PROGRESS ACTIVITY REPORT OF THE SEVENTEENTH SESSION OF THE COMMISSION FOR ATMOSPHERIC SCIENCES

(unedited)

MATERIAL ARRANGEMENTS FOR THE SESSION

Venue

At the kind invitation of the Government of Indonesia, the seventeenth session of the Commission for Atmospheric Sciences (CAS-17) will be held in Denpasar, Bali, Indonesia, from 23 to 24 October 2017. The opening ceremony will be held at 9.30 a.m. on 23 October 2017 at the Patra Bali hotel (website: http://www.thepatrabali.com).

The Science Summit will be held at the same venue from 20 to 22 October 2017.

Working languages

During the session, simultaneous interpretation in the six WMO official languages (Arabic, Chinese, English, French, Russian and Spanish) will be provided in the main conference room. Additional meeting rooms without interpretation facilities will also be available.

The Science Summit meeting will be in English only.

Documents

Delegations wishing to submit documents before the session are invited to send them to the WMO Secretariat as soon as possible, but not later than 60 days before the opening of the session, in accordance with the provisions of Regulation 190(b) of the WMO General Regulations, to allow time for translation. According to Regulation 189 of the WMO General Regulations, session documents should be distributed as soon as possible and preferably not later than 45 days before the opening of the session. Any document presented by a delegation should be submitted in the name of the Member of the Organization and not by an individual person.

Processes and documents workflow

The presentation of session documents and organization of the work during the session will differ this year from the practice of previous sessions, as explained in the information document CAS-17/INF.1(2) available via the CAS-17 website http://meetings.wmo.int/CAS-17.

Distribution of documents

Documents will be posted before and during the session on the session website, in line with WMO greening efforts to promote paper-smart meetings. Therefore, participants are kindly invited to bring internet-enabled portable computers capable of handling Microsoft Word 2010 and Adobe PDF formats so that they can work in paper-smart mode during the session.

Provisional abridged report

Approved documents showing amendments in all languages will be posted on the CAS-17 website as soon as possible after the session, in the folder 'PROVISIONAL REPORT (Approved documents)'.

Registration of participants

Online pre-registration is required for all participants of CAS-17. In view of their official status with WMO, Permanent Representatives of WMO Members (PRs) have been given access to an online Event Registration System allowing the pre-registration of their respective delegations.

More information concerning the online pre-registration will be provided in due course on the CAS-17 session website http://meetings.wmo.int/CAS-17.

A conference information and registration desk will be set up close to the meeting rooms to facilitate the registration of participants and provision of general information.

Registration for the Science Summit and CAS-17 will take place at the conference information and registration desk at the Patra Bali Hotel and start on 19 October 2017 from 4 - 6 p.m. Registration will continue throughout the Science Summit and the session. At the time of registration, participants will receive identification badges, which should be worn throughout the session.

Credentials

Pursuant to Regulation 21 of the General Regulations, prior to a session of a constituent body, other than the Executive Council, each Member should, if possible, communicate to the Secretary-General the names of the persons composing the delegation to that body, indicating which of these shall be regarded as its principal delegate. In addition, a letter giving these particulars and signed by, or on behalf of, an appropriate governmental authority of the Member shall be sent to the Secretary-General or handed to his representative at the session. This letter shall be regarded as appropriate credentials for the participation of the individuals named therein in all activities of the constituent body.

Representatives of international organizations invited as observers to the session should provide in advance, or bring to the session, a letter of representation signed by the appropriate authority from their organization.

List of participants

A provisional list of participants will be uploaded on the session website shortly after the beginning of the meeting. This list will be updated on a daily basis.

Videoconference facilities

A videoconference connection will be set up, if possible, between the main meeting room and WMO headquarters in Geneva.

Internet facilities

Wireless Internet connection will be available in the main conference room and at the venue hotel (Patra Bali Hotel).

Entry requirements

All participants requiring a visa to enter Indonesia should make their visa applications directly to the nearest embassy or consulate of Indonesia, submitting invitation letters issued, if necessary, by the Local Organizing Committee, together with other required documents. Holders of Diplomatic, Service, Official or specified passports from some countries may not require a visa by virtue of bilateral agreements.

Unless coming from one of the visa-exempt countries or one of the countries eligible for visa on arrival, all participants requiring a visa to enter Indonesia should apply for their visa directly from the Embassy or Consulate-General of Indonesia in their country, or a designated country in cases where no Indonesian Embassy or Consulate is available in their own country. Diplomatic and service visas and entry permits, where required, shall be granted free of charge and as speedily as possible for their effective participation throughout the duration of the meetings, provided the application for the visa is made sufficiently in advance, that is, more than one month before the beginning of the sessions.

If there is no Embassy or Consulate-General of Indonesia in the participant's country, they may apply for a Visa on Arrival (VoA) by sending prior information, such as the invitation letter from WMO, a letter of visa request and copies of their passport to BMKG, with a copy to the WMO Secretariat, not later than one month prior to the sessions. Please note that, prior to departure, participants need to obtain confirmation from BMKG that their application for a Visa on Arrival (at Denpasar, Ngurah Rai International Airport) has already been cleared.

To apply for the Visa on Arrival, the applicant's passport must be valid for at least 6 months from the date of entry and the participant must have a round-trip airplane ticket. The visa fee for staying up to 30 days is USD 35. Detailed information on Immigration Facilities in different countries is available on the Ministry of Foreign Affairs of Indonesia webpage: http://www.kemlu.go.id/itjen/en/layanan-visa/Pages/Visa-Kunjungan-Saat-Kedatangan.aspx.

If a letter of invitation is necessary for visa application, please send the information page of your passport to the local organizing committee (LOC), **before 20 September 2017.**

Local organizing committee

Ms Anni Arumsari Fitriany
Head of Division for Cooperation
BMKG
Telephone: +62 21 4246321 ext. 1122
Fax: +62 21 6546339
E-mail: anni.arumsari@bmkg.go.id

Mr Bagus Rachmat Rievan
Head of Sub Division for International Cooperation
BMKG
Telephone: +62 21 4246321 ext. 1122
Fax: +62 21 6546339
E-mail: bagus.rievan@bmkg.go.id

(**Please cc: international.cooperation@bmkg.go.id**)

Transportation

Participants are recommended to arrive at Ngurah Rai International Airport.

Ngurah Rai Airport to Hotel

Transport from the airport to the hotel is not provided by the host country. Participants can take a taxi from the airport to the hotel. The taxi counter is next to the Information desk after you walk through the little "Dufry" shopping arcade. The Bali airport taxi rate to the hotel is estimated at USD 10. (Payment should be made directly to the driver, not at the counter).

Currency

Currency exchange services are available at Ngurah Rai International Airport as well as in all banks (opening hours are 9 a.m. to 5 p.m., weekends: 10 a.m. to 4 p.m.). The local currency is the Indonesian Rupiah. Most businesses, tour operators, airlines and hotels accept major credit cards. The average exchange rate in Rupiah is as follows:

1 EUR = IDR 14,450 (fourteen thousand four hundred and fifty)
1 USD = IDR 13,500 (thirteen thousand five hundred)
1 CHF = IDR 13,300 (thirteen thousand three hundred)

Health requirements/medical services

Up-to-date information on international travel and health requirements are provided by the World Health Organization (WHO) at the following websites:

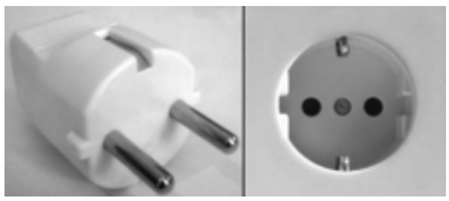
http://www.who.int/ith/en/
and
http://www.who.int/countries/idn/en/

It is strongly recommended that you take out personal medical insurance for the duration of the trip.

Electricity and mobile phone connection

Power systems are generally 220 volts and 50 Hz. An adaptor may be necessary (see pictures below).

Europlug socket



Schuko socket

SIM cards for mobile phones are available. For more details, please visit the websites of the Indonesian mobile phone operators, or contact your local service operator.

Local climate in October

Climate data during October in Denpasar are listed below:

Mean temperature	27.23 °C
Mean maximum temperature	31.26 °C
Mean minimum temperature	24.46 °C
Mean relative humidity	78.03 %
Mean precipitation	35.15 mm
Mean number of days with precipitation ≥1 mm	2 days
Mean duration of sunshine	6, 78 h/day

Updated weather information can be found on the BMKG website: www.bmkg.go.id.

Hotel reservation

Participants are strongly recommended to stay at the **Patra Bali Hotel**, where the meeting will be held. A block reservation has been made with very special rates. The reservation will be made on a first-come-first-served basis.

To secure the special rates at this hotel, participants are requested to fill in the hotel reservation form in Appendix B and return it to the hotel contact, with a copy to the local organizing committee (LOC) before **20 September 2017**.

Appendix A contains a list of other hotels within walking distance. Please note that there will be NO shuttle service provided by BMKG.

Information and contact details of the local organizing committee (LOC)

For any further information please contact the LOC at the following address:

Local organizing committee (LOC) :

Ms Anni Arumsari Fitriany
Head of Division for Cooperation
BMKG
Telephone: +62 21 4246321 Ext. 1122
Fax: +62 21 6546339
E-mail: anni.arumsari@bmkg.go.id

Mr Bagus Rachmat Rievan
Head of Sub Division for International Cooperation
BMKG
Telephone: +62 21 4246321 Ext. 1122
Fax: +62 21 6546339
E-mail: bagus.rievan@bmkg.go.id

(**Please cc:** **international.cooperation@bmkg.go.id**)

Appendices: 2 (available in English only)

APPENDIX A:
LIST OF RECOMMENDED HOTELS

Hotel	Address, E-mail, Telephone No.	Special Rates (in IDR/USD)	
		Standard (Single/Twin)	Suite
Patra Bali Hotel (5 ★) (MEETING VENUE)	Jl. Ir. H Juanda, South Kuta Beach, Kuta 80361 Bali, Indonesia Contact person: Ms. Mina E-mail: mina@thepatrabali.com Tel.: +62 361 935 1161 Fax: +62 361 935 2030	IDR 900,000 / USD 66 Includes: 2 breakfasts, Wi-Fi, service fees and tax	IDR 1,400,000 / USD 104 Includes: 2 breakfasts, Wi-Fi, service fees and tax
To secure the special rates at this hotel, participants are requested to fill in the reservation form in Appendix B and return it to the hotel contact, with a copy to the local organizing committee (LOC) before **20 September 2017**.			

Hotel	Address, E-mail, Telephone No.	Special Rates (in IDR/USD)
		Standard (Single/Twin)
HARRIS Hotel (4 ★) (0.95 km from the meeting venue) Shuttle service provided by hotel to the meeting venue	Jl. Dewi Sartika, Tuban, 80361 Bali, Indonesia Contact person: Mr. Toni Extranto E-mail: sm-harris-tuban@tauzia.com Tel.: +62 361 9365 255 Fax: +62 361 9366 258	IDR 590,000 / USD 44 Includes: 2 breakfasts, Wi-Fi, service fees and tax
To reserve this hotel, participants are requested to fill in the reservation form in Appendix B and return it to the hotel contact, with a copy to the local organizing committee (LOC) before **20 September 2017**.		

Hotel	Address, E-mail, Telephone No.	Special Rates (in IDR/USD)
		Standard (Single/Twin)
Bedrock Hotel (4 □) (1 km from the meeting venue) Shuttle service provided by hotel to the meeting venue	Jl. Wana Segara No.21, Kuta, Kabupaten Badung Bali, Indonesia Contact person: Mr. Andrey E-mail: salesmanager@bedrockhotel.co.id Tel.: +62 361 4727300 Fax: +62 361 4727833	IDR 475,000 / USD 36 Includes: 2 breakfasts, Wi-Fi, service fees and tax
To reserve this hotel, participants are requested to fill in the reservation form in Appendix B and return it to the hotel contact, with a copy to the local organizing committee (LOC) before **20 September 2017**.		

APPENDIX B:
HOTEL RESERVATION FORM

Participants attending the seventeenth session of the Commission for Atmospheric Sciences (CAS-17) are welcome to make their hotel reservation directly with the hotel by fax or email, or return the form by no later than **20 September 2017** to:

Mr Bagus Rachmat Rievan
Head of Sub Division for International Cooperation
BMKG
Telephone: +62 21 4246321 Ext. 1122
Fax: +62 21 6546339
E-mail: bagus.rievan@bmkg.go.id

(**Please cc: international.cooperation@bmkg.go.id**)

Name ______________________________

Country ______________________________

Address ______________________________

Tel. No. ______________________________

Fax No. ______________________________

E-mail ______________________________

	Flight No.	Date	Time
Arrival	____________	____________	____________
Departure	____________	____________	____________

Please reserve (specify one of the recommended hotels)

Name of hotel ______________________________

Standard/Suite Single ☐ Twin ☐

Check-in date ______________________________

Check-out date ______________________________

Credit card details for guarantee:

Type	____________	Number	____________
Name	____________	Expiry Date	____________
Date	____________	Signature	____________

____

DOCUMENT PROCESSING FOR CAS-17

Document types for CAS-17

1) CAS-17 will use two types of documents:

- **Doc.** (documents) have the contents listed below; these will appear in the final report.

- **INF.** (information) papers provide additional information relevant to decisions/ recommendations/resolutions at the meeting and will only appear in Part II of the report.

2) The documents of type **Doc.** will consist of up to five parts, and every document will contain a title page and at least one decision, resolution or recommendation. The parts are:

(a) **Title page** which identifies the document and lists the decisions/recommendations/ resolutions and actions to be taken;

(b) **Decisions** (optional) place on record instructions/directives to the Management Group that follow from CAS, Congress or EC resolutions or decisions, or provide records of CAS opinions/observations on a specific topic, procedural decisions and other decisions pertaining to the internal matters of CAS, corresponding to General Regulation 182(c);

(c) **Resolutions** (optional) are decisions of CAS which concern only the internal activities of the Commission, such as actions to carry out its part of the strategic programme of the Organization, the establishment and terms of reference of a working group or the designation of a rapporteur, corresponding to General Regulation 182(b);

(d) **Recommendations to Congress** (optional) are decisions of CAS requiring financial support or implementation action by Members, proposals for Secretariat action and proposals requiring coordination with other WMO bodies or with bodies outside the Organization, corresponding to General Regulation 182(a);

(e) **Background information** (optional) is additional information that is essential to support the decision/recommendation/resolution being made. This should be short and refer, so far as is possible, to pre-existing documents. This part of the document will not appear in the final report.

Document processing

3) The first version (DRAFT 1) of documents will be published on the CAS-17 session website, and members of the Commission will be invited to send suggestions for improving the document to the Secretariat (cas17.plenary@wmo.int). These proposals will be assessed and the second draft (DRAFT 2) posted on the CAS-17 session website. These documents will be available in all six WMO official languages.

4) Information documents will be posted to the CAS-17 website, but are not intended for amendment or discussion. These will normally only be available in English.

5) During the session, the chairperson for an agenda item will lead the discussion on the documents for that item. Within a document, each decision will be discussed separately. In many cases each component of that decision, such as related annexes, will be discussed individually. Following current practice, component parts of a document may be approved by the session while other components may still need additional debate. Documents amended during the session will be posted successively as DRAFT 2, DRAFT 3, and so forth, and the final approved version will be marked 'APPROVED'.

6) Discussion of the document may stop in two ways. The complete document may be approved, in which case any agreed changes to the document will be included and the approved version of the document published on the CAS-17 website in the 'PROVISIONAL REPORT' folder. Alternatively, the chairperson of the session may decide that no further progress can be made with the document at that time, in which case changes to the document will be included in the next draft of the document, and the modified document will be published on the CAS-17 website in the folder 'DRAFTS FOR DISCUSSION'. This will be published as the next draft in the sequence (DRAFT 2, DRAFT 3, and so forth), whereas the previous draft will be moved to the folder 'SESSION ARCHIVE'.

7) Versions of documents created during the session will only be available in English, with the understanding that the revised texts will be read out clearly, with interpretation in all WMO official languages.

Post-session publication

8) Approved documents from the session will be translated into all six WMO official languages and placed on the CAS-17 website in the folder 'PROVISIONAL REPORT (Approved documents)'.

9) The approved documents, the agenda and the list of participants will be combined to form the abridged report of the session that will be edited and published in the six WMO official languages. A second part of the report consisting of the compilation of information documents will also be published, in English only.

World Meteorological Organization
COMMISSION FOR ATMOSPHERIC SCIENCES
Seventeenth Session
Bali, Indonesia, 23 to 24 October 2017

CAS-17/INF. 2.1
Submitted by:
Secretary-General
~~15~~31.VIII.2017

[All amendments in the document have been made by the Secretariat]

REPORT BY THE PRESIDENT OF THE COMMISSION

The main challenges

During the sixteenth session of the Commission for Atmospheric Sciences (CAS-16), the following emerging challenges and opportunities in the decade to come were identified:

- High-impact weather and its socioeconomic effects in the context of global change;
- Water: modelling and predicting the water cycle for improved disaster risk reduction and resource management;
- Integrated Greenhouse Gas Information System: serving society and supporting policy;
- Aerosols: impacts on air quality, weather and climate;
- Urbanization: research and services for megacities and large urban complexes;
- Evolving technologies: their impact on science and their use.

Since CAS-16, related actions and research have been detailed in the implementation plans for the World Weather Research Programme (WWRP) and the Global Atmospheric Watch (GAW) programme. These challenges and opportunities remain valid and represent the top priorities for the Commission for Atmospheric Sciences (CAS) for the period up to 2023, in line with the WMO strategy as it evolves.

The relationship between the WMO Research Department and the working structures of CAS has been very constructive and efficient, and has played an important role in the progress made in WMO research and innovation since CAS-16. A heartfelt thank you is extended to all who have contributed.

Science for service

The Working Group on Numerical Experimentation (WGNE) has the responsibility for fostering the development of atmospheric circulation models for use in weather forecasting and climate prediction/projection on all time scales, and for diagnosing and resolving shortcoming in these models. WGNE therefore forms a key link between WCRP and the CAS programmes of WWRP and GAW.

During the reporting period, WGNE activities included:

- Building on the findings in the climate community of the importance of fully interactive aerosols in model simulations, the WGNE aerosols project has undertaken an investigation into their role in shorter range weather forecasting.
- The identification of systematic errors amongst weather and climate models is arguably one of WGNE’s most valuable functions. The fifth WGNE Systematic Error workshop was held in Montreal, Canada, in 2017, bringing the weather and climate communities together to initiate work to address common problems.

- A key activity of WGNE is the routine evaluation and verification of models. The Joint Working Group on Forecast Verification Research (JWGFVR) is a joint initiative of the WWRP and WGNE and continues to conduct research into verification methods.

CAS outlined the value chain in environmental services through the implementation plans of WWRP and GAW (based on the "Science for Service" approach), of which practical implementation requires closing the gap between research and operations.

CAS has worked actively in the constituent body reform process to demonstrate that the future success of the weather enterprise relies on research and the value chain thinking. The research component needs to be kept as a clearly visible and consolidated entity in WMO, and not fragmented, in order to motivate and foster the voluntary contributions we depend on from the research community. CAS and the World Climate Research Programme (WCRP) draw in the capabilities of a much larger community than only from National Meteorological and Hydrological Services (NMHSs). (In WWRP the membership of non-NMHS experts in the working groups and project steering groups is approaching 50%; for GAW it is more than 60%; and in WCRP it is above 80%). Furthermore, the success of all three Programmes has relied on significant research funding being obtained from national and international funding agencies.

In the constituent body reform process (conducted by the Executive Council Working Group on WMO Strategic and Operational Planning), CAS has been representing the technical commissions and has proposed that research does not need an intergovernmental body due to the fact that technical regulations are not developed by and for research. Ideally, to advance research and innovation in the Earth system framework, WMO needs a scientific advisory council consisting of a few leading scientists from universities, independent research institutes, governmental research institutes, including NMHSs, and industry, to advise the Secretary-General, the WMO Executive Management, Executive Council and Congress. In addition, a research implementation group is needed with its composition, mandate and terms of reference, based on the CAS Management Group of today, but more inclusive (bringing together internationally recognized scientists, regional representatives and chairpersons of GAW, WWRP, the Working Group on Numerical Experimentation (WGNE) and WCRP), and with representatives of research bodies other than NMHSs and of the main international funding agencies.

The Data-processing and Forecasting System (DPFS) supports the operational forecasting services of NMHSs. The WMO Information System (WIS) and the WMO Integrated Global Observing System (WIGOS, previously the Global Telecommunication System and the Global Observation System) are components of DPFS. Following Resolution 17 (EC-69) (WMO-No. 1196) - Seamless Data-processing and Forecasting System - CAS, with the Commission for Basic Systems (CBS), is co-chairing the development of a new generation of DPFS based on the seamless Earth system modelling concept. This is an important opportunity for CAS to strengthen links in the value chains that provide services, and for scientists and operations-oriented personnel to work in teams in an interactive manner, towards better services. The contribution of CAS to DPFS is an important practical consequence of Decision 50 (EC-69) (WMO-No. 1196) - An Integrated Research and Development Approach - which presents key principles to fill the gap between research and operations.

CAS has contributed to the review process of WCRP. There are several commonalities between WCRP and WWRP/GAW, both in the science and in their applications. Many aspects of climate science have moved from the curiosity-driven stage to a more mature stage where it is important to take stock and make sure that the most useful results are moved towards applications and user-informed services. An alignment of WCRP to the "Science for Service" thinking would support the Global Framework for Climate Services in the delivery of relevant, timely and high-quality products for climate adaptation. For mitigation, the Integrated Global Greenhouse Gas Information System (IG^3IS) is an essential component, being developed under GAW with significant support from stakeholders. The IG^3IG implementation plan will be ready by EC-70 and a governance structure is in place including plans for an IG^3IG office.

EC-69 also decided that the GAW Urban Research Meteorology and Environment Programme will lead the development of a guide for integrated urban services, together with CBS and in consultation with other technical commissions.

In the future, WMO would benefit from a tight coupling of, and a closer involvement between, WWRP, GAW and WCRP, utilizing, among others, WGNE, to address the research needs in hydrology and oceanography in order to fully succeed in seamless Earth system prediction and in the DPFS.

Care has been taken to rotate the terms of members of steering committees, working groups, science advisory committees and expert teams in accordance with the decisions of the Commission at its sixteenth session (Annex 1 to Resolution 2 (CAS-16) – Working structure of the Commission for Atmospheric Sciences) and to follow the procedures outlined when exemptions were warranted. The president has consulted with members of the CAS Management Group to ensure an optimal balance between new members and maintaining continuity in the work while also addressing the need to include more women in the work of the Commission.

Members made almost 300 experts available to work in the structures of CAS, and this contribution has been essential for progress. Among these experts, 77% were men (see CAS-17, INF 3.4). Members also contributed to the various research trust funds. All these contributions to the work of the Commission are acknowledged and highly valued. Considering the societal importance of environmental issues, the effort to attract young scientists has intensified, in particular through the Young Earth System Scientists (YESS) community, supported by Germany and Argentina. The YESS community was launched in 2010 for early-career researchers. The World Weather Open Science Conference in 2014 and the GAW 2017 Symposium provided important recruitment opportunities to involve early-career scientists in the work of the Commission.

The president has given science lectures, specifically on changes in atmospheric composition and how these impact on the climate system, humans and the environment, on three occasions to the United Nations International Law Commission, which is investigating the development of "The Law of the Atmosphere".

World Meteorological Organization
COMMISSION FOR ATMOSPHERIC SCIENCES
Seventeenth Session
Bali, Indonesia, 23 to 24 October 2017

CAS-17/INF. 2.4
Submitted by:
Secretary-General
14.VIII.2017

REPORT BY THE DIRECTOR OF THE RESEARCH DEPARTMENT (RES)

General

The symbiotic relationship between the WMO Research Department and the Commission for Atmospheric Sciences (CAS), and its working structures, has been a cornerstone for progress since the sixteenth session of the Commission for Atmospheric Sciences (CAS-16). This relationship is based on a culture of proactivity, effective communication and teamwork in support of the activities of the Management Group, the Global Atmosphere Watch (GAW) and the World Weather Research Programme (WWRP).

The Secretariat has paid particular attention to:

(a) Supporting progress on the six "Emerging Challenges and Opportunities in the Decade to Come", as identified by CAS-16, as well as focusing on polar and sub-seasonal to seasonal prediction proposed by CAS-15. The Secretariat worked closely with the broad scientific community and improved coordination with other WMO Programmes and activities to ensure progress;

(b) Promoting science and research as an essential component and the unifying force in the co-design and development of seamless services, through partnership between users and the research and operational communities;

(c) Ensuring a smooth post-THORPEX transition and accommodation of essential working groups on Data Assimilation and Observing Systems (DAOS) and Predictability, Dynamics and Ensemble Prediction (PDEF) in the working structure of WWRP, including the resources to accomplish this;

(d) Assisting in the development of implementation plans for both WWRP and GAW, with a strong focus on the "science for service" concept, in close cooperation with the scientific community and in phase with the WMO strategic plan for the period up to 2023.

Staff matters

Drs Liisa Jalkanen and Tetsuo Nakazawa retired as chiefs of GAW and WWRP respectively at the end of July 2014. On 1 August 2014, Drs Oksana Tarasova and Paolo Ruti assumed duties, building on previous achievements but also bringing fresh energy and innovative ideas to the Research Department. They have fostered a closer cooperation with the wider international scientific community, ensured better representation of research within WMO, established beneficial relationships with funding agencies and pursued the 'science for service' concept.

There have also been some other staff changes, the most important being the creation of an additional scientific officer post within the World Weather Research division, and having interns and junior professional officers to join the Research Department. These additional human resources are proving to be essential to support the growing number of CAS activities.

Major events

Some of the major events during the reporting period include the first-of-a-kind World Weather Open Science Conference (WWOSC), held in Montreal, Canada, 16 to 21 August 2014, with excellent support from the Canadian Government and under the able leadership of Drs Michel Béland, Alan Thorpe, Gilbert Brunet, Sarah Jones, and Professor Gregory Carmichael. The WWOSC discussions and recommendation created a strong foundation for further development of WWRP and has been well received among WMO Members, especially as the resulting book (see: https://public.wmo.int/en/resources/library/seamless-prediction-of-earth-system-from-minutes-months) was also translated into French and Spanish.

The 2017 Quadrennial GAW Symposium, held in Geneva from 10 to 13 April 2017, brought a large and diverse community to debate how best to strengthen the end-to-end nature of GAW, from observations to services and policy-relevant information in the fast-changing landscape of the atmospheric chemical composition research.

Communication, outreach and international relevance

The Secretariat has also been especially active in communication and outreach activities. The regular WMO Greenhouse Gas Bulletin, produced by GAW, remains a valuable and popular element to support climate policy. GAW has also launched new bulletins covering aerosols and reactive gases and has participated in events at both COP-22 and the United Nations Environmental Assembly in 2016.

Members of the Secretariat, in their personal capacity, have also maintained and enhanced the visibility of WMO in working with other international organizations (for example as co-chairs of groups in conventions and coalitions), particularly with the purpose of establishing cooperation with other international organizations and to help Members optimize national investments. Such activities include working with the secretariats of the United Nations Environment Programme (UNEP), UN HABITAT, and the World Health Organization (WHO). Other major events include the launch of the Year of Polar Prediction (YOPP) and its resonance in the international context, such as in the Arctic Circle, the first White House Ministerial on the Arctic, the UN Ocean Conference, and the Arctic Council to which WMO became an observer in 2017.

Both WWRP and GAW continue to issue newsletters for a large audience thereby ensuring that the relevant community stays abreast of developments in the Programmes. WWRP also produced a booklet, Driving Innovation Together: The World Weather Research Programme, which focused on the achievements, aims and resource requirements of the three core projects, the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) and the Aviation Research Demonstration Project (AvRDP).

Resource mobilization

A significant portion of GAW and WWRP activities were funded from extra-budgetary resources. In WWRP, the three core projects (the Subseasonal to Seasonal Project, the Polar Prediction Project and HIWeather) were supported by Members through dedicated trust funds, and the three Coordination Offices in China, Germany and the Republic of Korea. These contributions were much appreciated and a plea is made once again to CAS members to continue to support these initiatives. Recently, a research activity focusing on building resilience between nowcasting and seasonal timescales in the Lake Victoria area was successful in receiving funding from the United Kingdom.

GAW is also in the process of developing a funding proposal to the Green Climate Fund in cooperation with interested countries in relation to the observation and analyses of atmospheric composition, through the Integrated Global Greenhouse Gas Information System (IG^3IS). GAW also received some contributions from Members in support of its activities, and the numerous GAW stations and central facilities around the world are directly supported by

Members. One recent activity, related to measurement-model fusion for total deposition to enhance related products, was supported by Canada and the United States of America. Contributions were received from Canada to support the GAW Urban Research Meteorology and Environment (GURME) project and ozone activities, and from Switzerland to support Kenya ozone activities and the IG^3IS office.

The Secretariat has also managed to have some influence on the research calls by the European Commission, thereby benefitting the scientific community involved in both GAW and WWRP.

[All amendments in the document have been made by the Secretariat]

SCIENCE FOR SERVICE

Six "Emerging Challenges and Opportunities in the Decade to Come" were identified during CAS-16, and these remain valid beyond CAS-17:

- High-impact weather and its socio-economic effects in the context of global change;
- Water: Modelling and predicting the water cycle for improved disaster risk reduction and resource management;
- Integrated Greenhouse Gas Information System: Serving society and supporting policy;
- Aerosols: Impacts on air quality, weather and climate;
- Urbanization: Research and services for megacities and large urban complexes;
- Evolving technologies: Their impact on science and its use.

Implementation plans of the World Weather Research Programme and the Global Atmosphere Watch Programme

1) With its new implementation plan (IP), the World Weather Research Programme (WWRP) is connecting past achievements in weather science to the identified challenges and opportunities, seamlessly linking weather research to environmental and climate enterprises. The path towards seamless prediction of the Earth system from minutes to months during the period from 2016 to 2023, has been developed along four of the six challenges and opportunities, namely: high-impact weather, water, urbanization, and evolving technologies. For each of these, WWRP has identified the key scientific and implementation challenges, the need for international coordination and the resulting benefits for WMO Members. A set of action areas specify the concrete aims for WWRP research. These will be achieved through activities within the core projects – High-Impact Weather (HIWeather), Polar Prediction Project (PPP) and Sub-seasonal to Seasonal prediction (S2S), working groups and expert teams, research demonstration projects (RDPs) and forecast demonstration projects, and in collaboration with WWRP partners. As stated unequivocally in the WWRP mission statement, WWRP research aims to achieve "more accurate and reliable forecasts from minutes to seasons … to enhance society's resilience to high-impact weather, and the value of weather information to users". Specific service-oriented pilots have been proposed by S2S under the Priority Needs for the Operationalization of the Global Framework for Climate Services (2016–2018) (http://www.gfcs-climate.org/node/1057). "Science for Service" not only plays a special role in the core projects and the aviation RDP, but is central to all other activities.

2) The Global Atmosphere Watch (GAW) IP builds around research enabling services. The plan relies on the earlier achievements GAW has made since its establishment in 1989. The IP highlights the growing importance of atmospheric composition observations and predictions, and focuses on research that enables a wide variety of products and services related to atmospheric composition (based on high-quality observation, analysis and modelling – all at various spatial and temporal scales).

Applications addressed by the plan are summarized in three broad areas: monitoring (observation and analysis) of atmospheric composition and quantification of their changes; forecasting atmospheric composition changes on various scales; and providing atmospheric composition information to support conventions, policy, and services, including those in urban and other populated areas. The plan provides details of more specific actions in these three broad areas and describes the collaboration that has to be established in support of specific applications. The IP supports the WMO priority areas identified in the *WMO Strategic Plan* (WMO-No. 1161) and the priority areas defined by the Commission for Atmospheric Sciences (CAS) that allow for the development of services for WMO Members.

3) Full text of the WWRP Implementation Plan is available at: https://library.wmo.int/opac/doc_num.php?explnum_id=3511

4) Full text of the GAW Implementation Plan is available at: https://library.wmo.int/opac/doc_num.php?explnum_id=3395

A focus on service delivery

The goal of the WMO Strategy for Service Delivery and its Implementation Plan (http://www.wmo.int/pages/prog/amp/pwsp/documents/WMO-SSD-1129_en.pdf) is to help Members raise standards of service in the provision of weather, climate, water and related environmental products and services to users and customers. The Strategy implementation plan provides a flexible methodology to help Members evaluate their current service delivery practices and serves as high-level guidance for developing more detailed methods and tools that will enable Members to improve their service delivery process. Meeting the needs of users with fit-for-purpose products and services is vital for the success of Members as service providers. As the needs of users evolve, the capabilities of service providers should also adapt over time. Methods of distributing products and services are subject to change, especially in the modern era of information technology, and it is important that Members remain agile and capable of responding to these changes.

The Strategy describes a continuous cycle of four stages that define the framework for service delivery, and identifies six elements that detail the activities required for high-quality service delivery. The four stages of a continuous cyclic process for developing and delivering services are: user engagement and development of partnerships; service design and development; delivery; and evaluation and improvement.

The six elements necessary for moving towards a more service-oriented culture are: evaluate user needs and decisions; link service development and delivery to user needs; evaluate and monitor service performance and outcomes; sustain improved service delivery; develop skills needed to sustain service delivery; and share best practices and knowledge.

To offer the full and rapidly-developing service potential in environmental analysis and forecasting, the gap between research and operations needs to be closed. The National Meteorological and Hydrological Services (NMHSs) often show a significant gap between research and operations, and many do not have a research branch at all. This, however, does not imply that the research effort should be fragmented to service each component in the value chain towards service delivery. On the contrary, the underlying science is converging to a seamless Earth-system approach, which is optimally served with unified research with a strong link to operations. There has to be a two-way creative tension between research opportunities and service needs. In order to service the weather-dependent sectors of society (energy, transport, agriculture, water, health, climate), the relationship between the sectors and the service providers needs to be research- and user-driven. Research must be one of the standing (MC: maybe “long-standing”, “main”?) objectives within WMO, as one of the few truly scientific agencies in the United Nations system. In order to optimize the benefit of rapidly evolving scientific and technical opportunities, a good balance is needed between research and development (R&D) and operations.

Now and even more so in the future, societal sectors are served by back-end, specialized (post-processed) weather data streams (data or big data services) rather than by front-end services (human interface). This has profound implications for how service providers (including NMHSs) operate now and in the future.

Services are emerging from new tools that integrate observations and from new forecasting systems. This enhances the responsibility of the Commission for Basic Systems (CBS), the Commission for Climatology (CCl), the Commission for Hydrology (CHy), the Joint WMO-IOC Commission for Oceanography and Marine Meteorology (JCOMM) and the Commission for Aeronautical Meteorology (CAeM) to cooperate closely. It is a challenge to have the appropriate R&D in place as well as the capability to translate research results into operations and services, both now and in the longer term. This is partly a funding challenge and partly an organizational, cultural and intellectual challenge. The development of a seamless Data Processing and Forecast System (DPFS) as a joint CBS-CAS enterprise is a test of our integrating capability, as well as that of the relevant departments in the WMO Secretariat.

The "Science for Service" concept and integrated research

Underpinning research is needed to improve products and services for users and customers, and must be provided by the research programmes of WMO, in partnership with other organizations. To achieve this aim, new paradigms must be developed for the interaction between researchers and stakeholders.

One such paradigm is the value chain approach for services related to weather, climate, water and related environmental issues. This is an end-to-end approach that connects the relevant observations with an understanding and a description of the related processes, and integrates them into a model framework to provide services with analyses, forecasts and hindcasts that support downstream post-processing, as specified in close consultation with the users. This approach also integrates validation on a routine basis, and provides the technological and human platform for interaction with the users.

To reduce the gap between research and services, a behavioural change on the part of scientists is needed: they need to realize that although research is a long-term endeavour, individual research projects are time-limited and mature results must lead to implementation and not only publications. Researchers need to contribute expertise wherever needed along the value chain, in particular to strengthen the weakest links. The value chain thinking also implies that operations need to take on board the contribution of research and provide the necessary space for its impact on services. In this way, Members and especially NMHSs will be better prepared for the new, fast dynamics in service provision and will remain relevant.

In the context of weather, climate, water and related environmental matters, a value chain approach could, for example, be used to assess the effectiveness of information delivery. The approach considers obtaining and providing information from observations and models alongside the process of producing analyses, forecasts and warnings. It monitors the transmission of information to specific stakeholders and captures the resulting decisions and actions. It addresses the final outcome of the value chain for the community, for example in terms of lives saved or property protected.

The value chain approach can be used by researchers and stakeholders for co-design activities supporting "Science for Services". For each component of the value chain and the connections between them, the needs, requirements and potential issues can be assessed in the planning phase and addressed in the course of a specific project. Clear two-way communication within and across the components of the chain about what is possible and feasible, as well as about the requirements, will help identify research needs and establish the required pathway from science to operations. This heuristic approach is particularly useful to raise awareness of different perceptions, pose questions, identify gaps and opportunities, and to coordinate and integrate future research activities. It is reflective in nature, forcing stakeholders and researchers to spend time thoroughly defining and characterizing the subject, scope, and components of the chain. It can be used to identify and incorporate end-user preferences and values to drive product and service development. At a recent HIWeather workshop, it was re-emphasized that a useful approach for defining a new research project is to start with the needs of, and benefits to, users and work backwards.

Each value chain for weather, water, climate and related environmental services aims to consider the relevant information process in its entirety. As an integrator of research, the value chain provides evidence to help understand where existing research fits in the overall value chain, to identify gaps and to set priorities. At all points along the value chain, there is a need for developing ideas and theories and gaining knowledge in fundamental research, translating the knowledge gained into prototype applications, and implementing the applications in an operational setting. Just as the value chain only makes sense when considered as an entity in itself, research focusing on different aspects of the value chain must be brought together in coherent research programmes, to ensure an effective information exchange between researchers and stakeholders working on different aspects of the problem. Furthermore, a value chain approach for a specific service will have many research needs in common with other value chains, so that a "Science for Service" approach implies an effective and efficient central coordination for the implementation of WMO research.

It is well recognized that better integration of science and services requires a move from the current linear model of transferring research to operations as a one-off occurrence to an interactive model. Such a model will include multiple interactions between research, operations and users: stakeholders assess and articulate their future needs, researchers work in dialogue with stakeholders to define and implement appropriate research programmes, the research results are transferred into operations at appropriate intervals, and the stakeholder needs and research programmes are refined taking into account the knowledge and experience gained through the use of operational products and services. Specific larger projects are defined to address priority topics and often have a finite lifetime of 5-10 years.

The establishment of this integrated vision requires a substantial and active WMO research capacity, outside of NMHSs, as such capacity is fundamental for advancing the WMO Strategy for Service Delivery. Effective communication channels should be sought to convey user needs to research and to ensure the operational update of research results, while also providing a channel for effective feedback. There is a growing need for specialized services for many user communities (transport - including aviation, road, shipping and rail; energy production; agriculture; water availability and quality; health, etc.). WMO needs to attract scientists to carry out fundamental research for specific applications as well as to achieve a substantial increase in the resources available for the development of dedicated products and services for these sectors. As many services will potentially be implemented through the DPFS, this could become a primary unifying system to establish the new paradigm set out above.

Urban integrated services

Urbanization is one of the factors that drives a need for service delivery and one of the best examples of an area where research, operations and users need to work together. Today, more than 50% of the world's population lives in urban areas, and by 2050 this figure will have increased to between 66% and 75%. This massive migration requires metropolitan areas to absorb more than 3 billion additional people over the next 30 years. Large urban agglomerations – especially the so-called mega-cities with more than 10 million inhabitants – are inherently vulnerable entities. The supply of food, water and energy will need to be secured, and advance planning to respond to a wide range of potential natural or partly man-made disasters at various time-scales will provide a very strong driver for service delivery.

In recognition of the fact that urban areas are vulnerable to weather-related extremes including heatwaves, flooding, droughts, storm surges for coastal areas, air pollution and the consequences of climate change, WMO is paying particular attention to urban matters. High-resolution and short lead-time forecasting systems and services are required by urban complexes. For many meteorological hazards these must be embedded in probabilistic forecasts for the medium and extended range against the longer-term climate predictions and projections. These services will be relevant for urban resilience and sustainable development, city planning, infrastructure design, transport, power supply, water supply, food safety, disaster risk reduction, climate change adaptation and mitigation, the anticipation and mitigation of natural hazards (including flooding and droughts), reducing the vulnerability and exposure of the population, especially the poor, to natural hazards, and the health of citizens.

The seventeenth World Meteorological Congress adopted Resolution 68 (Cg-17), which calls for the establishment of a WMO cross-cutting urban focus. A focal group was formed to support this activity, including setting up priorities for activities relevant to urban issues, defining user needs, and developing a guide for an integrated service delivery strategy to address urban needs. The sixty-ninth session of the Executive Council further decided that the leadership in the development of the guide for urban services would be entrusted to the GAW Urban Research Meteorology and Environment Project (GURME), as a dedicated project working in urban areas. The GAW Urban Research Meteorology and Environment Project promotes joint activities between GAW and WWRP thereby capitalizing on the advances in research related to urban air quality and meteorology. The broader group will include contributions from the High-Impact Weather project, the hydrological community, the operational and service sector and the Global Framework for Climate Services (GFCS).

The United Nations Habitat III Conference, a key event occurring every twenty years, took place in Quito, Ecuador, October 2016. During the conference, a New Urban Agenda for the coming decades was presented. WMO assisted in the development of this agenda. For closer involvement of the urban meteorology scientific community in the realization of the WMO cross-cutting urban focus, a Memorandum of Understanding (MoU) between WMO and the International Association for Urban Climate (IAUC) was signed.

Development of integrated urban services will require utilization of recent advances in the understanding of the Earth system, including the interrelationships between atmosphere, ocean, cryosphere and biosphere, leading to improved predictive skill at all time scales in a seamless context. This will result in a strengthened forecast and warning performance for all Members as the interface between research and operations applies the best science for improving all components of the service value chain.

Key issues for the realization of “Science for Service”

The following key questions have been identified for discussion prior to and during the Science Summit. The outcomes of this discussion will be used to further develop the draft recommendations that will be submitted for discussion at the seventeenth session of the Committee for Atmospheric Sciences.

(a) How can the value chain approach be used by researchers, system developers, communication experts and stakeholders for ~~the co-design~~ promotion of “science for services” concept? How can ~~it~~ systems/service co-design be applied ~~so as~~ to attract research resources (people and funding) for basic, transitional and applied science?

(b) What are the key elements of an interactive model for ~~closing the gap between~~bringing research and operations~~?~~ closer together? Who are the key players? How can ~~we get them working~~they work together to ~~facilitate the process of identifying~~identify and ~~articulating~~articulate innovation requirements?

(c) How can specific regional priorities be best identified and realized for a given research objective?

(d) Which applications (often carried out on the basis of post-processing models) need most attention in the next six years, and why? In what areas should we expect significant challenges beyond 2023, and how do we prepare for them?

(e) What actions are neededHow should research develop to provide the underpinning research required support for the provision of integrated urban services?

____

World Meteorological Organization
COMMISSION FOR ATMOSPHERIC SCIENCES
Seventeenth Session
Bali, Indonesia, 23 to 24 October 2017

CAS-17/INF. 3.2
Submitted by:
Secretary-General
17.X.2017

[All amendments in the document have been made by the Secretariat]

SEAMLESS PREDICTION IN 2023

Introduction

New sources of observations, increased computing capacity and advanced scientific knowledge of the different components of the Earth system over the past decades have paved the way towards a more comprehensive approach in understanding the Earth system and predicting its future state. A seamless prediction system that integrates atmosphere, land, ocean and cryosphere will exploit sources of predictability on a variety of scales that are inherent in the interaction and memory of those Earth system components but are not captured properly in the current generation of models. It will thus provide Members with new opportunities for enhanced services. Developing such a seamless Earth system approach requires combined efforts and close collaborations, in particular across the meteorological, climatological, atmospheric composition, hydrological, oceanographic, geographic and biological communities.

In the context of WMO, seamless prediction considers not only all compartments of the Earth system, but also all disciplines of the weather–climate–water–environment value chain (monitoring and observation, models, forecasting, dissemination and communication, perception and interpretation, decision-making, end-user products) to deliver tailor-made weather, climate, water and environmental information covering minutes to centuries and local to global scales.

WMO is pursuing a new design philosophy to develop the future seamless prediction system (the Data-processing and Forecasting System (DPFS)), which constitutes the new engine of the WMO operational Earth system prediction system. The WMO observational, research, operational service and communication components are working closely together to co-design this system. The vision for the future seamless prediction system is to provide probabilistic guidance on urban (street canyons) to global space scales and on timescales ranging from very short-range to seasonal, decadal and beyond. The information required will span a variety of disciplines and socioeconomic applications, and will take into account the exposure and vulnerability of various communities in order to support risk-based communication and decision-making. The challenges for such a system include: observations for initializing, validating and evaluating model results at all spatial and temporal scales; models with variable horizontal resolution from a few tens of metres (in urban areas) to less than five kilometres (globally); ensembles with hundreds of members; coupled models for all components of the Earth system that include representations of physical, chemical, biological and social processes; and the provision of tailored information and products that can be used either directly or form the basis for end users to develop their own products. Central to the research contribution in this endeavour, is enhanced scientific understanding of the Earth System and improved prediction skill across the required time and spatial scales.

A number of key aspects must be considered to define the WMO research strategy for seamless prediction:

- What science is needed to develop a seamless Earth system prediction system which unlocks new sources of predictive skill?

- What are the resulting implications for the development of the future seamless DPFS as one of the main drivers for prioritizing WMO science development in the seamless context?
- What concrete steps need to be taken to improve seamless prediction by 2023 in order to realize the DPFS vision?

The research strategy must address the three main dimensions of a seamless system:

- Range of scales: From local to global, from minutes to decades, from urban to climate;
- Domains: Considering all components of the Earth system (water, air, land, ice, etc.,) to develop impact-based services across all sectors (energy, agriculture, fishing, insurance, health, ecosystem services, etc.);
- Users: Users' needs should be an integral part of the seamless system. A co-design approach should be implemented in order to understand to what extent the seamless system needs to be tailored.

How will activities of the Commission for Atmospheric Sciences support the development of seamless prediction in 2023?

With the new implementation plans, the World Weather Research Programme (WWRP) and the Global Atmosphere Watch (GAW) Programme are setting the stage for connecting past achievements in weather and environmental sciences to new societal challenges, seamlessly linking weather research to environmental and climate enterprises. Specifically, the WWRP implementation plan aims at seamless prediction by increasing convergence between weather, climate and environmental approaches. Seamless prediction in the WWRP context considers all compartments of the Earth system as well as disciplines of the weather enterprise value chain (monitoring and observation, models, forecasting, dissemination and communication, perception and interpretation, decision-making, end-user products) to deliver tailor-made weather information covering minutes to months and global to local scales. The objectives of WWRP for 2016–2023 will be achieved through research activities in the three core projects on high-impact weather, polar prediction, and sub-seasonal to seasonal prediction, as well as through the scientific guidance, technical advice and coordinating activities of the WWRP working groups and expert teams in collaboration with the Working Group on Numerical Experimentation (WGNE).

- **High-impact Weather Project (HIWeather)**

The mission of HIWeather is to promote cooperative international research to enhance the resilience to high-impact weather worldwide, through improving forecasts for timescales of minutes to two weeks and enhancing their communication and utility in social, economic and environmental applications. Project activities include:

  - Increase knowledge of the factors limiting the capability to predict, communicate and mitigate the impacts of high-impact weather events; identify how these limitations can be overcome; and demonstrate the resulting improvements for specific high-impact weather events from minutes to months, from global to local, for different users in different parts of the world;

  - Develop end-to-end approaches from meteorology to the impacts, in application areas of public health, commerce, industry, transport, water, energy, defense, agriculture, etc., taking into account the varying user needs in different parts of the world;

  - Share expert methods and tools enabling complex modelling systems to be run by a wider community.

- **Polar Prediction Project (PPP)**

The mission of PPP is to promote cooperative international research to explore the requirements for and evaluate the benefits of enhanced prediction information and services for various stakeholders in polar regions, through the development of improved weather and environmental prediction services for polar regions on timescales of hours to seasons. Project activities include:

  - Invest in methodological research (numerical methods, coupling strategies, assimilation methods, observational and model data information exploitation, including post-processing) to ensure that scientific enhancements can be implemented in future forecasting systems, and that systems can provide timely services;

  - Connect the knowledge and abilities to simulate high-impact weather events at high spatial and temporal resolution with larger-scale climate change expertise to more confidently attribute linkages to longer-term climate variability and change;

  - Improve understanding, observation, assimilation and modelling of the components of the integrated water cycle and its global, regional and local interactions.

- **Sub-seasonal to Seasonal Prediction Project (S2S)**

The mission of S2S is to improve forecast skill and understanding on the sub-seasonal to seasonal timescale with special emphasis on high-impact weather events, while promoting the uptake by operational centres and the exploitation by the applications community. Advances in model development, exploitation of observations and identification of untapped sources of predictability in the sub-seasonal to seasonal range will help to provide the best seamless forecast information possible. Project activities include:

  - Identify and characterize analysis and forecast uncertainty, and develop communication mechanisms which support decision-making;

  - Work with different science communities to develop modelling systems that fully integrate the most relevant components of the Earth system; link to and utilize socioeconomic models and data to assess impacts;

  - Assess and exploit new in situ and remotely-sensed hydrometeorological observations.

- **Numerical experimentation activities**

The Working Group on Numerical Experimentation has responsibility for fostering the development of atmospheric circulation models for use in weather forecasting and climate prediction/projection on all timescales, and for diagnosing and resolving shortcomings in these models. WGNE therefore forms a key link between the World Climate Research Programme (WCRP) and the CAS Programmes of WWRP and GAW. Recent WGNE activities include:

  - WGNE acts as a focal point for the development of dynamical cores across weather and climate. In connection with the expertise on dynamical cores, WGNE also pays close attention to the developments in supercomputing. This includes comparisons of how centres are currently using their supercomputing resource, but also being aware of likely developments in supercomputing, such as the move towards massively parallel machines and exascale computing;

- The identification of systematic errors among weather and climate models is arguably one of the most valuable functions of WGNE. The Fifth WGNE Systematic Error workshop was held in Montreal, Canada, in 2017. As in the past, this was very well attended, bringing the weather and climate communities together to discuss common issues and initiate work to address common problems;

- Fostering cooperation between the weather, climate, water and atmospheric composition modelling communities working towards a seamless approach for the Earth system.

- **GAW Urban Research Meteorology and Environment (GURME) Project**

The main objective of the GURME Project, a component of GAW involving collaboration with WWRP, is to develop improved air quality forecasting systems appropriate for the urban environment, primarily aimed at mitigating human health hazards. GURME contributes to the WMO integrated urban services initiative. GURME addresses research barriers to advance the predictive capacity at increasing resolution in urban environments, and coordinates pilot projects, many of which have led to operationalized air quality forecasting systems. These include the development of the System of Air Quality and Weather Forecasting and Research (SAFAR) by the Indian Institute of Tropical Meteorology in Pune, and the development of a new air quality and related services component of the Multi-hazard Early Warning System for the Shanghai World Expo in 2010. Decision 41 (EC-69) – Guidelines for the development of an integrated operational platform to meet urban service delivery needs, tasked GURME to steer the transition from research to operations in order to expedite the work on a Guide for Urban Integrated Hydrometeorological, Climate and Environment Services. In collaboration with the GAW Scientific Advisory Group on Applications, GURME also aims to better understand/characterize how air quality and meteorology in the urban environment interact with the regional and global scales.

- **GAW regional and global modelling applications**

GAW, under the leadership of the Scientific Advisory Group on Applications, is actively contributing to the development of a portfolio of new products and services, building on years of experience with numerical weather forecasting, and integrating knowledge on physical and chemical processes in the atmosphere, cutting-edge computing capabilities, and in situ and satellite observations. Core tasks include:

- Demonstrating the usefulness of exchanging atmospheric composition observations in near real time in support of forecasting and assessment applications related to natural and anthropogenic air pollution;

- Developing and delivering new inverse model and observation-model fusion products to enhance services and support policy;

- Exchanging and facilitating best practices among Members.

- **Intercommission Aviation Research Project**

During its sixty-eighth session, the WMO Executive Council considered the expansion of the WWRP Aviation Research and Development Project (AvRDP) into an Intercommission Aviation Research Project with the participation of the Commission for Aeronautical Meteorology, the Commission for Basic Systems and the Commission for Atmospheric Sciences. Building on the progress of the AvRDP, the Executive Council agreed at its sixty-eighth session with the proposed general principles for extended research activities on aviation and endorsed the organization in 2017 of the Aeronautical Meteorology Scientific Conference (AMSC-2017), which will recommend scientific research activities to be undertaken in the next 15 years in support of the evolving needs of aviation stakeholders envisaged in the International Civil

Aviation Organization's Global Air Navigation Plan and Aviation System Block Upgrades (2018–2028). Two of the topics to be discussed at AMSC-2017 are seamless numerical weather prediction related to aviation, and seamless iterative integration of new meteorological capabilities into existing air traffic management.

Key issues for developing novel underpinning research measures for future seamless systems

The following key questions have been identified for discussion prior to and during the Science Summit. The outcomes of this discussion will be used to further develop the draft recommendations that will be submitted for discussion at the seventeenth session of the Commission for Atmospheric Sciences.

(a) What scientific strategy is needed to cut across scales and enhance predictive ~~skill?~~ skills? The following aspects could be considered:

- Local vs global and short-term vs long-term: Harmonizing and bridging between global models (in the range of 5 to 10 km resolution) and local, high-resolution models (in the range of 100~~-~~ m to 1~~-~~ km resolution~~).~~) and between nowcasting, sub seasonal to seasonal and decadal forecasting. Enhancing a probabilistic prediction framework for high-resolution modelling at local-to-regional scale;

- Addressing knowledge gaps in key processes (like convection, cloud formation, exchange processes, atmospheric ~~chemistry, land surface, ice, coastal regions,~~chemical transformations etc~~.,)~~.) and in the capacity to model ~~their~~these processes and feedbacks across Earth system compartments (coupling);

- Designing and planning observational networks ~~based on~~using different modelling ~~approaches~~systems to support applications from nowcasting to sub-seasonal and seasonal prediction, and from seasonal prediction to climate projections. Optimizing ~~observational~~observing systems by ~~combining~~addressing different requirements from weather~~ to~~, water, climate~~,~~ and ~~dealing with~~environment, and considering diverse ~~requirements from, among others, the urban dweller to the water manager~~user communities;

- Investigating the possibility of ~~integrating high-~~assimilation of data of different quality~~ (less dense) and ~~, including high-end ground based, low-cost ~~(more dense) observation networks.~~ground based, air-born observations and remote sensing (both ground based and satellite).

(b) What scientific ~~approaches do we prioritize~~challenges should be addressed as a matter of priority by 2023 across disciplinary boundaries?

(c) What management strategies will lead to a reasonably open system that will facilitate downstream seamless products?

- A value chain approach needs to consider three main elements and their mutual interactions: observational systems, predictive and analysis capabilities and users;

- Evaluating the maturity in the value chain elements to operationalize research outcomes (e.g., land-surface modelling and assimilation of surface and groundwater vs a user's need of water availability).

~~(c) What operational strategy will lead to a reasonably open system that will facilitate downstream seamless products?~~

Research activities on seamless prediction should be facilitated by partnerships between National Meteorological and Hydrological Services, with academia, with the private sector and by downstream joint ventures to create new services feeding on the DPFS.

(d) How will a seamless-oriented research ~~structure~~approach for WMO support the development of the seamless DPFS by 2023?

[All amendments in the document have been made by the Secretariat]

FUTURE INFRASTRUCTURES

Introduction

Computing technologies increasingly provide the capability to develop and run operationally high-resolution and complex ensemble based numerical weather, climate and environmental prediction systems. Achieving the vision of seamless prediction of the Earth system places additional demands on the observing system, such as obtaining very high resolution observations in near-real time, securing long-term records of essential climate variables and improving our ability to monitor greenhouse gas and aerosol concentrations. Data from non-conventional sources may play an increasingly important role in developing and providing services. The increasing amount of data, both from models and observations, poses a challenge for data storage and archiving, as well as for the prediction chain to make new and improved forecasts available and accessible to a wide range of users in a timely manner. In addition, the landscape of observation data generators and owners, model developers and forecast service providers, as well as of users of these data and information, has become complex, moving away from having the National Meteorological and Hydrometeorological Services and research centres as the sole major players in the field.

Challenges which need to be addressed in order to exploit advances in computing and communication power include: data management - numerical methods, data assimilation algorithms and grid formulations; optimal processing of large ensembles, very high-resolution models, and reforecasts; risk information; and the right balance of how to use the computing power and communications bandwidth.

Enabling these technologies to function in an effective way and making these advancements beneficial for Members, and thus the citizens in their country, requires the development of a culture in governance of information of the Earth system, towards sharing the data as public goods and counteracting the development of expensive business models. Ways and solutions have to be sought, e.g., via public-private partnerships, data use policies and other means, on how to ensure that the development of such a culture is supported by and beneficial for all parties involved.

Challenges in optimising the observing system for a wide range of services including those based on seamless prediction also require extracting useful information from non-conventional observations; exploiting next generation ground-based and satellite remote sensing; availability of data on human impacts and responses; and the ongoing effort to assess the relative contributions of different observing system components. Quality assurance and quality control are, of course, an essential part of the development of new observation data sources.

Making data and tools available and accessible to the broader scientific community, in particular in developing countries, will allow researchers from all over the world to participate in and contribute to science and research efforts. This can help those countries to develop their own capabilities, which will contribute to their sustainable development.

A new culture in the use of Earth system data, models and the analytical tools applied to these, needs to be cultivated. There is a need to explore how a fair use of data, methods and tools can be ensured to sustain a healthy level of competition and opportunities in research. A possible approach for this could be to consider what type of oversight role could be played by funding organizations, science councils and regional consortia, and on how awareness could be shaped within the scientific communities.

How will the Global Atmosphere Watch (GAW) and World Weather Research Programme (WWRP) research projects/activities support the development of Future Infrastructures in the foreseeable future, based on their respective implementation plans?

(a) *Observational infrastructure*

Prepare for exploitation of information from new, advanced observing systems, as well as commodity-technology-based data, as detailed in the Implementation Plan, WWRP is working on:

- Polar Prediction Project (PPP): Promote the Year of Polar Prediction (YOPP) as providing a framework for testing innovative observing systems (e.g., aircraft deployable ice observing systems) in the context of improved forecast skill;

- High-Impact Weather Project (HIWeather): Analyse the information content and error characteristics of new and unconventional observations and, where appropriate, promote work to assimilate them;

- The Working Group on Data Assimilation and Observing Systems (DAOS): Use observing system simulation experiments (OSSEs) and modelling studies to help define the requirements for new observation networks (from large scale to urban scale) and their potential benefits on model performance;

- The Working Group on Predictability, Dynamics and Ensemble Forecasting (PDEF): Improve quantitative description of the uncertainty of the initial state, its evolution forward in time, and its propagation into impact forecasts and risk prediction;

- The Working Groups on Numerical Experimentations (WGNE) and on Forecast Verification Research: Develop capabilities to use information sourced from citizen observations and other unconventional data for verification and forecast quality improvement.

Inform the design of future global observations:

- Subseasonal to Seasonal Project (S2S) and PPP: Assess the impact of existing and supplementary observations on S2S forecasts during YOPP and the Year of the Maritime Continent (YMC);

- PPP: Assess the impact of existing and supplementary observations during YOPP, mainly through Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs);

- HIWeather: Promote the development, intercomparison and standardization of methods to quality control and store information extracted from unconventional data sources including social media;

- DAOS: Evaluate the potential of new instruments or opportunities for observation of the water cycle variables (e.g. cloud radar, water vapour lidar, Global Navigation Satellite System data for water vapour/soil moisture/ snow, 3rd party networks, ground water).

In order to meet the growing needs for atmospheric composition information and related services, GAW is working to:

- Assure the continued operation of existing high-quality observations that follow GAW Quality Assurance protocols and data sharing, in order to provide reliable observations to support assessment of trends and impacts of atmospheric composition;

- Improve the network to fill in spatial gaps, including enhancement of the vertical profiles observations, integration of satellite observations and bridge across spatial scales with respect to observations of air quality relevant to gases and aerosols;

- Support the development of increased capacity to deliver near-real-time (NRT) data and improve their accuracy through establishing standards and best practices, sharing experiences, and training;

- Adapt emerging measurement techniques for the purposes of specific applications and establishment of the Rolling Review of Requirements process;

- Encourage the continuous operation of GAW central facilities, which are operated by countries and carry out GAW Quality Assurance activities.

(b) *Modelling infrastructure*

Conduct methodological research (numerical methods, coupling strategies, assimilation methods, observational and model data information exploitation, including post-processing) to ensure that scientific enhancements can be implemented in future forecasting systems, and that systems can provide timely services:

- HIWeather: Support and facilitate studies on the development of data assimilation techniques suited to meet the operational needs and constraints of (probabilistic) very-short-range forecasting;

- Support the development of seamless Data Processing and Forecasting System (DPFS).

The GAW mission intrinsically carries the need for complementary and integrative activities regarding measurements, scientific analysis and modelling of the chemical composition of the atmosphere. As part of its modelling framework, GAW is focusing on:

- Developing a portfolio of modelling products and services;

- Exchanging model expertise and work on model development jointly with WWRP, the World Climate Research Programme (WCRP), the Working Group on Numerical Experimentation, etc.;

- Jointly developing common reference on skill standards and methods for integration of model results and observations across thematic areas and integration of observations with model development, including model evaluation, data assimilation and source attribution;

- Carrying out research focused on improving smoke, Sand-and-Dust Storms and Urban Air Quality forecasting systems, and evolving to support urban service delivery needs in matters related to weather and flooding; also in the context of climate change to help in adaptation;

- Extending capabilities to utilize atmospheric composition data to improve emission estimates through inverse modelling and to estimate trends in emissions, needed for an improved understanding of the carbon cycle and to support evaluation of policies; and, towards this end, finalizing the Implementation Plan for the Integrated Global Greenhouse Gas Information System (IG3IS);

- Further developing and supporting services related to health and other air quality impacts at large scales.

(c) *Computing and data infrastructure*

Enhance access to data and services (observations, model output, data collection and pre-processing and global models) that require exceptional high-performance computing (HPC) and data handling, as an enabler for research:

- S2S: Continue the development of the International Research Institute (IRI) data Library to (i) make the S2S dataset easier to be post-processed, allowing users with low-bandwidths to download much smaller data volumes, and (ii) enable data downloading in a variety of formats, so that the data can easily be loaded into the desired software tool used by NHMSs, to use the forecasts in combination with their own observational data.

To support the application areas and activities of GAW, the adequate management and provision of data and metadata play essential roles. GAW is in the process of designing and implementing a federated data management infrastructure that will include GAW Data Centres, data centres of contributing networks and the GAW Station Information System (GAWSIS), with the goal of enabling interoperable discovery of and access to atmospheric composition data, and ensuring harmonization with the WIGOS framework.

Key issues related to "Future Infrastructures"

The following key questions have been identified for discussion prior to and during the Science Summit. The outcomes of this discussion will be used to further develop the draft recommendations that will be submitted for discussion at the seventeenth session of the Committee for Atmospheric Sciences (CAS-17).

(a) *Observational infrastructures*

What science/research do we need to design and deploy observational networks to be optimally useful for weather, climate, water and environmental users/applications, including assessment of new measurement and analytical technologies?

How do we ~~extract value from~~make best use and optimize the benefits of existing measurements made at many different spatial and temporal scales by different international initiatives and organizations?

(b) *Seamless Modelling Infrastructures*

What science/research do we need to ensure the development and optimal use of probabilistic prediction systems able to capture local, short lived features? What will be the impact of such high resolution systems on the key elements of operational infrastructures?

How can high-resolution prediction systems ~~be linked with~~utilize crowd-sourced observations and other low-cost networks? What is needed to integrate these new data sources into a seamless prediction system?

How do we advance the integration of atmospheric chemistry within weather and climate models to improve a seamless prediction system?

(c) *Computing and Data Infrastructures*

How should the programming approach be developed to fully utilize the potential of future (multi-processor, cloud based, distributed) computing?

The traditional distinction between initialization, running a model and post-processing is not always sufficient. How do we design prediction systems that can intelligently adapt their run-time configuration (i.e., resolution, tailoring run-time outputs) to the predicted environmental risks?

What is needed to ensure that the legacy of projects and initiatives like the Year of Polar Prediction (YOPP) or the Year of the Maritime Continent (YMC), in particular in terms of data, is maintained and available to all relevant users? What should be the future data storage and sharing infrastructure to secure long-term availability of all observational data?

World Meteorological Organization
COMMISSION FOR ATMOSPHERIC SCIENCES
Seventeenth Session
Bali, Indonesia, 23 to 24 October 2017

CAS-17/INF. 3.4
Submitted by:
Secretary-General
17.X.2017

[All amendments in the document have been made by the Secretariat]

NURTURING SCIENTIFIC TALENTS

Introduction

At this point in time, there are more well-educated early-career researchers in the fields of Earth system science than ever before. Simultaneously, new challenges are emerging with respect to growing needs for interdisciplinary approaches and strengthened links between natural and social sciences, as well as between research and operations. These aspects, together with limited availability of financial resources, set the scene for the development of new, multi-faced career paths. Sustainable development is increasingly based on knowledge and information – two basic ingredients for innovation. A country's development can thus only be as good as the people it can attract, educate, train and retain for improving science, technology and innovation.

Key needs and ways forward

The value chain concept in service provision combines relevant observations, scientific process understanding and its mathematical description into a modelling framework to provide analysis, forecasts and hindcasts, which support downstream post-processing to services as specified in close consultation with the users. It also integrates validation on a routine basis, and provides the technological and human platforms for interaction with the users. The value chain is interactive, which means that a weakness in any link can feedback both upstream and downstream in the value chain, and researchers, technical staff and communication experts act and interact along the whole value chain.

Developing and implementing the concepts of seamless prediction and "Science for Service" requires ensuring access to well-educated and trained scientists. It also requires providing these scientists with a vision for their role within these concepts and for their future career. Furthermore, it calls for new approaches in the education and training of scientists, independent of their gender and nationality, and in the development and dissemination of knowledge. It has to be considered that the value chain is served by meteorologists, atmospheric chemists, engineers, IT personnel, communications experts, economists and other social scientists depending on the challenge at hand. These disciplines need to work together with a focus on customer requirements and satisfaction in order to succeed in service provision. Most educational programmes are disciplinary, meaning that meteorologists learn about clouds, atmospheric dynamics, radiation, etc., but with only little or no appreciation for other components of the value chain that support service provision. This is an important challenge for the education and training of scientists – they need both strong, disciplinary skills and an appreciation for the value chain.

Closer links between National Meteorological and Hydrological Services and national academic institutions will help shape educational programmes towards the required more interdisciplinary approaches and to address the evolving needs of Members. This could, for example, be achieved by developing new courses with a focus on service provision. Open access to data, models and tools, together with training activities on their use (for example, through engagement of Regional Training Centres), would further allow researchers from all over the world to participate in and contribute to science and research efforts and thus contribute to greater equality.

Education and training activities constitute an important element of capacity-building, which is one of the seven strategic priorities of WMO for the period 2016–2019. The overarching education and training goals of the research Programmes of WMO (World Weather Research Programme (WWRP), Global Atmosphere Watch (GAW) and World Climate Research Programme (WCRP)) are to foster training and emergence of future leadership in weather, climate and atmospheric composition research from all regions/countries with balanced gender representation. This includes enabling regional and global capabilities for the undertaking of sustainable activities by global research groups and projects, and building on existing networks and structures to ensure continuous and future leadership for weather, climate and atmospheric composition applications.

The topics of high-priority training, in the context of GAW and WWRP, are closely linked to developing seamless prediction capabilities and providing science for services. Specific emphasis is also required on training activities that focus on prediction of specific phenomena in particular regions (for example, sub-seasonal to seasonal prediction in regions facing monsoon impacts or water shortages).

Given that the world is increasingly connected through advances in information and communication technology, often due to initiatives by the private sector, new possibilities are emerging for training activities. Further exploration is needed of how new online training concepts, like web-based training or online workshops and conferences, could be implemented and used to complement ongoing conventional training activities. In addition to saving travel expenses and carbon emissions, such events can significantly broaden the accessibility to the knowledge transmitted by such events, in particular for people from developing countries in all regions.

To achieve their education and training goals, the WMO research programmes seek stronger cooperation with WMO Regional Training Centres in developing and implementing training activities and exploring new ways of providing such educational resources, also in languages other than English, and addressing different cultural contexts.

Increasing the benefit of weather forecasts and warnings to as many people as possible requires consideration of gender aspects, cultural differences and the needs of minorities. The WWRP High-impact Weather Project (HIWeather) is the only activity within WMO that also considers the social sciences aspects, such as communication or vulnerability and risk, in the context of developing early warning systems. To achieve the best outcomes possible that are tailored to user needs, the research and development of early warning systems in the context of HIWeather should thus also consider gender aspects, cultural differences and other issues that may impact the access and perception of forecasts and warnings, and the actions taken based on this information. This could, for example, be achieved by studies focusing on the perception of forecasts and warnings and the actions taken based on this information, which separate the results by gender and/or cultural background.

Current activities under the Commission for Atmospheric Sciences for nurturing scientific talents

Both GAW and WWRP have actively increased their efforts over recent years in nurturing scientific talents through training activities, support for early-career researcher activities, and by increasing gender balance in their working groups and expert teams.

WCRP, GAW and WWRP support the Young Earth System Scientists (YESS) community (http://www.yess-community.org/). YESS was established in 2010 by PhD students and postdocs as a bottom-up network of early-career researchers. With the strong support of the WMO research arms, YESS has since then grown into an extended network of young Earth system scientists from various disciplines, with more than 900 members from 80 countries. YESS also maintains close links with other early-career researcher networks, including the Association of Polar Early Career Scientists, the Young Hydrologic Society, and the Early Career Researchers Network of Networks. Based on a workshop at Deutscher Wetterdienst in 2015 (sponsored by WCRP, WWRP and GAW), an active group of the YESS community outlined their early-career scientists' vision on the future of Earth system science in an essay published in the *Bulletin of the American Meteorological Society* in July 2017. The generous support of the Argentinean National Weather Service (SMN) to host a YESS office, in operation as of 15 March 2017, is a more long-term and sustainable contribution towards this early-career researcher initiative.

GAW and WWRP also provide financial support for the organization and/or participation of early-career researchers in educational and training activities.

Among the activities supported by GAW, in collaboration with partners, are workshops and summer schools on improving the understanding and modelling of air quality and atmospheric chemistry from local to global scales, like the International Global Atmospheric Chemistry (IGAC) science conferences in 2014 and 2016, the ACCENT- Plus Summer School on Atmospheric Composition Change: Drivers, Feedbacks and Impacts in Air Quality and Climate Change in 2014, the International Conference and Early Career Scientists School on Environmental Observations, Modelling and Information Systems in 2014, sessions of the European Research Course on Atmospheres, and a training workshop on urban air-quality modelling for Southeast Asian nations in 2015, organized by the GAW Urban Research Meteorology and Environment Project.

Another pillar of the GAW education activities is the training of early-career researchers and technicians on the use of instruments and associated measurement, sampling and analysis techniques, and quality assurance. These include regular courses at the GAW Education and Training Centre, supported by Germany, with more than 350 participants over the last 15 years; regular courses organized by the World Calibration Centre on SF_6 or for ozone instrument operators; the Latin American and Caribbean Aerosol Measurements School: From Measurements Technologies to Applications in 2015; and the Atmospheric Aerosols Physics, Measurements and Sampling Winter School in India in 2014. The use of satellite products and ground observations for the detection of sand and dust storms (for example, through regular training on the WMO Sand and Dust Storm Warning Advisory and Assessment System), or for detecting and forecasting emissions from vegetation fires (through the IBBI-WMO-IGAC-BMKG workshop in 2016), complement GAW training and education activities.

Recent training activities of WWRP revolve around the topics of sub-seasonal to seasonal prediction (Advanced School and Workshop on S2S Prediction and Application to Drought Prediction in 2015, Advanced School on Tropical–Extratropical Interactions on Intra-Seasonal Time Scales in 2017), on polar prediction (Polar Prediction School in 2016), verification (sixth and seventh International Verification Methods Workshop and Tutorial Session in 2014 and 2017, respectively, and Roving Seminar on Weather Forecast Verification in 2015), monsoons (sixth International Workshop and Training Course on Monsoons in 2017 and Southern China Monsoon Rainfall Experiment Training Workshop in 2017), tropical cyclones (Typhoon Landfall Forecast Demonstration Projects Training Workshop for Forecasters in 2016) as well as aviation (Aviation Research and Development Projects Training Workshop in 2016). Furthermore, WWRP is providing financial assistance for early-career scientists to participate in various workshops and conferences, like the Data Assimilation Symposium in 2017 or other events, and events associated with WWRP research and development projects and forecast demonstration projects.

With respect to gender equality and equal opportunities, it can be recorded that females represent 23% of the membership of CAS expert teams and working groups, which is close to the average across the WMO technical commissions, and about 27% of the CAS Management Group. It is worth noting that the gender composition of delegates to CAS sessions has improved from a very low baseline (that is, 4% in 1998) to 24% in 2013 for both delegates and principal delegates. These numbers indicate that CAS is making progress towards the minimum of having at least 30% female members in the working structure of each of the technical commissions, as requested by Resolution 59 (Cg-17) – Gender equality and empowerment of women, but that there is still room for improvement.

Key issues for nurturing scientific talents

The following key questions have been identified for discussion prior to and during the Science Summit. The outcomes of this discussion will be used to further develop the draft recommendations that will be submitted for discussion at the seventeenth session of the Commission for Atmospheric Sciences.

1) What factors drive and influence the career decisions of early-career scientists in different cultural backgrounds?

2) What challenges are early-career scientists facing in their career development? What would help them ~~to~~ better cope with these challenges?

3) What are the roadblocks for achieving gender equality within the research community within different cultural environments?

4) How could WMO engage with public–private partnerships and foster collaboration within the public sector, to disseminate and increase the use of scientific data and tools including sharing the infrastructure to ~~do this~~nurture scientific talents across the world?

5) How can the use of new datasets and tools for educational purposes be further promoted, ~~for example~~e.g. in collaboration with WMO regional training activities?

[All amendments in the document have been made by the Secretariat]

INNOVATION AND RESOURCES

An innovation culture

Connections and networks are essential ingredients for innovation. Networks generate a cycle of innovation, and effective networks allow people with different kinds of knowledge and ways of tackling problems to cross-fertilize ideas. Building and participating in such networks requires seeking collaborations with the different sectors – private, public and academia – and engaging in their value chains to identify the contribution they can make to environmental prediction.

The well-known public–private partnerships concept needs to be explored further in order to co-design research and development activities and trigger innovation in the context of Earth system prediction. This would probably trigger joint initiatives and new resources. Boosting a country's scientific skill means creating the right competitive environment and the link with relevant stakeholders.

A changing landscape

Currently, the growth of private-sector involvement in all aspects of weather, climate, water and environmental topics and the development of new technologies are substantially expanding both opportunities and risks for all players within the global weather enterprise.

The "weather enterprise" is used to describe the multitude of systems and entities participating in the production and provision of meteorological, climatological, hydrological, marine and related environmental information and services. The weather enterprise includes public-sector entities (National Meteorological and Hydrological Services (NMHSs) and other governmental agencies), private-sector entities (such as equipment manufacturers, service-provider companies and private media companies) and academia, as well as civil society (community-based entities, non-governmental organizations, national meteorological societies, scientific associations, etc.). The weather enterprise has global, regional, national and local dimensions. This indicates that the enterprise, despite its reference to "weather" for brevity, encompasses the total weather, climate, water and related environment business areas of WMO, including weather, climate and water; and all core activities – observations, modelling, data-processing and forecasting, and other services and related research.

Within the weather enterprise, national, regional and international institutions and business models vary greatly. All stakeholders, however, help contribute to the core mission of the enterprise to help protect life and property, to help foster economic growth, and to improve quality of life. Governments, the private sector, academia and civil society all play important roles. By its Convention, WMO plays a key role in understanding and facilitating the contributions of Members participating in the weather enterprise.

Changes within the weather enterprise are evident across the globe, while its manifestations vary greatly by region and country. However, six primary factors can be identified that influence these changes:

1. Scientific and technological innovation;

2. Growing demand for meteorological, climatological, hydrological, marine and related environmental products and services;

3. Climate change and the United Nations Sustainable Development Goals;

4. Public sector institutional and resource constraints;

5. Ability to utilize research funding;

6. Private sector increased involvement, consolidation and globalization.

1. Scientific and technological innovation

Advances in the ways of data acquisition and data usage and in development of new, higher-resolution models and techniques mean that weather prediction now can extend beyond 10 days in both the northern and southern hemispheres, with substantially increased capability to give early warning of severe weather events. The linked development of ensemble methods gives practitioners the ability to also provide essential information on the probability of specific events, making weather information significantly more useful in decision-making.

The availability of high-resolution numerical weather prediction model output to the public and private sectors, combined with the affordability of systems available to both sectors, allows even small-to-medium enterprises to generate or repackage statistically and dynamically based products. These can be delivered freely off the Internet or through mobile applications.

Technologically, rapid advances in both instruments and information and communications technology (ICT) are propelling significant growth in supplementary observations and powering the emergence of a commercially-based observations sector. Produced both from cutting-edge satellites and from rapidly expanding networks of surface sensors (traditional as well as innovative sources, such as vehicles and cell phones), these supplementary observations enhance the volume of data available for potential application in local, national, regional and global models and forecasts. They also create an increased need for expert determination of what data within this enhanced flow are actually fit-for-purpose, given the needs of the weather enterprise, as the additional data could be seen as expanding the workload of NMHSs that must now respond to resultant weather rumours and 'fake news'.

Additional innovations in both computing power and connectivity are also driving change. Brisk expansion of Internet and cellular services, as well as the rapid adoption of smartphone technology worldwide, make novel arrangements for production and processing of data possible, as well as enabling a much faster and broader uptake of products and services.

Finally, technological innovation is also changing the way that NMHSs conduct their business across the value chain, through shifts such as increased automation of observing and forecasting systems. This innovation changes the mix of capabilities required within the NMHS and allows for greater agility and higher value deployment in activities such as user engagement and/or business development, posing both opportunities and potential challenges to private-sector business models.

In this context, open access to data and science outcomes is an important topic and ways have to be sought to provide such access, while maintaining a fruitful and fair competition within and across sectors.

2. Growing demand for products and services

A second driver affecting the weather enterprise today is the rising demand for its services. As both technological and scientific advances expand the accuracy, diversity and availability of products, they make these products more desirable, more accessible and more readily applied. Global social trends also are stimulating demand, as emerging economies build their weather infrastructures, and increasing development and urbanization in many countries make risk reduction for weather-related disasters ever more important.

3. Climate change and the United Nations Sustainable Development Goals

The Paris Agreement and the growing awareness of climate change and interest in adapting to and mitigating its effects also expand demand for products and services. So too is the United Nations '2030 Agenda for Sustainable Development'. Composed of 17 goals and 169 targets, the Agenda is an essential guide to national and international efforts to wipe out poverty, fight inequality and enhance medical and educational access over the next 15 years. Weather, water and climate services are identified as important tools in making and measuring progress towards the Sustainable Development Goals; thus decision-makers will increasingly make use of these Goals around which they can create and implement national and international policy.

4. Public-sector institutional and resource constraints

A fourth factor shaping the enterprise today is the ongoing resource constraints faced by publicly-funded NMHSs, as well as within other public entities such as academia. These public-sector entities are confronted with ongoing pressure from their governments to cut costs, including staff and operational expenses. The situation is particularly dire within certain developing and least-developed countries, where NMHSs have fallen into the 'poverty trap': insufficient public funding often results in budgeting only the basic operational needs, leaving the technical advancement of hydro-meteorological systems unfunded.

5. Ability to utilize research funding

There has been considerable recent success in securing funding for major weather, climate, water and environment related national and regional research projects, in many cases involving both academic institutions and NMHSs. There is a need, however, to both increase the amount of funding obtained and to ensure a focus of the resulting projects on the key issues for the weather enterprise. In view of the various funding mechanisms in different countries, regions and disciplines, it is necessary to use appropriate mechanisms for optimal resource mobilization.

6. Private-sector resource availability and increased involvement

The scientific and technological innovations described above are changing traditional business models within the weather enterprise – in no small part by increasing private-sector interest. They are both lowering the barriers against entering into business and creating substantial opportunities for growth and improvement in products and services themselves.

In response, a number of new private-sector companies are springing up, and established ones are expanding in fast and sometimes unexpected ways. Companies are leveraging the existing public infrastructure to expand into areas previously considered core NMHS capabilities and services.

A particularly dramatic change is occurring as large multinational organizations move into numerical weather prediction, satellite and ground-based observations, and weather and climate forecasts and services. In addition, other large companies are seeking expanded roles in the business of data, offering products and services that could both undercut open data policies outlined in Resolution 25 (Cg-XIII) – Exchange of hydrological data and products, and Resolution 40 (Cg-XII) – WMO policy and practice for the exchange of meteorological and related data and products including guidelines on relationships in commercial meteorological activities, and that could openly compete with NMHSs.

Amidst change, a constant reality is that it is in the best interest of all players to have a robust national and global meteorological infrastructure. This infrastructure forms the backbone of public- and private-sector activities.

Co-designed process

Facing the challenges that arise from the above-mentioned changes in the weather enterprise necessitates a move away from an isolated view on each major component, both of the Earth system and of the weather enterprise. Key sectors of the weather enterprise and their interfaces have to be identified and ideas that enable a smooth interaction across the interfaces have to be developed jointly by all players involved. Examples for this are, among others, the interaction between the Earth system science community and the reinsurance sector or the aviation industry, or satellite developers and users of advanced satellite data.

Such a co-designed process that connects all relevant components of research and applications, and the key contributors, can be of mutual benefit to all parties involved, but some efforts might be required to move toward such an approach. Ways have to be sought to get all key contributors to the value chain involved to create a culture of co-designing a common vision for the future of environmental information as well as its availability, usage and dissemination.

Establishing a culture of co-designing future activities that involves all players may also facilitate achieving some of the Sustainable Development Goals. It could further leverage access to financial resources, for example, from the societal sectors where proper user engagement is taking place or from international funding structures (World Bank, Green Climate Fund, Global Environmental Fund, regional banks, national authorities).

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

A global strategy

Recent research outcomes that had in-depth impacts in developing new services have been developed under large-scale international projects. Ensemble forecasting, which is widely used nowadays for weather and climate products, has been advanced significantly under the THORPEX umbrella. This success story was made possible by contributions from the national and international research initiatives of NMHSs, research institutions and universities. This also underpins the need for raising awareness on the necessity of such internationally concerted research approaches in organizations that are planning and funding large-scale initiatives, the outcomes of which can be effective worldwide and not only for developed countries. A unique voice for WMO research representing all programmes (Global Atmosphere Watch, World Weather Research Programme, World Climate Research Programme and research components in all technical commissions) would be an advantage.

Regional to local scale

Members need to be supported at the regional and local levels for leveraging their research and development capacity. In this context, important players are international funds and national agencies that are working to improve local development. The implementation of observational and computational facilities in countries with a certain degree of development through these means can facilitate the establishment of national and regional research programmes.

How to boost innovation is also related to the development of adequate tools on how to promote coordinated research activities at the global and regional levels. One of the reasons that WMO science is at the global forefront is because of the established vision in developing long-term projects to pursue fundamental research questions. The Polar Prediction (PPP, polarprediction.net) and the Subseasonal to Seasonal Prediction (S2S, s2sprediction.net) projects are two good examples of long-term WMO initiatives. There is a need to complement this long-term perspective, challenging the research community with short-term ad hoc projects as accelerators for technological development and networking capacity. For instance, the World Climate Research Programme and the Prince Albert II of Monaco Foundation are jointly promoting a Polar Challenge, which will reward the first team to complete a 2 000-km continuous mission with an Autonomous Underwater Vehicle under the sea ice in the Arctic or Antarctic. Such focused projects could advance scientific and technological development and improve the co-designed approach.

Another accelerator example is the Sub-seasonal Experiment (SubX), which has been launched by the National Oceanic and Atmospheric Administration (NOAA). This is a two-year project that combines multiple global models from NOAA, the National Aeronautics and Space Administration, Environment Canada, the US Navy, and the US National Center for Atmospheric Research to produce once-a-week real-time sub-seasonal experimental forecasts, complementing the S2S long-term vision. An additional investment to boost international leadership in Earth system science is the development of WMO awards focusing on improving innovative research, sustainability-focused interdisciplinary science and communicating scientific research and expertise.

As highlighted in Future Infrastructures (CAS-17/INF 3.3), the accessibility of data and numerical tools to the scientific community worldwide and the availability of adequate infrastructure will be key challenges in the near future for improving our capacity to assess and predict environmental risks and their multi-faceted impacts across different timescales and space scales (from weather to climate, from global to local). There is a need for developing scientific and technological catalysers able to assemble the best talent, to explore new business and technology areas, and to provide an opportunity to build new collaborative activities in the public–private partnership context. These catalysers, either virtual or physical, should bring us closer to an “unlimited simulation of the future”, with a predictive system able to provide the most accurate forecasts, in a probabilistic sense, tailored to user needs. A 1-km scale multimodel ensemble prediction system encompassing all components of the Earth system and providing both weather and climate information could be one example of a catalyser.

This could constitute a prerequisite for providing environmental risk assessment and prediction at an urban scale, meeting the challenge arising from increasing urbanization.

Key issues for enabling innovation and resources

The following key questions have been identified for discussion prior to and during the Science Summit, organized by the Commission for Atmospheric Sciences. The outcomes of this discussion will be used to further develop the draft recommendations that will be submitted for discussion by the Commission at its seventeenth session.

(a) Networks~~ generate a cycle of innovation and effective networks~~ allow people with different kinds of knowledge and ways of tackling problems to cross-fertilize ideas~~. What are possible new initiatives~~ which in turn drives innovations. How can this networking be leveraged on to promote innovation in the Earth system ~~context~~sciences? How can a better link be established ~~with~~between WMO activities and related existing initiatives?

(b) Currently, the ~~growth~~involvement of the private-sector ~~involvement~~ in all aspects of weather, climate, water and environmental topics and the development of new technologies ~~are substantially expanding.~~is increasing. What are the opportunities and risks related to research and ~~development~~innovation in this context?

(c) ~~Mechanisms~~Mechanism to boost innovation ~~are~~is also ~~related to the development~~through clear articulation of ~~adequate tools on how to promote coordinated~~ research ~~activities~~priorities and needs at the global and regional levels. One of the reasons that WMO science is at the global forefront is because of the established vision in developing long-term projects to pursue fundamental research questions. What are the future priorities for long-term projects that could attract strong interest from donors and key stakeholders? What mechanisms exist or must be developed to translate this interest into concrete research programmes?

(d) There is a need to complement ~~this~~a long-term perspective, challenging the research community with short-term ad hoc projects as accelerators for technological development and networking capacity. What mechanisms can be developed for this purpose?

____