Constellation Concept for Atmospheric Composition

Committee on Earth Observation Satellites (CEOS)

Introduction

The Atmospheric Composition (AC) Constellation is one of of four pilot projects initiated by CEOS to bring about technical/scientific cooperation and collaboration among space agencies that broadly meet the goals of the international Group on Earth Observations (GEO) as well as other national and international entities promoting environmental research and applications. The AC Constellation Concept will result in mission(s) or data delivery that serves the broader science and application community that can be advocated by the CEOS agencies. The Constellation concept has been indorsed in the GEO Work Plan, 2007-2009 (GEO AR-07-P1, Virtual Missions).

NASA has been selected as the lead CEOS space agency for developing a Constellation for "Atmospheric Chemistry". NASA has determined that it is appropriate to expand this topic to include aerosols and greenhouse gases and rename this particular Constellation concept the ,"Atmospheric Composition Constellation ". The Constellation will also include observations that link radiation and atmospheric composition. This expanded scope complies with the CEOS member agencies programs and better serves the GEO Societal Benefit Areas (SBAs). The Atmospheric Composition Constellation goal is to collect and deliver data to develop and improve predictive capabilities for changes in the *ozone layer, air quality and climate forcing* associated with changes in atmospheric composition. These data will support four of the nine GEO SBAs: Health (HE-07-P3), Energy (EN-07-02), Climate (CL-06-02), and Ecosystems.

User requirements for Atmospheric Composition measurements have been developed by national and international panels and user groups. These are mature and are supported by the Agencies in ongoing mission definition studies. Specific application for these data includes national forecasting and environmental protection agencies which require even more accurate and faster data delivery. Data for forecasting are needed on a global basis because of the impact of long range transported pollution on regional air quality. Climate and and environmental assessment users (IPCC, WMO/UNEP, USA CCSP, EU PROMOTE) require extremely accurate long term data, on a global basis to verify treaty and convention which protect and assess climate change (Montreal Protocol, Kyoto, etc.).

A. Science Questions and Scope

The atmosphere links all of the principal components of the Earth system interacting with the oceans, land, ice sheets, as well as terrestrial and marine plants and animals. Emissions from natural sources and human activities enter the atmosphere and are transported to higher altitudes and over the globe. Specifically the AC Constellation will address the following questions:

- How is ozone recovery responding to the Montreal protocol and what are the effects of climate change on the stratospheric ozone?
- How do changes in regional air quality effect ecosystems. What are the impacts of long range transport of pollution on local air-quality
- How do changes in atmospheric composition (radiatively active gases and aerosols) affect climate?

"*Observations have clearly shown that human activities are changing the composition of the Earths atmosphere. Research has demonstrated that there are important consequences of such changes for climate, human health, and the balance of ecosystems...* " IGOS-P/IGACO, 2004

Understanding Atmospheric Composition in the Earth system requires an integrated approach including a hierarchy of space based and ground systems which collect data of sufficient scope and accuracy for modeling and assessment for intelligent decision making. The Atmospheric Composition Constellation will result in a concept for the space component to meet this goal with the understanding that ground, balloon, and aircraft observations are necessary and complimentary.

At the present time Envisat, SciSat, Odin, and Aura are collecting high quality and comprehensive data on Atmospheric Composition. The oldest of these missions are four years and newest two years. At the present time continuity of a subset of these data will only be collected by METOP and its follow-on. Existing and follow-on observations will be primarily collected from low Earth orbit therefore temporal coverage will be limited. There is an increasing need for higher spatial and temporal resolution which will likely require missions with advanced instrumentation in alternative orbits such as geostationary or non-sun synchronous in the 2010 timeframe and beyond.

B. Participants in the AC Constellation

CEOS has pointed out that national observing requirements will continue to dominate space agency spending. However, it clear that requirements for GEOSS can not be met by a single nation. The developing NASA Science Plan recognizes that partnerships are essential, "...because of the complexity and breadth of these issues and that the atmosphere links all nations".

At the present time ESA, CSA, NASA, and Eumetsat (October 2006) have major assets presently in orbit. Other CEOS agencies have made substantial contribution in the form of technology and/or data distribution. The following lists these participants:

USA: NASA (HQ, GSFC, LaRC, JPL)
USA: NOAA (NESDIS, NWS)
EU/GMES
ESA (ESRIN, ESTEC)
Eumetsat

Japan:JAXA
Canada: CSA, MSC
Netherlands: NIVR
France: CNES
Germany: DLR
China: NSMC, CSSAR, CAST

C. Constellation Plan

CEOS has taken the responsibility to develop a planning process whereby it proposes to provide the space component of the international Group on Earth Observations System of Systems (GEOSS) Implementation Plan. In doing so it will establish a framework for long term coordination among the CEOS member agencies where the "Constellation" concept will demonstrate specific opportunities for meeting science discipline and application requirements by the agencies. The AC Constellation plan will include the following elements:

- Develop a consensus for priorities based on emerging societal needs and established user requirements from both operational and research communities
- Determine if there are inconsistencies or deficiencies among the various requirements and reconcile differences if necessary
- Evaluate existing and upcoming missions, both operational and research and compare with requirements
- Define enhancement in the area of cal/val, quality control, and data accessibility and interoperability
- Establish how existing and approved missions could work synergistically to meet the international user community requirements and in particular the GEO Societal Benefit Areas
- Develop rational and strategy for new mission(s) to meet existing requirements not being met and for possible new requirements. *Strategy to include architecture, schedule, and possibly costs*

In parallel to the AC Constellation study, CEOS will define how the Constellation concept will be implemented through a Process study. The study will begin to define standards on how space agencies can participate.

D. User Requirements

The CEOS agencies have considered and for the most part adopted requirements for Atmospheric Composition observations as a result of research conclusions, study

solicitations, user workshops, etc. The following are examples of published requirements in the US and the international community:

- US: NASA Science Plan, USA CCSP, NCAR AQ Workshop, NPOESS EDRs
- International: GEO GCOS, CAPACITY, GMES, PROMOTE, IGACO/WMO, SPARC, and Eumetsats post-EPS studies.

User requirements are mostly consistent and build-on or refer-to each other. The AC Constellation study will prioritize requirements and consider emerging needs. Science and application users will participate in the Constellation concept study to insure requirements are met.

E. In-orbit Capabilities

The space agencies have invested considerable resources in instrument technology and missions for observing atmospheric composition. Many of these assets were conceived prior to the present intensified concerns about the environment and climate change. For many important key measurements needed for long term trends or for environmental applications no follow-on missions are planned. As discussed above, existing upcoming and missions under consideration will be reviewed for consistency with requirements or how they may be configured if used synergistically. The AC Constellation plan will initially study how assets under consideration can be used to meet the needs of GEO as well as national priorities.

- Existing: Aura, Envisat, SciSat, ODIN, CALIPSO, Terra/MOPITT/CERES, Aqua/AIRS/CERES, POESS/SBUV-2, POLDER, Metop (launch Oct '06)

- Upcoming approved: OCO, GLORY, NPP/NPOESS (aerosol and ozone, no chemistry), EarthCARE, ADM-Aeolus, GOSAT, FY-3/SBUS-TOU

- ESA EE Pre-Phase A: TRAQ (AQ), PREMIER (UT/LS), A-SCOPE (CO2)

- Under Consideration: High resolution multispectral imagers in coordinated orbits: GMES, NASA (LEO, MEO, GEO, L1 orbits

F. Known Missing Capabilities/Components

Enormous breakthroughs in atmospheric research have been achieved over the past several years through recent satellite observations. Satellite observations for applications and decision support are now being actively investigated and implemented. Nevertheless new questions are unfolding as the Earth system begins to respond to climate changes, and new and more accurate observations are becoming apparent. The following is a draft list of known major issues facing the atmospheric sciences applications communities for remotely sensed measurements that will be addressed by the Atmospheric Composition Constellation study:

- Continuity of trace gas stratospheric measurements involved in ozone chemistry. These are needed to better understand trends and to quantify the effectiveness of the Montreal protocol (Measurements stop with Aura and Envisat)

- Accurate and continued monitoring in the UT/LS, with high vertical resolution, for climate research and applications (Limb measurements required)

- Improved accuracy and coverage of radiatively active gases and aerosols in the boundary layer needed for surface flux assessment, aerosol/cloud formation remain the largest uncertainties in climate forcing (Boundary layer measurements for gases remain a challenge)

- Short and long term temporal and spatial variation measurements of radiatively and chemically active trace gases and aerosols to determine their impact on air quality for improved inventories, predictions, and assessments. (Geostationary or non-polar/sun-sync orbits needed)

- Tracking trans-continental and -oceanic transport of tropospheric pollutants and their precursors. (Continuing global coverage needed)

- Interoperability of atmospheric composition data across existing and planned missions. Interoperability is a major objective of GEO, CEOS, WMO, etc.

G. Implementation

The AC Constellation will begin with the assembly of a study team consisting of CEOS Agencies with Atmospheric Composition assets and interests and who authorized to commit resources for this study and its implementation. The Agency study team will complimented by an Advisory group from the science and application communities to insure requirements are being properly considered and assist in establishing priorities The operation and interaction of the Agency and Advisory teams will be defined after the first meeting of the Agency participants. The combined Study team will consider the following elements of the AC Constellation:

- Develop a virtual constellation of existing and upcoming missions using synergies among the instruments. This will be a a cut attempt to establish how well GEOSS objectives can be met.

- Study advanced architecture with new space assets and varying orbits with expectations that new technology could also be brought forward to best meet user requirements

- Cal/Val is a crucial component of the Constellation. It is an end-to-end process, essential for insuring data accuracy, so that can be used for its intended purpose. This

will include an examination of the capabilities of the ground based systems for validation. *WGCV involvement*

- Data system interoperability is major GEO objective (AR-07-P1) to insure that data are useful, properly targeted, and easily accessible. *WGISS involvement*

- Data access and discovery from distributed systems will be provided via standard interfaces and protocols by national archives. *WGISS involvement*

G. Schedule

Implementation and schedule of the Constellations remains uncertain. The following are possible milestones.

- Presentation of the four candidate Constellation Concepts to the CEOS Strategic Implementation Team (SIT) in La Jolla, CA, September 19, 2006 Confirm membership and establish Constellation priorities

- First full draft at CEOS Plenary, November 14, 2006.

- Possible presentation at GEO Summit or Plenary

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