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Prepared by WMO
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Updated observational requirements for the Global Atmosphere Watch (GAW) Proposal for the Integrated Global Greenhouse Gas Information System (IG^{3}IS)

In response to CGMS action WG III A38.40
HLPP reference: 1.1

The document presents background material on the WMO Global Atmosphere Watch (GAW) Programme and on the planned Integrated Global Greenhouse Gas Information System (IG^{3}IS). The work accomplished so far by the GAW Task Team on Observational Requirements and by the GAW Scientific Advisory Groups (SAG) is described.

Three SAGs (Reactive Gases, Greenhouse Gases and Solar UV Radiation) have provided detailed requirements for a large suite of parameters of relevance to atmospheric chemistry and air pollution. These requirements have been passed on to the OSCAR Team for ingestion into the OSCAR Requirements Database. The other SAGs are preparing similar input.

An overview of relevant parameters within the three Application Areas pertinent to atmospheric chemistry is given in the document. Requirements specific to IG^{3}IS are also given.

Action/Recommendation proposed:

CGMS Members are invited to take note of the work carried out so far by the GAW Task Team on Observational Requirements and by the GAW Scientific Advisory Groups, and to provide their advice.

Updated observational requirements for the Global Atmosphere Watch (GAW); Proposal for the Integrated Global Greenhouse Gas Information System (IG^{3}IS)

1 INTRODUCTION

This document gives background information on the Global Atmosphere Watch Programme of GAW and the Integrated Global Greenhouse Gas Information System (IG^{3}IS), a new system being developed by WMO and partners. It then describes the progress in GAW on the Rolling Review of Requirements related to the three Application Areas that are concerned with atmospheric chemistry.

2 BACKGROUND

2.1 Global Atmosphere Watch

The Global Atmosphere Watch (GAW) Programme is implemented and undertaken by WMO Members and supported by international scientific communities. Together, these communities perform long-term observations of chemical composition and related physical characteristics of the atmosphere on a global scale, emphasizing quality assurance and quality control of the data, developing appropriate analysis and modelling tools and providing integrated products and services to users.

The **mission** of GAW is to

- Reduce environmental risks to society and meet the requirements of environmental conventions.
- Strengthen capabilities to predict climate, weather and air quality.
- Contribute to scientific assessments in support of environmental policy,

through

- Maintaining and applying global, long-term observations of the chemical composition and selected physical characteristics of the atmosphere.
- Emphasising quality assurance and quality control.
- Delivering integrated products and services of relevance to users.

Since its beginning, GAW has fulfilled a mandate from WMO Members by responding to their needs and clearly linking to the plans of national, regional, and international observing projects, programs, systems and strategies, e.g.:

- In providing a comprehensive set of high quality and long-term observations of atmospheric composition to support the United Nations Framework Convention on Climate Change (UNFCCC), especially by contributing to the implementation plan for the Global Climate Observing System (GCOS), the Intergovernmental Panel on Climate Change (IPCC) and to the development of Global Framework for Climate Services (GFCS).

- In supporting the Montreal Protocol for the Protection of the Ozone Layer and follow-up amendments.
- In supporting the Convention on Long-Range Transboundary Air Pollution (CLRTAP).
- In providing reliable observations to support assessment of the temporal and spatial variability of aerosols and reactive gases required to understand the impact of air quality on human health, ecosystems and infrastructures security.
- In providing high-quality data sets and forecasting tools for sand and dust storms (SDS) to reduce the impacts of this phenomenon.
- In providing guidance for optimizing regional observation networks (potential contributing networks) in atmospheric constituents observation.
- In promoting high-quality observations and enhancing the use of GAW's quality controlled data and inferred products in routine/operational services and research activities.
- In supporting studies on environmental protection, including marine and ecosystem health.
- In providing GAW products supporting agriculture and food security aspects.

2.2 Integrated Global Greenhouse Gas Information System

In order to provide GHG information that will support post COP21 action, there is a need for an Integrated Global GHG Information System (IG^3IS) working at the "policy-relevant" local, regional, and national scales, as well as global scales. IG^3IS combines atmospheric composition with bottom-up inventory data to better inform policy and decisions.
Goal: Combine atmospheric composition and socioeconomic activity data in partnership with the user community to:

- *Quantify progress of emission reduction agreements (e.g., Nationally Determined Contributions (NDCs)),*
- *Reduce uncertainty of emission inventory reports, and*
- *Inform additional mitigation actions*

IG^3IS Principles

- IG^3IS will serve as an international coordinating mechanism and establish and propagate consistent methods and standards.
- Diverse measurement and analysis approaches will fit within a common framework.
- Stakeholders are entrained from the beginning to ensure that information products meet user priorities and deliver on the foreseen value proposition.
- Objectives must be practical and focused.
- Success-criteria are that the information guides additional and valuable emission-reduction actions.
- IG^3IS must mature in concert with evolution of user-needs and policy.

Support of UNFCCC and Paris Agreement: *Quantify progress of agreements*

- Support "Global Stocktaking" in the context of the Paris Agreement:
    - More frequent and low latency trend assessment of *Intended Nationally Determined Contributions* (INDCs) are possible by combining

atmospheric composition and socioeconomic data. This will be in support of the Paris Agreement's desire to revisit the progress of countries' INDCs

- Guide Nations to use atmospheric composition and inverse modelling (e.g., UK example) in UNFCCC inventory reporting
- Enhancing Global Carbon Project methodology by increasing use of atmospheric composition data.

Key sub-national efforts and new mitigation: *Inform additional mitigation*

- GHG monitoring in large urban areas (megacities)
- Detection and attribution of CH_4 emissions from oil and gas sector

Improved Tools:

- Commercial aviation partnership to increase vertical GHG concentration profiles of atmospheric GHG concentrations (extend IAGOS concept)
- Isotopic top-down validation for fossil fuel CO_2 emissions (e.g., ^{13}C, ^{14}C).

More information on GAW is found here: http://www.wmo.int/gaw
More information on IG^{3}IS is found here:
http://www.wmo.int/pages/prog/arep/gaw/ghg/IG3IS-info.html

3 GAW TASK TEAM ON OBSERVATIONAL REQUIREMENTS

In 2011, the World Meteorological 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 that this work 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.

The Task Team was established in the autumn of 2014.
List of members: http://www.wmo.int/pages/prog/arep/gaw/documents/TT-Members-2015-07-10.pdf
Meeting reports and other relevant documents:
http://www.wmo.int/pages/prog/arep/gaw/TaskTeamObsReq.html

The Task Team has met twice. The first meeting took place in November 2014. There it was decided to define three application areas for the atmospheric chemistry theme:

- I. Forecasting Atmospheric Composition
- II. Monitoring Atmospheric Composition
- III. Providing Atmospheric Composition information to support services in urban and populated areas

The report from the first meeting is found here:

http://www.wmo.int/pages/prog/arep/gaw/Task-Team-Obs-Req/GAW_Report_2xy_WMO_GAW_TT_ObsReq_Report_DEC4_GRC-v2_clean.pdf

The second meeting took place in August 2015. At this meeting there was discussion on concrete variables to be measured. A report from that meeting can be found here: http://www.wmo.int/pages/prog/arep/gaw/Task-Team-Obs-Req/Summary%20of%20the%202nd%20TTObsReq%20Workshop.docx

The Scientific Advisory Groups (SAGs) of GAW have been engaged to work on the observational requirements for their respective parameters. Three SAGs have responded with Excel sheets with detailed requirements:

- Greenhouse Gas SAG
- Reactive Gases SAG
- Solar UV Radiation SAG

These Excel sheets have been passed on to the OSCAR team for ingestion into the OSCAR database. The Excel files are posted on the web and can be found at the bottom of this web page:
http://www.wmo.int/pages/prog/arep/gaw/TaskTeamObsReq.html

The Aerosol SAG is working on a scientific paper, which will be published in the peer-reviewed literature. Once that is accomplished, input will be provided for the OSCAR Requirements database. The SAG for Ozone is also working on the variables relevant for stratospheric ozone and ozone depletion.

4 OBSERVATIONAL REQUIREMENTS IN GAW

4.1 Observational requirements for Application Area I (Key parameters needed for Forecasting of Atmospheric Composition)

1. **All Global NWP variables** *(the requirements for these are assumed to be met from other application areas, flagged here are ones that should be checked to see if additional requirements may be needed to support atmospheric composition applications specifically)*
(e.g., PBL + Tropopause height) and others yet to be determined by WMO/GAW, cloud top/bottom, phase, COD, soil moisture

2. **Aerosols** *(here variables are listed generically, more specifics will be parsed out in requirements (e.g., wavelengths, chemical speciation, etc…)*
(aerosol mass, size distribution (or at least mass at 3 fraction sizes: 1, 2.5 and 10 micron) size 3nm-up, speciation and chemical composition, AOD at multiple wavelengths, PBL-AOD, AAOD, SSA, water content, ratio of mass to AOD, vertical distribution of extinction), wet deposition, pollen (key species)

3. **Reactive Gases, Trace gases (including GHG), Ozone Precursors** *(here variables are listed generically, more specifics will be parsed out in requirements*

(e.g., O_3 including in situ ground level, column, profile, etc.)

(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, OCS, TOA surface short/longwave radiation, UV

4.2 Observational requirements for Application Area II

(Key parameters needed for Monitoring of Atmospheric Composition)

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, PSC occurrence, H_2O, Clouds including COD, CCN, IN

2. **Aerosols**
   (aerosol mass, number, size/surface distribution (1, 2.5, 10 micron), speciation and chemical composition, AOD at multiple wavelengths, AOD night-time, 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, BrC) aerosol index, refractive index, wet deposition (composition), Hg, POPs, primary biological particles)

3. **Reactive gases, Trace gases (including GHGs), Ozone Precursors**

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, DMS, MSA, OCS, halogenated VSLS, HONO, organic nitrates

4. **Trace gas isotopes and air mass tracers**

CO_2, methane, N_2O, CO, (D, ^{13}C, ^{14}C, ^{17}O, ^{18}O, ^{15}N) also in the aerosol phase, for biomass burning, stratosphere, surface (radon, ^{7}Be, etc.)

5. **Others** *(this list is not complete, but is to capture info needed for emissions, parameterizations dependent of land use/cover, etc.)*

(Actinic flux, UV, short/long TOA surface, fire radiative power, land proxies, lightning, dry and wet deposition, pollen (key species), ocean colour, chlorophyll-A, LAI, PAR, FPAR, fluorescence, vegetation maps, land use maps, burned areas, night light, fire counts, wet lands, ship routes, forest inventory, biomass density, crop lands).

4.3 Observational requirements for Application Area III

(Key parameters needed for Urban applications)

The identification of requirements is under development: there will be similarity to what has been covered previously. Further input from the GURME SAG is needed here. The variables needed from observation include:

1. **All Global NWP variables**
(e.g., PBL) and others yet to be determined by WMO/GAW (plus elements not covered in NWP)

2. **Aerosols**
aerosol mass, size distribution (or at least mass at 3 fraction sizes: 1, 2.5 and 10 micron), speciation and chemical composition, AOD at multiple wavelengths, water content, ratio of mass to AOD, vertical distribution of extinction, concentrations of metals

3. **Reactive Gases, Trace gases, Ozone Precursors**
Total ozone, profile ozone, surface ozone, NO, surface NO_2, PAN, HNO_3, NH_3, CO, CO_2, CH_4, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics), surface SO_2, HCHO, HO_x

4. **Others**
Actinic flux, fire radiative power, land proxies, dry and wet deposition, pollen (key species)

Essential variables (list most essential, keep number < = ~10) are:
aerosol mass, size distribution (or at least mass at 3 fraction sizes: 1, 2.5 and 10 micron), speciation and chemical composition, AOD at multiple wavelengths, water content, ratio of mass to AOD, vertical distribution of extinction, profile ozone, surface ozone, surface NO_2 , CO, surface SO_2 , CO_2.

4.4 Sub-application areas

For each application area we identified important sub-application areas, and identified most important parameters to support them. This was used to help identify the priority and cross cutting parameters to focus RRR on.

Forecasting

- volcanic ash (SO_2, vertical ht, AOD, optical properties
- biomass burning smoke (PM trace gases (CO,O_3, ..), BC absorption, AOD, PBL, …)
- sand & dust (dust, AOD, depolarization, soil moisture…
- pollen
- GHGs
- air quality

- solar radiation (UV & energy)

Monitoring

- treaty/conventions (e.g., GHGs and stratospheric O_3),
- air quality (regulatory & health (global burden of disease)
- ocean acidification
- crop & ecosystem services
- climate (radiative forcing)
- trends including oxidizing capacity
- visibility
- emission constraint/updating
- water cycle including cryosphere

4.5 Priority variables across Application Areas

Priority variables were identified that cut across **all** application areas. These will be the list that we *must* define requirements for. Ideally we will over time establish requirements for more parameters.

Priority list:
Aerosol: PM2.5, PM10, BC, Dust (speciated), OA (including SOA), AOD, AAOD, wet deposition (speciated)

GHGs: CO_2, CH_4, CFCs, HCFCs, N_2O

Reactive Gases: O_3, SO_2, NO_2, CO, NH_3, HCHO, Isoprene, VOCs (speciated), HO_x Isotopes, water vapour

Also: TOA and surface short/long rad, actinic flux, UV
Others (which we may/will not set requirements for: clouds, PBL, tropopause height.

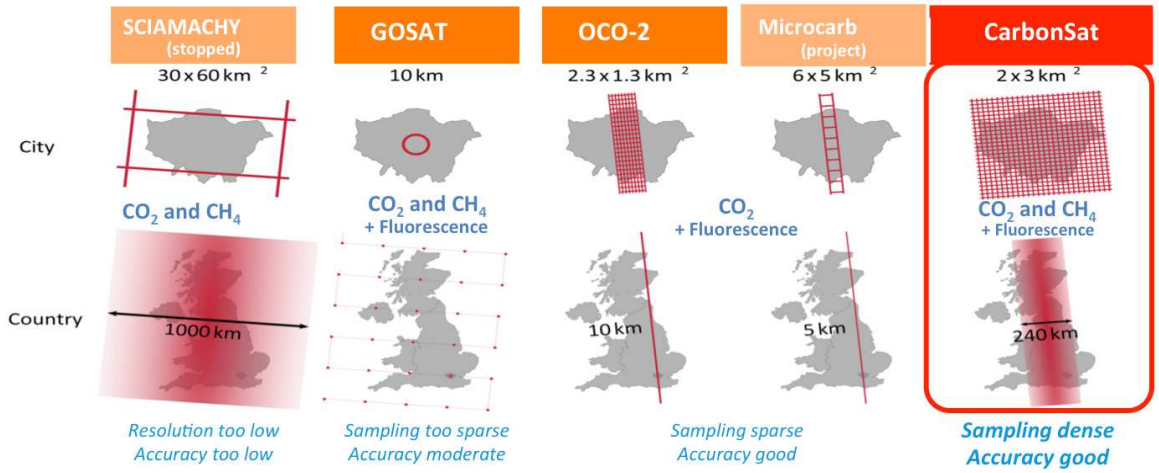
4.6 Requirements for IG^{3}IS

The Greenhouse Gases SAG has also developed requirements that are specific for the needs of IG^{3}IS, namely for the quantification of sources and sinks. They are given in the table below.

Objective	Temporal scale	Spatial scale (N-S) km x (W-E) km	Accuracy				
			Goal	Breakthrough	Threshold	Unit	Comment
CO_2 Regional Land	Monthly Annual	500 x 500[1]	0.2 0.05	0.5 0.1	1 0.25	gC m^{-2} day^{-1}	Corresponds to 5-14 $MtCO_2$ Corresponds to 17-33 $MtCO_2$
CO_2 Regional Ocean	Monthly Annual	1000 x 2000	0.005 0.005	0.01 0.01	0.03 0.03	gC m^{-2} day^{-1}	Corresponds to 1.1-2.2 $MtCO_2$ Corresponds to 13-27 $MtCO_2$
CO_2 City scale	Instantaneous (at overpass time)	N.A.	2	4	20	$MtCO_2$ yr^{-1}	For targets larger than 20 $MtCO_2$ yr^{-1} (*e.g.* Paris, Los Angeles, Berlin), excluding wind speed error (this corresponds to an accuracy between 10% and 20%)
CO_2 Point source	Instantaneous (at overpass time)	N.A.	1	2	10	$MtCO_2$ yr^{-1}	For targets larger than 10 $MtCO_2$ yr^{-1}, excluding wind speed error. Specified accuracy values correspond to instantaneous fluxes expressed on an annual time scale
CH_4 Regional	Monthly	500 x 500[2]	5	10	20	$mgCH_4$ m^{-2} day^{-1}	Corresponds to 38-112 $ktCH_4$
CH_4 point source	Instantaneous (at overpass time)	N.A.	4	8	40	$ktCH_4$ yr^{-1}	

With respect to the requirements for future instrumentation, the Greenhouse Gases SAG has made the following overview:

- **Dense sampling**: images of CO_2 and CH_4 weather and plumes
- **High spatial resolution**: capture emission hotspots and avoid clouds
- **High accuracy:** because atmospheric column gradients are small
- **Global coverage**: because most regions of the Earth have CO_2 and CH_4 fluxes



5 ACTIONS AND/OR RECOMMENDATIONS FOR CONSIDERATION BY CGMS

CGMS Members are invited to note the formation of the GAW Observational Requirements Task Team and the work carried out so far. The Task Team and the GAW Scientific Advisory Groups would be happy to receive advice.