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

Disasters Societal Benefit Area: Part One

GROUP ON EARTH OBSERVATIONS

User Interface Committee

US-09-01a Task Lead: Lawrence Friedl, USA/NASA
Disasters SBA Analyst: Stephanie Weber, Battelle Memorial Institute

2010

Group on Earth Observations

GEO Task US-09-01a:
Critical Earth Observation Priorities for Disasters SBA

Advisory Group Members & Analyst

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

Rosario ALFARO, Instituto Meteorologico Nacional, Costa Rica
Jay BAKER, Florida State University, USA
Jerome BEQUIGNON, European Space Agency, France
George CHOY, United States Geological Survey, USA
Silvia Burgos SOSA, Paraguayan Institute for Environmental Protection, Paraguay
Nicola CASAGLI, International Consortium on Landslides, Italy
Mumba Dauti KAMPENGELE, National Institute for Scientific and Industrial Research, Zambia
Ivan KOULAKOV, Institute of Petrol Geology and Geophysics, Russia
Goneri LE COZANNET, French Geological Survey, France
William LEITH, United States Geological Survey, USA
Warner MARZOCCHI, World Organization of Volcano Observatories, Italy
V. Madhava RAO, National Institute of Rural Development, India
Kaoru TAKARA, International Consortium on Landslides, Japan

The following person served as the Analyst for the Disasters Societal Benefit Area under GEO Task US-09-01a, providing overall coordination of the analysis and preparation of this report.

Stephanie WEBER, Battelle, USA

The following staff supported the Analyst:

Adam CARPENTER, Battelle, USA

Acknowledgment
The Analyst performed this task and prepared this report through the support of NASA Earth Science Division Applied Sciences Program, 300 E Street SW, Washington, DC 20546, USA, Contract No. GS-23F-8167H.

GEO Task US-09-01a
Lawrence FRIEDL (USA/NASA) is the Task Lead for GEO Task US-09-01a; he is a member of the GEO User Interface Committee.

Amy Jo SWANSON (USA/Science Systems and Applications, Inc) is the US-09-01a Task Coordinator, providing logistics and coordination amongst the Analysts.

Group on Earth Observations

GEO Task US-09-01a:
Critical Earth Observation Priorities for Disasters SBA

Summary

The goal of GEO Task US-09-01a is to identify the critical Earth observations for various societal benefit areas (SBAs). This analysis focused on identifying observation priorities for the Disasters SBA. The Analyst and research staff (Analyst Team) assembled an *ad hoc* Advisory Group of 13 members from around the world which helped narrow the focus of the analysis, identify documents from both developed and developing nations that address Earth observation priorities for disasters, and reviewed the methodology and results. The Advisory Group determined that the following three disaster types were of the greatest value for analysis in this task:

- *Earthquakes*
- *Landslides*
- *Floods.*

The Analyst Team identified potentially relevant documents through literature and internet searches. The Advisory Group also provided document recommendations. After evaluating the documents for their applicability to this task, the Analyst Team selected 22 documents that provided information on earthquake, landslide, and flood hazard observation priorities which were potentially relevant to the priority setting analysis.

The Analyst Team extracted observation priorities from the documents for each of the three disaster types individually. To provide a more complete picture of observation priorities, the Analyst Team grouped the aggregated observations into broad categories. Using an indexing scheme that weighted observation categories by the frequency with which they were identified as observation priorities, as well as the type of document and cross-hazard applicability, the Analyst Team generated a list of seven priority observation categories. The following are the observation categories of highest priority for end users of Earth observations related to earthquakes, landslides, and floods (in descending priority order):

- Surface Deformation
- Topography/Elevation
- Seismicity
- Precipitation
- Soil Parameters
- Gravity Fields
- Magnetic Fields.

These observation priorities represent a broad picture of global Earth observation priorities for disasters applications. The priorities of highest benefit to one geographic region may not provide any added value to another. However, regional, national, and local-level authorities and agencies will be able to use such priority lists in helping develop Earth observation strategies that are customized to their individual needs. Using this priority list, as further detailed in this report, the GEO User Interface Committee (UIC) will ultimately create a broad cross-SBA analysis intended to identify critical Earth observation priorities across all SBAs.

GEO Task US-09-01a:
Critical Earth Observation Priorities for Disasters SBA

Table of Contents

1 Introduction 1
  1.1 GEO and Societal Benefit Areas 1
  1.2 GEO Task US-09-01a 1
  1.3 Purpose of Report 2
  1.4 Scope of Report 2
2 Methodology 3
  2.1 Task Process 3
  2.2 Analyst and Advisory Group 4
    2.2.1 Analyst 4
    2.2.2 Advisory Group 4
  2.3 Methodology 6
    2.3.1 Documents 6
    2.3.2 Analytic Methods 6
    2.3.3 Prioritization Methods 7
3 Disasters SBA 9
  3.1 Disasters SBA Description 9
  3.2 Disaster Types 10
  3.3 Documents 10
4 Earth Observations for Disasters SBA 11
  4.1 Earth Observations for Earthquakes 12
  4.2 Earth Observations for Landslides 14
  4.3 Earth Observations for Floods 15
5 Priority Earth Observations for Disasters SBA 17
  5.1 Summary of Results 17
  5.2 Priority Observations 18
  5.3 Advisory Group Feedback on Priority Observations 24
6 Additional Findings 24
  6.1 Comparison of US-09-01a Final Priority List with Other Priority Setting Efforts 24
  6.2 Literature Focus on Remote Sensing Technologies 25
  6.3 Document Additions Late in the US-09-01a Process 26
7 Analyst's Comments and Recommendations 26
Appendix A: Abbreviations 28
Appendix B: Bibliography and References 29
  B.1 Documents Cited 29
  B.2 Documents Consulted 31

Tables and Figures

Tables

Table 1. Advisory Group for Disasters SBA 5
Table 2. Weighting Factors for Index Computation 8
Table 3. Disaster Types 9
Table 4. Example Secondary Product Priorities 12
Table 5. Earthquake Observation Parameters 13
Table 6. Landslide Observation Parameters 14
Table 7. Flood Observation Parameters 16
Table 8. Aggregated Characteristics of Priority Observation Parameters 22
Table 9. Priority Observation Comparison 25

Figures

Figure 1. Proportion of observations by geographic region for earthquake, landslide and flood disasters 11
Figure 2. Aggregated weighted index value for all observation categories by disaster type. 18

GEO Task US-09-01a:
Critical Earth Observation Priorities for Disasters SBA

1 Introduction

This report articulates Earth observation priorities for the Disasters Societal Benefit Area (SBA) based on an analysis of 22 publicly available documents, including documents produced by Group on Earth Observations' Member Countries and Participating Organizations.

1.1 GEO 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, airborne, *in situ,* 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
Human 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. In addition, researchers and practitioners have also identified and recommended key Earth observation needs in publications and peer-reviewed literature. Task US-09-01a focuses on compiling information on observation parameters from a representative sampling of these *existing* materials and analyzing across the materials to determine the priority observations.

This task considers all types of Earth observations, including ground, *in situ*, airborne, and space-based observations. The task includes direct measurements and derived parameters as well as model products. This task seeks to identify Earth observation needs across a full spectrum of

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

user types and communities in each SBA, including observation needs from all geographic regions with significant representation from developing countries.

GEO will use the Earth observation priorities resulting from this task to determine, prioritize, and communicate gaps in current and future Earth observations. GEO Member Countries and Participating Organizations can use the results in determining priority investment opportunities for Earth observations.

1.3 Purpose of Report

The primary purpose of this report is to articulate the critical Earth observation priorities for the Disasters SBA. 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 Disasters SBA are additional audiences for this report.

1.4 Scope of Report

This report addresses the Earth observation priorities for the Disasters SBA. In particular, this report addresses the disaster types of earthquakes, landslides, and floods within the Disasters SBA (see Section 3 for more details).

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

The report focuses on the Earth observations relevant to the Disasters 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 output) 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 to be 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 of this term 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 Disasters SBA and the specific disaster types that were part of the analysis. Section 4 articulates the specific Earth observations for each disaster type, and Section 5 presents the priority observations across the Disasters SBA. Sections 6 and 7 present additional findings from the analysis of the documents and recommendations. The Appendices include a list of abbreviations used throughout the document and a list of the documents cited and consulted for this analysis.

2 Methodology

2.1 Task Process

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

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

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

2.2 Analyst and Advisory Group

The Disasters SBA had an "Analyst" and an "Advisory Group" working together to identify documents, analyze them, and prioritize the Earth observations. The Analyst served as the main coordinator to manage the activities and was supported by an Analyst Team.

2.2.1 Analyst

For the Disasters SBA, the Analyst was Stephanie Weber. Ms. Weber is a research scientist at Battelle. She received her Master's degree in Atmospheric Science and has over 5 years of experience in data analysis of atmospheric and land processes, including literature reviews and large-scale data gathering efforts. Adam Carpenter assisted the Analyst. Mr. Carpenter is an Environmental Researcher with a Masters' degree in environmental science and policy.

For this task, the Disasters SBA Analyst Team served under contract to National Aeronautics and Space Administration (NASA) Earth Science Division Applied Sciences Program.

2.2.2 Advisory Group

The general methodology for GEO Task US-09-01a includes the formation of an expert Advisory Group to help identify appropriate documents, provide feedback on the analysis methods, and review the preliminary and final reports. For the Disasters SBA, the Analyst identified potential Advisory Group members through various sources. The Analyst solicited members of the Integrated Global Observing Strategy (IGOS) Geohazards Community of Practice for their participation. In addition, the Analyst contacted participants from developing nations that participated in an international training course on the use of satellite data for Earth observation applications to evaluate their interests and areas of expertise. The Analyst identified other potential members through organizational web sites, participation in major technical conferences, and publications.

Overall, between September and December 2008, the Analyst invited 36 experts to participate by serving on the Advisory Group or by recommending documents for the analysis. Thirteen experts expressed an interest in serving on the Advisory Group; five were unable to participate, but provided either document references or the names of alternate Advisory Group members; and 18 did not respond. For this task, it was important to have representation from both developed and developing nations so that a global view of disasters observation priorities could be captured. The 13 members of the Advisory Group included participants from nine countries across five continents. Table 1 provides a list of the confirmed Advisory Group members and their affiliations.

Table 1. Advisory Group for Disasters SBA.

Name	GEO Country or Organization	Affiliation	Geographic Region	Area of Expertise/ Specialty
Rosario ALFARO	Costa Rica	Instituto Meteorologico Nacional	South/Central America	Broad Disasters Experience
Jay BAKER	United States	Florida State University	North America	Hurricanes/Floods
Jerome BEQUIGNON	European Space Agency	European Space Agency	Europe	Disasters
George CHOY	United States	United States Geological Survey (USGS)	North America	Seismic Hazards
Silvia Burgos SOSA	Paraguay	Paraguayan Institute for Environmental Protection	South/Central America	Broad Disasters Experience
Nicola CASAGLI	Italy	International Consortium on Landslides	Europe	Landslides
Mumba Dauti KAMPENGELE	Zambia	National Institute for Scientific and Industrial Research	Africa	Broad Disasters Experience
Ivan KOULAKOV	Russia	Institute of Petrol Geology and Geophysics	Europe	Seismic Hazards
Goneri LE COZANNET	France	French Geological Survey	Europe	Disasters
William LEITH	United States	USGS	North America	Seismic Hazards
Warner MARZOCCHI	Italy	World Organization of Volcano Observatories	Europe	Volcanoes
V. Madhava RAO	India	National Institute of Rural Development	Asia/Middle East	Broad Disasters Experience
Kaoru TAKARA	Japan	International Consortium on Landslides	East Asia	Floods/Landslides

The Analyst sent all interested Advisory Group members a description of the task, including a summary of what their role would be in the US-09-01a process. Also, the Analyst asked each expert to supply document references for the analysis of priority observations. The Analyst held two conference calls and sent periodic emails to the Advisory Group throughout the course of the project to keep them apprised of the progress of the task, to request feedback on analysis methods, and to inform them of existing gaps in document identification including the lack of documents pertaining to smaller and/or developing nations.

2.3 Methodology

2.3.1 Documents

In order to identify as many publicly available documents as possible for consideration in the analysis of priority observations for the Disasters SBA, the Analyst Team sought out documents from various sources. The types of documents included international, regional, and national-level reports, workshop and conference proceedings, summaries and presentations, peer-reviewed journal articles, and other published documents. The Analyst Team used the following key methods in the document identification process:

- Requested document references for the three disaster types directly from the Advisory Group.

- Searched the websites of large national and international working groups and government agencies. Examples of such working groups and agencies include the IGOS Geohazards Community of Practice, the U.S. Subcommittee on Disaster Reduction (SDR), the Committee on Earth Observation Satellites (CEOS), USGS, and French Scientific and Technical Center in Geoscience (BRGM- France).

- Performed web-based literature searches using standard search tools and databases. The Analyst used combinations of specific disasters and Earth observation keywords (e.g., earthquake, observation, priorities, spatial resolution, etc.) to perform the searches.

- Referred to the references listed in the documents identified through other methods to provide potential new sources of information.

2.3.2 Analytic Methods

The Analyst Team evaluated each document for its usefulness based on the inclusion of specific observation priorities related to earthquakes, landslides, and/or floods. As a result, in order for a document to be included in the analysis, it had to explicitly identify required disasters-related Earth observations, and it had to contain information regarding the desired physical characteristics of the observation. The physical characteristics include the temporal resolution (frequency), spatial resolution, timeliness/latency (how quickly the observation is available), accuracy/precision, and coverage or extent of the observation. While the technical infrastructure required to collect and process these observations is an important aspect of Earth observations for disasters applications, this analysis focuses on the observations themselves.

The Analyst Team extracted detailed data from the documents that met the criteria for inclusion in the analysis. The Analyst then compiled all of the data extracted into a single database for further analysis. For each observation, the extracted information included the applicable disaster type(s) (earthquake, landslide, flood), the region of interest of the document (Global, Africa, Europe, Oceania, Asia and the Middle East, East Asia, North America, South and Central America), the type of document (e.g., international working group report, peer-reviewed journal

article, conference proceedings, etc.) and the desired physical characteristics of the observation, where available.

In addition to extracting as much information from the reports into the database as possible, the Analyst grouped each observation parameter into a broader category of observations. The aggregation of certain parameters that are similar in nature in this way provides a more robust analysis, since different documents use different terminology for parameters that are nearly identical or identical. For example, precipitation duration, precipitation intensity, and precipitation amount were combined into a single "precipitation" category that was carried forward into the prioritization analysis.

For each of the disaster types, the Analyst constructed a table of the observation priorities, as well as the aggregated observation categories, that were identified in at least one of the document references. Examples of references to the documents that explicitly identify each observation as a priority are also included in the tables.

2.3.3 Prioritization Methods

Using the data from the observation database generated during the document review process, the Analyst computed a weighted index in order to generate a list of priority disasters observations that is as objective as possible. The index value for each of the observation categories takes into account: (1) how frequently the observation category is mentioned in the documents as a priority, (2) document-specific weighting factors based on the cross-cutting applicability of the observation category, and (3) a report weight based on the type of document.

The cross-cutting applicability weight for each document is an integer value from 1 to 3 that is equal to the number of disaster types (earthquakes, landslides, and/or floods) to which a single observation applies, as identified by the document. This weight did not rely on the Analyst's judgment; rather it was assigned by the Analyst based only on the disaster types identified as applicable by the document.

The report weight is also an integer value from 1 to 3. International working group or consensus documents carry the highest weight with a value of 3, since they typically represent the viewpoints of scientists from a broad range of geographic locations and technical specialties. National-level government or working group documents have a weight of 2. The national-level documents have a slightly lower weight due to the narrowed geographic focus of the documents. Journal articles, conference presentations, conference proceedings, and unpublished studies have a weight of 1, as they typically represent the viewpoint of one or a few scientists, have a narrow geographic focus, and are not always subject to the peer-review process. Table 2 summarizes the weighting factors and gives examples of each document category.

Table 2. Weighting Factors for Index Computation.

Cross-Cutting Applicability		
Weight		**Definition**
1		1 Disaster Type
2		2 Disaster Types
3		3 Disaster Types
Document Type		
Weight	**Definition**	**Example**
1	Journal articles, conference presentations, conference proceedings and unpublished studies	Plag, H.P. 2006. *National Geodetic Infrastructure: Current Status and Future Requirements: The Example of Norway*. Nevada Bureau of Mines and Geology, Bulletin 112, 98 pp.
2	National-level government or working group documents	National Academy of Sciences (NAS). 2007. *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond.* ISBN: 978-0-309-10387-9, 456 pp.
3	International working group or consensus documents	Salichon, J., et al. August 2007. *IGOS Geohazards Theme Report*. BRGM/RP-55739-FR, Bureau de Recherches Géologiques et Minières, 89 pp.

The Analyst calculated the document-specific index value for each observation category, i_{d_o}, by taking the product of the weighting factor for the number of disaster types applicable for the observation category in the document, w_{n_o}, and the weighting factor for the document type, w_d, as seen in Equation 1.

$$i_{d_o} = v_{n_o} w_d \qquad \text{(Equation 1)}$$

The Analyst calculated the final aggregated weighted index for each observation category, I_o, for all documents by taking the sum of the document-specific index values for the observation category over all of the documents (Equation 2).

$$I_o = \sum_d i_{d_o} \qquad \text{(Equation 2)}$$

By taking the sum of the index values over all of the documents, the Analyst calculated the aggregated index value, which takes into account how frequently the observation categories are identified as priorities. Those observations that appear frequently have the highest aggregated index values. The final aggregated index values are the basis for ranking the observation priorities across all three hazard types and all documents.

3 Disasters SBA

3.1 Disasters SBA Description

The Disasters SBA focuses on those natural and human-induced events that can cause loss of life and property. Numerous events can be classified as disasters, such as weather related events, geologic phenomena, or human-induced incidents. The following is the brief statement of topics covered and key outcomes in the Disasters SBA from the GEOSS 10-Year Implementation Plan:

> *"Disaster losses can be reduced through observations relating to hazards such as: wildland fires; volcanic eruptions; earthquakes; tsunamis; subsidence; landslides; avalanches; ice; floods; extreme weather; and pollution events. GEOSS implementation will bring a more timely dissemination of information through better coordinated systems for monitoring, predicting, risk assessment, early warning, mitigating, and responding to hazards at local, national, regional, and global levels."*

Table 3 presents the disaster event types that receive particular attention in the GEO 2009-2011 Work Plan (GEO 2009b). Generic descriptions are included for informational purposes only.

Disasters affect millions of individuals around the world every year, causing human harm and substantial property damage. The Disasters SBA focuses on ensuring that the Earth observations necessary to help prevent (when possible), forecast, mitigate, respond to, and recover from disasters are available to the appropriate stakeholders around the world.

Table 3. Disaster Types.

Disaster Type	Brief Description
Wildland fires	Uncontrolled natural or human-caused burning of forests or other large areas of land
Volcanic eruptions	Smoke, ash, and lava flow from volcanoes
Earthquakes	Shaking or vibration of the Earth's crust caused by the discharge of stress accumulated along geologic faults and other causes
Tsunamis	Extremely large waves or rapid change in sea level locally, often caused by an off-shore earthquake
Subsidence	Sinking or lowering of the ground
Landslides	The movement of a mass of rock, debris or Earth down a slope
Avalanches	The violent tumbling and sliding of snow down a mountain or other slope
Ice	The freezing of water on surfaces creating hazards for walking, driving, and other forms of transportation
Floods	Inundation of water over land, through heavy rain, overflowing rivers, or any other source
Extreme weather	Meteorological events which may cause significant loss of life and property and cause environmental damage, such as violent storms, hurricanes, extreme heat and drought
Pollution events	Unhealthy levels of pollutants from a variety of potential natural and man-made sources.

3.2 Disaster Types

Step 2 of the Task US-09-01a process calls for the determination of the scope for the analysis. Due to the wide range of disaster types as described in Section 3.1, the Analyst, in collaboration with the Advisory Group, narrowed the focus of the effort to a limited number of disasters types as subtopics. The Analyst began this process by sending an email survey to the Advisory Group, asking each member to identify the two to four disaster types that he or she felt should be included in this analysis. The Analyst notified the Advisory Group that future GEO efforts may include analysis of the other disaster types. A limited number of responses resulted from this survey. The Analyst held a follow-up conference call on 10 December 2008 to discuss the options and confirm the narrowed scope, with four Advisory Group members participating in the call.

The Analyst and Advisory Group concluded that earthquakes, landslides, and floods would be the focus of this iteration of Task US-09-01a for the Disasters SBA. The Advisory Group members noted that it is important to consider those disaster types that are the most severe in terms of frequency and impact, in addition to the availability of observations and the opportunities for mitigation using the data. The three disaster hazards chosen have been the subject of much previous study, and the Advisory Group indicated that the observation priorities sought for these hazards could help contribute to real needs for societal benefit. Other disaster types that the Advisory Group members considered for inclusion were tropical cyclones, wildfires, and tsunamis. The Analyst relayed the outcome of the conference call to all members of the Advisory Group for feedback.

3.3 Documents

The document search effort, including website, database, and online literature searches and recommendations from Advisory Group members, yielded 52 documents that potentially contained Earth observation priorities for one or more of the disaster types. The Analyst performed a preliminary review of all of the documents to determine if the information provided specific disaster-related Earth observation priorities. If such observation priorities were present, the Analyst thoroughly reviewed the document and extracted the appropriate data into a database.

Of the 52 documents initially identified by the Analyst and Advisory Group, 22 (42%) of them contained Earth observation parameters for further analysis. Although many of the documents are applicable for hazard observations anywhere on the Earth, half (11) of the documents originated from U.S. organizations or scientists with a North American focus. Seven documents specified observation priorities for Asia/Pacific regions, while one focused on Europe. The remaining documents were global in nature, with participating authors or contributors from all over the world. No documents focused on the observation priorities for Africa or South America. This omission highlights a gap in identifying the priorities for the many developing nations on these continents.

4 Earth Observations for Disasters SBA

As stated in the summary of documents (Section 2.3.1), the goal of this task is to identify disaster observation priorities from documents that indicate the needs of both developed and developing nations. While examining the content of the 22 documents utilized in the report, the Analyst identified the primary geographic focus of the document based upon the region in which the author(s) and/or sponsoring institution were located. The Analyst assigned a global focus to those documents that came from international working groups or other organizations that by their nature are meant to cross many geographic regions.

Many of the observation priorities from an individual region may apply to global needs. However, the North American focus of most observations heavily outweighed the observations from other geographic regions, as illustrated in Figure 1.

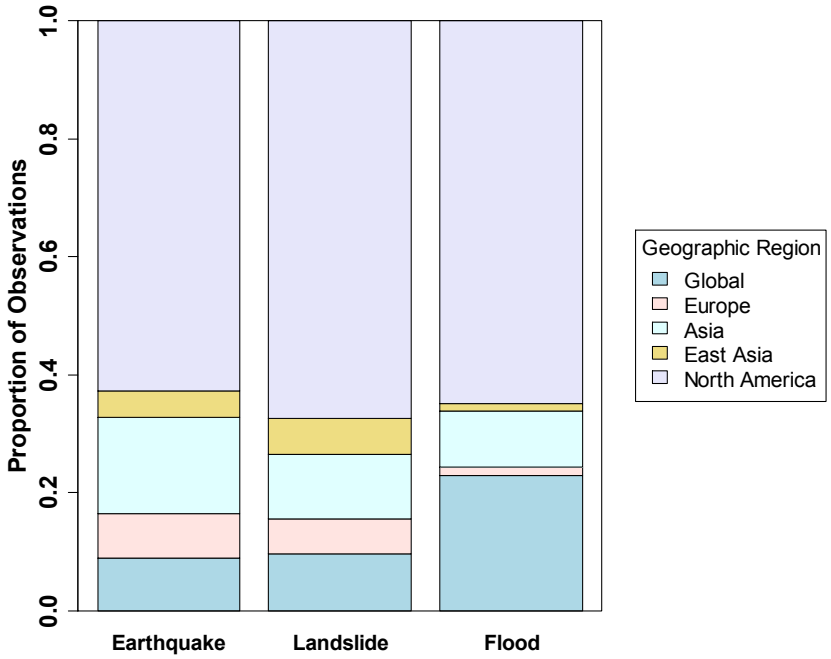

Figure 1. Proportion of observations by geographic region for earthquake, landslide and flood disasters.

GEO Task US-09-01a for the Disasters SBA seeks to identify specific Earth observation priorities from all sources, including those from ground-based, *in situ*, airborne, and satellite platforms. The Analyst identified a number of secondary product priorities in the documents that are not observations themselves, but that benefit from Earth observations. Examples of these secondary product priorities include medium- and long-term forecast models that are built on observations and hazard maps created through the aggregation of multiple Earth observations.

Table 4 presents examples of the secondary products mentioned in the documents. In many instances, the parameters that underlie these secondary products are captured in the required parameters list for each disaster type. For example, the secondary product of earthquake frequency maps relies upon accumulated seismic measurements, which are included in this analysis. However, in cases where the documents did not specify the underlying parameters for a particular secondary product, the underlying parameters are not included in this analysis.

Table 4. Example Secondary Product Priorities.

Hazard Maps
Risk Maps
Damage Assessment Maps
Infrastructure Status
Flood Plain Maps
Earthquake Frequency Maps
Improved Flood and Landslide Forecast Models

4.1 Earth Observations for Earthquakes

The sudden nature of earthquakes and other seismic hazards, and their ability to affect large areas, make them one of the most deadly and costly types of natural disasters (Salichon et al. 2007).

The physical mechanisms driving earthquakes do not lend themselves to the creation and adoption of accurate prediction methods. Earth observations related to earthquakes are useful for monitoring, assessing risk, locating fault lines and plate boundaries, developing mitigation strategies, and assessing post-disaster damage.

Table 5 lists the Earth observation priorities for earthquake hazards. The Analyst prepared this table based on the methodology in Section 2.3.3 of this report. The “Parameters” column indicates the specific observation, while the “Observation Category” column indicates the broader description of the observations used for aggregation. The observations and specific parameters in the table are those that the documents explicitly identify as observation priorities for earthquake hazards. The “Document Reference(s)” column provides examples of the documents from which the Analyst derived the parameter needs.

Table 5. Earthquake Observation Parameters.

Observation Category	Parameters	Document Reference(s)
Global Positioning	Global Positioning	Plag 2006 NAS 2007 NRC 2003
	Terrestrial Reference Frame	
Gravity Fields	Gravity Fields	Helz and Gaynor 2007 Plag 2006 SESWG 2002 Salichon et al. 2007 NAS 2007
Ground Water	Ground Water	Helz and Gaynor 2007
Location of Faults	Location of Faults	Salichon et al. 2007 Bhanumurthy and Behera 2008 Tralli et al. 2005 HERP 1997
Magnetic Fields	Magnetic Fields	Helz and Gaynor 2007 SESWG 2002 Salichon et al. 2007 NAS 2007
Electric Fields	Electric Fields	Helz and Gaynor 2007
Seismicity	Seismicity	Helz and Gaynor 2007 USGS 2003 SESWG 2002 UNESCAP 2005 Turner et al. 2008 Salichon et al. 2007 Bhanumurthy and Behera 2008 USGEO 2006 NRC 2003 Tralli et al. 2005 HERP 1997
Soil Parameters	Soil Type	Bhanumurthy and Behera 2008
	Depth of Water Table	
Surface Deformation	Surface Deformation	Helz and Gaynor 2007 Plag 2006 SESWG 2002 ESNL 2004 UNESCAP 2005 Nirupama and Simonovic 2002 Salichon et al. 2007 Shimizu 2008 USGEO 2006 NAS 2007 NRC 2003 Tralli et al. 2005 HERP 1997
	Strain	
	Creep	
	Slip	
Thermal Emission	Thermal Emission	Salichon et al. 2007
Topography/ Elevation	Elevation	Helz and Gaynor 2007 SESWG 2002 ESNL 2004 Salichon et al. 2007 Bhanumurthy and Behera 2008 USGEO 2006 NRC 2003
	Bathymetry	

4.2 Earth Observations for Landslides

Landslide disaster events are typically less severe than earthquakes, in terms of casualties, destruction, and economic consequences, but they are more widespread globally. Landslides occur when the shear stress on a slope exceeds the shear strength of the supporting material. The term "landslide" refers to many types of down-slope Earth movements, including falls, flows (soil/rock, debris, lahar, mud), lateral spreads, slides (rotational and translational) and topple (USGS 2003). Landslides have a number of different triggering mechanisms and can originate from natural processes, such as earthquakes or other seismic events, volcanic events, and intense rainfall, or from anthropogenic processes including mining, vibrations caused by transportation routes, and increasing loads due to drastic changes in land use.

Earth observations of landslide parameters are used for the following applications (NOAA 2002):

- Mapping landslide-related factors
- Characterization of landslide deposits monitoring
- Prediction, monitoring, and mitigation
- Response
- Research.

Table 6 lists landslide hazard Earth observation priorities. The Analyst prepared this table based on the methodology in Section 2.3.3 of this report. The observations and specific parameters in the table are explicitly identified in the documents as observation priorities for landslide hazards.

Table 6. Landslide Observation Parameters.

Observation Category	Parameters	Document Reference(s)
Flood Monitoring	Location of Flood	Shimizu 2008
General Weather	Temperature	Helz and Gaynor 2007 Salichon et al. 2007
Global Positioning	Global Positioning	Plag 2006 NAS 2007
	Terrestrial Reference Frame	
Gravity Fields	Gravity Fields	Plag 2006 SESWG 2002 Salichon et al. 2007
Ground Water	Ground Water Level	Helz and Gaynor 2007 Spiker and Gori 2003
Land Use	Land Use	Tralli et al. 2005 UDRM 2006
Magnetic Fields	Magnetic Fields	SESWG 2002 Salichon et al. 2007
Precipitation	Precipitation Intensity	Helz and Gaynor 2007 Spiker and Gori 2003 SESWG 2002 Nirupama and Simonovic 2002 Salichon et al. 2007 Tralli et al. 2005
	Precipitation Amount	
	Precipitation Duration	

Observation Category	Parameters	Document Reference(s)
		UDRM 2006 Catane et al. 2008
Seismicity	Seismicity	Helz and Gaynor 2007 USGS 2003 Spiker and Gori 2003 SESWG 2002 UNESCAP 2005 USGEO 2006 Catane et al. 2008
Soil Parameters	Pore Pressure	Helz and Gaynor 2007 Spiker and Gori 2003 SESWG 2002 Nirupama and Simonovic 2002 Salichon et al. 2007 Tralli et al. 2005 Catane et al. 2008
	Soil Moisture	
	Soil Composition	
	Soil Thickness	
	Soil Type	
	Rock Strength	
	Rock Spacing	
	Rock Permeability	
	Rock-Joint Orientation	
	Rock Fracture	
Stream/River Stage and Properties	Stream/River Height	Helz and Gaynor 2007 SESWG 2002 Tralli et al. 2005
	Stream/River Flow	
	Stream/River Stage	
Surface Deformation	Surface Deformation	Helz and Gaynor 2007 Spiker and Gori 2003 Plag 2006 SESWG 2002 ESNL 2004 UNESCAP 2005 Nirupama and Simonovic 2002 Salichon et al. 2007 Shimizu 2008 USGEO 2006 NAS 2007
	Strain	
	Creep	
	Slope Movement	
	Slope Movement Rate	
	Slope Movement Depth	
Thermal Emission	Thermal Emission	NAS 2007
Topography/ Elevation	Elevation	Helz and Gaynor 2007 SESWG 2002 ESNL 2004 UNESCAP 2005 Salichon et al. 2007 Bhanumurthy and Behera 2008 USGEO 2006 NAS 2007 Tralli et al. 2005
	Slope Angle	
	Slope Length	
	Slope Position	
	Curvature	

4.3 Earth Observations for Floods

Floods are the most common natural disaster in the world, with frequent occurrence in most geographic regions, with the exception of the dry, desert regions. The nature of flood events

makes it possible to use Earth observations for various stages of a flood disaster. These stages include:

- The pre-flood stage, where flood forecasting, prevention, and preparedness are the key goals
- The flood event, where observations aid in weather and flood monitoring and response efforts
- Post-flood activities including damage assessment and forecast/model validation.

The Analyst applied the same priority-setting methodology for floods as for earthquakes and landslides. Table 7 presents the list of observation priorities for floods and the aggregated observation category. The observations and specific parameters in the table are explicitly identified in the documents as observation priorities for flood hazards.

Table 7. Flood Observation Parameters.

Observation Category	Parameters	Document Reference(s)
Flood Monitoring	Location of Flood	Brakenridge et al. 2003 NOAA 2002 Nirupama and Simonovic 2002 Shimizu 2008 Lauritson 2002 Bhanumurthy and Behera 2008
	Flood Development	
	Flood Peak	
General Weather	Temperature	Helz and Gaynor 2007 Nirupama and Simonovic 2002
	Relative Humidity	
	Wind Speed	
Ice/Snow Parameters	Snow Cover Fraction	Helz and Gaynor 2007 NOAA 2002 Nirupama and Simonovic 2002 Lauritson 2002
	Snow Liquid Water Equivalent	
	Ice Location	
	Ice Thickness	
	Snow Pack	
	Snow Albedo	
	Snow Depth	
	Snow Wetness	
Land Use	Vegetation Cover	Lauritson 2002 Tralli et al. 2005
Precipitation	Precipitation Intensity	Helz and Gaynor 2007 SESWG 2002 NOAA 2002 UNESCAP 2005 Nirupama and Simonovic 2002 Lauritson 2002 Tralli et al. 2005 UDRM 2006
	Precipitation Amount	
	Precipitation Duration	
	Precipitable Water	
Soil Parameters	Soil Moisture	Helz and Gaynor 2007 SESWG 2002 NOAA 2002 Nirupama and Simonovic 2002 Lauritson 2002 Tralli et al. 2005
	Soil Wetness Index	
	Pore Pressure	
	Soil Composition	
	Soil Thickness	
	Soil Type	
	Rock Strength	

Observation Category	Parameters	Document Reference(s)
	Rock Permeability	
Solar Influx	Solar Influx	Helz and Gaynor 2007
Stream/River Stage and Properties	Stream/River Height	Helz and Gaynor 2007 Plag 2006 SESWG 2002 UNESCAP 2005 Tralli et al. 2005
	Stream/River Stage	
	Stream/River Flow	
	Stream/River Discharge	
	Stream/River Volume	
	Sea Level	
Surface Deformation	Surface Deformation	Shimizu 2008
Topography/ Elevation	Elevation	Helz and Gaynor 2007 SESWG 2002 NOAA 2002 UNESCAP 2005 Lauritson 2002 NAS 2007 Tralli et al. 2005
	Bathymetry	

5 Priority Earth Observations for Disasters SBA

This section contains the results from the prioritization method described in Section 2.3.3 applied to the observations identified in Section 4.

5.1 Summary of Results

The previous sections presented the observation priorities individually for earthquakes, landslides, and floods. After calculating the weighted index for each of the observation categories, the Analyst identified and ranked common observation priorities, shown in Figure 2. The Analyst then determined the index value for each observation category by disaster type. This information is also presented in Figure 2. The Analyst chose to use the top 75% of the total aggregated index values as the highest priorities, as highlighted by the gray box in Figure 2. The method used to determine the top observation priorities is explained in more detail in Section 5.2.

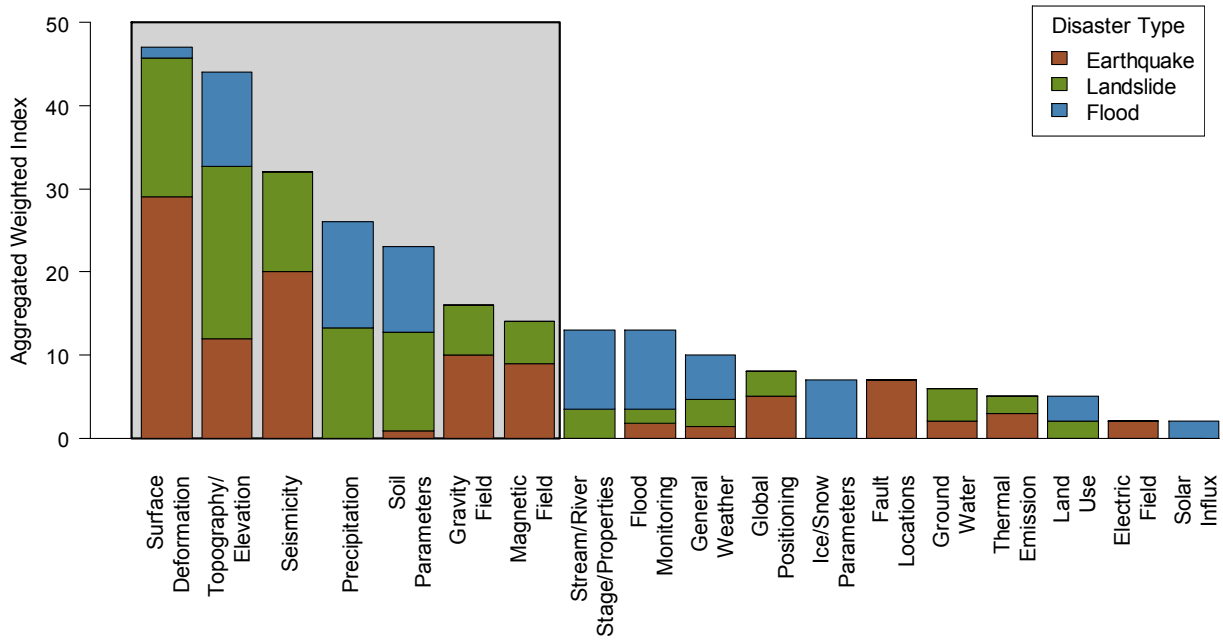

Figure 2. Aggregated weighted index value for all observation categories by disaster type.

5.2 Priority Observations

The remainder of this analysis focuses on those observations that have the highest priority, defined by the Analyst as the top observation categories that cumulatively represent 75% of the total index value. The Analyst chose 75% as the cut-off because it includes a manageable number of high-priority observations, acknowledging that other breakpoints could be equally valid. These categories are highlighted in the gray box in Figure 2. Using the 75% cut-off, the Analyst identified seven categories as the top priority Earth observation categories for the Disasters SBA. The following is a more detailed discussion of the observation categories, including information regarding the desired physical characteristics of the observations provided by the documents. For several of the parameters, some of the characteristics (coverage/extent, spatial resolution, temporal resolution, accuracy, and latency) were not indicated in the source documents and therefore could not be specified in this report. Those missing characteristics are indicated as blank cells or fields in Table 8.

Surface Deformation

Surface deformation is a visible response on the Earth's crust to processes that are occurring at depth. These processes drive seismic activity, volcanism, and landslides (NAS 2007). For disaster applications, various documents called for moderate to high spatial resolutions of surface deformation observations (including slip, slope movement, strain, and deformation), ranging from a resolution of "less than 100 km" down to 1 mm.

These spatial resolutions are described in more detail in Table 8. Frequency specifications ranged from seconds to days to approximately weekly observations. These resolutions mainly applied to the displacement and strain accumulation observations. Of the 13 documents that discussed surface deformation, one document stated that the spatial and temporal resolution of the observations should be high enough to measure all significant motions, including seismic and aseismic events, as well as the transients that occur before, during, and after earthquakes. However, this document did not specify how fine the spatial and temporal resolutions would need to be to accomplish these goals. Other documents had temporal resolutions ranging from 1 second up to one year (more details can be found in Table 8). All documents that specified accuracy characteristics indicated that sub-centimeter scale accuracy is required. Other documents went as far as to say that sub-millimeter is preferred. Several documents highlighted the need for these high-resolution, high-accuracy surface deformations in seismically active areas, along active fault lines and near fault zones.

Topography/Elevation
Many documents identified measuring changes in topography as critical for predicting, responding to, and monitoring floods, landslides, and earthquakes. Many documents describe the required spatial resolution as "high" without further quantification, with one document mentioning that 1 m resolution is required in targeted areas and 2 to 5 m is required globally. The vertical accuracy identified in the documents ranges from sub-decimeter for targeted areas and 0.5 m elsewhere. Target areas include areas of high landslide susceptibility and seismically active areas. The documents indicated that rapid updates were required after specific events (such as earthquakes) and that updated measurements were required in a range from monthly to every 3 years for elevation and bathymetry. The documents also indicated a latency of months, except for those rapid updates after specific events.

Seismicity
Seismic monitoring, including observations from the surface and from the ocean floor, allows investigation of the magnitude of Earth shaking, as well as the timeframe and magnitude of aftershocks. The documents indicated that expansion of seismic monitoring networks is required. Of the seven documents discussing seismicity, one document suggested that monitoring should be sufficiently dense (70 km on the national scale) to determine the source parameters, including the focal mechanisms of the seismic events. This document also recommended additional monitoring in urban areas (1 to 2 km), as well in areas close to active faults. The required sensitivity characteristics vary among documents from a magnitude of 1.5 to 2.0 in seismically active areas to 3.0 to 3.5 elsewhere. These observations are required to be available in real-time to the end users.

Precipitation
The precipitation category includes observations of the intensity, duration, and amount of rain or snowfall that are used for flood prediction and monitoring, as well as for landslide applications. The specified temporal resolution characteristics in the documents ranged from continuous to hourly. High temporal resolution is required since these variables can

change rapidly. The documents identified required spatial resolutions that range from 1 to 50 km, and the required accuracy was noted to be 1 to 2 mm. Coverage requirements indicated in the documents included near potential and actual landslides, in catchment areas, and in areas where flooding is taking place.

Soil Parameters
Soil properties in areas prone to floods and landslides are critical observations for disaster prevention, prediction, and mitigation. These properties consist of the type of soil, the amount of water in the soil, the soil thickness, and rock properties, as well as the pore water pressure in the soil. The pore water pressure is an indicator of soil strength, a valuable parameter for landslide applications. The documents indicated a range of required resolutions from 100 m to 10 km for soil moisture observations to 5 m for rock properties, with hourly to weekly frequency. One document indicated that a full soil composition and thickness assessment should be conducted every 5 to 10 years, while another specified that soil moisture observations should be available within one day.

Gravity Fields
Changes in the Earth's gravity field enable monitoring of near-surface deformation (SESWG 2002), and can provide information about the variation of stress with time when monitored after large seismic events (NAS 2007). Numerous documents listed observations of the gravity fields along active faults and near fault zones as priority observations. One document indicated a required accuracy for the gravity field as 0.3 μGal (micro units of gravity), another stated 1 μGal, and a third stated that it should be within a few mm of surface water equivalent load, and indicated a spatial resolution of 100km. Although some documents called for global coverage of the Earth's gravity fields with approximately monthly frequency, others stated that these observations are particularly important along active fault lines and near fault zones.

Magnetic Fields
Similar to gravity fields, observations of the magnetic fields along active faults and near fault zones were listed as priority observations in numerous documents. One document indicated that magnetic field measurements should be provided at an accuracy of within a few nT (nanoteslas). Even though observations of magnetic fields were listed as a priority in several documents, none indicated a required spatial resolution, temporal resolution, or latency.

Table 8 provides a summary of the observation categories, the specific priority observation parameters, and the desired characteristics for each, as follows:

- Coverage/Extent: the geographic region(s) over which the parameters should be observed.

- Spatial Resolution: the density of measurements or smallest measured unit (i.e., pixel size) required by the end users.

- Temporal Resolution: the frequency of the measurements of the parameters required by the end users.

- Accuracy: how close the observation needs to be to the actual value. In some cases, the accuracy column will indicate a detection threshold.

- Latency: how quickly the data need to be available to the end user after collection.

Table 8. Aggregated Characteristics of Priority Observation Parameters[a].

Observation Category	Parameter	Coverage/ Extent	Spatial Resolution	Temporal Resolution	Accuracy	Latency
Surface Deformation	Slip	• Seismically active areas • Along active fault lines/ near fault zones	• Moderate to High			
	Slope Movement	• Seismically active areas • Along active fault lines/ near fault zones	• 1 mm - 1 cm	• High Frequency		• Real-Time
	Strain	• Seismically active areas • Along active fault lines/ near fault zones	• 50 – 75 m	• Weekly	• Sub-cm	
	Deformation	• Seismically active areas • Along active fault lines/ near fault zones	• 1 m - 75 m	• 1 sec – 1 week • 1 month - 1 year	• sub-mm – 1 cm	
Topography/ Elevation	Elevation	• Global • Seismically Active Areas • Areas of high landslide susceptibility	• 0.15-5 m • 1 m for targeted areas • 2-5 m global	• Rapid updates after events • Monthly – 3 years	• sub-dm – 0.5m	• Months
	Bathymetry	• Near-Shore	• 90 m - < 1 km	• Monthly – 3 years		• Months
	Slope Angle, Length, Position	• Areas of high landslide susceptibility	• "High"			
	Curvature	• Areas of high landslide susceptibility	• "High"			
Seismicity	Seismicity	• National – Global Scales • Seismically Active Areas • Areas of high landslide susceptibility • Urban areas and critical facilities	• 70 km (national scale) • < 1 km - 2 km (urban areas)	• Real-Time	• Detection of Magnitudes of 3.0-3.5 (global) • Detection of Magnitudes of 1.5 - 2.0 (urban/regional)	• Real-Time
Precipitation	Precipitation Intensity, Duration, Amount	• Near potential and actual landslides • Catchment areas • Flood areas	• 1-50 km	• Continuous – Hourly • 2 times/day	• 1 – 2 mm	• Hourly

a Blank fields indicate that no specific characteristic was reported in the documents.

Table 8. (Continued).

		Aggregated Characteristics of Priority Observation Parameters				
Observation Category	**Parameter**	**Coverage/ Extent**	**Spatial Resolution**	**Temporal Resolution**	**Accuracy**	**Latency**
Soil Parameters	Soil Moisture		• 100 m - 10 km	• 4 times/day - weekly		• Within 1 day
	Soil Composition and Thickness			• 5 – 10 years • More frequent in affected areas		
	Pore Pressure					
	Rock Strength, Permeability, Spacing, Orientation		• 5 m			
Gravity Fields	Gravity Fields	• Global • Along active fault lines and near fault zones	• 100 km	• Approximately Monthly	• 0.3 µGal - 1 mGal	
Magnetic Fields	Magnetic Fields	• Global • Along active fault lines and near fault zones			• Few nT	

a Blank fields indicate that no specific characteristic was reported in the documents.

5.3 Advisory Group Feedback on Priority Observations

The Analyst gathered feedback from the Advisory Group throughout the process on the analytical methods used to determine the priority observations for earthquake, landslide, and flood hazards, as well as on the final list of priority observations. Overall, the Advisory Group was supportive of the objective quantitative methods used by the Analyst, but some expressed concern over how the results can be biased by the selection of documents and how the observations are classified.

Feedback from the Advisory Group also indicated that a large number of the documents identified were focused on remote sensing applications. As a result, observation categories, such as seismicity, that are typically based on measurements from ground-based sensors, may be underrepresented in the final assessment of observation priorities. The Analyst notes this as a valid concern but that the search methodology used was technology-neutral.

Another Advisory Group comment noted that some of the identified observation parameters are interrelated. For example, in the data extraction process, the Analyst found that documents identified global positioning both as a priority observation (e.g., an accurate terrestrial reference frame), as well as a required technology for obtaining other observation parameters, such as surface deformation (Table 5). Per the Task US-09-01a methodology, this task did not include consideration of the methods and technologies required to acquire the priority observations (see Section 1.4 above). This means that although the installation of a global positioning system (GPS) may be critical for achieving various observation priorities, it was not included in the analysis unless the document specifically identified such a system as required for global positioning observations.

The Advisory Group members also provided feedback on the priority observations for individual hazards. This analysis was intended to provide a cross-hazard analysis of the priority observations, and is not specific for any one hazard. In addition, an Advisory Group member expressed that the list of observation priorities should focus exclusively on those observation parameters that are currently needed by end users for disaster hazard analysis, and not those that may be useful in the future. However, the distinction between current and future user needs was outside the scope of Task US-09-01a.

6 Additional Findings

Through the course of this analysis, the Analyst identified additional information that could help provide context and insight to the findings, but was not itself directly relevant to the prioritization, as highlighted below.

6.1 Comparison of US-09-01a Final Priority List with Other Priority Setting Efforts

Among the 22 documents that are included in the final prioritization, there are two documents that also directly identify prioritized lists of observations relevant to the Disasters SBA. These documents are “Living on a Restless Planet: Solid Earth Science Working Group Report”

(SESWG 2002) and "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond" (NAS 2007). Although these two documents perform a broader analysis of disaster types than those analyzed in this US-09-01a SBA report, they provided relevant information, which the Analyst compared to the findings of this report. Table 9 presents the US-09-01a priority observation list, as defined in Section 5, as well as the priority observations (marked with an "X") identified by these two documents for comparison and validation purposes.

Table 9. Priority Observation Comparison.

Priority Observations from This Analysis	SESWG 2002[a]	NAS 2007[b]
Surface Deformation	X	X
Topography/Elevation	X	X
Seismicity		
Precipitation		
Soil Parameters		X *(Surface Composition)*
Gravity Fields	X	X
Magnetic Fields	X	X
Other	International Terrestrial Reference Frame	Thermal Properties

[a] "Living on a Restless Planet: Solid Earth Science Working Group Report (SESWG 2002)
[b] "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond (NAS 2007)

The priority-setting methodology employed in this analysis captures most of the observation priorities that were specifically identified as critical in the SESWG and NAS documents, except for seismicity and precipitation, which are not explicitly identified as priority observations in these documents. This omission is likely because the comparison documents are focused on remote sensing technologies, and these two parameters are typically (though not always) observed using *in situ* instruments.

6.2 Literature Focus on Remote Sensing Technologies

Throughout the literature review, the Analyst Team identified numerous documents that referenced priorities for specific technologies. For example, many of the documents that discussed surface deformation specifically identified Interferometric Synthetic Aperture Radar (InSAR), GPS, and other remote sensing techniques as the highest priority for Earth observations. In those instances where specific observation parameters (distinct from the observation techniques or technologies) were indicated, they were included in the analysis. However, some documents reference the need for specific technologies without indicating any characteristics of associated observations. This result may be due to the large number of documents used in this analysis that were focused on remote sensing *applications* of disasters Earth observations as opposed to remote sensing *requirements*. The focus on specific applications may have led to a focus on specific technologies.

6.3 Document Additions Late in the US-09-01a Process

As this document was being finalized for submission to GEO, the Analyst was notified of a report by the CEOS Disaster SBA team (CEOS 2008) that establishes Earth Observation requirements for a variety of hazard types. The report gathered information from subject matter experts in satellite applications for disaster mitigation, warning, response and recovery. The Analyst reviewed the report and found that the priority observations identified in the CEOS (2008) document were very similar to those identified in this priority analysis. While the CEOS document contained valuable information regarding observation requirements for earthquake, landslide, and flood hazards, the Analyst did not believe that the final rankings presented in Section 5 of this report would have been altered by including the CEOS document in this US-09-01a analysis. Nevertheless, the Analyst recommends that GEO take into account the recommendations from the CEOS document for future actions in the area of hazard and disaster management.

7 Analyst's Comments and Recommendations

Overall, the Analyst found that the steps outlined in the Task US-09-01a process were sufficient to accomplish the goal of identifying priority Earth observations for the Disasters SBA. As the entire process moves forward, and more SBA analyses are completed, the Analyst recommends that the UIC review the reports that have been completed to further refine the steps to ensure consistency and quality among all reports. In this section, suggestions for improving the task process based on the challenges and successes experienced by the Disasters SBA Analyst will be provided.

The Analyst believes that the response rate to the invitations sent to potential Advisory Group members would increase if the invitations were sent directly from GEO, or if an official GEO letter were attached. Some potential members may be hesitant to respond if they are not familiar with the Analyst's agency or organization. In addition, early contact by GEO may help to keep the Advisory Group engaged and active. For the Disasters SBA, the Advisory Group participated in narrowing the scope of topics as planned. However, some Advisory Group members, whose expertise was outside the topics of earthquakes, landslides, and floods, became less engaged with the group after the final three disaster types had been chosen for analysis. One solution to this loss of participation is to increase the number of Advisory Group members, so that the ultimate group (after attrition) will include more experts related to the topics within the narrowed scope. An alternate solution is for the Analyst Team to narrow the scope before engaging the Advisory Group, so that the members can see in advance that their particular expertise will be relevant to the SBA analysis.

Throughout the course of the task, the Analyst, Advisory Group, and fellow SBA Analysts had numerous discussions on which observations to include in the analysis with respect to directly observed, derived, modeled, and other types of parameters. The Analyst recommends that the task process description provide guidance on and specific examples of what should be considered an observation for the purpose of this task, because expert opinion varied on this question. However, the guidance should allow the Analyst flexibility in what is included based

on the individual nature of each SBA. In addition, the Analyst recommends providing clarification on what language should be included in a source document in order for the identified observation to be considered a priority. For example, in the case of precipitation observations, does the source document need to explicitly state that acquiring precipitation data is a priority within the SBA, or can the Analyst infer that the use of precipitation data in an existing landslide study is sufficient by itself to render the observation a priority?

The biggest challenge encountered by the Analyst and Advisory Group members was developing an analytic method to integrate disparate sources of information into a single priority-setting analysis. The analytical method was intended to be as objective as possible and only included observation priorities clearly acknowledged in publicly available documents. It considered how many of the documents identified an observation as a priority, what types of documents identified an observation as a priority, and the number of disaster types to which the observation applied, as indicated by the documents. If more documents provided observation priorities, including the specific physical characteristics (e.g., spatial and temporal resolution) of those observations, another layer of analysis could have been conducted that included the priority characteristics of each priority observation. The Analyst suggests that a summary of the analytic methods developed by each SBA be reviewed by the UIC to determine which method best suits the UIC's needs. To the extent possible, this method should be standardized across all future SBA analyses. A detailed description of the standardized method should then be included in the process documentation to ensure consistency among all Task US-09-01a analyses and subsequent analyses.

Appendix A: Abbreviations

BRGM	Bureau de Recherches Géologiques et Minières
CEOS	Committee on Earth Observation Satellites
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GOES	Geostationary Operational Environmental Satellite
GPS	Global positioning system
IGOS	Integrated Global Observing Strategy
InSAR	Interferometric Synthetic Aperture Radar
NASA	National Aeronautics and Space Administration
SBA	Societal Benefit Area
SDR	Subcommittee on Disaster Reduction
UIC	User Interface Committee
USGS	U.S. Geological Survey

Appendix B: Bibliography and References

B.1 Documents Cited

Bhanumurthy, V., and G. Behera. 2008. *Deliverables from Space Data Sets for Disaster Management - Present and Future Trends*. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 37, pp. 263-270.

Brakenridge, G. R., E. Andersona, S.V. Nghiemb, S. Caquard, and T.B. Shabaneh. 2003. *Flood Warnings, Flood Disaster Assessments, and Flood Hazard Reduction: The Roles of Orbital Remote Sensing.* Proceedings of the 30th International Symposium on Remote Sensing of Environment, 6 pp.

Catane, S. G., M.A.H. Zarco, and R.M. Saturay. November 2008. *Landslide-Risk Reduction Strategies and Practices in the Philippines*. Abstract for First World Landslide Forum, 4 pp.

Committee on Earth Observing Satellites (CEOS) Disaster SBA Team. 11 November 2008. *Use of Satellites for Risk Management, Volume I: Establishing Global Requirements for Earth Observation Satellite Data to Support Multi-Hazard Disaster Management Throughout the Disaster Cycle*. GEO DI-06-09 Report, 34 pp.

Earth Science Natural Laboratory (ESNL). 13 July 2004. *Geo-Hazards Natural Laboratory for the Asia Pacific Arc and Western North America Meeting Report*. Available at: <http://solidearth.jpl.nasa.gov/PDF/Maui_GeoHazards_Mtg_Report.pdf>. Accessed May 2009.

Group on Earth Observations (GEO). 13 January 2009b. *GEO 2009-2011 Work Plan*. Available at: <http://www.earthobservations.org/documents/work%20plan/geo_wp0911_rev1_090113.pdf>. Accessed May 2009.

Headquarters for Earthquake Research Promotion (HERP). 1997. *Fundamental Survey and Observation Plan for Earthquake Research. Available at: <http://www.jishin.go.jp/main/index-e.html>.* Accessed May 2009.

Helz, R.L., and J.E. Gaynor. 2007. *Reducing Loss of Life and Property from Disasters: A Societal Benefit Area of the Strategic Plan for the U.S. Integrated Earth Observation System (IEOS)*. US Geological Survey, OFR 2007-1147, 67 pp.

Lauritson, L. 2002. *Hazard Requirements from the Perspective of the CEOS Disaster Management Support Group.* Presented at Second GOES User Conference, Boulder, Colorado, October 1-3, 2002. Available at: <http://www.goes-

r.gov/downloads/GOES%20Users'%20Conference%20II/Lauritson/Lauritson.ppt>. Accessed May 2009.

National Academy of Sciences (NAS). 2007. *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond.* ISBN: 978-0-309-10387-9, 456 pp.

National Oceanic and Atmospheric Administration (NOAA). 2002. *The Use of Earth Observing Satellites for Hazard Support: Assessments & Scenarios, Final report of the Committee on Earth Observation Satellites (CEOS) Disaster Management Support Group*. Available at: <http://ceos.esa.int/plenary16/papers/plenary16_doc14_dmsg_final/final_report/DMSG_final.html>. Accessed May 2009.

National Research Council (NRC). 2003. *Living on an Active Earth: Perspectives on Earthquake Science*. Committee on the Science of Earthquakes, National Academies Press, Washington, DC, 432 pp.

Nirupama, [N.], and S.P. Simonovic. September 2002. *Role of Remote Sensing in Disaster Management.* ICLR Research Paper Series, No. 21, 107 pp.

Plag, H.P. 2006. *National Geodetic Infrastructure: Current Status and Future Requirements: The Example of Norway*. Nevada Bureau of Mines and Geology, Bulletin 112, 98 pp.

Salichon, J., G. LeCozannet, H. Modaressi, S. Hosford, R. Missotten, K. McManus, S. Marsh, M. Paganini, C. Ishida, H.P. Plag, J. Labrecque, C. Dobson, J. Quick, D. Giardini, K. Takara, H. Fukuoka, N. Casagli, and W. Marzocchi. August 2007. *IGOS Geohazards Theme Report*. BRGM/RP-55739-FR, Bureau de Recherches Géologiques et Minières, 89 pp.

Shimizu, T. 27 April 2008. *Disaster Management Satellite System Development and International Cooperation Promotion in Asia.* Science and Technology Trends Quarterly Review, National Institute of Science and Technology Policy, Vol. 27, 93-108.

Solid Earth Science Working Group (SESWG). 2002. *Living on a Restless Planet.* NASA Jet Propulsion Laboratory. Available at: <http://solidearth.jpl.nasa.gov/PDF/SESWG_final_combined.pdf>. Accessed February 2009.

Spiker, E.C., and P.L. Gori. 2003. *National Landslide Hazards Mitigation Strategy - A Framework for Loss Reduction.* USGS Circular 1244, 64 pp.

Tralli, D.M., R.G. Blom, V. Zlotnicki, A. Donnellan, and D.L. Evans. 2005. *Satellite Remote Sensing of Earthquake, Volcano, Flood, Landslide and Coastal Inundation Hazards*. ISPRS Journal of Photogrammetry and Remote Sensing, Vol. 50, pp 185-198.

Turner, J., R.D. Paulison, A. Bement, J. Nussle, J.H. Marburger, and M. Myers. March 2008. *Annual Report of the National Earthquake Hazards Reduction Program.* National Earthquake Hazards Reduction Program, 69 pp.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). 2005. *Framework for Regional Cooperation on Space Technology Supported Disaster Reduction Strategies in Asia and the Pacific*. Study report prepared for the Meeting of Experts on Space Applications for Disaster Management, Chiang Mai, China 25-28 July 2005, 38 pp.

United States Geological Survey (USGS). May 2003. *Understanding Earthquake Hazards in Urban Areas: ANSS-Reducing the Devastating Effects of Earthquakes.* USGS Fact Sheet FS-046-03, 4 pp.

United States Group on Earth Observations (USGEO) and Subcommittee on Disaster Reduction. September 2006. *Improved Observations for Disaster Reduction: Near-Term Opportunity Plan.* Available at: <http://usgeo.gov/docs/nto/Disaster_Observations_NTO_2006-0925.pdf >. Accessed May 2009.

Urban Disaster Risk Management (UDRM). June 2006. *Rapid Assessment: Flashflood and landslide disaster in the provinces of Uttaradit and Sukhothai, Northern Thailand, May 2006*. Report for Asian Disaster Preparedness Center, 18 pp.

B.2 Documents Consulted

Ardizzone, F., M. Cardinali, F. Guzzetti, and P. Reichenbach. November 2008. *Landslide Hazard Assessment, Vulnerability Estimation, and Risk Evaluation at the Basin Scale.* 2008, Abstract for First World Landslide Forum, November, 4 pp, Available at: <http://150.217.73.85/wlfpdf/12_Reichenbach.pdf>. Accessed May 2009.

Center for Research on the Epidemiology of Disasters (CRED). *Emergency Events Database (EM-DAT): The International Disaster Database.* Available at: <http://www.emdat.be>. Accessed May 15, 2009.

De Bernardinis, B. April 2007. *GMES Fast Track Emergency Response Core Service: GMES Strategic Implementation Plan.* Available at: < http://www.gmes.info/pages-principales/library/implementation-groups/emergency-response-core-service-ercs/?no_cache=1&download=ERCS_Strategic_Implementation_Plan_Final.pdf&did=42>. Accessed May 2009.

Galli, M., F. Ardizzone, M. Cardinali, F. Guzzetti, and P. Reichenbach. 2008. *Comparing Landslide Inventory Maps*. Geomorphology, 94, pp 268-289.

Global Climate Observing System (GCOS) Secretariat. 11 April 2007. *The Cross-Cutting of Observations Needed for Climate Across the Societal Benefit Areas Identified by GEO: Discussion Paper*. Available at: <http://www.wmo.int/pages/prog/gcos/documents/GCOS_Cross-cut_GEOSS_110407.pdf>. Accessed May 2009.

Granger, K. 1999. *An Information Infrastructure for Disaster Management in Pacific Island Countries.* Australian Journal of Emergency Management. Available at: <http://www.ema.gov.au/www/emaweb/rwpattach.nsf/VAP/(084A3429FD57AC0744737F8EA134BACB)~An_information_infrastructure_for_disaster_+management.pdf/$file/An_information_infrastructure_for_disaster_+management.pdf>. Accessed May 2009.

Group on Earth Observations (GEO) User Interface Committee (UIC), 2008, *Overview of GEO Task US-09-01a*. Available at: <http://sbageotask.larc.nasa.gov/GEOTaskUS0901aOverview.pdf>. Accessed March 2009.

Group on Earth Observations (GEO). 2009a. *About GEO.* Available at: <http://www.earthobservations.org/about_geo.shtml>. Accessed March 2009.

Guzzetti, F., L. Candela, R. Carla, G. Fornaro, R. Lanari, and G. Ober. November 2008. *Exploiting Earth Observation Technology to Map, Monitor and Forecast Landslides: the ASI MORFEO Project*. 2008. Abstract for First World Landslide Forum. Available at: <http://150.217.73.85/wlfpdf/01_Guzzetti.pdf>. Accessed May 2009.

Hollingsworth, A., S. Uppala, E. Klinker, D. Burridge, F. Vitart, J. Onvlee, J.W. DeVries, A. de Roo, and C. Pfrang. 2005. *The Transformation of Earth-system Observations into Information of Socio-Economic Value in GEOSS.* Q.J.R. Meterol. Soc.131, pp. 3493-3512.

Integrated Global Observing Strategy (IGOS). 2003. *IGOS Geohazards Theme Report.* Available at: <http://ioc.unesco.org/igospartners/docs/theme_reports/Geohazards.pdf>. Accessed May 2009.

Le Cozannet, G., S. Hosford, J. Douglas, J.J. Serrano, D. Coraboeuf, and J. Comte. 2008. *Connecting Hazard Analysts and Risk Managers to Sensor Information.* Sensors, Vol. 8, pp 3932-3937.

Le Cozannet, G., and J. Salichon. December 2007. *3rd International Geohazards Workshop 6th - 9th November 2007, Executive Report*. BRGM/RP-56038-FR, Bureau de Rechercherches Géologiques et Minières.

Le Cozannet, G., and J. Salichon. August 2007. *Geohazards Earth Observation Requirements.* European Space Agency: BRGM/RP 55719-FR. Available at: <http://dup.esrin.esa.int/files/project/131-176-149-30_200811512713.pdf>. Accessed May 2009.

Muhongo, S. 13 February 2008. *Grand Challenges on Natural and Human-induced Hazards and Disasters.* IYPE-Global Launch Event, UNESCO, Paris, 41 pp.

National Oceanic and Atmospheric Administration (NOAA). November, 2007. *Consolidated Observation Requirements List: Marine Transportation Systems Program: NOAA Program Observation Requirements Document*. Available at: <http://www.nosc.noaa.gov/docs/products/CT-MTS_Final_PORD_11-30-07_v4O3b-Signed.pdf>. Accessed May 2009.

National Science and Technology Council. April 2005. *Strategic Plan for the U.S. Integrated Earth Observation System.* Interagency Working Group on Earth Observations Report. Available at: <http://www.ostp.gov/pdf/eocstrategic_plan.pdf>. Accessed January 2009.

National Science and Technology Council, Committee on Environment and Natural Resources. June 2005. *Grand Challenges for Disaster Reduction.* Available at: <http://www.nehrp.gov/pdf/grandchallenges.pdf>. Accessed May 2009.

National Science and Technology Council, Committee on the Environment and Natural Resources. July 2003. *Reducing Disaster Vulnerability through Science and Technology: An Interim Report of the Subcommittee on Disaster Reduction*. Available at: <http://www.sdr.gov/SDR_Report_ReducingDisasterVulnerability2003.pdf>. Accessed May 2009.

Ocean US: The National Office for Integrated & Sustained Ocean Observations. 23 May 2002. *An Integrated and Sustained Ocean Observing System (IOOS) for the United States: Design and Implementation* Available at: <http://www.ocean.us/documents/docs/FINAL-ImpPlan-NORLC.pdf>. Accessed May 2009.

Ocean US: The National Office for Integrated & Sustained Ocean Observations. 2006. *Workshop on Regional Needs for Coastal Remote Sensing.* Ocean Workshop Report, US Publication No. 16, 32 pp.

Ostir, K., T. Veljanovski, T. Podobnikar, and Z. Stancic. 2003. *Application of Satellite Remote Sensing in Natural Hazard Management: the Mount Mangart Landslide Case Study.* Int. J. Remote Sen., Vol. 24, 3983 - 4002.

Plag, H-P., and M. Pearlman (Editors). 2008. *The Global Geodetic Observing System: Meeting the Requirements of a Global Society on a Changing Planet in 2020: The Reference Document (V0.18)*. International Association of Geodesy, 190 pp.

Rupasinghe, N., S. Herath, and S. Atapattu. November 2008. *Towards landslides risk reduction in Sri Lanka*. Abstract for First World Landslide Forum. Available at: <http://150.217.73.85/wlfpdf/02_Rupasinghe.pdf>. Accessed May 2009.

Subarya, C. 18-19 September 2006. *Geohazards as part of a Global Earth Observation System of Systems.* Presentation at the ICSU conference Regional Office for Asia and the Pacific, Kuala Lampur.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). 17-19 November 2004. *Policy Framework on Space Information Products and Services for Disaster Management - Study report synthesizing the recommendations of the Meeting of Experts on Policy Framework on Space Information Products and Services for Disaster Management.* Available at: <http://www.unescap.org/idd/pubs/STAS_Policy_framework_on_space_products_and_services_for_DM.pdf>. Accessed May 2009.

United States Group on Earth Observations (USGEO). 6 May 2005. U.S. Integrated Earth Observation System: Improved Observations for Disaster Warnings, 11 pp.

Urban Disaster Risk Management (UDRM). June 2006. *Rapid Assessment: Flashflood and landslide disaster in the provinces of Uttaradit and Sukhothai, Northern Thailand, May 2006*. Asian Disaster Preparedness Center. Available at: <http://www.adpc.net/enewsjuly/Uttaradit_rapidassessment.pdf>. Accessed May 2009.