GEO Task US-09-01a:
Critical Earth Observations Priorities

Climate Societal Benefit Area

GROUP ON
EARTH OBSERVATIONS

User Interface Committee

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Group on Earth Observations

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Advisory Group Members & Analyst

The following people served as expert panelists for the *ad hoc* Advisory Group for the Climate Societal Benefit Area (SBA) under GEO Task US-09-01a. The Advisory Group supported the Analyst by identifying source materials and reviewing this report.

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Summary

The goal of GEO Task US-09-01a is to identify the critical Earth observations for various societal benefit areas (SBAs). In this Climate SBA analysis, the Analyst focused on identifying the priority Earth observation needs of stakeholders as related to the Climate SBA. The Analyst covered three sub-areas: the atmosphere, the oceans, and lands. The Analyst also identified priorities for global climate observations and for regional observations as documented in source material representing international, regional, and national needs. An international Advisory Group of seven members assisted in identifying and reviewing source documents, and in reviewing a draft of this report.

The socially beneficial uses of climate observations and information about them are wide ranging. In describing the Climate SBA, the GEO notes that climate "has impacts in each of the other eight societal benefit areas" (*GEOSS 10-Year Implementation Plan*, Section 4.1.4). Many international and regional organizations have defined clear Earth observation priorities for examining the climate system. The Analyst built upon these existing prioritizations for climate, by seeking additional literature to include in this meta-analysis.

The Analyst conducted literature and internet searches and requested Advisory Group recommendations to identify documents for two purposes: (1) compiling a list of Earth observation needs, and (2) extracting the needs that appear to have the highest priority. The Analyst carried out these steps for both global and regional observations.

After evaluating 42 documents for their applicability to the task, the Analyst identified 40 that provided relevant information for the priority setting analysis. The Analyst extracted Earth observation needs from these 40 documents for the three sub-areas, including 27 documents for global needs and 16 documents for regional needs (three documents included both global and regional needs). Twelve of the 40 documents are previously compiled consensus reports by international organizations. These consensus reports served as the main source for identifying global requirements for all sub-areas, including observations specified as essential climate variables (ECVs) by the Global Climate Observing System (GCOS) and its supporting agencies. The ECVs and the observing systems needed to provide them are specified in the *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC* (GCOS 2004), which constitutes international consensus among the experts represented by GCOS. Beyond the consensus reports, the remaining 28 documents provided information with which the Analyst could identify high priority ECVs on regional and national scales.

The Analyst used a bibliometric method for identifying Earth observation priorities (see OTA 1986). This method involved simple counts and tabulations by the Analyst of the relative frequency with which specific requirements were cited in the source material. The Analyst made adjustments to avoid double-counting citations appearing in material with common sets of authors or produced by overlapping working groups. Discussion of advantages and limitations of this approach are included in this report.

At present, with a few exceptions, no organizations have collected and assembled comprehensive and detailed information on regional and national scale priority observations. The regional and national scale priorities identified in this report are drawn from a limited number of documents. This gap in documentation of user needs is recognized in the literature and noted further in this report.

The result of this analysis is a list of priority observations for both the global and regional dimensions of the Climate SBA. Observations of global and regional priority intersect but do not fully overlap. Global priority observations reflect the geographic breadth of the climate as an Earth system. Examples of such global observations are atmospheric concentrations of greenhouse gases (GHGs), Earth radiation and surface radiation budgets, many types of observations of the oceans, and other variables determined by carbon, hydrological, and other global cycles. Regional priorities center on terrestrial processes including river discharge, lakes, and groundwater. Other priority observations, such as precipitation extreme events, land cover, sea-ice, and aerosols, are common at both geographic scales.

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1 Introduction

This report articulates Earth observation priorities for the Climate SBA based on an analysis of 42 publicly available documents, including documents produced by Group on Earth Observations' Member Countries and Participating Organizations.

1.1 Group on Earth Observations

The Group on Earth Observations (GEO)[1] is an intergovernmental organization working to improve the availability, access, and use of Earth observations to benefit society. GEO is coordinating efforts to build a Global Earth Observation System of Systems (GEOSS)[2]. GEOSS builds on national, regional, and international observation systems to provide coordinated Earth observations from thousands of ground, in situ, airborne, and space-based instruments.

GEO is focused on enhancing the development and use of Earth observations in nine Societal Benefit Areas (SBAs): agriculture, biodiversity, climate, disasters, ecosystems, energy, health, water, and weather.

1.2 GEO Task US-09-01a

The objective of GEO Task US-09-01a is to establish and conduct a process to identify critical Earth observation priorities within each SBA and those common to the nine SBAs. Many countries and organizations have written reports, held workshops, sponsored projects, conducted surveys, and produced documents that specify Earth observation needs. In addition, researchers and practitioners have also identified and recommended key Earth observation needs in publications and peer-reviewed literature. Task US-09-01a focuses on compiling information on observation parameters from a representative sampling of these *existing* materials and analyzing across the materials to determine the priority observations.

This task considers all types of Earth observations, including ground, in situ, airborne, and space-based observations. The task includes direct measurements and derived parameters as well as model products. This task seeks to identify Earth observation needs across a full spectrum of user types and communities in each SBA, including observation needs from all geographic regions with significant representation from developing countries.

GEO will use the Earth observation priorities resulting from this task to determine, prioritize, and communicate gaps in current and future Earth observations. GEO Member Countries and

[1] GEO Website: *http:// www.Earthobservations.org*
[2] GEO 10-Year Implementation Plan: *http://www.Earthobservations.org/documents.shtml*

Participating Organizations can use the results in determining priority investment opportunities for Earth observations.

1.3 Purpose of Report

The primary purpose of this report is to articulate the critical Earth observation priorities for the Climate SBA. The intent of the report is to describe the overall process and specific methodologies used to identify documents, analyze and rank them, and determine a set of Earth observation parameters and characteristics. The report describes the prioritization methodologies used to determine the priority Earth observations for this SBA. The report also provides information on key challenges faced, feedback on the process, and recommendations for process improvements.

The primary audience for this report is the GEO User Interface Committee (UIC), which is managing Task US-09-01a for GEO. The GEO UIC will use the results of this report in combination with reports from the other eight SBAs. The GEO UIC will perform a meta-analysis across all nine SBA reports to identify critical Earth observation priorities common to many of the SBAs. Based on the nine SBA reports, the GEO UIC will produce an overall Task US-09-01a report, including the common observations and recommendations for GEO processes to determine Earth observation priorities in the future.

The report's authors anticipate that the GEO Secretariat, Committees, Member Countries, Participating Organizations, Observers, Communities of Practice, and the communities associated with the Climate SBA are additional audiences for this report.

1.4 Scope of Report

This report addresses the Earth observation priorities for the Climate SBA. In particular, this report addresses the sub-areas of the atmosphere, the oceans, and lands within the Climate SBA (see Section 3 for more details). The socially beneficial uses of climate observations and information about them are wide ranging. The GEOSS 10-Year Plan describes the Climate SBA as an SBA that "has impacts in each of the other eight societal benefit areas." Many international organizations have defined clear Earth observation priorities for examining the climate system. The Analyst chose to build upon these existing prioritizations for climate, by seeking additional literature to include in this meta-analysis.

The report provides some background and contextual information about the Climate SBA. However, this report is not intended as a handbook or primer on the Climate SBA and a complete description of the Climate SBA is beyond the scope of this report. Please consult the GEO website referenced above for more information about the Climate SBA.

The report focuses on the Earth observations within the Climate SBA, independent of any specific technology or collection method. Thus, the report addresses the "demand" side of observation needs and priorities. The report does not address the specific source of the observations or the sensor technology involved with producing the observations. Similarly, any

discussions of visualization tools, decision support tools, or system processing characteristics (e.g., data format, data outlet) associated with the direct use of the observations are beyond the scope of this report.

In this report, the term "Earth observation" refers to parameters and variables (e.g., physical, geophysical, chemical, biological) sensed or measured, derived parameters and products, and related parameters from model outputs. The term "Earth observation priorities" refers to the parameters deemed of higher significance that others for the given SBA, as determined through the methodologies described within. The report uses the terms "user needs" and "user requirements" interchangeably to refer to Earth observations that are articulated and desired by the groups and users in the cited documents. The term "requirements" is used generally in the report to reflect users' wants and needs; the use in this report does not imply technical, engineering specifications.

Following this introduction, the report discusses the overall approach and methodologies used in this analysis (Section 2). Section 3 describes the Climate SBA and the specific sub-areas that were part of the analysis. Section 4 articulates the specific Earth observations for each Climate sub-area, and Section 5 presents the priority observations across the Climate SBA. Sections 6 and 7 present additional findings from the analysis of the documents and recommendations. The Appendices include the abbreviations used in the report, the documents cited and sourced, and additional information on the results of the analysis of the Climate SBA.

2 Methodology

This section documents the general process followed and specific methodologies used to identify documents, analyze them, determine Earth observation parameters and characteristics, and establish a set of priority Earth observations for this SBA.

2.1 Task Process

The GEO UIC established a general process for each of the SBA analysts to follow in order to ensure some consistency across the SBAs. This general process for each SBA involves nine (9) steps, as summarized in the following list:

Step 1: Identify Analyst and Advisory Group for the SBA
Step 2: Determine scope of topics within the SBA
Step 3: Identify documents regarding observation priorities for the SBA
Step 4: Develop analytic methods and priority-setting criteria
Step 5: Review and analyze documents for priority Earth observations needs
Step 6: Combine the information and develop a preliminary report
Step 7: Gather feedback on the preliminary report
Step 8: Perform any additional analysis
Step 9: Complete the report on Earth observations for the SBA.

A detailed description of the general US-09-01a process is available at the Task website *http://sbageotask.larc.nasa.gov* or GEO website. Some steps in the process occurred simultaneously or iteratively, such as identifying documents (Step 3) and reviewing documents (Step 5).

2.2 Analyst and Advisory Group

The Climate SBA had an "Analyst" and an "Advisory Group" working together to identify documents, analyze them, and prioritize the Earth observations. The Analyst served as the main coordinator managing the activities.

2.2.1 Analyst

For the Climate SBA, the Analyst was Molly Macauley. She is a senior fellow at Resources for the Future (RFF). (RFF is a nonprofit research organization in Washington, DC, established in 1952 at the request of the President of the United States to assess global and national natural resources.) Dr. Macauley's research expertise includes policy and economic analysis of natural resources. She was previously a lead author for synthesis reports under the U.S. Climate Change Science Program and serves on several advisory boards providing expertise on climate and Earth observations policy, including those of the U.S. National Oceanic and Atmospheric Administration, the U.S. National Aeronautics and Space Administration, and the National Academy of Sciences. She also leads an international research team on Earth observations of forests and forest carbon.

Dr. Macauley prepared this report under a subcontract to Resources for the Future from Battelle Memorial Institute, Columbus, Ohio.

2.2.2 Advisory Group

The Advisory Group for the Climate SBA consisted of seven scientific, technical, and programmatic experts who focus on climate, climate variability, and impacts of climate on human and ecological systems. Table 1 lists the Advisory Group members.

The Analyst identified the Advisory Group members through literature searches, personal contacts, and referrals. The Advisory Group includes members from two international organizations, five countries, and four continents, including one from a developing country.

The primary roles of the Advisory Group were to assist in identifying documents, assess methodology and analytic techniques, assess prioritization schemes, review findings, and review the report. The primary contact with the Advisory Group was through email. The Advisory Group did not meet in person during the course of the analysis.

Table 1. Advisory Group for Climate SBA.

Name	GEO Country or Organization	Affiliation	Geographic Region/Country
Kwabena A. ANAMAN	Ghana	Institute of Economic Affairs	Africa
Ghassam ASRAR	World Climate Research Program (WCRP)	World Climate Research Program	Global
Stephan BOJINSKI	Global Climate Observing System	Global Climate Observing System	Global
Greg FLATO	Canada	Environment Canada	North America
Mitch GOLDBERG	USA	National Oceanic and Atmospheric Administration	North America
Teruyuki NAKAJIMA	Japan	University of Tokyo	Asia
Alexander ZAYTSEV	Russia	Voeikov Main Geophysical Observatory	Russia

2.3 Methodology

This section provides a general description of the processes, analytic methods, and approaches the Analyst and Advisory Group used to identify documents, analyze them, and establish a set of priority Earth observations. As noted in the Introduction, two types of priorities emerge as relevant for the Climate SBA. One is priority observations for understanding the global climate system. The other is priority observations for understanding climate at the regional scale.

2.3.1 Documents

The Analyst conducted literature reviews and internet searches, and requested Advisory Group recommendations to identify documents with information related to observation requirements. These search methods resulted in the identification of 42 publicly available documents with relevance to the Climate SBA.

After evaluating 42 documents for their applicability to the task, the Analyst identified 40 that provided relevant information for the priority setting analysis. The Analyst deemed documents relevant that named the specific climate-related parameter(s) required or used by an end user. Although the Analyst sought information on the required parameter characteristics (coverage/ extent, temporal resolution, spatial resolution, timeliness, and accuracy/precision), few documents provided such information. In fact, no regional-scale documents specified parameter characteristics, and only one global-scale document specified parameter characteristics (GCOS 2006a).

The Analyst extracted Earth observation needs from the 40 relevant documents for the three sub-areas, including 27 documents for global and 16 for regional requirements (three documents included requirements for both global and regional).

International working groups and intergovernmental agencies have previously compiled information about global Earth observation requirements for climate, and their reports are among the 40 documents included in the analysis. The authors of these reports include the World Meteorological Organization (WMO) and experts working under the auspices of the GCOS. The documents also include assessments by the Intergovernmental Panel on Climate Change (IPCC) of the United Nations Framework Convention on Climate Change (UNFCCC). The GCOS and its supporting agencies have specified ECVs and the observing systems needed to provide them in the *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC* (GCOS 2004). This document (GCOS 22004) constitutes international consensus among the experts represented by GCOS on the needs for global observations for climate.

Although limited in number, reports by regional and national working groups and agencies provided information about regional requirements. These documents include reports of regional workshops and assessments by national meteorological and environmental agencies. Mission planning documents for future Earth observation systems were also a source of information about priority requirements.

2.3.2 Analytic Methods

The Analyst identified information relevant to the Earth observation needs of users by accessing the Summaries and/or Table of Contents of documents and reading the appropriate sections. The Analyst recorded all relevant information provided in the document, including any mention of desired parameter characteristics. The parameter characteristics that the Analyst sought are as follows:

- Coverage/Extent
- Temporal resolution (frequency)
- Spatial resolution (vertical and horizontal, as relevant)
- Timeliness (availability of measurement)
- Accuracy/Precision.

The Analyst then compiled this information into a single master database listing all required observations and documenting all sources. The Analyst organized the information into three climate sub-areas, which were themselves divided into global and regional needs. Next, the Analyst constructed Tables 6-11 of this report, indicating which documents identified a need for which parameters. Because almost all of the documents used were consensus documents, many of which already indicated priority observations, the Analyst did not further narrow the list of priority observations for each sub-area that were identified in the documents. The final prioritization of parameters was carried out in the next step, as described in Section 2.3.3 (with results presented in Chapter 5).

2.3.3 Prioritization Methods

The Analyst worked with the Advisory Group to develop and refine a method of prioritization of the Earth observation parameters identified through the document meta-analysis. The prioritization method had three steps:

First, the Analyst harvested an established set of climate observation priorities, the ECVs, identified in documents by international teams of climate science and related experts convened under the auspices of the GCOS.

Second, the Analyst reviewed additional documents (still part of the 42 documents, but beyond those that identified ECVs) to understand the relative priorities of Earth observation parameters for users. The Analyst anticipated that the priorities identified in these additional documents would overlap with the ECVs identified in the first step. By taking account of the users' specific needs, the needs of these users could provide a sense of relative priority, for these users, among the ECVs. As described further in Section 3.4, these users include regional and national governments.

Third, the Analyst used a well-known bibliometric method for assigning priority (OTA, 1986). The Analyst assigned priority according to the relative frequency with which an observation was cited by the documents as a climate observation needed by users.

For identifying global priorities, and using the master database of all needed observations generated during the document review, the Analyst counted the number of documents in which a particular Earth observation was identified. The Analyst divided this value by the total number of documents in which global requirements are discussed.

For the regional priorities, the Analyst counted the number of regions for which an observation was described as a priority (for example, the number of regions for which extreme precipitation observations is required). The Analyst divided this value by the total number of possible regions, which this GEO task established to be nine regions. Several of the documents describe requirements for multiple regions. Appendix C identifies reports containing regional information.

Examples:

> Precipitation as a global observation: Precipitation is cited in four documents as a required observation (in addition, it is on the list of ECVs). There are 16 documents, in addition to those identifying the ECVs, in which global requirements are discussed. The portion of citations for the observation of precipitation is 4/16 = 0.25 = 25%.
>
> Precipitation as a regional observation: Precipitation is cited in the documents as a required observation for four regions. There are nine possible regions. The percentage of citations for the observation of precipitation is 4/9 = 0.44 = 44%.

Discussion on the limitations of the bibliometric approach, and the way in which the Analyst sought to address these limitations, is provided in Chapter 6.

3 Climate SBA

This section provides summary information on the Climate SBA and the specific sub-areas. This section also provides general discussion on the specific documents used in the meta-analysis and the user types for the Climate SBA.

3.1 Climate SBA Description

The following is the brief statement of topics covered and key outcomes in the Climate SBA from the GEOSS 10-Year Implementation Plan, Section 4.1.4:

> *"The climate has impacts in each of the other eight societal benefit areas. Coping with climate change and variability demands good scientific understanding based on sufficient and reliable observations. GEOSS outcomes will enhance the capacity to model, mitigate, and adapt to climate change and variability. Better understanding of the climate and its impacts on the Earth system, including its human and economic aspects, will contribute to improved climate prediction and facilitate sustainable development while avoiding dangerous perturbations to the climate system."*

3.2 Sub-areas

Working together with the Advisory Group, the Analyst chose to focus on three sub-areas of the Climate SBA, each describing a part of the physical Earth system and its climate processes: the atmosphere, the oceans, and lands. These three sub-areas are consistent with the treatment of climate in many of the source documents identified for this analysis (e.g., IPCC 2007a, b, c; CEOS 2006). Although the analysis addresses the sub-areas separately, the documents share a common theme emphasizing that the sub-areas interact and must be viewed as one system.

- The atmosphere (over land, sea, and ice): This sub-area characterizes Earth's surface and upper-air processes and phenomena such as temperature, wind speed, and water vapor. It also includes atmospheric composition such as gases and aerosols.

- The oceans: This sub-area includes the ocean surface such as sea-surface temperature, sea level, and sea ice. It also includes below surface (sub-surface) variables such as salinity, current, and carbon concentration.

- Lands: This sub-area includes land cover, snow cover, and changes in glaciers and ice caps.

Detailed description of the sub-areas and their interactions is in IPCC (2007c) and GCOS (2004)[3].

[3] An update of GCOS 2004 is currently out for public comment, as of February 2010, but was not completed in time for inclusion in this analysis.

3.3 Documents

Preparation of this report by the Analyst has benefited from consensus reports previously compiled by international organizations of experts, which identified priority global climate observations termed ECVs. The organizations participating in determination of these variables include but are not limited to the WMO, the WCRP, the GCOS, the Committee on Earth Observations Satellites (CEOS), the Global Ocean Observing System (GOOS), the Global Terrestrial Observing System (GTOS), and GEO Member countries and other Participating Organizations. The Analyst included twelve of the most recent of these reports compiled during 2006 to 2009 in this analysis as source material providing both background and context. The ECVs described in these consensus reports are included in the list of priority observations reported in Chapters 4 and 5.

The 28 additional documents collected and used in this analysis include international, regional-, and national-level government and working group reports, conference reports, and mission planning documents for future Earth observing instruments. Table 2 summarizes the documents.

Table 2. Document Sources for Climate SBA.

Geographic Region	Number of Documents *
International	27
Regional – General	3
Africa	2
Asia/Middle East	1
East Asia	1
Europe	3
North America	5
Oceania/Australia	1
South/Central America	1

* Total exceeds total number of documents because of overlapping regional relevance.

The Analyst sorted all 40 of the documents by authorship and on the basis of global versus regional scope. Sorting served three purposes: (1) to assist in matching the types of documents to the types of user groups (for the informal gap analysis discussed in Section 3.4); (2) to allow comparison of priorities among different authors and between global and regional priorities; and (3) to help to avoid double counting of commonly authored reports in the priority methodology (some documents are authored by common groups of experts). The sorting categories are described briefly in the next paragraphs and summarized in Table 3.

I. **Reports compiled by international organizations of experts for the purpose of understanding global climate processes.** Authorship of these reports is under the auspices of organizations such as the WMO, the WCRP, and the GCOS, including component systems of GCOS (such as the GTOS and the GOOS). These organizations include experts representing GEO member countries and many are GEO participating organizations. Examples of reports used in this analysis include *Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC*

2004-2008 (GCOS 2009b) and *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (GCOS 2004).*

II. **Reports compiled by the IPCC for the purpose of understanding the physical and social impacts of climate.** Authorship of these reports is under the auspices of the IPCC and includes experts in the physical sciences and experts on the impacts of climate on humans, marine and terrestrial ecosystems, agriculture, public health, and freshwater. Reports used in this analysis include *Climate Change 2007: the Physical Science Basis* (IPCC 2007c) and *Report of the Conference of the Parties on Global Observing Systems for Climate* (UNFCCC 2008).

III. **Reports compiled by organizations in response to IPCC reports and specifically addressing climate observations.** This set of reports bridges a gap between the focus on observations in Category I and the focus on climate impacts in Category II. Authorship of these reports is under the auspices of organizations such as the WMO, the European Space Sciences Committee, and space agencies. As an example, *Future Climate Research and Observations: GCOS, WCRP and IGBP Learning from the IPCC Fourth Assessment Report* (GCOS 2008) summarizes a workshop organized jointly by GCOS, the WCRP, and the International Exosphere-Biosphere Program (IGBP) and intended to "help guide future strategies for climate change observations and research" specifically in response to findings by the IPCC about the need to improve understanding of climate impacts.

IV. **Reports compiled by international, regional, and national organizations to identify priorities for regional climate observations.** Examples of these reports used in this analysis *include Africa Climate Report* (Washington et al., 2004) and *Initial Science Plan of the Monsoon Asia Integrated Regional Study* (Cfu et al., eds 2006). Information is also available in a set of reports on regional workshops under the auspices of the GCOS.[4]

V. **Reports compiled by organizations to guide planning for Earth observation missions related to climate.** In planning Earth observation missions, authoring organizations of these reports identify priority observations. Examples include reports on planning for the Global Monitoring for Environment and Security (GMES) Sentinel missions (ESA 2007a,b) and other observing missions (for example, NRC 2007).

VI. **Other documents**. The "other document" category ranges from published workshop reports defining priorities for the technical attributes of observations (such as spatial resolution, accuracy) to reports by climate experts in the global insurance sector, an international business sector not included specifically in other GEO SBAs and directly working with climate scientists to identify priority observations for integration into their Earth system models.

[4] See http://www.wmo.int/pages/prog/gcos/index.php?name=RegionalWorkshopProgramme.

Table 3. Document Categories for Climate SBA.

Document Category	Examples
I International Consensus on Climate Observations	*Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (GCOS, 2004)* *Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008* (GCOS 2009b)
II Intergovernmental Panel on Climate Change (IPCC) Assessment	*Climate Change 2007: The Physical Science Basis* (IPCC 2007c) *Report of the Conference of the Parties on Global Observing Systems for Climate* (UNFCCC 2008)
III Post-2007 IPCC Update	*Future Climate Research and Observations: GCOS, WCRP and IGBP Learning from the IPCC Fourth Assessment Report* (GCOS 2008)
IV Regional Assessment	*Africa Climate Report* (Washington et al., 2004) *Workshop on Evaluating and Improving Regional Climate Projections* (WCRP 2009)
V Proposed and Forthcoming Earth Observing Missions	*Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (NRC 2007) *GMES Sentinels 4 and 5 mission Requirements Document* (issue 1 revision 0) (ESA 2007a,b)
VI Other	*Earth Observations: A Catastrophe Risk Modeling Point of View* (Khare, 2008)

The Bibliography lists all source documents; in addition, Appendix C provides further details for all documents, including whether they are international, regional, or both in scope and the category to which each document was assigned.

3.4 User Types

The Analyst identified four major types of users of climate information: (1) primary users who perform modeling and scenario development, (2) secondary users who use results from models and scenarios, (3) policy users and decision-makers who design and implement policy, and (4) business and economic users who make resource management and economic decisions. Table 4 provides examples of each of these four types of users.

The Analyst chose to focus this US-09-01a analysis for the Climate SBA on the primary users, policy users, and business and economic users because the Earth observation needs of these users are most uniquely linked to the Climate SBA. The needs of the secondary users (such as those in resource science and management listed in Table 4) are captured within GEO Task US-09-01a reports for other SBAs (e.g., the Earth observation needs of Hydrologists are captured in the Water SBA US-09-01a report). In other words, the user types identified for the Climate SBA analysis are those whose requirements are "top down," centering uniquely or substantially on a set of climate observations for global, regional, or broad national purposes rather than for specific sectors such as agriculture or water management. Requirements identified for broad

purposes may reflect underlying priorities of sectors important in a region's economy, but individual sectors are not the focus here.

Table 4. Users of Climate Observations.

User Type	Use of Climate Observations	Examples
Primary Users	Modeling and scenario development	• Climate modelers • Integrated assessment modelers • Meteorologists • IPCC of the WMO and United Nations Environment Program (UNEP) by way of the international research community contributing to periodic assessments
Secondary Users	Use of model and scenario results	• Marine biologists • Hydrologists • Ecologists • Energy researchers and managers • Geographers • Earth system scientists • Environmental scientists • Conservationists
Policy Users	Use of scenario results and tools for policy design and implementation	• International, national, sub-national, and local governments for policy design for GHG stabilization, verification, monitoring, and adaptation • Non-governmental organizations focused on policy design • International and national governments assessing security risks related to climate change
Business and Economic Users	Use of scenario results and tools for resource management and economic decision-making	• Infrastructure managers, planners, and investors (such as the World Bank, United Nations Development Program, U.S. Army Corps of Engineers, energy project investors) • Commodity market managers

The following discussion provides additional information on the four types of users represented in this report, and provides example documents representing such users. The Analyst performed an informal gap analysis of user types by reviewing the documents identified for this US-09-01a report. The Analyst determined that, with one caveat, the primary users, policy users, and business/economic users are generally adequately represented by the documents included in this Climate SBA report. The caveat is that the number of documents available describing Earth observation needs for users at a regional and national level is limited, as further discussed in Chapter 4 and Section 7.2.

The primary users are those engaged in understanding the science of the global climate system in order to inform decision-makers. These primary users include climate modelers, integrated assessment modelers, and the international community contributing to the work of the IPCC. These users are working to characterize the state of the global climate system and its variability; monitor the forcing of the climate system, including both natural and anthropogenic contributions; support the attribution of the causes of climate change; support the prediction of

global climate change; enable projection of global climate change information down to regional and local scales; and enable characterization of extreme events important in impact assessment and adaptation, and assess risk and vulnerability. In the Analyst's experience, these primary users need Earth observations for understanding the global carbon and hydrologic cycles and their interactions in the atmosphere, the oceans, and terrestrial processes. An example of a document included in this meta-analysis that represents the Earth observation needs of primary users is "*Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*" (IPCC, 2007c).

The policy users are engaged at the level of international, regional, national, or local decision-making. These policy users are designing policy for GHG stabilization and monitoring and for climate change adaptation. They include regional, national, and local governments in both developed and developing countries as well as international intergovernmental organizations. An example of a document included in this meta-analysis that represents the Earth observation needs of policy users is "*Climate Information for Development Needs: An Action Plan for Africa*" (GCOS, 2006b).

Distinct but related to the policy users are large worldwide business and economic users such as insurers seeking to integrate climate observations in their catastrophic loss models, including but not limited to the purpose of assisting developing countries by offering climate-index-based lending. An example of a document included in this meta-analysis that represents the Earth observation needs of business and economic users is "*Earth Observations: A Catastrophe Risk Modelling Point of View*" (Khare 2008).

4 Earth Observations for Climate SBA

This chapter describes the Earth observation priorities for three sub-areas: atmosphere, oceans, and lands. For each sub-area, separate tables of global and regional needs are presented. The Analyst drew the global needs identified in this chapter mainly (but not exclusively) from documents in Categories I, II, and III. The regional needs were drawn mainly (but not exclusively) from the documents in Category IV. The Analyst used the inventory of Earth observation needs identified in this chapter to derive overall priority Earth observations for climate in Chapter 5. As noted in Section 2.3.1, the documents that focused on regional needs did not specify the required parameter characteristics. Similarly, only one document that focused on global needs specified required parameter characteristics (GCOS 2006a). Given this limited information, the required parameter characteristics are addressed (for global needs only) in Chapter 5 in a summary format, rather than being discussed or appended to the tables in Chapter 4.

The Analyst did not perform a prioritization of Earth observation parameters within each sub-area or within each region because of the relatively small number of documents for each sub-area and region. As noted in Section 3.4, the number of documents available describing Earth observation needs for users at a regional and national level is limited. The number of documents would have limited the robustness of such sub-area or regional analysis. As a demonstration of

such gaps in documents, the Analyst and Advisory Group did not find any documents that identified air temperature as an important Earth observation for Africa or Europe. Accordingly, Tables 6 through 12 contain a disclaimer regarding missing information on regional priorities. However, one document identified by the Analyst included an analysis of priority needs (and in some cases, specific parameters) by region. For information purposes, this regional prioritization is shown in Table 5. Specific regional concerns include, for example, frost monitoring in Central Asia, ocean-related observations of the Indian Ocean, and drought monitoring in many areas. These regional priorities are reflected in Tables 7, 9, and 11 in this section which address regional needs.

Table 5. Regional Priority Observations for Climate

Region	Priority Observations*
Pacific Islands	Restoration of upper air network (high); ocean observations for tsunami monitoring (high); sea level monitoring (medium)
Eastern and Southern Africa	Hydrological observations (high); urban observing (high); ocean observing in Western Indian Ocean (high)
Central America and the Caribbean	Monitor land cover change (medium)
East and Southeast Asia	None; priorities largely capacity building
Western and Central Africa	None; priorities largely capacity building
South America	Enhance surface and subsurface observations in Western South Atlantic (high); establish cryosphere observing system (low)
Central Asia	Improve GCOS surface and upper air networks (high); glacier monitoring (medium); improve satellite products with respect to aerosol, vegetation, and snow cover (high); permafrost monitoring (high); enhance coordination of China Climate System Monitoring Network with GCOS
South and Southwest Asia	Improve GCOS surface and upper air networks (high); establish aerosol monitoring in the region (high); establish an Indian Ocean observing system for climate (high); monitor glaciers for water resources (high); improve understanding of carbon cycle (high);
Eastern and Central Europe	Regional downscaling and modeling (high); drought monitoring (high)
Mediterranean Basin	Improve observations that could assist locust control (land use, precipitation -- high); control water use on irrigated lands using climate data (high)

*Includes level of priority – high, medium, low – specified in the source document.
Source: GCOS 2006c.

4.1 Atmosphere Earth Observation Needs

The documents analyzed indicated that information on the atmosphere is needed for monitoring climate change, for determining forcing of the climate system by GHGs and aerosols, and for attributing climate change to natural and anthropogenic influences. Atmospheric data are also needed for improving the skill of the climate prediction models used for impact, adaptation, and vulnerability assessments, and for determining the changing atmospheric composition.

Tables 6 and 7 contain a comprehensive inventory of all Earth observation needs from all documents with regard to the sub-area of atmosphere, for global and regional needs (respectively). The tables also identify the major source documents for each entry. Note that most of the cited documents are consensus documents (e.g., GCOS 2006a, NRC 2007, IPCC 2007c, etc.), which justifies the parameter's inclusion as a need even though not cited by multiple documents.

The global needs include observations of surface, upper air, and composition variables. For the sub-area atmosphere, the largest overlap between regional and global needs is for parameters related to precipitation extreme events, precipitation, air temperature, and aerosol properties. The most frequently cited regional need is extreme precipitation events, followed closely by aerosol properties, precipitation amount, and air temperature. As listed in Table 6, a wide variety of atmospheric composition and surface and upper air parameters were frequently cited by the documents as important.

Table 6. Inventory of Global Needs and Source Documents for Atmosphere.

Observation	Source Documents
Surface	
Air temperature	GCOS 2006a GCOS 2009b NRC 2007 GCOS 2008
Precipitation *Precipitation extreme events*	GCOS 2006a GCOS 2009b IPCC 2007a,b,c GCOS 2008 GCOS 2006a IPCC 2007a,b,c GCOS 2008
Air pressure	GCOS 2006a GCOS 2009b NRC 2007
Surface radiation budget	GCOS 2006a GCOS 2009b NRC 2007, 2008
Wind speed and direction	GCOS 2006a GCOS 2009b GCOS 2006a
Water vapor	GCOS 2006a GCOS 2009b NRC 2007 GCOS 2008 IPCC 2007c
Evaporation and evapotranspiration	WMO 2008a
Upper Air	
Earth radiation budget	GCOS 2006a GCOS 2009b NRC 2008 Ohring 2007 Bojinski 2008 IPCC 2007c
Upper air temperature	GCOS 2006a GCOS 2009b GCOS 2008
Wind speed and direction	GCOS 2006a G COS 2009b Khare 2008
Water vapor	GCOS 2006a GCOS 2009b IPCC 2007c GCOS 2008 ESA 2007b
Cloud properties Cover Ice profile (column) Water profile (column) Top height Top temperature	GCOS 2006a GCOS 2009b IPCC 2007c NRC 2007 Ohring 2007
Composition	
Carbon dioxide	GCOS 2006a GCOS 2009b GCOS 2008 IPCC 2007 a,b,c ESA 2007b Hamazaki 2008
Methane	GCOS 2006a GCOS 2009b GCOS 2008 IPCC 2007 a,b,c ESA 2007b Hamazaki 2008
Ozone	GCOS 2006a GCOS 2009b GCOS 2008 NRC 2008
Other long-lived greenhouse gases	GCOS 2006a GCOS 2009b GCOS 2008 IPCC 2007 a,b,c ESA 2007b
Aerosol properties	GCOS 2006a GCOS 2009b IPCC 2007c NRC 2007,2008 ESA 2007b

Notes: Italicized observations are GCOS Essential Climate Variables (see text).

Table 7. Inventory of Regional Needs and Source Documents for Atmosphere.*

Observation	North America	Central and South America and the Caribbean	Eastern and Southern Africa	Western and Central Africa	South and Southwest Asia	Central East and SE Asia	Pacific Islands	Europe	Mediter-ranean Basin
Surface									
Air temperature	CGEO 2009 MSCES 2008 NRC 2007				GCOS 2006c	GCOS 2006c	GCOS 2006c		
Precipitation	CGEO 2009 MSCES 2008 NRC 2009 Karl et al 2009		GCOS 2006b	GCOS 2006b				GCOS 2006c	GCOS 2006c
Precipitation extreme events	NRC 2009 Karl et al 2009	GEF 2004	GCOS 2006b	GCOS 2006b	Cfu and DeVries 2006		GCOS 2006c Salinger et al 2002		GCOS 2006c
Air pressure	NRC 2007						GCOS 2006c, Salinger et al 2002		
Surface radiation budget	NRC 2007,2008								
Wind speed and direction							GCOS 2006c, Salinger et al 2002		
Upper Air									
Clouds	CGEO 2009 MSCES 2008 NRC 2007					GCOS 2006c			
Composition									
Ozone	MSCES 2008								
Aerosol properties	MSCES 2008, NRC 2007		Washing-ton et al 2004	Washing-ton et al 2004	GCOS 2006c	GCOS 2006c			

Notes: *GCOS Essential Climate Variables in italics* (see text).
*Due to a limited number of documents on regional priorities, blank cells in this table do not necessarily mean that the parameter is not a priority for the region, but rather that the Analyst did not find documentation of the importance of the given parameter for the region.

4.2 Ocean Earth Observation Needs

The documents analyzed indicated that the ocean plays critical roles in the coupled ocean-atmosphere-land Earth climate system. Sea level is an important variable for low-lying regions, and is interrelated with ocean density and exchange of water between the oceans, ice, and the atmosphere. Global ocean data are critical for developing confidence in forecasts of oceanic variability and change.

Tables 8 and 9 contain a comprehensive inventory of all Earth observation needs from all documents with regard to the sub-area of oceans, for global and regional needs (respectively). The tables include observations of surface and subsurface variables, and identify the major source documents for each entry. For Earth observations related to oceans, the largest overlap between global and regional needs is for sea-surface temperature. The most frequently cited regional need is sea-surface temperature. The most frequently cited global need is information on sea level, followed closely by sea-surface temperature, sea ice, sea-surface salinity, and subsurface carbon.

Table 8. Inventory of Global Needs and Source Documents for Oceans.

Observation		Source Documents
Surface		
Sea-surface temperature		*GCOS 2006a* GCOS 2009b IPCC 2007c GCOS 2008 NRC 2008 Khare 2008
Sea-surface salinity		*GCOS 2006a* GCOS 2009b IPCC 2007c GCOS 2008
Sea level		*GCOS 2006a* GCOS 2009b IPCC 2007c GCOS 2008 NRC 2008 Ohring 2007 Bojinski 2008
Sea state		*GCOS 2006a* GCOS 2009b
Sea ice		*GCOS 2006a* GCOS 2009b IPCC 2007c[j] NRC 2007 Bojinski 2008
Current		GCOS 2009b
Ocean color		*GCOS 2006a* GCOS 2009b NRC 2008
Carbon dioxide partial pressure		GCOS 2009b GCOS 2008 Khare 2008
CO^2 flux across air/sea interface		GCOS 2008
Subsurface		
Temperature		GCOS 2009b GCOS 2008
Salinity		GCOS 2009b GCOS 2008
Current		GCOS 2009b
Nutrients		GCOS 2009b
Carbon		GCOS 2009b NRC 2007 GCOS 2008 IPCC 2007c
Ocean tracers		GCOS 2009b
Phytoplankton		GCOS 2009b

Notes: Italicized observations are GCOS Essential Climate Variables (see text).

Table 9. Inventory of Regional Needs and Source Documents for Oceans.*

Observation	North America	Central and South America and the Caribbean	Eastern and Southern Africa	Western and Central Africa	South and Southwest Asia	Central East and SE Asia	Pacific Islands	Europe	Mediter-ranean Basin
Surface									
Sea-surface temperature	NRC 2008, 2009	(Western South Atlantic) GCOS 2006c	(esp. Western Indian Ocean) GCOS 2006c Washing-ton et al 2004	Washing-ton et al 2004	(establish Indian Ocean observing system) GCOS 2006c		(monitor tsunamis) GCOS 2006c		
Sea level	NRC 2009 Karl et al 2009						GCOS 2006c		
Sea ice	CGEO 2009 MSCES 2008 NRC 2007 Karl et al 2009							GEO 2009	
Subsurface (no Regional Earth observation needs identified)									

Notes: *GCOS Essential Climate Variables in italics* (see text).
*Due to a limited number of documents on regional priorities, blank cells in this table do not necessarily mean that the parameter is not a priority for the region, but rather that the Analyst did not find documentation of the importance of the given parameter for the region.

4.3 Land Earth Observation Needs

The documents analyzed indicated that land, or terrestrial, data are increasingly critical for estimating climate forcing and better understanding of climate change and variability, as well as for impact and mitigation assessment. Land data includes information on snow pack and water equivalent, land use, fires, freshwater bodies, biomass, carbon content, and soil moisture.

Tables 10 and 11 contain a comprehensive inventory of all Earth observation needs from all documents with regard to the sub-area of lands, for global and regional needs (respectively). The tables include observations of snow cover area, area and elevation changes of glaciers and ice caps, albedo, and land cover and change, and identify the major source documents for each entry. For Earth observations related to lands, the regional needs generally overlap with global needs, with the exception of albedo, fraction of absorbed photosynthetically active radiation, leaf area index, biomass, and land/soil carbon. The most frequently cited regional need is land cover, followed by glaciers and ice caps, lakes, soil moisture, river discharge, water use and

groundwater. The most frequently cited global need is information on glacier and ice caps area and elevation changes, followed closely by land cover and snow cover.

Table 10. Inventory of Global Needs and Source Documents for Lands.

Observation		Source Documents
Snow cover area		*GCOS 2006a* GCOS 2009b IPCC 2007c NRC 2008 ESA 2007a
Glaciers and ice caps Area maps Elevation changes		*GCOS 2006a* GCOS 2009b UNFAO 2008a IPCC 2007c NRC 2007 GCOS 2008
Permafrost and seasonally-adjusted frozen ground		GCOS 2009b IPCC 2007c
Albedo		*GCOS 2006a* GCOS 2009b
Land cover *Type maps* *Change maps*		*GCOS 2006a* GCOS 2009b Patton 2008 ESA 2007a IPCC 2007a
Fraction of absorbed photo-synthetically active radiation		*GCOS 2006a* GCOS 2009b
Leaf area index		*GCOS 2006a* GCOS 2009b
Biomass		*GCOS 2006a* GCOS 2009b GCOS 2008
Fire disturbance		*GCOS 2006a* GCOS 2009b
Lakes *Level* Surface temperature		*GCOS 2006a* GCOS 2009b
Soil moisture		*GCOS 2006a* GCOS 2009b IPCC 2007c
River discharge		GCOS 2009b GCOS 2008
Water use *Groundwater*		GCOS 2009b IPCC 2007 a,b,c GCOS 2008 GCOS 2009b
Land/soil carbon*		NRC 2007 GCOS 2008

Notes: Italicized observations are GCOS Essential Climate Variables (see text).
* The updated version of GCOS 2004 will cover this parameter.

Table 11. Inventory of Regional Needs and Source Documents for Lands.*

Observation	North America	Central and South America and the Caribbean	Eastern and Southern Africa	Western and Central Africa	South and Southwest Asia	Central East and SE Asia	Pacific Islands	Europe	Mediter-ranean Basin
Snow cover area	CGEO 2009 MSCES 2008 NRC 2008, 2009					GCOS 2006c		GEO 2009	
Glaciers and ice caps	CGEO 2009, MSCES 2008	GCOS 2006c			GCOS 2006c	GCOS 2006c		GEO 2009	
Permafrost and seasonally-adjusted frozen ground	MSCES 2008 Karl et al 2009					GCOS 2006C			
Land cover	NRC 2009*	GCOS 2006c	(urban) GCOS 2006c, GCOS 2006b	GCOS 2006b		GCOS 2006c		ESA 2007a	GCOS 2006c
Fire disturbance	NRC 2009								
Lakes	NRC 2009		GCOS 2006c	Washing-ton et al 2004			Salinger et al 2002	GCOS 2006c	
Soil moisture	NRC 2009		GCOS 2006c	Washing-ton et al 2004				GCOS 2006c	
River discharge	Karl et al 2009		GCOS 2006c	Washing-ton et al 2004			Salinger et al 2002	GCOS 2006c	
Water use	NRC 2009			Washing-ton et al 2004				GCOS 2006c	GCOS 2006c
Groundwater	NRC 2009		GCOS 2006c	Washing-ton et al 2004			Salinger et al 2002		

Notes: *GCOS Essential Climate Variables in italics* (see text).

*Due to a limited number of documents on regional priorities, blank cells in this table do not necessarily mean that the parameter is not a priority for the region, but rather that the Analyst did not find documentation of the importance of the given parameter for the region.

5 Priority Earth Observations for Climate SBA

5.1 Summary of Results

Section 2.3.3 described the method for assigning priority. Appendix D shows the frequency results for all of the global and regional observations. A summary of these results is below; for this set of results, the relative frequency that the Analyst chose to assign priority (for inclusion in Table 12) is a value equal to or greater than the mean frequency value of 0.2 for both global and regional needs. This value means that 20% or more of the documents for global and regional needs cite the need for a given parameter. Choosing this value is conservative (that is, the value is low) and leads to a larger number of priorities than would a larger mean frequency value. The Analyst chose this conservative approach for several reasons, which should be kept in mind in interpretation of the priority setting results. These reasons include the physical nature of climate as a system, the complexity and interactions of which are best understood as a complete (large) collection of complementary observations (see Section 3.1). Another reason is related to the report methodology: the small number of documents available, particularly on a regional and national basis, leads to two if not even just one document carrying large relative weight.

5.2 Priority Observations

Table 12 shows the global and regional priority observations. It also lists the parameter characteristics, as available, desired by end users. Note that, as discussed in Chapter 4, parameter characteristics were only included in GCOS 2006a, and this document only provided desired parameter characteristics for global needs. Priorities common to both global and regional observations are shaded in orange. Priorities unique to global observations and to regional observations are shaded in green and yellow, respectively.

Table 12. Global and Regional Priorities.

ORANGE = Global and Regional Priority *GREEN = Global Priority* *YELLOW = Regional Priority*					
	GLOBAL**				**REGIONAL***
Parameter	**Accuracy**	**Spatial Resolution**	**Temporal Resolution**	**Stability*****	
The Atmosphere					
Surface					
Air Temperature	0.1K	25 km	3-hourly	N/A	N. America; Asia, Pacific Islands
Precipitation	0.1 mm h^{-1}	100 km hor	3-hourly	0.6%/decade	N. America, Africa, Europe, Mediterranean Basin
Precipitation extreme events		1 km hor	10 minutes		N. America, Central and S. America, Caribbean, Africa, Asia, Pacific Islands, Mediterranean Basin
Air pressure	0.5hPa	200 km	3-hourly	N/A	N. America, Pacific Islands
Surface radiation budget	5 W/m^2	25 km	3-hourly	N/A	
Water vapor	1%	25 km	3-hourly	0.3%/ decade	
Composition					
Carbon dioxide	3 ppm	10 – 250 km hor[a]	3-hourly	3-ppm (forcing) 1-ppm (sources and sinks)	
Methane	20 ppb	10 – 250 km hor[a]	3-hourly	3-ppm (forcing) 1-ppm (sources and sinks)	
Other long-lived greenhouse gases					
Aerosol properties	0.01 (optical depth)	1 km hor	Daily	0.005/decade	N. America, Africa, Asia

ORANGE = Global and Regional Priority *GREEN = Global Priority* *YELLOW = Regional Priority*					
	GLOBAL**				**REGIONAL***
Parameter	**Accuracy**	**Spatial Resolution**	**Temporal Resolution**	**Stability*****	
The Oceans					
Surface					
Sea surface temperatures	0.25°C	1 km hor	3 hourly	0.1°C	N. America Central and S. America, Caribbean, Africa,S. and SW Asia, Pacific Islands
Sea surface salinity					
Sea level	1 cm	25 km hor	Daily	0.5 mm/decade	N. America and Pacific Islands
Sea ice	5%	12 km hor	Daily	5%/decade	N. America and Europe
Carbon dioxide partial pressure	N/A	N/A	N/A	N/A	
Subsurface					
Carbon	N/A	N/A	N/A	N/A	
Lands					
Snow cover area	5% [b] Better than 1/3 IFOV w/target IFOV 100 m (complex terrain) I km (elsewhere)	100 m hor (complex terrain) 1 km (elsewhere)	Daily	5% [b] Better than 1/3 IFOV w/target IFOV 100 m (complex terrain) I km (elsewhere)	N. America, Central and SE Asia, Europe
Glaciers and ice caps Area maps Elevation changes	5% [b] Better than 1/3 IFOV w/ target IFOV 30 m 0.1 m	30 m hor 100 m hor	1 yr 1 yr	5% [b] Better than 1/3 IFOV w/ target IFOV 30 m 0.1 m	N. America, Central and S. America, Caribbean, Asia, Europe
Permafrost and seasonally-adjusted frozen ground	N/A	N/A	N/A	N/A	
Land cover Type maps Change maps	15%[c] Better than 1/3 IFOV w/ target IFOV 250 m 5%[c] Better than 1/3 IFOV w/ target IFOV 10-30 m	250 m – 1 km hor 10-30 m hor	1-yr 5-yr[d]	15%[c] Better than 1/3 IFOV w/ target IFOV 250 m 5%[c] Better than 1/3 IFOV w/ target IFOV 10-30 m	N. America, Central and S. America, Caribbean, Africa, Africa, Europe, Asia, Mediterranean Basin

ORANGE = Global and Regional Priority *GREEN = Global Priority* *YELLOW = Regional Priority*					
	GLOBAL**				**REGIONAL***
Parameter	**Accuracy**	**Spatial Resolution**	**Temporal Resolution**	**Stability*****	
Lands (continued)					
Lakes	N/A	N/A	N/A	N/A	N. America, Africa, Pacific Islands, Europe
Soil Moisture	N/A	N/A	N/A	N/A	N. America, Africa, Europe
River discharge	N/A	N/A	N/A	N/A	N. America, Africa, Pacific Islands, Europe
Water use	N/A	N/A	N/A	N/A	N. America, Africa, Pacific Islands, Mediterranean Basin
Groundwater	N/A	N/A	N/A	N/A	N. America, Africa, Europe

Notes:

hor = horizontal; IFOV = instantaneous field of view.

* Due to a limited number of documents on regional priorities, blank cells in this table do not necessarily mean that the parameter is not a priority for the region, but rather that the Analyst could not find documentation of the importance of the given parameter for the region.

** Technical requirements for global observations unless otherwise noted; source *GCOS 2006a.*

*** Ability of the data to detect long-term trends.

[a] Troposphere to stratosphere.

[b] Maximum error of omission and commission in glacier area maps.

[c] Maximum error of omission and commission in mapping individual classes.

[d] ntervals should coincide with UNFCCC requirements.

ORANGE = Global and Regional Priority GREEN = Global Priority YELLOW = Regional Priority

Several themes emerge in Table 12:

- The needs that are both global and required by at least one region (shaded in orange) are atmospheric observations of air temperature, precipitation and precipitation extreme events, clouds and aerosols; ocean observations of sea-surface temperature, sea level, and sea ice; and terrestrial processes of snow cover, glaciers and ice caps, land cover, and water use. Note that these "common" needs are not necessarily required by all regions, and that the regions differ in their climate observation needs (as demonstrated in Tables 7, 9, and 11).

- Observations of global but not regional priority (shaded in green) are atmospheric variables of surface radiation budget, surface water vapor, Earth radiation budget, upper air water vapor and GHGs, and ocean variables of sea-surface salinity, carbon dioxide partial pressure, and subsurface carbon.

- All of the lands parameters are regional priorities (for at least one region). Some of the lands parameters are also global priorities (but none are only global priorities).

- Observations of regional but not global priority (shaded in yellow) are atmospheric air pressure and terrestrial processes of permafrost and seasonally-adjusted frozen ground, lakes, soil moisture, river discharge, and groundwater.

6 Additional Findings

Beyond the priority observations listed above, this section presents general trends and patterns that emerged from the analysis; specific input, suggestions, and commentary from the Advisory Group; recognized limitations of the bibliometric ranking method used; and directions for future research into climate observations.

Trends and Patterns

Some patterns are suggested by this comparison of global and regional priorities. The differences between global and regional priorities may reflect the difference between understanding and management of climate as "global public good" compared with the need to respond at the regional and national geographic scale to the effects of climate change (see Barrett 2007; this point is also emphasized in GCOS 2006c, which describes findings of a workshop between global climate modelers and scientists and experts involved in IPCC discussion of climate impacts and regional adaptation to a changing climate). The least overlap between global and regional priorities is seen for two sub-areas: (1) the global but not regional priority accorded many of the ocean observations (representing climate phenomena that may be of lesser impact than perceived at the regional and national scale) and (2) the regional/national but not global priority accorded land-related (terrestrial) parameters such as water use, groundwater, lakes, and river discharge. In the case of ocean observations, for which few have regional priority, the exceptions of regional significance of sea level and sea-surface temperature are likely correlated with their role in anticipating and responding to extreme natural weather events (as indicated in the contextual discussion in regional documents of the Western South Atlantic [GCOS 2006c], the Western Indian Ocean [GCOS 2006c and Washington et al. 2004] and the problem of tsunamis in the Pacific Islands [GCOS 2006c]). Other ocean phenomena may be only indirectly regarded as required Earth observations for regional and national decision-makers. This pattern could suggest not only a difference in importance based on geographic scale but perhaps time scale as well; events with near-term effects (extreme precipitation, water use) may be more important for regional and national governments than those with more subtle temporal effects (Earth radiation budget, long-lived GHGs).

Another notable result is the lack of regional and national priority accorded atmospheric observations of carbon dioxide and methane. This result may be explained by the yet-to-be developed policy responses to GHG mitigation by policymakers (but this would not explain why these observations do not show up as a priority for Europe, where an emissions permit trading regime is in place). Alternatively, the result may be an artifact of the nature of the documents

surveyed; the regional and national documents tend toward adaptation to a changing climate rather than reduction and control of GHGs. A member of the Advisory Group points out that these GHG measures are likely to become regionally important as more nations begin to take actions for GHG control.

Advisory Group Commentary

The Advisory Group has provided additional perspective on priorities for the Climate SBA other than those of observations. The Advisory Group notes that there is an ongoing emphasis in climate modeling and observations on downscaling of global observations – an action seen as extremely high priority by the Advisory Group. Understanding of the global climate has been given the most active attention in scientific priority to date, but the need to observe and model climate at smaller spatial scales has long been recognized. The documents and Advisory Group noted that a major limitation of the mainstay of climate modeling -- global climate simulation with general circulation models (GCMs) -- is the coarse spatial resolution (typically on the order of kilometers). Both observations and an enhanced ability of models to simulate and predict climate at much higher spatial resolution (unspecified in the documents) are also required. Regional circulation models (RCMs) can be "nested" within the output from either observation data or GCM simulations. In addition, vulnerability to, potential impacts of, and national and local public policy intervention in response to climate change varies regionally and locally. Climate changes in some regions may be benign or beneficial; in others, climate changes can have disruptive social and economic effects (IPCC, 2007a).

The Advisory Group also emphasizes that *reanalysis* is needed – that is, an assessment of the effectiveness and use of existing climate records and modeling to identify their limits as climate science and information move into the future. Synoptic and continuous records from previous asynoptic and discontinuous measurements must also be created. The Advisory Group points out that in the future, inverting the usual continuum moving from observations to information to knowledge is also desirable—that is, asking first what information is required by decision-makers and the public as they embark on the design of public policy to address a changing climate. The Advisory Group also notes that additional top priorities for understanding climate and of relevance to GEO societal benefit emphases are: (1) developing archive, distribution, maintenance, reprocessing, and other procedures for the sound management of data, and (2) sustaining observations over time.

A member of the Advisory Group emphasizes that all of the ECVs are the result of an overall priority setting by the experts represented in GCOS. As he notes, there are hundreds of variables; of these, the GCOS has identified a set of essential variables, and this process itself represents the setting of priorities. He also emphasizes the scientific integrity of the set of ECVs taken together collectively. For reference and completeness in describing the ECVs, Appendix E reports the information on technical attributes (accuracy, spatial and temporal resolution, stability) for the ECVs not included in Table 12 (because of low prioritization scores).

This concern of breaking apart a collective set of ECVs (for prioritization purposes in this report) is an important context for the priority results reported in this report. Additionally, however, and as noted in GCOS 2008, experts involved with the IPCC process have discussed a subset of the

ECVs as particularly important in responding to and adapting to climate change. This report seeks to reflect these additional perspectives (as provided by an Advisory Group member) in the set of priorities identified in Table 12, but fully appreciates the scientific integrity represented by the collective list of all ECVs.

Limitations of Bibliometric Approach

The prioritization approach that was used is based on the assumption that frequency of citation is correlated with "significance" in the context of the analysis.[5] There are several widely recognized limits to bibliometric approaches (for example, see discussion in OTA 1986) and these limits serve as caveats to the prioritization results.

Limitations of the approach include:

(1) the size, representativeness, and quality of the sample of documents reviewed,

(2) the interpretation of a "citation," and

(3) the weight given to each citation and each document.

To address the first limitation, the size, representation, and quality of the documents assembled for this analysis were the result of an extensive search by the Analyst together with the additional assistance of the Advisory Group to identify and locate publicly available materials. Most of the documents were authored by teams of experts collaborating in high-level working groups, widening representation of priorities beyond those that might be conveyed by an individual author. Fewer documents were available than desired to provide a large sample size, however. The number of documents, particularly for each region, was often just one or two. While not in time to support this report, initiatives are now underway among regional and national working groups to identify their priorities (for example, the IPCC has urged enhanced understanding of regional needs (see GCOS 2008) and the World Climate Research Program (WCRP) and other organizations are regularly convening regional workshops (see WCRP 2009)).

In interpreting a "citation" and weighing its relative priority among all of the documents, the Analyst extracted citations from the subset of documents that described required observations in the context of decisionmaking for global and regional needs. To the extent the documents are comprehensive, the specific needs they identify can be interpreted as representing needs of users. The Analyst assigned equal weighting to each of the documents and each of the regions.

In tandem with the deepening understanding of climate as an integrated system of Earth's processes, the number of ECVs has continued to grow (in 2009, to include soil moisture). In addition, the priority observations identified in this report also overlap with many priority observations for weather (the Weather and Climate SBA analysts shared documents and exchanged ideas during the report preparation). Further analysis in the next stage of the overall

[5] Strictly speaking, bibliometrics is an approach used to identify citations and then count and relate them in a "map of science" for the purpose of quantitatively measuring areas of relatively "greater contribution." See OTA (1986).

UIC project may reveal significant overlap with priority observations for the other GEO SBAs, further demonstrating the overlap described in the Climate SBA in the GEOSS 10-Year Implementation Plan.

7 Analyst's Comments and Recommendations

7.1 Process and Methodology

7.1.1. Process

Advisory Group:
Use of an Advisory Group was extremely helpful to guide the Analyst and identify source material. The Advisory Group also generously shared perspectives on issues in requirements for understanding and managing climate in addition to the identification of priorities and provided the Analyst with additional context.

Report template and outline:
The role of the UIC leadership in drafting and supplying a common template and detailed outline greatly streamlined the process of compiling the report.

Report audience:
The role of the UIC leadership in defining the audience for the report was essential.

7.1.2. Methodology

Top-down approach:
The Analyst recommends that the top-down approach taken in this analysis was useful – it allowed reducing this task to a manageable scope. Also, it avoided the double-counting of parameters that may have occurred in a cross-SBA final analysis, if "climate" issues most relevant to a specific SBA, such as Water, were specifically called out in this Climate SBA report. The downside of the top-down methodology is the potential to overlook or under-prioritize parameters – as such, caution should be used by the Cross-SBA Analyst to identify and adjust for such possible under-prioritization.

Limitations on analyses drawn from written material:
The complexity of climate as interactions among Earth processes and the usefulness of coordinating observing systems have led to the use of large international working groups of experts to define priorities. The GCOS and its related activities have led much of this work to date. As GCOS 2008 demonstrates, the IPCC and GCOS are increasing their collaboration to better connect observations with policy, and to better connect observations with mitigation and adaptation actions. This means that large amounts of information are concentrated in a smaller number of documents than would have been the case in the absence of these collaborative

efforts. How best to weight them or to adjust for commonly authored documents is a challenge in bibliometric approaches.

Identifying priorities:
A methodology based on a count of documents, when the number is as small as the number used in this task, led to use of simple counts as the most transparent method for aggregating requirements and identifying priorities. The advantage of this approach is that it avoids errors or biases in judgment on the part of the Analyst. Readers have available the list of documents and can judge for themselves how representative the count approach is. The disadvantage is that contextual information in the documents and broader perspectives offered by the Advisory Group were difficult for the Analyst to integrate. Another disadvantage of an approach based on a small number of documents is that the method is not robust; it is sensitive to the number and quality of documents. The Analyst recommends that this bibliometric approach be considered for other SBAs. However, when the UIC receives these final US-09-01a reports, the UIC should take care to review the entirety of each report for context.

7.2 Challenges

At present, comprehensive and detailed information on regional and smaller spatial scale priority observations has yet to be collected and assembled. The regional priorities identified in this report are drawn from a very small number of documents. The gap is recognized in the literature (for example, see GCOS 2006c; IPCC 2007c; NRC 2009).

Another challenge is the gap between the science and application of observations, in both identifying requirements and setting priorities. This report sought to help close the gap by specifying both climate modelers and the policy community as two user types, and compiling and reviewing documents from both. A member of the Advisory Group emphasizes that a larger number of "users," including scientists, operational network managers, and policy-level experts, has been involved in the specification of the GCOS ECVs and associated requirements.

Appendix A: Abbreviations

CEOS	Committee on Earth Observation Satellites
ECVs	Essential Climate Variables
ESA	European Space Agency
ESF	European Science Foundation
GCM	General Circulation Model
GCOS	Global Climate Observing System
GEF	Global Environmental Facility
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GHG	Greenhouse gas
GMES	Global Monitoring for Environment and Security
GOOS	Global Ocean Observing System
GTOS	Global Terrestrial Observing System
IGBP	International Exosphere-Biosphere Program
IPCC	Intergovernmental Panel on Climate Change
MSCES	Meteorological Service of Canada – Environment Canada
NRC	National Research Council
RCM	Regional Circulation Model
RFF	Resources for the Future
SBA	Societal Benefit Area
UIC	User Interface Committee
UNEP	United Nations Environment Program
UNFAO	United Nations Food and Agriculture Organization
UNFCCC	United Nations Framework Convention on Climate Change
WCRP	World Climate Research Program
WMO	World Meteorological Organization

Appendix B: Bibliography

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and Space Administration, National Polar-Orbiting Operational Environmental Satellite System-Integrated Program Office, and Space Dynamics Laboratory of Utah State University, May 16 – 18, 2006).

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Appendix C: List of Documents with URL and Document Category

Reference	Doc Class	Title	Author	Year Published	Type of Document	Region	File
Bojinski et al 2008	III	Key Needs for Observing Climate Change from Space	Bojinski, Stephan	September 2008	Presentation	International	http://www.sapc.jaxa.jp/about/data/eoseminar02_04.pdf
CEOS 2006	I	Satellite Observation of the Climate System: The Committee on Earth Observation Satellites (CEOS) Response to the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC	CEOS	September 2006	Report	International	http://www.ceos.org/images/PDFs/CEOSResponse_1010A.pdf
Cfu et all 2006	IV	Initial Science Plan of the Monsoon Asia Integrated Regional Study	Cfu, Congbin and Frits Penning De Vries (eds)	2006	Report	Regional/Asia	http://www.mairs-essp.org/UserFiles/File/isp-1.1.pdf
ESA 2007a	IV and V	Sentinel-2: Mission Requirements Document (issue 2 revision 0)	ESA	February 2007	Mission Requirements Document	Regional/Europe	http://esamultimedia.esa.int/docs/GMES/GMES_Sentinel3_MRD_V2.0_update.pdf
ESA 2007b	V	GMES Sentinels 4 and 5 Mission Requirements Document (issue 1 revision 0)	ESA	April 2007	Mission Requirements Document	Regional/Europe	http://esamultimedia.esa.int/docs/GMES/Sentinel4and5MRDissue1rev0signed.pdf
ESF 2008	IV	Recommendations to the Ministerial Conference of ESA Member States	European Science Foundation	November 2008	Report	Regional/Europe	http://www.esf.org/nc/publications/space.html?tx_ccdamdl_cart[add]=20102
Federal Service 2008	IV	Assessment Report on Climate Change and its Consequences in Russian Federation	Federal Service for Hydrometeorology and Environmental Monitoring, Russian Federation	2008	Report	Regional/Russia	http://climate2008.igce.ru/v2008/pdf/resume_ob_eng.pdf

Reference	Doc Class	Title	Author	Year Published	Type of Document	Region	File
GCOS 2004		Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (GCOS-92)	GCOS	2004	Report	Global	http://www.wmo.int/pages/prog/gcos/Publications/gcos-92_GIP.pdf
GCOS 2006a	I	Systematic Observation Requirements for Satellite-based Products for Climate - Supplemental details to the satellite-based component of the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (GCOS-107)	GCOS	September 2006	Report	International	http://www.wmo.int/pages/prog/gcos/Publications/gcos-107.pdf
GCOS 2006b	IV	Climate Information for Development Needs: An Action Plan for Africa	GCOS and partners	November 2006	Report	Regional/Africa	http://www.wmo.int/pages/prog/gcos/Publications/gcos-108.pdf
GCOS 2006c	IV	Final Report of the GCOS Regional Workshop Programme (GCOS – 111B, WMO/TD No. 1474)	WMO	August 2006	Report	International and Regional	http://www.wmo.ch/pages/prog/gcos/Publications/gcos-111B.pdf
GCOS 2009a	I	Guideline for the Generation of Satellite-based Datasets and Products meeting GCOS Requirements	GCOS	March 2009	Report	International	http://www.wmo.int/pages/prog/gcos/documents/GCOS_Guideline_DatasetsProducts_March2009.pdf
GCOS 2009b	I	Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008	GCOS	April 2009	Report	International	http://www.wmo.int/pages/prog/gcos/Publications/GCOSProgressReport_ReviewDraft_080409.pdf
GCOS 2009c	I	GCOS Essential Climate Variables	GCOS	26 May 2009	Table	International	http://www.wmo.ch/pages/prog/gcos/index.php?name=essentialvariables
GCOS/WCRP/IGBP 2008a	III	Future Climate Change Research and Observations: GCOS, WCRP and IGBP Learning from the IPCC Fourth Assessment Report.	WMO	January 2008	Report	International	http://www.wmo.int/pages/prog/gcos/Publications/gcos-117.pdf

Reference	Doc Class	Title	Author	Year Published	Type of Document	Region	File
		GCOS-117, WCRP-127, IGBP Report No. 58 (WMO/TD No. 1418),					
GEF 2004	IV	It's Raining, It's Pouring, It's Time to Be Adapting: Report of the 2nd Assessment of Impacts and Adaptation to Climate Change (AIACC) Regional Workshop for Latin America and the Carribbean	Global Environmental Facility/AIACC	August 2004	Report	Regional/Latin America/Carribbean	http://www.aiaccproject.org/meetings/Buenos_Aires_04/Buenos_Aires.pdf
GEO 2009	I	Climate Achievements	GEO, members, and participating organizations	Ongoing	Status briefs	Regional	http://www.Earthobservations.org/geoss_cl_ea.shtml
Hamazaki 2008	III	JAXA Space Agency Contributions to Global Monitoring of Greenhouse Gases	Hamazaki, Takashi	September 2008	Presentation	International	http://sapc.jaxa.jp/about/data/eoseminar02_06.pdf
IPCC 2007a	II	Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change	IPCC	2007	Report	International	http://www.ipcc.ch/ipccreports/ar4-wg2.htm
IPCC 2007b	II	Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change	IPCC	2007	Report	International	http://www.ipcc.ch/ipccreports/ar4-syr.htm
IPCC 2007c	II	Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change	IPCC	2007	Report	International	http://www.ipcc.ch/ipccreports/ar4-wg1.htm

Reference	Doc Class	Title	Author	Year Published	Type of Document	Region	File
Karl et al 2009	IV	Global Climate Change Impacts in the United States	Karl, Thomas R. Et al	2009	Report (published by Cambridge University Press)	Regional/USA	http://www.globalchange.gov
Khare 2008	VI	Earth Observations: A Catastrophe Risk Modeling Point of View	Khare, Shree	July 2008	Presentation	International	http://www.csis.org/media/csis/events/080716_RMS.pdf
Long et al 2007	IV and V	CPC's Climate Monitoring Needs and the Certified NPOESS Program	Long, Craig S., Wayne Higgins, John Janowiak, S.K. Yang	October 2007	Presentation	Regional/USA	http://www7.nationalacademies.org/ssb/NPOESS_mitigate_descope_presentation_Long.pdf
Maynard 2008	VI	Global Data and Why Insurers Need It	Maynard, Trevor	July 2008	Presentation	International	http://www.csis.org/media/csis/events/080716_lloyd.pdf
MSCES 2008	IV	The Canadian National Report on Systematic Observations for Climate: National Activities with Respect to the Global Climate Observing System (GCOS) Implementation Plan	Meteorological Service of Canada-Environment Canada	November 2008	Report	Regional/Canada	http://unfccc.int/resource/docs/gcos/cangcose.pdf
NRC 2007	IV and V	Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. Committee on Earth Science and Applications from Space: A Community Assessment and Strategy for the Future, National Research Council	National Research Council of the National Academies	2007	Report	International and Regional/USA	http://www.nap.edu/catalog.php?record_id=11820
NRC 2008	V	Ensuring the Climate Record from the NPOESS and GOES-R Spacecraft	National Research Council of the National Academies	2008	Report	International	http://www.nap.edu/catalog.php?record_id=12254#toc

Reference	Doc Class	Title	Author	Year Published	Type of Document	Region	File
NRC 2009	IV and V	Informing Decisions in a Changing Climate	National Research Council of the National Academies	2009	Report	Regional/USA	http://www.nap.edu/catalog.php?record_id=12626
Ohring et al 2007	I	Achieving Satellite Instrument Calibration for Climate Change (ASIC3)	Ohring, George (ed.)	2007	Report	International	http://www.star.nesdis.noaa.gov/star/documents/ASIC3-071218-webversfinal.pdf
Patton 2008	VI	Earth Observation, Global Change and Insurance	Patton, Lindene	July 2008	Presentation	International	http://www.csis.org/media/csis/events/080716_zurich.pdf
Salinger et al 2002	IV	Pacific Island GCOS Action Plan	Salinger, Jim et al.	March 2002	Report	Regional/Pacific Islands	http://www.wmo.int/pages/prog/gcos/documents/PI-GCOS_AP.pdf
Stott 2008	VI	Observations for Climate Monitoring, Attribution and Prediction	Stott, Peter	July 2008	Presentation	International	http://www.csis.org/media/csis/events/080716_hadley.pdf
UNFAO 2008a	I	Terrestrial Essential Climate Variables for Climate Change Assessment, Mitigation and Adaptation	UNFAO	2008	Report	International	http://www.fao.org/docrep/011/i0197e/i0197e00.htm
UNFCCC 2008b	II	Report of the Conference of the Parties on Global Observing Systems for Climate	UNFCCC	14 March 2008	Report	International	http://unfccc.int/resource/docs/2007/cop13/eng/06a02.pdf
Washington et al 2004	IV	Africa Climate Report	Washington, Richard et al.	December 2004	Report	Regional/Africa	http://www.defra.gov.uk/environment/climatechange/internat/devcountry/pdf/africa-climate.pdf
WCRP 2008	III	Report from the Third Meeting of the WCRP Observation and Assimilation Panel (WOAP)	WCRP	November 2008	Report	International	http://www.wmo.int/pages/prog/gcos/Publications/gcos-125.pdf
WCRP 2009	IV	Workshop on Evaluating and Improving Regional Climate Projections	World Climate Research Program	February 2009	Report	International	http://wcrp.ipsl.jussieu.fr/Workshops/Downscaling/index.html

Reference	Doc Class	Title	Author	Year Published	Type of Document	Region	File
WCRP no date	IV	Monsoon Asia Integrated Regional Study	Earth System Science Partnership	No date	Report	Regional/Asia	www.mairs-essp.org/UserFiles/File/Brochure-new.pdf and also http://www.mairs-essp.org/
WMO 2008a	IV	An International Expert Review Meeting on Regional Climate Outlook Forums	WMO	November 2008	Report	International and Regional	http://www.wmo.int/pages/prog/wcp/wcasp/documents/RCOFReview2008ConceptNote.pdf
WMO 2008b	I	The Space-Based Global Observing System in 2008 (GOS-2008).	WMO	October 2008	Report	International	ftp://ftp.wmo.int/Documents/PublicWeb/sat/DOSSIERGOS-2008_Volumes-0-1-2-3-4.zip
WMO 2009	I	The Space-Based Global Observing System in 2009 (GOS-2009).	WMO	June 2009	Report	International	ftp://ftp.wmo.int/Documents/PublicWeb/sat/DossierGOS/Gos-2009-June.zip

Appendix D: Results of Relative Citation Frequency

Citation Frequency of Global and Regional Needs (see text for method)		
Observation	**Global**	**Region**
The Atmosphere		
Surface		
Air temperature	.2	.4
Precipitation	.3	.6
Precipitation extreme events	.3	.8
Air pressure	.1	.2
Surface radiation budget	.2	.1
Wind speed and direction	.1	.1
Water vapor	.3	0
Evaporation and evapotranspiration	.1	0
Upper Air		
Earth radiation budget	.3	0
Upper air temperature	.1	0
Wind speed and direction	.1	0
Water vapor	.3	0
Cloud properties Cover Ice profile (column) Water profile (column) Top height Top temperature	.3	.2
Composition		
Carbon dioxide	.4	0
Methane	.4	0
Ozone	.2	.1
Other long-lived greenhouse gases	.4	0
Aerosol properties	.3	.6
The Oceans		
Surface		
Sea-surface temperature	.3	.7
Sea-surface salinity	.2	0
Sea level	.4	.2
Sea state	.1	0
Sea ice	.3	.2
Current	.1	0
Ocean color	.1	0
Carbon dioxide partial pressure	.2	0
CO_2 flux across air/sea interface	.1	0
Subsurface		
Temperature	.1	.1
Salinity	.1	0
Current	.1	0
Nutrients	.1	.1
Carbon	.3	0
Ocean tracers	.1	0
Phytoplankton	.1	0

Citation Frequency of Global and Regional Needs (see text for method)		
Observation	**Global**	**Region**
Terrestrial Processes		
Snow cover area	.3	.3
Glaciers and ice caps Area maps Elevation changes	.3	
Permafrost and seasonally-adjusted frozen ground	.1	.2
Albedo	.1	0
Land cover Type maps Change maps	.3	.8
Fraction of absorbed photo-synthetically active radiation	.1	0
Leaf area index	.1	0
Biomass	.1	0
Fire disturbance	.1	.1
Lakes Level Surface temperature	.1	.6
Soil moisture	.1	.4
River discharge	.1	.6
Water use Groundwater	.3 .1	.4 .4
Land/soil carbon	.1	0

Appendix E: Technical Information for ECVs not Included in Table 12

Appendix E. GEO Task US-09-01a: Earth Observations Needs for Climate SBA: Technical Information for ECVs Not Included in Table 12

	GLOBAL				
ECV	Accuracy	Spatial Resolution	Temporal Resolution	Stability	
Surface Wind speed (and direction)	0.5m/s	10 km	Hourly		
Upper Air Wind speed (and direction)	2 m/s	100 km hor, 0.5km ver	3-hourly	2 m/s / decade	
Air Temperature	0.5 K	100km hor; 0.1 ver (PBL), 2 km (elsewhere)	3-hourly	0.05K/decade (troposphere); 0.1K/decade (LS)	
Ozone	Profile: 10% (troposphere), 5% (stratosphere) Column: 5 Dobson units	Profile: 5 km hor (troposphere); 50 km hor (stratosphere) 0.5 km ver (troposphere), 0.5-3km ver (stratosphere) Column: 5 km hor	3-hourly	Profile and Column: 1% (troposphere); 0.6% (stratosphere)	
Ocean colour	5%	1 km hor	Daily	1% / decade	
Sea state (significant wave height)	10 cm	25 km hor	3-hourly	5 cm / decade	
Sub surface Temperature	0.001 K (upper ocean); 0.002 K (deep ocean)	1 km (upper ocean); 50 km (deep ocean)	Daily (upper ocean); Monthly (deep ocean)	N/A	
Albedo (directional-hemispherical)	5%	1km	Daily	1%	
FAPAR	0.05	250m	Daily	0.05	
LAI	0.5 (average as per IFOV)	250m	Daily	0.5	
Biomass	5%	10-30 m hor	Yearly	5%	
Fire disturbance (area)	5% (maximum error of commission and omission)	250m	Daily	5%	

Appendix F: Input to the Cross-SBA Analysis

At the conclusion of the individual SBA priority-setting analysis, the Climate Analyst provided input on the overall critical Earth observation parameters for the Climate SBA for inclusion in the Cross-SBA meta-analysis. Upon receiving input from the SBA Analysts, the Cross-SBA Analyst reviewed the priorities and combined observation parameters that are the same or very similar but have different names (e.g., precipitation intensity and precipitation duration). In some cases, the Cross-SBA Analyst extracted observation parameters from aggregated observation categories that were identified as priorities by individual SBAs and included these observation parameters as input to the Cross-SBA analysis. As a result, the number of observation priorities identified by individual SBAs may vary from the number of observations that were included in the Cross-SBA analysis. To the extent possible, the Cross-SBA Analyst focused on retaining the observation parameter terminology employed by the majority of the SBAs, in order to minimize regrouping and splitting of observations.

The Climate SBA Analyst determined the overall critical Earth observation priorities for the Climate SBA using a bibliometric method, as described in Section 2.3.3 and Chapter 5. Based on the results of the prioritization analysis, the 27 observations listed below have the highest rankings and thus are considered to be the observation priorities for the Climate SBA. The Cross-SBA Analyst included these 27 observations in Methods 1-3 of the Cross-SBA analysis. Accounting for differences in observation terminology across the SBAs, the Climate Team effectively contributed 33 observation parameters to Methods 1-3 of the Cross-SBA analysis. The Climate SBA Analyst divided the 27 observations into the three tiers representing "High," "Medium," and "Low" priority observations for numerical weighing in Cross-SBA Methods 2 and 3. The Analysts designated "High" priorities as those with bibliometric scores of greater than or equal to 0.6 for either regional or global. The Analysts deemed "Medium" priorities as those that did not qualify as "High", but had combined (summed) scores of regional and global importance greater than or equal to 0.5. The Analyst deemed "Low" priorities as those that did not qualify as "High" or "Medium."

For Method 4, the Cross-SBA Analyst included the "High" and "Medium" priority observations in the Cross-SBA analysis, plus Surface Radiation Budget (the highest-ranked of the "Low" priority parameters), as the "15 Most Critical" observations. Accounting for differences in observation terminology across the SBAs, the Climate Team effectively contributed 22 observation parameters to Method 4 of the Cross-SBA analysis.

High
Reservoir/Lake Level and Surface Temeprature
River Discharge
Precipitation
Precipitation Extreme Events
Aerosol Properties
Sea Surface Temperature
Land Cover Type
Land Cover Change

Medium
Soil Moisture
Sea Level
Sea Ice
Snow Cover Area
Glacier/Ice Cap Area Maps
Glacier/Ice Cap Elevation
Water Use
Groundwater

Low
Surface Radiation Budget
Atmospheric Water Vapor
Atmospheric Carbon Dioxide
Atmospheric Methane
Other long-lived Greenhouse Gases
Sea Surface Salinity
Carbon Dioxide Partial Pressure (water)
Ocean Subsurface Carbon
Air Pressure
Permafrost/Frozen Ground
Air Temperature