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GEOSS, CEOS, and the Future Global Remote Sensing Space System for Societal Benefits

Stephen A. Mango  
Stephen P. Sandford  
Ranganath R. Navalgund  
Haruhisa Shimoda  

Editors

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Introduction

Significant progress has been made in the world’s efforts towards a Global Earth Observing System of Systems [GEOSS] since the GEOSS Conference at the Fifth SPIE Asia Pacific Remote Sensing Symposium in Goa, India in November 2006 and, to be sure, since the GEOSS Conference at the Fourth SPIE Asia Pacific Remote Sensing Symposium in Honolulu, Hawaii in November 2004.

It was realized at the turn of the century that a hallmark of the emerging Twenty-First Century was the emergence of globalization in many areas important to society. An important factor in achieving globalization to improve societal conditions would be the establishment of a global, integrated Earth observing system. In the last five years, many national and international agencies have met and agreed to the development of a cooperative strategy for understanding the Earth’s environment and its interactions with the peoples of the Earth. Several high-level activities have culminated in Earth Observation Summits, Group on Earth Observations Plenary Meetings and GEO Ministerial Summits and several Working Groups, Task Forces and Committees.

One of the key foundation stones for a Global Earth Observation System of Systems (GEOSS) and the Group on Earth Observations (GEO) was laid in place at the 2002 World Summit on Sustainable Development in Johannesburg, South Africa. At this Summit the participating countries and organizations “highlighted the urgent need for coordinated observations relating to the state of the Earth”. In June 2003 in Evian, France the Group of Eight (G8) Summit affirmed the importance of such an urgent need for coordinated observations relating to the state of the Earth. One month later in Washington, DC, July 2003, the first Earth Observation Summit (EOS-I) convened and adopted the Declaration to establish the ad hoc, intergovernmental Group on Earth Observations (GEO) to develop a 10-Year Implementation Plan to build a Global Earth Observation System of Systems (GEOSS) over the next decade. Summit EOS-II occurred in February 2004, in Tokyo, Japan, to adopt the Framework Document which defined the scope and intent of a Global Earth Observation System of Systems (GEOSS). One year later in February 2005 Summit EOS-III convened in Brussels, Belgium to endorse the GEOSS 10-Year Implementation Plan that had been formulated by many of the participating countries and organizations in separate and joint working groups and affirmed and approved in GEO Plenaries.

The formative GEO I Plenary took place May 3–4, 2005 in Geneva, Switzerland. It was at this Plenary that the all important, 10-Year Implementation Plan endorsed by all members at the EOS-III Summit in February 2005, was adopted for execution by the new GEO. As stated by the GEO, the GEOSS vision is embodied in its 10-Year Implementation Plan.
Subsequent GEO Plenaries in the next three and a half years significantly advanced the cooperative process of formulating a realizable GEOSS: GEO II—December 2005, Geneva, Switzerland, GEO III—November 2006, Bonn, Germany, GEO IV—November 28-29, 2007, Cape Town, South, Africa (and a Ministerial Summit, November 30, 2007 also in Cape Town) and the most recent GEO V—November 2008, Bucharest, Romania. GEO V—accepted a 2009–2011 Work Plan that details the actions governments and organizations will take to make the Global Earth Observation System of Systems (GEOSS) a reality. The stated intention is that these activities will build the fundamental infrastructure underpinning GEOSS and establish products and services for decision-makers in the nine Societal Benefit Areas. The next GEO-VI Plenary will be held in Washington, DC in late 2009.

Membership in the GEO and early participation in the planning for a GEOSS has led to a gathering storm of early commitments and activities. The GEO Secretariat clearly indicates that membership in the GEO is open to all member States of the United Nations, of which there are presently 192 member States, and to the European Commission, of which there are presently 25 members. As of November 2008 there are 76 countries plus the European Commission for a total of 77 registered as GEO Members (see Table 1). One of the only conditions of membership is the formal endorsement of the GEOSS 10-Year Implementation Plan.

Participating Organizations are welcome to join the GEO. At present there are 56 such International and National Organizations (see Table 2). New Organizations can be added subject to the approval of the Members meeting in any Plenary. In addition, the GEO may also invite any other relevant entities to participate in its activities as Observers.

The GEO Secretariat is based in Geneva, Switzerland. The GEO Headquarters is at 7 bis, avenue de la Paix, CP 2300; CH-1211 Geneva 2, Switzerland +41 22 730 8505; secretariat@geosec.org; www.earthobservations.org.

The GEOSS implementation plan is a manifestation of the essentially global scientific and political consensus that the complete assessment of the Earth requires continuous and coordinated observation of our planet on many scales. The plan includes the coordination of a wide range of space-based, air-based, and land-based environmental monitoring platforms, resources and networks—presently often operating independently. GEOSS is planned to be a distributed system-of-systems. It will work with and build upon existing national, regional, and international systems in order to provide the comprehensive, coordinated Earth observations distributed over the planet. The present version of the plan keys on tasks for the nine (9) GEOSS “societal benefit areas”—disaster reduction, health, energy resources, water resources, weather, climate, oceans, ecosystems-biodiversity, agriculture, and combating desertification.
In the last few years the Committee on Earth Observations (CEOS) has forged a long-term partnership with the GEO. While the GEO can be considered as a policy group at the governmental and international organization level, the CEOS can be considered as a technical group at the space agency and user organization level. CEOS has at the present time 28 members or space agencies and approximately 20 associates or user organizations (see Table 3). CEOS is recognized as the satellite arm of GEO and is developing a CEOS Implementation Plan for the space-based component of GEOSS. CEOS utilizes a Virtual Constellations concept to organize international collaboration. Currently, there are six Virtual Constellations: 1) AC—Atmospheric Composition (NASA and ESA leads); 2) PC—Precipitation (JAXA and NASA leads); 3) OST—Ocean Surface Topography (NOAA and EUMETSAT leads); 4) LSI—Land Surface Imaging (USGS and ISRO leads); 5) OCR—Ocean Color Radiometry; and 6) OSVW—Ocean Surface Vector Winds. Other Constellation teams are also under consideration.

This Conference—GEOSS, CEOS and the Future Global Remote Sensing Space System for Societal Benefits—focused on the future spacebased operational elements of the GEOSS, working in unison with current space-based systems and/or land-, air- or sea-based sensors, missions, and networks in order to make significant contributions to the GEOSS societal benefit areas. The GEOSS is being driven by societal benefits and this conference strived to show linkages between societal needs and the operational and research measurements systems required to meet these needs. Often these benefits require extensive modeling as well as measurements so these linkages are also very important to highlight as well. Key areas highlighted included a potential future operational climate system, disaster monitoring and response system, agriculture, land use and hydrology applications.

This Conference covered some of the CEOS contributions to the GEOSS, partnership models and measures that reflect the payoff of Earth observations and Earth system models, and collaborative mission opportunities among international space agencies to deliver new capabilities and efficiencies at the global system level.

Stephen A. Mango
Stephen P. Sanford
Haruhisa Shimoda
Ranganath R. Navalgund
Table 1: Group on Earth Observations [GEO] Member Countries (76)  
Plus European Commission  
[Source: Group on Earth Observations - as of November 2008]

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Table 2: Group on Earth Observations [GEO] Member Organizations (56)

[Source: Group on Earth Observations - as of November 2008]

1. AARSE: African Association of Remote Sensing of the Environment
2. ADIE: Association for the Development of Environmental Information
3. APN: Asia-Pacific Network for Global Change Research
4. CATHALAC: Water Center for the Humid Tropics of Latin America and the Caribbean
5. CEOS: Committee on Earth Observation Satellites
6. CGMS: Coordination Group for Meteorological Satellites
7. CMO: Caribbean Meteorological Organization
8. COSPAR: Committee on Space Research
9. DANTE: Delivery of Advanced Network Technology to Europe
10. DIVERSITAS
11. ECMWF: European Centre for Medium-Range Weather Forecasts
12. EEA: European Environmental Agency
13. EIS-AFRICA: Environmental Information Systems - AFRICA
14. ESA: European Space Agency
15. ESEAS: European Sea Level Service
16. EUMETNET: Network of European Meteorological Services/Composite Observing System
17. EUMETSAT: European Organization for the Exploitation of Meteorological Satellites
19. FAO: Food and Agriculture Organization of the United Nations
20. FDSN: Federation of Digital Broad-Band Seismograph Networks
21. GBIF: Global Biodiversity Information Facility
22. GCOS: Global Climate Observing System
23. GLOBE: Global Learning and Observations to Benefit the Environment
24. GDSS: Global Spatial Data Infrastructure
25. GOOS: Global Ocean Observing System
26. GTOS: Global Terrestrial Observing System
27. IAG: International Association of Geodesy
28. ICIMOD: International Centre for Integrated Mountain Development
29. ICSU: International Council for Science
30. IEEE: Institute of Electrical and Electronics Engineers
31. IGBP: International Geosphere-Biosphere Program
32. IGFA: International Group of Funding Agencies for Global Change Research
33. IHO: International Hydrographic Organization
34. IASA: International Institute for Applied Systems Analysis
35. IIFL: International Institute for Space Law
36. ISCO: International Council on Systems Engineering
37. IO3C: International Ozone Commission
38. IOCC: Intergovernmental Oceanographic Commission
39. ISCGM: International Steering Committee for Global Mapping
40. ISDR: International Strategy for Disaster Reduction
41. ISPR: International Society for Photogrammetry and Remote Sensing
42. OGC: Open Geospatial Consortium
43. POLO: Partnership for Observation of the Global Ocean
44. SICA/CCAD: Central American Commission for the Environment and Development
45. SPAC: South Pacific Applied Geoscience Commission
46. UNCBD: United Nations Convention on Biodiversity
47. UNECA: United Nations Economic Commission for Africa
48. UNEP: United Nations Environment Programme
49. UNESCO: United Nations Educational, Scientific and Cultural Organization
50. UNFCCC: United Nations Framework Convention on Climate Change
51. UNITAR: United Nations Institute for Training and Research
52. UNOOSA: United Nations Office for Outer Space Affairs
53. UNU-EHS: United Nations University, Institute for Environment and Human Security
54. WCRP: World Climate Research Programme
55. WFPHA: World Federation of Public Health Associations
56. WMO: World Meteorological Organization
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<td>4. CDTI</td>
<td>Centre for the Development of Industrial Technology</td>
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<td>19. NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>20. NASARDA</td>
<td>National Space Research and Development Agency</td>
</tr>
<tr>
<td>21. NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>22. NRSCC</td>
<td>National Remote Sensing Center of China</td>
</tr>
<tr>
<td>23. NSAU</td>
<td>National Space Agency of Ukraine</td>
</tr>
<tr>
<td>24. ROHYDROMET</td>
<td>Russian Federal Service for Hydro-meteorology &amp; Environmental Monitoring</td>
</tr>
<tr>
<td>25. ROSCOSMOS</td>
<td>Russian Federal Space Agency</td>
</tr>
<tr>
<td>26. SNSB</td>
<td>Swedish National Space Board</td>
</tr>
<tr>
<td>27. Tubitak-Uzay</td>
<td>Space Technology Research Institute of Turkey</td>
</tr>
<tr>
<td>28. USGS</td>
<td>United States Geological Survey</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CEOS Associates</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. CCRS</td>
<td>Canada Centre for Remote Sensing</td>
</tr>
<tr>
<td>2. CRI</td>
<td>Crown Research Institute</td>
</tr>
<tr>
<td>3. ESCAP</td>
<td>Economic and Social Commission of Asia and the Pacific</td>
</tr>
<tr>
<td>4. FAO</td>
<td>Food and Agriculture Organization</td>
</tr>
<tr>
<td>5. GCOS</td>
<td>Global Climate Observing System</td>
</tr>
<tr>
<td>6. GOOS</td>
<td>Global Ocean Observing System</td>
</tr>
<tr>
<td>7. GTOS</td>
<td>Global Terrestrial Observing System</td>
</tr>
<tr>
<td>8. ICSU</td>
<td>International Council for Science</td>
</tr>
<tr>
<td>9. IGBP</td>
<td>International Geosphere-Biosphere Programme</td>
</tr>
<tr>
<td>10. IOC</td>
<td>Intergovernmental Oceanographic Commission</td>
</tr>
<tr>
<td>11. IOCCG</td>
<td>International Ocean Colour Coordinating Group</td>
</tr>
<tr>
<td>12. ISPRS</td>
<td>International Society for Photogrammetry and Remote Sensing</td>
</tr>
<tr>
<td>13. NSC</td>
<td>Norwegian Space Centre</td>
</tr>
<tr>
<td>14. OSTC</td>
<td>Federal Office for Scientific, Technical &amp; Cultural Affairs</td>
</tr>
<tr>
<td>15. SAC/CSIR</td>
<td>Satellite Applications Centre/ Council for Scientific and Industrial Research</td>
</tr>
<tr>
<td>16. UNEP</td>
<td>United Nations Environmental Programme</td>
</tr>
<tr>
<td>17. UNESCO</td>
<td>United Nations Educational, Scientific and Cultural Organization</td>
</tr>
<tr>
<td>18. UNOOSA</td>
<td>United Nations Office of Outer Space Affairs</td>
</tr>
<tr>
<td>19. WCRP</td>
<td>World Climate Research Programme</td>
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<tr>
<td>20. WMO</td>
<td>World Meteorological Organization</td>
</tr>
</tbody>
</table>

Footnote A: European Commission - Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom

Footnote B: ESA - Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom (Czech Republic, is likely to be a member by the end of 2008; Canada, Hungary, Poland and Romania are Cooperating States)

Footnote C: EUMETSAT - Austria, Belgium, Croatia, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom (plus 9 Cooperating States: Czech Republic, Iceland, Hungary, Latvia, Lithuania, Poland, Bulgaria, Romania, Estonia)
GCOM-C Ocean-color research
[7151-5]

Hiroshi Murakami, Masahiro Hori, Keiji Imaoka, Keizo Nakagawa, Haruhisa Shimoda
Japan Aerospace Exploration Agency (Japan)

ABSTRACT

JAXA is establishing the Global Change Observation Mission (GCOM) which consists of GCOM-W and GCOM-C satellite series. Target dates of the first satellites are early 2012 and early 2014 respectively. The sensor and products are being designed and investigated for the effective observation of essential climate variables relating to the radiation budget, the carbon cycle, and the water cycle.
Cross-sensor band mapping for developing a consistent climate data record of Earth observations

Xianjun Hao, John J. Qu
George Mason Univ. (United States)

ABSTRACT

Data continuity and consistency is critical for the synergistic integration of measurements from different satellite remote sensing sensors under the GEOSS framework. Since each sensor has its own spatial and spectral specifications and lifecycle, it is desirable to develop the capability for spatial and spectral mapping between different sensors. Based on our previous work on AIRS/MODIS/VIIRS cross-sensor comparison, band mapping approaches are investigated for enhancing the data integrity, consistency and sustainability of the GEOSS data.
Detection of large scale natural disaster damages by MTSAT

[7151-14]

Takashi Moriyama
Japan Aerospace Exploration Agency (Japan)

ABSTRACT

The ultimate goal of satellite disaster monitoring is 24 hours per day of continuous monitoring by systems such as a geostationary Earth observation satellite with the appropriate high spatial resolution. The technical feasibility study for future GEO-EO satellite system is underway, and in parallel, the possibility of detection of land cover change such as large scale land slide has been studied by using MTSAT (Meteorological Satellite: Visible 1 km resolution). Fortunately, MTSAT observed the large scale land slide over the Leyte mountain Philippine. The image comparison study has been done. The result suggested that a large scale disaster such as a land slide can be detected by using MTSAT, indicating that high ground resolution is not actually needed to detect such a change. This paper describes one of the study results of a change detection of a large scale land slide by 1 km resolution data.
Europe watches the atmosphere
[7151-20]

Philippe L. Keckhut
Ctr. National de la Recherche Scientifique (France)

ABSTRACT

GEOMON (Global Earth Observation and Monitoring of the Atmosphere) is an Integrated Project of the 6th European frame work programme. The overall goal of the GEOMON project is to sustain and analyse European ground-based observations of atmospheric composition, complementary with satellite measurements, in order to quantify and understand the ongoing changes. GEOMON is a first step to build a future integrated pan-European Atmospheric Observing System dealing with systematic observations of long-lived greenhouse gases, reactive gases, aerosols, and stratospheric ozone.
Perspectives on international collaboration in Earth observations: CEOS Contributions to the GEOSS

Barbara J. Ryan, World Meteorological Association

Overview

- Historical Perspective
- International Collaboration
- Global Change as Forcing Function for Increased Collaboration
- The Way Forward
An Historical Comparison

Cataloged Objects in Earth Orbit

Number of Cataloged Objects

- Total
- Fragmentation Debris
- Rocket Bodies
- Spacecraft
- Mission-related Debris

Year


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Committee on Earth Observation Satellites (CEOS)

- Established in 1984 from the Economic Summit of Industrialized Nations
  - Need to coordinate satellite missions
  - Recognized value of cross-disciplinary efforts

- Outgrowth of two satellite coordinating groups:
  - Coordination on Land Observation Satellites
  - Coordination on Ocean Remote Sensing Satellites

- Best efforts organization – relies on voluntary contributions of members and associates

- 26 Members, 20 Associates

CEOS Members

- Members are national or international governmental agencies and/or organizations that are responsible for:
  - A civil spaceborne Earth observation program;
  - A significant ground-segment activity that supports CEOS objectives; and/or
  - A significant programmatic activity that supports CEOS objectives
CEOS Objectives

- To optimize benefits of spaceborne Earth observations through cooperation in mission planning and development of compatible data products, formats, services, applications, and policies;

- To serve as a focal point for international coordination of space-related Earth observation activities – the space segment of GEO;

- To exchange policy and technical information that promotes complementarity and compatibility among spaceborne Earth observation systems and their data.

The Group on Earth Observations (GEO) and Societal Benefits of Improved Earth Observations
Connecting Satellite Observation Systems to GEOSS

- Integrate observing systems, nationally and internationally, to benefit from the increased number and distribution of observations of any given event.
- Identify measures to minimize data gaps – to move toward a comprehensive, coordinated, and sustained Global Earth Observation “System of Systems”

CEOS Role in GEO

- CEOS is a GEO Participating Organization
- Represents international EO satellite community
- Coordinates provision of space segment for GEOSS
- Lead role for CEOS in many GEO Work Plan tasks
- CEOS Members also represented in GEO if their respective countries are GEO Members
Reinforcing the Linkages to GEO

- Coordinates provision of space segment for GEO
- Represents international EO civil satellite community
- Lead role for many GEO Work Plan tasks
- CEOS is a GEO Participating Organization
- CEOS Members/Agencies also represented in GEO if their respective countries are GEO Members

CEOS Virtual Constellations

- Synergies among national and regional satellite programs and focus dialogue and resources
- [6 Virtual Constellations contemplated so far]
  - Atmospheric composition
  - Global precipitation
  - Land surface imaging
  - Ocean surface topography
  - Ocean color radiometry
  - Ocean surface vector winds
- Common guidelines
- Optimal end-to-end capabilities
- Coordinated user requirements for future systems
Virtual Constellations Objectives

- Focus dialogue from “all topics/all agencies” to smaller, more specialized groups
- Focus resources to demonstrate what may be achieved
- Apply common thresholds/develop framework
  - Participants small and large, established and emerging
  - Understanding common criteria for contributions
  - Provide guidance to aspiring entrants

CEOS Virtual Constellations System Engineering Office

- Dedicated resources from NASA
- Provide Systems Engineering support to each Virtual Constellation Team
  - Requirements taxonomy
  - Mission gap analysis
- Provides cross-Constellation support
  - Communications
  - Consistency
  - Best practices
UN Framework Convention on Climate Change (UNFCCC)

- Actions from COP - 10, 11, and 12
- “Satellite Observation of the Climate System: The CEOS Response to the GCOS Implementation Plan”
- Response covers atmospheric, oceanic and terrestrial domains, as well as cross-cutting issues
- 59 actions identify where additional resources are needed to fill gaps
- Calls for a major, sustained satellite component

GCOS 26 Essential Climate Variables (ECVs)

<table>
<thead>
<tr>
<th>A.</th>
<th>Atmosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.1</td>
<td>Surface Wind Speed and Direction</td>
</tr>
<tr>
<td>A.2</td>
<td>Upper-air Temperature</td>
</tr>
<tr>
<td>A.3</td>
<td>Water A Vapour</td>
</tr>
<tr>
<td>A.4</td>
<td>Cloud properties</td>
</tr>
<tr>
<td>A.5</td>
<td>Precipitation</td>
</tr>
<tr>
<td>A.6</td>
<td>Earth Radiation Budget</td>
</tr>
<tr>
<td>A.7</td>
<td>Ozone</td>
</tr>
<tr>
<td>A.8</td>
<td>Atmospheric reanalysis (multiple ECVs)</td>
</tr>
<tr>
<td>A.9</td>
<td>Aerosols</td>
</tr>
<tr>
<td>A.10</td>
<td>Carbon Dioxide, Methane and other Greenhouse Gases</td>
</tr>
<tr>
<td>A.11</td>
<td>Upper-air Wind</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>O.</th>
<th>Oceans</th>
</tr>
</thead>
<tbody>
<tr>
<td>O.1</td>
<td>Sea Ice</td>
</tr>
<tr>
<td>O.2</td>
<td>Sea Level</td>
</tr>
<tr>
<td>O.3</td>
<td>Sea Surface Temperature</td>
</tr>
<tr>
<td>O.4</td>
<td>Ocean Colour</td>
</tr>
<tr>
<td>O.5</td>
<td>Sea State</td>
</tr>
<tr>
<td>O.6</td>
<td>Ocean Reanalysis</td>
</tr>
<tr>
<td>O.7</td>
<td>Ocean Salinity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>T.</th>
<th>Terrestrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.1</td>
<td>Lakes</td>
</tr>
<tr>
<td>T.2</td>
<td>Glaciers and Ice Caps, and Ice Sheets</td>
</tr>
<tr>
<td>T.3</td>
<td>Snow Cover</td>
</tr>
<tr>
<td>T.4</td>
<td>Albedo</td>
</tr>
<tr>
<td>T.5</td>
<td>Land Cover</td>
</tr>
<tr>
<td>T.6</td>
<td>IAPAR</td>
</tr>
<tr>
<td>T.7</td>
<td>LAI</td>
</tr>
<tr>
<td>T.8</td>
<td>Biomass</td>
</tr>
<tr>
<td>T.9</td>
<td>Fire Disturbance</td>
</tr>
<tr>
<td>T.10</td>
<td>Soil moisture</td>
</tr>
</tbody>
</table>
### ACC Traceability to GCOS ECVs

**[Atmospheric Composition Constellation]**

<table>
<thead>
<tr>
<th>Essential Climate Variable</th>
<th>Characteristic</th>
<th>Action required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ozone mapping</td>
<td>Profiles, columns</td>
<td>– Reprocessing to remove biases and gaps, improved algorithms, integrated product</td>
</tr>
<tr>
<td>Aerosol characteristics</td>
<td>Profiles, columns</td>
<td>– Employ Data Assimilation for data homogeneity and integration</td>
</tr>
<tr>
<td>Water vapor content</td>
<td>Profiles, columns</td>
<td>– Research observations enhanced and standardized for upcoming operational missions (R2O)</td>
</tr>
<tr>
<td>Greenhouse gases</td>
<td>Sources and Sinks</td>
<td></td>
</tr>
<tr>
<td>Cloud characteristics</td>
<td>Profiles</td>
<td></td>
</tr>
</tbody>
</table>

### Satellite Observations for Climate – Example of Domain ECV Status

[Graph showing Atmospheric Domain ECV Status as of Mid-2006]
ACC Traceability to GEO SBA’s

<table>
<thead>
<tr>
<th>ESA</th>
<th>Science and Measurements</th>
<th>GEO 2007-2009 Work Plan</th>
<th>GOES 2-year Plan</th>
<th>GOES 6-year Plan</th>
<th>GOES 10-year Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth Observation</td>
<td>Fires, smoke and air quality related sensor systems, ECO Pollution sources, air quality monitoring</td>
<td>06.06.07: Multi-hazard detection and mapping</td>
<td>Strengthening the international capacity to detect and monitor disasters and support response activities. Production of high-quality, multihazard information</td>
<td>Enhancing real-time monitoring of weather conditions. Expansion of the production of an inventory of remote sensing products</td>
<td>Enhancing real-time monitoring of weather conditions. Expansion of the production of an inventory of remote sensing products</td>
</tr>
<tr>
<td>Climate</td>
<td>Atmospheric Composition: CO2, CH4, Fluorinated gases, O3, and Aerosol Properties</td>
<td>06.06.09: Key Climate Data from Earth Observation Systems</td>
<td>Development and operation of new services. Establishment of scientific support for climate change.</td>
<td>Development and operation of new services. Establishment of scientific support for climate change.</td>
<td>Development and operation of new services. Establishment of scientific support for climate change.</td>
</tr>
<tr>
<td>Long-term measurements</td>
<td>NE 06.06: Energy and Heat Impacts</td>
<td>06.06.10: Key Climate Data from Earth Observation Systems</td>
<td>Energy and Heat Impacts</td>
<td>Energy and Heat Impacts</td>
<td>Energy and Heat Impacts</td>
</tr>
<tr>
<td>Health</td>
<td>Air Quality: trace gases, particulates, VOCs, bioaerosols</td>
<td>NE 06.06: Energy and Heat Impacts</td>
<td>Air Quality: trace gases, particulates, VOCs, bioaerosols</td>
<td>Air Quality: trace gases, particulates, VOCs, bioaerosols</td>
<td>Air Quality: trace gases, particulates, VOCs, bioaerosols</td>
</tr>
<tr>
<td>Energy</td>
<td>Chemical forecasting: energy, GPP, climate variables, aerosols, CH4, radiation</td>
<td>EN 06.06: Energy and Heat Impacts</td>
<td>Chemical forecasting: energy, GPP, climate variables, aerosols, CH4, radiation</td>
<td>Chemical forecasting: energy, GPP, climate variables, aerosols, CH4, radiation</td>
<td>Chemical forecasting: energy, GPP, climate variables, aerosols, CH4, radiation</td>
</tr>
</tbody>
</table>

Land Surface Imaging Constellation

- Terra
- Landsat
- ResOURCESAT
- ALOS
- SPOT
- CBERS

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Contributions of a LSI Constellation – Across Spatial, Spectral and Temporal Resolutions

International Partners – A Global Network

ASA: Alice Springs, Australia (L5/L7)
BJC: Beijing, China (L5)
BKT: Bangkok, Thailand (L5)
COA: Cordoba, Argentina (L5/L7)
CUB: Cuiaba, Brazil (L5)
DKI: Parepare, Indonesia (L7)
GLC: Gilmore Creek (L5)
GNC: Gatineau, Canada (L5)
HAI: Hatoyama, Japan (L5)
HIJ: Hiroshima, Japan (L7)
HOA: Hobart, Australia (L5/L7)
JSA: Johannesburg, South Africa (L5)
KIS: Kiruna, Sweden (L5)
LGS: Landsat Ground Station (L5/L7)
MTI: Matera, Italy (L5)
PAC: Prince Albert, Canada (L5)
PF1: Gilmore Creek (L5)
UPR: University of Puerto Rico (L7)
UNEP's Atlas of our Changing Environment

"One Planet, Many People"

Everglades
Florida

Monitoring Land Management Practices

Targhee National Forest (left) and Yellowstone National Park (right)
Land Subsidence

- More than 80% of the identified 17,000 square miles of land affected by subsidence in the Nation is a consequence of our exploitation of ground water -- National Research Council, 1991

- Most of the ground-water related subsidence is caused by the compaction of susceptible alluvial aquifer systems that typically accompanies overdraft of these systems

California's Central Valley
Major U.S. aquifers and locations where subsidence has been attributed to groundwater pumping

- California
  - Antelope Valley
  - Coachella Valley
  - Eltitioa Valley
  - LaVerne area
  - Lebec Valley
  - Mauve River Basin
  - Oxnard Plain
  - Pomona Basin
  - Sacramento Valley
- Nevada
  - Las Vegas Valley
- Idaho
  - Salt River area
  - Pocatello area
  - Boise area
- New Mexico
  - El Paso Basin
  - Albuquerque Basin
  - Menard Basin
- Texas
  - Houston
  - Galveston
  - Huco Bobon-El Paso-Juarez
- Louisiana
  - New Orleans area
- Geonca
  - Frankfort-Sandy area
  - Williamsburg-West Point area
- South Central Arizona
  - San Diego Valley
  - San Bernardino Valley
  - San Benito Valley
  - San Diego Valley
  - San Bernardino Valley
  - San Gabriel Valley
  - San Joaquin Valley
  - San Luis Obispo Valley

South Central Arizona
- Tucson
- Arizona
- November 1992 to January 1997

Subsidence due to Ground-Water Withdrawals
- 90 mm Subsidence
- Tucson
- Arizona
- November 1992 to January 1997

InSAR data from Envisat

Modified from Calowei et al., USGS Circular 1162.
Sea levels for 1870 to 2000 indicate a 20th century rise of about 1.7 mm yr\(^{-1}\) and an acceleration in the rate of rise.

Global Mean Sea Level Rise

- Linear trend: 3.2 mm/year
- Satellite altimetry
- Holgate and Woodworth, 2004
- 1.8 +/- 0.3 mm/yr (1960 to 2000)
- Church et al., 2004, 2006
Global Sea Level Rise

Satellite Altimetry

- Unique system to observe global variations in sea level rise

Working across the Constellations -- Mt. Etna InSAR
Virtual Constellation (ACC) Example of Value Chain

Societal Need

Volcanic Eruption Ash

Improved Indexes and Forecast Products

Decision Makers

Information

Societal Benefit

Disaster Warning System

Virtual Constellation (ACC) Example of Value Chain

Science

Improved knowledge and models

Mission

Improved technology

Measurements

AC Constellation provides improved continuity and coverage

AC individual missions provide limited continuity and coverage

The Way Forward

In conclusion, CEOS recognizes that both satellite and *in situ* data are required to better monitor, characterize, and predict changes in the Earth system. While *in situ* measurements will remain essential and largely measure what cannot be measured from satellites, Earth-observation satellites are the only realistic means to obtain the necessary global coverage, and with well-calibrated measurements will become the single most important contribution to global observations for climate.

www.ceos.org

The Way Forward – Working together with academia, industry, and policy makers