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COMMISSION FOR BASIC SYSTEMS
OPEN PROGRAMMME AREA GROUP ON
INTEGRATED OBSERVING SYSTEMS

EXPERT TEAM ON OBSERVATIONAL DATA REQUIREMENTS AND REDESIGN OF THE GLOBAL OBSERVING SYSTEM
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REVIEW AND UPDATE OF STATEMENTS OF GUIDANCE FOR OTHER APPLICATIONS

Statement of Guidance on Atmospheric Chemistry based on the IGOS Theme Report on Integrated Global Atmospheric Chemistry Observation (IGACO) led by WMO/GAW and ESA

(*Submitted by the Secretariat)*

Summary and Purpose of Document

This document is an Executive Summary of a strategy and requirements for a Global Observing System for atmospheric chemistry based on satellite, ground-based and aircraft observations. It falls under the responsibilities of the WMO Global Atmosphere Watch (GAW) Programme. GAW was established by Congress in 1989 combining the WMO Global Ozone Observing System (GO_3OS) and the Background Air Pollution Monitoring Network (BAPMoN) which had been in place for decades.

ACTION PROPOSED

The meeting is invited to take into account information presented in this document when discussing interrelation of the GOS with other observing programmes.

Integrated Global Atmospheric Chemistry Observations System

IGACO

Theme Report

draft 8

October 2003

1. Foreword

Long term measurements have clearly shown that human activities are changing the composition of the Earth's atmosphere. Research has demonstrated the important consequences of such changes for climate, human health, the balance of ecosystems and the ability of the atmosphere to cleanse itself of harmful pollutants and greenhouse gases. The awareness that chemical species in the atmosphere are key elements of the Earth system and public concern about the impact of man has led to international organizations, such as WMO, UNEP and ICSU, supporting national and international research programmes or assessments that lead to international conventions (e.g. Vienna Convention on Ozone Depletion, United Nations Framework Convention on Climate Change) and national directives.

In a declaration published on July 31, 2003, the International Earth Observation Summit held in Washington, D.C., emphasised the vital importance of Earth observation activities, encouraging the development of a comprehensive, coordinated, and sustained Earth observation system, as well as activities leading to improved utilisation of data by developing countries.

The "Integrated Global Atmospheric Chemistry Observations" (IGACO) theme was approved by the Integrated Global Observing Strategy (IGOS) Partnership as the fourth theme in June 2001, following those for the Ocean, the Global Water Cycle, and the Global Carbon Cycle. WMO and ESA convened a panel of international scientists which produced this theme report, with the able assistance of a number of distinguished reviewers. The panel is also grateful for constructive comments from the members of the secretariat and executive committee of the IGOS partnership, as well as the Strategic Implementation Team of CEOS.

The objective of this report is to initiate a process leading towards a globally coordinated development of future observation and integration programmes, whose components are either in place or, with careful planning, can be implemented within the next 10 years. The report will :

- identify the current major societal and scientific issues associated with atmospheric composition change;
- establish the requirements for observations of atmospheric composition and their analysis, integration and utilisation;
- review the existing observational systems including data processing and distribution systems and validation programmes vis-à-vis these requirements; and
- propose an implementation plan to adapt the systems to meet the identified requirements.

The emphasis of this report is on the need for long-duration observations and their societal and scientific applications. The focus will therefore be on operational systems providing continuity and reliability, and on establishing priorities of requirements, in order to establish a technically and programmatically feasible long-term solution. It should also be noted that this report deals with the *global* observation system. The schedule for implementation is divided into short and long term actions. One thing is evident; with the lead times for deploying satellites and for developing ground stations and routine aircraft programmes, planning for funding and implementation of both stages has to begin immediately if the aims of the report are to be fulfilled.

The report draws heavily upon the "WMO/CEOS report on a strategy for integrating satellite and ground-based observations of ozone". It has collected world-wide expertise and generated quantitative observation requirements and summaries of various observational systems.

It is the panel's sincere wish that the strategy proposed in this report commends itself to organizations, funding agencies and researchers around the world who would be involved in implementing an Integrated Global Atmospheric Chemistry Observation system. It is our hope that it will bring us one step closer both to observing the atmosphere and, with the knowledge gained, to alleviating the current chronic problems in the atmosphere caused by human activity.

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2. Executive Summary

The objective of this report is to define a feasible strategy for deploying an Integrated Global Atmospheric Chemistry Observation System (IGACO), by combining ground-based, aircraft and satellite observations with suitable data archives and global models. The purpose of the system is to provide representative, reliable and accurate information about the changing atmosphere to those responsible for environmental policy development and to weather and environmental prediction centres.

2.1 Motivation

The atmosphere, like the other components of the Earth System, is affected by the continuous increase in human population and activity, which have resulted in a variety of remarkable changes since the industrial revolution of the 19th century. Among these are

- the global decrease in stratospheric ozone and the attendant increased in surface ultraviolet radiation, emphasised by the "ozone hole" appearing over the Antarctic,
- the occurrence of summer smog over most cities in the world, particularly in developing countries, and the increased ozone background in the northern troposphere,
- the continuing increase in greenhouse gases and aerosols in the atmosphere,
- acid rain and the eutrophication of surface waters and other natural ecosystems by nitrate deposited from the atmosphere;
- enhanced aerosol and photo-oxidant levels due to biomass burning and other agricultural activity, and
- the increase in fine particles in regions of industrial development and population growth with an attendant reduction in visibility and an increase in human health effects; the effect appears as Arctic Haze in regions far from industrial activity.

Many of these changes in atmospheric composition have socio-economic consequences through adverse effects on human and ecosystem health, on water supply and quality and on crop growth. A variety of abatement measures have been introduced or considered to reduce the effects. However, continued growth in human activities to expand economies and to alleviate poverty, will ensure that these effects continue to be important for the foreseeable future.

2.2 The need for IGACO

Over the last half century, a variety of national networks have been installed to monitor atmospheric trace gases of local concern and, as the trans-boundary nature of air pollution was recognised, there has been some limited coordination of network development in North America, Europe and globally. Most of the activities concern ground-based stations, including balloon sondes and, lately, remote sensing. The first regular aircraft measurements were started in the 1990s by deploying unattended instrument packages on commercial airliners.

Initially, satellites added a new dimension by providing a global picture of the total column ozone. Now, it has become possible to measure from space vertical profiles in the stratosphere and total column amounts together with, in some key cases, tropospheric amounts and profiles of a number of important chemical constiutents. At the same time, global weather and climate models that incorporate chemical cycles are emerging, which are capable of assimilating a variety of observations into a global picture.

At present, these activities are largely separate and driven by specific scientific or legal objectives. Unfortunately, because of the lack of overall coordination and inherent shortcomings in the individual systems, none of the present monitoring activities achieves the completeness, representativeness and resolution required for obtaining a global view. There are thus large gaps in our picture of the atmosphere and in our understanding of the various influences that drive atmospheric variability and long-term changes.

To obtain a reliable global picture of the changing atmosphere, a coupled observational/modelling system is required, which is built partly on already available components, but is designed to obtain and fully integrate the best data that the diverse observation systems provide. The implementation of IGACO will require substantial investment to fill gaps in the existing satellite and other systems, whose current generation will cease operation just at the time when IGACO should go into operation. Clearly, if we want to avoid severe uncertainties in our diagnostic and prognostic capabilities, decisive steps towards the assembly of IGACO must be taken without delay.

2.3 The chemical species and ancillary parameters required for IGACO

Taking account of some realistic financial and logistic constraints, the chemical species and parameters to be included in IGACO were selected using the following three criteria:

- the constituent plays a key role in one or more of the major atmospheric chemistry issues, i.e., climate change, stratospheric ozone depletion, air quality, or oxidizing capacity of the atmosphere
- it is now possible, or will be likely within the next 10 years, to measure the constituent or parameter globally by both satellite and non-satellite systems;
- the constituent has the potential to be assimilated in global atmospheric models.

The selected chemical constituents and parameters are:

Group 1 components; to be implemented within the short term, i.e. before 2013:

ozone (O_3)	water vapour (H_2O)	carbon dioxide (CO_2)
carbon monoxide (CO)	nitrogen dioxide (NO_2)	bromine oxide (BrO)
CFC-12 (CF_2Cl_2)	HCFC-22 ($CHClF_3$)	

and the following aerosol optical properties:
optical depth (*VIS+IR*) + extinction coefficient (*VIS*) + absorption optical depth (*VIS*)

For these components, there needs to be a reasonably comprehensive set of global observations for both the troposphere and the stratosphere using a sparse number of satellites with Low Earth Orbit (LEOs), ground-based stations and aircraft platforms. Atmospheric modelling capabilities are required to begin to assimilate them into a global picture.

Necessary measures include the development of the next generation of satellites, the reinforcement of routine aircraft and ground-based observations, and the systematic development and implementation of data assimilation techniques. Existing networks require maintenance, gap-filling and coordination.

Group 2 components; to be implemented in the long term, i.e. beyond 2013:

methane (CH_4)	formaldehyde (HCHO)	ethane (C_2H_6)
sulfur dioxide (SO_2)	nitric acid (HNO_3)	chlorine nitrate ($ClONO_2$)
nitrogen monoxide (NO)	chlorine monoxide (ClO)	chlorine dioxide (OClO)

hydrogen chloride (HCl)	methyl bromide (CH_3Br)	halons (e.g. CF_3Br)

and J(NO_2) and J(O_3) (UV radiation at specific wavelengths in the troposphere).

For this group, all the current satellites are in the experimental "demonstration" mode and only have limited lifetimes. There are some ground based *in-situ* or total column networks, mainly in the developed countries. However, the global network is sparse.

Ancillary parameters

The following additional parameters are required for atmospheric chemical modelling and retrieval of remote sensing data:

temperature (T),	pressure (p),	fire frequency,
cloud top height,	cloud coverage,	albedo
solar radiation,	lightning flash frequency.	wind (u, v, w)

The report details the *targets and thresholds for precision, accuracy, temporal and spatial resolution* that must be met for each of the chemical species and parameters to be meaningful within IGACO.

2.4 Essential Components of IGACO

For maximum functionality the system should include the following four components.

- **Networks of ground-based instrumentation**, including balloon sondes, millimetre wave radiometers, lidars, UV-Visible spectrometers and FTIR , to measure static concentrations and vertical profiles of the principal chemical species, aerosols and ancillary parameters on a regular basis; effectively this means that the current network needs to be maintained and expanded to fill critical gaps in coverage.
- **Regular aircraft-based measurements** for chemical and aerosol measurements in the troposphere and particularly in the Upper Troposphere/Lower Stratosphere (UT/LS), which is sensitive to chemical and climate changes. The current fleet needs to be expanded with respect to instrumentation and global coverage and to include regional aircraft that monitor the lower to middle troposphere. Routine measurements in the lower to middle troposphere using non-commercial light aircraft could be a useful part of the system.
- **Satellite-based instrumentation**, preferably mounted on a combination of geostationary (GEO) and Low Earth Orbit (LEO) satellites; 4 GEO and 2 LEO satellites would be the minimum for IGACO; if only LEO satellites are an option, many more would be needed to provide measurements with the temporal and spatial resolution needed for sufficient coverage and data assimilation using atmospheric models. Strong consideration should also be given to measurements in the dark atmosphere.
- **A comprehensive modelling system** capable of assimilating the data for the chemical species, aerosols and ancillary parameters obtained from the three measurement components into a comprehensive global picture; assimilation techniques for chemical species other than ozone are still in the demonstration phase and need to be developed into operational procedures, which will require to develop physical parameterisations.

Further essential parts of IGACO are end-to-end quality assurance and quality control and data collection, integration and analysis.

2.5 The implementation of IGACO

Two steps are required to implement IGACO in good time and avoid gaps in data coverage.

IGACO Phase-1: short term (0-10 year, i.e. before 2013)

Specific actions should include:

a. Establishment of an IGACO system for all *Group 1* components.

b. Development of data harmonisation and Quality Assurance / Quality Control for all aspects of the initial system.

c. Upgrade of selected ground-based stations and routine aircraft platforms.

d. Development of automated algorithms necessary for satellite measurements in the troposphere for as many parameters as possible.

e. Development of modelling and assimilation tools, parameterisations and strategies to produce a reliable overall picture from the various measurement components.

f. Planning and initiation of a sustainable *long term* network for IGACO Phase-2, with emphasis on a coordinated satellite system of LEO and GEO instruments complemented by non-satellite observational networks.

IGACO Phase-2: long term (>10 year, ie. beyond 2013)

As shown by the timelines in Section 5, there is a looming gap in the provision of satellite-based instruments for atmospheric chemistry observations since, by then, the present "demonstration mode" satellites have finished their missions. For IGACO, new operational satellites as well as an enhanced non-satellite measurement network will be required.

Specific long-term requirements are to:

a. provide an operational network with 4 GEO and 2 LEO satellites; *immediate action* is required from the involved agencies to avoid a time gap in global surveillance.

b. provide satellite instruments for measurements of all *Group 1 and 2* components.

c. upgrade ground-based stations to measure *Group 1 and 2* components, and to install new stations in locations to which the assimilation models are particularly sensitive.

d. secure routine aircraft measurements, to implement instrumentation for *Group 1 and 2* components, and to add routes to improve global coverage.

e. further develop models and assimilation techniques to provide a reliable picture of the atmospheric variability and long-term changes.

2.6 Summary of IGACO Recommendations

As detailed in Section 6, the principal recommendations of IGACO are:

GR1 Establishment: An Integrated Global Atmospheric Chemistry Observation System (IGACO) should be established for a target list of atmospheric chemistry variables and ancillary meteorological data.

GR2 Continuity: The data products from satellite and non-satellite instruments that are to be integrated into a global picture by IGACO must have assured long term continuity

GR3 Management of IGACO. The responsibility for the co-ordination and implementation of the IGACO should rest with a single international body. International and national agencies responsible for aspects of IGACO should be committed partners and agree on their appropriate responsibilities.

GR4 Gaps in observational coverage: for each target species and variable, the present gaps in the current spatial and temporal coverage need to be filled by extending the existing measurement systems.

GR5 Long term ground validation of satellite observations: in order to ensure consistency over time and the accuracy of a satellite measurement, sustained quality assurance measures, over the entire lifetime of a series of satellite observations, is essential.

GR6 Validation of vertical profile data from satellite observations: A set of high performance scientific instruments using ground, aircraft and balloon platforms, possibly operated on campaign basis, must be maintained to provide the crucial validation data.

GR7 Comparability: The ability to merge observations of different types must be ensured by insisting that appropriate routine calibration and comparison activities linking diverse measurements together are part of an individual instrument measurement.

GR8 Distribution of data: universally recognised distribution protocols for exchange of data on atmospheric chemical constituents need to be established.

GR9 Establish multi-stake holder World Integrated Data Archive Centres for the targeted chemical variables.

GR10 The development of comprehensive chemical modules in weather and climate models with appropriate data assimilation should be an integral part of the IGACO system.

GR11 Strong coordination with meteorological services is essential for the ancillary meteorological data, required by IGACO, to be accessible.

GR12 The scientific requirements indicated in section 3 of this report should be adopted and funded as soon as possible.

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