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

Ecosystems Societal Benefit Area: Part Two

GROUP ON EARTH OBSERVATIONS

User Interface Committee

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GEO Task US-09-01a

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Summary

This report is part of GEO Task US-09-01a, with the objective of identifying critical Earth observation priorities for nine Societal Benefit Areas (SBAs). This report is the second of two reports that identify observation priorities for the Ecosystems SBA. The first report (Lough et al. 2010) focused on analysis of forests, coastal and near-shore marine systems, and watersheds. This second report (Part 2) focuses on analysis of inland/fresh water, oceanic islands and archipelagos, and tundra.

The basic methodology for identifying critical Earth observation priorities within an SBA relies on an Analyst working in coordination with an Advisory Group to select the scope of the analysis, identify and analyze relevant documents, and extract and prioritize relevant Earth observation parameters. The focus sub-areas were selected in consultation with the Advisory Group. The Advisory Group recommended documents for review by the Analyst Team to identify important parameters within the focus areas. The documents identified by the Advisory Group were supplemented by the Analyst Team by searching for additional documents that indicate the Earth observation needs of the focus areas.

The Analyst Team reviewed the selected literature and identified the Earth observation needs and characteristics of those needs, when reported (characteristics such as geographic scale and frequency at which data is needed). The identified needs, along with supporting information, were provided to the Advisory Group. The Advisory Group rated the importance of the various Earth observation needs. These ratings were used as the basis of the prioritization of the various Earth observation needs. The priorities were then vetted with the Advisory Group to ensure that no high priority need had been missed.

The prioritization process produced a list of priority parameters, given in Table S-1, that are applicable for observation across a range of ecosystems.

Table S-1. Highest Ranked Priority Observational Parameters for the Ecosystems SBA

Parameter	Rank
Permafrost condition and dynamics (degradation, reduction)	1
Vegetation cover, changes	1
Disturbance (fire, drought, land clearing, urbanization, desertification, cultivation, deforestation)	2
Extent, location, and fragmentation of ecosystem and habitat types (including stream and riparian habitat structure and condition)	3
Soil carbon	4
Biomass (phytomass), biomass spatial distribution, biomass moisture content	5
Forest fragmentation	5
Salinity (water)	6
Vegetation indices (NDVI+SAVI+EVI)	7
Forest cover	8

1 Introduction

This report articulates Earth observation priorities for the Ecosystems SBA, based on an analysis of 40 publicly available documents, many of which are produced by Group on Earth Observations (GEO) Member Countries and Participating Organizations.

1.1 Group on Earth Observations and Societal Benefit Areas

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 SBAs:

Agriculture	Biodiversity	Climate
Disasters	Ecosystems	Energy
Health	Water	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. 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 includes ground, in-situ, airborne, and space-based observations. The task includes both observed 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 and 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 Participating Organizations can use the results in determining priority investment opportunities for Earth observations.

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

1.3 Purpose of Report

The primary purpose of this report is to articulate the critical Earth observation priorities for the Ecosystems SBA. This report is the second of two GEO Task US-09-01a reports on the Ecosystems SBA, each with a different set of sub-areas of focus. The intent of the report is to describe the overall process and specific methodologies used to identify documents, analyze 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 Energy SBA are additional audiences for this report.

1.4 Scope of Report

This report addresses the Earth observation priorities for the Ecosystems SBA, with a focus on sub-areas that were not addressed in the previous Ecosystems SBA report (Lough et al. 2010). In particular, this report addresses the sub-areas of Inland/Fresh Water, Oceanic Islands and Archipelagos, and Tundra.

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

The report focuses on the Earth observations relevant to the Ecosystems 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 than 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 Ecosystems SBA and the specific sub-areas that are part of the analysis. Section 4 articulates the specific Earth observations for each Ecosystems SBA sub-area, and Section 5 presents the priority observations across the Ecosystems SBA. Sections 6 and 7 present additional findings from the analysis of the documents and recommendations. The appendices include the documents cited and consulted, a list of acronyms used throughout the document, and a summary of the input to the Cross-SBA analysis.

2 Methodology

2.1 Task Process

The basic methodology for identifying critical Earth observation priorities within an SBA relies on an Analyst working in coordination with an Advisory Group to select the scope of the analysis, identify and analyze relevant documents, and extract and prioritize relevant Earth observation parameters. 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 9 steps, as summarized in the following list:

Step 1: UIC Members identify Advisory Groups and Analysts for each SBA
Step 2: Determine scope of topics for the current priority-setting activity
Step 3: Identify existing 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 on the priorities
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 the GEO website. For the Ecosystems SBA analysis, many of these steps were conducted simultaneously. The Analyst identified existing documents (Step 3) concurrently with development of the analytic methods and priority-setting criteria (Step 4), in coordination with the Advisory Group. This allowed the methods to be tailored to the types of documents that were being identified. Also, as input was received from the Advisory Group, the Analyst continued to conduct Step 3 (document identification and analysis) iteratively throughout the process, as Advisory Group members continued to identify relevant documents.

2.2 Analyst and Advisory Group

The Ecosystems SBA had an "Analyst," "Analyst Team," and an "Advisory Group" working together to conduct the process of identifying documents, analyzing them, and prioritizing the Earth observations. The Analyst served as the main coordinator and manager of the activities.

2.2.1 Analyst Team

For the Ecosystems SBA, the Analyst was Dr. Harry Stone, and the Analyst Team consisted of Dr. Stone and Dr. Glynis Lough, both of Battelle, along with other Battelle staff. Dr. Stone is an ecologist with experience in landscape-level ecosystem modelling and planning. Dr. Stone has served as a facilitator or invited advisor in various government/private sector planning initiatives striving to balance ecosystem resilience and recovery with economic development. Dr. Stone has led multiple efforts to understand inland/fresh water Earth observing requirements and priorities. Dr. Lough is an Environmental Research Scientist with experience in environmental chemistry and environmental policy and planning. Dr. Lough has worked with in-situ and remote sensing measurements in a number of projects supporting climate change and environmental studies. The Ecosystems SBA Analyst and Analyst Team served through the Battelle Memorial Institute under contract to the National Aeronautics and Space Administration (NASA).

2.2.2 Advisory Group

The Analyst assembled the Advisory Group, which consisted of 17 scientific and technical experts, recognized as credible and respected in the field of water, island, or tundra ecology. The Advisory Group members are from both developed and developing countries, and encompass all regions of the world, representing GEO Countries and Participating Organizations, as listed in Table 1.

Table 1. GEO Task US-09-01a: Advisory Group for Ecosystems SBA

Name	GEO Country or Organization	Affiliation	Geographic Region	Area of Expertise/ Specialty
R. J. ASSAKO	Cameroon	University of Douala	Africa	Urban development and lake pollution
Neil DAVIES	French Polynesia	ED, Gump Station Moorea	Oceania/ Australia	Broad ecosystems expertise
Ana Laura DOMINGUEZ	Mexico	Instituto de Ecologia A.C.	North America	Coastal/Estuarine ecology and management
Scott J. GOETZ	United States	Woods Hole Research Center	North America	Aquatic ecosystem research
Anna KOZLOVA	Ukraine	Scientific Centre for Aerospace Research of the	Europe	GIS and Remote Sensing, forest ecosystems

Name	GEO Country or Organization	Affiliation	Geographic Region	Area of Expertise/ Specialty
		Earth		
Murari LAL	Fiji	PACE-SD, The University of the South Pacific	Oceania/ Australia	Water resource management and landscape ecology
Jorge LÓPEZ-PORTILLO	Mexico	Instituto de Ecologia A.C.	North America	Landscape ecology
Gabriel OLCHIN	United States	Council for Regulatory Environmental Modeling Office of the Science Advisor US EPA	North America	Large-scale ecosystem processes and modeling policy; remote sensing and high latitude ecosystems
Deb PETERS	United States	Lead Principle Investigator, Jornada Basin LTER, USDA-ARS	North America	Broad ecosystems expertise
Stuart PHINN	Australia	The University of Queensland	Oceania/ Australia	Geography, planning, and environmental management
Mui-How PHUA	Malaysia	Universiti Malaysia Sabah	Oceania/ Australia	Landscape-level conservation planning
Humberto REYES	Mexico	University of San Luis Potosí	North America	Ecosystems and natural resources management
Erick SANCHEZ	Mexico	Universidad Autónoma de Ciudad Juárez	North America	Remote Sensing and Spatial Analysis
Ashbindu SINGH	United States	United Nations Environmental Program	North America	Environment Early Warning & Assessment
Nicki VILLARS	The Netherlands	Deltares	Europe	Optical remote sensing data for calibrating and validating water quality models
Anton VRIELING	The Netherlands	University of Twente	Europe	Remote sensing, soil erosion, time series analysis, phenology

Name	GEO Country or Organization	Affiliation	Geographic Region	Area of Expertise/ Specialty
Frans-Emil WIELGOLASKI	Norway	University of Oslo	Europe	Fennoscandian Tundra Ecosystems

The Analyst developed the pool of candidates for the Advisory Group based on relevant publications in potential areas of focus. The Analyst Team invited each potential candidate to participate and provided each candidate with information on the expectations for Advisory Group members. The Analyst Team contacted 35 people from all geographic regions, resulting in 17 Advisory Group members representing every continent except Antarctica and South America. The role of the Advisory Group was to help identify relevant documents, comment on the analytic methods and priority-setting criteria utilized, and review the Analyst's findings, priorities, and reports.

2.3 Methodology

2.3.1 Documents

The Analyst followed the 9-step process as outlined by the UIC. In determining the scope of the report (Step 2), the Analyst, working with the Advisory Group, bounded the area of interest – i.e., eliminated sub-areas that are included as primary topics under other GEO Task US-09-01a reports, such as water quality (Water SBA report) and air quality (Human Health SBA report). Next, the Analyst and Advisory Group worked iteratively to suggest and review potential sub-areas, and ultimately identified inland/fresh water, oceanic islands and archipelagos, and tundra as topics of critical importance.

The Advisory Group members were asked to identify publicly available documents (Step 3) from both developed and developing nations on the Ecosystems SBA sub-areas. In addition, the Task US-09-01a methodology required the Analyst to examine a wide range of sources for potentially relevant documents, including:

- International, regional, and national consensus documents focused on data sources, applications, or research priorities
- Reports from major regional or national projects
- Workshop and conference summaries
- Peer-reviewed journal articles
- End-user documents (e.g., weed managers guidance).

The Analyst Team built the document list largely through literature searches and online searches. Searches applied a range of keywords to identify documents related to different types of studies and end user needs, such as discovery of new information, establishment of baseline values, investigation of trends, and application to decisions. Table 2 gives examples of the types of search terms utilized by the Analyst Team.

Table 2. Examples of Literature Search Terms Used

Application Terms	Ecosystems Terms	Observation Terms
Indicator	Watershed	Habitat
Monitoring	Lake	Nitrogen
Modeling	Aquatic	Pollution
Land cover	Landscape	Primary productivity
Land use planning	Nitrogen	Invasive species
Storm water	Freshwater	Riparian zone

The Analyst Team made efforts to represent the major geographic regions, including studies conducted in a region and/or reports from authors in the region. Documents from both developed and developing countries was represented in the document list. The Advisory Group reviewed the document list and provided additional documents to represent specific ecosystem types and to address observational needs.

The Analyst sought information both on the parameters that are needed by end users, and the desired characteristics of the parameters. The Analyst Team specifically sought documents that addressed observational needs, either explicitly or through discussion of shortcomings of currently available observations. The Analyst supplemented documents describing data needs with documents that indicated the application of the data. Together, the documents explicitly or implicitly provided insight into the coverage/extent, temporal resolution, spatial resolution, timeliness (availability of observation), and accuracy/precision that are needed by end users.

2.3.2 Focus and Organization of the Analysis

For Steps 3 and 4, the Analyst developed and used a conceptual ecological model as a framework for identifying observational needs; the framework helped ensure that information gaps, even if not well documented in the literature, would not be missed. The Analyst focused on identifying the breadth of ecosystem observations that are needed. Scientific studies create the knowledge that is translated and applied in practical applications, such as water management, fisheries management, and land use planning. Ecosystems observations provide a strategic role in three broad scientific and applied areas:

- Observing current conditions and trends in ecosystem structure, functioning, and services
- Predicting future conditions of ecosystem structure, functioning, and services, and
- Providing early detection and continuing observations necessary to inform policy options during extreme events (Committee on Earth Science and Applications from Space 2007).

As depicted in Figure 1, ecosystems observations to address the above-listed areas include natural and anthropogenic drivers/stressors that modify nutrient-related factors which impact ecosystems (including structure, functioning, dynamics, and services); changes in land use that impact ecosystems and services; and changes in disturbance cycles, including insects and invasive species, that impact ecosystems and services (Committee on Earth Science and Applications from Space 2007).

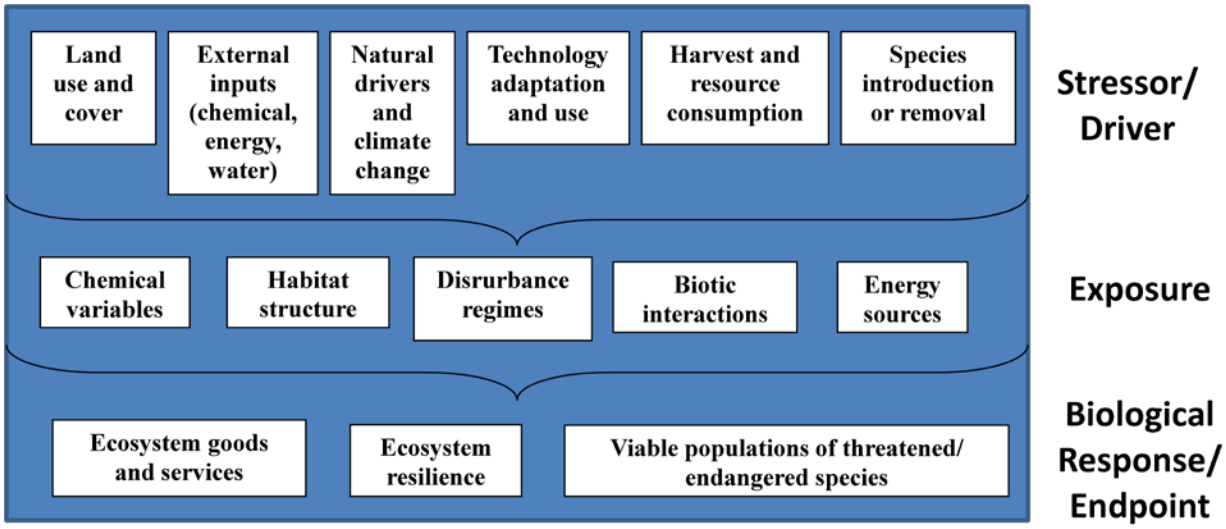

Figure 1. Conceptual ecological model linking human stressors and natural drivers to biological responses and endpoints modified from Millennium Ecosystem Assessment (2005), (Karr et al. 2000), (Karr and Yoder 2004).

The framework for understanding ecosystem observation needs, as well as subsequent prioritization, was grounded in the ecological models of Karr et al. (2004) and the World Resources Institute's Millennium Ecosystem Assessment (2005). These models link anthropogenic actions to ecological endpoints: biological endpoints are a function of land use, chemical and energy inputs, natural drivers and climate change, overharvesting, and introduced species) (modified from (Karr et al. 2004)). The relative strength of the various stressors depends on the magnitude of the stressor relative to specific resilience of an ecosystem, and on synergies among stressors, exposures, and biological endpoints. These relationships may be non-linear. The biological responses/endpoints, expressed as a production function, can then be linked to corresponding ecosystem services by an appropriate value function.

The categories of stressor/drivers, exposures, and biological response/endpoints provided the framework for identification of important Earth observation parameters within each category. The Earth observation parameters, presented and prioritized in Section 5, are those that were identified in the literature, or those that were identified by the Analyst Team and Advisory Group, as important for understanding the target ecosystems. The parameters include direct observations and indirect or modeled parameters derived from direct observations. Both direct and indirect parameters are included in the analysis.

2.3.3 Prioritization Methods

The Analyst determined that the prioritization of parameters should be performed by Advisory Group rankings, based on a list of critical Earth observation parameters derived from the literature reviewed by the Analyst Team. The Analyst selected this Advisory Group ranking method to maximize utilization of the expertise of the Advisory Group, and to avoid one of the potential limitations of bibliometric analysis, i.e. – bibliometric analysis may result in higher rankings for parameters that are frequently mentioned in literature rather than for those parameters that are necessarily needed most by end users. To develop the list of parameters for

Advisory Group ranking, the Analyst Team first considered whether the parameter fit within the ecological framework. Parameters were merged to the extent that they were measuring the same ecological component or endpoint.

To further inform the Advisory Group prioritization, the Analyst Team obtained bibliometric information as follows. The Analyst Team conducted an advanced search on www.scholar.google.com of key terms for each parameter to determine the number of "hits". Scholar.google.com searches the scholarly literature (journal papers, conference papers, technical reports). The search was constrained to include only documents with at least a summary on the internet that were published during the period of 2005 to 2010. Patents were excluded from the search. The keywords used for the search and the number of documents containing all of the keywords in the search are included in the tables of parameters in Section 4.

In addition to the results of the key word searches, the Advisory Group was provided with tables that listed the parameters identified by the Analyst Team and the associated references. The Advisory Group members were asked to rate each parameter on a scale of 1 to 4 (1 being the least important, 4 being the most important). To facilitate the rating process, the Advisory Group received a spreadsheet that listed the parameters identified by the Analyst Team.

The individual ratings received from Advisory Group members were averaged by the Analyst Team to determine the final rating for each parameter. The parameters with the highest mean values were selected as the highest priority parameters. Following the rating procedure, the priority ranking results were reviewed by the Advisory Group to identify any important gaps in high priority parameters, and to make modifications (and document those modifications) to the prioritization as necessary.

Finally, the Analyst Team combined the lists of prioritized parameters from the first Ecosystems SBA report (Lough et al. 2010) with the prioritized list of parameters in this second Ecosystems SBA report, to obtain an overall prioritization of end user needs across the six ecosystems sub-areas considered in the two reports. To start, the Analyst Team made a number of changes to the parameter names to align the lists of parameters from the two reports, as detailed in Appendix C. The Analyst Team next normalized the overall prioritization ranks from the first Ecosystems SBA report and the current report, and averaged the ranking for each parameter. If a parameter appeared in only one report, its ranked score was not averaged. The Analyst then extracted the 10 highest ranked parameters from this methodology, because 10 is a manageable number of parameters for this report, although other breakpoints would be equally valid.

3 Ecosystems SBA

The term "ecosystem" refers to the interconnected functions of plants and animals with water, land, and air. As such, ecosystems include both pristine natural environments and human-impacted environments, on scales ranging from global to highly local. The world's ecosystems provide valuable services that are the source of much of our natural resources, and house the numerous processes that provide clean water, clean air, and food (Costanza et al. 1997). Human activities and climate change are threatening or degrading ecosystems and the services they provide at a global level (World Resources Institute 2005). An ability to monitor and evaluate

ecosystem health, function, and change is crucial for decisions that impact the preservation, adaptation, or restoration of ecosystems.

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

> "Observations are needed on the area, condition, and natural resource stock levels in ecosystems such as forests, rangelands, and oceans. GEOSS implementation will seek to ensure methodologies and observations are available on a global basis to detect and predict changes in ecosystem condition and to define resource potentials and limits. Ecosystems observations will be better harmonized and shared, spatial and topical gaps will be filled, and in situ data will be better integrated with space-based observations. Continuity of observations for monitoring wild fisheries, the carbon and nitrogen cycles, canopy properties, ocean color, and temperature will be set in place."

3.1 Sub-areas

For this second (Part 2) Ecosystems SBA report, the Analyst selected the following three sub-areas based on input from the Advisory Group: inland/fresh water, oceanic islands and archipelagos, and tundra. Collectively, these three types of ecosystems represent vulnerable ecosystems that may serve as early indicators of impacts from global climate change, other anthropogenic stressors, and natural disturbances.

Inland/Fresh Water: Inland water ecosystems are among the most threatened ecosystem types and are often subjected to anthropogenic stressors. This sub-area focuses extensively on in-situ and modeled parameters for smaller inland water systems, as well as remote sensing products for larger inland water bodies. Observation needs impacting inland/fresh water can be viewed as a nested hierarchy, including terrestrial characteristics, such as impervious surface, as well as water body characteristics. As detailed in Chapter 4, the observational needs include, but are not limited to: physical changes, habitat degradation and fragmentation, water withdrawal, overexploitation, pollution, and invasive species. Factors that overlap with other GEO Task US-09-01a reports are generally not repeated here: water (quantity, hydrology), disasters (floods, droughts, insect pests), and climate (storms, temperature, precipitation).

Oceanic Islands and Archipelagos: Island ecosystems (terrestrial, freshwater, and marine) are particularly vulnerable to anthropogenic changes that may easily result in loss of species. Ecosystems such as oceanic islands have often evolved in isolation and, therefore, are not equipped for invasive species competition. Habitat loss and fragmentation impacts are accentuated by the constrained land area and lagoon/coastal slope. Insularity also limits the potential for species to migrate in response to climate change. The observation needs, as detailed in Chapter 4, include, but are not limited to: biodiversity, invasive species (plants and animals), habitat loss and fragmentation, loss of mangrove swamps and wetlands, and climate change impacts (e.g., coral bleaching, sea level rise, ocean acidification). Factors that overlap with other GEO Task US-09-01a reports are generally not repeated here: climate, disasters (earthquakes, tsunamis), and biodiversity.

Tundra: Tundra ecosystems include the Arctic, high-altitude areas (above the tree line), and Antarctic ecosystems. All tundra ecosystems are expected to experience rapid change due to climate change. Human impacts in the Arctic have intensified in recent years with increased focus on natural resources such as oil and possible new northern shipping routes. Tundra vegetation is primarily shrubs, grasses, mosses, and lichens, with stunted trees in some areas. A relatively small number of animals live full time in the tundra, but many birds, insects, and sea mammals migrate to the tundra in the brief summer months. Observation needs, as detailed in Chapter 4, for tundra ecosystems include, but are not limited to those related to change and response to disturbance from climate change and human activity. Some observation needs related to water are important, but are being included in other GEO Task US-09-01a reports, or in the inland/freshwater sub-area of this report, and are not repeated here: water quality, quantity, and hydrology.

3.2 Documents

The Analyst Team and Advisory Group initially identified over 100 documents that are potentially relevant to prioritization of Ecosystems observation parameters needed by end users. Based on review of the potentially relevant documents, the Analyst Team selected a subset of the 40 most relevant documents. Table 3 lists the number of the documents on the final list pertinent to geographic regions and ecosystem observation categories used in this report. Many of the documents were relevant to more than one geographic region or ecosystem sub-area.

Table 3. Categorization of Document Used by Geographic Region and SBA Sub-Area

Geographic Region	Number of Documents
Global or Non-specific	12
Africa	1
Asia/Middle East	4
East Asia	0
Europe	4
North America	15
Oceana/Australia	6
Polar Regions	0
South/Central America	2

SBA Sub-Area	Number of Documents
General or Multiple Areas	8
Inland/Fresh Water	18
Oceanic Islands and Archipelagos	10
Tundra	4

Among the final list of 40 documents, there are 10 consensus and review documents that address ecosystem observational needs:

- Integrated Global Observing Strategy (IGOS) Partnership Land Theme Report (Townshend et al. 2008)
- Physical Stream Assessment: A Review of Selected Protocols for Use in the Clean Water Act Section 404 Program (U.S. Army Corps of Engineers [USACE] and U.S. Environmental Protection Agency [USEPA] 2005)

- Sourcebook on Remote Sensing and Biodiversity Indicators, Prepared by the NASA-NGO Biodiversity Working Group and UNEP-WCMC to support implementation of the Convention on Biological Diversity (Strand et al. Eds. 2007)
- Australian River Assessment System: Review of Physical River Assessment Methods — A Biological Perspective (Parsons et al. 2002)
- Ecosystems and Human Well-being: Wetlands and Water, Millennium Ecosystem Assessment (World Resources Institute 2005)
- Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan Reference Document (GEO 2005)
- Filling the Gaps: Priority Data needs and Key Management Challenges for National Reporting on Ecosystem Condition (Heinz Center 2006)
- Integrated Global Observations of the Land: a proposed theme to the IGOS-Partnership, version 2 (Integrated Global Observing Strategy Partnership 2004)
- Wetlands Mapping Standard (Federal Geographic Data Committee 2009)
- National Imperatives for the Next Decade and Beyond (National Research Council 2007)

4 Earth Observations for Ecosystems SBA

The tables in this Chapter list the Earth observations needed by end users, and the parameter characteristics, where specified in the documents. Where the documents included information about parameter needs, the Analyst Team recorded coverage/extent, spatial resolution, temporal resolution, latency of data availability, and accuracy.

Coverage/extent refers to the area of observation, and was recorded as global, regional, or local. The Analyst Team recorded spatial resolution quantitatively, if available in the documents. If only qualitative descriptions were listed, the Analyst Team applied standardized definitions of high (<15 m), moderate (15 to 100 m), or coarse (>100 m), similar to descriptions generally used in the documents for spatial resolution of remote sensing measurements. The Analyst Team recorded temporal resolution quantitatively if specified, but more frequently this parameter was recorded as hourly, daily, weekly, or monthly based on Analyst expert judgment.

4.1 Inland/Fresh Water

Inland/fresh water parameter needs, shown in Table 4, were classified by the Analyst Team under the following observational categories, derived from the conceptual model in Figure 1:[3]

- Chemical variables, including dissolved oxygen, nutrients, and toxins
- Disturbance regimes, addressing changes in natural patterns of disturbances, e.g., stream flow patterns
- Ecosystems resilience and ecosystem services, addressing biological indicators of resilience, e.g., presence of keystone species

[3] Note that certain Earth observations of ecological importance, such as climate change, water use, and fire regimes, are not included because they are addressed directly in other GEO Task US-09-01a reports.

- Energy sources, including abiotic as well as biotic energy transformation and status, e.g., primary productivity and heat flux
- Habitat structure, including extent, location, fragmentation, and condition, e.g., riparian zone landscape structure and condition
- Land use and land cover, including anthropogenic as well as natural conditions, e.g., impervious surface
- Species introduction and removal, addressing harvesting impacts, incidental removal, and invasive species, e.g., fish harvest intensity
- Viable populations of threatened and endangered species, addressing vulnerable species and ecosystems

Table 4. Observation Parameters for Inland/Fresh Water

Desired Parameters and Characteristics for Inland/Fresh Water					
Observation Category	**Parameter**	**Characteristics of the Observation Parameters**			
		Coverage/ Extent	**Spatial**	**Temporal**	**Other†**
Chemical Variables	**Suspended solids/ sediment loads** (Casatti et al. 2006) (Liu 2003; Nelson 2003; USACE and USEPA 2004; GEO 2005; Vörösmarty et al. 2005; Lawford 2008; Townshend et al. 2008)	Regional to Local	<15m	Sub-daily to Daily	16,000: suspended + solids + ecology 16,000: sediment + load + ecology
Chemical Variables	**Aquatic nitrogen** (content, flux, deposition, cycling) (Casatti et al. 2006) (Liu 2003) (Parsons et al. 2002; Nelson 2003; Integrated Global Observing Strategy Partnership 2004; USACE and USEPA 2004; GEO 2005; Vörösmarty et al. 2005; Heinz Center 2006; Committee on Earth Science and Applications from Space 2007; Townshend et al. 2008)	Global (Vörösmarty et al. 2005), National (Heinz Center 2006), Regional, State, Local	<15m (current practice)	Multiple times per year (monthly and high flow events)	23,300: aquatic + nitrogen + ecology
Chemical Variables	**Aquatic phosphorus** (content, flux, cycling) (Casatti et al. 2006) (Liu 2003) (Parsons et al. 2002; Integrated Global Observing Strategy Partnership 2004; USACE and USEPA 2004; Vörösmarty et al. 2005; Heinz Center 2006; Townshend et al. 2008)	Global (Vörösmarty et al. 2005), National, Regional, State	<15m	Multiple times/year	14,800: aquatic + phosphorus + ecology
Chemical Variables	**Aquatic dissolved oxygen** (content) (Parsons et al. 2002; USACE and USEPA 2004; Casatti et al. 2006)	Regional to Local	<15m	Daily to Weekly	16,000: aquatic + dissolved + oxygen + ecology
Chemical Variables	**Carbon: Dissolved organic carbon** (content, flux, cycling), **dissolved inorganic carbon, particulate organic carbon** (GEO 2005; Vörösmarty et al. 2005)	Local	<15m	Daily to Weekly	27,700: dissolved + carbon + ecology 15,600: particulate + carbon + ecology
Chemical Variables	**Colored (chromogenic) dissolved organic matter** (Lawford 2008) (Liu 2003; Nelson 2003; USACE and USEPA 2004; GEO 2005)	National	<15m	Daily to Weekly	662: chromogenic + dissolved + organic + matter + ecology

Desired Parameters and Characteristics for Inland/Fresh Water					
Observation Category	**Parameter**	**Characteristics of the Observation Parameters**			
		Coverage/ Extent	**Spatial**	**Temporal**	**Other†**
Chemical Variables	**Other chemistry (pH, salinity, hardness, toxic chemicals, metals, persistent pollutants, conductivity, oxidation-reduction potential, surface oils, etc.)** (Casatti et al. 2006) (Liu 2003; Focardi et al. 2006) (Parsons et al. 2002; Integrated Global Observing Strategy Partnership 2004; USACE and USEPA 2004; Vörösmarty et al. 2005)	Global	<15m		Not evaluated due to imprecision of results.
Disturbance Regimes	**River discharge pattern; current velocity** (Casatti et al. 2006); (Pichon et al. 2006; Lawford 2008) (Parsons et al. 2002; GEO 2005; Vörösmarty et al. 2005)	Global, Continental (Lawford 2008)	1-10 km (Lawford 2008)	1-10 days	18,500: river + discharge + ecology 42, 500: current + velocity + ecology
Disturbance Regimes	**Ecosystem demand for water; conservation demand for water** (Townshend et al. 2008)	Regional to Local		Monthly	18,800: ecosystem + demand + water 32,100: conservation + demand + water
Disturbance Regimes	**Water elevation (lake)** (Townshend et al. 2008)	Global	30m	Weekly	15,400: lake + water + elevation + ecology
Ecosystem Resilience	**Species composition; fisheries trophic index; index of biotic integrity** (Casatti et al. 2006; Barbour et al. 1999; GEO 2005; Heinz Center 2006; Committee on Earth Science and Applications from Space 2007; Townshend et al. 2008)	National, Regional, Local (Barbour et al. 1999)	50 - 75m (Committee on Earth Science and Applications from Space 2007); <15m*	30 day to daily; annually to 5 year cycle	319,000: species + composition + ecology 12,100: index + biotic + integrity
Ecosystem Resilience	**Ecosystem dynamics, vegetation health, and insect outbreaks** (Integrated Global Observing Strategy Partnership 2004; GEO 2005; Townshend et al. 2008)	Global, Regional to Local	50 - 75m (Committee on Earth Science and Applications from Space 2007); <15m*	30 day to daily during episodes	36,500: ecosystem + dynamics 20,800: vegetation + health + ecology 14,200: insect + outbreaks + ecology

Desired Parameters and Characteristics for Inland/Fresh Water					
Observation Category	**Parameter**	**Characteristics of the Observation Parameters**			
		Coverage/ Extent	**Spatial**	**Temporal**	**Other†**
Ecosystem Resilience	**Aquatic keystone species** (Committee on Earth Science and Applications from Space 2007)	Global, Regional to Local	50 - 75m (Committee on Earth Science and Applications from Space 2007); <15m*	30 day to daily	4,860: aquatic + keystone + species
Ecosystem Resilience (Aquatic)	**Aquatic ecosystem condition** (fish to bacteria; phytoplankton community; algal blooms; eutrophic zones) (GEO 2005; Heinz Center 2006; Committee on Earth Science and Applications from Space 2007; Townshend et al. 2008)	National (Heinz Center 2006)	50 - 75m (functional groups of organisms) 250m (algal blooms) (Committee on Earth Science and Applications from Space 2007)	30 day to several times daily (algal blooms); 5-10 year cycle (indicator)	14,400: aquatic + ecosystem + condition
Ecosystem Resilience and Ecosystem Service	**Wetland Mapping: emergent plant classification and submerged plant classification** (Sawaya 2003; Heinz Center 2006; Jones et al. 2006)	Regional/ Local	1 m (Jones et al. 2006; Wetlands Subcommittee 2009)	Annually	14,600: mapping + emergent + plant + wetland 6,870: mapping + emergent + plant + wetland
Ecosystem Resilience and Ecosystem Service	**Wetland Mapping: inundation of vegetation** (forests, grasses, and forbs), including impounded streams (Heinz Center 2006; Strand et al. 2007)	Regional/ Local	1 m (flooded part of growing season) (Wetlands Subcommittee 2009)	Annually or more frequently to identify areas flooded during part of growing season	9,690: mapping + inundation + vegetation

Desired Parameters and Characteristics for Inland/Fresh Water					
Observation Category	**Parameter**	**Characteristics of the Observation Parameters**			
		Coverage/ Extent	**Spatial**	**Temporal**	**Other†**
Ecosystem Resilience and Ecosystem Service	**Wetland, lakes, reservoirs, ponds (area), rivers and streams (miles) mapping** (Heinz Center 2006; Gardiner 2007; Townshend et al. 2008)	Global, Regional, Local	30m to <15m(Heinz Center 2006; Gardiner 2007); 10-30m (Townshend et al. 2008)	10 years	Also called "Key Habitat Elements" (Heinz Center 2006) 13,300: mapping + wetland 17,500: mapping + lakes 17,900: mapping + rivers
Energy Source	**Clarity, Secchi disk transparency** (Casatti et al. 2006) (Liu 2003; Lawford 2008) (Parsons et al. 2002; Nelson 2003; USACE and USEPA 2004; GEO 2005; Heinz Center 2006; Townshend et al. 2008)	National, Regional, Local	30m (larger waterbodies), 4m (smaller waterbodies) (Sawaya 2003)	Biweekly	15,700: water + transparency + ecology
Energy Source	**Maximum/minimum temperature at surface and in stream; sensible heat flux; latent heat flux; soil heat flux** (Parsons et al. 2002; USACE and USEPA 2004; GEO 2005; Lawford 2008)	Global (Lawford 2008)		Monthly to Seasonal	19,400: stream + surface + temperature + ecology
Energy Sources	**Aquatic primary productivity and NPP; aquatic chlorophyll concentration; respiration** (Kerr et al. 2003; Liu 2003; Nelson 2003; GEO 2005; Committee on Earth Science and Applications from Space 2007; Strand et al. 2007; Lawford 2008)	Western Hemisphere (Committee on Earth Science and Applications from Space 2007)†	250 m (Committee on Earth Science and Applications from Space 2007)†; <15m*	Several times per day	15,600: aquatic + primary + productivity
Energy Sources	**Leaf Area Index** (Kerr et al. 2003; GEO 2005)	Global, Regional to Local	50 - 75m (Committee on Earth Science and Applications from Space 2007); <15m*	30 day to daily	40,400: leaf + area + index
Energy Sources	**Photosynthetically Active Radiation** (PAR, fPAR) (Kerr et al. 2003)	Regional to Local	15m to 100m	7 to 16 days	11,800: fraction + photosynthetically + active + radiation

Desired Parameters and Characteristics for Inland/Fresh Water					
Observation Category	**Parameter**	**Characteristics of the Observation Parameters**			
		Coverage/ Extent	**Spatial**	**Temporal**	**Other†**
Habitat Structure	**Extent, location, and fragmentation of ecosystem and habitat types** (including stream and riparian habitat structure and condition) (GEO 2005) (Parsons et al. 2002; Goetz 2006)	Global, Regional to Local	<30m (Gardiner 2007)	At least annually	16,100: ecosystem + fragmentation
Habitat Structure	**Abiotic in-stream habitat composition, substrate, cover, embeddedness, bank stability, etc.** (Casatti et al. 2006) (Barbour et al. 1999; Parsons et al. 2002; Pichon et al. 2006)	National, Regional to Local (Barbour et al. 1999)	<15m* ; stream reaches 10-30km in length (Parsons et al. 2002)	5 year intervals	14,500: in-stream + habitat 17,500: bank + stability + ecology
Habitat Structure (Riparian Zone)	**Vegetative cover** (Parsons et al. 2002; Focardi et al. 2006; Goetz 2006; Pichon et al. 2006; Committee on Earth Science and Applications from Space 2007)	Global, Regional to Local	50 – 75 (Committee on Earth Science and Applications from Space 2007); <15m (Goetz 2006);	30 day to daily	14,300: vegetative + cover + ecology 16,000: riparian + zone + ecology
Habitat Structure (Riparian)	**Riparian Vertical Structure** (Parsons et al. 2002; GEO 2005; Goetz 2006; Committee on Earth Science and Applications from Space 2007; Townshend et al. 2008)	Global	50 – 150 m (Committee on Earth Science and Applications from Space 2007); 20 m (Goetz 2006); 10-30m (Townshend et al. 2008)	Monthly	12,300: riparian + vertical + structure
Habitat Structure (Riparian)	**Riparian zone landscape structure and condition; standing biomass** (GEO 2005; Goetz 2006; Heinz Center 2006; Committee on Earth Science and Applications from Space 2007)	Global	50 – 150 m (Committee on Earth Science and Applications from Space 2007; Gardiner 2007); 30m - <15 m	Monthly; 5-10 year cycle	14,700: riparian + zone + landscape + structure

Desired Parameters and Characteristics for Inland/Fresh Water					
Observation Category	**Parameter**	**Characteristics of the Observation Parameters**			
		Coverage/ Extent	**Spatial**	**Temporal**	**Other†**
Land Use and Cover	**Impervious surface** (Sawaya 2003; Vörösmarty et al. 2005; Goetz 2006; Heinz Center 2006)	Global/Regional/ Local	<30m (Heinz Center 2006);	Annually	6,080: impervious + surface + ecology
Land Use and Cover	**Land use, land cover** (Kerr et al. 2003; Integrated Global Observing Strategy Partnership 2004; Vörösmarty et al. 2005; Heinz Center 2006; Committee on Earth Science and Applications from Space 2007; Gardiner 2007)	Global	<30 m (Heinz Center 2006) 15-50 m, 250m – 1km (Integrated Global Observing Strategy Partnership 2004)	Annually (low resolution); 5 year cycle (high resolution)	336,000: land + use + ecology 91,100: land + cover + ecology
Species Introduction and Removal	**Non-native aquatic, wetland, or riparian species** (Lopez et al. 2001; GEO 2005; Heinz Center 2006; Committee on Earth Science and Applications from Space 2007)	National (Heinz Center 2006)	10 m (Williams et al. 2010)	Daily to 5-year cycles	17,200: invasive aquatic species
Species Introduction and Removal	**Fish harvest intensity (GEO 2005)**	Local	Not specified	Weekly to Monthly	16,500: fish + harvest + intensity
Viable Populations of Threatened and Endangered Species	**At risk freshwater/wetland species/communities (Heinz Center 2006)**	National (Heinz Center 2006)	50 - 75m (Committee on Earth Science and Applications from Space 2007); <15m*	30 day to daily; 5 years	17,100: endangered + aquatic + species

* The judgment of the Analyst Team and Advisory Group were used to interpret the coverage/extent, spatial, and temporal characteristics of observation parameters. All characteristics that were available in the documents are recorded.

† Included in the "Other" column is the number of hits in Scholar.Google.com for the keywords shown. See Section 2.3.3 for details.

4.2 Oceanic Islands and Archipelagos

Parameters in the documents for oceanic island and archipelagos, shown in Table 5, focused on observations for key drivers/stressors that are, or are likely to, change as a result of natural and anthropogenic impacts. The Millennium Ecosystem Assessment (World Resources Institute 2005) stated that the factors impacting island ecosystems for the past 50-100 years and projected into the future are:

- Habitat change (high impact in past, continuing to be high)
- Climate change and sea level rise (low impact in past, increasing rapidly)
- Invasive species (very high impact in past, continuing to be very high)
- Over-exploitation (high impact in past, continuing to be high)
- Pollution, including nutrients (nitrogen and phosphorus) (low impact in past, increasing rapidly).

Based on these factors of concern and a review of the literature, the Analyst Team determined that the following topics for oceanic island and archipelagos are of most common concern:

- Coral reef health and resistance/susceptibility to climate change
- Invasive species and the factors that promote their spread
- Mapping and tracking health of mangroves and their susceptibility/resilience to climate change
- Susceptibility of land systems to human or climate disturbance (e.g., fire regimes, land cover, fragmentation, sea level)
- Understanding complete systems – synoptic changes, sum of reef processes, sub-zone processes (e.g., local respiration in different sections of the reef)
- Improving system model

The Analyst Team mapped parameters identified in the literature to the observational categories derived from the conceptual model in Figure 1. Very few of the documents identified for this sub-area discussed spatial and temporal resolution needs. The Analyst Team was able to assess the needed coverage or extent of the parameters from the documents. Because of the geographic size and remoteness of most oceanic islands and archipelagos, the majority of parameters required local or regional coverage or extent. Because the Analyst Team was able to assess needs for spatial and temporal resolution for a relatively small number of parameters, they removed those columns from the table and included information on spatial and temporal resolution in the “other” column when it was provided.

Table 5. **Observation Parameters for Oceanic Islands and Archipelagos**

Desired Parameters and Characteristics for Oceanic Islands and Archipelagos			
Observation Category	Parameter	Characteristics of the Observation Parameters	
		Coverage/Extent	Other†
Chemical Variables	**Atmospheric CO_2** {Gilman, 2008 #23; Gledhill, 2009 #103}	Global, Regional	Data needed monthly; Estimated w/in 1ppm. 13,400: atmospheric + carbon + dioxide + islands
Chemical Variables	**Atmospheric optical properties** {Brock, 2006 #12}	Global, Local	Same resolution as other satellite products for inputs to models 16,000: atmospheric + optical + properties + islands
Chemical Variables	**Biogeochemistry** {Rodriguez, 2004 #89}	Regional, Local	15,400: biogeochemistry + islands
Chemical Variables	**Chlorophyll** {Gledhill, 2009 #103}	Local	14,100: chlorophyll + islands
Chemical Variables	**Deepwater mixing processes** {Gledhill, 2009 #103}	Local	12,500: deepwater + mixing + processes + islands
Chemical Variables	**Groundwater salinity** {Vander Velde, 2006 #58; Nayak, 2008 #80}	Local	9,700: groundwater + salinity + islands
Chemical Variables	**Nutrient (N, P) concentrations, availability, cycling** {Rodriguez, 2004 #89; Asner, 2005 #82; Goetz, 2005 #21; Brock, 2006 #12; Gilman, 2008 #23}	Local, Regional	14,700: nitrogen + islands
Chemical Variables	**Plant chemistry** {Asner, 2005 #82; Goetz, 2005 #21}	Local	16,500: plant + chemistry + islands
Chemical Variables	**Pollution** {Nayak, 2008 #80}	Local, Regional, Global	15,800: pollution + islands

Table 5 (continued). Observational Parameters for Oceanic Islands and Archipelagos

Desired Parameters and Characteristics for Oceanic Islands and Archipelagos			
Observation Category	Parameter	Characteristics of the Observation Parameters	
		Coverage/Extent	Other†
Chemical Variables	**Salinity, salinity at the surface (seawater)** {Gilman, 2008 #23; Brock, 2006 #12; Vander Velde, 2006 #58; Gledhill, 2009 #103}	Local	15,900: seawater + surface + salinity + islands
Energy Source	**Sea surface temperature, water temperature**, {Donner, 2005 #100; Gledhill, 2009 #103; Brock, 2006 #12}	Local	15,700: seawater + surface + temperature + islands
Energy Source	**Temperature** {Fordham, 2010 #18; Asner, 2008 #85; Gledhill, 2009 #103; Asner, 2005 #82}	Local	Data needed daily, mean annual needed; Generally 1°F accuracy for annual mean Hits not determined; search too general
Chemical Variables	**Sea surface gas exchange** {Gledhill, 2009 #103}	Regional	16,000: sea + surface + gas + exchange + islands
Chemical Variables	**Sea surface thermodynamics** {Gledhill, 2009 #103}	Regional	8,490: sea + surface + thermodynamics + islands
Chemical Variables (Water chemistry)	**Dissolved O_2** {Brock, 2006 #12}	Local	Need spatial detail, diurnal variation, seasonality, and replicate observations 16,000: dissolved + oxygen + islands
Chemical Variables	**Alkalinity, calcium** ({Brock, 2006 #12; Gledhill, 2009 #103}	Local	Need spatial detail, diurnal variation, seasonality, and replicate observations 6,820: alkalinity + islands

Table 5 (continued). Observational Parameters for Oceanic Islands and Archipelagos

Desired Parameters and Characteristics for Oceanic Islands and Archipelagos			
Observation Category	Parameter	Characteristics of the Observation Parameters	
		Coverage/Extent	Other†
Chemical Variables	**Dissolved CO_2, carbonate, bicarbonate** {Gledhill, 2009 #103}	Local	Need spatial detail, diurnal variation, seasonality, and replicate observations 23,200: dissolved + carbon + dioxide + islands + ecology
Chemical Variables	**pH** {Brock, 2006 #12}	Local	Need spatial detail, diurnal variation, seasonality, and replicate observations Hits not determined; search too general
Disturbance Regimes	**Deforestation** {Rodriguez, 2004 #89}	Local	Data needed monthly 13,200: deforestation + island + ecology
Disturbance Regimes	**Disturbance** {Brock, 2006 #12; Fordham, 2010 #18; Rodriguez, 2004 #89; Asner, 2008 #104}	Regional, Local	Data needed weekly to annually 18,500: disturbance + island + ecology
Disturbance Regimes	**Forest Fragmentation** {Fordham, 2010 #18}	Local, Regional	Data needed annually 16,100: forest + fragmentation + island + ecology
Disturbance Regimes	**Hydroperiod** {Gilman, 2008 #23}	Regional	1,070: hydroperiod + island + ecology
Disturbance Regimes	**Fire fuel load, fire regime** {Asner, 2008 #85; Fordham, 2010 #18}	Local, Regional	15,900: fire + regime + island + ecology

Table 5 (continued). Observational Parameters for Oceanic Islands and Archipelagos

Desired Parameters and Characteristics for Oceanic Islands and Archipelagos			
Observation Category	Parameter	Characteristics of the Observation Parameters	
		Coverage/Extent	Other†
Disturbance Regimes	**Sea Level** {Fordham, 2010 #18; Gilman, 2008 #23}, Sea level pressure {Gledhill, 2009 #103}	Regional, Local	17,200: sea + level + pressure + island + ecology
Disturbance Regimes	**Storms, storm surges** {Gilman, 2008 #23}	Regional, Local	4,010: storm + surge island + ecology
Ecosystem Resilience	**Ecosystem function** {Fordham, 2010 #18; Gilman, 2008 #23}	Local	17,300: ecosystem + function + island + ecology
Ecosystem Resilience	**Erosion (reefs, sandbars)** {Nayak, 2008 #80}	Local	16,700: erosion + island + ecology
Ecosystem Resilience	**Groundwater recharge rate** {Vander Velde, 2006 #58}	Local	3,210: groundwater + recharge + rate + island + ecology
Ecosystem Resilience	**Resilience** {Donner, 2005 #100; Gilman, 2008 #23; Rodriguez, 2004 #89}	Local, Regional	14,600: resilience + island + ecology
Ecosystem Resilience	**Species composition (plants, animals, canopy, and understory), taxonomic composition** {Asner, 2008 #104; Asner, 2005 #82}	Local, Regional	38,000: species + composition + island + ecology
Ecosystem Resilience and Ecosystem Service	**Hydrology** {Gilman, 2008 #23; Rodriguez, 2004 #89; Strand, 2007 #76}	Local	15,800: hydrology + island + ecology

Table 5 (continued). Observational Parameters for Oceanic Islands and Archipelagos

Desired Parameters and Characteristics for Oceanic Islands and Archipelagos			
Observation Category	Parameter	Characteristics of the Observation Parameters	
		Coverage/Extent	Other†
Ecosystem Resilience and Ecosystem Service	**Phenology** {Gilman, 2008 #23}	Local/Regional	9,970 : phenology + island + ecology
Ecosystem Resilience and Ecosystem Service	**Sedimentation, sediment accretion** {Fordham, 2010 #18; Gilman, 2008 #23; Nayak, 2008 #80; Strand, 2007 #76}	Local	15,700: sedimentation + island + ecology
Ecosystem Resilience and Ecosystem Service	**Physiological status** {Asner, 2008 #104}	Local	15,000: physiological + status + island + ecology
Ecosystem Resilience and Ecosystem Service	**Water column bio-optical state** {Brock, 2006 #12}	Local	279: water + column + bio-optical + state + island + ecology 10,800: water clarity island ecology
Ecosystem Resilience and Ecosystem Service	**Water residence time (in the reef)** {Brock, 2006 #12}	Local, Regional	2,290: coral + reef + water + residence + time
Ecosystem Resilience and Ecosystem Service	**Precipitation** {Asner, 2008 #85; Gilman, 2008 #23; Millennium Ecosystem Assessment, 2005 #38; Vander Velde, 2006 #58; Asner, 2005 #82}	Local, Regional	Data needed daily with annual average; For annual, used 250mm/year accuracy 15,900: precipitation + island + ecology
Energy Source	**Light penetrating canopy** {Asner, 2008 #85; Asner, 2005 #82}	Local	10,900: island+ light + penetrate + canopy

Table 5 (continued). Observational Parameters for Oceanic Islands and Archipelagos

Desired Parameters and Characteristics for Oceanic Islands and Archipelagos			
Observation Category	Parameter	Characteristics of the Observation Parameters	
		Coverage/Extent	Other[†]
Energy Source	**Photosynthetically Active Radiation (PAR)** in photic zone and benthic {Brock, 2006 #12}	Local	4,890: island + photosynthetically + active + radiation
Energy Source	**Net community production (reef)** {Brock, 2006 #12}	Local	13,100: reef + net + community + production
Energy Source	**Net primary production (NPP)**, net primary surface ocean production { Brock, 2006 #12; Gilman, 2008 #23;Gledhill, 2009 #103}	Local, Regional	44,700: ocean + primary + surface + production
Energy Source	**Respiration** {Gledhill, 2009 #103}	Local	16,800: island + respiration
Energy Source	**Shortwave infrared irradiance** {Asner, 2008 #104}	Local	524: island + shortwave + infrared + irradiance
Energy Source	**Upwelling (water)** {Gledhill, 2009 #103}	Local	13,900: island + water + upwelling
Energy Source	**Upwelling radiation** {Brock, 2006 #12}	Local	Needed; can estimate from general albedo observations 3,640: island + upwelling + radiation
Energy Source	**Wind speed** {Gledhill, 2009 #103}	Local, Regional	22,300: island + wind + speed
Energy Source	**Ocean circulation patterns** {Gilman, 2008 #23}	Global, Regional	17,200 : open + ocean + circulation + patterns

Table 5 (continued). Observational Parameters for Oceanic Islands and Archipelagos

Desired Parameters and Characteristics for Oceanic Islands and Archipelagos			
Observation Category	Parameter	Characteristics of the Observation Parameters	
		Coverage/Extent	Other[†]
Habitat Structure	**Landscape structure** {Fordham, 2010 #18}	Global, Regional	27,500 : island + landscape + structure
Habitat Structure	**Substrate age, substrate chemical composition** {Asner, 2008 #104; Asner, 2005 #82}		38,100: island + substrate
Habitat Structure	**Subterranean geology** {Vander Velde, 2006 #58}	Local	Related to groundwater 3,710: island + subterranean + geology
Ecosystem Resilience and Ecosystem Service	**Leaf Area index (LAI)** {Asner, 2005 #82; Strand, 2007 #76}	Local	17,400: island + leaf + area + index
Ecosystem Resilience and Ecosystem Service	**Mangrove extent** {Strand, 2007 #76}	Global, Regional, Local	10,200 : island + mangrove + extent
Energy Source	**NDVI** {Rodriguez, 2004 #89; Strand, 2007 #76}		2,270: island + NDVI
Land Use and Cover	**Red-edge position** {Asner, 2005 #82}		27,900: island + red + edge + position
Ecosystem Resilience and Ecosystem Service	**Land use, land cover** {Asner, 2008 #104; Rodriguez, 2004 #89}	Local	29,400: island + land + use + cover

[†] Included in the "Other" column is the number of hits in Scholar.Google.com for the keywords shown. See Section 2.3.3 for details.

4.3 Tundra

Parameters for tundra, shown in Table 6, focused on observations for key drivers/stressors that are, or are likely to, change as a result of natural and anthropogenic impacts. Tundra regions have been inhospitable for human habitation and therefore buffered from the direct impact of growing human populations and resource consumption. However, airborne pollution and climate change are impacting tundra globally. Given the very short growing season and corresponding low productivity of tundra, recovery from ecological damage in tundra regions will be exceedingly slow. Millennium Ecosystem Assessment (World Resources Institute 2005) stated that mountain and polar impacts in the past 50-100 years and projected into the future included:

- Habitat change (in mountains: high impact in past, continuing to be high; in polar regions: low impact in the past, increasing)
- Climate change and rate of melting snow/ice (moderate to high impact in past, increasing rapidly)
- Invasive species (low impact in past, continuing to be low)
- Over-exploitation (low-moderate impact in past, continuing or increasing)
- Pollution, including nutrients (nitrogen and phosphorus) (low-moderate impact in past, increasing rapidly)

Temperature change is the most significant factor likely to impact tundra. Tundra is the biome at the extreme of low temperature and the extreme fringe of continental land mass and mountain heights. While other biomes may have the potential to migrate in the face of climate change, tundra is already at the extreme limits of land; migration or adaptation is unlikely to occur. One of the key ecosystem services provided by tundra is the photosynthetic capture and cold storage of carbon. Overall, the tundra literature emphasis is on the critical point at which water freezes – which alters the biology and chemistry of the tundra. These temperature-driven concerns included observations in the literature related to:

- Effects of climate variability and change
- Understanding warming snow/ice melting rates
- Carbon stocks and potential releases

Earth observations that are generally applicable for inland/fresh water (above) and water quantity (separate report) are also important for water within the tundra (e.g., alkalinity, nutrients and nutrient cycling, hydrology, and precipitation), but are not repeated in this table of parameters. The Analyst Team mapped parameters identified in the literature to the observational categories derived from the conceptual model in Figure 1. Because the Analyst Team was able to assess needs for spatial and temporal resolution for a relatively small number of parameters in the tundra documents, they removed those columns from the table and included information on spatial and temporal resolution in the “other” column when it was provided.

Table 6. **Observation Parameters for Tundra**

Desired Parameters and Characteristics for Tundra			
Observation Category	**Parameter**	**Characteristics of the Observation Parameters**	
		Coverage/Extent	**Other**†
Chemical Variables	**CO_2, CH_4 fluxes** (Serreze 2000; Shaver 2007)	Regional, Local	4,350: carbon + dioxide + flux + tundra 1,910: methane + flux + tundra
Chemical Variables	**Evaporation, evapotranspiration** (Serreze 2000);(Hinzman et al. 2005; Wang et al. 2006; Nagler et al. 2008); (Shahgedanova et al. 2009)	Regional, Local	3,820: evaporation + tundra
Chemical Variables	**Nutrients in soil, nutrient availability, nutrient cycling** (Sturm 2001; Walker 2006; Wookey 2008; Post et al. 2009)	Regional, Local	Nutrients and cycling/mineralization are limited in Tundra 9,810: nutrients + tundra
Chemical Variables	**Soil carbon** (Hinzman et al. 2005; Fuchs et al. 2009)	Regional, Local	9,680: soil + carbon + tundra
Chemical Variables	**Soil moisture, soil water table level** (Serreze 2000; Hinzman et al. 2005) (Stow 2004; Shaver 2007) (Sturm 2001) (Walker 1993)	Regional, Local	7,630: soil + moisture + tundra
Chemical Variables	**Soil redox potential** (Hinzman et al. 2005)	Local	635: soil + redox + potential + tundra
Chemical Variables	**Temperature (air)** (Serreze 2000; Ranson et al. 2004; Chapin et al. 2005; Hinzman et al. 2005; Nagler et al. 2008; Fuchs et al. 2009; Post et al. 2009)	Regional, Local	Data needed hourly, daily, and annually; 0.01° C accuracy/year 11,500: air + temperature + tundra
Disturbance Regimes	**Insects (expansion of range and activity)** (Potter et al. 2005) (Hinzman et al. 2005; Post et al. 2009)	Regional	6,130 insect + range + tundra
Disturbance Regimes	**Disturbance (fire, drought, land clearing)** (Stow 2004; Potter et al. 2005; Sturm 2005; Walker 2006; Wookey 2008)	Regional, Local	8,080: disturbance + tundra
Disturbance Regimes	**Sea level** (Hinzman et al. 2005)	Global, Regional	Hits not determined; search too general
Disturbance Regimes	**Storm events** (Hinzman et al. 2005; Potter et al. 2005)	Regional	4,780: storm + tundra
Disturbance Regimes	**Weather pattern changes** (Hinzman et al. 2005)	Regional	7,980: weather + pattern + tundra
Ecosystem Resilience	**Animal activity (range, season length)** (Rees 2002; Hinzman et al. 2005; Post et al. 2009)	Regional	10,700: animal + activity + tundra

Desired Parameters and Characteristics for Tundra			
Observation Category	**Parameter**	**Characteristics of the Observation Parameters**	
		Coverage/Extent	**Other**†
Ecosystem Resilience	**Animal population health (fitness, abundance)**	Regional	10,900: animal + population + tundra
Ecosystem Resilience and Ecosystem Service	**Sedimentation** (Stow 2004)	Local	5,670: sedimentation + tundra
Ecosystem Resilience and Ecosystem Service	**Water availability** (Hinzman et al. 2005)	Regional, Local	9,390: water + availability + tundra
Ecosystem Resilience and Ecosystem Service	**Thermokarst (presence)** (Serreze 2000; Stow 2004; Hinzman et al. 2005; Fuchs et al. 2009)	Local	722: thermokarst + tundra
Energy Source	**Atmospheric circulation** (Serreze 2000)	Global, Regional	3,290: atmospheric + circulation + tundra
Energy Source	**Biomass (phytomass), biomass spatial distribution, biomass moisture content** (Sturm 2001; Rees 2002; Potter et al. 2005)	Regional, Local	8,170: biomass + tundra
Energy Sources	**Carbon (aboveground, storage)** (Fuchs et al. 2009)	Regional, Local	6,490: carbon + storage + tundra
Energy Sources	**Cloud cover (**Chapin et al. 2005; Wang et al. 2006)	Global	Data needed hourly, daily; Need better certainty 3,630: cloud + cover + tundra
Energy Sources	**Energy exchange** (Chapin et al. 2005)	Regional, Local	5,780: energy + exchange + tundra
Energy Sources	**Net primary production (NPP)** (Wookey 2008)	Regional, Local	Data showing seasonal variation is needed 10,600: primary + production + tundra
Energy Sources	**Solar radiation, Surface net radiation, surface radiation flux** (Stow 2004; Wang et al. 2006; Shaver 2007)	Regional, Local	Flux is needed 3,560: solar + radiation + tundra
Energy Sources	**Wind speed, Wind pattern** (Sturm 2001; Hinzman et al. 2005)	Regional, Local	5,060: wind + speed + tundra

Desired Parameters and Characteristics for Tundra			
Observation Category	**Parameter**	**Characteristics of the Observation Parameters**	
		Coverage/Extent	**Other**[†]
Habitat Structure	**Elevation** (Nagler et al. 2008)	Local	Hits not determined; search too general
Habitat Structure	**Erosion rate (shoreline)** (Hinzman et al. 2005)	Local	5,160: erosion + rate + tundra
Habitat Structure	**Geomorphology** (Hinzman et al. 2005)	Regional, Local	2,350: geomorphology + tundra
Habitat Structure	**Permafrost temperature, deep bore-hole temperature** (Serreze 2000; Hinzman et al. 2005)	Local, Regional	4,440: permafrost + temperature + tundra
Habitat Structure	**Permafrost active layer thickness** (Serreze 2000; Fuchs et al. 2009)	Local	1,240: permafrost + active + layer + thickness + tundra
Habitat Structure	**Permafrost thickness** (Serreze 2000)	Local	1,820: permafrost + thickness + tundra
Habitat Structure	**Permafrost condition and dynamics (degradation, reduction)** (Serreze 2000)	Local	Need better spatial coverage/ continuity 4,520: permafrost + condition + tundra
Habitat Structure	**Topography, slope, aspect** (Zimmermann et al. 2007; Nagler et al. 2008)	Local	Hits not determined; search too general
Land Use and Cover	**Albedo** (Sturm 2005; Wang et al. 2006)	Regional, Local	1,960: albedo + tundra
Land Use and Cover	**Date of ice-in and ice break-up on lakes, rivers** (Serreze 2000)	Local	Annual data is needed 2,410: ice-in + tundra
Land Use and Cover	**Ice cover** (Serreze 2000; Stow 2004; Wang et al. 2006)	Regional, Local	10,600: ice + cover + tundra
Land Use and Cover	**Vegetation cover, changes** (Rees 2002; Walker 2006)	Regional, Local	11,900: vegetation + cover + tundra
Land Use and Cover	**Forest cover** (Potter et al. 2005) (Fuchs et al. 2009)	Regional, Local	12,800: forest + cover + tundra
Land Use and Cover	**Treeline location, tree line advance** (Ranson et al. 2004; Chapin et al. 2005)	Regional, Local	1,570: tree line + advance + tundra
Land Use and Cover	**Shrub cover and extent** (Sturm 2005; Tape 2006)	Regional, Local	6,970: shrub + cover + tundra

Desired Parameters and Characteristics for Tundra			
Observation Category	**Parameter**	**Characteristics of the Observation Parameters**	
		Coverage/Extent	**Other**[†]
Land Use and Cover	**Glacier extent, glacier mass balance (Serreze 2000)** (Shahgedanova et al. 2009)	Regional, Local	Need better spatial coverage 5,450: glacier + extent + tundra
Land Use and Cover	**NDVI, changes in photosynthetic activity** (Zimmermann et al. 2007);(Shaver 2007)	Regional, Local	927: NDVI + tundra
Land Use and Cover	**Snow cover (extent, duration, depth, snow-water equivalent)** (Serreze 2000; Hinzman et al. 2005; Nagler et al. 2008)	Regional, Local	11,200: snow + cover + tundra
Land Use and Cover	**Date of snowmelt** (Serreze 2000; Nagler et al. 2008)	Local	1,890: date + snowmelt + tundra
Land Use and Cover	**Date of soil thaw** (Serreze 2000)	Local	2,060: date + soil + thaw + tundra
Land Use and Cover	**Stand volume** (Fuchs et al. 2009)	Local	6,360: stand + volume + tundra
Species Introduction and Removal	**Invasive species population, range** (Wookey 2008)	Regional	2,300: invasive + species + tundra
Viable Populations of Threatened and Endangered Species	**Migration patterns** (Rees 2002; Hinzman et al. 2005)	Regional	6,170: migration + patterns + tundra
Viable Populations of Threatened and Endangered Species	**Species composition, species distribution (plants, animals)** (Walker 2006; Post et al. 2009)	Regional, Local	10,700: species + composition + tundra

[†] Included in the "Other" column is the number of hits in Scholar.Google.com for the keywords shown. See Section 2.3.3 for details.

5 Priority Observations

5.1 General description

To determine the priority observation parameters for Ecosystems, the Analyst Team identified observations from the literature. The Analyst Team provided a list of the parameters to the Advisory Group members for weighting. The Advisory Group members used their expert judgment to evaluate the importance of the observation for monitoring and evaluating ecosystem health, function, and change. The weighting by the Advisory Group was used to rank the priority of the observations.

Following the weighting procedure, the results were reviewed by the Advisory Group to identify any important gaps in parameters of high priority. A consensus was reached by the Advisory Group on the high priority parameters to include in this report. The overall weighting and ranking of parameters is included in Appendix C.

5.2 List of priority observations and characteristics

The Advisory Group members were asked to weight each parameter using the following definitions:

- Low ecological importance: 1
- Moderate ecological importance: 2
- High ecological importance: 3
- Very high priority ecological importance: 4
- No opinion

The observational parameters ranked as of high or very high priority ecological importance (mean score of 3.0 or higher) by the Advisory Group were considered to be priority observations, and are shown in Tables 7-9.

Table 7. High Priority Inland/Fresh Water **Observation Parameters**

Inland/Fresh Water Parameters
At-risk freshwater/wetland species/communities
Extent, location, and fragmentation of ecosystem and habitat types (including stream and riparian habitat structure and condition)
Carbon: Dissolved organic carbon (content, flux, cycling), dissolved inorganic carbon, particulate organic carbon
Species composition; fisheries trophic index; index of biotic integrity
Fish harvest intensity
Wetland, lakes, reservoirs, ponds (area), rivers and streams (miles) mapping
Riparian zone landscape structure and condition; standing biomass
Aquatic primary productivity and NPP; aquatic chlorophyll concentration; respiration
Suspended solids/ sediment loads
Ecosystem demand for water; conservation demand for water
Aquatic ecosystem condition (fish to bacteria; phytoplankton community; algal blooms; eutrophic zones)
Land use, land cover

Table 8. High Priority Oceanic Islands and Archipelagos Observation Parameters

Islands and Archipelagos Parameters
Disturbance
Deforestation
Forest fragmentation
Mangrove extent (CBD)
Land use, land cover
Ocean circulation patterns
Erosion (reefs, sandbars)
Sea level , sea level pressure
Species composition (plants, animals, canopy and understory), taxonomic composition
Net primary production (NPP) , net primary surface ocean production
Biodiversity (mangroves)
Nutrients (N, P), nutrient concentrations, nutrient availability, nutrient cycling
Pollution
Storms, storm surges
Invasive species, invasive species location (plants)
Groundwater salinity
Ecosystem function
Canopy cover, canopy density
Sea surface temperature, water temperature

Phenology
Landscape structure
Disturbance

Table 9. High Priority Tundra Observation Parameters

Tundra Parameters
CO_2, CH_4 fluxes
Biomass (phytomass), biomass spatial distribution, biomass moisture content
Permafrost condition and dynamics (degradation, reduction)
Vegetation cover, changes
Soil carbon
Disturbance (fire, drought, land clearing)
Carbon (aboveground, storage)
Forest cover
Treeline location, tree line advance
Glacier extent, glacier mass balance
Permafrost temperature, deep bore-hole temperature
Permafrost active layer thickness
Nutrients in soil, nutrient availability, nutrient cycling
Temperature (air)
Net primary production (NPP)
Permafrost thickness
Snow cover (extent, duration, depth, snow-water equivalent)
Species composition, species distribution (plants, animals)
Phenology
Thermokarst (presence)
Ice cover
Shrub cover and extent
NDVI, changes in photosynthetic activity
Migration patterns

The Analyst Team next combined the three prioritized lists for the individual sub-areas to develop a list of overall prioritized parameters. Many of the parameters were specific to an individual sub-area, but several appeared on multiple lists. The Analyst Team combined several parameters that were similar in the final prioritized list, listing them at the highest ranking of the individual combined parameters, as described in Appendix C. Table 10 lists the overall prioritization across the three sub-areas for all parameters with rank of 3 or higher, and indicates the mean rank and the standard deviation. The full list of parameters is included in Appendix C.

Table 10. High Priority Observation Parameters

Prioritized list of Ecosystems parameters: Inland Water, Oceanic Islands and Archipelagos, and Tundra		
Parameter	**Mean**	**SD***
CO_2, CH_4 fluxes	3.83	0.41
At risk freshwater/wetland species/communities	3.67	0.52
Biomass (phytomass), biomass spatial distribution, biomass moisture content	3.67	0.82
Permafrost condition and dynamics (degradation, reduction)	3.67	0.52
Vegetation cover, changes	3.67	0.52
Disturbance (fire, drought, land clearing)	3.57	0.79
Extent, location, and fragmentation of ecosystem and habitat types (including stream and riparian habitat structure and condition)	3.57	0.53
Carbon (aboveground, storage)	3.50	0.55
Soil carbon	3.50	0.55
Forest fragmentation	3.43	0.53
Land use, land cover	3.43	0.79
Mangrove extent (CBD)	3.43	0.53
Carbon: Dissolved organic carbon (content, flux, cycling), dissolved inorganic carbon, particulate organic carbon	3.33	0.82
Forest cover	3.33	0.82
Glacier extent, glacier mass balance	3.33	0.82
Ocean circulation patterns	3.33	0.82
Treeline location, treeline advance	3.33	0.82
Erosion (reefs, sandbars)	3.29	0.76
Fish harvest intensity	3.29	0.76
Net primary production (NPP) , net primary surface ocean production	3.29	0.49
Sea level , sea level pressure	3.29	0.95
Species composition; species distribution (plants, animals); fisheries trophic index; index of biotic integrity	3.29	0.76
Permafrost active layer thickness	3.20	0.84
Permafrost temperature, deep bore-hole temperature	3.20	0.84
Biodiversity (mangroves)	3.17	0.75
Nutrients (N, P), nutrient concentrations, nutrient availability, nutrient cycling	3.17	0.75
Permafrost thickness	3.17	0.75
Riparian zone landscape structure and condition	3.17	0.75
Snow cover (extent, duration, depth, snow-water equivalent)	3.17	0.41
Temperature (air)	3.17	0.98

Prioritized list of Ecosystems parameters: Inland Water, Oceanic Islands and Archipelagos, and Tundra		
Parameter	**Mean**	**SD***
Wetland, lakes, reservoirs, ponds (area), rivers and streams (miles) mapping	3.17	0.98
Net primary production (NPP)	3.17	0.98
Invasive species population, range; invasive species location (plants)	3.14	0.90
Chlorophyll	3.14	0.90
Pollution	3.14	0.90
Storms, storm surges	3.14	0.69
Aquatic ecosystem condition (fish to bacteria; phytoplankton community; algal blooms; eutrophic zones)	3.00	0.58
Canopy cover, canopy density	3.00	0.82
Ecosystem demand for water; conservation demand for water	3.00	0.82
Ecosystem function, ecosystem dynamics, and vegetation health	3.00	0.89
Groundwater salinity	3.00	1.00
Ice cover	3.00	0.63
Landscape structure	3.00	1.00
Migration patterns	3.00	0.63
NDVI, changes in photosynthetic activity	3.00	0.89
Phenology	3.00	0.89
Sea surface temperature, water temperature	3.00	0.82
Shrub cover and extent	3.00	1.26
Suspended solids; sediment loads; sedimentation, sediment accretion	3.00	0.82
Thermokarst (presence)	3.00	1.10

*SD = Standard Deviation

5.3 Summary of Overall Results for Ecosystems SBA

The Analyst Team combined the lists of prioritized parameters from the first Ecosystems SBA report for sub-areas watersheds, forests, and coastal and near-shore marine (Lough et al. 2010) with the prioritized list of parameters in this second Ecosystems SBA report, in accordance with the methods outlined in Section 2.3.3. This resulted in an overall prioritization of end user needs across the six ecosystems sub-areas considered in the two reports. The full list of ranked parameters is given in Appendix C (Table C-5).

The Analyst Team defined the top 10 observation parameters as a subset of the list in Table C-5. For this prioritization, the Analyst Team selected the top 10 high-priority parameters to provide a manageable list, though other subsets of the list in Table 11 may be equally valid. The tenth parameter on the list, forest cover, is tied for eighth place in the overall ranking with dissolved carbon, glacier extent, and tree line location. The Analyst Team selected forest cover to occupy the tenth position on this priority list because it is applicable to the majority of the six sub-areas included in the two ecosystems SBA reports. The prioritization process produced a list of

priority parameters, given in Table 11, that are applicable for observation across a range of ecosystems.

Table 11. Summary of Combined High Priority Observation Parameters for the Ecosystems SBA

Parameter	Normalized Average	Rank
Permafrost condition and dynamics (degradation, reduction)	0.06	1
Vegetation cover, changes	0.06	1
Disturbance (including fire, drought, and land clearing) (urbanization+desertification+cultivation+ deforestation)	0.07	2
Extent, location, and fragmentation of ecosystem and habitat types (including stream and riparian habitat structure and condition)	0.09	3
Soil carbon	0.12	4
Forest fragmentation	0.15	5
Land use, land cover	0.15	5
Mangrove extent	0.15	5
Biomass (phytomass), biomass spatial distribution, biomass moisture content	0.16	6
Vegetation indices (NDVI+SAVI+EVI)	0.17	7
Carbon: Dissolved organic carbon (content, flux, cycling), dissolved inorganic carbon, particulate organic carbon	0.18	8
Forest cover	0.18	8
Glacier extent, glacier mass balance	0.18	8
Ocean circulation patterns	0.18	8
Treeline location, treeline advance	0.18	8
Erosion (reefs, sandbars)	0.21	9
Fish harvest intensity	0.21	9
Chlorophyll	0.21	10
Permafrost active layer thickness	0.24	11
Permafrost temperature, deep bore-hole temperature	0.24	11
Primary production (net, gross), community production	0.25	12
Leaf Area Index	0.26	13
Permafrost thickness	0.26	14
Riparian zone landscape structure and condition; standing biomass	0.26	14
Temperature (air)	0.26	14
Wetland, lakes, reservoirs, ponds, rivers, and streams - location and classification	0.26	14
PAR, fPAR FAPAR	0.27	15
Sea level	0.27	16
Non-native aquatic, wetland, or riparian species; Invasive species population, range	0.29	17
Storm events, storms, storm surges	0.29	17
Precipitation (rain, snow)	0.30	18
Species composition; species distribution (plants, animals); fisheries trophic index; index of biotic integrity, at-risk species and communities	0.31	19
Depth (shallow, near-shore)	0.31	20
Nutrients in soil, nutrient availability, nutrient cycling	0.31	21

Parameter	Normalized Average	Rank
Biodiversity	0.32	22
Aquatic ecosystem condition (fish to bacteria; phytoplankton community; algal blooms; eutrophic zones)	0.32	23
Canopy cover, canopy density	0.32	23
Ecosystem demand for water; conservation demand for water	0.32	23
Ecosystem function, ecosystem dynamics, vegetation health	0.32	23
Groundwater salinity	0.32	23
Ice cover	0.32	23
Landscape structure	0.32	23
Migration patterns	0.32	23
Shrub cover and extent	0.32	23
Thermokarst (presence)	0.32	23
Aquatic keystone species	0.35	24
Atmospheric CO_2	0.35	24
Coral Reef Classification	0.35	24
Insects (outbreaks, expansion of range and activity)	0.35	24
Soil moisture, soil water table level	0.37	25
Hydrology	0.37	26
Inundated vegetation (forests, grasses, and forbs), including impounded streams	0.38	27
Water elevation (lake)	0.38	27
Carbon (aboveground, storage, uptake, CO2 and CH4 flux)	0.38	28
Pollutants (load, concentration)	0.40	29
Salinity (water)	0.40	30
Water availability	0.41	31
Weather pattern changes	0.41	31
Albedo	0.42	32
Wind speed	0.44	33
Phenology	0.45	34
Evaporation; evapotranspiration	0.45	35
Atmospheric circulation	0.47	36
Community metabolism (reef)	0.47	36
Date of soil thaw	0.47	36
SST, water temperature, sea surface thermodynamics	0.50	37
Excess production (Biomass accumulation or export)	0.50	38
Topography, slope, aspect	0.51	39
Fire fuel load, fire regime, fuel characteristics	0.51	40
Impervious surface	0.52	41
Date of snowmelt	0.53	42
Herbaceous, woody cover	0.56	43
Groundwater amount, Groundwater recharge rate	0.57	44
Suspended solids/ sediment loads; Sedimentation	0.57	45
Aquatic nutrients (load, concentration)	0.58	46

Parameter	Normalized Average	Rank
Forest structure (Canopy height, Canopy structure, Canopy volume, Stand volume, Stand density)	0.58	47

6 Additional Findings

During the US-09-01a analysis, the Analyst Team identified some common themes and additional findings. This section discusses the additional findings, as well as information related to ecosystem observation parameters that is not directly represented in the prioritizations above.

Based on input from the Ecosystems Advisory Group that emphasized the agricultural importance of grasslands, the Ecosystems Analyst recommended the topics of grasslands and desertification to the Agriculture SBA Analyst for analysis; ultimately the Agriculture SBA Analyst and Agriculture Advisory Group did not choose to focus explicitly on grasslands and desertification. Grassland ecosystems are recognized as a global provider of ecosystem services.

The parameters important for understanding inland/fresh water ecology appear to be globally universal. These parameters include temperature, precipitation, and geology at the biome level, and, at the watershed (catchment) to point local geographic scale, chemical variables, with nutrients being most significant, habitat structure, disturbance regimes, biotic interactions, and energy sources. Additionally, important parameters include those that measure endpoints, such as community composition and viable populations of rare, threatened or endangered species.

Oceanic islands and archipelagos bring together all ecological parameters, providing a microcosm of global ecology and powerful model ecosystems for biocomplexity science. Coral reefs are a unique feature of some oceanic islands and archipelagos. Oceanic islands and archipelagos tend to have high endemism. The high priority parameters for oceanic islands and archipelagos include those related to coral reef health, such as climate change and ocean acidification, invasive species that threaten endemic species, mangrove health (including climate change impacts, disturbance regimes and habitat fragmentation. Overall, better systems models for oceanic islands and archipelagos are needed to understand current conditions, to better understand the most critical drivers that structure and maintain the resilience of the ecosystems, and to better anticipate the impact of changes in stressors and drivers of ecology. Islands, particularly those with coral reefs, are especially sensitive to global change and thus serve as powerful model ecosystems to observe the patterns and understand the processes of human-environment interactions.

The parameters most important for understanding tundra are those that focus on the climate interaction with ecosystem functioning and ecosystem services, specifically carbon capture, stocks, and release. Climate change represents a threat to the long-term survival of the tundra biome. Many of the parameters for observation of tundra are related to understanding the critical point at which water freezes, and the effect of spatial or temporal changes in freezing patterns that impact biological and chemical processes in the tundra. An Advisory Group member noted

particularly that there is a need for augmented sampling of tundra and other high-latitude systems in Eurasia, which is under-represented in the literature relative to North America.

7 Analyst Comments and Recommendations

The Analyst Team found the nine-step process outline by the GEO UIC to be very useful. More specifically, the Analyst Team found the ranking system developed and employed in this report to be very effective, in which the Advisory Group members were asked to rank individually all of the parameters. Rather than recommending just a few parameters, the Advisory Group members individually ranked the full list of parameters for each sub-area. The rankings of the Advisory Group provided the Analyst Team with a large data set and a clear picture of the relative importance of various parameters.

Throughout the analysis, the Analyst Team found ecosystems to a very broad topic. The variety of potential observations in ecosystems is vast, and is closely interrelated with other SBAs – biodiversity, climate, health, disasters, water, and agriculture. Following the experience in the first Ecosystems SBA report, the Analyst Team took steps to more clearly define the scope of this second Ecosystems SBA report. The Analyst Team included parameters necessary to observe the health, function, and change of ecosystem sub-areas, as well as observation needs for ecosystem services (e.g., clean water, timber, food, carbon sequestration, disease control, and hydropower, among many others). Many of these ecosystems services are integral to other SBAs, so Analyst Team more narrowly defined the sub-areas in this report to minimize duplication of the work being done under task US-09-01a for other SBAs. The sub-areas in this report (inland/fresh water, oceanic islands and archipelagos, and tundra) are globally important but well-defined spatially and functionally.

In general, when ecosystems documents included discussion of observation needs, they tended to focus on the general need for more data, rather than identification of an ideal set of observations. The application of existing observations was discussed in the literature far more than the needs for ideal observations. The Analyst Team found that identification of general inadequacies of current observations was not sufficient to make certain conclusions regarding necessary parameter characteristics.

Appendix A: Abbreviations

EVI	Enhanced Vegetation Index
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
fPAR	Fraction of Photosynthetically Active Radiation
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
IGOS	Integrated Global Observing Strategy
NASA	U.S. National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NGO	Non-governmental organization
NPP	Net Primary Productivity
PAR	Photosynthetically Active Radiation
SAVI	Soil-Adjusted Vegetation Index
SBA	Societal Benefit Area
SD	Standard Deviation
UIC	User Interface Committee
UNEP	United Nations Environment Programme
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency

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Appendix C: Ranking of Parameters

The Advisory Group members were asked to weight each parameter using the following definitions:

- Low ecological importance: 1
- Moderate ecological importance: 2
- High ecological importance: 3
- Very high priority ecological importance: 4
- No opinion

The mean and standard deviation of the importance values assigned by the Advisory Group are shown in Tables C-1, C-2, and C-3.

Table C-1. Prioritized Inland/Fresh Water **Observational Parameters**

Inland Water Parameters		
Observation Category	**Mean**	**SD***
At risk freshwater/wetland species/communities	3.67	0.52
Extent, location, and fragmentation of ecosystem and habitat types (including stream and riparian habitat structure and condition)	3.57	0.53
Carbon: Dissolved organic carbon (content, flux, cycling), dissolved inorganic carbon, particulate organic carbon	3.33	0.82
Species composition; fisheries trophic index; index of biotic integrity	3.29	0.49
Fish harvest intensity	3.29	0.76
Wetland, lakes, reservoirs, ponds (area), rivers and streams (miles) mapping	3.17	0.41
Riparian zone landscape structure and condition; standing biomass	3.17	0.75
Aquatic primary productivity and NPP; aquatic chlorophyll concentration; respiration	3.14	0.90
Suspended solids/ sediment loads	3.00	0.82
Ecosystem demand for water; conservation demand for water	3.00	0.82
Aquatic ecosystem condition (fish to bacteria; phytoplankton community; algal blooms; eutrophic zones)	3.00	0.58
Land use, land cover	3.00	0.82
Ecosystem dynamics, vegetation health, and insect outbreaks	2.86	0.69
Aquatic keystone species	2.86	0.38
Vegetative cover	2.86	0.69

Inland Water Parameters		
Observation Category	**Mean**	**SD***
Water elevation (lake)	2.83	0.98
Wetland Mapping: emergent plant classification and submerged plant classification	2.83	0.75
Wetland Mapping: inundation of vegetation (forests, grasses, and forbs), including impounded streams	2.83	0.75
Non-native aquatic, wetland, or riparian species	2.71	0.95
Impervious surface	2.67	1.37
Fraction Photosynthetically Active Radiation (Net and PAR)	2.57	0.98
Leaf Area Index	2.50	1.05
Riparian Vertical Structure	2.50	1.05
Aquatic nitrogen	2.33	0.52
Aquatic dissolved oxygen	2.33	0.52
Water chemistry (pH, salinity, hardness, toxic chemicals, metals, persistent pollutants, conductivity, oxidation-reduction potential, etc.)	2.33	1.21
Abiotic in-stream habitat composition, substrate, cover, embeddedness, etc.	2.33	1.03
River discharge pattern	2.29	0.95
Temperature (Max/Min at surface and in stream); sensible heat flux; latent heat flux; soil heat flux	2.29	0.76
Secchi disk transparency	2.20	0.84
Aquatic phosphorus	2.00	0.63
Colored (chromogenic) dissolved organic matter	1.67	0.82

*SD is standard deviation

Table C-2. Prioritized Islands and Archipelagos **Observational Parameters**

Islands and Archipelagos Parameters		
Observation Category	**Mean**	**SD***
Disturbance	3.57	0.79
Deforestation	3.43	1.13
Forest fragmentation	3.43	0.53
Mangrove extent (CBD)	3.43	0.53
Land use, land cover	3.43	0.79
Ocean circulation patterns	3.33	0.82
Erosion (reefs, sandbars)	3.29	0.76
Sea level , sea level pressure	3.29	0.95
Species composition (plants, animals, canopy and understory), taxonomic composition	3.29	0.76
Net primary production (NPP) , net primary surface ocean production	3.29	0.49
Biodiversity (mangroves)	3.17	0.75
Nutrients (N, P), nutrient concentrations, nutrient availability, nutrient cycling	3.17	0.75

Islands and Archipelagos Parameters		
Observation Category	**Mean**	**SD***
Pollution	3.14	0.90
Storms, storm surges	3.14	0.69
Invasive species, invasive species location (plants)	3.14	0.90
Groundwater salinity	3.00	1.00
Ecosystem function	3.00	0.89
Canopy cover, canopy density	3.00	0.82
Sea surface temperature, water temperature	3.00	0.82
Phenology	3.00	0.89
Landscape structure	3.00	1.00
Atmospheric CO_2	2.86	1.21
Coral reef classification	2.86	0.69
Net community production (reef)	2.86	1.07
Groundwater recharge rate	2.71	1.25
Precipitation	2.71	0.49
Photosynthetically Active Radiation (PAR) in photic zone and benthic	2.71	1.11
Upwelling (water)	2.71	0.76
Wind speed	2.71	0.76
Leaf Area index (LAI)	2.71	0.76
Chlorophyll	2.67	0.82
Fire fuel load, fire regime	2.67	0.82
Hydrology	2.67	0.82
Community metabolism (reef)	2.67	1.03
Excess production (biomass accumulation or export)	2.67	0.82
Respiration	2.67	0.82
Biomass	2.57	1.13
Canopy height, canopy structure, canopy volume	2.57	1.13
Fractional cover (photosynthetic vegetation, non-photosynthetic vegetation, bare substrate)	2.57	0.79
Herbaceous, woody cover	2.57	0.79
Temperature	2.57	0.53
pH	2.50	0.55
NDVI	2.50	0.55
Salinity, salinity at the surface (seawater)	2.43	0.53
Sea surface gas exchange	2.43	0.79
Dissolved O_2	2.43	0.53
Dissolved CO_2, carbonate, bicarbonate	2.43	0.53
Sedimentation, sediment accretion	2.43	0.79
Shortwave infrared irradiance	2.43	0.98
Biogeochemistry	2.33	1.21
Hydrodynamics near reef (surface heating, upwelling)	2.33	0.52

Islands and Archipelagos Parameters		
Observation Category	**Mean**	**SD***
Benthic community distribution	2.33	0.52
Plant chemistry	2.33	0.82
Resilience	2.33	1.03
Sea surface thermodynamics	2.29	0.76
Light penetrating canopy	2.29	1.11
Upwelling radiation	2.29	0.95
Substrate age, substrate chemical composition	2.29	0.76
Hydroperiod	2.20	0.45
Physiological status	2.20	0.45
Alkalinity, calcium	2.14	0.38
Water residence time (in the reef)	2.14	1.21
Deepwater mixing processes	2.00	0.63
Geomorphology (reef structure)	2.00	0.63
Bottom class/bottom type	2.00	0.63
Subterranean geology	2.00	0.58
Atmospheric optical properties	1.86	1.21
Red-edge position	1.80	0.84
Elevation/altitude	1.71	0.95
Water column bio-optical state	1.60	0.89

*SD is standard deviation

Table C-3. Prioritized Tundra **Observational Parameters**

Tundra Parameters		
Observation Category	**Mean**	**SD***
CO_2, CH_4 fluxes	3.83	0.41
Biomass (phytomass), biomass spatial distribution, biomass moisture content	3.67	0.82
Permafrost condition and dynamics (degradation, reduction)	3.67	0.52
Vegetation cover, changes	3.67	0.52
Soil carbon	3.50	0.55
Disturbance (fire, drought, land clearing)	3.50	0.84
Carbon (aboveground, storage)	3.50	0.55
Forest cover	3.33	0.82
Treeline location, tree line advance	3.33	0.82
Glacier extent, glacier mass balance	3.33	0.82
Permafrost temperature, deep bore-hole temperature	3.20	0.84

Tundra Parameters		
Observation Category	**Mean**	**SD***
Permafrost active layer thickness	3.20	0.84
Nutrients in soil, nutrient availability, nutrient cycling	3.17	0.75
Temperature (air)	3.17	0.98
Net primary production (NPP)	3.17	0.98
Permafrost thickness	3.17	0.75
Snow cover (extent, duration, depth, snow-water equivalent)	3.17	0.41
Species composition, species distribution (plants, animals)	3.17	0.75
Phenology	3.00	0.89
Thermokarst (presence)	3.00	1.10
Ice cover	3.00	0.63
Shrub cover and extent	3.00	1.26
NDVI, changes in photosynthetic activity	3.00	0.89
Migration patterns	3.00	0.63
Precipitation (rain, snow)	2.83	1.17
Albedo	2.83	1.17
Weather pattern changes	2.80	0.84
Water availability	2.80	1.30
Evaporation; evapotranspiration	2.67	0.82
Sea level	2.67	1.51
Atmospheric circulation	2.67	0.82
Date of soil thaw	2.67	0.52
Invasive species population, range	2.67	0.82
Date of snowmelt	2.60	0.55
Soil moisture, soil water table level	2.50	0.55
Solar radiation, Surface net radiation, surface radiation flux	2.50	1.05
Date of ice-in and ice break-up on lakes, rivers	2.40	0.55
Animal activity (range, season length)	2.33	1.03
Energy exchange	2.33	0.52
Stand volume	2.25	1.50
Sedimentation	2.20	1.10
Insects (expansion of range and activity)	2.17	1.17
Storm events	2.17	0.98
Animal population health (fitness, abundance)	2.17	0.75
Erosion rate (shoreline)	2.17	0.98
Soil redox potential	2.00	0.82
Cloud cover	2.00	0.63
Wind speed	2.00	0.63

Tundra Parameters		
Observation Category	**Mean**	**SD***
Topography, slope, aspect	2.00	0.63
Elevation	1.83	1.17
Geomorphology	1.80	0.45

*SD is standard deviation

The Analyst Team next combined the three prioritized lists in Tables C-1, C-2, and C-3 to develop a list of overall prioritized parameters. Many of the parameters were specific to a sub-area, but the Analyst Team combined several parameters that were similar in the final prioritized list. The Analyst Team listed the combined parameters at the highest ranking of the individual combined parameters, making the following changes:

- Biomass (2.57) was removed as a separate parameter and included with Biomass (phytomass), biomass spatial distribution, biomass moisture content (3.67)
- Stand volume (2.25) was removed as a separate parameter and added to "Canopy height, canopy structure, canopy volume, *stand volume* (2.57)
- Disturbance (fire, drought, land clearing) (3.5) was removed as a separate parameter and the parenthetical description was added to Disturbance (3.57)
- Elevation/Altitude (1.71) was removed as a separate parameter and included with Elevation (1.83)
- Geomorphology (1.8) was removed as a separate parameter and added to Geomorphology (reef structure, *land*) (2.0)
- Invasive species population, range (2.67) was removed as a separate parameter and added to Non-native aquatic, wetland, or riparian species; *invasive species population, range* (2.71)
- Sedimentation (2.2) was removed as a separate parameter and added to Suspended solids; sediment loads; *sedimentation* (3.0)
- Species composition, species distribution (plants, animals) (3.17) was removed as a separate parameter and added to Species composition; *species distribution (plants, animals)*; fisheries trophic index; index of biotic integrity (3.29)
- Vegetative cover (2.86) was removed as a separate parameter and included in Vegetation cover, changes (3.67)
- Fractional cover (2.57) was removed as a separate parameter and included in Land use, land cover (3.0)
- Aquatic net primary production, aquatic chlorophyll concentration, respiration (3.14) was removed as a separate parameter. Aquatic NPP and respiration were included as part of Net Primary Production (3.17). Also, the Chlorophyll (2.67) parameter was promoted to 3.14, the former position of Aquatic chlorophyll concentration.
- Deforestation (3.43) was removed as a separate parameter and included as part of Disturbance (3.57). Disturbance was used in the first Ecosystems report to refer to the combined effects of deforestation, urbanization, desertification, and cultivation.

- Aquatic phosphorous (2.0) and Aquatic nitrogen (2.33) were combined as Aquatic nutrients (load, concentration) (2.33) to be parallel to the previous Ecosystems report.
- Secchi disk transparency (2.2) was renamed Attenuation coefficient (2.2) to be parallel to the previous Ecosystems report.
- Ecosystem dynamics, vegetation health, and insect outbreaks (2.86) was removed as a separate parameter. Ecosystem dynamics and vegetation health were added to Ecosystem function, *ecosystem dynamics, and vegetation health* (3.0). Insects (expansion of range and activity) (2.17) was removed as a separate parameter and combined with insect outbreaks (2.86).
- Abiotic in-stream habitat composition, substrate, cover, embeddedness, etc. (2.33) was removed as a separate parameter and included in Extent, location, and fragmentation of ecosystem and habitat types (including stream and riparian habitat structure and condition) (3.57).

The resulting list of parameters, prioritized across the three sub-areas in the report, is given in Table C-4.

Table C-4. Prioritized list of observational parameters for the three Ecosystems sub-areas in this report: Inland Water, Oceanic Islands and Archipelagos, and Tundra

Observation Category	Mean
CO_2, CH_4 fluxes	3.83
At risk freshwater/wetland species/communities	3.67
Biomass (phytomass), biomass spatial distribution, biomass moisture content	3.67
Permafrost condition and dynamics (degradation, reduction)	3.67
Vegetation cover, changes	3.67
Disturbance (fire, drought, land clearing)	3.57
Extent, location, and fragmentation of ecosystem and habitat types (including stream and riparian habitat structure and condition)	3.57
Carbon (aboveground, storage)	3.50
Soil carbon	3.50
Forest fragmentation	3.43
Land use, land cover	3.43
Mangrove extent (CBD)	3.43
Carbon: Dissolved organic carbon (content, flux, cycling), dissolved inorganic carbon, particulate organic carbon	3.33
Forest cover	3.33
Glacier extent, glacier mass balance	3.33
Ocean circulation patterns	3.33
Treeline location, treeline advance	3.33
Erosion (reefs, sandbars)	3.29
Fish harvest intensity	3.29

Observation Category	Mean
Net primary production (NPP) , net primary surface ocean production	3.29
Sea level , sea level pressure	3.29
Species composition; species distribution (plants, animals); fisheries trophic index; index of biotic integrity	3.29
Permafrost active layer thickness	3.20
Permafrost temperature, deep bore-hole temperature	3.20
Biodiversity (mangroves)	3.17
Nutrients (N, P), nutrient concentrations, nutrient availability, nutrient cycling	3.17
Nutrients in soil, nutrient availability, nutrient cycling	3.17
Permafrost thickness	3.17
Riparian zone landscape structure and condition; standing biomass	3.17
Snow cover (extent, duration, depth, snow-water equivalent)	3.17
Temperature (air)	3.17
Wetland, lakes, reservoirs, ponds (area), rivers and streams (miles) mapping	3.17
Invasive species population, range; invasive species location (plants)	3.14
Pollution	3.14
Storms, storm surges	3.14
Chlorophyll	3.14
Aquatic ecosystem condition (fish to bacteria; phytoplankton community; algal blooms; eutrophic zones)	3.00
Canopy cover, canopy density	3.00
Ecosystem demand for water; conservation demand for water	3.00
Ecosystem function, ecosystem dynamics, and vegetation health	3.00
Groundwater salinity	3.00
Ice cover	3.00
Landscape structure	3.00
Migration patterns	3.00
NDVI, changes in photosynthetic activity	3.00
Phenology	3.00
Sea surface temperature, water temperature	3.00
Shrub cover and extent	3.00
Suspended solids; sediment loads; *sedimentation, sediment accretion*	3.00
Thermokarst (presence)	3.00
Insect outbreaks, insect range and activity	2.86
Aquatic keystone species	2.86
Atmospheric CO_2	2.86
Coral reef classification	2.86
Net community production (reef)	2.86
Albedo	2.83
Precipitation (rain, snow)	2.83

Observation Category	Mean
Water elevation (lake)	2.83
Wetland Mapping: emergent plant classification and submerged plant classification	2.83
Wetland Mapping: inundation of vegetation (forests, grasses, and forbs), including impounded streams	2.83
Water availability	2.80
Weather pattern changes	2.80
Groundwater recharge rate	2.71
Leaf Area index (LAI)	2.71
Non-native aquatic, wetland, or riparian species	2.71
Photosynthetically Active Radiation (PAR) in photic zone and benthic	2.71
Precipitation	2.71
Upwelling (water)	2.71
Wind speed	2.71
Atmospheric circulation	2.67
Community metabolism (reef)	2.67
Date of soil thaw	2.67
Evaporation; evapotranspiration	2.67
Excess production (biomass accumulation or export)	2.67
Fire fuel load, fire regime	2.67
Hydrology	2.67
Impervious surface	2.67
Respiration	2.67
Sea level	2.67
Date of snowmelt	2.60
Canopy height, canopy structure, canopy volume, stand volume	2.57
Fraction Photosynthetically Active Radiation (Net and PAR)	2.57
Herbaceous, woody cover	2.57
Temperature	2.57
pH	2.50
Riparian Vertical Structure	2.50
Soil moisture, soil water table level	2.50
Solar radiation, Surface net radiation, surface radiation flux	2.50
Dissolved CO2, carbonate, bicarbonate	2.43
Dissolved O2	2.43
Salinity, salinity at the surface (seawater)	2.43
Sea surface gas exchange	2.43
Shortwave infrared irradiance	2.43
Date of ice-in and ice break-up on lakes, rivers	2.40
Animal activity (range, season length)	2.33

Observation Category	Mean
Aquatic dissolved oxygen	2.33
Aquatic nutrients (load, concentration)	2.33
Benthic community distribution	2.33
Biogeochemistry	2.33
Energy exchange	2.33
Hydrodynamics near reef (surface heating, upwelling)	2.33
Other chemistry (pH, salinity, hardness, toxic chemicals, metals, persistent pollutants, conductivity, oxidation-reduction potential, etc.)	2.33
Plant chemistry	2.33
Resilience	2.33
Light penetrating canopy	2.29
Maximum/minimum temperature at surface and in stream; sensible heat flux; latent heat flux; soil heat flux	2.29
River discharge pattern	2.29
Sea surface thermodynamics	2.29
Substrate age, substrate chemical composition	2.29
Upwelling radiation	2.29
Stand volume	2.25
Hydroperiod	2.20
Physiological status	2.20
Attenuation coefficient	2.20
Animal population health (fitness, abundance)	2.17
Erosion rate (shoreline)	2.17
Spectral imaging	2.17
Storm events	2.17
Alkalinity, calcium	2.14
Water residence time (in the reef)	2.14
Bottom class/bottom type	2.00
Cloud cover	2.00
Deepwater mixing processes	2.00
Geomorphology (reef structure, land)	2.00
Soil redox potential	2.00
Subterranean geology	2.00
Topography, slope, aspect	2.00
Wind speed	2.00
Atmospheric optical properties	1.86
Elevation/altitude	1.83
Red-edge position	1.80
Colored (chromogenic) dissolved organic matter	1.67
Water column bio-optical state	1.60

*SD is standard deviation

Prioritization across two ecosystems SBA reports: The Analyst Team combined the lists of prioritized parameters from the previous Ecosystems report for sub-areas watersheds, forests, and coastal and near-shore marine (Lough et al. 2010) (Eco Rpt 1) with the prioritized list of parameters in the current report to obtain an overall prioritization across the 6 ecosystem sub-areas considered in the two reports. The Analyst team made a number of changes to the parameter names to align the lists of parameters from the two reports:

- Animal activity (range, season length) (2.33) - removed as a separate parameter and combined with Migration patterns (3.0) as Animal activity (range, season length, migration patterns) (3.0).
- Stand density (Eco Rpt 1) and Forest structure (Eco Rpt 1) - added to Canopy height, canopy structure, canopy cover, stand volume, stand density (2.57) and labeled Forest Structure (canopy height, canopy structure, canopy cover, stand volume, stand density).
- CO_2, CH_4 fluxes (3.83) and Carbon (aboveground, storage) (3.5) - combined as Carbon (aboveground, storage, uptake, CO_2 and CH_4 fluxes) (3.83) to parallel Carbon (stores, uptake, flux) from Eco Rpt 1
- Deepwater mixing processes (2.0) - renamed Ocean currents and deepwater mixing processes (2.0) to parallel Ocean currents (Eco Rpt 1).
- Groundwater recharge rate (2.71) and Groundwater amount (Eco Rpt 1) - combined and labeled Groundwater amount and recharge rate.
- River discharge pattern (2.29) and River discharge quantity (Eco Rpt 1) - combined and labeled River discharge quantity, pattern.
- NDVI, changes in photosynthetic activity (3.0) - combined with Vegetation indices (NDVI, SAVI, EVI) (Eco Rpt 1) and labeled as such.
- Wetland Mapping: emergent plant classification and submerged plant classification (2.83) - combined with Submerged aquatic vegetation (composition and extent) (Eco Rpt 1) and labeled Submerged and Emergent aquatic vegetation (composition and extent).
- Fire fuel load, fire regime (2.67) - combined with Fuel characteristics (Eco Rpt 1) and labeled Fire fuel load, fire regime, fuel characteristics.
- Aquatic nutrients (2.33) and Nutrients (load, concentration) (Eco Rpt 1) - combined as Aquatic nutrients (load, concentration).
- Biodiversity (mangroves) (3.17) - combined with Biodiversity (Eco Rpt 1), which referred to biodiversity of plants and animals in the ecosystem.
- Species composition; species distribution (plants, animals); fisheries trophic index; index of biotic integrity (3.29) - removed as a separate parameter and combined with At-risk freshwater/wetland species/communities (3.67) as Species composition; species distribution (plants, animals); fisheries trophic index; index of biotic integrity, at-risk species and communities (3.67), parallel to Species composition (Eco Rpt 1).
- Invasive species population, range (2.67) and Non-native aquatic, wetland, or riparian species (2.71) were removed as separate parameters and added to *Invasive species population, range;* invasive species location (plants); *non-native aquatic, wetland, or riparian species* (3.14)

- Sedimentation (2.2) and Sedimentation, sediment accretion (2.43) were removed as separate parameters and added to Suspended solids; sediment loads; *sedimentation, sediment accretion* (3.0)
- Salinity (Eco Rpt 1) and Salinity at the surface (seawater) were combined as Salinity (seawater). Salinity of fresh surface waters is included in the parameter "other chemistry" (pH, salinity, hardness, toxic chemicals, metals, persistent pollutants, conductivity, oxidation-reduction potential, etc.)

The Analyst Team next normalized the overall prioritization ranks from Eco Rpt 1 and the current report, so that the range of scores was between zero and one (top-ranked parameters have low scores on this scale). The Analyst Team normalized the rankings from the two reports because the number or parameters was not the same in the reports. Next, the Analyst Team averaged the normalized rankings. If a parameter appeared in only one report, its ranked score was not averaged. Results are listed in Table C-5, with parameters tied for a given rank listed alphabetically.

Table C-5. Prioritized list of observational parameters for the two Ecosystems SBA reports, including six sub-areas

Parameter	Normalized Average	Rank
Permafrost condition and dynamics (degradation, reduction)	0.06	1
Vegetation cover, changes	0.06	1
Disturbance (including fire, drought, and land clearing) (urbanization+desertification+cultivation+ deforestation)	0.07	2
Extent, location, and fragmentation of ecosystem and habitat types (including stream and riparian habitat structure and condition)	0.09	3
Soil carbon	0.12	4
Forest fragmentation	0.15	5
Land use, land cover	0.15	5
Mangrove extent	0.15	5
Biomass (phytomass), biomass spatial distribution, biomass moisture content	0.16	6
Vegetation indices (NDVI+SAVI+EVI)	0.17	7
Carbon: Dissolved organic carbon (content, flux, cycling), dissolved inorganic carbon, particulate organic carbon	0.18	8
Forest cover	0.18	8
Glacier extent, glacier mass balance	0.18	8
Ocean circulation patterns	0.18	8
Treeline location, treeline advance	0.18	8
Erosion (reefs, sandbars)	0.21	9
Fish harvest intensity	0.21	9
Chlorophyll	0.21	10
Permafrost active layer thickness	0.24	11
Permafrost temperature, deep bore-hole temperature	0.24	11
Primary production (net, gross), community production	0.25	12
Leaf Area Index	0.26	13

Parameter	Normalized Average	Rank
Permafrost thickness	0.26	14
Riparian zone landscape structure and condition; standing biomass	0.26	14
Temperature (air)	0.26	14
Wetland, lakes, reservoirs, ponds, rivers, and streams - location and classification	0.26	14
PAR, fPAR FAPAR	0.27	15
Sea level	0.27	16
Non-native aquatic, wetland, or riparian species; Invasive species population, range	0.29	17
Storm events, storms, storm surges	0.29	17
Precipitation (rain, snow)	0.30	18
Species composition; species distribution (plants, animals); fisheries trophic index; index of biotic integrity, at-risk species and communities	0.31	19
Depth (shallow, near-shore)	0.31	20
Nutrients in soil, nutrient availability, nutrient cycling	0.31	21
Biodiversity	0.32	22
Aquatic ecosystem condition (fish to bacteria; phytoplankton community; algal blooms; eutrophic zones)	0.32	23
Canopy cover, canopy density	0.32	23
Ecosystem demand for water; conservation demand for water	0.32	23
Ecosystem function, ecosystem dynamics, vegetation health	0.32	23
Groundwater salinity	0.32	23
Ice cover	0.32	23
Landscape structure	0.32	23
Migration patterns	0.32	23
Shrub cover and extent	0.32	23
Thermokarst (presence)	0.32	23
Aquatic keystone species	0.35	24
Atmospheric CO_2	0.35	24
Coral Reef Classification	0.35	24
Insects (outbreaks, expansion of range and activity)	0.35	24
Soil moisture, soil water table level	0.37	25
Hydrology	0.37	26
Inundated vegetation (forests, grasses, and forbs), including impounded streams	0.38	27
Water elevation (lake)	0.38	27
Carbon (aboveground, storage, uptake, CO2 and CH4 flux)	0.38	28
Pollutants (load, concentration)	0.40	29
Salinity (water)	0.40	30
Water availability	0.41	31
Weather pattern changes	0.41	31
Albedo	0.42	32
Wind speed	0.44	33
Phenology	0.45	34

Parameter	Normalized Average	Rank
Evaporation; evapotranspiration	0.45	35
Atmospheric circulation	0.47	36
Community metabolism (reef)	0.47	36
Date of soil thaw	0.47	36
SST, water temperature, sea surface thermodynamics	0.50	37
Excess production (Biomass accumulation or export)	0.50	38
Topography, slope, aspect	0.51	39
Fire fuel load, fire regime, fuel characteristics	0.51	40
Impervious surface	0.52	41
Date of snowmelt	0.53	42
Herbaceous, woody cover	0.56	43
Groundwater amount, Groundwater recharge rate	0.57	44
Suspended solids/ sediment loads; Sedimentation	0.57	45
Aquatic nutrients (load, concentration)	0.58	46
Forest structure (Canopy height, Canopy structure, Canopy volume, Stand volume, Stand density)	0.58	47
Snow cover (extent, duration, depth, snow-water equivalent)	0.58	48
Solar radiation, Surface net radiation, surface radiation flux	0.59	49
Dissolved CO2, carbonate, bicarbonate	0.62	50
Dissolved O2	0.62	50
Sea surface gas exchange	0.62	50
Bathymetry	0.62	51
Submerged and emergent aquatic vegetation (composition and extent)	0.62	52
Burned area	0.64	53
Date of ice-in and ice break-up on lakes, rivers	0.65	54
Animal activity (range, season length,migration patterns)	0.68	55
Aquatic dissolved oxygen	0.68	55
Benthic community distribution	0.68	55
Biogeochemistry	0.68	55
Energy exchange	0.68	55
Hydrodynamics near reef (surface heating, upwelling)	0.68	55
Resilience	0.68	55
Water chemistry (pH, salinity, alkalinity, toxic chemicals, metals, persistent pollutants, conductivity, oxidation-reduction potential, etc.)	0.68	55
Light penetrating canopy	0.71	56
Substrate age, substrate chemical composition	0.71	56
Temperature (Maximum/minimum at surface and in stream); sensible heat flux; latent heat flux; soil heat flux	0.71	56
Upwelling radiation	0.71	56
Ocean color	0.71	57
Attenuation Coefficient	0.76	58
Hydroperiod	0.76	59

Parameter	Normalized Average	Rank
Animal population health (fitness, abundance)	0.79	60
Erosion rate (shoreline)	0.79	60
Ocean currents and deepwater mixing processes	0.82	61
Water residence time (reef)	0.82	62
River discharge pattern, quantity	0.83	63
Ocean waves (height and period), near-shore upwelling	0.83	64
Bottom class/bottom type	0.85	65
Cloud cover	0.85	65
Geomorphology (reef structure, land)	0.85	65
Soil redox potential	0.85	65
soil type	0.88	66
Atmospheric optical properties	0.88	67
Elevation	0.91	68
Litter (forest)	0.93	69
Red-edge position	0.94	70
Colored (chromogenic) dissolved organic matter	0.97	71

Appendix D: Input to the Cross-SBA Analysis

At the conclusion of the individual SBA priority-setting analysis, the Ecosystems SBA Analysts provided input on the overall critical Earth observation parameters for the Ecosystems SBA for inclusion in the Cross-SBA meta-analysis.[4] Upon receiving input from the SBA Analysts, the Cross-SBA Analyst reviewed the priorities in order to harmonize the terminology employed across SBAs. The Cross-SBA Analyst aggregated 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 also disaggregated observation parameters from observation categories that were identified as priorities by individual SBAs. 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.

The Ecosystems SBA Analysts determined the overall critical Earth observation priorities for the Ecosystems SBA by using a weighted indexing method to rank the observation categories identified for the six ecosystems sub-areas of analysis: forests, coastal and near-shore marine systems, watersheds, tundra, inland/fresh waters, and oceanic islands and archipelagos as described in Sections 2.3.3 and 5.3. Based on the results of the prioritization analysis, the 77 observations listed below have the highest rankings and thus are considered to be the observation priorities for the Ecosystems SBA. The Cross-SBA Analyst included these 77 observations in Methods 1-3 of the Cross-SBA analysis. The Ecosystems SBA Analysts divided the 77 observations into the three tiers representing "High," "Medium," and "Low" priorities in Cross-SBA Methods 2 and 3. The Cross-SBA Analyst included the 15 highest-ranked "High" priority observations (italicized) in Method 4 of the Cross-SBA analysis. Accounting for differences in observation terminology across the SBAs, the Ecosystems SBA Team effectively contributed 22 observation parameters to Method 4 of the Cross-SBA analysis.

High

Permafrost Condition and Dynamics (degradation, reduction)
Vegetation Cover, Changes
Disturbance (fire, drought, land clearing, urbanization, desertification, cultivation, deforestation)
Extent, Location, and Fragmentation of Ecosystem and Habitat Types (including stream and riparian habitat structure and condition)
Soil Carbon
Forest Fragmentation
Land Use, Land Cover
Mangrove Extent
Biomass (phytomass, biomass spatial distribution, biomass moisture content)
Vegetation Indices (NDVI+SAVI+EVI)

[4] For full description of methods and results, refer to: Group on Earth Observations. Task US-09-01a. Critical Earth Observation Priorities. Final Report. October 2010. Available on GEO Task US-09-01a website: http://sbageotask.larc.nasa.gov/.

Carbon (dissolved organic carbon, dissolved inorganic carbon, particulate organic carbon)
Forest Cover
Glacier Extent and Mass Balance
Ocean Circulation Patterns
Treeline Location and Advance
Erosion (reefs, sandbars)
Fish Harvest Intensity
Chlorophyll
Permafrost Active Layer Thickness
Permafrost and Deep Bore-Hole Temperature
Primary Production (net, gross)
Leaf Area Index
Permafrost Thickness

Medium
Riparian Zone Landscape Structure and Condition; Standing Biomass
Air Temperature
Wetland, Lakes, Reservoirs, Ponds, Rivers, and Streams (location and classification)
Photosynthetically Active Radiation (PAR, fPAR FAPAR)
Sea Level
Non-Native Aquatic, Wetland, Riparian Species; Invasive Species Population, Range
Storm Events, Storms, Storm Surges
Precipitation (rain, snow)
Species Composition and Distribution (plants, animals); Fisheries Trophic Index; Index of Biotic Integrity, At-Risk Species and Communities
Depth (shallow, near-shore)
Nutrients in Soil, Nutrient Availability, Nutrient Cycling
Biodiversity
Aquatic Ecosystem Condition (fish to bacteria; phytoplankton community; algal blooms; eutrophic zones)
Canopy Cover and Density
Ecosystem Demand for Water; Conservation Demand for Water
Ecosystem Function, Ecosystem Dynamics, Vegetation Health
Groundwater Salinity
Ice Cover
Landscape Structure
Migration Patterns
Shrub Cover and Extent
Thermokarst (presence)
Aquatic Keystone Species

Low
Atmospheric CO_2
Coral Reef Classification
Insects (outbreaks, expansion of range and activity)
Soil moisture, Soil Water Table Level

Hydrology
Inundated Vegetation (forests, grasses, and forbs), including impounded streams
Water Elevation (lake)
Carbon (aboveground, storage, uptake, CO_2 and CH_4 flux)
Pollutants (load, concentration)
Salinity (water)
Water Availability
Weather Pattern Changes
Albedo
Wind Speed
Phenology
Evaporation; Evapotranspiration
Atmospheric Circulation
Community Metabolism (reef)
Date of Soil Thaw
SST, Water Temperature, Sea Surface Thermodynamics
Excess Production (biomass accumulation or export)
Topography, Slope, Aspect
Fire Fuel Load, Fire Regime, Fuel Characteristics
Impervious Surface
Date of Snowmelt
Herbaceous, Woody Cover
Groundwater Amount, Groundwater Recharge Rate
Suspended Solids/ Sediment Loads; Sedimentation
Aquatic Nutrients (load, concentration)
Forest Structure (canopy height, canopy structure, canopy volume, stand volume, stand density)

The Cross-SBA Analyst also incorporated a subset of the priority observations from the Agriculture SBA-Forests sub-analysis, listed below, into the results of the Ecosystems SBA analysis. The Cross-SBA Analyst included this step to reflect the overlap between the Agriculture and Ecosystems SBAs in the area of forests. The Agriculture SBA-Forests Analyst was also a member of the Ecosystems SBA Analyst Team, and selected the specific priority observations that were incorporated into the Ecosystems SBA results.

Forest Use (forest management practices)
Forest Structure
Forest Cover
Urbanization
Vegetation (type)