GAW Report No. 221

Report of the First Meeting of the WMO GAW Task Team on Observational Requirements and Satellite Measurements (TT-ObsReq) as regards Atmospheric Composition and Related Physical Parameters

(Geneva, Switzerland, 10-13 November 2014)

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GLOBAL ATMOSPHERE WATCH

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Report from the First Meeting of the WMO GAW Task Team on Observational Requirements and Satellite Measurements (TT-ObsReq) as regards Atmospheric Composition and Related Physical Parameters

(Geneva, Switzerland, 10-13 November 2014)

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GLOBAL ATMOSPHERE WATCH

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1. SUMMARY

The World Meteorological Organization (WMO) Integrated Global Observing System (WIGOS) shall be a framework for all WMO observing systems and the contributions of WMO to co-sponsored observing systems in support of all WMO Programmes and activities. The Global Atmosphere Watch (GAW) Programme is one of several networks and programmes that will constitute WIGOS. WIGOS activities take place within a number of application areas. A WMO application area is an activity involving primary use of observations, in a chain of activities which allow National Meteorological and Hydrological Services (NMHS) or other organizations to render services contributing to public safety, socio-economic well-being and development in their respective countries, in a specific domain related to weather, climate and water. The concept of a WMO application area is used in the framework of the WMO Rolling Review of Requirements (RRR) and describes a homogeneous activity for which it is possible to compile a consistent set of observational user requirements agreed by community experts working operationally in this area.

The RRR is the process used for matching the user requirements of all application areas supporting WMO Programmes against the observational capabilities represented by all WIGOS component systems recorded in the Observing Systems Capability Analysis and Review Tool (OSCAR) databases. The RRR is a key activity used within WIGOS in its aim to design and develop observing networks that support not just one, but many application areas simultaneously.

In the context of developing an RRR process for the GAW Programme, and following a recommendation from WMO Congress XVI (2011), a Task Team (TT) was established in the fall of 2014. This TT met from 10-13 November 2014 at the WMO Secretariat in Geneva. The first undertaking of the TT was to develop a better definition of the application areas where GAW contributes. Originally, the WMO application area for GAW had been defined as “atmospheric chemistry”. Although GAW deals with atmospheric chemistry, this is not an application area but rather a scientific discipline. As a result of the deliberations of the TT, “atmospheric chemistry” has now disappeared as an official WMO application area and has been replaced by three new ones, namely: 1) forecasting atmospheric composition; 2) monitoring atmospheric composition; 3) providing atmospheric composition information to support services in urban areas.

The TT also made good progress toward developing updated lists of variables in support of the new application areas and to establish requirements for these variables. A process for completing this process and for maintaining the RRR entries in the future is currently being developed in collaboration between the Commission for Atmospheric Sciences (CAS) and the Commission for Basic Systems (CBS) with support from the WMO Secretariat.

2. OPENING OF THE MEETING

The meeting of the GAW Task Team on Observational Requirements and Satellite Measurements (TT-ObsReq) was opened at the WMO Secretariat at 2 p.m. on the 10th November 2014 by the Task Team Chairperson, Prof. Gregory Carmichael, who welcomed the participants to the meeting.

The list of participants to the session can be found in Annex A. A Tour de Table was carried out so that all the participants became acquainted. Apologies had been received from Ronald van der A who was not able to attend. Sander Houweling took part in the meeting via teleconferencing.

3. ADOPTION OF THE AGENDA

The agenda is available in Annex B. The agenda was adopted without changes.

4. INTRODUCTION AND SCENE-SETTING

Gregory Carmichael gave an introduction, explaining the background for the establishment of the Task Team (TT) and the expected outcome of the work to be carried out by the TT. The powerpoint presentation can be found on the TT web page:
http://www.wmo.int/pages/prog/arep/gaw/TaskTeamObsReq.html

Lars Peter Riishøjgaard gave a presentation on the Rolling Review of Requirements (RRR) and the Observing Systems Capability Analysis and Review Tool (OSCAR) database. This was followed by Paolo Ruti's presentation, who discussed developments within the World Weather Research Programme (WWRP) and potential communities that can set up user requirements for observations.

The Global Atmosphere Watch (GAW) Programme in its Addendum for the Period 2012 – 2015 to the WMO GAW Strategic Plan 2008 – 2015 tasked each of its Science Advisory Groups (SAGs) to establish the RRR process in each focal area (ozone, greenhouse gasses, reactive gasses, atmospheric wet deposition, UV radiation and aerosols) as well as consider the requirements within the GAW Urban Research Meteorology and Environment (GURME) project.

The comparison of user requirements with observing system capabilities for a given application area is called a Critical Review. The output of this is reviewed by experts in the relevant application area and used to prepare a Statement of Guidance (SOG), the main aim of which is to draw attention to the most important gaps between user requirements and observing system capabilities, in the context of the application. The SOG serves as a guiding document for the Members to develop an observational network which is appropriate for the applications.

The SOG for Atmospheric Chemistry was prepared in 2004 and approved by the Expert Team on the Evolution of the Global Observing Systems (ET-EGOS) in December 2005. It was, to a large extent, based on the IGACO Report "The Changing Atmosphere – An Integrated Global Atmospheric Chemistry Observation Theme for the IGOS Partnership", which was published in September 2004 jointly by WMO and the European Space Agency (GAW Report no. 159). The SOG and the IGACO Report have served as guidance for setting up observational requirements and observational network development in the GAW Programme. Neither observational requirements, nor the observational capacity has been critically evaluated since then. Hence, there is an urgent need to update the recommendations, the overview of measurement capabilities and the identification of gaps in the observational network. The application area "atmospheric chemistry" also serves rather as a place holder than a real application area. In addition, satellite agencies require user based information on what is needed for future missions as regards observations of atmospheric composition and related physical parameters, because the observational capacity is delivered by a composite observing system (including ground and satellite based platforms).

According to decisions of WMO Congress, all component observing systems under the WMO Integrated Global Observing System (WIGOS) framework will use the RRR process to vet and document observations data requirements, assess observational capabilities and provide guidance regarding future evolution of observing systems. This process is relatively mature for certain components (notably the Global Observing System), but is now increasingly being adopted also by other WIGOS components (e.g. GAW).

This led WMO's sixteenth Congress in 2011 to make the following recommendation[a]

Regarding satellite measurements of atmospheric chemical constituents and related physical parameters, Congress recommended for GAW to set up an ad-hoc Task Team to review the needs for GAW regarding satellite measurements and the IGACO recommendations on these that date back to 2004. Congress further recommended for this work to be done in coordination with the CBS Expert Team on Satellite Systems (ET-SAT) and the Expert Team on Evolution of the Global Observing Systems (ET-EGOS), the Committee on Earth Observation Satellites (CEOS) Atmospheric Composition Constellation group and the Coordination Group for Meteorological Satellites (CGMS) and also taking into consideration GCOS requirements and the vision for the GOS in 2025. Congress highlighted that the required coverage, precision, spatial and temporal resolution called for geostationary and low earth orbit observation capabilities to be implemented and sustained. Congress requested Members operating satellites to include atmospheric sensors of proven capability aboard future spacecraft, and to maintain continuous atmospheric composition measurements for as long as possible, making a selection of data available to all interested users. Congress recognized that such remote sensing observations are meaningful when they are combined with the in-situ observations to produce global three dimensional high resolution and high quality products. The importance of the in-situ observations by Members is not at all reduced by the presence of satellite and aircraft observations.

5. PURPOSE OF THE TASK TEAM

The Task Team (TT) will help to define application areas for GAW in cooperation with the Scientific Steering Committee for Environmental Pollution and Atmospheric Chemistry (EPAC SSC) under CAS. Further, the TT will assess the needs within GAW and other WMO Programmes for measurements in the general area of atmospheric composition (within identified application area) in cooperation with the EPAC SSC. The TT will review how atmospheric composition measurements relate to the current application areas within the RRR process (http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html). The TT should refer to the above-mentioned Statement of Guidance in atmospheric chemistry application area. The communities that will require this information are those working with atmospheric chemistry and climate, air pollution and human and ecosystem health, air quality forecasting, and inclusion of atmospheric composition data in meteorological models. The information provided by the TT will be incorporated in the OSCAR database supporting the RRR process for all WIGOS components and all WMO application areas. Furthermore, the task team will assist the EPAC SSC to establish the RRR process as an integrated part of GAW within the WIGOS framework. The Terms of Reference are given in Annex C.

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[a] *Sixteenth World Meteorological Congress, Geneva 16 May – 3 June 2011. WMO-No. 1077. Chapter 3.2.3, p. 39.*

6. BACKGROUND

WMO continues to develop an over-arching framework for the coordination and evolution of WMO observing systems, and the contributions of WMO to co-sponsored observing systems, with the goal to enable more efficient and effective service delivery. The GAW Programme is a key component of this framework. The TT-ObsReq has several objectives: 1) to provide a contribution to GAW advisory groups on potential application areas; 2) make a first assessment of user requirements in these application areas; 3) to help GAW develop a strategy for the integration of satellite observations of atmospheric composition and related physical parameters into the GAW Programme.

Towards this end the meeting focused on the following major activities:

1. Provide input into the identification of key application areas. A critical component in designing an observing system is the intended application. Currently in the WMO documents the application area that most closely links to GAW is “atmospheric chemistry.” Atmospheric chemistry is clearly too broad a topic for use in defining an observing system. The group discussed/identified key application areas (a few) that require atmospheric composition observations. These application areas should be sufficiently specific that observing requirements can be established (e.g. air quality forecasting of PM2.5 and ozone). Application areas usually describe the routine activities or services.
2. Discuss the role of atmospheric composition observations in support of the other WMO application areas. The complete list of WMO application areas (http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html) includes: Global Numerical Weather Prediction (GNWP); High-Resolution Numerical Weather Prediction (HRNWP); Nowcasting and Very Short Range Forecasting (NVSRF); Seasonal and Inter-Annual Forecasting (SIAF); aeronautical meteorology; atmospheric chemistry; ocean applications; agricultural meteorology; hydrology; climate monitoring (as undertaken through the Global Climate Observing System, GCOS); climate applications and space weather. In addition, the observational requirements for WMO polar activities and the Global Framework for Climate Services (GFCS) are also to be considered under WIGOS.
3. Review the current and planned satellite missions and discuss their contribution to the application areas where atmospheric composition data are used.

Further background information can be found at:
http://www.wmo.int/pages/prog/arep/gaw/TaskTeamObsReq.html

7. MAIN ACTIONS

A. The Task Team discussed what application areas should be used instead of the placeholder “atmospheric chemistry” application area currently identified used in WMO, taking into consideration the WMO strategic plan, CAS priorities and the upcoming GAW Implementation Plan (IP) for the period 2016-2023. Three recommended applications areas were identified that encompasses major elements of GAW research that is data driven and in-line with the theme “GAW – research enabling services”:

- **Forecasting Atmospheric Composition (F)** – Covers applications from global to regional scales (with horizontal resolutions similar to global NWP (~ 10 km and coarser) with stringent timeliness requirements (NRT) to support operations such as sand and dust storm and chemical weather forecasts.
- **Monitoring Atmospheric Composition (M)** - Covers applications related to evaluating and analysing changes (temporally and spatially) in atmospheric composition regionally and globally to support treaty monitoring, climatologies and re-analyses, assessing trends in composition and emissions/fluxes, and to better understand processes, using data of controlled quality (and with less stringent time requirements (not needed in NRT)), and used in products such as Ozone and Greenhouse Gas Bulletins, and State/Health of the Atmosphere reports.
- **Providing Atmospheric Composition information to support services in urban and populated areas (U)** - Covers applications that target limited areas (with horizontal resolution of a few km or smaller and stringent timeliness requirements to support services related to weather/climate/pollution, such as air quality forecasting. (The GURME SAG will review all related entries).

B. The committee identified key parameters needed for these applications.

Forecasting Atmospheric Composition (F)

1. All Global NWP variables (e.g. planetary boundary layer (PBL) + Tropopause height) and others we want to add and that will be determined through a dialogue between the TT and the SAGs.
2. Aerosols (aerosol mass, size distribution (or at least mass at 3 fraction sizes: 1, 2.5 and 10 micron), speciation and chemical composition, aerosol optical depth (AOD) at multiple wavelengths, Aerosol Absorption Optical Depth (AAOD), water content, ratio of mass to AOD, vertical distribution of extinction).
3. Total ozone, profile ozone, surface ozone, NO, NO_2 (surface, column, profile), PAN, HNO_3, NH_3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics), SO_2 (surface and column), CH_4, CO_2, N_2O, HCHO, HO_x, Cl_x, ClO, BrO, OClO, $ClONO_2$, HDO, CFCs, HCFCs, HFCs, Rn, SF_6.
4. Others: actinic flux, fire radiative power, land proxies, lightning, dry and wet deposition, pollen (key species), OCS.

Monitoring Atmospheric Composition (M)

1. All Global NWP variables (e.g. PBL + tropopause height) and others we want to add: SST, deep ocean temperature, solar variability, albedo, land use, soil moisture, precipitation, sea ice cover, snow cover, polar stratospheric clouds (PSC) occurrence.
2. Aerosols (aerosol mass, number, size/surface distribution (1, 2.5, 10 micron), speciation and chemical composition, AOD at multiple wavelengths, AAOD, water content, ratio of mass to AOD, vertical distribution of extinction), stratospheric aerosol backscatter coefficient, PSC composition, concentration of metals, chemical composition of PM (sulphate, nitrate, ammonium, BC, OC, OM, dust, sea salt, BS, SOA) aerosol index, refractive index, precipitation chemistry composition, Hg, persistent organic pollutants (POPs), primary biological particles.

3. Total ozone, profile ozone, surface ozone, NO, NO_2 (surface, column, profile), PAN, HNO_3, NH_3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics), SO_2 (surface, column), CH_4, CO_2, N_2O, N_2O_5, NO_3, HCHO, HO_x, Cl_y, ClO, BrO, OClO, $ClONO_2$, HDO, CFCs, HCFCs, HFCs, halons, CH_3Br, CH_3Cl, $BrONO_2$, Rn, SF_6, glyoxal, methyl chloroform, H_2O, H_2O_2, H_2, O_2/N_2 ratio, dimethyl sulphide (DMS), methanesulphonic acid (MSA), OCS.
4. Isotopes of CO_2, methane, N_2O, CO, (D, ^{13}C, ^{14}C, ^{17}O, ^{18}O, ^{15}N) also in the aerosol phase.
5. Actinic flux, fire radiative power, land proxies, lightning, dry and wet deposition, pollen (key species), ocean colour, chlorophyl-A, Leaf Area Index (LAI), Photosynthetically Active Radiation (PAR), fraction of PAR (fPAR), fluorescence, vegetation maps, land use maps, burned areas, night light, fire counts, wet lands, ship routes, forest inventory, biomass density, crop lands.

Providing Atmospheric Composition information to support services in urban and populated areas (U)

GURME in cooperation with the Data Processing and Forecasting (DPFS) Division of WMO will be asked to further develop a list of variables and respective requirements.

C. The TT developed a strategy to begin the RRR process and to populate the OSCAR database for the above applications. The process will engage the SAGs and the SSC. The committee started the process of identifying the atmospheric composition and related parameters needed to support the applications and began to fill out an Excel table with user requirements that will be used to populate the OSCAR database after evaluation by the SAGs. The SAGs will be asked to discuss the application areas, including the sorts of specific applications that are important within the overarching application, and the parameters needed for the applications (making suggestions for adding and/or removing parameters) and continue filling out the tables of user requirements for the parameters that fall in their domain.

The outline of the process is:

1. An email with the Excel file and the meeting report should be sent out to the TT by 5 December 2014.
2. An initial review of application areas will be done with a conference call with the SAGs/SSC before 19 December, with corrections and comments submitted to the chairperson before 15 January 2015.
3. The final meeting report and the Excel file will be sent to the SSC and the SAG Chairpersons before 22 January 2015 as background for the enlarged SSC meeting in February 2015.
4. Discuss the applications areas, the observational requirements and the RRR process at the enlarged SSC meeting (18-20 February).
5. Send the results of the discussion in 4) to the SAGs by the end of February and ask for feedback from the SAGs by 13 March 2015.
6. Assemble the feedback from the SAG and send to the TT by 20 March 2015.
7. Teleconference with the TT before Easter to review the progress so far.

8. Write a progress report before the end of April to be presented at Congress in May 2015.
9. RRR continues.

D. The committee reviewed the other WMO applications that have identified requirements for atmospheric composition variables. While GAW does not have overall responsibility of these applications, it has important contributions to make (for example in those related to climate, aeronautics and agriculture). Important aspects to ensure are addressed in these application areas include (but not limited to) short-lived climate pollutants (SLCPs), aerosol-weather interactions and their impact on NWP, ecosystem services, biomass burning, UV/Vis radiation to support renewable energy/agricultural meteorology applications. The TT-ObsReq, working with the Secretariat, will develop a plan for collaborating with the application groups to provide input from GAW into the RRR and OSCAR databases for these areas. As an example of the possible modes of carrying this out, there is a meeting being planned with agriculture meteorology (in the spring) where the atmospheric composition requirements will be discussed in detail.

E. Other

The team reviewed the upcoming satellite missions with respect to their capability to help deliver the observations needed to support the application areas. The TT-ObsReq will continue to review the status and develop a statement that summarizes the status and articulates the need for future observing system to fill gaps.

The team recognized that the list of observations to support the applications is long. The RRR process needs to continue to identify/review the basic requirements. A more expansive list can be included in supporting documents.

The team recognized the need to write/update the Statement of Guidance for the Atmospheric Chemistry- focused applications. Plans for this activity will be developed.

8. NEXT STEPS

The Secretariat should establish a connection with the owners of user requirements in the other application areas and bring them in contact with this TT and SAGs concerning atmospheric composition variables. Prior to the joint meeting of the SSC, SAG Chairs and ET Chairs in February 2015, TT-ObsReq and SAGs should agree on 1) overarching application areas; and 2) variables required to support these applications. Overarching application areas should constitute an essential part of the GAW IP. First proposed user requirements tables due to be delivered to SAGs before June 2015. During June-September SAGs consider the proposed table and through joint telephone conferences with TT-SAT finalize the requirements. End of September 2015 user requirements are placed in the OSCAR database. During October-December the gaps in the current and planned observing system are analysed and a Statement of Guidance is developed for each application. SSC becomes an owner of applications and assigns a focal point for each application as soon as the list is finalized. Focal point will be responsible for the update of user requirements and Statements of Guidance through established links with SAGs on a regular basis.

GURME and others begin identification of observations needed for urban applications. This group should finalize user requirements and Statements of Guidance by the end of 2015.

SAGs will work with other application areas that need atmospheric composition data depending of variables to develop a plan to discuss atmospheric chemistry requirements. Key contacts and actions need to be identified through the Secretariat.

9. CLOSURE OF THE MEETING

The meeting closed at 12:10 on Thursday 13 November 2014.

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ANNEX A

First Meeting of the WMO GAW Task Team on Observational Requirements and Satellite Measurements as regards Atmospheric Composition and Related Physical Parameters

(Geneva, Switzerland, 10-13 November 2014)

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ANNEX B

First Meeting of the WMO GAW Task Team on Observational Requirements and Satellite Measurements as regards Atmospheric Composition and Related Physical Parameters

(Geneva, Switzerland, 10-13 November 2014)

Agenda

Monday 10 November

14:00 – 14:15	**Welcome, logistics and *tour de table*** *Welcome by TT Chair and the Secretariat*
14:15 – 15:00	**Introduction and scene-setting** *TT Chair* Background: Congress Recommendation from 2011 What do we expect as outcome from the Task Team's work? IGACO Report of 2004 and the Statement of Guidance for Atmospheric Chemistry are now 10 years old GAW Strategic Plan 2008-15 and GAW Implementation Plan 2016-2023 Relevant GCOS Reports Other strategy reports, such as those from EU and ESA, for example. Work plan and the way forward (first meeting, telecons etc.)
15:00 – 15:30	**Overview of RRR and the OSCAR database** *Lars Peter Riishøjgaard or Stephan Bojinski*
15:30 – 16:00	**Examples from user communities** *Paolo Ruti (WWRP) and Michel Rixen (WCRP)*
16:00 – 16:30	**Coffee Break**
16:30 – 18:00	**Discussion and definition of key Application Areas** *All*
18:00	**Adjourn**

Tuesday 11 November

09:00 – 10:00 **Discussion on important variables**

All

What are the important variables to measure?

Are there parameters missing in the GAW Programme?

10:00 – 10:30 **An overview of the GAW Observing System**

Gregory Carmichael

10:30 – 11:00 **Coffee break**

11:00 – 12:00 **Mapping of GAW variables in the OSCAR database**

All

Variables measured by GAW appear not only under the "Atmospheric Chemistry" Application Area but also under other "Areas" such as Agricultural Meteorology and SPARC. We need to check the correctness and completeness of the requirements related to "Atmospheric Chemistry" and GAW.

12:00 – 13:00 Lunch

13:00 – 15:00 **Mapping of GAW variables in the OSCAR database cont.**

All

15:00 – 15:30 **Coffee break**

15:30 – 18:00 **Mapping of GAW variables in the OSCAR database cont.**

All

18:00 **Adjourn**

Wednesday 12 November

09:00 – 12:00 **Mapping of GAW variables in the OSCAR database cont.**

All

12:00 – 13:30 **Lunch**

13:30 – 14:30 **Discussion on the role of atmospheric composition observations in support of other WIGOS application areas**

All

14:30 – 15:15 **Overview of existing and planned satellite missions of relevance to atmospheric composition in all application areas**

Rosemary Munro (EUMETSAT) and Ben Veihelmann (ESA)

15:15 – 15:30 **Overview of aircraft programmes**

Oksana Tarasova

15:30 – 16:00 **Coffee Break**

16:00 – 17:30 **Discussion on observational requirements, aircraft and satellites**

All

17:30 **Adjourn**

19:00 **Group dinner**

Thursday 13 November

09:00 – 12:00 **More on the RRR process**

Discussion to be led by the TT Chair

How can the work of this group constitute the beginning of a continually ongoing RRR process?

12:00 – 12:30 **The way forward**

Next meeting (telecon). How can output from the TT serve as input for other strategy documents?

12:30 **Close**

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ANNEX C

Terms of Reference (ToRs)

1. To take note the current WIGOS overall application area of atmospheric chemistry and consider a revision resulting in a number of application areas covered by its activities to be done in close cooperation with EPAC SSC. Suggest an update of the inventory of application areas within the field of atmospheric chemistry to be supported under the RRR and used in the GAW Implementation plan for the period 2016-2023.
2. For identified application areas to review user requirements for observations of atmospheric composition and related physical parameters, focusing on GAW variables, in a broad technology-free manner. Review user requirements for observations of atmospheric composition and related physical parameters for other than atmospheric chemistry applications areas already identified in WIGOS.
3. To review the current observational capabilities in support of identified applications areas.
3. To review current use of available satellite information in this field and how to enhance its use.
4. To consider timelines for the need of delivery of satellite products.
5. To consider needs for collocation of instruments for vertical distribution and surface measurements as relates to satellite observations, for inclusion in models and for satellite validation, especially for high resolution data.
6. To identify current and future gaps in observational capability, given the needs for observations and the observational capability.
7. To provide an input to the respective GAW bodies necessary for the update of the Tables and Figures in the SOG (and the IGACO Report) that give an overview of key atmospheric constituents to be targeted, an overview of existing and planned platforms and instruments addressing these key constituents and tables with observational requirements for inclusion into the OSCAR database.
8. To study the ongoing work on the WMO Rolling Review of Requirements (RRR) described at: http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html and the Observing Systems Capabilities Analysis and Review tool (OSCAR), a component of the RRR for recording observational requirements and observing capabilities (both space-based and surface-based), and conducting critical reviews, please see: http://www.wmo.int/pages/prog/www/OSY/RRR-DB.html.
8. Assist the EPAC SSC with drafting the procedures to establish the RRR process as an integrated part of GAW within the WIGOS framework.

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LIST OF RECENT GLOBAL ATMOSPHERE WATCH REPORTS*

149. Comparison of Total Ozone Measurements of Dobson and Brewer Spectrophotometers and Recommended Transfer Functions (prepared by J. Staehelin, J. Kerr, R. Evans and K. Vanicek) (WMO TD No. 1147).

150. Updated Guidelines for Atmospheric Trace Gas Data Management (Prepared by Ken Maserie and Pieter Tans (WMO TD No. 1149).

151. Report of the First CAS Working Group on Environmental Pollution and Atmospheric Chemistry (Geneva, Switzerland, 18-19 March 2003) (WMO TD No. 1181).

152. Current Activities of the Global Atmosphere Watch Programme (as presented at the 14th World Meteorological Congress, May 2003). (WMO TD No. 1168).

153. WMO/GAW Aerosol Measurement Procedures: Guidelines and Recommendations. (WMO TD No. 1178).

154. WMO/IMEP-15 Trace Elements in Water Laboratory Intercomparison. (WMO TD No. 1195).

155. 1st International Expert Meeting on Sources and Measurements of Natural Radionuclides Applied to Climate and Air Quality Studies (Gif sur Yvette, France, 3-5 June 2003) (WMO TD No. 1201).

156. Addendum for the Period 2005-2007 to the Strategy for the Implementation of the Global Atmosphere Watch Programme (2001-2007), GAW Report No. 142 (WMO TD No. 1209).

157. JOSIE-1998 Performance of EEC Ozone Sondes of SPC-6A and ENSCI-Z Type (Prepared by Herman G.J. Smit and Wolfgang Straeter) (WMO TD No. 1218).

158. JOSIE-2000 Jülich Ozone Sonde Intercomparison Experiment 2000. The 2000 WMO international intercomparison of operating procedures for ECC-ozone sondes at the environmental simulation facility at Jülich (Prepared by Herman G.J. Smit and Wolfgang Straeter) (WMO TD No. 1225).

159. IGOS-IGACO Report - September 2004 (WMO TD No. 1235), 68 pp, September 2004.

160. Manual for the GAW Precipitation Chemistry Programme (Guidelines, Data Quality Objectives and Standard Operating Procedures) (WMO TD No. 1251), 186 pp, November 2004.

161 12th WMO/IAEA Meeting of Experts on Carbon Dioxide Concentration and Related Tracers Measurement Techniques (Toronto, Canada, 15-18 September 2003), 274 pp, May 2005.

162. WMO/GAW Experts Workshop on a Global Surface-Based Network for Long Term Observations of Column Aerosol Optical Properties, Davos, Switzerland, 8-10 March 2004 (edited by U. Baltensperger, L. Barrie and C. Wehrli) (WMO TD No. 1287), 153 pp, November 2005.

163. World Meteorological Organization Activities in Support of the Vienna Convention on Protection of the Ozone Layer (WMO No. 974), 4 pp, September 2005.

164. Instruments to Measure Solar Ultraviolet Radiation: Part 2: Broadband Instruments Measuring Erythemally Weighted Solar Irradiance (WMO TD No. 1289), 55 pp, July 2008, electronic version 2006.

165. Report of the CAS Working Group on Environmental Pollution and Atmospheric Chemistry and the GAW 2005 Workshop, 14-18 March 2005, Geneva, Switzerland (WMO TD No. 1302), 189 pp, March 2005.

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* *(A full list is available at http://www.wmo.int/pages/prog/arep/gaw/gaw-reports.html)*

166. Joint WMO-GAW/ACCENT Workshop on The Global Tropospheric Carbon Monoxide Observations System, Quality Assurance and Applications (EMPA, Dübendorf, Switzerland, 24 – 26 October 2005) (edited by J. Klausen) (WMO TD No. 1335), 36 pp, September 2006.

167. The German Contribution to the WMO Global Atmosphere Watch Programme upon the 225th Anniversary of GAW Hohenpeissenberg Observatory (edited by L.A. Barrie, W. Fricke and R. Schleyer (WMO TD No. 1336), 124 pp, December 2006.

168. 13th WMO/IAEA Meeting of Experts on Carbon Dioxide Concentration and Related Tracers Measurement Techniques (Boulder, Colorado, USA, 19-22 September 2005) (edited by J.B. Miller) (WMO TD No. 1359), 40 pp, December 2006.

169. Chemical Data Assimilation for the Observation of the Earth's Atmosphere – ACCENT/WMO Expert Workshop in support of IGACO (edited by L.A. Barrie, J.P. Burrows, P. Monks and P. Borrell) (WMO TD No. 1360), 196 pp, December 2006.

170. WMO/GAW Expert Workshop on the Quality and Applications of European GAW Measurements (Tutzing, Germany, 2-5 November 2004) (WMO TD No. 1367).

171. A WMO/GAW Expert Workshop on Global Long-Term Measurements of Volatile Organic Compounds (VOCs) (Geneva, Switzerland, 30 January – 1 February 2006) (WMO TD No. 1373), 36 pp, February 2007.

172. WMO Global Atmosphere Watch (GAW) Strategic Plan: 2008 – 2015 (WMO TD No. 1384), 108 pp, August 2008.

173. Report of the CAS Joint Scientific Steering Committee on Environmental Pollution and Atmospheric Chemistry (Geneva, Switzerland, 11-12 April 2007) (WMO TD No.1410), 33 pp, June 2008.

174. World Data Centre for Greenhouse Gases Data Submission and Dissemination Guide (WMO TD No. 1416), 50 pp, January 2008.

175. The Ninth Biennial WMO Consultation on Brewer Ozone and UV Spectrophotometer Operation, Calibration and Data Reporting (Delft, Netherlands, 31-May – 3 June 2005) (WMO TD No. 1419), 69 pp, March 2008.

176. The Tenth Biennial WMO Consultation on Brewer Ozone and UV Spectrophotometer Operation, Calibration and Data Reporting (Northwich, United Kingdom, 4-8 June 2007) (WMO TD No. 1420), 61 pp, March 2008.

177. Joint Report of COST Action 728 and GURME – Overview of Existing Integrated (off-line and on-line) Mesoscale Meteorological and Chemical Transport Modelling in Europe (ISBN 978-1-905313-56-3) (WMO TD No. 1427), 106 pp, May 2008.

178. Plan for the implementation of the GAW Aerosol Lidar Observation Network GALION, (Hamburg, Germany, 27 - 29 March 2007) (WMO TD No. 1443), 52 pp, November 2008.

179. Intercomparison of Global UV Index from Multiband Radiometers: Harmonization of Global UVI and Spectral Irradiance (WMO TD No. 1454), 61 pp, March 2009.

180. Towards a Better Knowledge of Umkehr Measurements: A Detailed Study of Data from Thirteen Dobson Intercomparisons (WMO TD No. 1456), 50 pp, December 2008.

181. Joint Report of COST Action 728 and GURME – Overview of Tools and Methods for Meteorological and Air Pollution Mesoscale Model Evaluation and User Training (WMO TD No. 1457), 121 pp, November 2008.

182. IGACO-Ozone and UV Radiation Implementation Plan (WMO TD No. 1465), 49 pp, April 2009.

183. Operations Handbook – Ozone Observations with a Dobson Spectrophotometer (WMO TD No. 1469), 91 pp, March 2009.

184. Technical Report of Global Analysis Method for Major Greenhouse Gases by the World Data Center for Greenhouse Gases (WMO TD No. 1473), 29 pp, June 2009.

185. Guidelines for the Measurement of Methane and Nitrous Oxide and their Quality Assurance (WMO TD No. 1478), 49 pp, September 2009.

186. 14th WMO/IAEA Meeting of Experts on Carbon Dioxide, Other Greenhouse Gases and Related Tracers Measurement Techniques (Helsinki, Finland, 10-13 September 2007) (WMO TD No. 1487), 31 pp, April 2009.

187. Joint Report of COST Action 728 and GURME – Review of the Capabilities of Meteorological and Chemistry-Transport Models for Describing and Predicting Air Pollution Episodes (ISBN 978-1-905313-77-8) (WMO TD No. 1502), 69 pp, December 2009, electronic version - July 2009.

188. Revision of the World Data Centre for Greenhouse Gases Data Submission and Dissemination Guide (WMO TD No.1507), 55 pp, November 2009.

189. Report of the MACC/GAW Session on the Near-Real-Time Delivery of the GAW Observations of Reactive Gases, Garmisch-Partenkirchen, Germany, 6-8 October 2009, (WMO TD No. 1527), 31 pp. August 2010.

190. Instruments to Measure Solar Ultraviolet Radiation Part 3: Multi-channel filter instruments (lead author: G. Seckmeyer) (WMO TD No. 1537), 55 pp. November 2010.

191. Instruments to Measure Solar Ultraviolet Radiation Part 4: Array Spectroradiometers (lead author: G. Seckmeyer) (WMO TD No. 1538), 43 pp. November 2010.

192. Guidelines for the Measurement of Atmospheric Carbon Monoxide (WMO TD No. 1551), 49 pp, July 2010.

193. Guidelines for Reporting Total Ozone Data in Near Real Time (WMO TD No. 1552), 19 pp, April 2011 *(electronic version only)*.

194. 15th WMO/IAEA Meeting of Experts on Carbon Dioxide, Other Greenhouse Gases and Related Tracers Measurement Techniques (Jena, Germany, 7-10 September 2009) (WMO TD No. 1553). 330 pp, April 2011.

195. WMO/GAW Expert Workshop on Global Long-term Measurements of Nitrogen Oxides and Recommendations for GAW Nitrogen Oxides Network (Hohenpeissenberg, Germany, 8-9 October 2009) (WMO TD No. 1570), 45 pp, February 2011.

196. Report of the Second Session of the CAS JSC OPAG-EPAC and GAW 2009 Workshop (Geneva, Switzerland, 5-8 May 2009) (WMO TD No. 1577).

197. Addendum for the Period 2012 – 2015 to the WMO Global Atmosphere Watch (GAW) Strategic Plan 2008 – 2015, 57 pp, May 2011.

198. Data Quality Objectives (DQO) for Solar Ultraviolet Radiation Measurements (Part I). Addendum to WMO/GAW Report No. 146 - Quality Assurance in Monitoring Solar Ultraviolet Radiation: State of the Art (*electronic version only*).

199. Second Tropospheric Ozone Workshop. Tropospheric Ozone Changes: observations, state of understanding and model performances (Météo France, Toulouse, France, 11-14 April 2011), 226 pp, September 2011.

200. WMO/GAW Standard Operating Procedures for In-Situ Measurements of Aerosol Mass Concentration, Light Scattering and Light Absorption (Edited by John A. Ogren), 134 pp, October 2011.

201. Quality Assurance and Quality Control for Ozonesonde Measurements in GAW (Prepared by Herman Smit and ASOPOS Panel), 95 pp. October 2014.

202. Workshop on Modelling and Observing the Impacts of Dust Transport/Deposition on Marine Productivity (Sliema, Malta, 7-9 March 2011), 50 pp, November 2011.

203. The Atmospheric Input of Chemicals to the Ocean. Rep. Stud. GESAMP No. 84/GAW Report No. 203. 69 pp. (ISSN: 1020-4873).

204. Standard Operating Procedures (SOPs) for Air Sampling in Stainless Steel Canisters for Non-Methane Hydrocarbons Analysis (Prepared by Rainer Steinbrecher and Elisabeth Weiß), 25 pp. September 2012.

205. WMO/IGAC Impacts of Megacities on Air Pollution and Climate, 309 pp. September 2012 (ISBN: 978-0-9882867-0-2).

206. 16th WMO/IAEA Meeting of Experts on Carbon Dioxide, Other Greenhouse Gases and Related Tracers Measurement Techniques (GGMT-2011), Wellington, New Zealand, 25-28 October 2011, 67 pp, October 2012.

207. Recommendations for a Composite Surface-Based Aerosol Network, Emmetten, Switzerland, 28-29 April 2009, 66 pp. November 2012.

208. WMO GURME Workshop on Urban Meteorological Observation Design, (Shanghai, China, 11-14 December 2011).

209. Guidelines for Continuous Measurements of Ozone in the Troposphere (Prepared by Ian E. Galbally and Martin G. Schultz), 80 pp, February 2013 (WMO-No. 1110, ISBN: 978-92-63-11110-4).

210. Report of the Third Session of the CAS Joint Scientific Committee of the Open Programme Area Group on Environmental Pollution and Atmospheric Chemistry (JSC OPAG-EPAC), (Geneva, Switzerland, 27-29 April 2011) (*electronic version only*).

211. Rationalizing Nomenclature for UV Doses and Effects on Humans (CIE209:2014/GAW Report No. 211) . (ISBN: 978-3-902842-35-0)

212. Standard Operating Procedures (SOPs) for Spectral Instruments Measuring Spectral Solar Ultraviolet Irradiance, 21 pp. June 2014.

213. 17th WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases and Related Tracers Measurement Techniques (GGMT-2013), (Beijing, China, 10 - 13 June 2013), 168 pp. July 2014.

214. Report of the GAW 2013 Symposium and the Fourth Session of the CAS JSC OPAG-EPAC, Geneva, Switzerland, 18-20 March 2013, 82 pp, October 2014.

215. Report of the First Session of the CAS Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee (EPAC SSC), (Geneva, Switzerland, 10-12 June 2014), 32 pp. December 2014.

216. Seventh Intercomparison Campaign of the Regional Brewer Calibration Center Europe (RBCC-E), Lichtklimatisches Observatorium, Arosa, Switzerland, 16-27 July 2014, 106 pp. March 2015.

217. System of Air Quality Forecasting And Research (SAFAR – India), 60 pp. June 2015.

218. Absorption Cross-Sections of Ozone (ACSO), Status Report, 47 pp. June 2015.

219. Izaña Atmospheric Research Center, Activity Report 2012-2014, 157 pp. June 2015.