Report of the 2017 Global Atmosphere Watch Symposium and Fourth Session of the CAS Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee (EPAC SSC)

Geneva, Switzerland, 10-13 April 2017
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PART I - REPORT OF THE 2017 GAW SYMPOSIUM

1. WELCOME AND INTRODUCTION

The 2017 Global Atmosphere Watch Symposium was opened at the headquarters of the World Meteorological Organization (WMO) in Geneva at 9 a.m. on 10 April 2017 by Deon Terblanche, Director of the WMO Research Department who subsequently invited Petteri Taalas, Secretary-General of WMO to give the official welcome.

Mr Taalas highlighted the importance of work of WMO as a technical agency of the United Nations on weather, water, climate and related environmental issues. He highlighted that data sharing in the development of WMO services plays an important role and encouraged an open data policy. Mr Taalas spoke about the increasing role that atmospheric chemical composition plays in the global agenda from pollution health impacts to aviation safety. WMO puts an increased emphasis on seamless predictions based on the Earth System modelling and he emphasized the increasing role of research in developing forecasting capabilities and services. A holistic description is required linking different components such as climate, ecosystems and the marine system. Mr Taalas brought up as an example the multiple aspects of black carbon which is important atmospheric pollutant and climate forcer. He further articulated the important role WMO plays in capacity development.

Oksana Tarasova, Chief of the Atmospheric and Environment Division gratefully acknowledged MeteoSwiss as a Symposium sponsor and thanked everyone who helped with the preparations, including her staff. The Symposium agenda (see Annex II) consisted of plenary and breakout sessions as well as poster sessions. WMO offered a chance to those who could not attend in person to participate remotely.
2. SETTING UP THE SCENE: ROUND-TABLE WITH CHAIRPERSONS OF THE ENVIRONMENTAL POLLUTION AND ATMOSPHERIC CHEMISTRY SCIENTIFIC STEERING COMMITTEE, SCIENTIFIC ADVISORY GROUPS AND EXPERT TEAM

This introduction session of the Symposium was moderated by Deon Terblanche (WMO) with Ranjeet Sokhi (University of Hertfordshire) as rapporteur. The objectives of this introductory session of the GAW Symposium was to evaluate the current state of the GAW Programme and map it against the objectives set up in the GAW Implementation Plan. The outcomes of the session fed into more dedicated discussions at the plenary and breakout sessions. The session consisted of presentations from the Chairpersons of all GAW steering bodies including EPAC-SSC, the eight SAGs and the Expert Team on the World Data Centres, followed by a discussion focused on four overarching questions:

- Role of GAW as a Global programme?
- Optimization of the role of GAW in supporting environmental policy?
- The biggest environmental/health threats faced by society in the 21st century and role of GAW in addressing them?
- Sustainability of atmospheric observation.

**Greg Carmichael, Chairperson of EPAC-SSC** opened the sessions with a general presentation on the state of implementation and components of GAW. He emphasized that GAW is essentially a research programme consisting of global cooperation, international observation platforms for delivering integrated, long-term observations and analysis for improving our understanding of atmospheric composition. GAW is based on a partnership of over 100 countries. The GAW Implementation Plan (GAW IP) for 2016 to 2023 highlights the importance of atmospheric composition and the role it plays in a number of areas including climate, weather forecasting, health impacts, and terrestrial and aquatic environments. The vision set out for GAW is to grow the international network of high-quality observations across local to global scales, and to use these data to drive high impact science and generate research enabled products and services. The overarching goal of GAW is to understand the processes that drive changes in atmospheric chemical composition and utilize the improved knowledge of these processes to deliver science-based products and services in cooperation with the operational and user community.

Meeting the growing needs of the atmospheric science community and related services requires:

1. Increased effort to enhance the GAW observing systems and to increase the interactions with research activities to support the development of services with high societal impact; enhanced modelling efforts (modelling is now integral in the GAW IP).
2. Improved information management infrastructure made fit for purpose; strengthened efforts to build collaborations, capacity, and communication among communities.
3. The promotion of a research value chain from observations to services.
There is also a greater need to identify emerging applications that bring together observations and predictions and this is now becoming a priority. The GAW IP articulates three broad application areas: “atmospheric composition forecasting”, “atmospheric composition analysis and monitoring”, and “urban services” that generalize the broad spectrum of the applications related to atmospheric composition. These are used to streamline research and implementation strategies that build on the observations acquired under the GAW Programme.

Mr Carmichael articulated several actions that can help promote the GAW IP from better engagement with user community (e.g. health sector) to observing systems integration and enhanced modelling capabilities.

**Craig Sinclair, Chairperson of the SAG on solar UV Radiation** provided updates on the status of the UV activities in GAW and a vision for the future activities. The interests of the UV SAG are largely on high quality long-term UV measurements and detection of the UV radiation changes associated with climate change, intense episodic events and stratospheric ozone changes. SAG promotes establishment of the new measurement sites and supports the archival of UV data at the World Ozone and UV Radiation Data Centre (WOUDC). SAG promotes use of the observational data for estimates of the UV Index for public information. SAG has very close ties to the user community and with its products and services it contributes to the Sustainable Development Goals and is forming closer ties to other UN agencies like UNEP\(^1\) and the World Health Organization (WHO). The plans include a GAW Training and Education Centre (GAWTEC) workshop on UV monitoring, further promotion of observations and public dissemination of the UV Index; continued support toward the development of the WOUDC; development of a UN partnership with WHO, UNEP, International Labour Office (ILO) and WMO with a specific focus on UV.

**Veronique Bouchet, Chairperson of SAG on the GAW Urban Research Meteorology & Environment (GURME) Project** presented the main activities and the outlook of the SAG. The purpose of GURME is to enhance the research related to the provision of urban-environmental forecasting and air quality services of high quality, illustrating the linkages between meteorology and air quality. GURME has been active in building capacity internationally, e.g. through the involvement in SAFAR (System of Air Quality and Weather Forecasting and Research) project (the first air quality forecasting system in India). GURME focuses on models and applications appropriate for the urban environment and interactions with the regional and global scales. GURME research activities are aimed at modelling at higher resolutions in the urban context, addressing research gaps/questions that transcend disciplines and require leveraging a broader community, and promoting seamless modelling approaches all the way to urban systems. An example of a research activity underway is a partnership with the UK/India PROMOTE project that aims to investigate meteorology and air quality interactions in the planetary boundary layer with a view to improve the SAFAR forecasting

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\(^1\) In 2018, UNEP was renamed to UN Environment
system. GURME is also initiating a review on the accessibility and use of urban surface characteristics in high resolution modelling. GURME demonstration activities are underway in Santiago, Delhi, Shanghai and Mumbai. Research to operation activities include pilot projects that have led to air quality forecasting that continue to be operated after the R&D phase, providing advice on expansion, improvements and downscaling to better represent the urban environment. SAG GURME collaborates with the SAG on Applications on nesting from global to urban scales.

**Martin Schultz, Chairperson of the SAG on Reactive Gases**, presented recent achievements and the plans of the SAG. He highlighted the successful data collection, quality assurance, and data analysis for volatile organic compounds (VOCs) and ozone that has led to the productions of the first WMO Reactive Gases Bulletin and the Tropospheric Ozone Assessment Report. A special Issue of Elementa, Science of the Anthropocene has been published and a new World Data Centre for Reactive Gases has been established. There are strong links between reactive gases and urban air pollution and hence different scales are at play. These interactions require measurements that represent different spatial scales. Future activities of the SAG aim towards increased use of integrated products, composition analysis and assessment; integrated data through regional networks and use of aircraft and satellite observations with models; expansion of monitoring networks; and improvement of data quality including benefiting from new technologies, e.g. NH$_3$ is being included in measurement programmes.

**Alkiviadis Bais, Chairperson of the SAG Ozone**, updated meeting participants on developments, priorities and progress of stratospheric ozone research. SAG supports participating countries in implementation of recommendations, tasks and projects related to stratospheric ozone, monitors the status of the ozone observational network and calibration centres; reviews the development of new and improvement of existing instrumentation and methods; develops and maintains Standard Operating Procedures (SOPs) for instruments, data processing and data submission. It also fosters synergies among stations and collaborations with other relevant measurement networks and the satellite community and supports combined use of ground-, satellite-, and aircraft-based observations, as well as model simulations; and assesses community needs and promotes development of products and services for different application areas engaging also WMO Data Centres.

Among recent achievements the adaptation of the new dataset of ozone absorption cross sections approved by the International Ozone Commission can be mentioned. The SAG will oversee the implementation of the new data in the retrieval algorithms by the Dobson and Brewer instruments. Another recent accomplishment is the establishment of The European Brewer Network (EUBrewNet) under COST Action 1207 in cooperation with AEMET with 38 stations at present.
Jörg Klausen, Chairperson of the Expert Team on the World Data Centres (ET-WDC) presented the view of ET on the future data management. The ET-WDC is responsible for metadata and data management in support of GAW’s research objectives; as well as interoperability and the development of GAW Station Information System (GAWSIS) as the central catalogue linking the WDCs and the Contributing Networks Data Centres.

An existing challenge in terms of how GAW data are managed today is that data providers have to submit their data to many data centres and users need to access many archives, while metadata are shared centrally via GAWSIS. As part of implementing a GAW federated data management system, the ET-WDC is looking at reducing complexity and accessibility through the use of the WMO Integrated Global Observing System (WIGOS) metadata standard and schema as a basis to exchange metadata with WDCs and GAWSIS, and to re-connect GAW WDCs and connect GAW Contributing Data Centres to GAWSIS. When it comes to data, ET-WDC needs to specify a common data exchange format for GAW as well as converters between the traditional formats. Data providers should be allowed to either submit in existing formats or the new common format. Data users should be able to obtain data in existing formats and new format(s), mainly supported by web-services. GAW Contributing Networks Data Centres will also be called upon to integrate their offerings. WIGOS metadata schema is ready for testing and World Ozone and UV Radiation Data Centre has been the front-runner. Other data centres are encouraged to follow this lead.

Vincent-Henri Peuch, the Chairperson of the SAG on Applications, presented the first activities and challenges of this newly composed group. He articulated that the main objective of the SAG is to develop a portfolio of modelling products and services related to atmospheric composition, and in particular to demonstrate the usefulness of exchanging chemical observational data in near real time in support of monitoring and forecasting applications. The SAG’s work streams include: assessments (health, climate and ecosystems); improving emissions; further developments of Near-Real-Time (NRT) systems; data aspects; developing scientific activities and outreach.

Current challenges include aligning a large number of international initiatives that have their own agenda and plans. SAG App plans to further increase the visibility of GAW and document the usefulness of quality-controlled observations; promote good practices and benchmarking for emerging applications. It will work on identification of current scientific deadlocks underpinning progress in the performance of applications; support (along with GURME) the development of regional Air Quality observation and forecasting information in areas where they do not exist or struggle to emerge; constitute a portfolio of compelling end-to-end cases of why (quality-controlled, NRT) atmospheric composition observations and analysis matter.

Wenche Aas, presented the activities of the SAG Total Atmospheric Deposition (on behalf of the Chairperson Ariel Stein). The main goal of the SAG-TAD is to provide a more comprehensive understanding and quantification of total atmospheric deposition. The SAG’s ongoing activities include support of the data archive by the World Data Centre on Precipitation Chemistry and data evaluation to produce datasets for user communities. The quality and data
harmonization are ensured through the establishment of measurement guidelines, laboratory intercomparison studies and training. A new activity of SAG is related to establishment of consistency between the methods and developing guidelines to estimate dry deposition, and a measurement-model fusion project for estimating global distribution of the total atmospheric deposition. Following a workshop on Measurement-Model Fusion for Total Atmospheric Deposition (MMF-TAD) held in February 2017, a multi-phase GAW project to generate global maps of total atmospheric deposition will be established that will include the use of ensemble models and measurements for year 2010 and stitching of regional MMF-TAD products.

GAW is a facilitator of communities on total atmospheric deposition including modelling and measurement communities, policy and science, regions and effect groups (such as climate and health). A major role should be to make atmospheric observations sustainable - deliver high-quality products, make efforts more visible and recognize that branding is important for everyone.

Alex Vermeulen, Chairperson of the SAG on Greenhouse Gases updated the meeting on the state of the greenhouse gas research in GAW. Mr Vermeulen stressed that according to observations at the GAW network the levels of the Greenhouse Gases (GHGs) continue to rise. The increasing GHG level have increased the level of radiative forcing from 1990 by 37%. While the global GHG balance and net GHG growth rates are well determined, the regional scale remains uncertain. Transport model resolution has increased but are still too coarse for accurate data assimilation techniques needed at smaller scales. Vertical mixing is proving to be critical. There is a revolution in new or improved instruments (laser based) for in situ observations but a lack of vertically resolved measurements. Also, large areas of the planet lack network coverage.

The way forward for GAW’s GHG programme includes sustained long term and high accuracy observational capacity; improved spatial coverage of the network; open data policies and true data sharing (open linked data); and dissemination of data with use of more powerful visualizations. It includes initiatives like the Integrated Global Greenhouse Gas Information System (IGG3IS), which will lead to improved network coverage in under-sampled regions, regional budget studies, estimates of fossil fuel related anthropogenic emissions, and support actions of emission reductions required by the Paris Agreement. Considering the landscape in the area of carbon cycle, the collaborations with diverse players will be investigated and exploited.

Paolo Laj, Chairperson of the SAG on Aerosol updated the meeting on the recent development in GAW aerosol research. The terms of reference of the Aerosol SAG are to coordinate GAW’s aerosol measurements programme including QA/QC and data policy compliance procedures; promote free and open access to data; organize aerosol GAWTEC courses and other training; promote better coordination among and establishment of regional networks toward a composite surface-based aerosol network (GAW Report No. 207); develop and promote applications targeting global challenges; and elaborate scientific reviews/assessment reports in support of international initiatives. Recent achievements of the
SAG include an increase in the number of stations providing aerosol parameters to the World Data Centre for Aerosols (WDCA); in the number of users of WDCA and in the number of instruments calibrated by the World Calibration Centre for aerosols.

The scientific challenge ahead is to reduce uncertainty in assessing total anthropogenic aerosol impacts on climate and health. This will require progress in all aspects of climate-aerosol science, including the work of the SAG Aerosol to improve quality and coverage of observations from ground to space; to achieve more effective use of measurements to constrain models; and to produce a more accurate representation of aerosols and clouds in models. Additional complexity appears to be increasing across the observation system including multiple players, too many systems, multiple responsibilities from operators to stakeholders and multiple requirements of funding agencies make it difficult to implement coherent observations and data sharing protocols. The challenge ahead is to limit entropy of the system with a clear GAW vision and implementation strategy.

SUMMARY OF THE DISCUSSION AND RECOMMENDATIONS

How do we see the role of GAW as a global integrator and why is such a role important?

The world is increasing in complexity when it comes to atmospheric composition knowledge and GAW has an important role to play. Diversity of knowledge comes from diversity of funding sources and regulations/stakeholders and one of the roles of GAW is to provide direction for groups seeking funding. This can be done via targeted initiatives, increasing links with the broader community, focusing on fewer, but stronger, messages, linking observations and modelling in cooperation with the weather services to develop new relevance. Here GAW can serve as a facilitator of global cooperation between different communities. There is an increasing importance of research focused on the urban scale, which must be linked to a diverse global urban community. GAW’s involvement at the urban scale will facilitate interactions and capacity building at various levels from observations, to modelling and emission estimates. It is clear that SAGs have to reconsider their specific roles as many are still solely focus on observations and quality assurance, and there is a growing emphasis that the teams must adapt to a changing world. It is also the role of GAW to encourage different communities (met services and other researchers) to collaborate more closely, both with one another, and across disciplines and groups. GAW’s role in the exchange of robust scientific information, informed outreach, and objective review of products is vital.

A good example of a beneficial interaction and cooperation is that between WMO and UNEP on ozone. Development of the global ozone observations and ozone research programme to support environmental policy is a clear success story. Ozone is a global concern and there is a need for integrated data to understand its evolution. There is an increase of instruments but there are only a few long-term series of data that allow to track the evolution of ozone in the atmosphere. The back-side of this success story is that funding for ozone observations and
research has decreased as there is a perception that the “ozone story” is complete. There is an “aging” of the ground-based ozone observational network and continuous need for the validation of satellite data. Homogenization of ozone soundings is also a success story. UTLS (upper troposphere/lower stratosphere) interactions and exchange are very important for understanding the distribution of ozone in the atmosphere.

**How can we optimize the role of GAW in supporting environmental policy, including climate policy through the Intergovernmental Panel on Climate Change (IPCC) and United Nations Framework Convention on Climate Change (UNFCCC) processes?**

GAW works with diverse groups of variables that support different directions of environmental policy. The example of the stratospheric ozone was provided above. In connection to climate policy, GAW has an advantage of expertise across multiple climate forcers (long-lived greenhouse gases and short-lived climate pollutants, (SLCPs)). GHG levels are expected to increase and improved resolution of instruments, especially for regional scales, is important to determine the baseline and to maintain consistency (e.g. instrument validation). At the same time the role of GAW in the global GHG observations and research is not recognized by IPCC. It is extremely important to increase visibility of GAW through IPCC-type mechanisms by encouraging the community to produce peer reviewed publications promoting GAW GHG products. The GAW aerosol network was recognized by IPCC as an important contribution. The difficulty is that there is a lack of measurements in many parts of the world and GAW should be a key player toward filling these gaps. The close connection between GAW and AEROCOM (who use GAW products) is an example of how to strengthen the connections between observational and the modelling communities. These types of activities should be further encouraged in the programme.

**What are the biggest environmental/health threats faced by society in the 21st century and what role can GAW play in these?**

The data on atmospheric composition evolution (past changes and forecasting) have been useful for many societal applications. Information on the UV Index is transmitted by mobile networks and informs or even alters people’s behaviour. Regional and global observations and modelling were an important tool to support Environmental Conventions (e.g. Montreal Protocol and Vienna Convention, Convention on the Long-Range Transboundary Air Pollution). GAW worked toward harmonization of the global observations and improvement of their quality but the efforts are needed to sustain and extend these activities given that many regions are experiencing economic and population growth with increased air pollution and resulting health impacts. GAW can give direction in development of the policies to reduce the effects of pollution, however, appropriate measurements are not available in the countries and regions that could benefit from such advice. GAW can serve as a bridge to provide information and guidance, e.g. for Africa, where limited assessment capacity is present. To have an opportunity to attribute pollution sources, the underlying observations need to be coordinated. At the same time, there is a disconnect between Air Quality and Climate policies (policy gap). GAW can play a role in articulating the importance of the integrated policies. GAW has an important role to play in support of implementation of the Paris Agreement by providing science-based tools to
support policy. Role of the SLCPs is also emerging, while the international policy making is missing robust evidence to support its development. Black Carbon (BC) is one of those SLCPs. GAW can play an important role here by promoting a harmonized approach to observations, assessment and even to definition of BC itself.

At the time GAW was established in 1989, acidification was the main global threat. There has been significant environmental improvement, and though substantial improvement was achieved in some regions of the world, other regions continue to be impacted by pollutants’ deposition. One of the critical areas for such regions is food security as ozone deposition is associated with substantial crop loss. Combination of observations and modelling can help to identify the regions under the highest risk. In the parts of the world where pollution levels are high, their deposition can represent a threat to biodiversity.

Today, we face air quality issues with impacts on health and ecosystems and increasing impacts of climate change. The role of GAW should be to combine measurements and modelling tools and to assist in filling the research gaps in the regions of the world that need it. Improved air quality forecasting tools are needed for the health community. Such tools will assist in avoiding the acute health episodes related to air pollution. Toxic air pollution (such as PAH, benzene, 1,3 butadiene, and POPs among others) also create widespread public health concern, though those pollutants are addressed by other agencies.

As people are spending more time outside and travelling the related risks of exposure to UV Radiation are increasing. More consistent global products are required in order to deliver the necessary scientific information to the public. At the same time, pollution in many parts of the world leads to the insufficient exposure to the UV Radiation that creates deficit of the vitamin D.

**How can we make atmospheric observation more sustainable by addressing user requirement/needs through a science for services approach?**

In the area of greenhouse gases, the user community is interested in the services related to mitigation support. Such services require understanding of GHGs distribution, sources and sinks on a regional and sub-regional scale. Hence, there is a need for the tools that can assist countries with development of mitigation strategies, and such tools are based on the fit-for-purpose observations. Some groups are looking at these issues, but efforts need better coordination. For example, there is a need for development of a joint strategy between different initiatives that would allow to evaluate where carbon comes from and where it goes to and this work should be placed in an international setting.

In terms of air quality and its impacts on health, there are multiple locations around the globe where the pollution levels regularly exceed recommendations made by WHO, especially in some regions of Asia and Africa. This does not correspond to the supply of funds which are
needed for sustaining observations. GAW could help in encouraging links between air quality and climate as they share similar emissions sources. GAW could also help with links with policy-makers.

Black carbon was mentioned as an important component of both the air quality and climate agendas. GAW can help to highlight the evidence on BC changes and provide guidance for measurements and establishing long-term datasets. UNEP has been preparing Emissions Gap Reports that cover the role of the SLCPs in closing the emission gap to reach the Paris Agreement target. Sustainable long-term measurements are needed to support this activity, which requires countries to have ownership of the measurements. The community needs simultaneous efforts from air quality, climate and health sides and in this context the role of SLCPs is critical. At the same time, local, regional and global scales have to be considered and GAW can help to mobilize and coordinate this effort.
3. SCIENCE FOR SERVICES

The moderator and rapporteur of this first plenary session were Paolo Laj (University of Grenoble-Alpes) and Isobel Simpson (University of California-Irvine), respectively. The objective of the session was to arrive at a common understanding of what is meant by “Science for Services” concept, who does/is responsible for what in Science for Services and what areas are to be addressed by the community to be able to implement this concept. The session consisted of five invited speakers and four short interventions, followed by a discussion focused around the following questions:

- What are the barriers to establishing atmospheric services?
- What is the role of the GAW community in delivering/supporting/developing services?
- What elements are in place/are missing in GAW to support services?

Mr Laj initiated the session by defining service as “the action of helping or doing work for someone”, and cited the IPCC Assessment Reports as examples of atmospheric science providing services to society. The retrospective question “So what’s new about Science for Services?” was posed. Is it the type of services, the time allowed for delivering services, services vs operational services, the traceability of delivered services, the customers requiring services, the economic model of science for services, a simple outreach issue, or a new paradigm for the atmospheric scientific community?

SUMMARY OF PRESENTATIONS

*Atmospheric Composition Matters to Air Quality, Weather, Climate and More*

By Greg Carmichael, University of Iowa

Science for Services was defined as research supporting services and a synthesis of knowledge to meet demands. An example of a service is improving prediction capabilities via incorporating/integrating atmospheric composition, weather and climate. The following five priority science areas were highlighted:

1. Advance the fundamental atmospheric chemistry knowledge that enables predictive capability for the distribution, reactions, and lifetimes of gases and particles.
2. Quantify emissions and deposition of gases and particles in a changing Earth System.
3. Advance the integration of atmospheric chemistry within weather and climate models to improve forecasting.
4. Understand the sources and atmospheric processes controlling the species most deleterious to human health.
5. Understand the feedbacks between atmospheric chemistry and the biogeochemistry of natural and managed ecosystems.
Specific actions to address scientific gaps in each priority area were also listed. The growing interest in improving air quality predictions/services and the role of atmospheric composition in weather and climate applications offer great opportunities for the GAW community.

**What’s the Atmosphere Like Today? CAMS Atmospheric Services**
By Vincent-Henri Peuch, ECMWF

Sciences for Services was defined as linking science to actionable information. Examples of actionable information include global air quality forecasts and related products, which have found their way to decision makers and the public. The Copernicus Atmosphere Monitoring Service (CAMS; [http://atmosphere.copernicus.eu](http://atmosphere.copernicus.eu)) was cited as a flagship European Programme that contributes to the international commitment to monitor the effectiveness of policies and treaties regarding the Earth’s environment and climate. By assimilating data and technology, Copernicus is equipping society with appropriate tools to understand and adapt to the changing environment.

**IG³IS: Integrated Global Greenhouse Gas Observation System**
By Stefan Reimann, Empa

Science for Services was defined as science-based information services that actively entrain users and coordinate with partners. Scientists need to build confidence that science-based information services are part of climate change solutions, not just the alarm bell. The Integrated Global Greenhouse Gas Observation System (IG³IS) provides measurement-based tools for estimating greenhouse gas emission in support of international agreements and was endorsed by the WMO in 2016 ([http://www.wmo.int/pages/prog/arep/gaw/ghg/IG3IS-info.html](http://www.wmo.int/pages/prog/arep/gaw/ghg/IG3IS-info.html)). For example, Swiss HFC-134a emissions have been assessed and compared to national emission inventories based on measurements at Jungfraujoch, Switzerland.

**Services for Air Quality Management**
By Markus Amann, IIASA

Science for Services was defined as targeted, solution-oriented atmospheric services. The example was degraded air quality which imparts concerns as a major public health crisis, and there is an urgent need to reduce the health burden from air pollution throughout the world. Because exposure to air pollution costs the world’s economy some USD$5.1 trillion/yr in welfare losses, the potential health benefits and costs savings are huge. Even though the major health burden is in Asia and Africa, high-quality observational data on population exposure are sparse in the most polluted areas, and this is especially true in many developing nations where air quality monitoring is insufficient. Effective air quality management must build on robust knowledge input from GAW/atmospheric services, including population exposure, source attribution, interactions between pollutants, and linkages with climate change. Addressing the needs of the health sector requires the extension of the activities on the urban scale.
**Future Global Data-Processing and Forecasting System (GDPFS)**
By Michel Jean, WMO Commission for Basic Systems

Science for Services was defined as enabling seamless activities from research to operations to service for the benefits of members (Figure 1). For example, the Global Data-Processing and Forecasting System (GDPFS) is organized as a three-level system to carry out meteorological functions at the global, regional, and national levels, with current work to add a fourth urban layer ([http://www.wmo.int/pages/prog/www/DPS/gdps.html](http://www.wmo.int/pages/prog/www/DPS/gdps.html)). The goal of the GDPFS is to be an effective and adaptable monitoring and prediction system, which will cover all timescales from short-term to multi-annual. The GDPFS seeks to facilitate the provision of impact-based forecasts and risk-based warnings through partnership and collaboration. It is a framework for integrating all WMO data-processing and forecasting systems under a common regulatory and management system.

![A Seamless Services Production Chain](image)

*Figure 1. Illustration of the convergence of weather, climate and environment in a seamless model system supported by observational systems that need to be interoperable, research and routine oriented and interdisciplinarity.*

*Source: M. Jean’s presentation*

**Short interventions**

Duong Van Khanh (National Hydro-Meteorological Service, Viet Nam) viewed Science for Services as a new concept that requires new awareness by leaders of nations and the public. GAW has the role of coordinating, directing and implementing the overall system while taking advantage of existing station infrastructure.
Oyunchimeg Dugerjav (Environment Mongolia) noted that greenhouse gases in Mongolia are increasing continuously even though there are no large greenhouse gas sources in Mongolia. A more complex study of regional air quality and its effects is needed, for example a GAW monitoring station should be established and a better assessment of pollution transport from other countries should be performed.

Augustín Garcia-Reynoso (Universidad Nacional Autónoma de México) noted several barriers to establishing atmospheric services, including lack of legal framework in some countries, lack of budget for hazard prevention, and lack of cooperation between different agencies and communities at the national level (e.g. between research and operational communities). The role of GAW in delivery/support/development of the services is to provide case studies to demonstrate benefits from the atmospheric services; facilitate web platforms; and list products that are considered atmospheric services.

Paulo Saldiva (University of São Paolo) discussed biomonitoring the health effects of climate and air pollution in the urban scenario. For example, black spots were found on the lungs of people living in São Paolo, and response curves show that mortality increases on the hottest days. Research in this area includes geocoding autopsy results and time spent in traffic. Translating from Science to Services requires a message equivalent to: “It will rain, bring an umbrella.” He mentioned that several factors play a role in delivering atmospheric services for the health community. He noted that there is a need for less expensive instrumentation to assess health impacts of air pollution and better collaboration with WHO.

Vincent-Henri Peuch highlighted that existence and provision of the Copernicus Atmosphere Monitoring Service (CAMS) services requires continuity in the operation on the satellite programmes. Guy Brasseur emphasized that the community should recognize that services development needs advances in science.

It was also noted that the GAW community should not concentrate on the services only and continue providing high-quality measurements as they have a direct value for policy. GAW has been providing this type of service continuously.

One of the ways for the service delivery is a prototyping together with the user community. Communication with the user community must be improved as it may turn out that the research community was focused on the questions with low social demand. The two-level approach was proposed where initially data are collected for research purposes and later it is transformed into the products for general public. There should be a clear understanding who is a ‘customer’ and what exactly he/she requires; as such, it is difficult to implement a science for services concept as a top-down approach. Therefore, the implementation of the concept requires a clear understanding of the potential economic model of service delivery under GAW. The role of media was pointed out as one of the important elements in conveying the information.
SUMMARY OF THE DISCUSSION AND RECOMMENDATIONS

What do we mean by Science for Services?

The definitions of a service were varied but focused on the common themes of research supporting services and the bridge between people, with an emphasis that it must be a synergistic feedback process that is responsive to users, or even a three-way process that also includes policy. In other words, science should not be so separated from service. Conversely, the role of relatively fundamental research needs to be recognized, because service also needs science (not just science for service). It was noted that there are larger budgets for services than for research, and society needs to recognize the value of the service in order for the feedback loop to work well.

Several definitions of research supporting services include: (a) science to actionable information; (b) a synthesis of knowledge to meet demands; (c) an advancement of fundamental atmospheric chemistry knowledge to address societal changes; and (d) a spectrum from research to testing to operational activities. Measurements and models can provide new evidence-based information to help decision-making and guide solutions to problems related to air quality, climate change and human health.

Who is responsible for what tasks in Science for Services?

Scientists are responsible for field, laboratory and modelling studies, which characterize pollution sources, help understand feedbacks, increase predictive capabilities, and so forth. Scientists synthesize knowledge and build confidence that science-based information services need to be part of climate change, air quality, and human health solutions. Scientists actively entrain users and create awareness within the user community (the public, leaders, etc.), and they coordinate with and listen to users. Finally, scientists are involved in the regulatory and management framework.

Users include the public, scientists, policymakers, companies, etc. They have the responsibility to be involved, provide feedback and adapt to new technologies.

What areas must be identified by the community in order to implement the “Science for Services” concept?

Several areas were identified as needing to be addressed by the community, including addressing barriers (budgets, legal frameworks, etc); creating awareness of atmospheric services among the public, leaders, and scientists; strengthening connections with communities; developing effective user cases to show how establishing science-based services can work; translating research into clear messages for the users; and connecting research to policy.
What are the barriers to establishing atmospheric services?

Several barriers to establishing atmospheric services were noted, including lack of funds, infrastructure, awareness, and connections.

Lack of funds. The economics of service were discussed, in particular that there is a growing demand for information about the environment, but limited funds to support this. There is a cost associated with going beyond observations to service. It was also noted that there are two kinds of services. One kind of service is given freely to the public (paid by taxpayers), for example weather and hazard forecasts. Other services are commercially viable, for example fitness centres. In some countries, less value may be placed on atmospheric services because of more immediate concerns, or because having this information would show that government leaders needs to act.

Lack of infrastructure. Some countries have scant information which makes it difficult for communities to be aware of and access GAW products. Solutions include finding ways to help GAW products reach communities and broadening the range of GAW country contacts. For example, GAW could consider sending an expert to develop long-term programmes in universities in developing countries, in connection with existing GAW programmes, in order to help solve this disconnect.

Lack of awareness. People need to be educated about the importance of atmospheric composition. The first-time science is presented to users can be negative because humans react against change, which can make it difficult to establish services. The other problems related to communications were discussed in the following sessions. One solution is to develop effective user cases (for example in Kenya or Mongolia) in order to show that the services can work. This also allows GAW show its added value to the community.

Lack of connections. In order to be able to provide effective Science for Service, various levels of connections must be established or strengthened. Scientists and users must communicate to one another and respond to each other’s feedback. As an example, scientists can measure and model ammonia emissions, but someone needs to talk to agricultural business leaders on how to achieve reductions in ammonia emissions. In order to close the feedback loop, it was suggested to have users at the table from the beginning, rather than having scientists serve what we believe the community needs. At the same time, it was well recognized that without educating the user community, a lot of people who could benefit never show up because they don’t realize the connection between their actions and the problem under study. Outreach to the correct people is difficult. Lack of connections between different scientific communities was also noted, for example the role of meteorological services vs academics in some countries. Efforts are encouraged to try to reconcile these communities.
What is the role of the GAW community in delivering/supporting/developing services?

GAW has at least three key roles in delivering, supporting and developing atmospheric science services. First, GAW advances fundamental atmospheric chemistry knowledge by conducting assessments for scientists, policymakers and the public. Second, GAW can build confidence in science-based information services by actively entraining users, coordinating with partners, and providing case studies to demonstrate benefits. Efforts to find ways to close the loop between scientists and users and to make products available are encouraged. Third, GAW’s role is to coordinate the overall implementation by supporting solution-oriented atmospheric services, responding to feedback from users and their needs, and facilitating web platforms.

What elements are in place/are missing in GAW to support services?

Numerous elements were viewed to be in place in GAW to support services. These include: existing infrastructure and monitoring frameworks (in many countries); existing pathways for producing assessments, bulletins, etc.; existing connections between communities; existing data centres; and existing web resources.

Elements that were viewed to be missing include the diversity of ways to actively entrain users, the tool to create awareness, connect to communities, and provide the user communities tools for engagement; more ways to respond to user feedback and connect to policy; more focus on cost-effective emission controls; and more ways to provide larger budgets for services.
4. INTEGRATED OBSERVATIONS

The moderators of this plenary session were Michael Kurylo (USRA/GESTASR) and Luciana Gatti (INPE). The rapporteurs were Ellsworth J. Welton (NASA Goddard Space Flight Center) and Karla Longo (USRA/GESTASR). The objective of the session was to assess the state of global capabilities for atmospheric observations, thereby assessing the opportunities for and approaches to their integration. The session consisted of five presentations from invited speakers, four short interventions, and a discussion focused around the following questions:

- What is the meaning of integrated observations?
- What is the appropriate role for WMO/GAW to play in such integration?
- How can ground-based networks with overlapping measurement foci be coordinated and integrated most efficiently (i.e. without unnecessary duplication of efforts)?
- What are the challenges in combining observations from different networks and platforms?
- How does one deal with varying uncertainties across instruments and platforms?
- How should we evaluate the potential roles and capabilities of new measurement methods and techniques that may be less expensive and more automated?
- How do we properly evaluate the performance of an integrated observing system?

SUMMARY OF PRESENTATIONS

**Integrated in situ observations in ICOS: strengths and opportunities**
By Alex Vermeulen, Lund University

The Integrated Carbon Observation System (ICOS) has set a very good example in the establishment of an infrastructure for an integrated ground-based observing system in support of atmospheric research and climate needs. The integration of the network was initiated following the identification of a clear scientific mission and was built on many years of scientific collaborations. It has a clear operational structure within which the individual components maintain their core identities, thereby ensuring the continuity of national funding. Its uniform design (across specific protocols) follows GAW recommendations and it performs individual station performance evaluations. As an integrated system, it maintains a clear understanding of what it will and will not do. It has a documented data policy, with a data flow that is initiated at the measurement stations (where the principal investigators (PIs) are responsible for measurement verification).

**IAGOS observations: strengths, weaknesses and opportunities for integration**
By Andreas Petzold, Forschungszentrum Jülich

The In-Service Aircraft for a Global Observing System (IAGOS) project exemplifies the integration of aircraft measurements with those from the ground and from satellites (Figure 2). It, too, began with specific measurement foci. While it has an open data policy, the individual
PI’s are responsible for the QA/QC, while following GAW recommendations for SOPs. The system recognizes the limitations of utilizing the aircraft measurements alone and the enhancements provided by integrating satellite data. IAGOS incorporates an important modelling component, particularly in data interpretation. The measurement components retain an independent status, with management playing a “soft overarching role” and providing for the “harmonization of data quality”.

**Strength, weaknesses and opportunities for the integration of satellite observations**

By Richard Eckman, NASA

The Committee on Earth Observation Satellites (CEOS) concept of virtual constellations of space-based instruments in support of the Group on Earth Observations (GEO)’s objectives demonstrate that significant value can be realized prior to the actual construction of integrated satellite systems. The proactive role of CEOS with respect to projects that utilize existing network datasets (such as for the harmonization of total ozone records from various measurement sources) could serve as one example of the role that WMO/GAW could play with respect to network data. CEOS’s development of constellation concepts has been done with full recognition of its potential weaknesses.

**WIGOS concept: challenges and opportunities**

By Sandro Fuzzi, National Research Council of Italy

The WIGOS concept for providing a framework for the coordination and integration of WMO observing systems is certainly commendable. It has the goal of changing and improving the way in which observations are delivered to meet user needs. However, the stated shortcomings associated with the component observing systems are very disconcerting, in so far as the issues and shortcomings mentioned appear to be far more prevalent than seen in some of the existing long-term ground-based measurement networks in which stringent operational protocols were formulated at the outset. The WIGOS concept will comprise all elements of WMO’s global observing system. It is not clear how this will be applied to the various contributing networks. There appears to be uncertainty within the WMO community about the importance of measurements of atmospheric composition to other user areas. WMO/GAW can assist in documenting the significant cost benefit of atmospheric composition measurements by identifying other user groups and establishing the communications links that will make these user groups aware of such data and allow them to better understand their value. An important next step would be the promotion of coordination and integration among existing networks so as to better address previously unappreciated user needs while not detracting from the originally established (and still valid) network foci.

**What does ‘integrated observations’ mean?**

By Greg Bodeker, GRUAN

The GCOS Reference Upper Air Network (GRUAN) has been established with its own collective long-term strategy. Nevertheless, it recognizes the value to be gained through coordination
and integration of components of other measurement systems or networks where measurement protocols and QA/QC are consistent with those of GRUAN. Its use of modelling and Observing System Simulation Experiments (OSSEs) to identify needed measurement locations goes beyond simple identification of geographical gaps and focuses on the fulfilment of the objectives that underlie its formation. GRUAN leadership has identified items of potential concern associated with multi-network integrations. These include the need for flexibility to adapt to evolving priorities, the challenges associated with delivering consistent data products, and a resiliency to recover from the cessation of a single measurement component.

**Short interventions**

Luciana Gatti (INPE) spoke about existing efforts to construct the Brazilian GHG Network. Duong Van Khanh (Viet Nam National Hydro-meteorological Service) presented answers to the session’s discussion questions and recommendations.

Jianguo Tan (Shanghai Institute of Meteorological Science) spoke about the characteristics of integrated observations from an urban environment point of view.

Norazura Binti Zakaria (Malaysian Meteorological Department) briefly expressed the importance and benefits of integrated observations.

![Figure 2. Illustration of integrated carbon/GHG observations and players](source: Andreas Petzold’s talk)
SUMMARY OF THE DISCUSSION AND RECOMMENDATIONS

GAW can play a significant role in facilitating the coordination and integration of different measurement systems. It can “harness leading science and technology” in the pursuit of quality assured atmospheric measurements as well as provide “a value-added chain of taking observations to a broader user community”. GAW’s coordination role can also facilitate the identification of duplication in sibling measurement networks and, where necessary, advise on the steps to remove that duplication.

In the future, new measurement technologies may be developed and implemented outside of customary scientific research channels. This brings forward an important question: is there a role for GAW in identifying such possibilities to guide or facilitate the development of new purpose-driven technological innovations? Therefore, GAW also has a role to play in assessing the quality and utility of measurements made using new technologies and, in particular, data arising from the large-scale deployment of inexpensive sensors by private agencies that do not fall under the auspices of WMO community. GAW must be seen as a trusted source of information on the quality and utility of inexpensive sensors, and their suitability for several atmospheric applications.

During the discussion, it was noted that development and sustaining of the network requires articulation of the value proposition for the acquired data. For example, the particular services should be made aware of the consequences of decline in the integrated observing systems and how and what products it will impact.

Upon discussing each of the questions, the following recommendations were made:

GAW’s role as a coordinator

- Identify locations where new measurements are required to fill geographical gaps in the global network.
- Assimilate measurements from across the network to provide a global picture of trace gas distribution to highlight the gaps in our knowledge.
- Articulate GAW’s value proposition to governments to ensure that the resources required for GAW operations in target countries are supported.
- Participate in implementation and coordination meetings of contributing networks with the goal of identifying and adopting common tools, and identifying and reducing unnecessary duplication.

New technologies

- Explore new technologies for dissemination of GAW data in a way that capitalizes on recent developments in machine learning, big data analytics, and semantic data models.
- Act as a trusted source for independent information on emerging measurement technologies.
- Ensure coordination with CIMO (Commission on Instruments and Methods of Observations), organize joint technical meetings and training courses to ensure that new technologies are adopted across WMO in a coordinated way.

**Partnerships**

- Provide guidance on potential partnerships to fill in the gaps in observing system and promote integration.
- Develop improved interactions between representatives from non-Met Service and those from the Met Services within the WMO national partners.

**Combining measurements from multiple platforms**

- Developing products and services that draw on data from multiple disparate sources → dealing with biases between data sources, combining data with different uncertainties etc.
- How to extract value from measurements made at many different spatial and temporal scales → data assimilation is one option but should not be the only option.
- New GAW focus on water vapour needs to combine measurements from multiple sources to obtain high vertical resolution profiles of water vapour through the troposphere and stratosphere; presently there is no network to achieve this and GAW can take a leadership position in defining the requirements for such a network.

**Near-real-time data delivery**

- Increasing appreciation of the commercial value of NRT data as a service to users; GAW needs to assist data providers in deriving possible revenue streams in the provision of such NRT data.
- Participate in national and international projects focused on implementing rapid data delivery together with data quality assurance.
- GAW needs to coordinate the collection of such NRT data, and to promote the use of these data in services for societal benefit.

While not explicitly addressed in this session, the objectives of the “Partnership” session (i.e. to establish new and improve existing partnerships) are very pertinent to the establishment of a more integrated observing system.

A secondary outcome of the session was a refinement of specific activities and responsible parties towards addressing the corresponding actions of the Observations component of the GAW Implementation Plan.
5. MODELLING ACTIVITIES IN GAW

This first breakout session of the Symposium was moderated by Veronique Bouchet (Environment and Climate Change Canada) and Vince-Henri Peuch (European Centre for Medium-Range Weather Forecasts), with Valentin Foltescu (UN Environment) and Mikhail Sofiev (Finnish Meteorological Institute) as rapporteurs. The objective of the session was to assess the state and the future of modelling activities in GAW with a view of setting a limited set of collaboration activities with other programmes/bodies/organizations. The session consisted of four presentations from invited speakers, five short interventions, and a discussion focused around the following questions:

- How could GAW better support the entire atmospheric composition modelling community (data, standards, harmonization, applications, etc.)?
- Multi-scale mapping of air pollution: what are the best practices, and what are the possible applications?
- What are the current challenges with data assimilation of atmospheric composition data and inverse modelling for source estimations?
- How do we facilitate and support emergence of reliable air quality services in developing countries?

SUMMARY OF PRESENTATIONS

*Modelling of atmospheric deposition and global mapping*

By Frank Dentener, EC, Joint Research Centre

There have been a number of recent global benchmark model intercomparison and evaluation studies. Photocomp 2006, an intercomparison of 10 models aimed to inform IPCC AR4, showed that for nitrogen wet deposition ensemble models almost always performed better than individual models with the best agreement in North America, then Europe, and mixed results in Asia and Africa. Vet et al., 2014’s Global Assessment of Precipitation Chemistry and Deposition used the HTAP Phase 1 ensemble for 2000 to provide information in regions where no observations were available including a budget analysis. This exercise demonstrated the usefulness of data to identify model weaknesses. Vet et al., concluded that total deposition relies almost completely on model estimates, that dry/total global deposition patterns mimic wet deposition and that the model ensemble overestimated sulphur total deposition in Europe and North America but did a better job with nitrogen deposition. The assessment also concluded that given gaps in models, their use should be limited in under-sampled regions of the globe. In ACCMIP (Lamarque, 2013), chemistry climate models were run for 1850-2100 to inform the IPCC AR5 report. The performance statistics of ACCMIP, HTAP1 and Photocomp were very similar showing that models did not improve much and that any differences may be due to emission inaccuracies. Global model intercomparison data are also becoming available from HTAP 2, with regional “components” in AQMEII (North America and Europe) and the Model Intercomparison Study for Asia (MICS Asia). HTAP 2 offers an opportunity to get consistent global deposition maps with more resolution over North America and Europe.
AQMEII3, an ensemble of regional models with boundary conditions from global models used to simulate the impact of emission reductions on wet deposition, can be used to evaluate the difference in deposition processes in regional/global models.

A GAW workshop on Measurement-Model Fusion (MMF) for Global Total Atmospheric Deposition was held to review the state of the science on MMF and establish a GAW project in order to generate global maps of total atmospheric deposition, important atmospheric gases and particles. The conclusions and recommendations from the workshop were presented. There was buy-in from major modelling and measurement groups including GAW Scientific Advisory Groups for this activity, and a clear link to policy and science drivers. The recommendation was to proceed with a phased approach with an initial focus on sulphur, nitrogen, and ozone.

- Phase 1 Short Term activities: MMF of existing 2010 ensemble global model results with existing datasets (HTAP, AQMEII). Products to include comprehensive dataset and model ensemble output files and gridded MMF maps.
- Phase 2 Medium Term: activities Stitching together existing and new regional/global MMF-TAD maps (Canada, USA, UK, Sweden, Norway, Asia, Europe) to produce global maps + a journal article.
- Phase 3 Long Term activities: Ongoing operational reanalysis using data assimilation (ECMWF/Copernicus/CAMS).

**Air quality forecasting from global to urban scale**
By Guy P. Brasseur, Max Planck Institute for Meteorology

Monitoring, Analysis and Prediction of Air Quality (MAP-AQ) is a science- and user-driven platform for facilitating global cooperation in air quality forecasting. MAP-AQ’s modelling system is an ensemble of different global and regional chemical/meteorological models, and includes downscaling to sub-regional and city scale (down to a city block). Other components of MAP-AQ are data assimilation of satellite observations, an operational data management system, dissemination platforms and a model evaluation platform. The MAP-AQ business model is to create the demand through the co-design of products and co-development of services where air quality forecasts are viewed as a public service. It can be complemented by a private-public partnership. PANDA and MARCOPOLO projects in China were presented as an example of what can be done. Finally, the overarching research need is to improve prediction capabilities via incorporating/integrating composition, weather and climate.

**Climate-atmospheric composition modelling (global scale)**
By Paul Young, Lancaster Environment Centre

Models are used to understand the past, project possible futures, explore processes and interpret observations of the state of environment. This information is useful to stakeholders and scientists. In the case of climate models, information on emissions, GHG levels, sea surface temperatures and sea ice, and meteorology are fed into the model in order to obtain a
spatially complete and time evolving state of the atmosphere. Uncertainty is inherent in models and needs to be quantified in order to determine which models are useful, what uncertainty we can tolerate, and which models we can trust to simulate possible futures. This can be achieved through model evaluations. Model comparisons need to be appropriate and representative. GAW links to climate-composition modelling include the Chemistry Climate Model Initiative and the use of observations for model process evaluation and understanding. Enabling model-observations comparisons involves observations that are appropriate and representative for models, guidance on comparisons, making comparisons available, format, and promoting interactions between observations and model experts. Other aspects to consider are the role of data science (IT and statistical expertise), analyses of model intercomparison projects, emerging constraints, downscaling and bias correction, the use of models to guide observations, and co-design with stakeholders.

Some thoughts on atmospheric inverse modelling
By Léonard River, Laboratoire des Sciences du Climat et de l’Environnement

Many concentration gradients are primarily driven by meteorology rather than by CO$_2$ sources and sinks, therefore, there is a need for accurate information about atmospheric transport over long periods (> months) and for exceptionally accurate measurements. Globally, we need to understand how the carbon sink is distributed between tropics and mid-latitudes and how it varies with ENSO and volcanic eruptions. Le Quéré & al. (2016) estimated three atmospheric inversions and associated uncertainties using multi-model means. At the subcontinental scale, estimates of the annual CO$_2$ budget within the EU (Bastos et al., 2016), including the natural sink, show that the net sink varies with the North-Atlantic Oscillation modulated by the East-Atlantic pattern. From a local perspective, an atmospheric inversion, based on data from the CO$_2$-MegaParis network (ANR) and ORE RAMCES stations (Breon et al., 2015), suggests a significant emission overestimate in the AirParif inventory. The main audience of atmospheric inversions has been the GHG scientific community but it is moving towards other users linked to regulations and international treaties. Current issues that hamper this move are: the cost of well-calibrated surface sensors, the sensitivity and methodological issues (how to isolate the GHG signal from the rest) of the satellite platforms, the resolution and accuracy of transport models and inversions (partially linked to available computational power) and the capability to discriminate between emission processes (multi-tracer approach) and emission ratios variation in in space and time. Atmospheric inversion is still an important research topic.

Short interventions

Brian Golding (UK Met Office) spoke about WMO’s High Impact Weather Project (HIWeather) in the context of urban air quality warnings as well as some of the HIWeather modelling issues.

Raymond Ellul (University of Malta) spoke about the Giordan Lighthouse GAW Station in Gozo, Malta and modelling studies done to evaluate Etna’s volcanic ash load on Malta and pollution from ships.
Agustin Garcia-Reynoso (Centro de Ciencias de la Atmósfera, UNAM) proposed a list of other communities with whom GAW should co-develop new applications and services, including IBM Green Horizons.

Najmi Houda (Maroc Meteo)’s short intervention was on air quality activities in Maroc Meteo, in particular, their urban air quality observing network and modelling system.

Duong Van Khanh (National Hydro-Meteorological Service, Viet Nam) offered some recommendations based on the discussion questions for this session.

**SUMMARY OF THE DISCUSSION AND RECOMMENDATIONS**

**How could GAW better support the entire atmospheric composition modelling community (data, standards, harmonization, applications, etc.)?**

In order for GAW to better support the atmospheric composition modelling community it is recommended that GAW:

- Continue facilitating the interactions between the observing and the modelling communities.
- Make available observations at the highest possible time resolution (raw) in near real time as far as possible, in established formats, assuring traceability to enable explaining possible bias and discrepancies between observational and/or model datasets.
- Enforce the provision of systematically detailed error estimates (e.g. representativeness, averaging kernels, etc.) and more detailed metadata, as they are essential for model verification or assimilation.
- Establish common standards for simulations, observations and reanalysis making them more interoperable (co-design infrastructure elements?).
- Gather applications/user requirements and propagate them upstream to influence evolution of observational and modelling infrastructures (e.g. NRT).
- Refreshing the model evaluation metrics from a user point of view and adapted to the applications (borrowing ideas from numerical weather prediction (NWP) e.g. precipitation: exceedances vs root-mean-square).
- Enhance the number of observations near emissions sources (dust, fires, anthropogenic…), especially in Africa, Asia and South America where there is a paucity of data.

**Multi-scale mapping of air pollution: what are the best practices, and what are the possible applications?**

Recommended best practices are to:

- Carefully frame the message to policy-makers when providing information on source
attribute to ambient air pollution in real time. This is not just “neutral” information (different from weather information).

- Start from user requirements and work backwards to select the modelling solution (type of model, scale, etc.): push-pull/co-design of technical solutions.
- Statistical methods, deterministic methods or a combination of both, can help produce suitable solutions. Selection should be based upon robust metrics that are specifically suited for the required time and geographical scales. One must also remain pragmatic.
- Emerging actors (e.g. private sector) need to be agile and seize opportunities to develop new technologies useful to multi-scale mapping.
- When possible, blend the requirements for modelling of long-lived and short-lived species: address air quality and climate issues jointly (economy of scale and avoid conflicting mitigation measures).

**What are the current challenges with data assimilation of atmospheric composition data and inverse modelling for source estimations?**

An opportunity, rather than challenge, is the increasing interest from decision-makers, especially in sectoral emissions (not primarily surface concentrations) from joint top-down/bottom-up approaches. The number and quality of measurements is a limiting factor in the skill of current inversion systems (fluxes, emissions, etc.). It is recommended that GAW:

- Consolidate the case for increasing the coverage of networks and their sustainability, and investigate cost effective monitoring solutions.
- Strengthen the message about the complementarity of satellite and ground-based/in situ observations.
- Comparison between applications in different regions is difficult; therefore, more comprehensive metrics are needed to assess how “transferable” results are.
- Error characterization needs further efforts, especially through joint collaboration across the observation and modelling/data assimilation communities.

**How to facilitate and support emergence of reliable AQ services in developing countries?**

Strong local involvement is needed to assess context and requirements. Training and capacity building are also needed at this stage. It is recommended that GAW:

- Analyse the needs and set up what is pragmatic, depending on the existing infrastructure, to run modelling systems. Provide a range of solutions, including very cheap/easy/light ones as a first step.
- Where possible, try to use existing infrastructure (e.g. Meteo services).
- Include the imperative of leaving a legacy as part of the project and ensure sustainability of technical solutions.
• Support the establishment of observation networks (e.g. deposition), as they must go hand in hand with modelling.
• Encourage and support the application of GAW programmes, such as MAP-AQ, to engage new areas of research, such as the planned MAP-AQ initiative for Africa.
6. **GAW QUALITY ASSURANCE**

This second breakout session was moderated by Herman Smit (Forschungszentrum Juelich) and Emilio Cuevas (Izaña Atmospheric Research Centre), with Dagmar Kubistin (DWD) as rapporteur. The objective of the session was to assess the state and the future of quality assurance activities in GAW – from measurements to easily accessible calibrated data with known and documented quality traceable to reference standards. The session consisted of three presentations from invited speakers, nine short interventions, and a discussion focused around the following questions:

- How do the objectives and principles of GAW QA reflect applications? What are the gaps?
- How do we ensure continuity of Central Facilities?
- What is the role of the metrology community in calibration facilities?
- What is the role of data centres in data QC?
- What is the role of the QA/SAC in data quality assurance (as a scientific issue)?

Herman Smit introduced the session by showing Figure 3 of the GAW IP which shows the elements and workflow of the GAW QA system. He stated that depending on the parameter or instrument, central facilities (namely PS, CCL, WCC/WRC, and QA/SAC) may play different roles.

Figure 3. Elements of the Quality Assurance system, QA activities and workflow in GAW

*Source: Figure 15 from the GAW IP*
SUMMARY OF PRESENTATIONS

Concept of the GAW Quality Assurance
By Paolo Laj, Chairperson of GAW SAG Aerosol

The GAW Quality Assurance principles include full support of the GCOS Climate Monitoring Principles, network-wide use of a single reference/primary standard, full traceability to the primary standard, a clear definition of data quality objectives (DQOs), establishment of guidelines for meeting DQOs, regular independent assessments of data quality, and timely submission of data and metadata to World Data Centres (WDCs). QA/QC in GAW is organized through Central Facilities (CCL, WCC/RCC, WDCs), with a primary focus by these facilities is to ensure the data collected and archived in GAW WDCs are of known quality for the benefit of the user. The workflow for developing SOPs for measuring black carbon was shown as an example of the process within GAW (Figure 4).

![Figure 4. Workflow for developing SOPs for measuring black carbon](image)

Real-world challenges lie ahead for GAW QA/QC because of rapid expansion of the network leading to increasing workload and costs or the World Calibration Centre (WCC) for aerosol QA/QC. There is a need for the establishment of additional regional calibration centres and attempts to date have yet not been successful. There is a need to evaluate the balance between efforts required against gains of ensuring traceability of data quality in WDCs as users might sometimes not care about data quality. QA/QC of contributing networks is not yet a part of GAW QA/QC, and it is important to apply clear QA/QC procedures and traceability to GAW reference standards to these networks. It must be acknowledged that data quality may vary according to user requirements (e.g. low-cost sensors), though it is not yet understood what protocols should be followed for these types of measurement initiatives. The submission of NRT data needs to be pushed forward, perhaps with less stringent data quality objectives for NRT data than for the standard data sharing, and procedures need to be developed to articulate the key differences between NRT data that may have been subjected to less
stringent QA/QC and more refined finalized data that followed a full GAW QA/QC protocol. Training for QA/QC for data providers and users is ongoing via end-to-end training and online courses.

**Difference in traceability concepts in GAW and metrology community**

By Joëlle Viallon, International Bureau of Weights and Measures (BIPM)

The definition of traceability within the metrological community is the “property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty”. The unbroken chain is a pyramid with the SI reference at the top, followed by the national standard, the calibration laboratory standard, and the working standard at the bottom which defines measurement uncertainty. Standards come with uncertainty and National Metrology Institutes (NMIs) or other expertise are needed to lower the uncertainty. The International Committee for Weights and Measures’ Mutual Recognition Agreement (CIPM-MRA) is the framework through which NMIs demonstrate the international equivalence of their measurement standards and the calibration and measurement certificates they issue. Within the CIPM-MRA, key comparisons between NMIs are performed regularly with each participant providing the best estimate of the “true value” and associated uncertainty based on some agreed calculation.

Within GAW, the principle is “Network-wide use of only one reference standard or scale (primary standard). In consequence, there is only one institution that is responsible for this standard”. The question is what is the measurement uncertainty that should be included? Also, how does the system deal with uncertainties associated with the measurements that do not follow WMO traceability chain? If the uncertainty on standards is negligible compared to DQOs that is one solution. Another solution is for some uncertainty components to be cancelled out. Maintaining a short-term calibration chain and long-term stability are other challenges that need to be considered. Long-term stability in the calibration chain is a continual challenge for the Central Calibration Laboratory (CCL), as even the most stable standards can drift, and this can impart additional uncertainty in long-term calibration efforts. Scales need to be linked and detailed documentation is essential. The drift needs to be included in the uncertainty of the standard.

There are several examples of strong collaboration between GAW and NMIs. The WCC for ground level ozone (Empa) is a regular participant of the BIPM. QM-K1 comparison and is therefore linked to NMIs. Recent improvements include reduced uncertainties in the NMIs CH$_4$ standard preparation method and a change of WMO scale in 2006. The uncertainty on primary standards is now comparable to the DQO although it should still be lower. Improvements related to GHGs, VOCs and aerosols in collaboration with NMIs are in progress. In conclusion, metrological traceability to the SI is a recognized way to ensure that measurements are compatible in space and time. Measuring small trends can be very challenging. Short calibration chains to a Central Laboratory combined with measurements guidelines to reduce
biases and other sources of uncertainties is a good way forward. CCLs can demonstrate their capabilities (quality, stability) by taking part in CIPM’s key comparison programme.

**Low-cost sensors and their role in the future observing systems**

By Christoph Zellweger, Empa

The trend in the development of high-end instruments over the last decade has gone from single to multi species analysis, from slow to fast measurements, from quasi-continuous to continuous measurements and toward an increasing use of spectroscopic techniques. On the low-end side, the development of low-cost sensors has involved diverse components and old technologies with insufficient technical information from the manufacturers. The market for environmental sensors is exploding but tests in lab have shown that the majority of low-cost sensors do not work at all. Low-cost sensors were discussed during the meeting of the SAG-RG in November 2016 and a short “Technical advice note on lower cost air pollution sensors” was written with several recommendations. The presentation summarized the findings and recommendations from this note. It is important to consider the requirements for the measurement uncertainty before installing low-cost sensors. Maintaining clear traceability and calibration in monitoring networks and calculating uncertainty budgets is relatively straightforward for high end instruments. Traceability in low-cost sensor based networks is unclear and difficult, uncertainty budget calculations are demanding, and there is a need for calibration procedures. The GAW SAG-RG’s recommendations for applying low-cost sensors are as follows:

- **Recommendation 1**: It is essential that users identify the underpinning sensor technologies being used since this impacts data quality and fit to application.
- **Recommendation 2**: Sensor measurements can be impacted by a wide range of different chemical and physical interferences. Any corrections that are made to account for these needs to be validated against reference measurements.
- **Recommendation 3**: Air pollution sensors must be treated like any other analytical instrument. They will likely require regular field calibration and will show long-term changes and drift in sensitivity and response.

An evaluation of sensor performance was carried out at Zurich Sensornet in order to answer the questions: Do low-cost sensors add information in the network? And what is needed to operate a low-cost sensor network? The main conclusion was that good data quality can be achieved after well-thought-out data processing but it was still not good enough for the intended application. By applying QA/QC for low-cost sensors, the costs are not low anymore. There is a clear need for improved sensors. Low-cost sensors might be sufficient for achieving temporal and spatial coverage, but not for concentration and long-term trends. Also, sensor uncertainties need to be better understood.
SAG RG ‘Technical advice note on lower cost air pollution sensors’

Figure 5. Synthesis of results from technical advice note on low-cost air pollution sensors

Source: C. Zellweger’s presentation

Short interventions

Martin Steinbacher (Empa) spoke about the role of QA/Science Activity Centres within the GAW Quality Management Framework. He emphasized that visibility of QA/SAC is low despite the fact they have a central role in GAW QA/QC. Communication among the QA/SACs lacks refinement. Available resources to serve all global GAW stations are limited. The way forward is to sharpen and identify QA/SACs interfaces, improve communication among QA/SACs, find a way for QA/SACs to complement one another and use available resources to achieve maximum benefit for the GAW community.

Christoph Zellweger (Empa) spoke about the WCC for surface O₃, CO, CH₄ and CO₂. He mentioned the WCC-Empa has contributed to the GAW programme for the last 20 years with a number of important accomplishments such as audits and parallel measurements. He identified a number of gaps in the GAW QA/QC system including the lack of clear traceability at regional stations (where audits are only performed for global stations and not regional ones), a limited
number of established WCCs, some measurement parameters are not covered. QA/QC infrastructure at the regional level (RCCs) is sparse, and the role of data centres in QA/QC could be strengthened.

Rainer Steinbrecher (KIT) spoke about traceability in the GAW-VOC network data. GAW has 21 VOC target compounds. CCL and target components are defined in GAW Report No 171. Results of 20 intercomparisons and 14 facilities audits show good analytical performance in the GAW-VOC network for Non-Methane Hydrocarbons (NMHCs) targets but improvements are still possible for ethyne analysis where a small bias was observed but the cause not identified. The future needs to include QA/QC for all GAW-VOC targets possibly with real air standards.

Sergey Assonov (IAEA) spoke about achieving GAW DQOs for stable isotope data in GHGs. It involves long-term data compatibility, proper use of Reference Materials (RMs) to define scales, and an estimation of total combined uncertainty and proper documentation. IAEA is the custodian of stable isotope scales and primary RMs. In order to address GAW DQOs, several fit-for-purpose RMs and QA and SOPs on their use and on stable isotope measurements need to be developed. The stable isotope CCL needs to work closely with IAEA.

Wenche Aas (NILU) spoke about the role of data centres which are responsible for documentation and traceability. Methodologies and information on SOPs used must be part of the metadata. Measurement uncertainties need to be reported in a harmonized way, and sanity checks (outliers, negative values, etc.) are also needed. EBAS, responsible for the WDCA and the WDCRG, defined metadata for QA measures administered by external institutions, WCC centres and others. The documentation is imported into the database. With respect to the synergy of GAW QA with other QA programmes (such as the European Monitoring and Evaluation Programme (EMEP), Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS)), there can be large differences in methods across regional programmes and it needs to utilize available resources in other programmes. Future challenges for GAW QA include the handling of dry deposition data for total atmospheric deposition work (measurement techniques are highly diverse, no standards yet).

Anatoly Tsvetkov (Voeikov Main Geophysical Observatory) spoke about the World Radiation Data Centre. He showed examples of dynamic visualization of large amounts of data, as well as examples of QC of global and diffuse radiation data.

Herman Smit presented some slides on behalf of Duong Van Khan (NHMS in Viet Nam) who was not present. The slides provided a summary of many of the issues previously raised in terms of gaps, the role of data centres and calibration facilities, traceability and collaboration with other QA partners. The presentation also mentioned the role of CIMO test beds and regional instrumental centres and how this has helped to support GAW members from developing countries.
Norazura Zakaria (Malaysia) presented a statement requesting that GAW develop guidelines for data quality assurance for all GAW focal areas in tropical countries.

Emilio Cuevas presented a slide on the QA system in EUBREWNET. This is not a physical centre but rather an expert body that acts as QA/SAC. Data quality assurance is done by the data centre for submission to the WOUDC.

Herman Smit spoke about the In-service Aircraft for a Global Observing System (IAGOS). IAGOS has adapted the GAW QA/QC system. The IAGOS QA/SAC is a body of instrumental experts. IAGOS QA/SAC has currently implemented the concept of QA/QC evaluation and harmonization. It includes QA protocols (calibrations, internal/external consistency checks) and evaluation by internal and external experts.

**SUMMARY OF THE DISCUSSION AND RECOMMENDATIONS**

There was considerable discussion on low-cost sensors. The audience appreciated the presentation by Christopher Zellweger. A number of comments were made with respect to unknown data quality associated with the use of low-cost sensors or the high cost of QA/QC required. Sensors may be operated by people with little training on data quality and there is a risk of cross sensitivities (e.g. CO$_2$/NO$_2$ interferences) and the need to characterize these in order to drive the evolution of low-cost sensors.

There was a discussion about whether there is a scientific need for a low-cost sensor network. Carbosense was mentioned again as a global, dense, lower power sensor research network for CO$_2$ that is already being proposed. It is to be combined with atmospheric model transport models. One of the aims is to quantify carbon sinks and sources. This CO$_2$ sensors clearly cannot replace the GAW CO$_2$ instruments, but the community should be open to new technologies and to find their potential while proceeding with care. There has also been an initiative for low-cost PM sensors. Low-cost sensors are evolving because of the anxiety of people over air quality issues, however, it is imperative that they be treated as all other instrumentation with calibration and uncertainties and that databases are quality checked. Also, the total cost of ownership needs to be considered in the overall cost. Lastly, the experience with CO$_2$ and O$_3$ sensors has been that they are all highly sensitive to water vapour, especially solid-state sensors (optical sensors perform a bit better), and these interferences need to be better evaluated. Those sensors are not selective therefore they could only be used as "total environmental sensors".

GAW needs to face the fact that sensors are coming to being and care needs to be taken that those observations are not overrated and find their way to policy regulations. GAW has a responsibility to comment on those sensors.
In summary, it is premature to rely on small sensors to perform reliable measurements. They have a very unstable baseline and when applied it should be only in combination with high-end instrumentation. They can provide “finger printing measurements” to obtain a morphology of local or regional pollution. Generally, they should not to be treated or handled as a GAW data product. The development of small sensors is proceeding rapidly and GAW should encourage the QA testing of small sensors. Optical sensors are particularly promising for future applications. New sensors are rapidly reaching the market, with significant improvements observed over time in terms of sensor reliability.

The rest of the discussion focused on some of the questions set out for the session with respect to GAW QA/QC. The initial statement was that not all components of the QA/QC system are being fulfilled as a result of limited funding and personnel. The question is how to be most efficient under the current situation. The following are some of the main points raised in answer to the discussion questions:

- QA/SACs collect information for WMO but there is no active evaluation of their activities (e.g. a body of experts).
- WCC Aerosol offers calibration of instruments but the instruments have to be sent to Tropos. This works for ACTRIS but not for GAW. A large number of stations do not respond and they lack funding, and this has led to a gap in observations. Instruments are typically sent to WCC as there have been bad experiences in sending around WCC instruments to stations (e.g. were returned broken). Also, only one audit per year is possible. GAW needs to re-evaluate options on how to handle this problem.
- The culture of calibration is well established within the O₃ community. Stations queue up for Dobson intercomparisons and instruments are sent around. O₃ intercomparisons are paid via the Vienna Convention trust fund and a Canadian trust fund, however funding will likely become more difficult in the future.
- The question of what would be a better strategy, one or multiple calibration systems, was discussed based on CH₄ as an example. Calibrations are performed for contributing stations with traceability to WMO primary standards. There was criticism on the use of a single technique. There is strength in having more variety. Using different scales and techniques are less susceptible to drift, though there are pros and cons to both approaches. Internal and external consistency checks are needed. GAW needs to refer to one common standard, so if it is biased it can be corrected consistently.
- More links and collaboration with air quality networks and their calibration centres may help. There are existing connections with National Metrological Institutes as CCLs which facilitate regional connections.
- QA/QC needs to be more practical within the existing budget and a certain quality needs to be guaranteed from operational stations. In Europe, funding comes from Research Institutes (RIs) after the completion of pilot projects. RIs provide research sustainability for the community (e.g. IAGOS, ACTRIS, ICOS). Within RIs international collaborations are required, although this is less strong for the atmospheric community at the moment. One possibility would be to establish ICOS-like operational stations in other regions outside Europe.
• Responsibility over the data lies with data providers. It is not clear what to do if data quality is not maintained by stations or if stations do not comply with terms of reference. We can put quality flags on data to make their quality known.

• It was mentioned that the SAGs should not be the "police" and do the quality flagging and that this should be performed by a QC-body while SAGs conduct assessments. In the case of the TOAR assessment, data quality control was done by the SAG-RG (instead of the WDC) and quality control plots were submitted to the EBAS data centre and data providers as feedback. A similar activity was done for Aerosols within GAW/ACTRIS and value-added products are available at WDCA as well as by SAG-TAD.

• A fundamental gap in light of the new GAW IP is that there is no QA although some recommendations on the benchmarking and performance matrices were made by the modelling breakout group.

The session concluded that in general the GAW network is suffering from limited funding, mostly short-term missions (Delta-Fundings), and only few long-term commitments. QC should stand for Quality Control, but GAW is far off from that due to lack of resources (i.e. staff). It is more realistic to call it Quality Check of the network. There are not many active WCCs therefore traceability is not always guaranteed. Measurements are often missing uncertainty estimates and quality flags. The training component is often suffering, QA/QC infrastructure at the regional level is sparse. Evaluation of QA/QC of the submitted and archived data is mostly missing. Linkage to other networks is mostly non-existent. The role of SAGs and particularly the role of QA/SACs are not well defined.

To summarize the recommendations, more funding is required in order to properly implement the GAW QA System. Existing funding should be directed toward the highest QA priority, which is measurements and their calibrations and traceability. The QA/SAC should play a more prominent and creative role in: (a) the regular evaluation of QA/QC of the measurements; and (b) stronger feedback with stations, data centres and SAGs. The profiles of the QA/SACs should be sharpened and communication among QA/SACs should be improved so they can further complement each other. The GAW Secretariat needs a stronger role in promoting the QA/SACs and their missions.
7. **PARTNERSHIP**

The moderators of this third plenary session were Paul Monks (University of Leicester) and Kobus Pienaar (North-West University) and the rapporteurs were Michela Maione (University of Urbino) and Haeyoung Lee (Korean Meteorological Administration). The objective of the session was to establish new and improve existing partnerships. Two questions were addressed:

- What value do Partners think they can derive from GAW data and services?
- What should GAW do for the Partners that it is not doing?

The session included speakers from quite diverse organizations, with whom two-way collaborations have been already established. These include the World Bank, UN Environment, BIPM, IAEA, WHO, ICLEI, GESAMP, CLRTAP, IGAC and SPARC.

**SUMMARY OF PRESENTATIONS**

**World Bank (WB)**

By Lek Kadeli, WB Environment and Natural Resources Practice

Pollution management and environmental health is one of the business lines of the WB’s Global Practice for Environment and Natural Resources and it includes air quality management. Components of relevance to GAW include a strengthening of air quality management, conducting research on optimizing local air quality, public health and climate objectives, and dissemination and awareness to develop a Like-Minded Nation and Organization Alliance. WB is working with low and middle income countries and is already taking the lead on education/awareness on air quality management topics (e.g. air quality monitoring and data management). Opportunities for partnership between WB and GAW include supporting the improvement of global remote sensing products to inform local station partners; and expanding activities under GURME and the WDCs to support operational data management for continuous monitoring technologies deployed in lower and middle income countries. WB and WMO have three agreements but may need a separate one on air quality management either separately or in combination with UNEP and WHO. The current approach to collaboration is to engage WMO through the Technical Advisory Group.

**UN Environment**

By Valentin Foltescu

UN Environment’s Bali Strategic Plan for Capacity Building and Technology Support aims to reinforce its role and make it more responsive to country needs, provide a coherent platform for all actors, strengthen cooperation and partnerships with the private sector, impact...
significantly on socio-economic development in the provision of environmental goods and services, and build on existing capacities. There is a recognition of low-cost sensors as a possible tool for assessment of air quality, but standard operating procedures need to be in place to support them. It also involves national ownership to sustain capacities, bottom up needs assessment, and well-coordinated and non-duplicative efforts. An important focus of research is on source attribution of air quality to inform cities.

**International Bureau of Weights and Measures (BIPM)**

By Joëlle Viallon

The BIPM has the mandate to provide the basis for a single, coherent system of measurements throughout the world, traceable to the SI (International System of Units). In 2010, WMO signed the CIPM-Mutual Recognition Arrangement (CIPM-MRA) of international equivalence of measurements. BIPM and GAW have a number of common scientific areas of interest and WMO/GAW is an important stakeholder for BIPM and National Metrology Institutes. BIPM is a partner in GAW Quality Assurance and Quality Control activities, through information sharing on vocabulary and concepts in metrology, invitation of CCLs in international comparisons, existence of CCLs in some metrology institutes, and invitation of WMO representatives to metrology community meetings. The value derived from GAW data and services is the increased awareness of BIPM member states that measurements of atmospheric composition are challenging. BIPM’s recommendation is the signing of a MoU for additional inclusion of metrology concepts in measurement guidelines and designation of additional CCL and/or WCC in the CIPM-MRA when services covered.

**International Atomic Energy Agency (IAEA)**

By Manfred Groening

IAEA is involved in a number of areas of common interest with GAW. IAEA is responsible for stable isotope reference materials and has developed a new RM for the improved measurement and monitoring of greenhouse gases including CO₂. The IAEA also develops calibration tools and actively supports the biennial WMO/IAEA Greenhouse Gas Measurement expert meetings. IAEA hosts the International Coordination Centre on Ocean Acidification and studies marine processes on ocean acidification. There is potential for cooperation on deposition of radionuclides and on the influence of pH on nutrient solubility. IAEA maintains the Global Network Isotopes in Precipitation and its database with 120000 records of 1200 precipitation stations covering 100 countries. IAEA’s Incident & Emergency System Prediction of dispersion and deposition of aerosols in case of any radioactivity release works with 8 WMO meteorological centres. IAEA Member states request aerosol measurement networks as part of Technical Cooperation Regional Projects such as one on “Apportioning Air Pollution Sources on a Regional Scale” and GAW expertise would be useful.
World Health Organization (WHO)
By Carlos Dora

WHO is also a global platform for understanding and evaluating the causative efforts of worldwide mortality and morbidity. They recognize the importance of air quality impacts on human health, and value that there are significant co-benefits to pollutant reduction across health improvement and climate change, especially from short-lived climate pollutants such as black carbon. There is a strong need for spatiotemporally-resolved maps of pollutants across the world to inform the global burden of disease reports, and this can be leveraged to inform effective and efficient policy that are based on where pollution comes from and how it might impact a community. The WHO also seeks tools to provide predictive capacity to poor air quality conditions which are based on sound measurements and models, that can be used to identify current and near-future acute events, including forecasting of future air quality.

ICLEI - Local Governments for Sustainability
By Miriam Badino

ICLEI is a leading global network of over 1500 cities, towns and regions committed to building a sustainable future. ICLEI can derive value from GAW data and services in terms of local capacity development, replicable solutions for Urban Development Challenges, reliable data on the urban environment, contribution to enhanced policies to tackle climate change and air quality, and support for reaching ambitious national targets under the Paris Agreement. GAW could benefit from ICLEI’s access to the local level where implementation is needed and in areas where there is less coverage, increased knowledge of local government needs for tackling air pollution, local government reported data from the carbon Climate Registry (cCR, https://iclei.org/en/cCR.html) to be brought to the attention of national policymakers to help co-design of vertically integrated approaches, a link to smart cities, and an opportunity to help shape messages to mobilize local stakeholders and raise citizen awareness.

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection – (GESAMP)
By Tim Jickells, University of East Anglia

GESAMP is an inter-agency body of the United Nations and its purpose is to provide authoritative, independent, interdisciplinary scientific advice to organizations and governments to support the protection and sustainable use of the marine environment. GESAMP has 7 active working groups covering topics of specific interest to the UN sponsoring agencies plus correspondence groups to scope out emerging issues (e.g. the causes and impacts of massive accumulations of Sargassum seaweed in the Caribbean and West Africa). WMO is the lead agency of WG 38 on the Atmospheric Input of Chemicals to the Ocean. The WG has recently published a number of scientific papers on the impacts of nitrogen deposition to the oceans. Much of the oceans are nitrogen limited and the atmosphere is the dominant external source of...
nitrogen to the oceans currently enhancing productivity by about 0.4%. The WG is now investigating changes in the acid/base balance of the atmosphere and ocean and their subsequent impacts on air/sea chemical exchange. Potential areas of common interest between GESAMP and GAW include an expansion of the GAW network to include more ocean-relevant stations and a more comprehensive set of measurement determinants; the atmospheric deposition of nutrients, their biogeochemical cycles and their influence on ocean and atmospheric acidification and on biological phenomena; long-distance transport and transformations of contaminants, and climate engineering. Remote marine stations are important for ocean inputs and long-range transport of air pollutions.

The Convention on Long-Range Transboundary Air Pollution - (CLRTAP)
By Laurence Rouil, EMEP Steering Body

CLRTAP was established in 1979, has 51 Parties (Europe, USA and Canada) and 8 protocols. Its structure includes the EMEP Steering Body and its Task Forces as well as the EMEP monitoring programme for air/aerosol and precipitation. A partnership between GAW and CLRTAP/EMEP is already informally established with common monitoring sites and a common data centre. Both implement QA/QC processes and WMO-GAW co-chairs EMEP’s Task Force on Measurement and Modelling. Formalized cooperation regarding monitoring activities through a partnership agreement will be considered in the upcoming CLRTAP work plan. Evaluation and recommendations for the use of new observation data sources (satellite retrievals, micro-sensors) could be established jointly. Lessons learnt from CLRTAP could help support air pollution control strategies in other countries.

International Global Atmospheric Chemistry – (IGAC)
By Megan L. Melamed

IGAC is an open international community of atmospheric scientists actively collaborating across geographical boundaries and disciplines in order to contribute to addressing the most pressing global change and sustainability issues through scientific research. WMO/GAW is represented in IGAC’s Scientific Steering Committee. IGAC builds scientific capacity through its national and regional working groups, its early career scientists’ programme, its biennial conferences and facilitation of numerous thematic workshops. IGAC provides intellectual leadership by identifying current and future areas within atmospheric chemistry that need to be addressed and promoted that would benefit from research across disciplines and/or geographical boundaries. IGAC aims to continue expanding the capacity of the international atmospheric chemistry community to understand atmospheric composition by fostering fundamental scientific research on emissions and atmospheric processes.

Stratosphere-troposphere Processes And their Role in Climate (SPARC)
By Fiona Tummon

SPARC is a core project of the World Climate Research Programme (WCRP). SPARC’s themes are atmospheric dynamics and predictability, chemistry and climate, and long-term records for
climate understanding and has a number of activities underway on atmospheric temperature changes, stratospheric sulphur, water vapour, ozone trends, etc. Emerging activities include short-lived climate forcers, composition trends and variability, and unified error reporting. SPARC develops scientific capacity via regional working groups, training schools and by working with early career researchers. SPARC uses GAW products and services for model evaluation and validation, long-term trend analyses, and data assimilation activities, including satellite trends of long-term data such as ozone. GAW data and services help SPARC in addressing research questions and GAW observations provide the basis for research feeding into assessments. GAW should work together with users to make data and associated uncertainties more easily available, provide information on representativeness of observations, and enhance links between observationalists and modellers.

SUMMARY OF THE DISCUSSION AND RECOMMENDATIONS

Areas of interest among the organizations spanned from the local to the global scale with needs going from data to services. Despite such diversity, several commonalities have been identified. To avoid duplications, a better organization of efforts is necessary. Taking into account the well-known co-benefits of reducing air pollutant and greenhouse gas emissions, the need for joint projects on air quality and climate, involving a vertical approach from the local to the global scale, was frequently mentioned.

There is a common need for reliable emission estimates and for source apportionment studies. These are particularly relevant to air quality issues, to assess citizens’ exposure to atmospheric pollutants in urban environments and to identify effective measures for reducing emissions. This implies the need for assessing the quality of observational data to be used by modellers and of improving modelling capabilities for chemical weather and acute episodes’ forecast, enhancing the links between observations and modelling communities.

In many instances, the need for implementing citizen science as well as the need expanding the use of low-cost sensors were mentioned. This would be also important in order to raise awareness of citizens on air quality and climate issues. However, a crucial point is how to improve and assess the quality of data and how to organize the data flow system. The involvement of the private sector in the development of new sensors should also be taken into account.

Other common issues include the need to improve satellite capability and data assimilation activities as well as the need for satellite data intercomparisons.

Finally, since many programmes are focusing on developing countries, GAW capacity building activities must be enhanced.
With regard to the actions in the GAW Implementation Plan, the following are still missing:

- **A-P-3.** *With the help of the partners, develop the resource mobilization strategy that will ensure continued operation of the GAW Programme with a special emphasis on the atmospheric composition related service delivery* → see breakout session on “Resource Mobilisation”

- **A-P-6.** *Encourage all NMHSs and other interested national organizations to establish internal co-operation between appropriate laboratories and institutes, especially with National Environmental Protection Agencies, Health Authorities and national development agencies.*
8. KEY REQUIREMENTS ON DATA MANAGEMENT FOR GAW AS A PROVIDER OF SCIENCE-BASED SERVICES

The moderators of this third breakout session were Jörg Klausen (MeteoSwiss) and Ray Ellul (University of Malta) with Richard Eckman (NASA) as rapporteur. The objectives of the session were to establish requirements and needs of users and providers of observational and modelling data, to identify the gaps in the existing data management system, to inform data users and providers on the WIGOS metadata standard and reflect the intention to establish a federated GAW data management infrastructure. The session featured five invited speakers and two short interventions. Following the presentations, three parallel group discussion sessions considered the following questions:

- What kind of chemical composition data do you work with?
- Do you generally think of atmospheric composition data as "GAW data"?
- Where and how do you discover and obtain these data?
- Are you satisfied with the products/services that are provided by GAWSIS and the WDCs? If not, how can they be improved and what is missing?
- What is / should be the role and added value of "one-stop shops"? What products/services should be delivered this way?
- How can consistency of data across different repositories and over time be ensured?
- What is / should be the role of operational forecasting centres in atmospheric composition data management?
- What is / should be the role of the private sector in delivering environmental data and services?
- Do you support the “anonymous and fair use” data policy of GAW? Do you see a need to change it?

Jörg Klausen introduced the topic and noted that the amount of GAW and partner programme data is growing rapidly. The WIGOS metadata standard, approved at WMO Cg-17 in 2015, and its related schema can transcend GAW use. Further, data providers wish to be relieved from having to deal with the underlying complexity of data systems. Participants were interested in how users currently discover and obtain data and whether a one-stop “shop” or portal would be useful. The role of the private sector in providing these data and interacting with GAW was also addressed. Issues relating to the free and open use of GAW data, as articulated in its data policy, were also discussed.

SUMMARY OF PRESENTATIONS

Global chemistry-climate modelling use and needs of observations
By Paul Young, Lancaster University

Model developers are typically interested in any data that is appropriate and representative for the purpose under investigation (from multiple sources including satellites, aircraft, balloon,
and in situ). While basic model/data comparisons use monthly or annual data, there is increasing interest in examining extremes, using higher-resolution data, at hourly time scales. Event-based metrics, species-species correlations, and fluxes are also of interest. There is a desire to get closer to process understanding, getting the model “right” for the right reasons. “Data science methods” are being used to explore why different models behave in different ways. One method is to develop an emulator, essentially a model of one’s model, which is constructed from a number of sensitivity simulations. One can explore the full model space using the emulator, allowing the researcher to figure out what processes are most important for a particular phenomenon. These emulators, together with observations, can constrain the models. “One-stop shops” could be valuable to the modelling community, particularly if data formats allow for easy reading and coding.

Agriculture, energy, and air quality perspective in climate change
By Jun Wang, University of Iowa

In agricultural research, rapidly growing population coupled with linear crop yield growth points to significant concerns. Air quality has a significant impact on agriculture. For example, surface ozone can reduce crop yields. UV radiation also has significant impacts on crop yield. USDA has only ~30 stations measuring surface UVB. But, these levels can also be derived by satellite measurements, e.g. from OMI. There is good correlation between the OMI values and surface networks. Agricultural processes can also be a source of reactive gases. High temperatures can have impacts on soil emissions. Agriculture is a source for dust and smoke particles, especially in drought years. Aerosols deposited on solar panels can cause significant power generation reductions. There is a need for two-way interaction between the data providers and user communities. There is also a clear need to measure emissions from the agricultural sector and a need to integrate GAW data with models to provide end-user services. There is a need to deliver both weather and composition data simultaneously in this era of citizen science and big data.

Data requirements for aerosol observations
By Judd Welton, NASA

Defining data requirements for a large number of aerosol measurement variables is not an easy task. LIDARs are able to contribute measurements of aerosol variables. Layer detection often depends on more than backscatter and extinction profiles. The GAW Aerosol Lidar Observations Network (GALION) is composed of multiple networks that have their own mature data centres. These data centres provide many functions beyond data archiving. A unified portal would be worthwhile and GALION is working on this. The harmonization of QC/QA flags and metadata across individual centres is in process.
Atmospheric composition data, from the African perspective
By Constance Okuku, Kenya Meteorological Department

There are large areas in Africa lacking GAW data, but the demand for atmospheric and environmental data is escalating rapidly. Topics of significant interest include extreme weather and climate phenomena, air pollution and health issues, impacts on agricultural production. Some African countries have started making measurements of critical composition values, like CO, CO$_2$, O$_3$, CH$_4$, and particulate matter. Uses include weather/climate prediction and policy decision-making. African countries need to be more proactive in increasing data provision. More training of scientists and operators is needed.

Short interventions

Agustin Garcia-Reynoso (Universidad Nacional Autónoma de México) made a short intervention noting that air quality time series are needed. Some satellite data are being used. The consistency of data across multiple repositories needs to be ensured.

Wenche Aas (NILU) asked whether end users cared about the “GAW” branding of data. She suggested that users often do not care, but the data providers may desire this labelling. She also noted that data usage statistics are poorly known and that there’s a need to improve this knowledge. Digital object identifiers (DOIs) are increasingly used for tracking data usage and for referencing in publications, and it was noted that their use is important. Ideally, in the future, all data repositories should export data in the same formats, this may be an insurmountable challenge.

SUMMARY OF THE DISCUSSION AND RECOMMENDATIONS

What kind of chemical composition data do you work with?

The answers were diverse and reflected the interests and expertise of the discussants. A few general observations are that modellers take a wider variety of measurements, but prefer to use quality-assured data to not introduce biases in the model results. Measurement uncertainty and its documentation should be a key element in WIGOS. There was strong agreement that QA of observations was vital.

Do you generally think of atmospheric composition data as "GAW data"?

There was some concern that GAW shouldn’t force branding. It’s an important label for providers (more than users) to sell the observations to funding agencies. It was noted that some private sector entities see the GAW label as a “gold standard”. However, some communities, like those interested in optical aerosol variables, do not yet see GAW as a recognizable brand. There was a suggestion that GAW branding could be an effective means of improving stakeholder awareness of data availability and raising overall data visibility.
Where and how do you discover and obtain these data?

The consensus is that data are being discovered everywhere. But, there is a critical need for consistent metadata. Young users need more guidance on where to find data.

Are you satisfied with the products/services that are provided by GAWSIS and the WDCs? If not, how can they be improved and what is missing?

For some communities, e.g. lidar data, the community is not satisfied with data provision (although this is not specifically with respect to GAWSIS). Surface ozone data (from TOAR) were sometimes difficult to ingest. Metadata consistency and data continuity were noted as concerns.

What is / should be the role and added value of "one-stop shops"? What products/services should be delivered this way?

The one-stop shop concept could be very helpful to new users, but many obstacles were noted. Some communities, like modellers, would like higher level data products (e.g. level 4) and forecasts, which could dramatically increase the scope of what is intended to be provided. The role of satellite data was discussed; it is highly dispersed, but it should at least be discoverable. Amazon.com was mentioned as a role model involving user feedback and dispersed products (marketplace).

How can consistency of data across different repositories and over time be ensured?

The issue of long-term funding was noted as important in ensuring consistency. Metadata consistency, QA/QC approaches, and DOIs, all discussed previously, were considered significant to this question. The issue of assuring consistency if one goes from time series to gridded data products was noted.

What is / should be the role of operational forecasting centres in atmospheric composition data management?

There was agreement that the operational centres have significant resources to contribute to data management. The operational centres can have major impact on the use of new data sources. Forecasts are in some instances providing useful feedback to data providers by flagging potentially poor data. For satellite data, this process is automated, but there would be considerable effort required to replicate this feedback process for non-satellite data sources. GAW could benefit from the enhanced role of operational forecasting/met offices (e.g. CAMS) in data management activities.
What is / should be the role of the private sector in delivering environmental data and services?

The private sector could be important at certain scales, particularly urban and local where coverage is otherwise lacking. There was concern about the sector’s uncertain long-term commitment to data provision. IG³IS plans working with the private sector as potential user and in some specific cases as a provider of observations for the services required by this user. GAW cannot dictate needs to the private sector and should rather respond to its requirements.

Do you support the “anonymous and fair use” data policy of GAW? Do you see a need to change it?

In general, participants supported the current data policy, but noted that it may raise some barriers to provision of private sector data. While user registration and the collection of statistics was considered potentially worthwhile, this raises significant issues in the US for privacy reasons. The GAW policy may not work well for larger data products. Other licensing concepts might be explored for these larger datasets.

The following key priorities were identified from the discussions:

- Establish interoperability between data centres and GAWSIS (WDCs, contributing data centres) for metadata and data.
- Consider expansion of a federated system to address the needs of user communities for improved support of applications/services. This will require enhanced engagement of user communities.
9. OUTREACH AND CAPACITY BUILDING

The moderators of this final breakout session of the Symposium were Melita Keywood (CSIRO) and Paul Monks (University of Leicester). The rapporteurs were Sam Cleland (Australian Bureau of Meteorology) and Silvina Carou (WMO Secretariat). The objective of the breakout session was to find ways to improve GAW’s communication and capacity development efforts. The session consisted of four invited talks and one short intervention. A cafe style discussion with participants rotating among three discussion groups followed the presentations. The groups and questions discussed were as follows:

Group 1 – Outreach
- Is the value of GAW effectively communicated?
- How does GAW communicate with partners? Is this effective? Can it be improved?

Group 2 – Outreach
- What are some innovative ways GAW’s value can be communicated?
- What are innovative ways to motivate the scientific community (from GAW as well as partner organizations) to be an active participant in GAW communication activities?

Group 3 – Capacity Building
- How can GAW’s capacity development programme be improved to ensure that the community is better equipped to apply research and observations that provide more relevant information and services to society?

SUMMARY OF PRESENTATIONS

Utilizing mass media to apply our science
By Craig Sinclair (Cancer Council Victoria)

Mass media can be utilized to apply the science. One needs to think about how to communicate data and educate in order to motivate and influence the broader population toward a health behaviour change and ultimate health gain. Changing population-level attitudes and behaviours involves two components: reach and impact. Impact is more likely when you maintain high population exposure over time and through multiple channels. Be wary and aware of alternate messages that can lessen impact, e.g. product advertising contradicting health message. It is important to complement concurrent changes in policy and available health services. In the case of protection from UV, there is the internationally standardized UV Index. Australia also launched a “SunSmart” UV Alert to view UV forecasts at locations around the country and created a SunSmart App that clearly communicates the times sun protection is required and a SunSmart widget that can be taken up by other organizations/institutions and shown on their websites and is already embedded in >3,600 websites. The App and widget statistics provide a metric for effectiveness of advertising through unpaid and paid promotion including magazines, online mobile advertising,
conferences, radio and print, etc. The key message is that mass media works like a spring to combat persistently unhealthy population habits.

**Building capacity and getting the message across - some thoughts**
By Fiona Tummon (SPARC)

Capacity building within SPARC is a continuous activity that has been more focused since 2014. It involved establishing goals, identifying gaps based on existing activities and surveying of needs. This exercise culminated in a 2-day workshop leading to an implementation plan. Risk analysis and monitoring and evaluation are part of the effort. SPARC’s capacity development strategy is available on their website [http://www.sparc-climate.org/publications/implementation-plans/](http://www.sparc-climate.org/publications/implementation-plans/). Capacity development requires the right people to put in time and effort and to develop a culture of capacity building. It is important to recognize there is a limit to individual's capacity for capacity building therefore identify realistic targets and activities. It is preferred to draw on motivated volunteers and leverage funding from outside sources. SPARC capacity development consists of regional working groups, training schools and early career researchers (Young Earth System Scientists network). A suggestion is for GAW to get more involved with early career scientists. Some ideas for GAW are a mentor/mentee programme, a “Get Involved” page on the GAW website providing information that empowers interested researchers, extend twinning where possible, online seminars, use of new technologies, an expert database, and a working group that focuses on capacity building that meets (virtually) regularly. In terms of communication, it is difficult to get the message right. There is a multitude of levels and types of communication and these need to be tailored to each audience. One has to think about the target audience, and what information they need and how often, and how to get those communities to identify with GAW and get involved.

**Capacity building in GAW by the example of GAWTEC**
By Mirella Glor (German Environment Agency)

The GAW Training and Education Centre (GAWTEC) is an example of capacity building in GAW. Education and training activities for GAW station personnel is an integral part of GAW. Training is recognized as critical. Since the first GAWTEC course in 2001, there have been 31 courses and 352 participants from 63 countries with 42% women. The objectives are to train on the broad aspect of measurement requirements in order to improve participants’ skills in chemistry, physics, meteorology, etc. to exchange measurement related experiences, to increase their ability to interpret data and to identify measurement errors in order to improve data quality. Application to the courses is via the GAWTEC web page. There are no costs for participants. Their living and travel expenses are paid for by the German government and WMO and lecturers are funded by their own organization. In terms of outreach, feedback from participants is requested at the end of the course. One outcome of GAWTEC is that participants build contacts with experts in the field. Some outreach ideas for the future could include the use of social media, a GAWTEC newsletter, use of video courses, etc. but these can be time intensive.
How does the GAW Programme contribute to capacity development in Indonesia and can it be improved?
By Melita Keywood on behalf of Komariah Kokom (Universitas Sebelas Maret)

The Indonesian GAW Station Bukit Kototabang is located in a mountain-tropical forest zone in West Sumatra and has been operating since 2004. The station is supported by the Indonesian National Agency for Climatology, Meteorology and Geophysics. Capacity development at the station includes atmospheric data provision via publications, training for staff, student internships, periodic data reporting to government and receiving visitors to socialize services. An example of a service connected to policy is related to forest fires and impacts to health from the smoke. GAW Kototabang intensively monitors air quality and the Department of Education is alerted to manage student activities when air quality is very bad. Industry and vehicle growth are also a big problem for air quality in Indonesia. Data from GAW Kototobang are reported to the government who then issues annual rules on GHG emissions for industries and vehicles. Indonesia is a large and climatologically/geographically disparate country. Two new GAW stations were recently opened in the east part of the country but more stations are required. Information distribution to the public is poor. The use of social media would be an effective way to widely disseminate information.

Short interventions

Norazura Binti Zakaria (Malaysian Meteorological Department) conveyed the message that Malaysia is lacking some of the atmospheric expertise required and would benefit from expert guidance and training on measuring techniques and data handling.

A number of comments were made following the presentations. The point was raised that the important part of capacity building is the concept of mutual obligation, in that those that receive the assistance and training need to take what they learned on board and use it to build capacity. Helping people to develop the right ecosystem sometimes takes time and requires long-term development rather than "fly-in fly-out" training. It was suggested that existing training (e.g. GAWTEC) needs to be complemented with new ways of learning and training not just on instruments but also on data handling, how to turn data into information, and how to distribute the information. Providing mentoring could also be effective. The problem of people who have been trained moving on to other jobs will always be a reality and this should be taken into consideration. Also, perhaps broader education (e.g. school-age children) could be contemplated.

With regards to communication, it requires large resources and it is important to not over reach.

WMO’s communication office is an available resource (e.g. produced a short animation on carbon and a video on sand and dust storms). The scientific community has to take responsibility for dissemination and requires people who are keen on doing so. Using social
media can be challenging and little training seems to be available. WMO has a social media strategy and GAW is encouraged to work with the communications staff implementing it.

SUMMARY OF THE DISCUSSIONS AND RECOMMENDATIONS

Outreach

Participants were asked to convey in three words the value of GAW for them. The most used descriptor was “quality” followed by “collaboration” and “reliable”. Figure 6 shows all words used to describe GAW with the frequency of their use depicted by the size of the font.

Despite the high regard of participants for the programme, the common message is that GAW visibility is insufficient. The importance of long-term observations, the degree to which they are used (e.g. by partner organizations), and the benefit needs to be better communicated in order to increase data usage as well as funding. To influence one has to not just communicate but educate so as to empower people, and to have both reach and impact. Multi-pronged outreach activities add value and repeat/complimentary messages reinforce learning. We need to show off our achievements and highlight that our work is accepted to the highest level. There is also a real opportunity for GAW to sell the beauty of the programme (i.e. scenic station locations) and the people behind it through pictures of stations and the people who run
the stations. Videos, blogs, conference booths are examples of good vectors for this. Care is needed not to aim higher than resources realistically allow in order to avoid burning people out.

The following recommendations on how to improve outreach in innovative ways were made:

- Find ways to activate the GAW community to communicate the science as much as possible, while continuing to use the GAW Secretariat to handle central communication.
- Communication should be timely, with a single and simple message at a time, and frequent.
- Focus on communicating the impact of GAW.
- Improve visibility via more effective communication of the importance of long-term observations.
- Invest in high-level infographics (i.e. outsource to graphic designers), including graphics that convey the value and impact of GAW.
- Craft an "About GAW" statement (with emphasis on benefit/impact to society) and append it to most communications to external parties.
- Produce a standard slide pack for participants to use internally and externally.
- Leverage available professional communication capabilities to effectively use new media platforms, e.g. youtube videos, social media.
- Investigate the generation of widgets, such a "latest CO2" widget, with GAW branding, that could be taken up by other institutions/companies/groups/etc. that they can embed into their own web pages.
- Improve outreach to graduate students by ensuring they receive newsletters and reports.
- Continually review distribution lists for GAW info products.

**Capacity building**

One issue related to training may be poor uptake. One avenue for resolution is to better instill a sense of mutual obligation whereby the trainee takes responsibility for taking what they learned and applying it toward building capacity at their station or in their country. An aspect of mutual obligation should be mentor/mentee relationships and follow up. Another avenue is to tailor training to change the embedded "ecosystem" of an organization in order to encourage high quality long-term observations. Another weakness of GAW is that the data produced in a region are not always used within the region. This could be improved with better collaboration between the met services and universities, which is essential to foster research. Finally, it was suggested based on the experience of SPARC that a working group focused on improving capacity building within the programme that meets (virtually) regularly may be highly valuable.
The following recommendations on how to improve capacity building in GAW were made:

- Develop/participate in graduate programmes on atmospheric composition research that use GAW observations (e.g. GAW PhD scholarship programme).
- Understand what other training programmes are available and reach out to them, e.g. ACAM, summer schools etc.
- Work toward end-to-end training – from obtaining data through to analysis and products.
- WMO should strongly encourage meteorological agencies to ensure that there is sufficient overlap time for training when trained personnel decide to move to another job, and to focus more on mutual obligation within mentor-mentee relationships.
- Enhance twinning efforts and extend them to partners, and enhance the link between developed and developing countries. A mentoring role should include helping to make the measurements, submitting data, etc.
10. **WAY FORWARD**

In summary, the following activities were recommended during the discussion as priorities for GAW:

- Communicating a convincing and compelling story.
- GAW acting as a global integrator to provide better direction for groups that seek funding.
- GAW acting as a facilitator of cooperation, including in the context of improving the observational network (e.g. over Africa).
- Addressing regional scale needs addressing all areas of atmospheric composition – GHG, aerosols, etc. – more integrated approach is needed.
- Involvement at the urban scale requires combinations of different approaches: low-cost sensors, local stations, remote sensing, modelling, cooperation, etc.
- SAGs must to be agile and to adapt to a changing world, rather than keep focus on observations only.
- Increasing cooperation within the UN family is required, especially with WHO, UN Environment, and other relevant agencies that have related mandates.
- Increasing visibility of GAW in policy related bodies (IPCC, UNFCCC) is strongly required.
- There is a need to taking a critical look at the observational requirements for stratospheric ozone.
- Enhancing the link between climate and air quality – black carbon and other SLCPs is strongly required.

The GAW Symposium was closed by Deon Terblanche, Co-Director of the Research Department, at noon on 13 April 2017.
PART II - REPORT OF THE 4TH SESSION OF THE CAS ENVIRONMENTAL POLLUTION AND ATMOSPHERIC CHEMISTRY SCIENTIFIC STEERING COMMITTEE (EPAC SSC)

1. ADOPTION OF THE AGENDA, GOALS AND UPDATES

The Fourth Session of the CAS Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee (EPAC SSC) was held at the World Meteorological Organization (WMO) on 13 April 2017 from 1 p.m. to 5 p.m. in Geneva, Switzerland. Gregory Carmichael, Chairperson of the EPAC SSC chaired the meeting. He explained that this was a short SSC session and its main objective was to take the most critical decisions and reflect on the priority activities including cross-cutting topics for 2017 and beyond considering the outcomes of the GAW Symposium. A short welcome address was given by Deon Terblanche, Director of the Atmospheric Research and Environment Branch and Co-Director of the Research Department.

Gregory Carmichael explained to the participants the scope of activities of the meeting and asked them to propose additional agenda items. No new items were proposed and the agenda was approved (see Annex IV).

This face-to-face meeting was followed up by the two dedicated teleconferences in summer 2017 and this report reflects on both the face-to-face and remote parts of the meeting. The face-to-face meeting was attended by the members of SSC, Chairpersons of the SAGs or their representatives.
2. REVIEW OF THE PROGRESS ON ACTION ITEMS FROM THE 3RD SSC MEETING

Gregory Carmichael went through the Action Items identified at the previous SSC meeting. The summary of the progress and connections with the Action Items from the previous SSC meetings is presented in the table below.

<table>
<thead>
<tr>
<th>Action item</th>
<th>Content</th>
<th>Responsible</th>
<th>Deadline</th>
<th>Connection with the AI from the previous meetings</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>AI-1.3</td>
<td>Develop a strategy on Reactive Nitrogen (EPAC SSC).</td>
<td>EPAC SSC</td>
<td></td>
<td>In progress, attended Reactive Nitrogen planning meeting, discussed at GAW 2017 Symposium. Need to assign SAG TAD/App/RG responsible.</td>
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<tr>
<td>AI-2.3</td>
<td>Establish a joint planning committee (WHO/UNEP/WMO) for the next Global Burden of Disease workshop planned for early 2017.</td>
<td>Alexander Baklanov and Greg Carmichael</td>
<td>20 April 2016</td>
<td>In progress, worked together on the 3rd meeting held in Madrid in March 2017, follow-up activities related to modelling are through a project with App-SAG.</td>
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<tr>
<td>AI-3.3</td>
<td>Plan a Workshop on low-costs sensors together with UNEP and WHO.</td>
<td>Valentin Foltescu and Paolo Laj</td>
<td>April 2018</td>
<td>In progress, writing group has been established (July 2017) with the goal of producing a guidance document for EC in April 2018.</td>
<td></td>
</tr>
<tr>
<td>AI-4.3</td>
<td>Work on UNEP/WHO/GAW joint data coordination, perhaps starting with a request to member nations for Air Quality observations and data submission, and also explore use of GAWSIS as a front end.</td>
<td>Valentin Foltescu and Jörg Klausen</td>
<td>End of 2016</td>
<td>No action, Jörg participated in EPA/WB/UNEnv workshop on filling the gaps (July 2017). Jörg will participate in meeting report which will contain items related to data coordination.</td>
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<td>AI-5.3</td>
<td>EPAC SSC to work with GAW Secretariat to develop concepts and business models for resource mobilization in the form of one-pagers highlighting GAW needs aligned with the Implementation Plan, such</td>
<td>EPAC SSC and GAW Secretariat</td>
<td>End of 2016</td>
<td>Related to AI-28.3</td>
<td>In progress, resource mobilization was a topic of discussion at the GAW 2017 Symposium. Resource proposals have been developed</td>
</tr>
<tr>
<td>AI-6.3</td>
<td>Develop an initial strategy about source attribution and top down constraints of emissions and the role for GAW. This is a possible topic for SAG-Apps and the 2017 GAW Symposium.</td>
<td>EPAC SSC and Greg Carmichael</td>
<td>End of 2016</td>
<td>In progress, this topic is a priority area identified by SAG-App, workshop planned for 2018.</td>
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<tr>
<td>AI-8.3</td>
<td>Build a better relation and better communications with GCOS. Summarize a document to give to Jim Butler, as CAS-representative on AOPC, w.r.t. to GAW needs of using GAW data in official documents.</td>
<td>Oksana Tarasova and Greg Carmichael</td>
<td>24 May 2016</td>
<td>In progress, Greg was added as a member to the GCOS AOPC. He attended the first meeting and is working with Jim Butler to help define observation requirements for the AOPC strategic plan, making them consistent with the requirements that GAW is producing for WIGOS.</td>
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<tr>
<td>AI-10.3</td>
<td>Update the expertise of persons on EPAC SSC, SAGs and ETs to provide the list of expertise of the current members and place on the web.</td>
<td>GAW Secretariat, EPAC SSC and Greg Carmichael</td>
<td>1 July 2016</td>
<td>Related to AI-3.2</td>
<td>Need to follow-up.</td>
</tr>
<tr>
<td>AI-11.3</td>
<td>For further progress of the GAW Rolling Review of Requirements there is a need to compile requirements and devise a way to transfer/populate OSCAR. There is a process that needs to be followed. There is also need to draft documents.</td>
<td>Greg Carmichael</td>
<td>1 May 2016</td>
<td>Related to AI-1.1</td>
<td>Progress has been made, need to get into OSCAR database. Need to find a new Chairperson for this activity to replace Greg.</td>
</tr>
<tr>
<td>AI-13.3</td>
<td>Communicate to appropriate SAGs that GESAMP papers and reports are not making use of GAW data due to lack of data over oceans. Data on iron and phosphorus are needed. Request SAGs (SAG-TAD, SAG Aerosol) to take this into consideration. Datasets from cruises should be made available via GAW Secretariat and EPAC SSC</td>
<td></td>
<td>15 May 2016</td>
<td>Have made contact with GESAMP and they have requested help in hosting their ocean datasets. This is a good opportunity to use their data and to build concrete collaborations. Started</td>
<td></td>
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<td>AI-14.3</td>
<td>Ensure that isotope standards are adequately included in GAW QA/QC.</td>
<td>GAW Secretariat</td>
<td>1 July 2016</td>
<td>No progress made</td>
<td></td>
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<tr>
<td>AI-15.3</td>
<td>Develop a strategy to further engage Young Scientist into GAW, such as ways to formalize networking of those we support, leverage summer school opportunities, working closely with WWRP and WCRP. Also consider adding a Young Scientist representative to EPAC SSC.</td>
<td>GAW Secretariat and EPAC SSC</td>
<td>1 July 2016</td>
<td>In progress, this will be a topic of the CAS-17.</td>
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<tr>
<td>AI-16.3</td>
<td>Enhance GAW Communications by developing: i. Communications around the Anniversary of Cape Grim ii. Develop a story entitled: Around the world with 30 GAW global stations. The aim is to highlight important science and key persons iii. A 4-pager annual report highlighting GAW data and news of atmospheric composition. iv. Develop a document targeting PRs, focused on their importance and need for them to help.</td>
<td>i. Melita Keywood ii. Paul Monks iii. Melita Keywood iv. EPAC SSC</td>
<td>Related to AI-22.2 (i), AI-7.1, AI-23.2 (iii)</td>
<td>In progress ... Melita has worked on this, it was a topic of the GAW Symposium 2017. No progress was made on the publications.</td>
<td></td>
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<tr>
<td>AI-24.3</td>
<td>Discuss deposition of Radiation Data Centre at CAS Management Group meeting.</td>
<td>Greg Carmichael and GAW Secretariat</td>
<td>1 June 2016</td>
<td>Discussed, need to find a new home for this.</td>
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<tr>
<td>AI-25.3</td>
<td>Continue efforts on water vapour, review what’s in OSCAR (expert team), and identify where its home will be in GAW.</td>
<td>EPAC SSC and Geir Brathen</td>
<td>Related to AI-17.2</td>
<td>In progress, have had discussions for example with GRUAN. To date having problems getting agreement between GCOS and GAW.</td>
<td></td>
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<tr>
<td>AI-26.3</td>
<td>Explore concept and establish assignments of EPAC SSC members (e.g. w.r.t. cross-cutting activities which could be assigned to EPAC SSC members).</td>
<td>Greg Carmichael</td>
<td>Related to AI-18.1</td>
<td>In progress.</td>
<td></td>
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</table>
3. UPDATES ON THE IMPLEMENTATION OF THE GAW IP

An initial effort was made to establish an IG$^3$IS Steering Group that would supervise the activities of the IG$^3$IS Science Team. The Steering Group is chaired by Paul Monks. The group had an initial teleconference but did not get actively involved in the work of IG$^3$IS Science Team. The scope of the Steering Group was discussed and it needs revision.

There was a short report on the resource mobilization strategy presented by Kobus Pienaar. He also reflected on the results of the dedicated brainstorming on resource mobilization that was organized during the GAW Symposium. He stressed that to have the involvement of the funding bodies we need to inform the stakeholders about the value of GAW. There is a challenge to propagate GAW achievements through the Permanent Representatives as many of the NMHSs do not have atmospheric composition in their scope, at the same time it is believed that NMHSs would feel proud about the national contribution to the GAW Programme. Another idea is to clearly demonstrate the impact of the information on atmospheric composition change and atmospheric monitoring to decision-making process. As the long-term funding must come from governments, GAW will need to reach out to them. The harmonized and efficient resource mobilization strategy still has to be developed.

Melita Keywood presented updates on the implementation of the outreach strategy. She emphasized that the ways of communication were discussed in detail at the GAW Symposium and the corresponding recommendations were made. The meeting participants noted that GAW should tell a compelling story. Many found the GAW web site old fashioned and not very attractive. At the same time information distributed through the electronic newsletter also demonstrates low uptake with only 20% of e-Zine being opened.

Greg Carmichael presented to the group the outcomes of the GAW Symposium and how they are related to the action items in the GAW Implementation Plan. He highlighted that some of the discussions are not well captured in the current version of the plan and they should be included in the mid-term review and revised version of the plan (to be produced by 2020).

The discussion followed by the reflections of the SAG Chairpersons or the SAG representatives on their activities and on the relevance of the GAW Symposium discussions to the SAG activities.

Martin Schultz presented the activities of the SAG Reactive Gases. He highlighted the activities related to the nitrogen cycle as one of the priority activities for SAG and he appreciated the organization of the dedicated side event at the GAW Symposium. To foster nitrogen cycle research the SAG decided to include ammonia as an additional variable in the SAG activity. Tropospheric ozone data assessment will be produced for the inclusion in IPCC report through TOAR (Tropospheric Ozone Assessment Report) activity, where GAW is involved.
Veronique Bouchet presented the work of GURME. She highlighted the discussion at the GAW Symposium on the modelling activities in GAW and the need to connect different scales (global to urban) and develop the common performance matrices. She also stressed that the urban agenda becomes very important for the Member countries. She emphasized that cooperation with SAG-App and the World Weather Research Programme (WWRP) must be enhanced. To make further progress she called for the creation of the joint activity where several teams are involved (e.g. in South Africa) and enhance the cooperation. She further stressed that urban activities are poorly supported by observations, so far no "local stations" were established, though they play a critical role in linking different scales. She articulated the need for the engagement with the data flows from the potential contributors and have them register in GAWSIS, submit data and make them available. SAG planned to contribute to the work of the cross-cutting urban task team and several members have been proposed to be involved. Ms Bouchet further anticipated that the SAG start looking at the different aspects of urban environment, such as health. There are some projects that currently work only on urban meteorology, GURME can start partnering with these projects. There is a need to form task teams to involve a broader community.

Oksana Tarasova confirmed that the task teams on the specific aspects could be formed and dissolved if their work can be done by telecons. Additional financial constraints on the physical meetings of such teams are difficult to include in the limited GAW budget.

Jörg Klausen reported the activities of the Expert Team on World Data Centres. He highlighted that ET-WDC is linked to the thematic SAGs but this connection works only one way. ET-WDC members participate in the SAG meetings, but do not always provide feedback on the outcomes back to ET-WDC. ET-WDC was working on the implementation of the WIGOS GAWSIS-OSCAR project and had interaction with the Task Team on Atmospheric Composition Vocabulary.

Paolo Laj updated the meeting on the recent activities of the SAG Aerosol. He mentioned that the SAG works closely with Betsy Andrews from NOAA and the AEROCOM community and promotes the link between observational and modelling communities working on aerosol optical properties. He highlighted that to be eligible for the next IPCC report, one has to go through the obs4MIP process, requiring a reference paper which SAG is planning to develop. He also articulated the need to add SAG members to represent the modelling community.

Alex Vermeulen reported on the recent activities of SAG on Greenhouse Gases. He discussed the connection of SAG activities with IG³IS, collaborations with the Integrated Carbon Observing System and the work within SAG dedicated to the conversion of the GHG Bulletin into a peer reviewed paper.

Activities of the SAG Ozone were presented by German Smith and activities of the SAG-UV were presented by Craig Sinclair. Both SAGs so far have been focused on observations and Quality Assurance issues.
The presentations by the thematic SAGs were followed by the discussions on the potential merge between SAGs ozone and UV. The reaction of the community on such a request was rather controversial. SAG-UV articulated its intentions to move towards health applications, while SAG-O3 desired to continue with the observational activity and data utilization for the support of the joint work with UNEP within the Vienna convention. The only common element between the two SAGs is the data centre. SSC nevertheless recommended to look again at the mandate of the SAG and develop common terms of reference and activities between these two groups.

Another aspect which was discussed after the SAGs’ presentations was the need for a better approach to training. In particular, SAG-RG and Aerosol articulated the need for the combined training as well as the need for the inclusion of the data centres in the training programme. There should be efforts made to improve a connection between GAW observing system and WIGOS and related training should be included in the programme. Training could be linked to low-cost sensors activities as well as there is an increasing amount of data coming from non-traditional data sources (e.g. coming from private sector and crowd data).

It was noted that SAGs are not always aware of the activities of each other which makes it difficult to establish cross-SAG activities. SSC recommended that a SAG meeting report should be shared on a mandatory basis.
4. NEW ACTIONS REQUIRING SSC ATTENTION

SAGs brought to the attention of SSC several issues that would require discussions, decisions or endorsements. The question was raised on the need for the dedicated SAG or Working Group on socio-economics or on impacts. Such groups exist in the WWRP and it has been proved to be very useful in articulating the value of the programme. SSC did not reach the conclusion on this topic but took note of it in a view of the mid-term programme review.

Martin Schultz requested SSC to approve the rotation of the members in the SAG-RG. SSC approved the following new members: Isobel Simpson, Paul Young, David Simpson, Aijun Ding. He also informed that SAG-RG keeps the pool of “affiliated” members, those who are the past members or interested individuals who would like to contribute.

Jörg Klausen stressed that there are very few "real" members in the expert team as it consists of the data centre managers. He proposed SSC to add new members: Oystein Godoy, Sandy Starkweather, Martin Schultz and Judd Welton. SSC agreed with this proposal. It was also recommended that ET-WDC engage ICOS for the sharing of the experience on "open link data".

Veronique Bouchet proposed to add Ranjeet Sokhi to the SAG and to appoint Luisa Molina as a SAG Co-Chairperson. SSC agreed with this proposal. SSC also encouraged other SAGs to consider appointing Co-Chairpersons to better distribute the workload in the SAGs.

Herman Smith noted that there is a need to update the membership of SAG on Ozone to include Irina Pertopavlovskih, and SSC requested to make a formal nomination from the SAG Chairperson.

The meeting proceeded to the discussion of the GAW brand. The participants noted that the programme has a misleading name (Watch in a sense focuses on observations). The meeting did not reach a conclusion on this topic.

The meeting also discussed that in the future a decision is required if SAG discuss the parameters, the focal areas or the research directions. It was also recommended that SAG better focus on science questions while the quality assurance should be done by the group consisting of central facilities and led by QA/SACs. This work share should be planned in the evolution of the GAW Programme.

The meeting continued with addressing the technical issues of the GAW implementation. There was some discussion about the responsibility for the coordination of CO observations and research. Currently, the molecule is assigned to the SAG-RG because of its chemical properties, though it is usually measured in the same suite as the major greenhouse gases. SSC decided to more the responsibility for CO from SAG-RG to SAG-GHG.
Another molecule of the interest is water vapour. So far very limited progress was made on incorporating water vapour in GAW activities. An initial discussion has taken place with GRUAN and an agreement was reached to improve collaboration. At the same time, SSC was under the impression that GRUAN is trying to develop its “own measurement guidelines” for the measurements of ozone vertical distribution which may create an offset for the whole network. SSC requested SAG Ozone and WMO Secretariat to have a discussion with GRUAN to verify how their intention fits into GAW practices.

The meeting further discussed the advances made with the implementations of the federated data management. Alex Vermeulen described how the open link data works in ICOS. As the data architecture in ICOS could be useful for GAW, Jörg Klausen suggested to invite ICOS as a contributing network. Such plans are being developed and the work is in progress to submit the application to SSC. Paolo Laj objected to this proposal. He stressed that ACTRIS (which is similar to ICOS research infrastructure, but focused on aerosols and reactive gases) is seen as a European component of GAW, so to him it was unclear why ICOS should be treated as a contributing network. Alternatively, Martin Schultz suggested to think of "thematic" or "regional" networks. Paolo Laj noted that ACTRIS develops a concept for sustainable long-term funding and global community has benefits of this as ACTRIS supports several GAW Central Facilities. SSC decided that upon reception of the ICOS proposal it will be accepted as a contributing network and observational data will stay in ICOS data centre.

The meeting had an extensive discussion in the role of the contributing networks and how they should be managed in GAW. The proposal was made to approach the research infrastructures and involve them in the work of GAW. The particular issues with the contributing networks is lacking financial stability, though this issue is better addressed by the research infrastructures. Several SSC members noted that the term “contributing networks” is rather discouraging and prevents the two-way collaboration with the networks, the proposal was made to change the name to “thematic”, “collaborating” or “regional” networks. Jörg Klausen objected to that proposal indicating that there are already too many categories of stations accepted in GAW and that there are specific requirements that apply to the contributing networks including internal data consistency and developed QA/QC procedures. This was reconfirmed by Oksana Tarasova, who referred the meeting to the provisions of the GAW Implementation Plan. Martin Schultz proposed to revise the requirements in the GAW Implementation Plan by substituting “stations should submit” by “ensure data is submitted”. In that case a central entity can take over submission.

SAG Chairpersons identified IG3IS as a cross-SAG activity and expressed their intentions to get involved and support its implementation.
5. SETTING PRIORITIES FOR 2017

SSC discussed the priority activities for the GAW Programme to be undertaken in 2017.

The work on the low-cost sensor was clearly articulated as a priority activity. SSC requested the Secretariat to consider the organization of the dedicated workshop as soon as possible where the presentations of the groups working on this technology (similar to Empa) can be shared. It was also requested that the position paper or statement is prepared for the next session of WMO Executive Council. SSC also recommended to get CIMO involved. It also requested the Secretariat to create a dedicated web page where the experience of the community can be shared. The discussions on the low-cost sensors should be carried out in the context of the GAW Data Quality Objectives and the Rolling Review of Requirements process.

There was a very short discussion on the cooperation with WHO on the global health platform. Several members of the community are already involved including Greg Carmichael and several members of SAG-App. This involvement will be continued.

SSC agreed that resource mobilization strategy in GAW should be re-enforced and additional efforts are required both from the Secretariat and GAW steering bodies to ensure the programme sustainability.

Unfortunately, there was not enough time to address the other aspects under this agenda item.
6. INTERNAL SSC BUSINESS

SSC discussed the organization of work within SSC and its membership. SSC noted that the current membership of five members and a Chairperson is not enough to cover the diverse aspects of the GAW Programme. Several members of SSC have an extremely high workload and can only dedicate very limited time to the GAW leadership. Potential candidates were discussed who could bring energy and “free hands” to support the GAW implementation. It was also noted that a quarterly call with SSC and SAG/ET Chairpersons would help to run the programme more smoothly.

The meeting finished with the summary of the decisions and action items which are listed in Annexes V and VI.

Gregory Carmichael invited participants for the final reflections and closed the meeting at 5 p.m. on 13 April 2017.
# Participant list

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GLOBAL ATMOSPHERE WATCH SYMPOSIUM
Geneva, Switzerland, 10-13 April 2017

Agenda

Monday 10 April 2017

8:00-9:00 - Registration and posters set up

9:00-9:15 – Welcome (Petteri Taalas, WMO Secretary-General)

9:15-9:25 – Logistical note (Oksana Tarasova)

9:25-12:00 - Introduction session: Round-table with SSC and SAG/ET Chairpersons

(Moderator - Deon Terblanche; Rapporteur - Ranjeet Sokhi)

- Greg Carmichael (SSC, IP intro)
- Craig Sinclair - UV
- Véronique Bouchet - GURME
- Martin Schultz - RG
- Alkiviadis Bais - Ozone
- Jörg Klausen - Data
- Vincent-Henri Peuch - Apps
- Wenche Aas - TAD
- Alex Vermeulen - GHG
- Paolo Laj - Aerosol

12:00-13:00 - Side Event 1: “From Urban Meteorology and Environment Research to Integrated City Services”

(Moderators V. Bouchet and A. Baklanov)

- Sue Grimmond - Integrated Urban Services: concept and research needs (by videoconference)
- Jhoon Kim - Role of satellite and remote sensing in the urban environment
- Felix Vogel - Urban GHG footprint studies in IG³IS
- Jianguo Tan - Shanghai city MHEWS and integrated observations

13:00-14:00 - Side Event 2: “How can GAW contribute to nitrogen cycle assessments?”

(Moderators Martin Schultz and Silvina Carou)
• Martin Shultz – Recent conclusions and recommendations related to N ambient concentrations
• Wenche Aas – Recent conclusions and recommendations related to N deposition
• Tim Jickells – Observation and modelling needs over the oceans

14:00-17:00 - **Plenary 1: “Science for services”**
(Moderator Paolo Laj, Rapporteur Isobel Simpson)

Invited talks:

- Greg Carmichael - State of atmospheric sciences: Recent National Academy of Sciences report
- Vincent-Henri Peuch - CAMS Atmospheric Services
- Stefan Reimann - IG³IS concept
- Markus Amann - Science for air quality management
- Michel Jean - Future Seamless Global Data-Processing and Forecasting System (via telecon)

Short interventions:

- Duong Van Khanh
- Oyunchimeg Dugerjav
- Augustin Garcia-Reynoso
- Paulo Saldiva

17:00–18:30 - **Poster session 1: NATIONAL AND REGIONAL AIR QUALITY AND ATMOSPHERIC CHEMISTRY ACTIVITIES**

**Tuesday 11 April 2017**

8:00-9:00 – Registration

9:00–12:00 - **Plenary 2: “Integrated Observations”**
(Moderators Michael Kurylo and Luciana Gatti; Rapporteurs Ellsworth J. Welton, Karla Longo and Greg Bodeker)

Invited talks:

- Alex Vermeulen - Integrated in situ observation in ICOS: strength, weaknesses and opportunities
- Andreas Petzold - IAGOS observations: strength, weaknesses and opportunities for integration
- Richard Eckman - Strength, weaknesses and opportunities for integration satellite
- Sandro Fuzzi - WIGOS concept: challenges and opportunities
- Greg Bodeker - What does ‘integrated observations’ mean?
Short interventions:

- Luciana Gatti
- Duong Van Khanh
- Jianguo Tan
- Norazura Binti Zakaria

12:00-13:00 - Side event 3: “WMO Sand and Dust Storm – Warning advisory and Assessment System”

- Enric Terradellas (State Meteorological Agency of Spain): Observational needs
- Emilio Cuevas (State Meteorological Agency of Spain): Ground observation
- Taichu Tanaka (Japan Meteorological Agency): Satellite observation
- Valentin Foltescu (United Nations Environment Programme): UNEP view

13:00-14:00 - Side event 4: “Coordination of near-real-time total ozone measurements from the network of Brewer and Dobson spectrophotometers”

(Moderator A. Bais)

- John Rimmer - EuBrewNet and the future of the Brewer Network
- Tom Kralidis - Woudc (via telecom)

14:00-17:00 - Breakout 1: “Modelling activities in GAW”

(Moderators Veronique Bouchet and Vincent-Henri Peuch, Rapporteur Valentin Foltescu)

Invited talks:

- Frank Dentener - modelling of atmospheric deposition and global mapping
- Guy Brasseur - Air Quality forecasting from global to urban scale
- Paul Young - Atmospheric composition-climate modelling
- Leonard Rivier - Advances in inverse modelling

Short interventions:

- Brian Golding
- Raymond Ellul
- Agustin Garcia-Reynoso
- Najmi HOUDA
- Duong Van Khanh

14:00-17:00 - Breakout 2: “GAW Quality Assurance”

(Moderators Emilio Cuevas and Herman Smit; Rapporteurs Dagmar Kubistin and Elke Ludewig)

Invited talks:

- Paolo Laj - Concept of the GAW Quality Assurance
• Joëlle Viallon - Difference in traceability concept in GAW and metrology community (addressing impact on uncertainties)
• Christoph Zellweger - Low-cost sensors and their role in the future observing systems

Short interventions:

- Martin Steinbacher
- Christoph Zellweger
- Rainer Steinbrecher
- Sergey Assonov
- Wenche Aas
- Anatoly Tsvetkov
- Duong Van Khanh
- Norazura Binti Zakaria

17:00-18:30 - Poster session 2: QUALITY ASSURANCE AND DATA MANAGEMENT

Wednesday 12 April 2017

8:00-9:00 – Registration

9:00-2:00 - Plenary 3: “Partnership”

(Moderators Paul Monks and Kobus Pienaar, Rapporteurs Michela Maione and Haeyoung Lee)

• World Bank (Lek Kadeli)
• UNEP (Valentin Foltescu)
• BIPM (Joëlle Viallon)
• IAEA (Manfred Groening)
• WHO (Carlos Dora)
• ICLEI - Local Governments for Sustainability (Miriam Badino)
• GESAMP (Tim Jickells)
• CLRTAP Convention (Laurence Rouil)
• IGAC (Megan L. Melamed)
• SPARC (Fiona Tummon)

12:00-13:00 - Brainstorming on resource mobilization

4:00-17:00 - Breakout 3: “Key requirements on data management for GAW as a provider of science-based services”

(Moderators Jörg Klausen and Ray Ellul, Rapporteur Richard Eckman)

Invited talks:

• Jörg Klausen - Introduction and objectives of session
• Paul Young - Chemistry-Climate GAW data use and needs
• Jun Wang - Air quality, agriculture, energy sector research GAW data use and needs
• Ellsworth J. Welton - Data requirements for aerosol observations
• Constance Okuku - Kenyan and greater African GAW data use
Short interventions:

- Agustin Garcia-Reynoso
- Wenche Aas

14:00-17:00 - **Breakout 4: “Outreach and capacity building”**

*Moderators Melita Keywood and Paul Monks; Rapporteur Sam Cleland*

Invited talks:

- Craig Sinclair - Utilizing mass media to apply our science
- Fiona Tummon - Building capacity and getting the message across - some thoughts
- Mirella Glor - Capacity building in GAW by the example of GAWTEC.
- Komariah Kokom (remotely) - How does the GAW Programme contribute to capacity development in Indonesia and can it be improved?

Short interventions:

- Norazura Binti Zakaria

17:00-18:30 - **Poster session 3: ANALYSIS OF OBSERVATIONS, PRODUCTS AND SERVICES**

**Thursday 13 April 2017**

9:00-10:15 - Session rapporteurs and SSC work on recommendations

10:15-10:45 - Coffee break

10:45-12:00 - Plenary “Recommendations and way forward”

- Round table
- Plenary 1 Science for Services
- Plenary 2 Integrated Observations
- Plenary 3 Partnership
- Breakout 1 Modelling
- Breakout 2 Quality Assurance
- Breakout 3 Data Management
- Breakout 4 Outreach and Capacity Building

12:00 - Meeting closure

13:00-17:00 - Meeting of SSC and SAG/ET Chairpersons (by invitation only)
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P2 - quality assurance and data management  
P3 - analysis of observations, products and services
ANNEX IV

4th Session of the CAS Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee (EPAC SSC)
13 April 2017

Agenda

13:00 - Adoption of the Agenda, Goals and Updates (Greg Carmichael/Oksana Tarasov)

13:15 - Review of Progress on Action Items from 3rd SSC Meeting (Greg Carmichael)

13:45 - Reports on the implementation of the GAW IP and future strategy:

a1) - IG³IS (Paul Monks)
a2) - Resource mobilization (Kobus Pienaar)
a3) - Outreach (Melita Keywood)
b) - Reflection of GAW Symposium outcomes in the GAW IP
c) - Discussion of cross cutting topics & strategy

14:30 - New actions requiring SSC attention:

a) - SAG structure and membership
b) - The GAW brand
c) - Network status/issues (e.g. ozon sondes and water vapour, ...)
d) - CAS TECO preparations
e) - Strategic collaborations within and external to WMO (WWRP, WCRP, UNE, GCOS, etc.)

15:15 - Setting priorities for 2017

16:30 - Internal SSC matters

17:00 - Closure of the meeting
Meeting Decisions

D1. Responsibility for CO goes from RG to GHG SAG.

D2. ICOS will be contributing network and data stays in ICOS data centre.

D3. RG SAG. New members: Isobel Simpson and Paul Young, David Simpson and Aijun Ding.

D4. GURME: New member: Ranjeet Sokhi. Lisa Molina is accepted as a Co-Chairperson for the rest of her term.

D5. Low-cost sensors activities should be a high priority for 2017.

D6. All SAGs should make their meeting reports available online.
4th Session of the CAS Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee (EPAC SSC)  
13 April 2017

**Meeting Action Items**

AI-1.4. To develop GAW position on GRUAN and O3 and water vapour (on hold) measurements in it.

AI-2.4. Discuss Irina Petropavlovskih as a new SAG member in O3 SAG meeting upon receipt of the official proposal from the SAG Chairperson.

AI-3.4. Consider idea to merge UV and Ozone SAGs (SSC supports) keeping Co-Chairpersons.

AI-4.4. Continue to review ways to organize the SAGs (focal areas vs parameters), and develop a strategy to better link the theme-oriented SAGs with GAW measurements and instruments.

AI-5.4. Improve GAW website with the inputs from SSC and SAGs.

AI-6.4. Assess the current state and future direction of low-cost sensor performance and their use within GAW and beyond, through the development of a living document of guidance and facilitated by a workshop on low-cost sensors (before end of 2018).

AI-7.4. Schedule a follow-up SSC meeting in the form of telecons before the summer vacation (this action item was closed before the finalization of this report).

AI-8.4. Name a new Chairperson for RRR activity to replace Greg Carmichael.

AI-9.4. Advance federated data management (include establishing issues identified in CAMS contract, & GESAMP data) in particular through the next GEOSS project.

AI-10.4. Advance interactions with IGAC through possible joint workshop related to top down estimates of emissions with APP-SAG – possible coordination with IG²IS activities. Need to follow-up with APP-SAG.

AI-11.1. Set up focus groups to advance priority areas. Those identified to date are: outreach, resource mobilization & partnerships implement a communication strategy identified at the Symposium (lead by Karla Longo and Melita Keywood).
AI-12.4. Execute some of the visioning statements on outreach, resource mobilization and collaboration as identified at the Symposium through the workshop in South Africa (lead by Kobus Pienaar).

AI-13.4. Initiate and prioritize cross cutting project(s).

AI-14.4. Develop and advance MAP-AQ partnership.

AI-15.4. Establish further activities in Africa – with World Bank, UN-Env, WHO, low-cost sensors, MAP-AQ. We have a workshop taking place in South Africa in early December 2017 to discuss developing projects in Africa.

AI-16.4. Continue developing the highest priority areas identified: IG³IS; low-cost sensors, model fusion and urban.

AI-17.4. Better organize the work of SSC by revising membership, making assignments, and setting up quarterly conference calls.

AI-18.4. Advance and support model-observation fusion activities.

AI-19.4. Engage with new Pandora network to form a collaborative network of GAW.

AI-20.4. All SAGs should make their meeting reports available online, add dates to the action items and identify responsible people (3 months after the SAG meetings).

AI-21.4. Enhance interactions with SPARC for example by working together on SLPC chapter of IPCC. Set up conference call with SPARC Chairperson and discuss further at CAS.
LIST OF RECENT GAW REPORTS*


239. Calibration Methods of GC-\(\mu\)ECD for Atmospheric SF6 Measurements, 26 pp., 2018.

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For more information, please contact:

World Meteorological Organization
Research Department
Atmospheric Research and Environment Branch
7 bis, avenue de la Paix – P.O. Box 2300 – CH 1211 Geneva 2 – Switzerland
Tel.: +41 (0) 22 730 81 11 – Fax: +41 (0) 22 730 81 81
Email: GAW@wmo.int

Website: http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html