen in terms of diagnostic in the medical profession, for example. More than likely, it will be very useful in connection to forecasting hyperlocalized impact as they are really moving towards services that are more impact-based and customized. So, clearly the question is how we can get ready to explore that richness and how that brings forecasters to the next level.

Question: We know that public-private engagement can help in bringing together the best talent from different companies and organizations. It's already happening at ECMWF Centres of Excellence and that NOAA's Earth Prediction Innovation Center (EPIC) programme. So perhaps you could talk to us about how these programmes and others find the right partners, the best and the brightest, outside their own organizations.

Mr Craig McLean: I think, as in ECMWF, and also at our Geophysical Fluid Dynamics Laboratory, and other centres around the world, we have the opportunity to be attracting people because of the concentration of skill that exists in these areas. So, people are constantly knocking on the doors to gain access. We have, for example, at Geophysical Fluid Dynamics Laboratory (GFDL), insurance companies, energy companies, nongovernmental organizations, philanthropies, sponsoring scientists, and their outlook is to share the products. Now EPIC came along with the idea of opening up the access to the model code. So, you don't have to be in one of our specific centres like Geophysical Fluid Dynamics Laboratory to really be focusing on the operational model. And we've done so by further opening up with a unified forecast system that has all of the elements of the model available for academics or commercial sector to come in and work through. So EPIC is a virtual centre that allows people to get guidance, have access to the code and to be walked through to what has been termed as, I will quote our former NOAA Deputy Administrator, Neil Jacobs – "the graduate student test", i.e. it should be easy for graduate students to gain access, upload, and work with the code. And it's become quite successful even without us as yet offering funding for these opportunities. So, I'll go back to Dr Petty's comments, which I think we're right on target of. Try to find the motivation, and then harvest from that suite of opportunities to properly motivated individuals to get the best possible product. And where we can combine with commercial sector for the skill and the intellect, as commercial enterprises are right now sending people to work with us, we'll be sending people through the EPIC experience and working with our unified forecast tools. There may be a profit motivation for a commercial company. But that doesn't dissuade us. There's a remarkable eight to nine billion-dollar commercial weather industry built upon what the US government provides domestically free and open. So, everyone's gain is everyone's gain. The opportunity is there. And we think that this is a very compatible methodology for us to be improving our own numerical weather prediction skill. And once achieved, we'll be taking that into other modelling components that are reaching beyond the days, i.e. the seasons or the outlook of weather forecasting. But I think the skill and the opportunity can find the right model for the match whether the expertise comes from the commercial sector, the academic sector, or nongovernmental organizations, and we're thrilled about the opportunity.

Question: The white paper that was issued about a month ago recognizes the need to fill the existing capacity gap in order to allow less developed countries to benefit from the big improvements that are expected from weather and climate forecasts. So, what should be done differently in the coming years to ensure that no one is left behind?

Prof. Pauline Dube: We all have been working on capacity building, and we realize that we need to do more and move from capacity building to also capacity enabling, so that the capacity can be built and maintained. It's clear that there are a lot of exciting technological developments that are happening in the climate, weather and water areas, but some regions remain behind. And clearly it means there is no trickle-down in terms of the know-how, so we have to really make effort to put out multiple strategies that are region-specific, in order to deal with this increasing gap in capacity as the technology advances.

And I think the most important thing is really to aim for a self-reinforcing capacity building process. If you are thinking of how we implement this self-reinforcing capacity building process, we only have to go back to the WMO goal in the Convention where we talk about promoting indigenous capacity building. It means the interest in capacity for weather, climate and hydrological and environmental services needs to come from within the societies themselves. And to me, it means we have got a huge goal of building a demand for the weather, climate, hydrological and environmental services, and creating awareness to make a need for such services in all sectors of society, so that when it's not available, people can feel that they need something. In that way, you encourage countries to actually begin to prioritize putting their own resources on the issues of building capacity for weather, climate, and environmental services. In the long run, for the sake of global security, it doesn't help having some regions become the centre for a high-level capacity taking the advancements of technology while others are remaining behind. I think it's critically important that all regions of WMO are capacitated in the whole cycle of weather, climate and water science, technology and service delivery. We shouldn't have some regions being consumers of products that they don't really have a background of. Every region must have a critical mass of people that are really trained in these sectors and be able to run, maybe, nodes or centres. Then they can link with the universities in those regions and with the National Meteorological and Hydrological Services for further training at a lower level, rather than to rely completely on having specialized and very advanced centres in some regions. I think, for the sake of global security, we need to expand to make sure that the technologies are available across regions.

And then the other thing is to broaden the capacity itself in those regions so as to look more into co-designing the science, the products, the services, and to engage in the society, which means the social science should be brought into the framework, linking with policy and also linking with communication skills, because you want to build that demand for weather service and to make people see the value of it in their everyday life. We need people with specialized communication skills to reach out to the society in the way it operates. We are perhaps doing that, but we are doing that as scientists and in a technical way and failing to really reach out to the way that society operates. We need to be infusing the weather, climate and water into conventional subjects like finance, infrastructure investments, and the insurance for risk management, having them as part of building human capital itself. Advanced technologies like computing, data science, internet connectivity and machine learning have been talked about by the different speakers, but those are not being picked up in the less developed regions, which means the gap increases further and further. That's why it's really important that we first build the need. Currently, we are still focused on sectors like agriculture and water, and less on really advancing the issue of weather and climate in the wider part of the society. There are new players that are coming in from the private sector. WMO cannot do this alone, and they will need to engage other parties. And that brings out the question of quality assurance and standardizing the whole process of capacity building. Wherever it is produced, it is critically important to maintain the quality of service delivery across the board.

Question: Despite all our progress, severe weather still carries substantial hazard in many vulnerable communities. As a representative of many small island developing states, which are particularly vulnerable, what are your expectations from the white paper? For instance, do you expect that hurricane forecast so important, of course, for your region would be radically improved, and what sort of partnerships are needed to contribute to that?

Dr Arlene Laing: I do expect improvements in particular areas that are deadly and particularly destructive. I will mention one impactful and complex aspect of hurricane forecasting, the problem of storm surge and coastal inundation. We've actually already seen radical improvement in this aspect during the most recent hurricane seasons because of the implementation of the WMO Coastal Inundation Forecasting Initiative (CIFI) in Hispaniola, which covers the Dominican Republic and Haiti. And that's an effort led by the National Hurricane Center and WMO. Those forecasts and the responses really illustrate innovative ways of applying probabilistic forecast scenarios, along with track forecasts, socio-economic data, biophysical data, land use data and other data at the local level. Through these innovative applications of research to storm surge forecasting, we are now able to see nearly instantaneous forecasts that can be adjusted with storm track changes. And I'm looking forward to further improvements with the incorporation of heavy rainfall and riverine flooding, which is one aspect that hasn't been quite married with this coastal storm surges yet. The white paper also speaks of bridging high-impact weather and climate services, which is really valuable to the Caribbean, especially the challenge of forecasting sub-seasonal clustering of hurricanes. For example, in 2020, NOAA's alert of the La Niña conditions during September was a big indication that we could expect major hurricanes in the Caribbean. Whereas the early part of the season had a number of hurricanes, mostly were minimal. However, with the expectation of major hurricanes during the La Niña in that latter part, you had an alert at a climate scale or sub-seasonal scale. And then you had, in combination, the successful forecasts of individual tracks, wind, storm surge, and heavy rainfall. And the result was that fatalities from Hurricanes Iota and Eta were reduced dramatically from what was in 1998 with Hurricane Mitch, from tens of thousands of deaths in 1998 to a few hundred in 2020. So, we're expecting more of these improvements with hurricane forecast.

But not only the hurricane forecast improvements, we see a value in improving resilience through partnerships that have been developed with the International Weather-Ready Nations (WRNs) which is funded by the USAID and the WMO CIFI, as well as regional coordination within the Caribbean and within Central America. So, the partnerships that we're looking at are research partnerships that focus on operation-directed challenges, which are really critical to improving hurricane forecasts. Forecasts are also successful when used to make better decisions. That occurs with dialogue and partnerships that are focused on regional challenges, which is what we're trying to do in Region IV. Among forecasters, decision makers and producers of the varieties of data that are needed for this kind of impact-based forecasting, and in particular, for hurricanes, national coordination that is supported by international agencies and donors really will contribute to that success. I share this particular example, because it's really a good example of the success of partnering with model developers, operational forecasters, and users working together to co-design products, services and information flows. And it's supported by the agencies that are funding them. Because too often agencies might be working on a subset of groups within a country and then others don't know what they're doing. And they all need to come together in a nationally-coordinated effort, or regionally if that is the case. So, the forecasting of sub-seasonal clustering of hurricanes is a major challenge where I hope to see a bigger improvement, because that has a boon to forecast-based action and resource mobilization and preparedness and response. And the white paper does speak of successfully applying forecast-based finance schemes aimed at improving assistance to developing countries sufficiently ahead of time before being hit by a severe weather event. So, the forecast probabilities being increased in scale would be highly welcomed by the Caribbean.

Question: You work in the disaster relief area, your work is very much dependent on timely and accurate forecasts. So what are your expectations over the next five to ten years, when it comes to impact-based forecasting? For instance, the white paper predicts that forecasts will be delivered on a human scale, for instance, being able to have it on the smartphone, wherever you are.

Mr Madhab Uprety: I think, at the reference centre, like climate centre, we have been trying a lot in terms of how better we can integrate the forecast information into the overall humanitarian programme within the Red Cross movement. In coming years, we will be seeing a lot of demands in terms of the accurate and reliable forecasts for different lead times. But at the same time, the need for more actionable forecasts will also be there. How better we can also forecast the impacts is really crucial in terms of reducing the potential impacts by those hazards or disasters. How better we could capacitate the national hydrometeorological agencies to offer this impact-forecasting services would be the defining point for particularly the humanitarian agencies like us so that we could save lives and livelihoods of the people. So, in coming years, we really expect to see a lot of partnership and collaboration particularly in relation to the development or the co-production of these impact-forecasting services in different countries, particularly in the developing world where the climate and weather risk is really high. In terms of providing this kind of services at human scales, we do acknowledge that it's a bit of a challenge. But at the same time, the importance for all of us would be to also ensure those information, whatever forecast dimension, will be delivered at the human scale, relevant to him or her on how better he or she could relate those information to his or her life/livelihoods and also economy. I think that is really crucial. How better we can provide different forecast information so that we could inform or link this whole chain of early warnings to reaction is something that we, as a red cross movement, do expect in coming years.

Question: Many private sector companies in the service delivery domain rely on NWP products from NOAA, ECMWF and so on. So, there's expected improvements in this, as the white paper outlined, which should be good news all around. But how do you see better engagement between the private sector and the public sector to boost socio-economic benefits?

Mr Jim Anderson: You're absolutely right. Certainly, everybody benefits, including the private sector, from continued improvements in modelling capacity and performance. I think Kevin said it really well in how we partner. Those principles applied to a partnership across the entire enterprise: academic, the private sector, the public sector, etc. I think we tend to think about these things as having to be pretty structured. And I love how Craig described this as being actually a really fluid exchange between the public sector and the private sector. In a lot of cases where there's just, mutual benefits, it's absolutely win-win, and we can set up sort of an institutional structure that makes that possible. And I would say another area where these can be applied, and related to Professor Dube's comments about the need to be able to build capacity. We see this as HMEI, as an organization, that really enables capacity development across the globe, especially in the developing world, in areas where observations are needed the most to support better NWP. If we can set up a better framework for allowing more win-win public-private partnership in these areas, then the private sector has the capacity to provide services to enable not just the deployment of observing systems but also the operation and maintenance of those systems over time, and do that in a way that cooperates with local institutions to build capacity and expertise at local level, and ultimately create a sustainable business model for the maintenance and continued operation of those systems that provides those observations for the modelling community over time. So, I think that's what we have to look to and try to do to make it meaningful and relevant for those communities.

Question: The white paper states that all of the expected improvements in numerical weather prediction will have a huge impact on production and delivery of services. And this is something that Gilbert also emphasized about improving forecast verification. What needs to be done to ensure that, from a quality control perspective, we're able to quickly discard erroneous information in order to build the end users' confidence. How can those same quality checks be applied to providers from all sectors?

Mr Ian Lisk: Verification and validation are fundamentally important to continuously improve, and to obviously challenge what we all do as well. And one of the fundamental questions there is: who do we need to be working through within our weather community to affect those improvements? It's really important, verification and validation. It puts the user and what the user wants at the heart of what we all do, asking that question: what is it that I'm providing? Why is it important to the user? And how can I give them exactly what they need? What's really important, though, from a WMO perspective, is that in order to actually do verification and validation, you do actually have to have underpinning benchmarking, underpinning sort of quality standards that we've all agreed to in the first place. And I certainly think that through the WMO Technical Regulations, working with all our partners in academia, the private sector and Members, we've got a big job to do here to actually do a better job on those service quality standards within the Technical Regulations, and provide the appropriate guidance, standards, recommended practices, and also the guidance and the guides in how we actually engender this culture of compliance. Just one last thing, obviously, in terms of those sectors, I know we're focusing on weather and climate today. But of course, we're talking about water, that's hydrology and marine. We're also talking about these other environmental sectors that we are also looking to provide elements for coordination on health, on space weather, and I could go on with a list as long as you like. Finally, just reflecting on Kevin's word about those productive partnerships, we're looking good in terms of that productive partnership. We're doing a good job already. Let's continue to do that.

Question: The white paper talks about forecasts with spatial and temporal resolution going down to the human scale. What innovation and public-private engagement is needed to ensure that this detailed information could get to everybody everywhere on time.

Dr Kevin Petty: I think many of our panellists have touched on some key aspects of looking at even beyond our core technology around NWP. How do we utilize other technologies such as artificial intelligence and machine learning to further extract out information at those higher resolutions? But what I really want to highlight here is something that Professor Saulo said earlier. Many times, we focus as a community on the technology side of how our forecast verify, and we apply certain metrics to verify that forecast. However, we really need to bring in the public and the end users' perspective into that from the social science dimension, because we can say, hey, our forecast verified really well. But as a user who just lost their house, that forecast may impact me in a different way. So, while we move towards these higher resolutions and higher capability, absolutely, it's a great step in the right direction. But we have to bring in that human element of not only accuracy, but perception of accuracy. And I think that's something that we need to really account for moving forward.

Question: We are staying in the same realm about global models getting more accurate with higher resolution, but smaller national met services may still have needs that cannot be fulfilled by those global models. What needs to be done to ensure that they can make full use of the information and the tools that are available from the global centres?

Dr Florence Rabier: Gilbert showed how numerical weather predictions are going to scales of the order of 1–3 km, which is great, because they can resolve processes with better accuracy. But this means there is a huge amount of data which can be difficult to access. So, the first challenge is really for users and met services around the world to have access to the data efficiently. I think that's where cloud technology comes into play, because they are broadly available, and they can give access to the data. That can solve the bandwidth issue if you want. This is something we have been developing in particular with EUMETSAT, i.e. the European Weather Cloud, to give access to our own data, satellite data and NWP data. We've been developing that with our Member States, which is still a pilot. But it will be open for the Members of WMO for official duty starting from next year when it's not a pilot anymore. Of course, there are also private providers of cloud, which is something absolutely great. You can also run your own limited-area models because we know that global models can also be complemented by regional/local models. The global models going to reach 1–3 km in resolution doesn't mean that you don't need to refine it with more. This better description of local processes may be supplemented by other observations, local observations that may not be available or usable for the global models. So, maybe in the cloud, you can also run these limited-area models. And for the NMHSs who do not have the resources to run models on the cloud, new technologies like AI and machine learning can complement and can downscale the global models by using in particular reforecast of the global models, local information, and local observations. Then they can make the most of these global models by downscaling to the local scale for knowing what is available and what is interesting for their users. So, I think this is another interesting avenue to complement the information provided by global models.

Question: We know that one of the big developments aside with the increase in resolution has been the increasing use of ensemble approaches to forecasting. There's a lot of agreement that these are going to become increasingly ubiquitous, of course, especially the shorter timescales, with convective processes dominating there. But how are we going to educate the users to understand effectively use these probability-based products and services?

Dr Gilbert Brunet: I think for the very short timescale, ensemble will eventually be very valuable. But still, you will need to increase more the space resolution at those timescales. But for longer timescales, we clearly need more and more ensemble, and it's having a lot of added value. About communicating uncertainties, this is nothing new and it goes back to the 19th century with Fitzroy. The difficulty can be to communicate the uncertainties of the forecast to customers. And I would like to remind the World Meteorological Organization has guidelines on how to communicate forecast uncertainty. When it comes to ensemble prediction system, I don't think there is a one-size-fits-all there, and always think that there are three types of people who use probabilistic information. I would say the first one is the technical users, the one who understand very well the problem and what they need to do with the probabilistic information. And these people tend to adapt quickly to the actualization of probability forecasts and adjust their decision-making process. With experience of using more of those ensemble systems, they developed a very nice framework for making decisions. The second type of people using that information is a more difficult one, those who need to make really difficult risk averse decisions even when the outcome is very difficult to put a market price on the outcome or to quantify the impact, as an example, when there will be loss of life. That's certainly a place where we need to do more work to understand what's going on. And I would say the third type of users are the lay people, the people who are not technically educated. For them, the products need to be very well-developed. They need to be tailored to the users' needs, and tested a lot. It depends on the cultural background and on the type of activity that people are doing. It could be outdoors, sport activity, etc. That's a place where we need to have more user engagement on this.

IV. CLOSING OF THE FIRST DAY

Dr Elena Manaenkova, WMO Deputy Secretary-General

To us, this is a very exciting white paper and really great innovative thinking. I should say big thanks to all contributors, writers, reviewers and special big thanks to Dr Gilbert Brunet for taking the leadership and putting this all together. The paper is really an extraordinary work. And the event is also great. I am sure that there are a lot of participants following the event, and they are part of our ecosystem. For me, the future really looks very bright, but we need to start hard working right now. WMO is already looking at this paper to see how we should incorporate it in the future strategy which is coming in a couple of years. We also really invite and encourage NMHSs and partner institutions to look at this paper and to start planning for the mid- and long-term because the things will change. And they will change a lot in the way we hope if we embrace all the opportunities and innovations, and really utilize the breakthroughs. Then we can accelerate our science-to-operation cycle and improve our seamless Earth System forecast from minutes to season. And this is our global public goods, something which gives benefits to everybody and so WMO really cares. The public good gives the best possible information tool. This improvement will also make us rethink: are we doing a good job at regional and national levels? What should we do so that our cascading system will also transform into something more meaningful and more flexible? In this whole endeavour, the role of the private sector is extremely important. The role of academia is extremely important. We do value our partnerships. And we should constantly enhance our partnerships as we go. And finally, I should also stress that in the Geneva Declaration 2019, WMO highlighted the need for community approach at all levels, and the title of Geneva Declaration 2019 is “building community for weather, climate and water actions”. So, this mechanism of OCP is a baby mechanism, but it started proving that it really does a meaningful job to bring us all together. Thanks again for all speakers, panellists, writers and for Gilbert. And thanks for all who are following us today.

THE SECOND THEMATIC SESSION

I. OPENING

Prof. Gerhard Adrian, WMO President

I wish to thank the hundreds of participants from all parts of the world for your interest in this event of OCP. I would like to remind you that one of the tasks of the OCP mechanism is to establish collaboration between the public, private and academic sectors, in an attempt to build a common vision for the major components of our enterprise with the horizon of 2030 and beyond. This is absolutely necessary in order to forecast and then guide our own future in an informed and scientific way. Yesterday, we discussed the vision of the future of the weather and climate forecasting as a key component of the enterprise. We are convinced that there will be a great progress in the next five to ten years, which will help us to serve the society better and to meet the expectations of the user communities who depend on us. The theme for today's session is also very interesting and of great importance for the whole community. It is about evolving roles and responsibilities, with a focus on a vision for the future of National Meteorological and Hydrological Services. Many PPE discussions over the last two or three years spoke about these evolving roles, e.g. the growing role of the private sector in service delivery, the importance of research and the need for a stronger regulatory function of government in the multi-stakeholder enterprise. Thus, building a common vision is very important in order to make the future more predictable, foresee eventual disruptions and cope with them through dialogue. We should remember that the NMHSs are the core element of the global system built over the last 150 years. They are the agencies designated by the state governments to fulfil the requirements of the WMO Convention and to make possible the delivery of services to save life, protect property, and support the well-being of people. NMHSs are providers of core infrastructure and services. They are the official authoritative voice in the early warning systems and climate services. They provide basic data for national and international use in accordance with WMO data policy. Thus, they also facilitate the operations of private companies delivering weather and climate services. Therefore, there is a big opportunity for cooperation between the public and private sector. But we should also acknowledge the great diversity of NMHSs across different countries in terms of their mandates and responsibilities, budget and size, capabilities, business models, human resources, etc. Yet the international obligations are quite similar among them, including the fundamental commitment to share data, products and knowledge, which are the prerequisites to the success in serving the global community. We also realize that many NMHSs are more than 100 years old, with long and stable traditions, while others are younger. Some are struggling to bring their capabilities to the required level. The vast majority of the NMHSs belong to the public sector, but there are also some exceptions. There has always been interaction between the public and private sector in many ways, but the last two decades really raised the level of public-private engagement. And this is one of the main trends shaping the future. We have a great panel today. Three invited speakers will present typical national cases. The panel is dominated by directors or CEOs of NMHSs, and we have also representatives of the private sector, development partners and regional organizations. I hope that can substantially cover the complexity of the thematic issue for today.

II. PRESENTATIONS

Presentation 1 by Ms Marianne Thyrring

I think the theme “the Roles and Responsibilities of the National Meteorological and Hydrological Services” is really a central question which we should be discussing continuously. I’ll try to tell you the story about DMI, the Danish Meteorological Institute. She is an old aunt of almost 150 years. I would like to explain how we took off from being a very product-oriented institute to becoming much more society-oriented. In fact, this is DMI’s answer to the question: what is the role and responsibility of a National Meteorological and Hydrological Service in future?

In 2016, we were in a serious budget trouble because our commercial business was not running very well. My personal view is that we should not be in competition with the private sector. We should only deal with the responsibilities that you can give to a public body. And what are the responsibilities you can give to a public body? The core business of a national meteorological service is weather authority that speak with a single authoritative voice. We are very keen on that at DMI and are building up this function. We are building up our understanding of impact-based weather warnings, and our collaboration with other public bodies in order to serve the society the best we can. What we have also decided is that providing data to society should be a core part of our authority as well. I call it a data pusher, which means that we are walking towards free and open data and we want to make our data free for everybody to use.

But it is not something that you on a Monday morning make that decision and then it works. First of all, there is a financial issue. And I think most colleagues around the globe do realize that giving your raw material, our data, just away could be a very expensive exercise. We had to work very hard towards the political system, towards our ministry and the parliament in order to persuade them to see that the societal value of having a meteorological institute in Denmark would grow enormously if we were allowed to open our data and if the parliament were to give us the budget, which made it possible for us not only to make the relevant IT structure, databases, and APIs, but also to reimburse what we lost in our commercial business as well. And again, it is not a discussion you can finalize within one afternoon. It went on for a couple of years. And what we did was to have our stakeholders, private users, interest organizations, local municipalities, and everyone around us to be the voice and put pressure on government by explaining that they want this meteorological institute to have a new role as the pusher of climate and weather data. So, an important conclusion is that if one wants to define a new role and responsibility like what we did, you have to find someone outside your national meteorological institute to call for this and ask you to do it, speaking in favour of you. If that is not the case, it is never going to happen. Even though we are correct in our understanding, we are never going to make it only by ourselves. And where did we get? Within a whole set of policy initiatives on digitalization, the parliament has decided on opening the DMI data and making the data free and available for everybody. And we also managed to modernize our old and over-complicated IT infrastructure and also the collection of data to make sure that our production systems do work in one channel and the open channel works effectively when we put on the task of being the authority to push data to everyone.

This whole exercise was in fact a test of the trust and confidence through the meteorological service. Having been in trouble in commercial activities, one could fear that the political situation would be around us in which we would lose the trust and confidence on us. So, asking for new tasks and new responsibilities, e.g. open data, would give us the answer to the question whether we are relevant to the society in future. We did manage to persuade the political system that without relevant meteorological and climate data, we are not going to deliver on the greening of the economy, which is high on the agenda in Denmark and everywhere else in the world.

We now have to get into the issues we are discussing here today, the co-creation with the private sector, not only other meteorological institutes but also the meteorological enterprises in a wider sense. It is all about making people do make better decisions on climate- and weather-related situations because they have access to DMI data in a free and open way. I think we still have a lot of challenges to work with, including the change of mindset. We have to do a lot of changes in how we work together with the outside world. We have to listen much more to our stakeholders. And this is a new exercise where we really have to swallow things we didn't expect to swallow, because the outside world might not want what we expected them to want. So, for us it is really a world we have started. And our ambition is that we will become better and better in understanding the outside world, being thereby able to fulfil our task and role for the future.

Presentation 2 by Prof. Mansur Bako Matazu

I will try to answer the following question from the background that Nigeria has the biggest economy in Africa, and I'll share experience on how we have started planning from the 1950s and support fully this country and big economy in the future, and also on what we are doing to prepare for such a huge challenge. Weather is a major challenge in achieving sustainable development. Weather-related, and also weather-caused, weather-dependent disasters are frequently affecting different countries, including African countries. And many of such effects are very catastrophic in nature. So, for us to achieve sustainable development, we must therefore understand weather first, then we adapt to it and the changes, and then also try as much as possible to mitigate the effects and, if possible, to control it. To do all this very huge task will require contribution of all, and that is the breakthrough in need of partnership. The world globally needs development to eliminate inequality and instability. Achieving development is always a very huge challenge. We have multiple stakeholders that need to come together to meet up with this huge challenge. The public sector alone can't do it. Therefore, the UN Sustainable Development Agenda particularly emphasizes the need for partnership among countries. Partnership in weather service delivery is the very key to achieving sustainable development.

Meteorological services like NiMet are not only custodian of weather data, but also provide lead in delivering services. We therefore need partnership since we can't always do it alone. The public sector has this advantage in that they are providing the public goods, but we also need to create an enabling environment for the private sector to thrive. The idea here is to see the private sector not as a competitor but as a partner in progress. The private sector is primarily for profit making, but they also need to be corporately responsible. As public finance becomes limited to us, the public sector is now forced, as much as possible, to go towards commercialization, and that is the basic thing. In the global public-private enterprises, there are well-established and successful partnerships where both sectors share common goals. And there is new opportunity emerging to develop this partnership. WMO and the World Bank are trying on this, and the target is to enable the whole enterprise to grow and produce more accurate and reliable weather forecasts. What can the private sector offer to the weather sector? Basically, it is trying to address how best we can operationalize innovation from research and development. And of course, the private sector is sometimes more capable and more efficient. So, the private sector has the advantage to invest in sophisticated areas with higher risks that the public sector cannot always cope with. And many small and large companies already are adding value, as we have seen, in many areas in terms of consumption of weather and climate services, and in production and delivery of service as well. And it can also particularly help smaller meteorological services across Africa in public numerical weather prediction, which is capital intensive. It can of course also help in disseminating weather forecasts widely, because the requirement of generating forecast, enabling the environment and getting to user communities, is a very big task that requires many partners on board. And of course, the private sector can on the other hand also help the meteorological services by technology transfer to improve our services. As I mentioned earlier, Africa faces very huge, difficult development challenges. In addition, our climate is the most dynamic and difficult to monitor. And, of course, the meteorological infrastructure is not well-developed in Africa. These three key challenges, therefore, require that African meteorological services like NiMet to be more effective and promote saving lives and property. And of course, we can't do it alone as government. The private sector has a very huge potential in the region, like in Nigeria, and can also help in raising and deploying private venture capital for high-tech developments, especially in measurements, computing or data technology.

What are the roles of meteorological services and the private sector altogether? We, as meteorological services, need to meet up with so much emerging expectation. And the technology is moving fast. Meteorological services like NiMet cannot easily meet up with the needs to catch up. A colleague of mine is mentioning that you need to continue to run in order for you to remain where you are in this world now. We can't continue to stay where you are because we need to meet up with the very challenge that we have to catch up with very fast. We need to start delivering new products and services. And the private sector now can become more involved in nearly all aspects of public life, in the weather enterprise. From observation

to tailor-made products, the private sector can really come and work together with meteorological services. The prospects are very high in term of private sector engagement. And solid partnership can be built. But there are some challenges. There are some misunderstanding and even mistrust between the private sector and meteorological services that I've seen from recent experience in Africa. Greater engagement is needed between the two to dispel the perceived obstacles. I very much appreciate WMO and the World Bank for their trying on this challenge. The mistrust arises due to lack of knowledge and clarity. We now come together to share experience. And we clarify issues about individual roles and responsibilities of both meteorological services and the private sector as well as how they can best work together. NiMet's engagement with the private sector is a result of the fact that the private sector engagement in public service delivery is well considered in Nigeria. Our government has a unit called ICRC established in 2015, and there is a governing law to guide partnership. In NiMet, we need thousands of varied, recording and analytical instruments. We provide per-minute and per-second operation to 24 plus 6 international airports in the country, and we provide agrometeorological services to more than 260 million populaces. We also provide marine meteorological services to the marine community of over 800 kilometres' coastline. The technology and resources to maintain and manage all these tasks are not completely available. But the market to generate and deliver the products and services is very big as Nigerian population is currently about 260 million. Therefore, we are leveraging the use of ICRC models regarding funding, revenue sharing and benefits realization. This quickly leads to technical partnership for good service delivery in Nigeria. Examples include: an MoU with UBIMET in 2017 for installation of lightning and thunderstorm detectors in our 22 federal airports and 14 state airports; an MoU for a project to install automatic weather stations targeting about 9 400 stations nationwide; partnership with Earth Network for lightning and thunderstorm detecting; partnership with the bank NIRSAL to provide weather insurance schemes to de-risk the activities of about 4 million farmers; and partnership with the four major GSM service providers in the country, based on which we've developed an App that could easily relay information of real-time including short range and long range forecast to farmers and other users in Nigeria.

We've learned some lessons from this experience. Partnership is a two-way venture, requesting us as meteorological services to do a lot in terms of technical, financial and procedural as well as administrative frameworks. At the beginning, the start-up costs are very high, and many developing countries may not have enough to spare, and immediate return on investment is not always instant. And legal framework need to be very strong to venture into PPP. And some of us already have concession in some of our activities. I also wish to quickly share with you some of the key challenges. For climate and other meteorological services in Africa, we cannot continue to depend on ourselves alone. Government funding for provision of meteorological infrastructure is not sustainable. Therefore, we need this weather enterprise, a global, public-private partnership. And if we do, meteorological services can rely on the weather enterprise to meet up with the infrastructure deficiencies that are existing. And if we properly back this by legal and other frameworks, weather enterprise can bring substantial revenue streams in meteorological service, as we have seen in Nigeria.

Presentation 3 by Mr Naoyuki Hasegawa and Mr Masanori Obayashi

The public-private collaboration has been quite good in Japan, and we are now trying to strengthen the ties even more to respond to the changing and increasing requirements. The Meteorological Service Act supports the overall sound development of meteorological services provided by not only JMA but also private companies and various other entities. It was enacted in 1952 and has been amended more than 30 times. JMA's roles under that Act are to establish and maintain infrastructure for observation, forecast and warnings, and communication networks. It stipulates that only JMA shall issue warnings, which ensures a single authoritative voice in DRR activities. Promoting public utilization of meteorological data is also part of JMA's mission. The Act is also intended to maximize private sector activity. It stipulates observation standards and an instrument certification system to ensure observation data quality. The Act also stipulates a forecasting licensing system to ensure the quality of private forecasting services. Many media forecasters are certified under this system. More than 80 licensed private companies now provide a wide variety of forecasts, including personalized forecasts to be displayed on smartphones and customized forecasts for energy, agriculture, shipping, among others. IBM Japan is one of the licensed companies.

As required by the Act, most of the data and information collected and created by JMA is provided in real-time by a designated public foundation with distribution costs and with no restrictions on usage. Data amounts and types are increasing rapidly. The number of non-licensed entities using this data provision service is increasing, indicating greater application of meteorological data for individual activities. In addition to the sharing roles and data provision mechanisms stipulated in the Act, room was also found for further public utilization of meteorological data. Modern technologies such as AI and IoT were also expected to provide new ways to utilize the data. Against this background, the Weather Business Consortium, or WXBC, was established four years ago to promote socio-economic productivity. With the participation of service providers, academia and potential data users, the number of members has increased to today's figure of more than 1 000. The consortium functions as an important platform for sharing knowledge and experience and for the promotion of mutual understanding through ongoing dialogue. JMA serves as the Secretariat and also provides new data and related processing techniques in response to the needs arising from the dialogues. Let's look at a case study conducted in cooperation with the Japan Soft Drinks Association, or JSDA. The JSDA's sales statistics were combined with meteorological data for an investigation on the relationship between hot and cold drink sales and atmospheric temperature. The results showed increased hot drink sales when the temperature drops below 22 degrees Celsius. The results were used to conduct an experiment with vending machine restocking in reference to two-week temperature forecasts. When the temperature was expected to drop sharply below the threshold, the sales plan was changed, and cold drinks were replaced with hot drinks in a certain number of vending machines in advance. The results showed increased sales over a scenario in which temperature forecasts were not referenced. Demonstration of this kind of application is expected to lead to more advanced and broader use of meteorological data.

JMA has recently strengthened its efforts to improve its services in collaboration with academia and the commercial sector. A recent example is a joint research project which began with RIKEN, a top-level research institute in Japan. JMA signed an agreement with the institute two years ago to develop observation and forecasting technology, using RIKEN's cutting-edge AI expertise. Work is being conducted in areas such as observation data quality control and the integrated interpretation of numerical prediction outputs. Another example is the system for location-based notification for increased risk of heavy rain or flooding. The system is intended to ensure that people in hazardous areas are informed of risks and can evacuate quickly. This involves a combination of JMA's gridded risk maps and private companies' communication capabilities. JMA runs the service in collaboration with five commercial operators. Last year, JMA's advisory body, which is also stipulated in the Act, deliberated on public-private-academic engagement, and recommended more comprehensive engagement towards future development. This was in recognition of vital academic-sector roles in innovation with state-of-the-art technology and the private sector roles in enhancing data utilization in socio-economic activities. The advisory body also highlighted the importance of continuous dialogues and mutual understanding to create positive synergies for better services for public good. JMA

should oversee and coordinate whole activities, while promoting infrastructural services such as observation and NWP. To wrap up, meteorological services in Japan have been developed and underpinned by the Meteorological Service Act, with JMA having responsibility not only for its operations, but also for the whole system nationwide. JMA facilitates further use of meteorological data and services in economic and social activities through initiatives such as WXBC, while working to improve its own infrastructural services in collaboration with the private sector and academia. For versatile response to rapidly changing social environments and technologies, it is of vital importance to promote engagement of stakeholders through continuous dialogues and mutual understandings.

III. PANEL DISCUSSION

Question: We heard about the problems with public funding for the Hungarian national meteorological service, but there were positive changes recently. From your experience, what is the optimum funding model for an NMHS of a medium-sized country and economy?

Dr Kornélia Radics: The state budget of Hungarian Meteorological Service was the lowest in Europe in the last years. It was under 20%, which has been even decreasing from year to year. And consequently, Hungary was the country which has the highest prices for meteorological data and information in Europe. To get out of this tricky financial situation here in Hungary, a new business model has been settled. Recognizing the advantages and importance of free and unrestricted exchange of meteorological data, a consultation has been initiated in 2015 to advocate open data policy in the government. One of our triggers was the changing legal background within the European Union. It was here in Hungary a very long process. But as a result of our efforts, we got this significant budget compensation from our government, so the Hungarian Metrological Service could introduce open data policy from 1 January this year. We have got the legal mandate to make weather and climate information available through an open data server. As a result of this budget compensation, we received from the government our state budget with a super increase from 20% to 85%. It is not easy to answer your question: what is the optimum funding model for a meteorological service in a medium-sized country like Hungary? I think the appropriate business model varies from country to country, such as the legal framework. And the different National Meteorological and Hydrological Services have different obligations, responsibilities, capabilities and human resources. And besides the traditional areas of responsibilities, new challenges have emerged in the last decades to meet the rapidly expanding needs of society and economy. I think the most important thing is to find the right balance between the official duties which are funded by the government, and those roles and responsibilities which have to be financed independently or commercially, while we also serve the global initiatives and roles, e.g. the WMO GBON initiative, to maintain the observation system, to fulfil free and unrestricted data sharing or to contribute to regional Multi-Hazard Early Warning System. In Hungary, the current 85% state budget is perfect to serve these roles.

Question: We often hear concerns from NMHSs in Africa which themselves lack the capacity for provision of services at the required level, but they fear marginalization by the growing private sector. On the other hand, there are countries who put public-private engagement into practice and report positive results. So, what do you anticipate in this regard for African NMHSs over the next 5 to 10 years and what should be the regional approaches in Africa for public-private engagement?

Mr Daouda Konate: From our perspective, the meteorological services that we are planning in Africa for 2030 are well developed agencies that can provide climate and weather services to end users and socio-economic sector, which is public mission. This requires challenges to be addressed. The first is that infrastructure needs to be strengthened, e.g. a reliable observation system that meets WMO GBON and WIGOS standards. This will contribute to improved global numerical prediction and the production of climate services. The second is that meteorological agencies need to be much more involved in research and modelling to provide climate solutions for communities and policy/decision-making agencies. And we will need closer collaboration with the private sector to identify more opportunities for greater technical capacities and the development of climate services. We don't forget we are government agencies. Governments in developing countries should support and accelerate public investment in the observational system, information system, and computational capabilities needed by the meteorological agencies and the private sector as well. A model for public-private partnership can be adapted to various national scenarios. The other key point that I want to highlight here is we must have investment by funding and development agencies for efficient and tailored project targeting the capacity of national meteorological agencies and contributing to solutions for resilience to climate and hydrometeorological risks. The involvement of development partners in the PPE mechanisms is very crucial because developing countries lack resources to implement a PPE project. Project, in our perspective, will be developed in collaboration with the meteorological agencies. And funding by

development agencies and private sectors will be used for implementing this project. We have experience in Côte d'Ivoire with the World Bank, which funded a project in which a private company and national meteorological agency work together to develop a climate solution for our agricultural sectors, and it was a great success. And we are discussing with two other private companies to have the same experience, for which new projects we are looking for the budget from funding agencies.

About the second question on regional approach to PPE, it was discussed at WMO Regional Association for Africa a few weeks ago. All meteorological services expressed their support to PPE. And the Regional Association in this meeting has decided on some actions as follows. We have a vision to take due account of the WMO Guidelines for Public-Private Engagement in planning relevant regional activities, particularly those aiming at fostering mutual knowledge and trust between the sectors, and using the opportunities offered by public-private partnership to bridge capacity gaps. The second action is to encourage Member states in Africa to use this Guideline to establish cooperation, collaboration, and partnership at the national level between the public, private, academic and civil society sectors that share common goals in the interest of society, and to consider appropriate mechanisms for sectors to participate in the design and implementation of project initiatives in the region. The third is to encourage Members to share examples of good national practices in collaboration and cooperation with the private and academic sectors, like the examples in Nigeria and also in Japan, and to communicate them to the WMO Secretariat as Members' good practices. Finally, we will consider a regional forum on public-private partnerships to examine region-specific issues. As you know, we have specific challenges, opportunities and initiatives to increase cooperation and collaboration between sectors in the interest of socio-economic benefits. This is our regional approach to push forward PPE by 2030.

Question: A for-profit company is in competition with other companies. But the spirit of competition can be counterproductive when you're trying to produce forecasting tools and products that are necessary to protect life and property. What can be done to encourage collaboration instead of competition? And does the private sector need a well-performing NMHS in each country?

Mr Patrick Benichou: Indeed, collaboration and partnership are key words in this respect. I will focus on developing and emerging countries which are more than 80% of the world. I think that we can start with sharing a simple vision – main objective in meteorology everywhere is now to create value. This means that a well-performing NMHS, as you say, is nothing but an NMHS able to implement the value chain properly. This ranges from basic infrastructure, including broadband internet connectivity, to observation, data processing and service delivery capacity on top of everything. But a well-performing NMHS is also one that is able to guarantee sustainable operation of the full process across this value chain and keep skilled people at the right place along the line. Therefore, you can feel that the main challenge for NMHSs in the next decade is to continuously adjust the technical infrastructure to their main objective, and at the same time to adapt the organization to turn to a user-centric organization or society-centric organization. Can NMHSs face such challenges totally? Certainly not. They have to set priorities on how they implement the value chain, i.e. where they should put focus and energy and for which benefit. Can the NMHSs face such challenges by themselves only? Certainly not. And this is where the private sector can bring a lot through fitted collaboration and partnership. NMHSs need resources to move forward and speed up their development. Public-private engagement can bring leverage for that as they cannot do everything by themselves. Now their strategy says that they are not willing to do everything by themselves. PPE can take place on several parts of the value chain. It can take place on the observation part to provide data service, e.g. by playing a role as partners in the new SOFF initiative by implementing a fully user-oriented information system as MFI is doing, by assisting cost recovery and by providing last-mile service or warning delivery, including impact-based forecasts sometimes.

From the NMHS' point of view, partnership with the private sector should be seen as a booster of such development, although it means a major cultural change. From the private sector perspective, entering into PPE agreement with an NMHS is also a key to a sustainable business

and value sharing. So, the private sector and local PPE arrangements can certainly help especially if they are based on mutual interest and trust, and if they contribute to helping NMHSs to be stronger, or if they contribute to creating value from NMHS' output. However, PPEs are meaningless if they do not come along with fitted long-term business models. Those business models should comply with the local legal framework as it was said before. They may involve not only NMHSs and the private sector, but also local Ministry of Finance, governments and even development partners. On the long run, the accumulated created value that comes in the form of socio-economic benefit for the country should be higher than the cost of implementing and running those PPEs. WMO and its Member states already made a great step forward with the Geneva Declaration and promotion of the PPE concept since then. However, I feel that people are still unclear with the concept and how to proceed. This is why we now have to build and share concrete success stories of PPE implementation with daring partners of all kinds, and thus strengthen the weather enterprise as a synergetic hold.

Question: As computer models continue to improve forecast accuracy, the need for human intervention in operational forecasting is decreasing. But at the same time, the need for effective decision support for stakeholders like emergency managers, hospitals, transportation authorities and so on is increasing. So, how do you think NMHSs are handling this workforce challenge?

Dr Louis Uccellini: First of all, the role of the forecasters is changing. And I don't think their workload is decreasing in the process. That's my number one message I would hope people carry away. I want to thank Arlene, yesterday for noting that we all are already living in a revolutionary change of the models. The research in operational communities that have helped make that happen should be proud of themselves. Secondly, Gilbert noted that as part of this revolutionary change, and as a direct outcome of THORPEX, for example, is the use of ensemble models, actually the multi-model ensembles that the forecasters are using, and post-processing, which are certainly advanced. Then everything we heard about Artificial Intelligence, Machine Learning and other techniques are very important in that regard. The reason that this is important is because the useful skill of the forecast is being extended, but there's still a lot of uncertainty associated with that. But they're good enough to alert the forecasters to the likelihood, possibilities of extreme events 7, 8, 9 or 10 days in advance. And this is across all of our service areas. Now from a National Meteorological and Hydrological Services' perspective, this is important, because we're realizing that decision makers are focused on public safety and mitigating property loss, and increasingly require this information well before the extreme events for evacuations and pre-positioning assets to mitigate the impact of these storms, which actually starts 7–8 days in advance, even in the face of that uncertainty. That's a big challenge for all of us. So, forecasters have their work to cut out for them to connect with decision makers before, during and after extreme events to ensure every community is ready, responsive and resilient.

And this is not only a function of the national services. As we have seen in the US and through our collective Weather-Ready Nation initiatives, this effort requires the entire public-private enterprise in order to succeed. We really do need the PPE as a part of this effort. And from a global perspective, we see a growing number of countries embracing this Weather-Ready Nation strategic outcome, either through their own initiatives or through what we call Weather-Ready Nations and effort that we're expanding through our State Department. So, the role of the forecaster is changing. And their job doesn't end with just the forecast as we all were probably educated, but it increasingly goes beyond the forecast to connect with decision makers, understand their needs, and provide the decision-support services out to 7–11 days prior to an event. That represents a big challenge. I can say that generally we're seeing tremendous successes around the world. Arlene also noted yesterday, if you compare the results of response to Eta and Iota hitting Central America, several-hundred lives lost was still a tragedy, but well less than 10 000+ lives that were lost in Mitch when countries were not prepared to deal with the onslaught of that kind of a storm. We look in the United States, with Dorian, a Category 5 storm that set 100 miles off the coast of Florida and devastated the Bahamas. One of the decisions that had to be made was whether or not to evacuate the entire City of Miami, Florida. If it wasn't for the impact-based decision support services being provided 8, 9 and 10 days in advance all the way to the event, they would have evacuated.

But through the IDSS and working with them to explain the uncertainties, they did not evacuate the City of Miami, saving hundreds of millions of dollars in the process. And it allowed the emergency managers to focus on those areas that needed to be evacuated. We can go through a lot more events. There's a whole litany of events, whether they are hurricanes, floods, fire weather, blizzards, in terms of seeing the increased linkages to decision-making that has improved community response, mitigated property loss, restored normal public services much sooner after those events and saved lives. There's no doubt in my mind.

With respect to what I see for the future, forecasting can still be improved. Even in day 1, we have cases in which we have more uncertainty at day 1 than we have at day 5. Think about what that means when you're communicating with decision makers. How do you communicate this deep uncertainty, which it has been called, in terms of users still having to make decisions based on the uncertainty? What the scientists are pointing to is there has to be a human factor being involved working with decision makers to allow them to get through that uncertainty because they still have to make a decision one way or the other. This is a big issue that we're confronting. We are succeeding because we've developed a trusted relationship with the decision makers. I think from a research perspective, we still have major predictability issues. "Why is one system predictable out to 8 days, and why we are more successful in using that to get a community ready and responsive?" They expect us to be able to do that all the time. And then for the next system, we have predictability issues at day 1, hour 12. That's a major research issue that needs to be dealt with, and it will drive how an NMHS centre works to it. I would argue that we can only address this through an Earth system science approach, and it can only succeed with the public-private enterprise being fully engaged with those national services. It's not an either-or. We have to work in partnership.

Question: The business model for MetService New Zealand is the first fully private for-profit NMHS. So, how's that working? Are government officials, end users, people who work for the MetService, everyone who has a stake in this? How do they think that it's working so far? And should this model be promoted to other countries?

Mr Stephen Hunt: Firstly, I'd say that MetService New Zealand is not a private enterprise. It's a government-owned entity, a commercial entity. Under the commercial model, a market will self-regulate. If many NMHSs become commercial, that market will self-regulate. Oversupply will drive down prices and the viability of inefficient or low-quality competitors. The global market is absolutely huge, and it's very, very complex. It's clear that the market is growing at the speed that the weather industry is innovating. The market and customers are hungry for the improved productivity and the reduced risk that these services can provide them. So, if NMHSs go a commercial route, each will be facing a different situation where they'll have different capabilities or have different products and cultures. And each will be less or more competitive due to their national economies, commercial capabilities, their cost structures, and how they manage their data as well. If an NMHS is becoming more commercial, it also depends on the constraints of their own national legal framework that authorizing environment provides them. That legal framework will give them not only the permissions and freedoms, but also limitations and constraints that will build boundaries about how competitive they can be. So, as I mentioned before, in New Zealand, MetService is under the state-owned enterprise model, and that allows us and requires us to be competitive, and this does come with some constraints. However, while we must be profitable, we must commercialize internationally only those products that we develop for our domestic market. That avoids any incentives to serve a profitable offshore market to the detriment of our domestic market. So, this means there's a critical fine line balancing the imperatives of public good commitments and the imperatives of our commercial activities. So, we need to protect us, as an NMS, our single authoritative voice, while also being commercially lean, agile and stimulating our scientific R&D to suit the market and domestic needs. So, this trade-off also means we have to have different risk appetites, according to those two dimensions I just mentioned. Also, an innovative and active commercial NMHS will inevitably stimulate domestic competition. But those competitors won't have to make those same trade-offs that an NMHS will have to do to maintain a single authoritative voice. And it also depends on the settings on availability of data.

So, entering the commercial market is not something that you want to do quickly or lightly or easily. Commercial capabilities, such as brand value, market penetration, differentiated products, are all built over many, many years. And they will be governed by the legal framework of the country where you are. The final point is striking that right balance between maintaining your services for the public good while also delivering official and efficient commercial activities is not an easy transition and always a very fine balance. And you will be competing against other commercial weather companies which are private, not government-owned, and won't have your constraints as well. So, you have to stay sharp on your toes and limbs.

Question: One of the most pervasive and dangerous threats for all comes from flooding. In some countries, hydrology is under the NMHS's umbrella. In other countries, it's a completely separate organization. In your view, which is the better model to ensure effective warnings of hydrological hazards?

Dr Ken Takahashi: My NMHS has both hydrology and meteorology. Current increasing demands from the users in terms of accuracy, quality and diversity of meteorological and hydrological products and services are forcing the two communities to come together within the framework of the Earth system approach. For example, flood forecasting needs, as an essential input of precipitation, both observations and forecasts. And perhaps traditionally, hydrologists have produced their own data and products for precipitation to put into their hydrological models. But when you're working at the small temporal and spatial scales, we need to have a much more accurate representation of the precipitation. That requires hydrologists to work with meteorologists that produce high-resolution nowcasting products, which is more effective and more efficient. Another example in which hydrology and meteorology have to come together is with respect to data, including data access and data quality. Now the new WMO data policy is emphasizing again the Earth system approach. Hydrological data should be effectively integrated into the data streams not only for the production of products both internationally and nationally, but also for a diversity of new users' demands that are increasing with the new developments in technology. So, in general, although WMO is the international authority of operational hydrology, the representation of WMO in countries is usually the NMSs. That implies that the effective implementation of the WMO data policy requires the central role of NMHSs in coordinating with the providers of hydrological data. For instance, in Peru, we're working on establishing regulations to ensure that the hydrometeorological data has the quality expected from the users by enforcing the WMO Regulations, and also to serve as a way of sharing that data with users internationally.

We find some of the challenges for this closer collaboration between hydrology and meteorology. First of all, it's typical that within each country, there are several water-related institutions. So, the governance of the water is very complex. And their interests are not necessarily aligned. But as we heard yesterday, that is okay. We just need to find common goals, and make sure we can figure out what the different roles are for each of these institutions. And, for example, last year in Peru, in collaboration with the National Civil Defence Institute, and with the approval of the presidency of the Council of Ministers, we established a protocol for the issuing of flood and heavy rainfall warnings. And that is now the basis for the governance of the establishment of early warning systems we're setting up across the country. Now the issue of risk reduction is clearer in our country, but there are several other applications in which we do not have necessarily a government-level national regulation for establishing roles. That is a challenge that NMHSs will have to take on. Another issue with this is related to education. Meteorologists and hydrologists follow typically and traditionally separate careers and are with different perspectives. While it's most likely that these disciplines will remain separate, they should be able to understand each other and talk in common language to understand the limitations and the strengths of each so as to have more effective collaboration. So, the Earth system approach again has to be strongly emphasized in both formal education and training in both disciplines.

Question: The CMA is the biggest national meteorological service in the world. Recently special attention has been given to expanding Public-Private Engagement there. So, what have been the primary challenges thus far with working with private companies and have you seen mutual benefit from the PPE?

Mr Xiaonong Shen: As the most populous country in the world, China is experiencing rapid socio-economic development, and China is also prone to various meteorological disasters. Therefore, meteorological service in China is closely related to life safety, economic development, living-standard improvement, and bad ecological environment. CMA may be the largest national meteorological service in the world for the time being, with its more than 70 000 full-time employees and near US$ 5 billion annual budget. As such, the CMA is the authority for public meteorological service and early warning in China. As a ministry-level organization, CMA acts as a government regulator, meteorological infrastructure developer, meteorological system operator and service provider. With government's continued support and technological innovation, CMA makes every effort to achieve comprehensive observation and monitoring, precise forecasting and tailored service. This gives a full play to the role of meteorological service as the first line of defence in meteorological disaster prevention and mitigation in China.

For last several years, we've gained some experience in working with the private sector. CMA and multiple entities have enjoyed a win-win partnership to meet enormous demands for meteorological service. CMA cannot meet such a demand by itself alone. From CMA's viewpoint, the private sector has flexible mechanisms and a strong innovation ability. Thus, CMA encourages market entities to engage in the value chain of the meteorological service through such mechanisms as service purchase, joint development of operational systems and coordinated meteorological service delivery. China Meteorological Service Association, which has now 475 members, including private companies, academia, universities, and CMA subsidiary service bodies, has been established as a platform for dialogue, consultation, and coordination between the public and private sectors. CMA also faces some challenges in PPE. An example is that related legal system needs to be further improved to clarify roles and responsibilities of CMA and the market entities. In addition, considering that the service providers are diversified, we need to establish an assessment system for service quality. With this assessment system in place, meteorological enterprise will better serve the societal needs. In general, I believe that NMHSs and the private sector can complement each other with their unique advantages. As long as the roles and responsibilities of NMHS and the market entities are more clearly defined, their advantages could be brought into full play. And when the proper roles are set up and observed by both sides, NMHSs and market entities can achieve a positive interaction for win-win development and better serve the public good.

Question: The World Bank has built up a lot of experience in assisting meteorological services with very low capacity and helping them to modernize. But the problem is that sustaining that progress is always difficult. In the situation that a meteorological service is failing or has failed because it just doesn't have support from its own government, is there any scenario where it should be replaced with some other solution to provide vital services?

Mr Vladimir Tsirkunov: Indeed, our institution has significant experience in this sector. During the last 10 years, the main portfolio of hydrometeorology has tripled. At present it exceeds US$ 1 billion, spreading over 60 projects in different countries. But my understanding of your question is that it is about what our institution can do if there is a need to improve hydrometeorological services in a particular country when the NMHS in that country is not capable of delivering what is required. This is not unusual situation. But nevertheless, the governments are requesting World Bank to help modernize NMHS anyway. In such cases, of course, our team are trying to develop the scope of project which fits NMHS's limited capacity. In addition, we insist on the introduction of technical long-term support teams, usually private companies or groups of individual consultants, to ensure the development of integrated new systems and services responding to national demand. Unfortunately, this approach, nevertheless, is very challenging. One of the main challenges to NMHSs in developing countries, besides traditional lack of government support and resources, is how to reorganize and organize themselves in the transformational process from traditional manual data

collection agencies, such as many NMHSs in developing countries which are underfunded and understaffed, to modern NMHSs which have high-tech ICT systems providing a broad range of specialized and integrated services. This is not a trivial task for any institution. But for developing countries, there is no well-established solution so far. At least, we don't know that. Therefore, the capacity gap between many NMHSs in developing countries and the most advanced NMHSs is not reducing. Some people argue that this gap is increasing.

Several years ago, we realized that facilitating a more active partnership between the rapidly advancing private sector and traditional NMHS is a promising direction to mitigate this and other challenges. We commissioned a study which produced the report "The Power of Partnership: Public and Private Engagement in Hydromet Services", which provided basic analytical underpinnings of partnerships in this area. We also created jointly with WMO and HMEI the Global Weather Enterprise Forum, an open dialogue between representatives of public, private and academic sectors. We joined forces to generate new ideas on how to improve delivery and sustainability of hydrometeorological services. Many panellists of our meeting yesterday and today participated in GWE forums, webinars, online forums, weather pods, and other events during last year. We'll continue supporting these activities in collaboration with the OCP.

To conclude, NMHSs and their governments should recognize the value of building mutually beneficial partnerships between their institutions and the private and academic sectors. In some countries, these, as well as allocation of additional government support for implementation of NMHS' public functions, will be critical for their survival in the future. The World Bank on its part will continue its efforts to facilitate this process by raising awareness of the government of NMHS' significant socio-economic value, building partnerships with the private and academic sector and find innovative solutions to strengthen the sector, which have never been so important to the society.

Question: When talking about the evolving role of the national meteorological services, questions about data sharing, both national and international, are often raised. For the past year or so, you've been leading some of the most difficult tasks around the revised WMO data policy. So, what would be your main message to NMHSs regarding the data exchange with regard to their future roles and responsibilities?

Dr Sue Barrell: I guess my overarching message is that the benefits of free and unrestricted data exchange far outweigh the fees that we often hear about. Effective future NMHSs will use the WMO data policy proactively to drive and deliver an integrated Earth system's approach from both operational and strategic design perspectives. I highlight three points in particular. Firstly, NMHSs act as role models in open data and in building and sustaining national data partnerships. This involves bringing together those institutions, research bodies and private entities that can and do contribute data relevant to delivering on Members' mandate both nationally and as a Member of WMO for demonstrating the economic benefits of free and open exchange of public data through sharing and advocating standards, policies and practices in relation to the measurement, collection and exchange of Earth system data, through communicating transparently the data that shall and should be freely exchanged, and importantly, the benefits of doing so for the entities involved across all sectors, and for the national public good, and in convening the appropriate coordination and collaboration mechanisms to support us. Secondly, NMHSs act as designers and operators of national observational and data infrastructure through fully implementing WIGOS as an integrated approach to Earth system's data, consistent with the WMO strategy, through promoting investments in observational networks that are coordinated with numerical prediction development, with the implementation of GBON as an important first step, through monitoring performance and identifying needs for assistance, including by the SOFF, where it's available, through reflecting on the requirements of the unified data policy for free and unrestricted exchange in planning their investments in infrastructure, and also in establishing contracts for data acquisition, where they choose to do that, and in monitoring the evolving data requirements across all of the Earth system domains. Thirdly, NMHSs empower and sustain the science-to-service value chain, through providing and advocating free access to all of the data required for research that support the future evolution of public services, especially NWP and

the transition of research outcomes into operations, and through acknowledging the dependency of NMHSs on research-funded data collections, especially across the ocean, atmosphere and cryosphere components. Finally, data is the lifeblood of the modern weather, water, climate, environment enterprise. International data exchange necessarily underpinned by collaborative national data exchange is key to sustaining it into the future. The most successful NMHSs post 2030 will be those who understand the importance of data in partnering, designing, investing, and delivering across the science-to-service value chain.

Question: Now there are many instances around the world where NMHSs have collaborated to develop regional institutions. One of these is the regional integrated multi-hazard early warning system, which is active in South Asia and in East Africa, headed up by Dr Subbiah. Dr Subbiah, many things that have traditionally been done at national level can now be done regionally and leveraging financial and human resources like ECMWF and your own organization, which are good examples of this. But there's also views that regionalization could possibly weaken some NMHSs. So, what's your view on this? What can be done better at regional level and then that should free up national resources for national priority tasks?

Dr A.R. Subbiah: This question is central to our work. And this particular process comes through the pressure of both technological changes and also socio-economic changes. Huge expectation comes both from the national policymakers and the public, which leads to a huge demand for NMHS. There is also recently additional demand coming from technology. For example, there are global forecast centres which are able to produce high-resolution forecasts, and also information technology is able to turn data into information. Demand is also coming from the climate change mitigation and adaptation communities. So, unlike in earlier times, the demand from many aspects is coming on the NMHS. They need support to meet those additional demands. And that support is facilitated by regional institutions like RIMES. There is going to be a kind of transition from a traditional forecast system to a modern system embracing the 2030-decade and on, which is going to be a major kind of change in the NMHS, both in social and technological terms. Particularly in the developing countries, there is also this kind of transition, whether there is a system of sharing data or not. Now, unless they share the data, they cannot get the high-resolution forecast products.

The transition from the original forecast system to user-based institutional mechanism is facilitated by regional institutions like RIMES. For example, we have two major programmes supported by the World Bank, i.e. South Asia Hydromet Forum and the Climate Change Adaptation and Resilience Project (CARE). These two projects provide for this transitional process in South Asia, and the countries are welcoming it. We collect real-time observational data from these countries and send the data to ECMWF after quality check. ECMWF uses the data for producing high-resolution forecast which goes to the countries. And that transition is taking place in these countries as they are really benefiting from this kind of process. This transition has just begun and will be sustained. As long as the transition process is there, they need regional institutions for support. That's why it is a very symbiotic kind of support to the NMHSs. Since the NMHSs get this kind of different role to play, they will become more popular with the national systems and communities because they are going to provide value-added services which their user communities need. When they become popular, they are stronger. Actually, we are strengthening NMHSs, instead of weakening them. The strengthening of NMHSs is supported by regional cooperation and regional mechanisms. That is why this system is now working so well.

In the next five years, this kind of transition will be there. In that process, NMHSs also need support of engagement with the private sector and academic institutions. The roles need to be demarcated between the private sector and NMHSs through legislation and policy changes. So, there is need for a kind of mechanisms, including training and capacity building, to facilitate the transition. This process is done by the RIMES institution in collaboration with the ECMWF at the beginning with the support from the World Bank, South Asia Hydromet Forum and CARE project. So, I see a kind of major changes, because NMHSs will be closer to communities, and they will get investment support from the national policymakers and others. They will be therefore strengthened rather than weakened. It is going to be a kind of major transformation for good.

IV. CLOSING OF THE SECOND DAY

Prof. Gerhard Adrian, WMO President

It was a very interesting discussion, with many contributions, which has motivated us to give many comments and ask many questions. The key words that I have in my mind are: trust between the partners and transparency between the private and the public sector, which is very much connected with the legislation, as we have heard. That means we need the governments. I recognize that the recognition of science-based services is increasing and enhancing in the society, which is a driver for us to proceed. As a director of a national meteorological service, a public-funded institution, I wish to say that it is our common responsibility and also our challenge to enable the maximum use of the information we provide to serve the society. I think that's our common challenge on which we have to work together. How to proceed? Now, you have seen the concept of this white paper, which was developed by Dimitar Ivanov. I want to take the opportunity to thank Dimitar for all the work he has done, beginning from the last two WMO Congresses through the preparations for the discussions at this moment. What we have discussed today will be used as an input to the next white paper. I will try to support this white paper, and we will invite many others to contribute to this white paper very soon. Thank you very much to all the organizers, the contributors, the speakers, and moderators.

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APPENDIX 3: LIST OF ACRONYMS

Acronyms	Definition
A	
AI	Artificial Intelligence
AMD	Advanced Micro Devices, Inc.
API	Application Programming Interface
C	
CARE	Climate Change Adaptation and Resilience Project
CIFI	Coastal Inundation Forecasting Initiative
CMA	China Meteorological Administration
COVID	Coronavirus Disease
CPU	Central Processing Unit
D	
DDN	DataDirect Networks
DMI	Danish Meteorological Institute
DRR	Disaster Risk Reduction
E	
ECMWF	European Centre for Medium-Range Weather Forecasts
EPIC	Earth Prediction Innovation Center
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EuroHPC	European High Performance Computing
G	
GBON	Global Basic Observing Network
GDPFS	Global Data-processing and Forecasting System
GFDL	Geophysical Fluid Dynamics Laboratory
GNSS	Global Navigation Satellite Systems
GPU	Graphics Processing Units
GRAF	Global high-Resolution Atmospheric Forecast
GSM	Global System for Mobile Communications
GWE	Global Weather Enterprise
H	
HMEI	Association of Hydro-Meteorological Equipment Industry
HPC	High Performance Computing
I	
IBM	International Business Machines Corporation
ICRC	Infrastructure Concession Regulatory Commission
ICT	Information and Communication Technology
IDSS	Impact-based Decision Support Services
IFRC	International Federation of Red Cross and Red Crescent Societies
IFS	Integrated File System
INFCOM	Commission for Observation, Infrastructure and Information Systems
IoT	Internet of Things
IT	Information Technology
J	
JMA	Japan Meteorological Agency
JSDA	Japan Soft Drinks Association

Acronyms	Definition
M	
MFI	Météo France International
MHEWS	Multi-Hazard Early Warning System
ML	Machine Learning
MoU/MOU	Memorandum of Understanding
MPAS	Model for Prediction Across Scales
N	
NCAR	National Center for Atmospheric Research
NEWP	Numerical Earth system and Weather-to-climate Prediction
NiMet	Nigerian Meteorological Agency
NIRSAL	Nigeria Incentive-Based Risk Sharing System for Agricultural Lending
NMHS	National Meteorological and Hydrological Service
NMS	National Meteorological Service
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
O	
OCP	Open Consultative Platform
OCP-HL-1	the first High-Level Round Table for the Launch of the OCP
OCP-HL-2	the second High-Level Session of the OCP
P	
PPE	Public-Private Engagement
PPP	Public-Private Partnership
R	
R&D	Research and Development
RIKEN	Institute of Physical and Chemical Research of Japan (acronym for the formal name Rikagaku Kenkyūjo in Japanese)
RIMES	Regional Integrated Multi-Hazard Early Warning System for Africa and Asia
S	
SAP	Scientific Advisory Panel
SOFF	Systematic Observations Financing Facility
T	
THORPEX	The Observation System Research and Predictability Experiment
U	
UBIMET	Institute for Ubiquitous Meteorology
USAID	United States Agency for International Development
W	
WIGOS	WMO Integrated Global Observing System
WIS	WMO Information System
WMO	World Meteorological Organization
WRNs	Weather-Ready Nations
WXBC	Weather Business Consortium

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