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

Disasters Societal Benefit Area: Part Two

GROUP ON EARTH OBSERVATIONS

User Interface Committee

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Group on Earth Observations

GEO Task US-09-01a:
Critical Earth Observation Priorities for Disasters SBA – Part 2

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GEO Task US-09-01a
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Group on Earth Observations

GEO Task US-09-01a:
Critical Earth Observation Priorities for Disasters SBA – Part 2

Summary

The goal of GEO Task US-09-01a is to identify the critical Earth observations for various societal benefit areas (SBAs). This report is the second of two reports that identify observation priorities for the Disasters SBA. The first report (Weber, 2010) focused on analysis of *earthquakes, landslides, and floods*. This second report (Part 2) focuses on analysis of *wildfires, volcanic eruptions, and tropical cyclones*.

To assist with the Part 2 analysis, the Analysts and research staff (Analyst Team) assembled an ad hoc Advisory Group of 23 members from around the world. Responsibilities of the Advisory Group included selecting the types of disasters for analysis, recommending relevant documents that highlight critical Earth observation priorities, and reviewing prioritization methods and the results.

To supplement document recommendations from the Advisory Group, the Analyst Team conducted literature and internet searches. In all, the Analyst Team and Advisory Group identified 185 potentially relevant documents. After evaluating these documents for their applicability to this task, the Analyst Team selected 63 documents that provided information on wildfire, volcanic eruption, and tropical cyclone observation priorities that were relevant to the priority setting analysis.

The Analyst Team extracted Earth observation priorities from the documents for each of the three types of disasters and then grouped the aggregated observations into broad observation categories for clarity and ease of interpretation. In order to determine which observation categories have the highest priority, the Analyst Team analyzed the observation categories using two different prioritization methods. The Prioritization Method #1 is an objective indexing scheme that weighted observation categories in three ways: a) by the frequency with which they were identified as observation priorities in documents, b) by the type of document in which they were listed, and c) by cross-hazard applicability. Prioritization Method #2 is a subjective scheme based on rankings of the importance of each observation category by the members of the Advisory Group, who are experts in wildfires, volcanic eruptions, and tropical cyclone hazards.

Based on the results derived from Prioritization Methods #1 and #2, the Analyst Team generated two lists of priority observation categories for wildfires, volcanic eruptions, and tropical cyclones. The top 5 observation categories derived using Prioritization Method #1, the objective aggregated weighting scheme, for wildfires, volcanic eruptions, and tropical cyclones are (in descending priority order):

- Wind Properties
- Atmospheric Emissions

- Elevation/Topography Properties
- Thermal Properties
- Fire Location.

The top 5 observation categories derived using Prioritization Method #2, the subjective Advisory Group ranking scheme, for wildfires, volcanic eruptions, and tropical cyclones are (in descending priority order):

- Fire Location
- Fire Extent
- Seismic Properties
- Eruption Properties
- Fire Properties.

In order to obtain an overall ranking of Earth observation priorities for the Disasters SBA, the Analyst Team combined the results of Prioritization Method #1 from this report with the results from the first Disasters SBA Task US-09-01a report (Weber, 2010), which were derived using Prioritization Method #1. The Analysts considered only the results of Prioritization Method #1 in order to be consistent across both Disasters SBA reports. To reflect the risk of disasters to human life and property, the Analyst Team took the results of the objective weighting of all of the observation categories and conducted an additional weighting analysis using data on the impacts of observed worldwide disasters for the past 30 years. Based on the results of these combined analyses, the Analyst Team generated a list of 6 priority observation categories for earthquakes, landslides, floods, wildfires, volcanic eruptions, and tropical cyclones. The overall Earth observation categories of highest priority for the Disasters SBA are as follows; the Analyst Team considers all 6 of these observation categories to be of equal importance for the Disasters SBA:

- Elevation/Topography Properties
- Precipitation Properties
- Surface Deformation
- Wind Properties
- Seismic Properties
- Soil Properties.

The specific parameters that make up these observation categories are detailed within this report. 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. The list of Disasters SBA priority observations was used in the Cross-SBA analysis to identify critical Earth observation priorities across all SBAs.

GEO Task US-09-01a:
Critical Earth Observation Priorities for Disasters SBA – Part 2

1 Introduction

This report articulates Earth observation priorities for the Disasters Societal Benefit Area (SBA) based on an analysis of 185 publicly available documents, including documents produced by the 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
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. This task includes direct measurements and derived parameters as well as model products. This task seeks to identify Earth observation needs across a full spectrum of user types and communities in each SBA, including observation needs from all geographic regions with significant representation from developing countries.

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

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 the Report

The primary purpose of this report is to articulate the critical Earth observation priorities for the Disasters SBA. The intent of this 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. This report describes the prioritization methodologies used to determine the priority Earth observations for the Disasters SBA. This 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 the Report

This report addresses the Earth observation priorities for the Disasters SBA. This report is the second of two reports for the Disasters SBA. The first report (Weber, 2010) focused on analysis of *earthquakes, landslides, and floods*. This second report (Part 2) focuses on analysis of *wildfires, volcanic eruptions, and tropical cyclones*. This report also provides an overall assessment of Earth observation priorities for all of the types of disasters analyzed as part of Task US-09-01a, including earthquakes, landslides, floods, wildfires, volcanic eruptions, and tropical cyclones.

This 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.

This 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 types of disasters that were part of this analysis. Section 4 articulates the specific Earth observations for each disaster type, and Section 5 presents the priority observations across the Disasters SBA. Section 6 presents 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. Appendix D summarizes the input to the Cross-SBA 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 "Analysts" and an "Advisory Group" working together to identify documents, analyze them, and prioritize the Earth observations. The Analysts served as the main coordinators, and they managed the activities of the Task. The Analysts were supported by an Analyst Team.

2.2.1 Analyst Team

The Analysts for the Disasters SBA were Amy K. Huff and Stephanie Weber, who are both research scientists at Battelle. Dr. Huff has a Ph.D. in Chemistry and a M.S. in Meteorology. She has 17 years of experience in scientific research, project management, and technical writing. Ms. Weber has a Master's degree in Atmospheric Science and over 5 years of experience in data analysis of atmospheric and land processes, including literature reviews and large-scale data gathering efforts. Amy Leibrand assisted the Analysts. Ms. Leibrand is an environmental researcher at Battelle with a Bachelor's degree (magna cum laude) in environmental science.

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 prioritization methods, and review the preliminary and final reports. For the Disasters SBA Part 2 report, the Analysts identified Advisory Group members through various sources. The Analysts began with a core set of 5 members who continued from the Advisory Group that served as part of the analysis of earthquakes, landslides, and floods. The Analysts also solicited the GEO UIC and the GEO Secretariat for participation and suggestions of potential Advisory Group members. Dr. Huff recruited potential Advisory Group members from among her professional contacts, members of disasters organizations, participants in major technical conferences, and authors of relevant publications.

Overall, between November 2009 and January 2010, the Analysts invited 37 experts to serve on the Advisory Group. Nine experts were unable to participate, but they provided the names of alternate Advisory Group members; 16 experts did not respond. Of the 25 experts who agreed to serve on the Advisory Group, 2 did not participate in any of the Group activities, and as a result, the Analysts removed them from the Group. For this task, it was important to have representation from both developed and developing nations, to ensure that a global view of disasters observation priorities could be captured. The 23 members of the Advisory Group represent 14 countries across 6 continents, including the geographic regions of North America, Central/South America, Europe, Africa, East Asia, and Oceana/Australia. Table 1 provides a list of the Advisory Group members and their affiliations.

Table 1. Advisory Group for Disasters SBA – Part 2

Name	GEO Country or Organization	Affiliation	Geographic Region	Area of Expertise
Mr. Jérôme BÉQUIGNON	France	European Space Agency (ESA)	Europe	Broad Disasters Experience
Dr. CHENG Cho-ming	China	Hong Kong Observatory	East Asia	Tropical Cyclones
Mr. Emil CHERRINGTON	Belize	Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC)	Central/South America	Broad Disasters Experience
Dr. George CHOY	USA	United States Geological Survey (USGS)	North America	Seismic Hazards
Mr. Francisco DELGADO	Panama	Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC)	Central/South America	Broad Disasters Experience
Mr. Farai DONDOFEMA	South Africa	Environmental Consultant	Africa	Wildfires
Ms. Andrea FERRAZ YOUNG	Brazil	National Institute for Space Research (INPE)	Central/South America	Landslides, Floods, Sea Level Rise
Dr. Diana GREENSLADE	Australia	Centre for Australian Weather and Climate Research (CAWCR)	Oceana/Australia	Tropical Cyclones
Dr. Bruce HARPER	Australia	Systems Engineering Australia Pty Ltd	Oceana/Australia	Tropical Cyclones
Mr. Jamie KIBLER	USA	NOAA SSD, Satellite Analysis Branch	North America	Wildfires and Volcanic Eruptions
Mr. Gonéri LE COZANNET	France	French Geological Survey	Europe	Broad Disasters Experience
Dr. Warner MARZOCCHI	Italy	World Organization of Volcanic Observatories (WOVO)	Europe	Volcanic Eruptions
Dr. Enrico (Eric) PARINGIT	Philippines	University of the Philippines	East Asia	Tropical Cyclones
Dr. Matthew PATRICK	USA - Hawaii	Hawaiian Volcano Observatory	Oceana/Australia	Volcanic Eruptions
Dr. Andrés PÁVEZ	Chile	University of Chile	Central/South America	Volcanic Eruptions
Dr. Hans-Peter PLAG	USA	Nevada Bureau of Mines and University of Nevada, Reno	North America	Seismic Hazards
Dr. Marino PROTTI	Costa Rica	National University	Central/South America	Volcanic Eruptions

Name	GEO Country or Organization	Affiliation	Geographic Region	Area of Expertise
Dr. Guy SÉGUIN	Canada	Committee on Earth Observing Satellites (CEOS)	North America	Broad Disasters Experience
Dr. Narisara THONGBOONCHOO	Thailand	King Mongkut's Institute of Technology	East Asia	Wildfires
Dr. Richard THORNTON	Australia	Bushfire Cooperative Research Centre	Oceana/Australia	Wildfires
Dr. Dewald VAN NIEKERK	South Africa	North West University	Africa	Broad Disasters Experience
Dr. Eutizio VITTORI	Italy	Geological Survey of Italy	Europe	Broad Disasters Experience
Dr. Tsehaie WOLDAI	Netherlands	International Institute for Geoinformation Sciences & Earth Observation (ITC)	Africa	Broad Disasters Experience

The Analysts sent all interested Advisory Group members a description of the task, including a summary of their role in the Task US-09-01a process. Also, the Analysts asked each expert to supply document references for the analysis of priority observations. The Analysts held two conference calls and sent periodic emails to the Advisory Group throughout the course of the project to keep them apprised of the Analyst Team's progress.

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 types of disasters 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 Committee on Earth Observation Satellites (CEOS), the World Meteorological Organization (WMO), and the World Organization of Volcano Observatories (WOVO).

- Performed web-based literature searches using standard search tools and databases. The Analyst used combinations of specific disasters and Earth observation keywords (e.g., wildfire, observation, priorities, spatial resolution) 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 wildfires, volcanic eruptions, and tropical cyclones. 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 characteristics of the observation. The 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. The analysis did not include information on the technical infrastructure required to collect and process critical Earth observations, even though information on the technical infrastructure is an important aspect of Earth observations for disasters applications.

The Analyst Team extracted detailed data from the documents that met the criteria for inclusion in the analysis. For each observation, the extracted information included the applicable disaster type(s) (wildfires, volcanic eruptions, and/or tropical cyclones), the region of interest of the observation (Global, Africa, Europe, Oceania/Australia, Asia/Middle East, East Asia, North America, or Central/South America), the type of document (e.g., international working group report, peer-reviewed journal article, conference proceeding), and the desired characteristics of the observation, when available.

The Analyst Team also grouped each specific observation parameter into a broader observation category. The aggregation of similar parameters in this manner provided a more robust analysis and avoided redundancy, since authors of the documents often used slightly different terms to describe the same parameter and frequently failed to identify detailed observations. For example, “fire dimensions,” “fire line resolution,” and “fire size” were combined into a single “Fire Extent” category. There were a total of 33 observation categories (listed in Table 3) for wildfires, volcanic eruptions, and tropical cyclones that the Analyst Team carried forward into the prioritization analysis. The entire list of 152 observation parameters and their corresponding 33 observation categories is given in Appendix B.

2.3.3 Prioritization Methods for Wildfires, Volcanic Eruptions, and Tropical Cyclones

In order to determine the highest priority observation categories, the Analyst Team analyzed the wildfire, volcanic eruption, and tropical cyclone observation categories using two different methods.

Prioritization Method #1. The first method is an objective indexing scheme that weighted observation categories based on three factors:

1. The number of times that the observation category is mentioned in a document as a priority
2. The cross-cutting applicability of the observation category
3. The type of document.

The number of times that the observation category is mentioned in a document as a priority is an integer value of at least 1; the maximum value was 40 for the "Atmospheric Emissions" category. 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 (wildfires, volcanic eruptions, and tropical cyclones) to which a single observation applies, as identified by the document. The weighting for the type of document is also an integer value from 1 to 3, based on the type of document, as outlined in Table 2. 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. National-level documents have a slightly lower weight due to their narrower geographic focus. 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.

To calculate the document-specific index value for each observation category, i_{d_o}, the Analyst Team took 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 shown in Equation 1.

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

The Analyst Team 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 Team calculated the aggregated index value, which takes into account how frequently the observation categories are identified as priorities. As a last step, the Analyst Team normalized the aggregated index values by the number of documents for each specific type of disaster (i.e., wildfires, volcanic eruptions, and tropical cyclones), in order to prevent bias based on an unequal distribution in the number of documents identified for each disaster type. The final aggregated index values are the basis for the objective ranking of the observation priorities across all three hazard types and all documents. Observation categories that occurred most frequently in the documents have the highest aggregated index values.

Table 2. Factors for Weighted 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.

Prioritization Method #2. The second method is a subjective indexing scheme based on rankings of the importance of each observation category by the members of the Advisory Group. The motivation for including this subjective analysis is based on feedback from the Advisory Group regarding results from the first Disasters SBA report for Task US-09-01a (Weber, 2010). The Analyst for the first Disasters SBA report used Prioritization Method #1 as the sole method to develop the list of critical observation categories for earthquakes, landslides, and floods. While the Advisory Group generally agreed with the final outcome, experts on earthquakes and seismic hazards raised concerns about specific priorities that were not accurately represented in the final list. In particular, Advisory Group members indicated that seismicity is the single most important observation for earthquakes, which was not reflected in the available documents used in the first Disasters SBA report. As a result, the Analyst Team decided to include a subjective ranking of the observation categories for wildfires, volcanic eruptions, and tropical cyclones in this report. The Advisory Group is composed of recognized experts in these disasters fields, so their input is considered reflective of user needs. The Advisory Group ranking is designed to augment the purely objective approach of Prioritization Method #1 and avoid possible misrepresentation of critical observation priorities due to lack of information in the literature.

The Analyst Team sent Advisory Group members a spreadsheet containing the 33 observation categories based on the parameters extracted from the available scientific documents, as shown in Table 3. The Analyst Team asked the Advisory Group members to rank each observation category on a scale of 0 to 3, based on their estimation of the relative importance of the observations. 0 indicates that the Advisory Group member has no opinion or knowledge of the

category, 1 indicates low priority, 2 indicates medium priority, and 3 indicates high priority. 21 of the 23 Advisory Group members responded with rankings. The Analyst Team averaged the rankings for each observation category to give an overall mean Advisory Group ranking for the observation categories.

Table 3. Wildfire, Volcanic Eruption, and Tropical Cyclone Observation Categories Distributed to Advisory Group Members for Subjective Rankings

Observation Category	
Ash Cloud Properties	Lava Properties
Atmospheric Emissions	Magma Properties
Atmospheric Gas Concentrations	Magnetic Field
Atmospheric Plumes	Ocean Properties
Atmospheric Properties	Precipitation Properties
Electric Field	Seismic Properties
Elevation/Topography Properties	Smoke Properties
Eruption Properties	Soil Properties
Fire Properties	Surface Deformation Properties
Fire Extent	Temperature Properties
Fire Intensity	Thermal Properties
Fire Location	Vegetation Properties
Fuel Properties	Volcano Location
Gravity Field	Water Properties
Tropical Cyclone Properties	Wave Properties
Ice/Snow Properties	Wind Properties
Lahar Properties	

2.3.4 Prioritization Methods for Disasters SBA

In addition to the individual prioritization analyses for wildfires, volcanic eruptions, and tropical cyclones, the Analyst Team conducted overall analyses of the critical observation priorities for all six types of disasters covered by the two Task US-09-01a Disasters SBA reports, including earthquakes, landslides, and floods. The Analyst Team used Prioritization Method #1 as the basis of the overall Disasters SBA analysis in order to be consistent across both Disasters SBA reports, since the Analyst for the first Disasters report used only Prioritization Method #1 to analyze the critical observation priorities for earthquakes, landslides, and floods (Weber, 2010). In order to reflect the risk of disasters to human life and property, the Analyst Team used data on observed impacts of worldwide disasters for the past 30 years to conduct additional weightings on the results derived from Prioritization Method #1. The Analyst Team obtained data on the impacts of disasters on human life and property from the International Disaster Emergency Events Database (EM-DAT) (http://www.emdat.be/); global averages of the disasters impacts data are summarized in Table 4. The information is organized by type of disaster and includes the number of disaster events worldwide, the number of people killed, the number of people

affected, and the estimated damage in US$ during the period 1981-2010. The Analysts calculated a weighting factor for each type of disaster (earthquakes, landslides, etc.) and category of impact (number of people killed, number of people affected, and estimated damage in US$) as the percentage of the total impact for the six disasters. For example, the weighting factor for the number of people killed by tropical cyclones was calculated as the number of people killed by tropical cyclones (404,994) divided by the sum of the total number of people killed from earthquakes, landslides, floods, wildfires, volcanic eruptions, and tropical cyclones (1,022,017). The Analyst Team used these weighting factors to calculate overall aggregated index values for the six types of disasters weighted by worldwide estimated damage in US$, the number of people affected, and the number of people killed by each disaster during the past 30 years.

Table 4. Impacts of Six Types of Disasters on Human Life and Property Worldwide during the Period 1981-2010

Type of Disaster	Number of Events	People Killed	People Affected	Estimated Damage in US$
Earthquakes	705	379,801	134,229,352	395,103,945
Landslides	389	19,900	7,069,525	6,075,838
Floods	3,078	190,318	2,807,396,391	416,293,288
Wildfires	301	1,888	5,827,681	46,625,730
Volcanic Eruptions	142	25,116	4,186,593	2,010,769
Tropical Cyclones	1,199	404,994	517,973,614	540,645,421

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

As stated in the GEOSS 10-Year Implementation Plan, the Disasters SBA uses Earth observations for the following applications:

- Monitoring
- Predicting
- Risk assessment
- Early warning
- Mitigating
- Responding to disasters at the local, national, and global levels.

Table 5. Disaster Types

Disaster Type	Brief Description
Wildland fires (Wildfires)	Uncontrolled natural or human-caused burning of forests or other large areas of land
Volcanic eruptions	Gases, 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 Team, in collaboration with the 5 core members of the Advisory Group, narrowed the focus of the effort to wildfires, volcanic eruptions, and tropical cyclones. The core Advisory Group members noted that it is important to consider the availability of observations for each disaster type and the opportunities for mitigation using the data. Another important aspect considered by the Analyst Team and the Advisory Group was severity of the disaster types. Table 4 lists the worldwide impacts during the past 30 years on human life and property from the six disasters analyzed in the Disasters SBA US-09-01a reports. These data indicate that all of the selected disaster types represent a significant threat to life and property, although there is a range in the degree of impact due to variations in the frequency and amount of destruction of individual events.

Tropical cyclones have a particularly high impact, due to their frequent occurrence and high degree of devastation per event.

The three disaster hazards chosen for analysis in this report have been the subject of much previous study, and the Advisory Group indicated that the observation priorities sought for these hazards could contribute to real needs for societal benefit. Wildfires and tropical cyclones had been considered for analysis by the Analyst and Advisory Group for the first Disasters SBA report, so it was logical to include them in the Part 2 analysis. After selecting wildfires, volcanic eruptions, and tropical cyclones for analysis, the Analyst Team recruited experts in these disasters to serve on the Advisory Group and supplement the general expertise of the 5 core members.

3.3 Documents

The document search effort, including website, database, and online literature searches and recommendations from Advisory Group members, yielded 185 documents that potentially contained Earth observation priorities for one or more of the disaster types. The Analyst Team 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 Team thoroughly reviewed the document and extracted the appropriate data.

Of the 185 documents initially identified by the Analyst Team and Advisory Group, 63 (34%) of them contained Earth observation parameters for further analysis. References for all of the documents are listed in Appendix C as “Documents Cited” and “Documents Consulted.” The Analyst Team identified the primary geographic focus of the 63 relevant documents based upon the region in which the author(s) and/or sponsoring institution were located. The Analyst Team 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. As illustrated by Figure 1, 48 (76%) of the relevant documents were global in nature, while 8 (12%) of the relevant documents were from North America and 4 (6%) were from Europe. There were 2 useful documents (3%) from Oceana/Australia, and 2 from East Asia. No relevant documents focused on the observation priorities for Africa, Asia/Middle East, or Central/South America. This omission highlights a gap in identifying the priorities for the developing nations on those continents.

The 63 documents that contained Earth observation parameters for further analysis were not distributed equally among the three types of disasters that were the focus of the analysis. As shown in Figure 2, the majority of the relevant documents (50%) described observation priorities for wildfires. 31% of the documents focused on volcanic eruptions, and 19% dealt with tropical cyclones. It is important to note that there was overlap between documents, as some documents dealt with more than one disaster. Due to the unequal distribution of documents for the three disasters, the Analyst Team normalized the aggregated index values developed using Prioritization Method #1, as described in Section 2.3.3.

Figure 1. Geographic Distribution of Relevant Documents for Wildfires, Volcanic Eruptions, and Tropical Cyclones

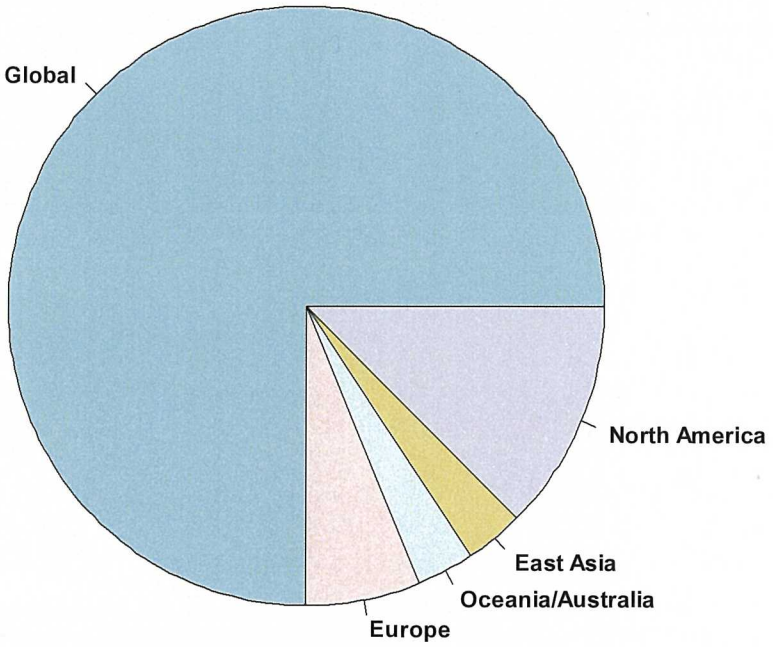
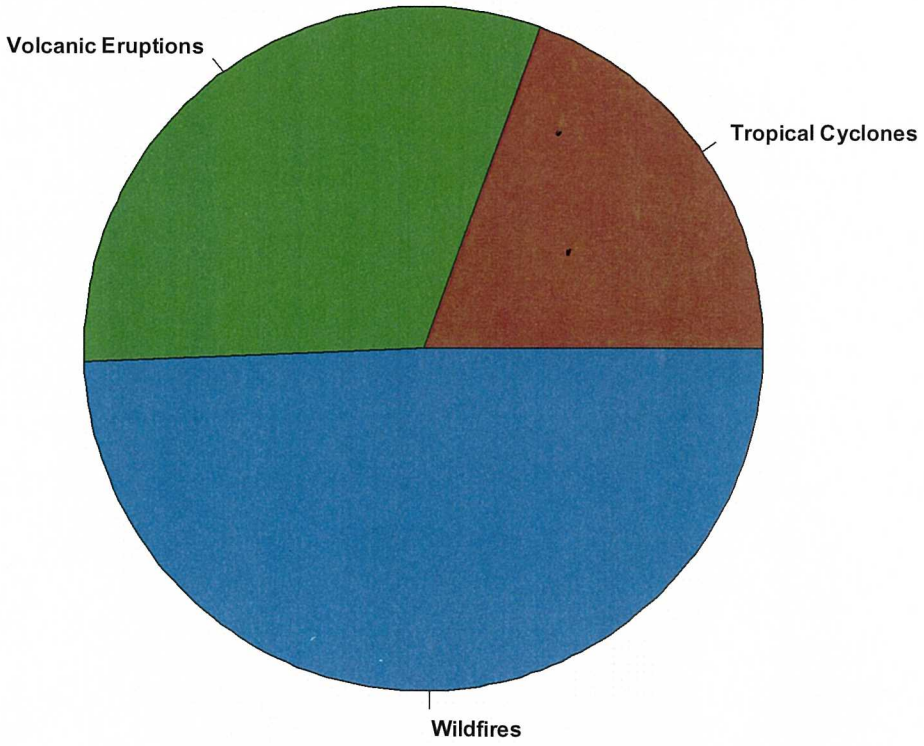


Figure 2. Distribution of Relevant Documents for Wildfires, Volcanic Eruptions, and Tropical Cyclones by Type of Disaster



3.4 User Types

There are a wide variety of users of Earth observations of wildfires, volcanic eruptions, and tropical cyclones, and an equally large number of applications of these datasets. First responders and relief organizations use Earth observations in their emergency response and disaster management efforts, especially in situations where environmental conditions are changing rapidly. Research scientists, including volcanologists, meteorologists, climate change scientists, geologists, and hydrologists, depend on Earth observations to improve prediction capabilities for risk management and mitigation. Many of these same researchers, along with staff at civil and governmental agencies, use Earth observations to forecast and monitor the development and evolution of wildfires, volcanic eruptions, and tropical cyclones

The Analyst Team identified 32 general types of users of wildfire, volcanic eruption, and tropical cyclone observations. The user types are listed in Table 6. The Analyst Team grouped individual user types into 5 application areas, also shown in Table 6: "Research," "Forecasting and Monitoring," "Emergency Management," "Public Outreach," and "Infrastructure and Risk Assessment." The Analyst Team utilized these user types during the document search to ensure that all types of users were represented by the documents, and that no gaps or biases existed.

Table 6. Users of Wildfire, Volcanic Eruption, and Tropical Cyclone Observations

Application Area	User Type
Research	University Professors and Staff
	Graduate Students
	Research Center Scientists
	Environmental Consultants
Forecasting and Monitoring	Weather Forecasters and Modelers
	Wildfire Forecasters and Modelers
	Volcanic Eruption Forecasters and Modelers
	Hurricane/Typhoon Forecasters and Modelers
	Satellite Analysts
	Volcanologists
	Geologists
	Hydrologists
	Meteorologists
	Climate Change Scientists
	Forest/Land Management Personnel
Emergency Management	Risk Mitigation Managers
	Emergency Managers
	Hospitals and Disaster Response Organizations
	Non-Governmental Organizations (NGOs)
	Military Personnel
	Aviation Agencies and Airlines

Application Area	User Type
Public Outreach	Weather Service Providers
	Print, Broadcast, and Online Media
	Local Law Enforcement/Fire Department Officers
	Public Health Officials
Infrastructure and Risk Assessment	Civil and Environmental Engineers
	Water Resource Managers
	Transportation Managers
	Energy/Utility Planners
	Regional/Municipal Planners and Zoners
	Insurance Assessors
	Risk Assessors

4 Earth Observations for Individual Disasters

To determine the observation priorities for each of the individual disasters analyzed in this report, the Analyst Team considered only the results from Prioritization Method #1, the objective indexing scheme, described in Section 2.3.3. The Analyst Team did not apply Prioritization Method #2 to individual disasters, but rather to the three disasters as a whole, as shown in Section 5.1.

4.1 Earth Observations for Wildfires

Table 7 lists the Earth observation priorities for wildfires in descending order of importance. The "Parameters" column indicates the specific observation parameter, 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 used in the analysis explicitly identify as observation priorities for wildfire hazards. Figure 3 shows the top 5 observation categories for wildfires as a function of their aggregated index values. "Fire Location" is the dominant observation category, followed by "Vegetation Properties." "Fuel Properties," "Precipitation Properties," and "Smoke Properties" are roughly comparable and next in importance.

Table 7. Observation Categories for Wildfires (in descending order of priority) and Associated Parameters

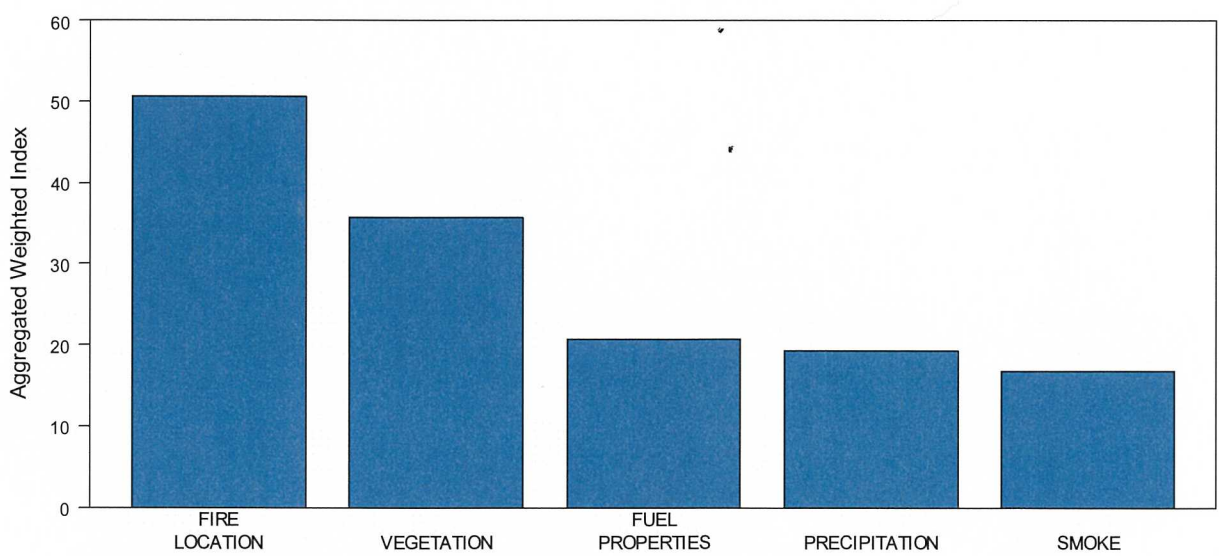
Observation Category	Parameters
Fire Location	fire location
	location of fire injection height profile
Vegetation Properties	amount of area burned

Observation Category	Parameters
	fire scars
	GEMI
	NDVI
	normalized burn ratio
	stressed vegetation
	type of vegetation
	type of vegetation burnt
Fuel Properties	fuel amount
	fuel load
	fuel moisture content
	fuel structure
Precipitation Properties	precipitation amount
	precipitation duration
	precipitation intensity
	precipitation rate
	precipitation type
Smoke Properties	smoke amount
	smoke location
	smoke transport
Fire Intensity	fire intensity/temperature
	fire radiated power
Wind Properties	10-m wind
	20-ft wind peak
	20-ft wind speed
	land surface winds
	mountain winds
	ocean surface wind
	ocean surface wind direction
	ocean surface wind velocity
	ocean vector wind
	outer wind radii
	peakedness of wind profile
	radius of gales
	tropospheric winds
	wind direction
	wind field
	wind speed
	wind velocity
Atmospheric Emissions	acid emissions
	aerosols emitted

Observation Category	Parameters
	carbon dioxide emissions
	fire emissions
	gas emissions flux
	gas emissions species
	hydrogen fluoride emissions
	hydrogen sulfide emissions
	sulfur dioxide emissions
	trace gas emissions
	vertical distribution of fire emissions
Soil Properties	soil moisture
Atmospheric Properties	air mass boundaries
	air mass differences
	atmospheric moisture
	atmospheric profile
	atmospheric temperature
	atmospheric water vapor
	cloud structure
	cloudiness
	dew point/humidity
	relative humidity
Thermal Properties	hotspot detection
	thermal emissions/flux characterization
	thermal feature characterization
Elevation/Topography Properties	bathymetry
	seafloor topography
	topography (DEM)
	topography characterization
	topography monitoring
Fire Properties	burn severity
	fire behavior
	fire characterization
Temperature Properties	land surface temperature
Fire Extent	fire dimensions
	fire line resolution
	fire size
Ice/Snow Properties	ice volume
	snow cover depth
	snow cover duration
	snow cover extent

Observation Category	Parameters
Atmospheric Gas Concentrations	carbon dioxide amount
	carbon monoxide amount
	fumarole chemistry
	gas concentration
	methane amount
	nitrogen dioxide amount
	ozone amount
	sulfur dioxide amount
Ash Cloud Properties	ash characterization
	ash cloud direction
	ash cloud location
	ash cloud particulate density
	ash cloud SO_2 concentration
	ash cloud temperature
	ash cloud velocity
	ash cloud vertical mass distribution
	ash cloud visibility
	high altitude ash clouds
	volcanic clouds

Figure 3. Top 5 Observation Categories for Wildfires



4.2 Earth Observations for Volcanic Eruptions

Table 8 lists the Earth observation priorities for volcanic eruptions in descending order of importance. 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 volcanic eruptions hazards. Figure 4 shows the top 5 observation categories for volcanic eruptions as a function of their aggregated index values. "Atmospheric Emissions," "Ash Cloud Properties," "Surface Deformation Properties," and "Thermal Properties" are all approximately equal in importance, followed closely by "Elevation/Topography Properties."

Table 8. Observation Categories for Volcanic Eruptions (in descending order of priority) and Associated Parameters

Observation Category	Parameters
Atmospheric Emissions	acid emissions
	aerosols emitted
	carbon dioxide emissions
	fire emissions
	gas emissions flux
	gas emissions species
	hydrogen fluoride emissions
	hydrogen sulfide emissions
	sulfur dioxide emissions
	trace gas emissions
	vertical distribution of fire emissions
Ash Cloud Properties	ash characterization
	ash cloud direction
	ash cloud location
	ash cloud particulate density
	ash cloud SO_2 concentration
	ash cloud temperature
	ash cloud velocity
	ash cloud vertical mass distribution
	ash cloud visibility
	high altitude ash clouds
	volcanic clouds
Surface Deformation Properties	3-D displacements
	creep
	deformation
	geodetic data

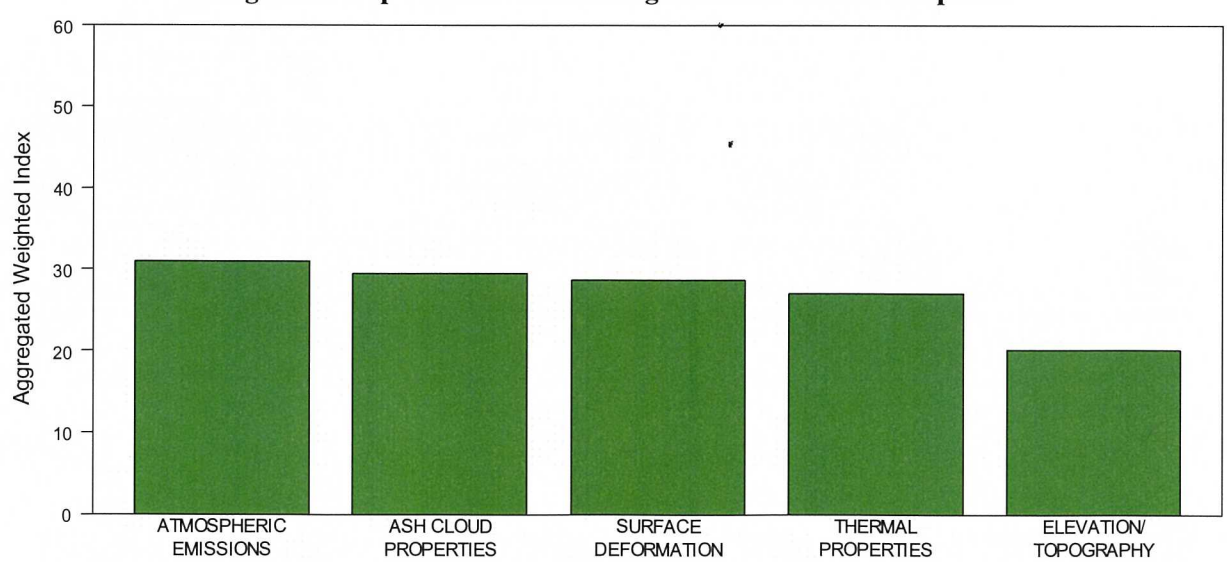
Observation Category	Parameters
	ground tilt
	strain
	stress
Thermal Properties	hotspot detection
	thermal emissions/flux characterization
	thermal feature characterization
Elevation/Topography Properties	bathymetry
	seafloor topography
	topography (DEM)
	topography characterization
	topography monitoring
Seismic Properties	magnitude
	seismicity
	type of earthquake
Eruption Properties	eruption columns
	eruption location
Gravity Field	changes in gravity
	gravity field
Water Properties	coastal water levels
	pH
	stream flow
	water chemistry
	water level
	water temperature
	water volume
Precipitation Properties	precipitation amount
	precipitation duration
	precipitation intensity
	precipitation rate
	precipitation type
Atmospheric Plumes	aerosol plumes
	sulfur dioxide cloud
Atmospheric Properties	air mass boundaries
	air mass differences
	atmospheric moisture
	atmospheric profile
	atmospheric temperature
	atmospheric water vapor
	cloud structure
	cloudiness

Observation Category	Parameters
	dew point/humidity
	relative humidity
Wind Properties	10-m wind
	20-ft wind peak
	20-ft wind speed
	land surface winds
	mountain winds
	ocean surface wind
	ocean surface wind direction
	ocean surface wind velocity
	ocean vector wind
	outer wind radii
	peakedness of wind profile
	radius of gales
	tropospheric winds
	wind direction
	wind field
	wind speed
	wind velocity
Lahar Properties	lahar location
	lahar flow velocity
	lahar direction
Smoke Properties*	smoke amount
	smoke location
	smoke transport
Atmospheric Gas Concentrations	carbon dioxide amount
	carbon monoxide amount
	fumarole chemistry
	gas concentration
	methane amount
	nitrogen dioxide amount
	ozone amount
	sulfur dioxide amount
Lava Properties	lava dome height
	lava dome temperature
	lava dome location
	lava dome volume
	distinct lava units
Magma Properties	magma flow
Magnetic Field	magnetic field

Observation Category	Parameters
Electric Field	electric field
Volcano Location	volcano location
Vegetation Properties	amount of area burned
	fire scars
	GEMI
	NDVI
	normalized burn ratio
	stressed vegetation
	type of vegetation
	type of vegetation burnt
Ice/Snow Properties	ice volume
	snow cover depth
	snow cover duration
	snow cover extent

* While "smoke" is not technically a volcanic eruption parameter, it is included in the results of this Task US-09-01a volcanic eruptions analysis because it was used in the 2008 CEOS Disaster SBA Team – GEO DI-06-09 Report ("Detect and monitor smoke and ash clouds, acids & aerosols," p. 22). Prioritization Method #1 counts the use of parameters without any modification. Since "smoke" was applied to volcanic eruption monitoring in the 2008 CEOS report, the use of the term transferred to this report.

Figure 4. Top 5 Observation Categories for Volcanic Eruptions



4.3 Earth Observations for Tropical Cyclones

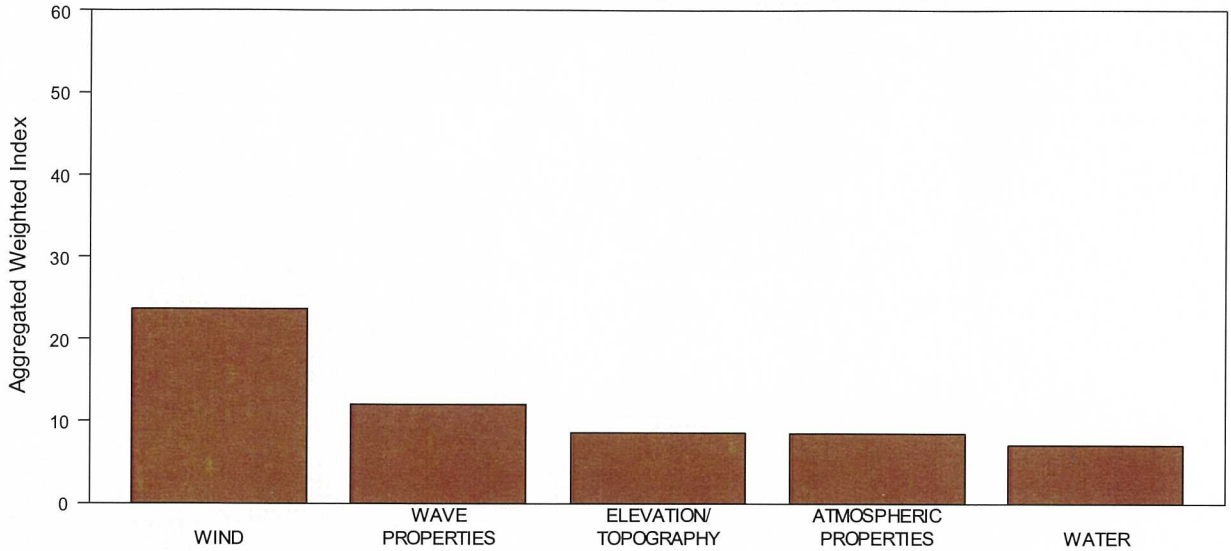
Table 9 lists the Earth observation priorities for tropical cyclones in descending order of importance. The "Parameters" column indicates the specific observation, while the "Observation Category" column indicates the broader description of the observations used for aggregation. The observations and specific parameters in the table are those that the documents explicitly identify as observation priorities for tropical cyclone hazards. Figure 5 shows the top 5 observation categories for tropical cyclones as a function of their aggregated index values. "Wind Properties" is by far the most important observation category, followed by "Wave Properties." "Elevation/Topography Properties," "Atmospheric Properties," and "Water Properties" are roughly comparable and next in importance.

Table 9. Observation Categories for Tropical Cyclones (in descending order of priority) and Associated Parameters

Observation Category	Parameters
Wind Properties	10-m wind
	20-ft wind peak
	20-ft wind speed
	land surface winds
	mountain winds
	ocean surface wind
	ocean surface wind direction
	ocean surface wind velocity
	ocean vector wind
	outer wind radii
	peakedness of wind profile
	radius of gales
	tropospheric winds
	wind direction
	wind field
	wind speed
	wind velocity
Wave Properties	sea state
	storm surge
	surface wave direction
	surface wave height
	wave currents
	wave heights
	wave patterns
Elevation/Topography Properties	bathymetry
	seafloor topography
	topography (DEM)

Observation Category	Parameters
	topography characterization
	topography monitoring
Atmospheric Properties	air mass boundaries
	air mass differences
	atmospheric moisture
	atmospheric profile
	atmospheric temperature
	atmospheric water vapor
	cloud structure
	cloudiness
	dew point/humidity
	relative humidity
Water Properties	coastal water levels
	pH
	stream flow
	water chemistry
	water level
	water temperature
	water volume
Precipitation Properties	precipitation amount
	precipitation duration
	precipitation intensity
	precipitation rate
	precipitation type
Tropical Cyclone Properties	extent of damage
	tropical cyclone intensity
	tropical cyclone location
	moisture fields
	moisture in core
Ocean Properties	ocean salinity
	sea surface height
	sea surface temperature
	upper ocean temperature
Soil Properties	soil moisture

Figure 5. Top 5 Observation Categories for Tropical Cyclones



5 Priority Earth Observations for Disasters SBA

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

5.1 Summary of Results for Wildfires, Volcanic Eruptions, and Tropical Cyclones

The previous sections presented the observation priorities individually for wildfires, volcanic eruptions, and tropical cyclones, based on the results of Prioritization Method #1. After calculating the weighted aggregated index individually for each of the disaster types, the Analyst Team combined and ranked the 33 total observation priorities (listed in Table 3) for all three types of disasters. Figure 6 shows the 33 observation categories as a function of their normalized aggregated index values for the combined objective analysis. "Wind Properties" is the highest priority observation category, and it is important for each of the three types of disasters. There is a relatively steady decrease in importance for the rest of the observation categories, with "Volcano Location" ranked as the lowest priority observation category.

The Analyst Team also used the results of Prioritization Method #2, the subjective rankings of the 33 observation categories by the Advisory Group members, to prioritize the observation categories for all three types of disasters. Figure 7 shows the 33 observation categories as a function of their average ranking by Advisory Group members. There is no clear high priority observation category, and in fact most of the categories have a mean ranking between approximately 2.0-2.8. Only the lowest ranked 3-4 observation categories show a clear decrease in relative importance. These results indicate that the Advisory Group members, who are recognized experts in the fields of wildfires, volcanic eruptions, and tropical cyclones, consider

the majority of the observation categories to be medium-to-high priority, with no consensus on which observations categories are the highest priority.

It is interesting to note that there are several observation categories that were ranked as high priority by Prioritization Method #1 but as low priority by Prioritization Method #2, and vice versa, including "Elevation/Topography" (ranked 3rd by Prioritization Method #1 and 25th by Prioritization Method #2), "Thermal Properties" (ranked 4th by Prioritization Method #1 and 19th by Prioritization Method #2), "Fire Extent" (ranked 29th by Prioritization Method #1 and 2nd by Prioritization Method #2), and "Fire Characteristics" (ranked 25th by Prioritization Method #1 and 5th by Prioritization Method #2). This result suggests that available documents used for Prioritization Method #1 may not have accurately reflected all of the most critical observation priorities for wildfires, volcanic eruptions, and tropical cyclones, perhaps due to an overrepresentation of documents related to remote sensing techniques. Alternatively, this result may indicate a bias in the composition of the Advisory Group toward wildfire expertise, which indicates that for future analyses, Analysts should normalize Advisory Group rankings by the area of expertise of the members. The Analyst Team did not normalize the results of Prioritization Method #2 in this report because several Advisory Group members have expertise in more than one area, and the Analysts wanted to maintain a high level of transparency. In general, the results of the analyses for wildfires, volcanic eruptions, and tropical cyclones underscore the importance of including a subjective ranking by Advisory Group member experts, in order to avoid possible misrepresentation of critical priorities due to gaps in the available literature, but highlight the need for normalization of Advisory Group input to avoid possible bias.

Figure 6. Normalized Aggregated Weighted Index Values for All 33 Observation Categories for Wildfires, Volcanic Eruptions, and Tropical Cyclones

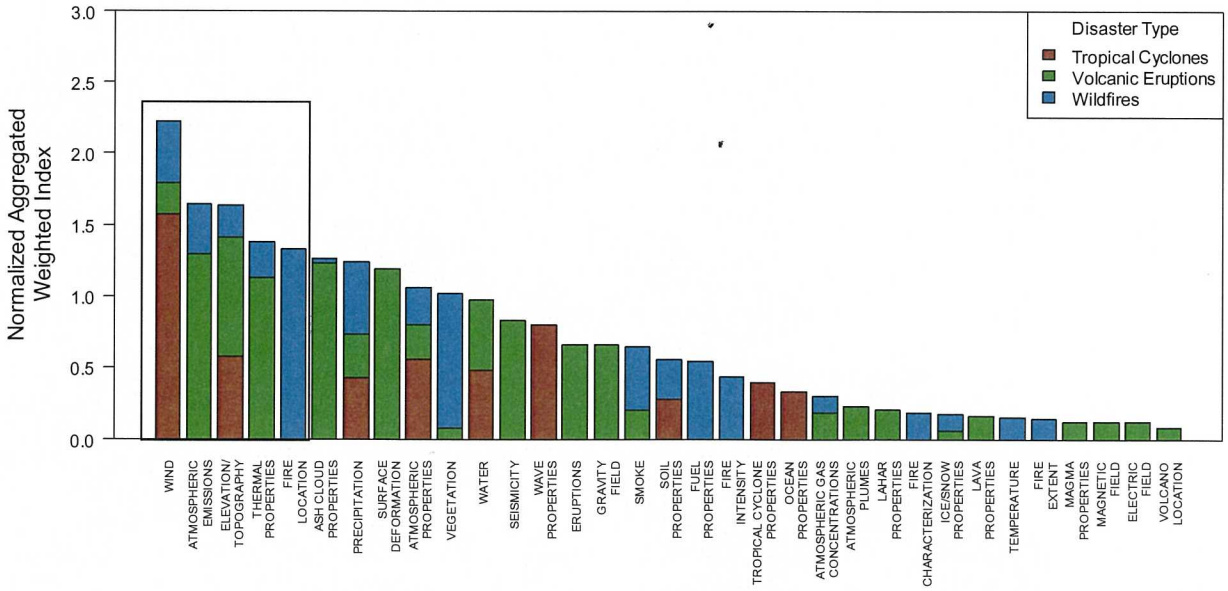
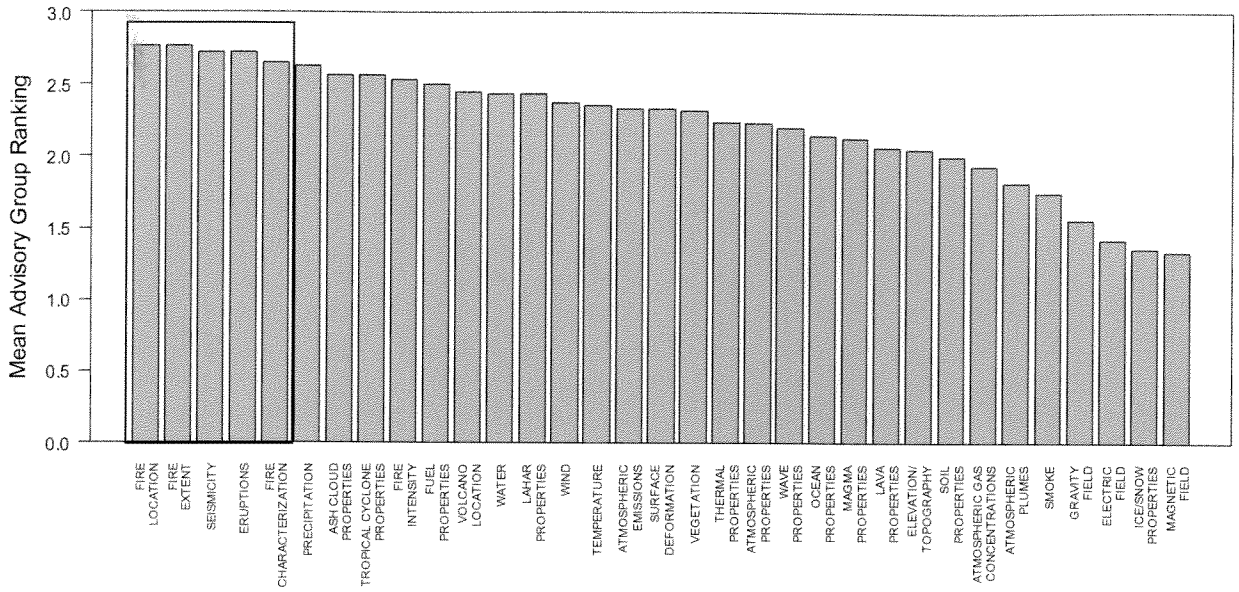


Figure 7. Mean Rankings by Advisory Group Members of All 33 Observation Categories for Wildfires, Volcanic Eruptions, and Tropical Cyclones



5.2 Priority Observations for Wildfires, Volcanic Eruptions, and Tropical Cyclones

The Analyst Team has defined the top 5 observation categories derived from Prioritization Methods #1 and #2 as those that have the highest priority for wildfires, volcanic eruptions, and tropical cyclones. The Analyst Team selected this cut-off point because it includes a manageable number of high-priority observations; other breakpoints may be equally valid. The top 5 observation categories for Prioritization Methods #1 and #2 are highlighted by the boxes in Figures 6 and 7, respectively.

As shown in Figure 6, the top 5 observation categories derived using Prioritization Method #1, the objective aggregated weighting scheme, are (in descending order of importance):

- Wind Properties
- Atmospheric Emissions
- Elevation/Topography Properties
- Thermal Properties
- Fire Location

As shown in Figure 7, the top 5 observation categories derived using Prioritization Method #2, the subjective Advisory Group ranking scheme, are (in descending order of importance):

- Fire Location
- Fire Extent
- Seismic Properties
- Eruption Properties
- Fire Properties

"Fire Location" is the only observation category that is common to both analysis methods, which suggests that it is definitively a priority observation for wildfires.

During the course of executing Prioritization Method #1, the Analyst Team compiled the desired characteristics of the individual observation parameters indicated in the relevant documents. The types of desired characteristics include:

- **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.

The following are brief summaries of the desired characteristics and user type information for the top 5 observation categories derived from Prioritization Methods #1 and #2. These characteristics are based on information in the 63 source documents identified by the Analyst Team and Advisory Group. Not all of the relevant documents indicate observation characteristics for each parameter, and in some cases, observation characteristics were not indicated in the source documents and therefore could not be captured by the Analyst Team.

Wind Properties

The "Wind Properties" observation category is critical for all three types of disasters analyzed in this report. The primary user groups for "Wind Properties" are forecasters and modelers. The most common applications of this observation category are monitoring of wildfires, volcanic eruptions, and tropical cyclones; prediction of tropical cyclones; early warning of wildfires and tropical cyclones; and inputs to models of wildfire prediction. "Wind Properties" encompasses 17 individual parameters, including various types of winds (e.g., land surface, mountain, ocean surface, tropospheric), wind speeds/velocities, and wind directions. Spatial resolution specifications range from 100 m to 10 km, depending on the parameter, with several documents indicating only a generic "higher" resolution. Temporal resolution requirements vary depending on the specific parameter, from 1 minute – 1 hour to 6 hours. Documents specify accuracy characteristics for both wind speed in m/s and wind direction in degrees.

Atmospheric Emissions

"Atmospheric Emissions" observations are most important for volcanic eruption hazards, due to their use in monitoring and early warning of volcanic eruptions. "Atmospheric Emissions" are also important for wildfires. Major user groups of this observation category include forecasters and modelers, volcanologists, risk mitigation managers, emergency managers, disaster response organizations, and the media. The most common applications of "Atmospheric Emissions" are monitoring of volcanic eruptions and wildfires; detection and early warning of volcanic eruptions and wildfires; mitigation of wildfires; and responding to

volcanic eruptions and wildfires. "Atmospheric Emissions" includes 11 individual parameters, including emissions of various gases (e.g., carbon dioxide, hydrogen fluoride, hydrogen sulfide, sulfur dioxide, trace gases) and general species (e.g., acids, aerosols, fire emissions). Preferred spatial and temporal resolutions for this observation category vary depending on the specific parameter. Spatial resolution requirements range from 90 m to 10-25 km, while requested temporal resolutions include hourly, daily, continuous, and near real-time.

Elevation/Topography Properties

"Elevation/Topography Properties" are a priority for all three types of disasters, with the main use split between volcanic eruptions and tropical cyclones. Forecasters and modelers, volcanologists, hydrologists, emergency managers, insurance and risk assessors, and planners and managers are the primary user groups for this observation category. Common applications of "Elevation/Topography Properties" include monitoring and detecting volcanic eruptions, tropical cyclones, and wildfires; mitigating the impacts of volcanic eruptions and tropical cyclones; and assessing the risk of volcanic eruptions and tropical cyclones. "Elevation/Topography Properties" encompasses 5 individual parameters: bathymetry, seafloor topography, topography (DEM), topography characterization, and topography monitoring. Documents provided the most detailed observation characterization information for bathymetry and topography (DEM). Requested spatial resolution is 100 m in the horizontal and 1 m in the vertical for bathymetry, while for topography (DEM) it is 5 m in the horizontal and 0.5-1 m in the vertical. Temporal resolution ranges from 5 years for bathymetry to 1-3 years with a decadal update for topography (DEM). The preferred coverage of the observations is global, with a focus on continental shelf areas for bathymetry and coastal areas for topography (DEM).

Thermal Properties

"Thermal Properties" are critical mainly for volcanic eruption hazards, and also for wildfires, to a lesser degree. The main user groups are forecasters and modelers, emergency managers, and disaster response organizations. The most common applications of this observation category are monitoring and detecting volcanic eruptions and wildfires and early warning of volcanic eruptions and wildfires. The "Thermal Properties" category encompasses 3 individual parameters: hotspot detection, thermal emissions/flux characterization, and thermal feature characterization. Observation characteristics vary depending on the individual parameter. Preferred temporal resolution for hotspot detection is 30 minutes – 1 hour, while it ranges from 15-30 minutes to 30 days for thermal feature characterization. Data accuracy requirements included several formats, such as 0.5 K, at 3.96-4 μm, and 5% for thermal emissions/flux characterization, reflecting the fact that remote sensing techniques are used to make many of the parameter measurements in this category.

Fire Location

The "Fire Location" category is a priority exclusively for wildfire hazards. It is utilized primarily by wildfire forecasters and modelers, emergency managers, disaster response organizations, and planners and managers. Common applications include monitoring and predicting wildfires, early warning of wildfires, and mitigation of wildfires. In addition to

the specific parameter for fire location, this category also includes the location of fire injection height profile. The characteristics for the fire location parameter are unique to the size of the fire and specific application (e.g., fire management, warning and response, mitigation). For example, documents indicate a temporal resolution of 6 hours for warning and response applications. In addition, many of the requested fire location parameter characteristics for spatial resolution, temporal resolution, and accuracy are specific to satellite measurements, since satellites provide many fire location observations on a global scale.

Fire Extent
The "Fire Extent" category is also a priority exclusively for wildfires. Wildfire forecasters and modelers, emergency managers, disaster response organizations, the media, and planners and managers are the primary users of this category of observations. The most common applications of "Fire Extent" are similar to those for "Fire Location" and include monitoring and predicting wildfires, early warning of wildfires, and mitigation of wildfires. This category encompasses the individual observation parameters of fire size, dimensions, and line resolution. Desired characteristics are more comprehensive coverage over boreal and tropical forests, spatial resolution ranging from 1 m to 50 km, near real-time latency, and accuracy in fire size detection of 0.25 acres (0.1 ha).

Seismic Properties
"Seismic Properties" are critical for volcanic eruptions. The main user groups are volcanic eruption forecasters and modelers, volcanologists, engineers, and planners. The most common applications of this observation category are monitoring, detecting, and early warning of volcanic eruptions. The "Seismic Properties" category encompasses the individual parameters of magnitude, seismicity, and type of earthquake. Preferred coverage for seismicity measurements includes 12-20 stations within 20 km of a volcano, 2-3 stations within 5 km, and 1 strong motion station within 5 km. Documents indicate that desired temporal resolution for seismicity measurements ranges from daily to continuous, and desired latency is near real-time to hours.

Eruption Properties
"Eruption Properties" observations are a priority for volcanic eruption hazards. Major user groups of this observation category include forecasters and modelers, volcanologists, emergency managers, disaster response organizations, and the media. The most common applications of "Eruption Properties" are monitoring, detection, characterization, and early warning of volcanic eruptions and responding to volcanic eruptions. "Eruption Properties" includes two individual parameters: eruption columns and location. Preferred coverage for eruption location observations includes global, in Japan, and at specific eruption sites. Desired spatial resolution for eruption location is 100 m to 1 km, and specified temporal resolution ranges from 1-6 hours to several times per day.

Fire Properties
The "Fire Properties" observation category is critical exclusively for wildfires. The primary user groups for "Fire Properties" are wildfire forecasters, modelers, and researchers, emergency managers, and disaster response organizations. The most common applications

of this observation category are detection, monitoring, and early warning of wildfires. "Fire Properties" encompasses 3 individual parameters: burn severity, fire behavior, and fire characteristics. Available documents specify only spatial resolution characteristics of 15-30 m, 0.1-1 km, and < 30 m for burn severity, fire behavior, and fire characterization, respectively.

Table 10 lists the detailed desired characteristics of the top 5 observation categories derived from Prioritization Method #1 for wildfires, volcanic eruptions, and tropical cyclones. In many cases, documents did not state the specific characteristics that are required for a particular observation parameter, or only indicated that resolution should be "higher" or "better" without providing quantification. Thus, the list in Table 10 should not be taken as definitive. Missing characteristics are indicated as blank cells in Table 10. The Analysts consider the priority observation categories derived using Prioritization Method #1 to be the primary focus for analysis of desired characteristics since they originated from the objective analytic method. The Analyst Team did not compile a detailed summary of the desired characteristics for the remaining top 4 observation categories derived using Prioritization Method #2 due to the subjective nature of the analysis, which makes it difficult to definitively discern the relative importance of the observation categories.

Table 10. Characteristics of the Parameters for the Top 5 Observation Categories for Wildfires, Volcanic Eruptions, and Tropical Cyclones using Prioritization Method #1[a]

Observation Category	Parameter	Coverage/Extent	Spatial Resolution	Temporal Resolution	Accuracy	Latency
Wind Properties	**10-m wind**		• 100 m - 10 km	• 1 min - 1 hr	• 1 - 2 m/s • 5 - 10°	
	20-ft wind peak			• hourly		
	20-ft wind speed		• higher	• higher		
	land surface winds			• 6 hours		• hours
	mountain winds		• higher			
	ocean surface wind	• global	• higher			
	ocean surface wind direction	• all oceans - within 2.5 km of coast	• 1-2.5 km	• 1-6 hours	• 5 m/s • 10 - 20° • measurement range: 0 - 360°	• 15-60 min
	ocean surface wind velocity	• all oceans - within 2.5 km of coast	• 1-2.5 km	• 1-6 hours	• +/- 1 m/s • measurement range: 0 - 82.5 m/s	• 15-60 min
	ocean vector wind		• 2 km	• < 9 hours		
	outer wind radii					• real time
	peakedness of wind profile					• real time
	radius of gales					• real time
	tropospheric winds	• global	• higher			
	wind direction		• 300 m	• hourly	• 10°	• 1 hour
	wind field		• 100 m - 10 km • 100 m vertical	• 15 min- 1 hr	• 1 - 2 m/s • 5 - 10°	
	wind speed		• 300 m	• hourly	• 1 m/s	• 1 hour
	wind velocity	• global	• higher	• higher	• better	• real time
Atmospheric	**acid emissions**	• in situ		• near real time • daily or better		• hours

Observation Category	Parameter	Coverage/Extent	Spatial Resolution	Temporal Resolution	Accuracy	Latency
Emissions	**aerosols emitted**	• global • more comprehensive coverage over boreal and tropical forests • Northern Europe and Africa	• 10- 25 km	• 1-6 hours • hourly	• < 2.5 µm diameter	• near-real time to real time
	carbon dioxide emissions	• in situ	• higher	• near real time	• tons per day	• weekly, monthly or annually
	fire emissions	• global	• moderate	• 15 min for geostationary satellites • daily for global satellites		
	gas emissions flux	• global	• higher	• daily	• better	• near-real time to real time • hours
	gas emissions species			• daily or better		hours
	hydrogen fluoride emissions	• in situ		• near real time		
	hydrogen sulfide emissions			• continuous		
	sulfur dioxide emissions	• in situ	• 90 m	• 16 days • near real-time • continuous/daily	• tons per day	• real time • weekly, monthly, or annually
	trace gas emissions			• daily to weekly		• days
	vertical distribution of fire emissions	• global	• 25 km	• 1-6 hours		• near-real time
Elevation/ Topography	**bathymetry**	• global • continental shelf areas	• 100 m horizontal • 1 m vertical	• 5 years	• better	

Observation Category	Parameter	Coverage/Extent	Spatial Resolution	Temporal Resolution	Accuracy	Latency
Properties	**seafloor topography**	• global			• 50 m vertical • 5 km horizontal	
	topography (DEM)	• global • coastal areas	• 0.5-1 m hyperspectral • 5 m horizontal • 0.5-1 m vertical	• 1-3 years • decadal update	• 1 m vertical • 5 m horizontal	• weeks
	topography characterization		• higher			• as needed
	topography monitoring					• weekly
Thermal Properties	**hotspot detection**			• 30 min - 1 hour		
	thermal emissions/flux characterization	• global • regional • local	• 30 m-1 km (anomaly) • 250 m	• daily – monthly • 5-120 min (persistent) • 10-30 sec (transient) • 6-12 hr in crisis (anomaly)	• split window data • 3.96 µm channel • 5% • at 4µm • 0.5 K	• near real time to real time
	thermal feature characterization	• local	• 10-30 m • pixel size of < 90 m for satellites	• 15-30 min • daily or better • 30 days	• 0.1-50 K	• hours

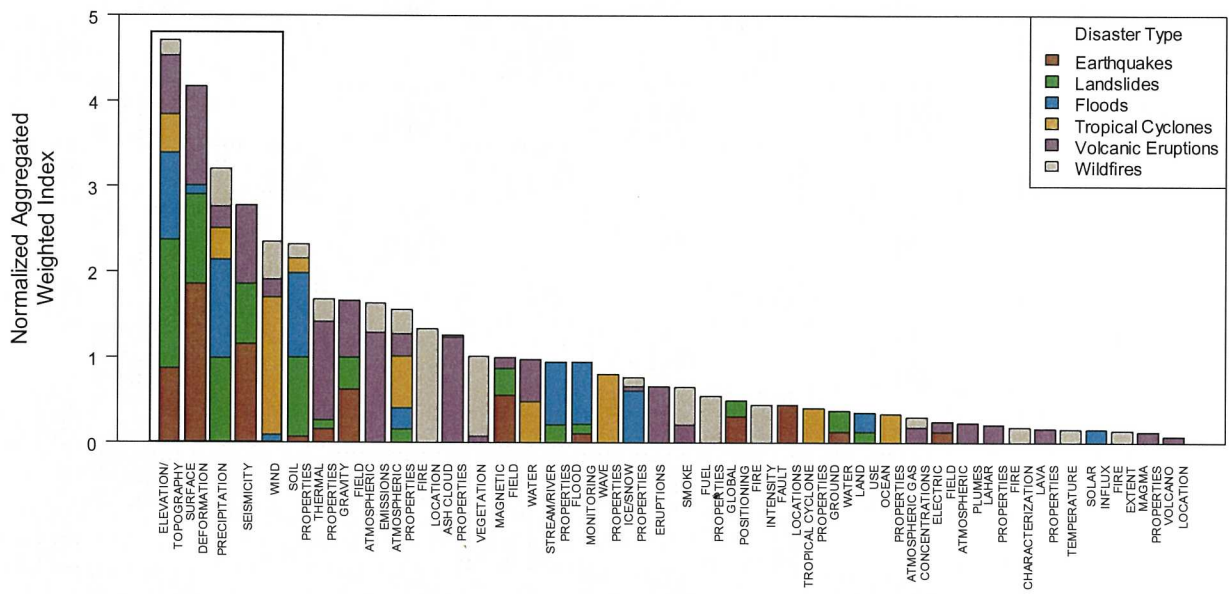
Observation Category	Parameter	Coverage/Extent	Spatial Resolution	Temporal Resolution	Accuracy	Latency
Fire Location	**fire location**	• global • regional • local • more comprehensive coverage over boreal and tropical forests • geographic areas requiring rapid response • Japan	• < 20 m - 1 km • 2 km for small fires • 500 m - 1 km for polar-orbiting satellites • < 30 m for targeted satellites	• 2-3 hours for small fires • continuous • near real time or every 15-30 minutes • 12 hr – 1 day • 6 hr for warning and response • daily to weekly for mitigation • 5 min for minimum size of 0.25 acres • 15 min for minimum size of 300-500 m • 15 min for regional and global geostationary satellites • daily for polar-orbiting satellites • 24 hr for targeted satellites	• <1 pixel • 5% max error • < 5% false alarm rate • 750 K • >355 K in 3.9µm band (elevated saturated temperature) • 700 K in 3-4 µm bands • 400 K • no saturation at 325 K • detection of fires < 1 ha • minimum detection size of 0.1 ha • location accuracy within 500 m	• 5-30 minutes • 12-48 hours • real time • 15 minutes for active fire management • within 48 hours for large fire events • 2-4 hr for warning and response • days for mitigation • 15-30 minutes from start of fire
	location of fire injection height profile	• global	• 25 km	• 1-6 hours		• near-real time

[a]Blank fields indicate that no specific characteristic is reported in the documents.

5.3 Summary of Overall Results for Disasters SBA

The Analyst Team combined the results of Prioritization Method #1 from this report with the results from the first Disasters SBA Task US-09-01a report (Weber, 2010), which were derived using Prioritization Method #1, to obtain an overall ranking of observation priorities for the Disasters SBA. There are 40 total observation categories for earthquakes, landslides, floods, wildfires, volcanic eruptions, and tropical cyclones. The Analyst Team determined the aggregated index value for each of these observation priorities; Figure 8 shows the 40 observation categories as a function of their normalized aggregated index values for the overall combined objective analysis. "Elevation/Topography Properties" is the most important overall observation category, and it is critical for all six types of disasters.

Figure 8. Normalized Aggregated Weighted Index Values for All 40 Observation Categories for Earthquakes, Landslides, Floods, Wildfires, Volcanic Eruptions, and Tropical Cyclones



In order to account for the risk of disasters to human life and property, the Analyst Team used globally-averaged information on observed disasters from the past 30 years to conduct additional weightings on the overall aggregated index values derived using Prioritization Method #1, as described in Section 2.3.4. Figures 9, 10, and 11 show the 40 common observation categories weighted by worldwide estimated damage in US$, the number of people affected, and the number of people killed, respectively, for each of the six types of disasters during the period 1981-2010. Figures 9 and 11 are dominated by observation priorities for earthquakes, tropical cyclones, and floods, since these disasters cause the most damage and kill the most people, on average, as shown by the data in Table 4. Figure 10 is dominated by observation priorities for floods, because they are the most common type of disaster worldwide, and thus they affect the most people, as illustrated by the data in Table 4.

Figure 9. Normalized Aggregated Weighted Index Values for All 40 Observation Categories Weighted by Estimated Damage in US$ Worldwide during the Period 1981-2010

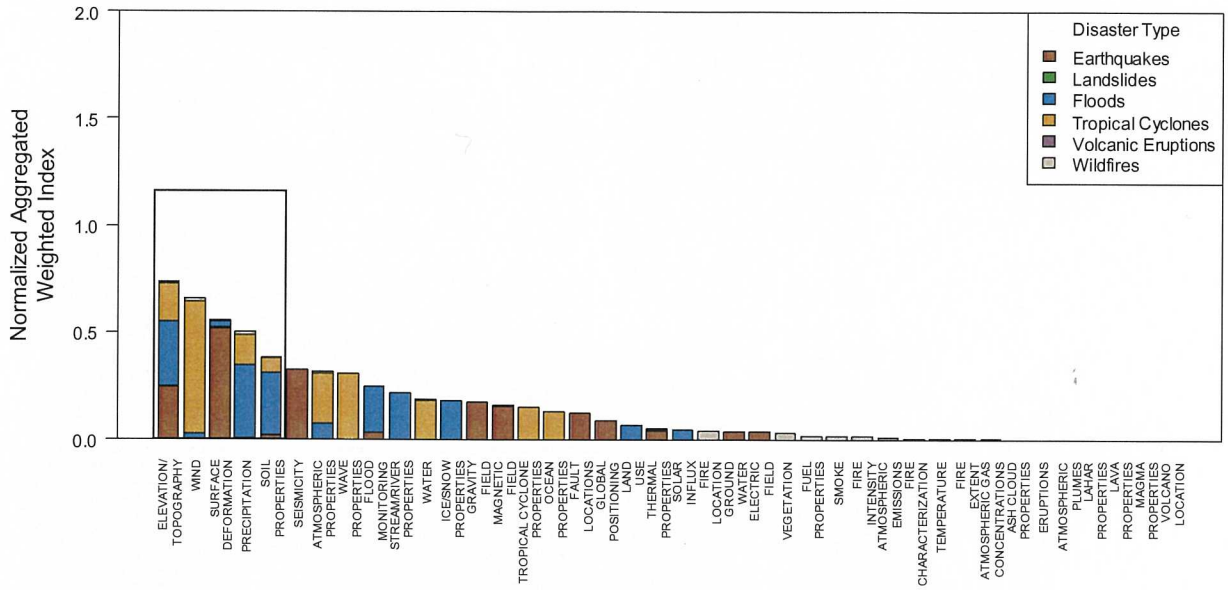


Figure 10. Normalized Aggregated Weighted Index Values for All 40 Observation Categories Weighted by Number of People Affected Worldwide during the Period 1981-2010

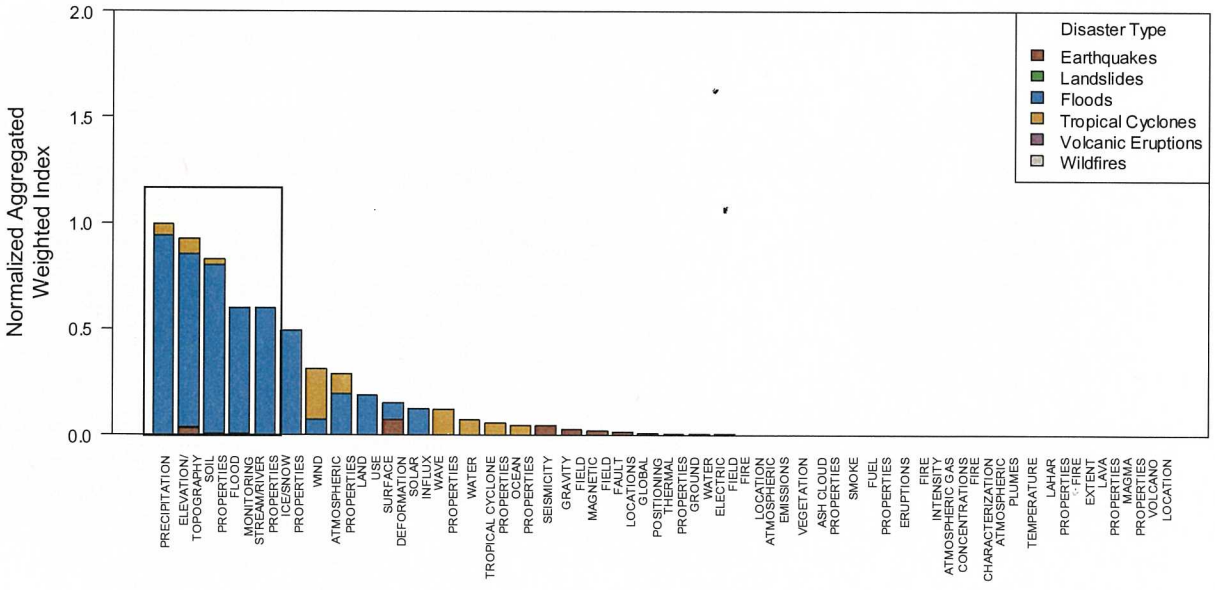
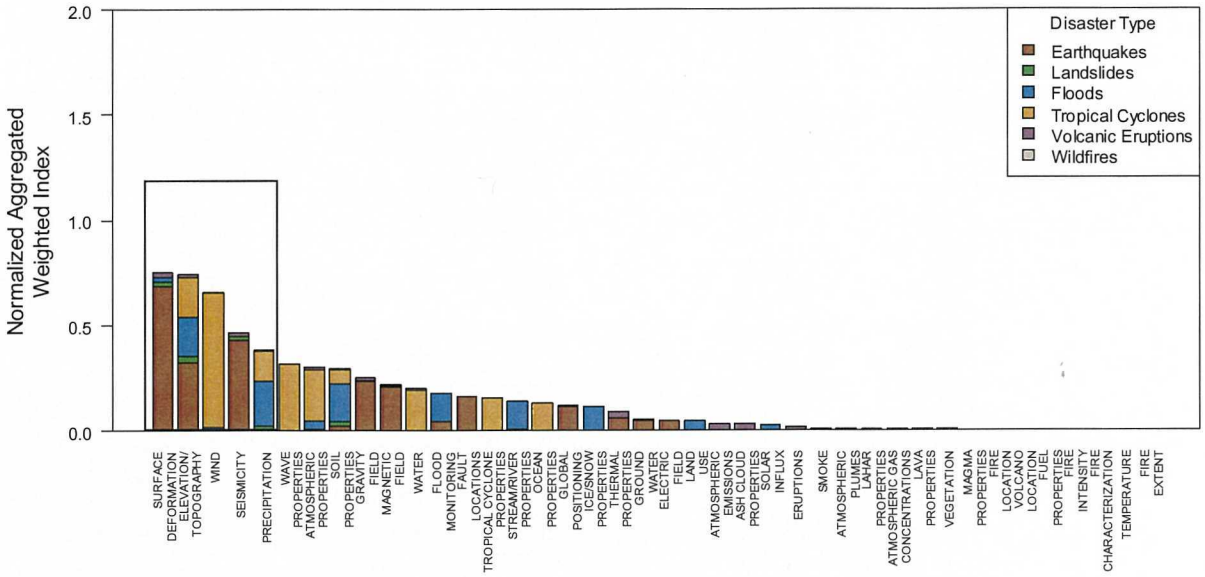


Figure 11. Normalized Aggregated Weighted Index Values for All 40 Observation Categories Weighted by Number of People Killed Worldwide during the Period 1981-2010



5.4 Overall Priority Observations for Disasters SBA

The Analyst Team has defined the top 5 observation categories derived using Prioritization Method #1 and the additional human life and property weighting analyses as those that have the overall highest priority for the Disasters SBA. The Analyst Team selected the top 5 cut-off point because it includes a manageable number of high-priority observations; other breakpoints may be equally valid. The top 5 observation categories derived using Prioritization Method #1 and the additional human life and property weighting analyses are highlighted by the boxes in Figures 8-11.

As shown in Figure 8, the top 5 observation categories derived using Prioritization Method #1, the overall objective aggregated weighting scheme, are (in descending order of importance):

- Elevation/Topography Properties
- Surface Deformation
- Precipitation Properties
- Seismic Properties
- Wind Properties

As shown in Figure 9, the top 5 observation categories for Prioritization Method #1, the overall objective aggregated weighting scheme, weighted by worldwide estimated damage from the six disasters in US$ during the past 30 years are (in descending order of importance):

- Elevation/Topography Properties

- Wind Properties
- Surface Deformation
- Precipitation Properties
- Soil Properties

As shown in Figure 10, the top 5 observation categories for Prioritization Method #1, the overall objective aggregated weighting scheme, weighted by the number of people affected worldwide by the six disasters during the past 30 years are (in descending order of importance):

- Precipitation Properties
- Elevation/Topography Properties
- Soil Properties
- Flood Monitoring Properties
- Steam/River Properties

As shown in Figure 11, the top 5 observation categories for Prioritization Method #1, the overall objective aggregated weighting scheme, weighted by the number of people killed worldwide by the six disasters during the past 30 years are (in descending order of importance):

- Surface Deformation
- Elevation/Topography Properties
- Wind Properties
- Seismic Properties
- Precipitation Properties

These results demonstrate that there is a great deal of overlap in the priority observation categories derived from the four analyses. "Elevation/Topography Properties" and "Precipitation Properties" are likely major priorities for the Disasters SBA, as they appear in the lists of overall top 5 rankings for all four of the approaches. "Surface Deformation" and "Wind Properties" are also likely important, as these categories appear in three of the four lists of overall top 5 rankings. "Seismic Properties" and "Soil Properties" are next in importance, as these categories appear in two of the four lists of overall top 5 rankings. Based on these areas of overlap, the Analyst Team concludes that the overall priority observations for the Disasters SBA are as follows; the Analyst Team considers all six of these observation categories to be of equal importance for the Disasters SBA:

- Elevation/Topography Properties
- Precipitation Properties
- Surface Deformation
- Wind Properties
- Seismic Properties
- Soil Properties.

5.5 Advisory Group Feedback and Recommendations

The Analyst Team gathered feedback from the Advisory Group throughout the process on the analytic methods used to determine the priority observations for wildfires, volcanic eruptions, tropical cyclones, earthquakes, landslides, and floods hazards, as well as on the final list of priority observations. Overall, the Advisory Group was supportive of the methods used by the Analyst Team, but provided feedback on some perceived shortcomings after they saw the results of the analyses.

Several Advisory Group members indicated that individual observation parameters were redundant, inaccurate, or were unknown to them. For example, a tropical cyclone expert informed the Analysts that "ocean surface wind," "ocean surface wind direction," "ocean surface wind velocity," and "ocean vector wind" were redundant and could be combined into a single "ocean vector wind" parameter. In another instance, a volcano expert questioned the parameter "distinct lava units," a term with which he was not familiar. These discrepancies are due to the fact that the Analyst Team lifted individual parameters directly from the 63 documents used for Prioritization Method #1 without any modification. As a result, redundancy of individual parameters was unavoidable, because the authors of different documents often used slightly different terms to describe the same observation parameter. It was for this reason that the Analyst Team grouped observation parameters into broader observation categories, as described in Section 2.3.2. In some cases, the observation terms used by the authors of these documents varied from those familiar to the Advisory Group members. For example, after the Analyst Team provided the volcano expert with the source document, he determined that "distinct lava units" referred to the mapping of individual lava flows. To minimize any redundancies or inaccuracies in terminology in future analyses, the Analyst Team should provide the list of observation parameters and categories to the Advisory Group for their feedback before conducting the prioritization analysis.

One volcano expert state that it is reasonable to weigh each disaster hazard by its potential impact on human life and property, but asked how the amount of damage and number of people affected by volcanic eruptions might be changed by the recent eruption of the Eyjafjallöjokull volcano in Iceland. According to the New York Times, the Eyjafjallöjokull eruption caused a nearly weeklong delay in air flights in Europe in mid-April that cost airlines hundreds of millions of dollars and disrupted the travel of millions of passengers. The volcano expert pointed out that considering data on observed impacts of worldwide disasters for the past 30 years may be reasonable for frequently occurring disasters, such as floods and tropical cyclones, but it would be advisable to consider a significantly longer time period for volcanic eruptions, since they are relatively rare events. Another Advisory Group member noted that the degree of damage from disasters depends on the region and countries involved; developed countries have better infrastructure and more resources to deal with the impacts of disasters, while developing countries do not. A recent example is the magnitude 7.0 earthquake that devastated Haiti on January 12, 2010, and the associated devastation of the capital, Port-au-Prince. The Advisory Group member recommended that the UIC take the difference in disaster preparedness and response into consideration when assessing the results of Task US-09-01a.

Some Advisory Group members expressed concern over how the results can be biased by the selection of documents as part of Prioritization Method #1, but they appreciate the Analyst

Team's efforts to clarify all the steps in the analysis methods and identify the possible sources of bias. Several Advisory Group members expressed reservations about Prioritization Method #2, the subjective ranking system, which the Analyst Team used for the analysis of wildfires, volcanic eruptions, and tropical cyclones. One member was concerned that the Advisory Group may not constitute a sufficiently large or diverse group of experts on these disasters to provide accurate rankings. Another Advisory Group member commented that it was difficult to complete the subjective ranking of Prioritization Method #2, because he found that all of the observation categories are highly important. He supported the idea of Prioritization Method #2, and suggested that an alternative approach would be to ask each expert to select the top 5 or 10 observation parameters, and then the Analyst Team could select the 5-10 priority observations from among the most popular choices. Yet another member felt that the ranking may not be meaningful since it depends on the areas of expertise of each Advisory Group member. For example, if there are more experts on wildfires in the Group, then the results will be skewed toward priority observations for wildfires. This outcome can be avoided by normalizing the results of a subjective analysis by the expertise of the individual Advisory Group members. The Analyst Team did not normalize the results of Prioritization Method #2 in this report because several Advisory Group members have expertise in more than one area, and the Analysts wanted to maintain a high level of transparency. If the UIC decides to include subjective analytic methods in future US-09-01a, the Analysts recommend incorporation of a normalization technique in order to ensure that the composition of the Advisory Group does not skew the prioritization results.

Three Advisory Group members stated emphatically that the results of the Disasters SBA priority observation analysis must be tied to risk management policy and decision-making in order to contribute to reducing human and property losses from disasters. One expert expressed hope that the effort by the UIC to catalog disasters observation priorities will promote a shift in emphasis from emergency management to risk management and increase incentives for acting on the root causes of disasters rather than responding to the consequences. Similarly, another Advisory Group member pointed out that there is a need to distinguish the purpose of the observation parameters as part of the prioritization process. For example, one observation may be useful for monitoring, another for forecasting, and yet another for emergency management. This Advisory Group member recommends that future analyses separate the rankings of observations by their purpose, for maximum usefulness by the disasters community. The third Advisory Group member questioned the overall results of the analyses because they are not related to the risk management cycle or the results of disaster reduction research. For example, hazard and risk assessment require different parameters than early warning, disaster damage assessment, response, and recovery, and this difference is not reflected in the analyses conducted by the Analyst Team, since it was outside the scope of Task US-09-01a. This Advisory Group member also questioned the objectivity of Prioritization Method #1. The Analyst Team received approval from the Advisory Group on the analytic methodology and Prioritization Methods #1 and #2 before conducting the analysis, so the Analysts were limited in their options after receiving this feedback from Advisory Group members after the analysis had been completed. The Analysts suggest, as outlined in Section 7, that the UIC adopt a standard analytic method across all SBAs for any future analyses as part of Task US-09-01a, in order to minimize issues associated with the prioritization analysis.

6 Analysts' Comments and Recommendations

Overall, the Analysts 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. Based on the experience of preparing the first Disasters SBA report, however, the Analysts made a minor modification to Steps 1 and 2 for the Part 2 report that proved to be very successful. The Analyst for the first Disasters SBA report assembled the Advisory Group and then they narrowed the scope of topics, per the order of the Task US-09-01a steps listed in Section 2.1. Subsequently, several Advisory Group members lost interest in the task because their expertise was outside of the three disaster types that had been chosen for analysis (earthquakes, landslides, and floods). To circumvent this problem and help ensure maximum Advisory Group participation in the Part 2 report, the Analysts worked with the 5 core members of the Advisory Group who had participated in the first Disasters SBA report to narrow the focus of the Part 2 analyses *before* the Analysts recruited the majority of the Advisory Group members, as described in Section 3.2. Consequently, the Analysts were able to recruit additional Advisory Group members who were experts in the three types of disasters selected for the Part 2 analysis (wildfires, volcanic eruptions, and tropical cyclones). This approach resulted in much greater participation in the Task US-09-01a process by the Part 2 Advisory Group members compared to those for the first Disasters report. For future reports, the Analysts recommend that the scope of topics within each SBA be identified first, either by the UIC or by a core group of SBA experts who will comprise part of the Advisory Group. In this way, the Analyst(s) for each SBA can assemble an Advisory Group comprised of experts in the selected topics, which will help guarantee Advisory Group engagement throughout the course of the task. In addition, the Analysts found that sending regular email updates, approximately 1-2 per month, to Advisory Group members kept them up-to-date on the progress of the Analyst Team and promoted their involvement in the Task US-09-01a process.

As was the case for the first Disasters report, the Analysts found that the greatest challenge in the Task US-09-01a process was developing an analytic method that integrated disparate sources of information on Earth observations into a single priority-setting analysis that yielded accurate results. The method developed by the Analyst Team for the first Disasters report (Prioritization Method #1, described in Section 2.3.3) was well-received by the first Advisory Group and the UIC, so the Analysts used it as the basis of the analysis for the Part 2 report. This method is 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. Despite the careful development and execution of Prioritization Method #1 in the first Disasters report, Advisory Group members informed the Analyst Team that some specific observation priorities were not accurately represented in the final rankings for earthquakes, landslides, and floods, due to the absence of these observations from available documents used in the analysis. To address this apparent shortcoming of Prioritization Method #1, the Analyst Team included Prioritization Method #2 in the Part 2 report, which is a subjective ranking of the observation categories for wildfires, volcanic eruptions, and tropical cyclones by Advisory Group members. The goal of including Prioritization Method #2 in the Part 2 analysis was to avoid possible misrepresentation of critical observation priorities due to lack of information in

the literature. The Analysts consider the input of the Advisory Group to be highly pertinent and reflective of user needs, since the Group is composed of recognized experts in the disasters fields of wildfires, volcanic eruptions, and tropical cyclones.

Despite the best efforts of the Analysts and the Advisory Group, there is disagreement between the final results of the Prioritization Methods #1 and #2. In particular, one volcano expert member of the Advisory Group is concerned that the priority observations for volcanic eruptions (Section 4.2), as determined by Prioritization Method #1, do not contain seismic properties. According to this Advisory Group member, seismicity is the most important parameter for volcano monitoring, and the absence of seismicity from the list of priority observations makes the Advisory Member concerned that Prioritization Method #1 did not accurately represent the highest priorities for volcanic hazards. It is possible that there is a disproportionate influence from documents on remote sensing techniques for volcano monitoring that skewed the results of Prioritization Method #1 away from some of the standard ground-based measurements, such as seismicity.

Prioritization Methods #1 and #2 generated dissimilar rankings of priority observations for wildfires, volcanic eruptions, and tropical cyclones, as described in Sections 5.1 and 5.2. This result suggests that the objective approach of Prioritization Method #1 is limited by the assumption that the highest priority observations are reflected in the available literature. A related shortcoming of Prioritization Method #1 is that it is impossible to identify every available document that describes priority requirements for Earth observations of disasters hazards. In fact, the Advisory Group identified 8 documents that contain potentially relevant information *after* completion of the priority setting analysis (Korontzi et al., 2003; Wadge, 2003; Smith et al., 2005; Lentile et al., 2006; Lay et al., 2009; Prata, 2009; Russell-Smith et al., 2009; Fournier, 2010). A quick scan of these documents indicates that they contain information similar to documents used in the analysis, so the Analyst Team does not expect that their absence compromised the results of the analysis. In this regard, however, Prioritization Method #1 is not comprehensive, particularly for documents that are not written in English and therefore are not readily accessible to the Analyst Team.

As the Disasters SBA reports demonstrate, there is no perfect analytic method for Task US-09-01a, and the choice of method can lead to very different results. This concern was also shared by several Advisory Group members. The Analysts suggest that the UIC review a summary of the analytic methods developed by each SBA and determine which method best suits the UIC's needs. To the extent possible, this method should be standardized across all future SBA analyses to ensure consistency among all Task US-09-01a analyses and subsequent analyses.

The Analysts found that a secondary challenge was developing an overall list of priority observations for the Disasters SBA based on two sets of analyses, each focused on three types of disasters. The overall results are a function of the types of disasters that were analyzed, and therefore likely would have been different had a different set of disasters been chosen, such as tsunamis, avalanches, and ice, for example. These concerns were echoed by several members of the Advisory Group. There is no obvious alternative approach for the Disasters SBA, which encompasses a variety of disasters, as outlined in Table 5. One possibility recommended by an Advisory Group member is to consider each type of disaster separately, and not generate an

overall list of priority observations that are meant to be valid for the entire Disasters SBA. Thus Analysts would submit individual lists of observation priorities for earthquakes, landslides, floods, etc., without making generalizations across the Disasters SBA. Although this approach might produce more representative results for each individual type of disaster, it would not satisfy the purpose of Task US-09-01a, which is to compile a single list of Earth observation priorities for each SBA.

Appendix A: Abbreviations

CEOS	Committee on Earth Observation Satellites
DEM	Digital Elevation Model
GEMI	Global Environmental Monitoring Index
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
IGOS	Integrated Global Observing Strategy
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
SBA	Societal Benefit Area
UIC	User Interface Committee
WMO	World Meteorological Organization
WOVO	World Organization of Volcano Observatories

Appendix B: Observation Parameters and Categories

Observation Category	Parameters
Ash Cloud Properties	ash characterization
	ash cloud direction
	ash cloud location
	ash cloud particulate density
	ash cloud SO_2 concentration
	ash cloud temperature
	ash cloud velocity
	ash cloud vertical mass distribution
	ash cloud visibility
	high altitude ash clouds
	volcanic clouds
Atmospheric Emissions	acid emissions
	aerosols emitted
	carbon dioxide emissions
	fire emissions
	gas emissions flux
	gas emissions species
	hydrogen fluoride emissions
	hydrogen sulfide emissions
	sulfur dioxide emissions
	trace gas emissions
	vertical distribution of fire emissions
Atmospheric Gas Concentrations	carbon dioxide amount
	carbon monoxide amount
	fumarole chemistry
	gas concentration
	methane amount
	nitrogen dioxide amount
	ozone amount
	sulfur dioxide amount
Atmospheric Plumes	aerosol plumes
	sulfur dioxide cloud
Atmospheric Properties	air mass boundaries
	air mass differences
	atmospheric moisture
	atmospheric profile
	atmospheric temperature

Observation Category	Parameters
	atmospheric water vapor
	cloud structure
	cloudiness
	dew point/humidity
	relative humidity
Electric Field	electric field
Elevation/Topography Properties	bathymetry
	seafloor topography
	topography (DEM)
	topography characterization
	topography monitoring
Eruption Properties	eruption columns
	eruption location
Fire Properties	burn severity
	fire behavior
	fire characterization
Fire Extent	fire dimensions
	fire line resolution
	fire size
Fire Intensity	fire intensity/temperature
	fire radiated power
Fire Location	fire location
	location of fire injection height profile
Fuel Properties	fuel amount
	fuel load
	fuel moisture content
	fuel structure
Gravity Field	changes in gravity
	gravity field
Tropical Cyclone Properties	extent of damage
	tropical cyclone intensity
	tropical cyclone location
	moisture fields
	moisture in core
Ice/Snow Properties	ice volume
	snow cover depth
	snow cover duration
	snow cover extent
Lahar Properties	lahar location
	lahar flow velocity

Observation Category	Parameters
	lahar direction
Lava Properties	lava dome height
	lava dome temperature
	lava dome location
	lava dome volume
	distinct lava units
Magma Properties	magma flow
Magnetic Field	magnetic field
Ocean Properties	ocean salinity
	sea surface height
	sea surface temperature
	upper ocean temperature
Precipitation Properties	precipitation amount
	precipitation duration
	precipitation intensity
	precipitation rate
	precipitation type
Seismic Properties	magnitude
	seismicity
	type of earthquake
Smoke Properties	smoke amount
	smoke location
	smoke transport
Soil Properties	soil moisture
Surface Deformation Properties	3-D displacements
	creep
	deformation
	geodetic data
	ground tilt
	strain
	stress
Temperature Properties	land surface temperature
Thermal Properties	hotspot detection
	thermal emissions/flux characterization
	thermal feature characterization
Vegetation Properties	amount of area burned
	fire scars
	GEMI
	NDVI
	normalized burn ratio

Observation Category	Parameters
	stressed vegetation
	type of vegetation
	type of vegetation burnt
Volcano Location	volcano location
Water Properties	coastal water levels
	pH
	stream flow
	water chemistry
	water level
	water temperature
	water volume
Wave Properties	sea state
	storm surge
	surface wave direction
	surface wave height
	wave currents
	wave heights
	wave patterns
Wind Properties	10-m wind
	20-ft wind peak
	20-ft wind speed
	land surface winds
	mountain winds
	ocean surface wind
	ocean surface wind direction
	ocean surface wind velocity
	ocean vector wind
	outer wind radii
	peakedness of wind profile
	radius of gales
	tropospheric winds
	wind direction
	wind field
	wind speed
	wind velocity

Appendix C: Bibliography and References

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Appendix D: Input to Cross-SBA Analysis

At the conclusion of the individual SBA priority-setting analysis, the Disasters Analysts provided input on the overall critical Earth observation parameters for the Disasters SBA for inclusion in the Cross-SBA meta-analysis.[3] Upon receiving input from the SBA Analysts, the Cross-SBA Analyst reviewed the priorities and combined observation parameters that are the same or very similar but have different names (e.g., precipitation intensity and precipitation duration). In some cases, the Cross-SBA Analyst extracted observation parameters from aggregated observation categories that were identified as priorities by individual SBAs and included these observation parameters as input to the Cross-SBA analysis. As a result, the number of observation priorities identified by individual SBAs may vary from the number of observations that were included in the Cross-SBA analysis. To the extent possible, the Cross-SBA Analyst focused on retaining the observation parameter terminology employed by the majority of the SBAs, in order to minimize regrouping and splitting of observations.

The Disasters Analysts determined the overall critical Earth observation priorities for the Disasters SBA by using an aggregated weighting index to rank the observation categories identified for the six disasters sub-areas of analysis: earthquakes, landslides, floods, wildfires, volcanic eruptions, and tropical cyclones, as described in Sections 5.3 and 5.4. The weighting index included the risk of disasters to human life and property. Based on the results of the prioritization analysis, the 15 observation categories listed below have the highest rankings and thus are considered to be the observation priorities for the Disasters SBA. The Cross-SBA Analyst included these 15 observation categories in Methods 1-3 of the Cross-SBA analysis. Accounting for differences in observation terminology across the SBAs, the Disasters Team effectively contributed 34 observation parameters to Methods 1-3 of the Cross-SBA analysis. The Disasters Analysts divided the 15 observation categories into the three tiers representing "High," "Medium," and "Low" priority observations for numerical weighing in Cross-SBA Methods 2 and 3. The Cross-SBA Analyst included the "High" and "Medium" priority observations as the "15 Most Critical" observations in Method 4 of the Cross-SBA analysis. Accounting for differences in observation terminology across the SBAs, the Disasters Team effectively contributed 30 observation parameters to Method 4 of the Cross-SBA analysis.

High
Elevation/Topography Properties
Precipitation Properties
Surface Deformation Properties
Wind Properties
Soil Properties
Seismic Properties

Medium
Atmospheric Properties
Flood Monitoring Properties

[3] 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/.

Wave Properties
Stream/River Properties

Low
Gravity Field
Water Properties
Ice/Snow Properties
Magnetic Field
Thermal Properties