Use of Satellites for Risk Management

Volume I

Establishing Global Requirements for Earth Observation Satellite Data to Support Multi-hazard Disaster Management throughout the Disaster Cycle

November 11, 2008

A CEOS Disaster SBA Team – GEO DI-06-09 Report

Version 1.0

Use of Satellites for Risk Management

Table of Contents

Introduction

This report is the result of the efforts of several parallel groups working over several months, in particular: the GEO DI-06-09 working groups on user requirements and satellite architecture, the CEOS Disaster SBA Team on satellite architecture and the UN-SPIDER meetings held in Vienna and Bonn in June 2007 and October 2007.

This report builds on the heritage of several other reports which laid the groundwork for a comprehensive compilation of disaster requirements. These include the work of the Committee on Earth Observation Satellites (CEOS) Disaster Management Working Group report from 2004, the Geohazards Earth Observation Requirements report from IGOS-P in August 2007, the GMES Emergency Response Core Service Strategic Implementation Plan from 2007, the RADARSAT Constellation User Requirements Document from 2006 and the Athena Global Disaster Report, also from 2006. However, none of these reports have addressed requirements on both a global and multi-hazard basis, with a view to eventually prioritizing requirements and matching them against available systems and resources.

Traditionally, reports addressing the contribution satellites can make to disaster management have either been very general in their application, which has led to problems in implementation, or have been based on specific missions and technologies, instead of starting from a user need pull perspective. This report aims to address needs from a user perspective, and thus necessarily touches on numerous issues not of immediate concern to the satellite community, such as integrated service provision, capacity needs within the user community and interoperability of systems. However, the report also aims to provide clear direction for the development of specific satellite architecture options that will address user needs. This will be addressed in volume II of the report. In this sense, the concerns of user are articulated in terms that can readily be translated into mission requirements and can be matched against existing and planned systems. This process of matching user needs with architecture and specific recommendations, while not addressed in this report, has already begun, and should be completed during 2009 and documented in volume II. Its conclusions will form the basis for future recommendations to both GEO and the CEOS plenary.

Inevitably, in an effort to be precise and exhaustive, this compilation of user requirements will touch on a wide range of needs, many of which are to some degree either already met or easily met with little effort on behalf of users. This report nonetheless needs to address the full scope of requirements in order to assess where new satellite missions can make the most meaningful and valuable contribution to disaster management.

I. Overview of Global Disasters

Growing global populations, increasing severity of weather systems, widespread poverty in the developing world and build up in fragile areas in the developed world have led to a strong increase in the severity of the impact of disasters over the past decades.

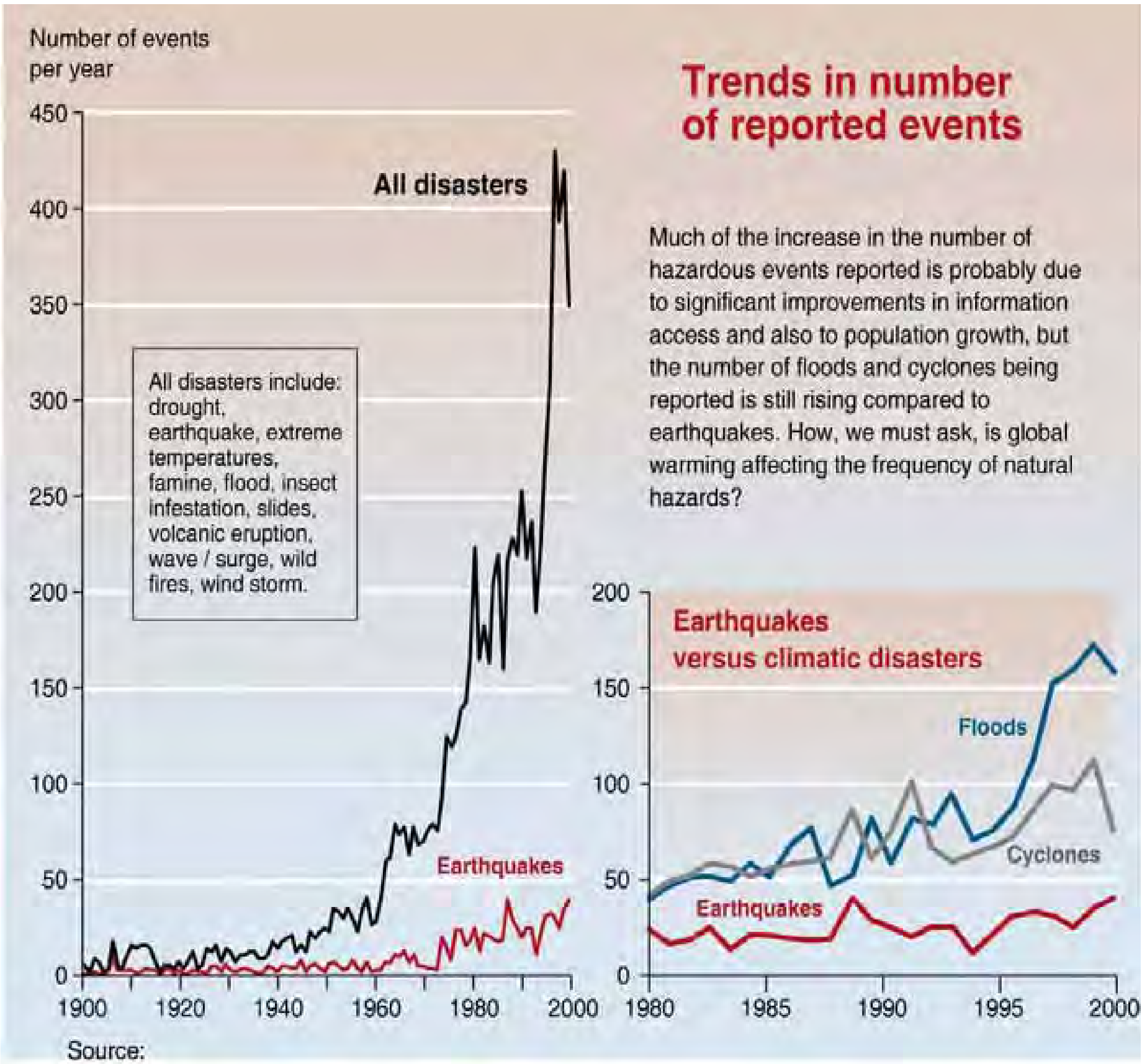

FIGURE 1: TRENDS IN NATURAL DISASTERS. (2005). IN UNEP/GRID-ARENDAL MAPS AND GRAPHICS LIBRARY. RETRIEVED 16:00, OCTOBER 30, 2008 FROM HTTP://MAPS.GRIDA.NO/GO/GRAPHIC/TRENDS-IN-NATURAL-DISASTERS.

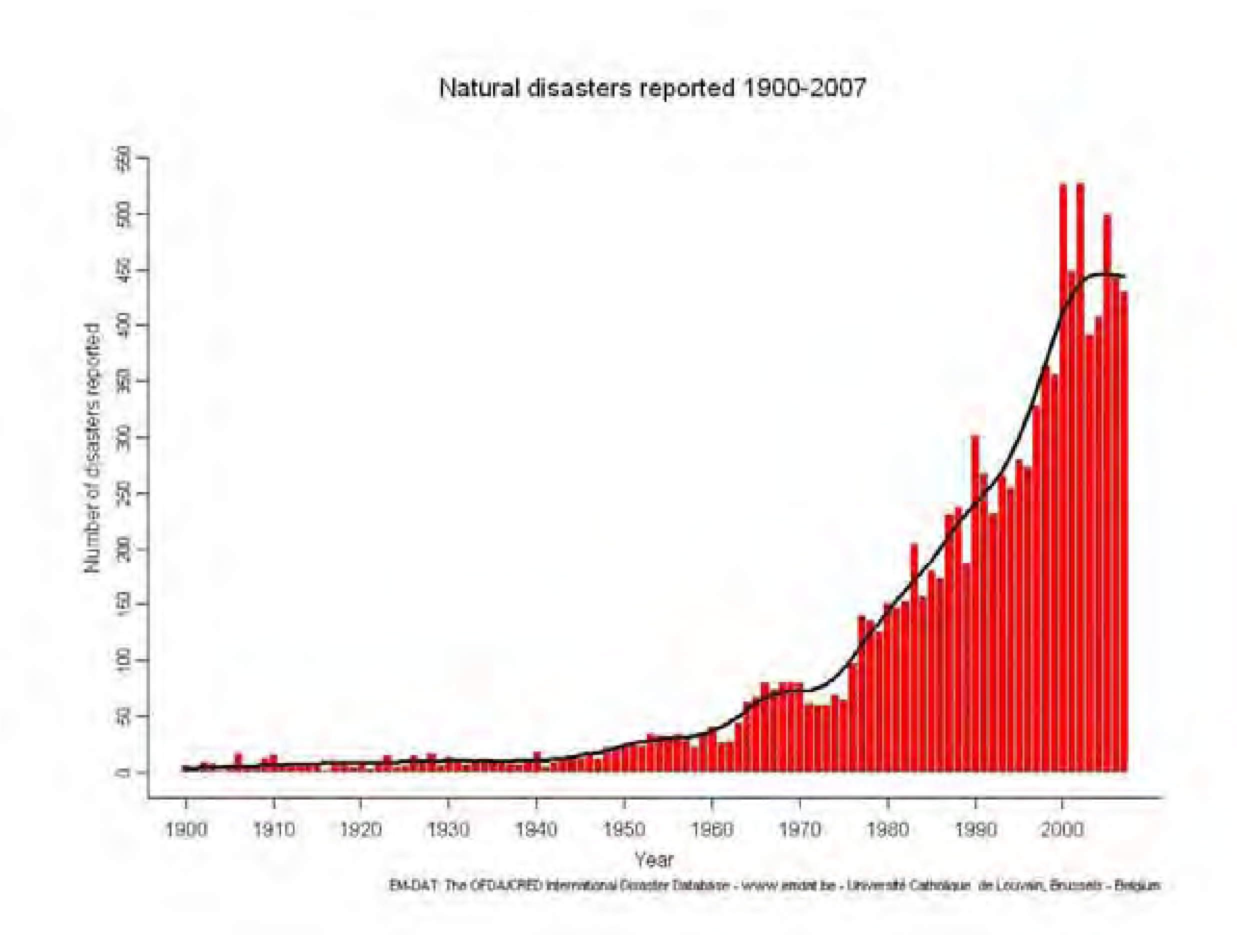

FIGURE 2: NATURAL DISASTERS REPORTED 1900-2007

In parallel, the rapid progress of technology has led to the development of assets that can make a substantial contribution to effective disaster avoidance or management. Satellite systems already in orbit are used on an ad hoc basis to better manage disasters. However, a dedicated international effort providing satellites designed to address disaster needs could make a substantially improved contribution, even without further technology advancement.

Disasters are generally thought of as events by the general public. For those tasked with their management however, they are viewed in a more complex spectrum or cycle, that begins long before the event, during the period where action can be taken to prepare for or mitigate against the impact of probable disasters (mitigation). The cycle extends from there to a warning phase, during which a known disaster is approaching, and populations can be warned of its arrival. The event itself follows, and it is in turn followed by a short period of several days during which managers attempt to save lives and protect property from further ravages. The final phase is one of assessment and recovery, during which one takes stock of the impact and begins the long process of recovering and returning to “normal” activities. The type of data and systems available to address different phases varies, as does their relative usefulness. This may and does also vary according to the type of disaster, and the geographic area in which it occurs. A more detailed definition of each phase is provided below in section III.

II. Disaster Managers

The international user community involved in disaster management is a varied and complex group of organizations. Each level of disaster management involves a different type of user organization, with different preoccupations. Some of the different types and their concerns are given below:

- Responders – time critical, low tech, aversion to new systems, communications issues
- Local decision makers – time critical for response, offers overview useful to integrated approach, cost issues
- Regional decision makers – cost issues, mitigation focus
- National decision makers – briefing up, mandate issues
- International organizations – varies according to mandate

No effort is made in this report to rank the relative importance of the needs of these various types of users, or the extent to which satellite data is well or ill-suited to meet specific types of needs. Ultimately, there may be entire categories of users for whom satellite data is not the most useful type of data and for whom other data sources are to be privileged. In the long run, it is hoped that by identifying information needs and sources of data to contribute to them, satellite data will become one indistinguishable source of data, amongst many that operate seamlessly in near-real time.

The differences above focus on different levels of operational responsibility during the response phase. There are also differences according to the phase of the disaster, for example:

- Mitigation – amount of data required, lack of resources, overlapping mandates, capacity building issues
- Warning – overlapping mandates, technology in developing world
- Recovery – extent and cost of damages

III. An Analysis of Disaster Needs by Disaster Type and Phase

For the purposes of this report, disasters are analyzed according to four phases:

Disaster Mitigation: involves all activities between disasters that identify risk or prepare populations and property with a view to reducing the impact of the disaster.

Disaster Warning: refers to all activities in the days and hours immediately before a disaster, once the onset of the disaster is considered likely, that are aimed at saving lives and protecting property through improved information about the likely impact of the disaster, or through steps taken to avoid impacts or to evacuate people.

Disaster Response: refers to the period during and immediately after the disaster during which efforts are underway to identify the immediate impact and save lives of those directly affected and improve the material situation of those affected. Typically lasts two to three days.

Disaster Recovery: refers to the period after the disaster response, which may last for weeks or even months in the case of large scale disasters, during which a detailed assessment and evaluation of the impact of the disaster is made, and efforts are undertaken to return the disaster zone to "normal" activities. In some severe cases, this recovery period may last years to rebuild infrastructure or rehabilitated damaged environments.

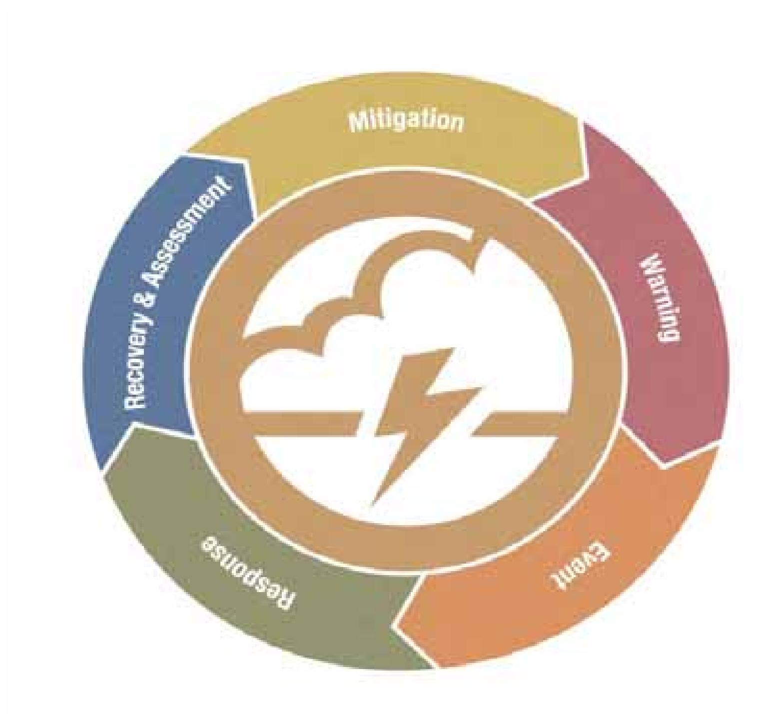

FIGURE 3: DISASTER CYCLE ©ATHENAGLOBAL

Methodology for compiling user needs

This report began as a GEO effort to identify the needs of disaster managers across all phases of disaster management: mitigation, warning, response and recovery. After an initial assessment was made of user requirements across all phases, users concluded that each phase required a specific approach. The phases are addressed by different actors and have been using satellite data to varying degrees. For example, the International Disaster Charter provides access to a wide range of satellite data for disaster response, but the data is not easily available for other phases of disaster management. Disaster mitigation, which represents the greatest opportunity to save lives and protect property, also presents some of the greatest challenges. The large areas to be covered require very large volumes of data. Typically, budgets available for mitigation are the smallest of any phase, even though the needs are greatest. It is hoped that this report will allow users to create a hierarchy of needs across all phases, and establish which data types and systems can provide the highest return on investment, in order to prioritize needs and future system development.

Recognizing the limits imposed by financial constraints, participants in this exercise were asked to identify areas where it was more important to obtain information than others. Most participants agreed that criteria to judge relative importance could be a combination of frequency of disaster, severity of disaster (economic impact) and number of people affected. Ultimately, those involved in the study felt that an objective third-party source should be used as a starting point for geographic consideration of user needs. This source ultimately became the World Bank for a number of disaster types, as they presented a comprehensive analysis of disasters and their impacts over 15-25 years, using the well-established CRED data base on disaster impacts at the Université Catholique de Louvain in Belgium.

In order to establish a common set of characteristics for user requirements, the following approach was used for each disaster type and phase:

- Identify region of interest (priority areas)
- Identify target characteristics (what do we want to see?)
- Identify temporal revisit period
- Establish timeliness/latency requirements
- Identify end use for data by intermediate user (application, service, etc)

Once the approach was approved by the participating organizations, the user requirements were defined in a tabular format and circulated to the entire group for review. These were then refined to obtain the existing, validated requirements. Organizations included in this validation process included end user groups such as civil defence agencies, meteorological agencies, national and regional disaster response agencies, international aid organizations and others involved in the supply of information, such as space agencies.

Identifying the region of interest for disaster managers was one of the most complex decisions of the user needs compilation process. This region varies wildly depending the phase of the disaster. During the warning and response phases, the information needed covers a small area – the area threatened by the disaster. Even for large scale events, this area is typically limited in scope and can be readily imaged by satellites, with the exception of droughts and some floods. Even in these cases, larger areas can be scanned by lower resolution satellite imagery providing regular and useful composite information.

During the mitigation phase, the issue of area of interest is much more difficult to resolve. In fact, when one considers multiple hazards, almost every inhabited area of the world is at risk to some extent for some type of disaster. Even uninhabited areas are of interest because of their interaction with inhabited areas, particularly for approaching windstorms over the ocean, or flooding, or the spread of wildfires.

Using current technology, it is not economically feasible to image the entire world at a high resolution using different types of satellites on a frequent basis. This is what would be required if a comprehensive mitigation program were to be conducted. In addition, the imagery would need to be processed and integrated into comparative value added products that provide specific information about specific types of disasters.

In order to identify an intermediate step, the members of the working group chose to work on mitigation in areas that offer the highest likelihood of disaster, and that presented the potential for the largest loss of life and economic impact.

The World Bank and Columbia University conducted a similar analysis several years ago and identified on a global basis the most vulnerable areas of the world for a number of different disaster types. It was decided to use these maps as a starting point to limit the amount of data required and thus prioritize user needs during the mitigation phase according to international priorities.

Once these areas were identified, it was necessary to analyze for each disaster and during each phase the type of information required. Data were collected and placed in the table below. For each of the following sections, the tables that roll up requirements represent the main contribution of participants to the process. It was through the tables that information was compiled and validated.

Phase Requirements	Mitigation	Warning	Response	Recovery
Target Information				
Revisit				
Timeliness				
End use				

TABLE 1: METHODOLOGY OF COMPILING EO REQUIREMENTS BY PHASE

Target information refers to data about the nature of the target in relation to the disaster. For example, for fires, information about fuel (vegetation) state and its likelihood of burning, as well as wind vectors, is important. For flooding, information about topography and precipitation and soil moisture and traditional flood plains is all important.

Revisit refers to the frequency of observations required in order to derive an information product.

Timeliness refers to the acceptable lapse of time between when the need for the data is realized and when the data or information product is actually delivered. This calculation includes both the latency for the collection of the data due to orbital and ordering constraints, and the overall time lag to create a useable product.

End use refers to the ultimate destination for the data collected. Understanding how the data will be integrated into information systems is a critical component to ensuring that data collected is actually used for risk management rather than simply collected but never used.

This report does not aim to examine all disaster types. The types of disasters analyzed in report are:

- Flooding (slow on-set and flashfloods) ,
- Windstorms,
- Earthquakes,
- Landslides,
- Volcanoes,
- Drought,
- Wildfires,
- Tsunamis.

While other types of disasters such as insect infestations are also important to many disaster managers, these eight disaster types were retained because of their widespread impact, and the potential for satellite imagery and its associated applications to make a difference in disaster management efforts.

i. Flooding

FIGURE 4: FLOODING IN NEW ORLEANS AFTER HURRICANE KATRINA, 2005 © NOAA

*"Between 1987 and 1997, 44% of all flood disasters affected Asia, claiming 228,000 lives (roughly 93% of all flood-related deaths worldwide). Economic losses for the region (in this period) totaled **$US 136 billion**." (UNESCO).*

One of the world's most dramatic and devastating disasters is flooding. Despite being in many cases predictable, and even recurring in areas such as Mozambique and Bangladesh, endemic poverty makes it difficult to mitigate the effects of these disasters. Flooding does not affect all countries or all areas equally.

That being said, developed countries suffer terribly from flooding as well, as evidenced in this image of New Orleans, USA, after the devastating passage of Hurricane Katrina in 2005.

The figure below shows the areas of the world most affected by flooding. Red areas are most critically affected, followed by yellow and blue areas.

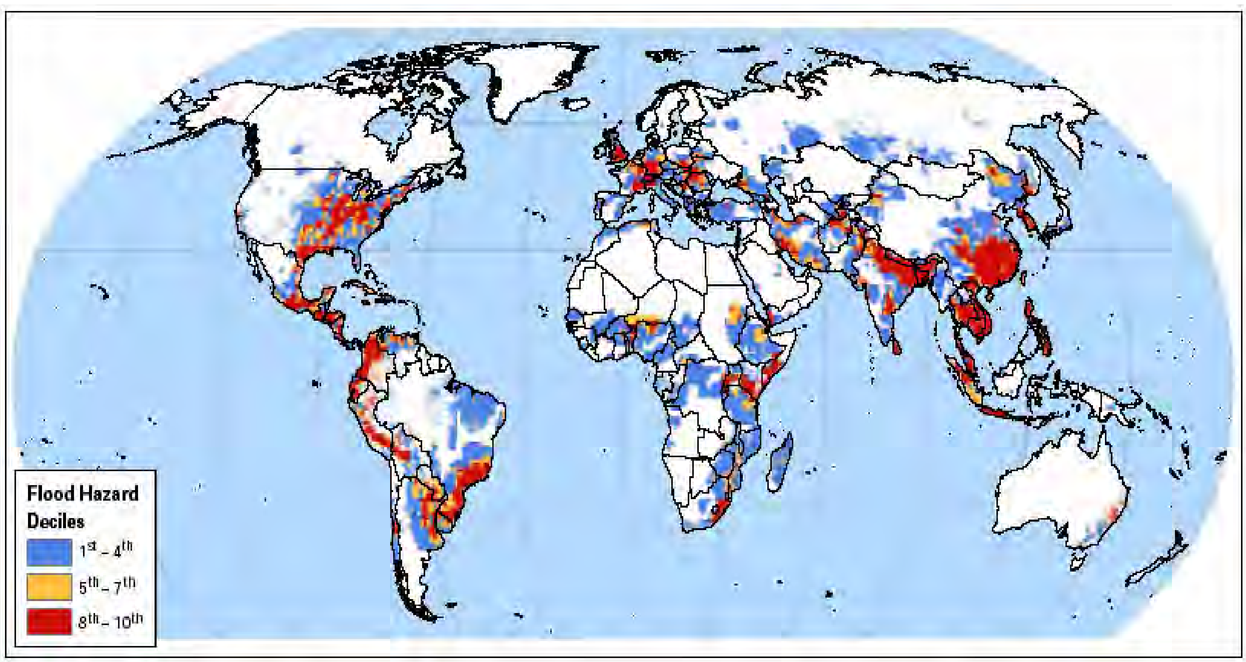

FIGURE 5: GLOBAL DISTRIBUTION OF CATASTROPHIC FLOODING RISK (SOURCE: THE WORLD BANK – NATURAL DISASTER HOTSPOTS: A GLOBAL RISK ANALYSIS)

Phase Requirements	Mitigation	Warning	Response	Recovery
Target	Topography Hydrological models Historical atlas of floods Flood models/simulations New infrastructure, houses Land-use classification Monitoring of dikes and dams Tropical cyclone seasonal predictive models/simulations Monitoring sea surface temps Monitoring sea-level rise	Precipitation Water level (rivers, lakes) Weather forecast Soil moisture Snow-water equivalent Signs of catastrophic infra failure Signs of active or high tropical cyclone activity Sea-level Signs of coastal erosion and inundation	Water level (rivers, lakes) Extent of flood Status of critical infrastructure Weather forecast Status of coastal infrastructure Predictive model simulations for rising sea level effects	Status of critical infrastructure Damage assessment Flooded areas
Revisit	Monthly (models during season) 1 to 3 years (imagery) 5 to 10 yrs (topography)	Daily or better during high risk period	Daily in early morning; twice daily if possible	Weekly (major floods) for several weeks to several months
Timeliness	Weeks Months (for seasonal predictions) Years (for Global Change)	Hours Days to Months (for tropical cyclone activity)	Hours (2-4 max)	1 day Years (for Global Change)
End use	Integration in land use planning/zoning Baseline for response Integration in coastal area planning/zoning (Global Change)	Decision support for warnings & evacuation Decision support for infrastructure building and population relocation	Situational awareness Resource allocation support Initial damage assessment Impact planning/action	Tracking affected assets Charting progress Assessing scope of Global Change impacts and ability to cope

TABLE 2: EO REQUIREMENTS FOR FLOODING

ii. Windstorms

"Windstorm is the most important natural hazard of recent decades, in terms of the frequency of loss events, the total expanse of the areas affected, and, above all, the scale of the damage caused. The insurance industry has consequently had to carry higher and higher losses due to windstorm, the natural hazard responsible for about 79% of the $US 370 bn (2007 values) which the insurance industry had to pay for major natural disasters between 1950 and 2007." (Munich Re)

Figure 6: Tropical Cyclone ©e-picworld

Windstorms such as hurricanes, typhoons, cyclones and tornados account for a dramatic percentage of property losses because they affect developed and undeveloped areas indiscriminately, are difficult to predict and impossible to totally prevent in any event. Many windstorms, such as hurricanes, cause a slew of related disasters such as landslides and flooding in their aftermath.

The figure below indicated the regions of the world most likely to be affected by windstorms, by increasing category of risk.

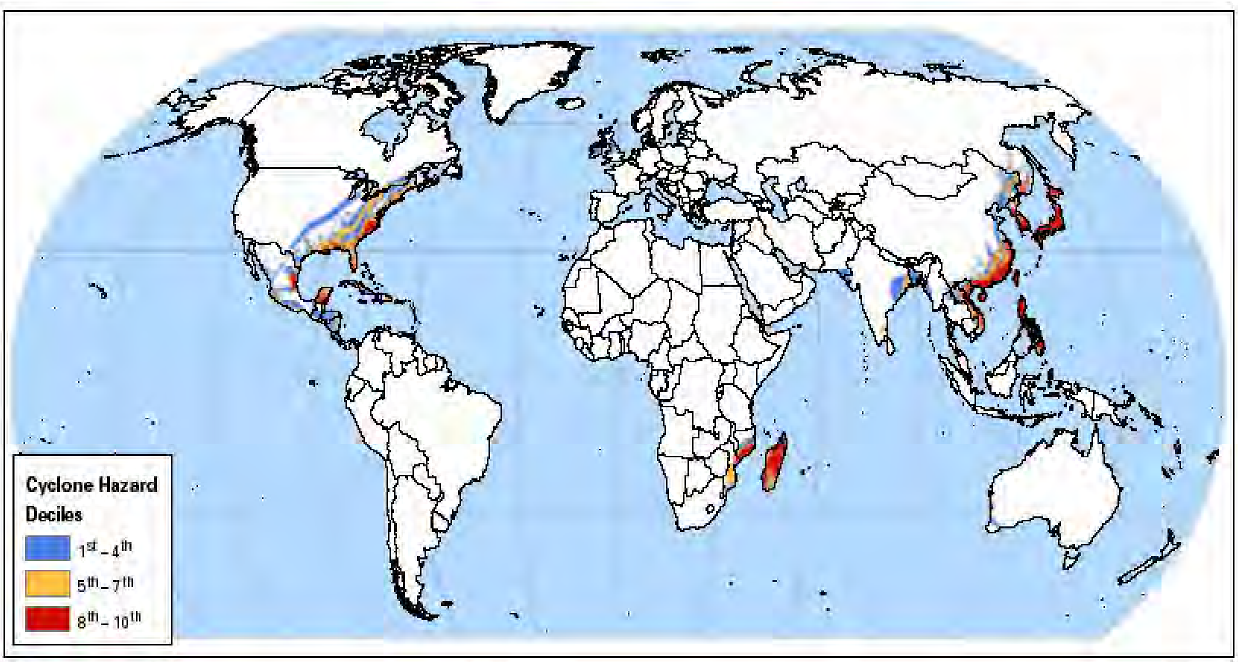

Figure 7: Global Distribution of Catastrophic Windstorm Risk (Source: The World Bank – Natural Disaster Hotspots: A Global Risk Analysis)

Phase Requirements	Mitigation	Warning	Response	Recovery
Target	Topography (DEM) Coastal zone of impact - recent map	Windspeed Wave height Location of windstorm days/hours before landfall Weather forecast	Water level Critical infrastructure Weather forecast Extent of damaged area	Critical infrastructure Water level Damage assessment
Revisit	Every 1 to 3 years	Twice daily or more up to hours before landfall	Daily in early morning; twice daily if possible	Weekly (major storms) for several weeks to several months
Timeliness/ latency	Weeks	2 hours or less	Hours (2-4 max)	1 day
End use	Integration in land use planning/zoning Baseline for response	Decision to issue warnings, evacuate (1-day before), protect	Map of affected area Logistics planning Initial insurance damage assessment	Tracking affected assets

FIGURE 8: EO REQUIREMENTS FOR WINDSTORMS

iii. Earthquakes

"It is estimated that there are 500,000 detectable earthquakes in the world each year. 100,000 of those can be felt, and 100 of them cause damage." (USGS)

Earthquakes are not as common in most parts of the world as other types of disasters, however, when they strike, they can cause dramatic damages, particularly if they strike unexpectedly in areas less prone to major earthquakes, where construction standards are not as rigorous as in earthquake prone areas.

FIGURE 9: COMPLETELY DESTROYED CONCRETE FRAME OFFICE BUILDING, GREAT HANSHIN-AWAJI (KOBE) EARTHQUAKE, JAN 1995
PHOTO CREDIT: DR. ROGER HUTCHISON, NGDC, NOAA

There are in fact two different ways to assess the degree to which people are affected by earthquakes. One is severity; the other is frequency. It is clear that frequent earthquakes allow a much better indication of the likelihood of a new earthquake affecting a given area. However, it is the severity of the earthquake that determines the damages. Many areas prone to earthquakes have small regular tremors but suffers only minimal damages.

On a global basis, the table below provides an indication of the regularity of extremely severe earthquakes. The largest earthquakes, which measure over 8 on the Richter scale, usually occur only once a year on a global basis.

Magnitude	Average Annually
8 and higher	1 [1]
7 - 7.9	17 [2]
6 - 6.9	134 [2]
5 - 5.9	1319 [2]
4 - 4.9	13,000 (estimated)
3 - 3.9	130,000 (estimated)
2 - 2.9	1,300,000 (estimated)
[1] Based on observations since 1900. [2] Based on observations since 1990.	

FIGURE 10: FREQUENCY OF OCCURRENCE OF EARTHQUAKES (USGS)

The map below provides a clear view of areas where severe earthquakes are most likely to strike.

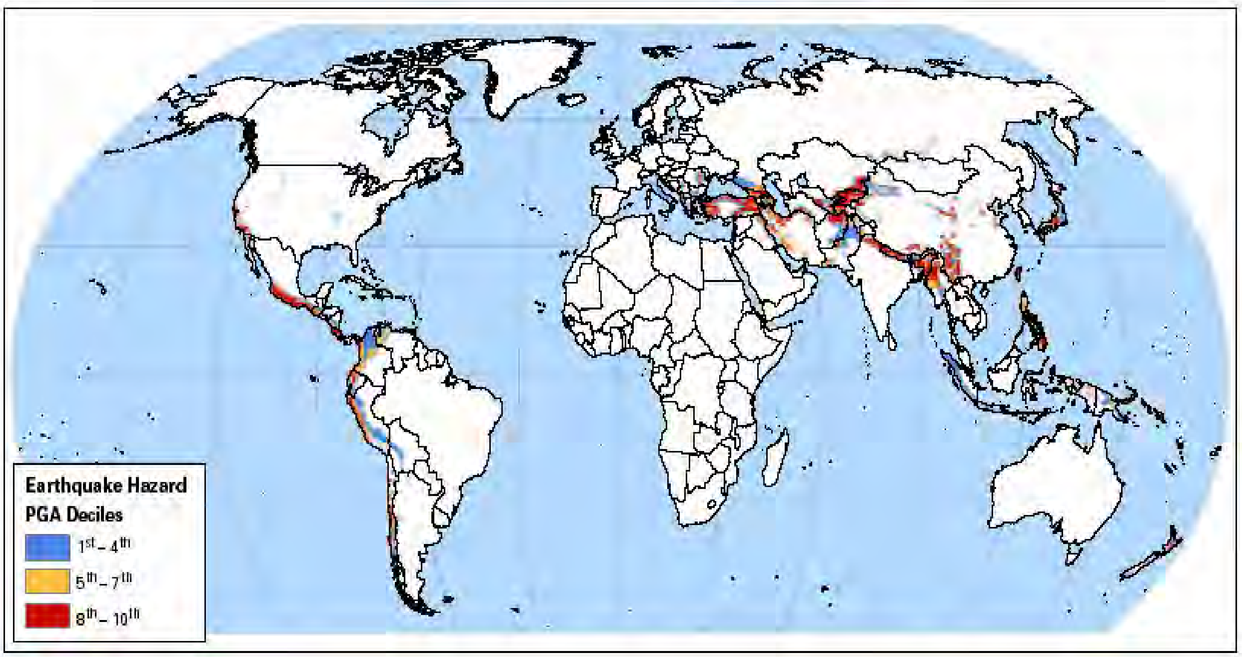

FIGURE 11: GLOBAL DISTRIBUTION OF CATASTROPHIC EARTHQUAKE RISK BY SEVERITY (SOURCE: THE WORLD BANK – NATURAL DISASTER HOTSPOTS: A GLOBAL RISK ANALYSIS)

The map below, in contrast, provides a view of where earthquakes of all strengths are likely to strike. This analysis favors frequency over severity.

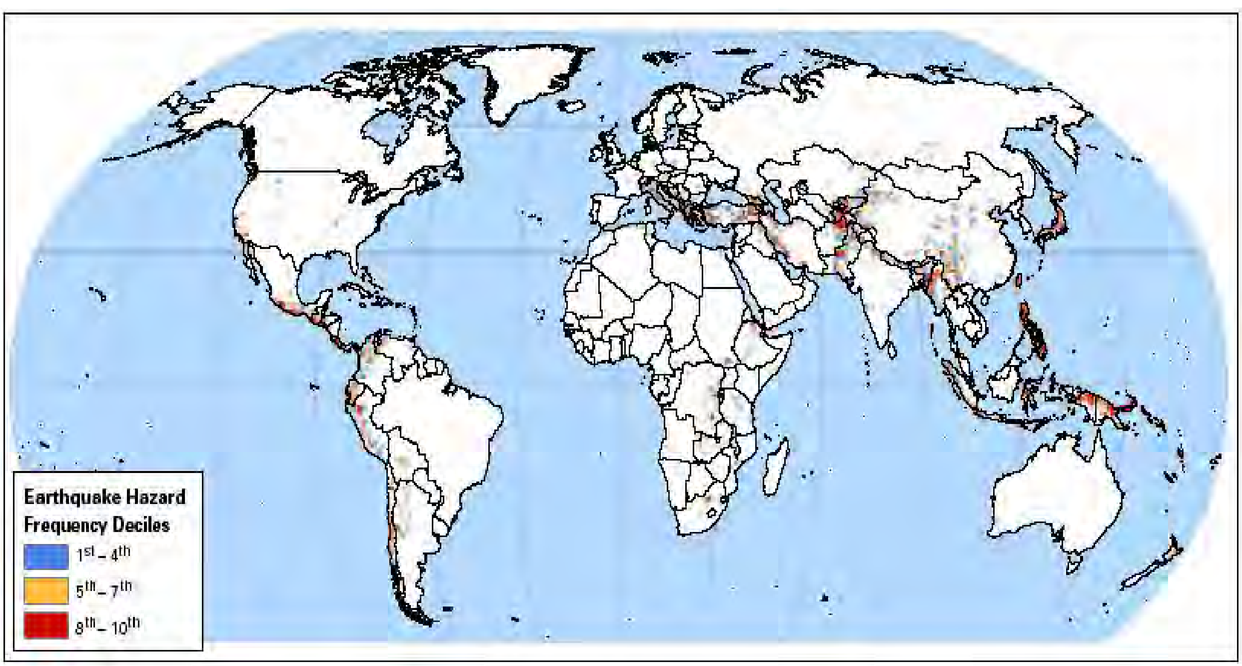

FIGURE 12: GLOBAL DISTRIBUTION OF CATASTROPHIC EARTHQUAKE RISK BY FREQUENCY (SOURCE: THE WORLD BANK – NATURAL DISASTER HOTSPOTS: A GLOBAL RISK ANALYSIS)

Phase Requirements	Mitigation	Warning	Response	Recovery
Information	Digital topography (DEM) Hydrology & water features Geologic mapping and physical properties of earth materials (surface and subsurface); detailed mapping and dating of surface deposits - for shake maps. Liquefaction effects Risk assessment: location and probability of occurrence, population density, economic impact Land-use, location and condition of existing infrastructure, building codes 3-D deformation monitoring (regional scale and hi-resolution in vicinity of faults) Seismic history Hi-resolution measurements of gravity, electrical and magnetic fields	Location and magnitude of seismic activity or ground motion (RT seismic and GPS networks) Strong motion sensors 3-D deformation monitoring Gas emissions by species and flux Characterization of time varying thermal features Water levels (groundwater), pore pressure, soil moisture Water chemistry - natural and contaminated	Topography (DEM) - hi resolution Location of earthquake (from seismology) Magnitude of earthquake (from seismology and RT GPS) Population distribution (census + satellite data) Exposure: structure inventory, engineering properties, expected response to hazard Land-use information Location and condition of infrastructure and transportation routes Extent of damage (% destruction) Location of rescue teams Weather forecast	Status of relocation and reconstruction efforts Documentation and assessment of effects during and after event
Revisit	Baseline with update as needed (i.e., decadal update to topography, 5- yr update on infrastructure and population, weekly to monthly deformation information)	Daily or better during high risk period	Daily in early morning; twice daily if possible	Weekly (major earthquakes) for several weeks to several months
Timeliness/ latency	Weeks	Hours	Hours (2-4 max)	1 day
End use	Identify regions at greatest risk Mitigation efforts to reduce risk or potential adverse consequences of an event Baseline for response planning and preparedness	Decisions to issue warnings, place infrastructure in safe-mode, evacuate people	Estimate and verify location, extent and magnitude of damage Response logistics planning Situational awareness for responders	Monitor progress of rebuilding/ restoration of infrastructure.

FIGURE 13: EO REQUIREMENTS FOR EARTHQUAKES

iv. Landslides

"Landslides are quick. In Canada, one landslide caused a riverbank to move 680 meters in less than an hour. In America, between 25 and 50 people are killed in landslides each year." (EMA)

FIGURE 14: LANDSLIDE COLONIA LAS COLINAS (EL SALVADOR)
PICTURE CREDITS: USGS (ED HARP)

Landslides offer particular challenges for Earth observation, particularly during the warning phase, as landslides in many regions are spontaneous events caused by excessive rain. However, information about soil moisture and saturation can provide indications of risk, and information about land cover and proximity of populated areas can provide indications of potential for damage. In some areas where rocky faces are prone to regular landslides, monitoring of freeze and thaw cycles using remote sensing can indicate portions of the slides that are active and likely to move again.

During the response and recovery phase of landslides, Earth observation is a valuable tool to rapidly determine the extent and severity of the slide and estimate damages. Years later, Earth observation information about large slides can provide a synoptic overview of recovery and regeneration of natural vegetation.

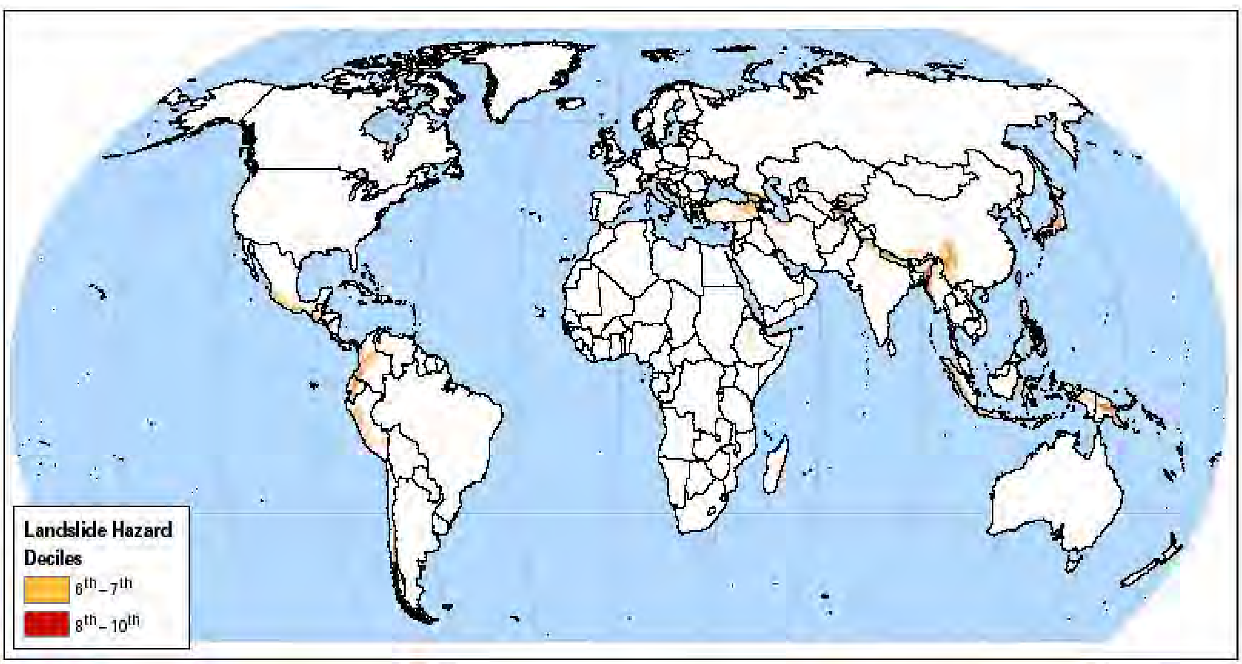

FIGURE 15: GLOBAL DISTRIBUTION OF CATASTROPHIC LANDSLIDE RISK (SOURCE: THE WORLD BANK – NATURAL DISASTER HOTSPOTS: A GLOBAL RISK ANALYSIS)

Phase Requirements	Mitigation	Warning	Response	Recovery
Information	Digital topography (DEM) (both DTED-1 and high resolution) Hydrology - water features Geologic mapping and physical properties of earth materials (surface and subsurface); detailed mapping and dating of surface deposits Risk assessment: location and probability of occurrence, population density, economic impact Location of infrastructure and transportation routes Land-use and vegetation cover - high resolution Structure inventory, engineering properties, and response to hazards 3-D deformation monitoring Seismic monitoring Water levels (groundwater), pore pressure, soil moisture	Location and magnitude of ground motion (RT seismic and GPS networks) 3-D deformation monitoring Water levels (groundwater), pore pressure, Soil moisture Stream flow: stage, discharge, volume Precipitation Snow: area, depth, water-equivalent Inundation area (flood, storm surge, tsunami, etc.) Wave heights and patterns	Topography (DEM) - hi resolution Location(s), extents and magnitudes of events Population distribution (census + satellite data) Exposure: structure inventory, engineering properties, expected response to hazard Land-use information Location of infrastructure and transportation routes Extent of damage (% destruction) Location of rescue teams Weather forecast	Status of relocation and reconstruction efforts Documentation and assessment of effects during and after event
Revisit	Baseline with update as needed (I.e., decadal update to topography, 5- yr update on infrastructure and population, weekly to monthly deformation)	Daily or better during high risk period	Daily in early morning; twice daily if possible	Weekly (major earthquakes) for several weeks to several months
Timeliness/ latency	Weeks	Hours	Hours (2-4 max)	1 day
End use	Risk assessment Monitoring of conditions likely to trigger an event Baseline for response planning and preparedness Advise engineering and/or policy decisions to reduce risk and to limit potential adverse consequences of an event	Advise of an imminent event- location, likelihood, and possible adverse consequences	Estimate and verify location, extent and magnitude of damage Provide situational awareness and information relevant to tactical response.	Monitor progress of rebuilding/ restoration of infrastructure.

TABLE 3: EO REQUIREMENTS FOR LANDSLIDES

v. Volcanoes

"About 1,900 volcanoes on Earth are considered active, meaning they show some level of activity and are likely to explode again. Many other volcanoes are dormant, showing no current signs of exploding but likely to become active at some point in the future." (National Geographic)

FIGURE 16: ERUPTION OF MOUNT ST. HELENS 1980 © D. SWANSON (USGS)

The usefulness of Earth observation for tracking volcanic plumes, which are a major hazard for aviation, and for monitoring lava flows and assessing damages caused by eruptions is well-known and self evident. Perhaps less well-known is the ability to determine when a volcano is becoming active and to assess likelihood of eruption using SAR interferometry. This technique is being used today on an experimental basis on a number of volcano ranges by the USGS, and eventually could become an effective tool for monitoring remote volcanic ranges, or even for more comprehensive monitoring of volcanic activity in ranges where in-situ sensing is also used. The map below provides some indication of where volcanoes offer the greatest risk of catastrophic damage. More generally however, given the unexpected nature of awakening volcanoes, it is perhaps more useful to consider major volcanic ranges on a global basis and introduce a regular monitoring program for these ranges. When volcanoes are inactive, monitoring every few months would be sufficient to determine that they remain inactive. When signs of awakening are detected, monitoring every few weeks and even more frequently in some cases would provide warning of impending eruptions and allow for a better targeted in-situ monitoring program.

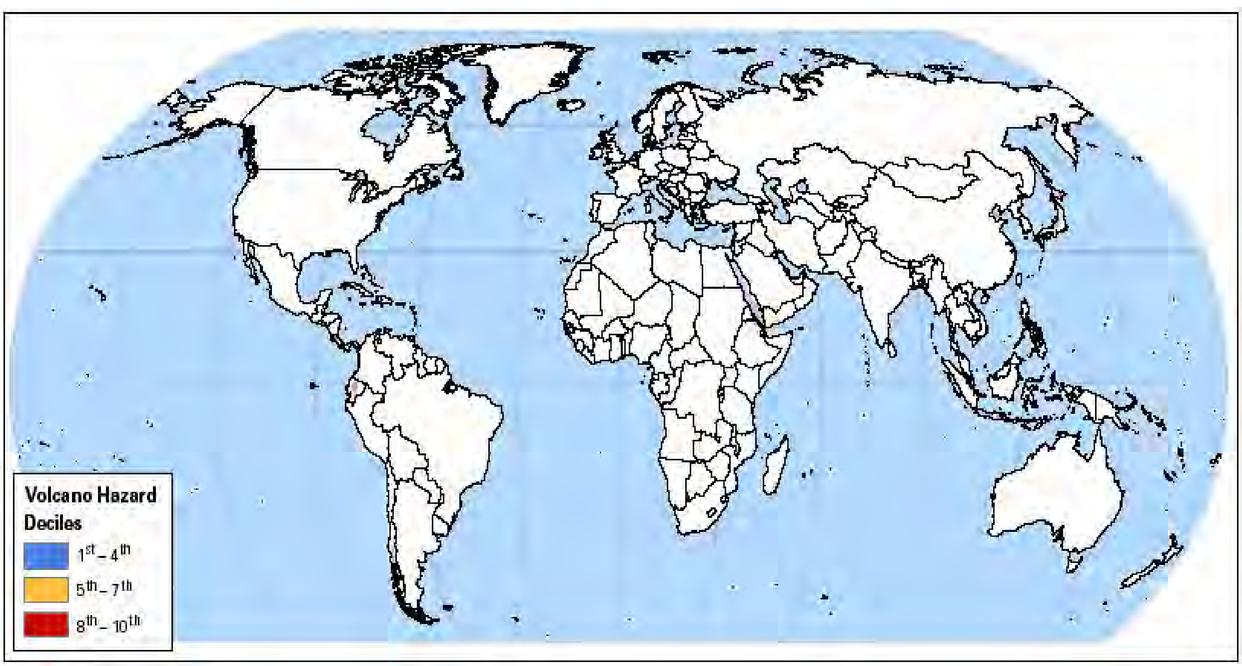

FIGURE 17: GLOBAL DISTRIBUTION OF CATASTROPHIC ERUPTION RISK (SOURCE: THE WORLD BANK – NATURAL DISASTER HOTSPOTS: A GLOBAL RISK ANALYSIS)

Phase Requirements	Mitigation	Warning	Response	Recovery
Information	Digital topography (DEM) Hydrology and water features Geologic mapping and physical properties of earth materials (surface and subsurface); detailed mapping and dating of surface deposits. Liquefaction effects. Risk assessment: location and probability of occurrence, population density, economic impact Land-use, location and condition of existing infrastructure, building codes 3-D deformation monitoring (regional scale and hi-resolution in vicinity of faults) Seismic history Hi-resolution measurements of gravity, electrical and magnetic fields	Location and magnitude of seismic activity or ground motion (RT seismic and GPS networks) 3-D deformation monitoring Gas emissions by species and flux Characterization of time varying thermal features Detect and monitor smoke and ash clouds, acids & aerosols Wind velocity and direction Atmospheric temperature, moisture and air masses/boundaries Stream flow: stage, discharge, volume Precipitation Snow: area, depth, water-equivalent	Topography (DEM) - hi resolution Population distribution (census + satellite data) Exposure: structure inventory, engineering properties, expected response to hazard Land-use information Location of infrastructure and transportation routes Extent of damage (% destruction) Location of rescue teams Weather forecast	Status of relocation and reconstruction efforts Documentation and assessment of effects during and after event
Revisit	Baseline with update as needed (i.e., decadal update to topography, 5- yr update on infrastructure and population, weekly to monthly deformation information)	Daily or better during high risk period	Daily in early morning; twice daily if possible	Weekly (major earthquakes) for several weeks to several months
Timeliness/ latency	Weeks	Hours	Hours (2-4 max)	1 day
End use	Identify regions at greatest risk Mitigation efforts to reduce risk or potential adverse consequences of an event Baseline for response planning and preparedness	Decisions to issue warnings, place infrastructure in safe-mode, evacuate people	Estimate and verify location, extent and magnitude of damage Response logistics planning Situational awareness for responders	Monitor progress of rebuilding/ restoration of infrastructure.

TABLE 4: EO REQUIREMENTS FOR VOLCANOES

vi. Drought

"One of the worst droughts of the Twentieth Century occurred in the Horn of Africa in 1984 and 1985. [It] led to a famine which killed 750,000 people." (Earth Observatory)

FIGURE 18: SOMALIA: A SHEPHERD SEEKS WATER FOR HIS GOAT AT A LARGE CATCHMENT AREA OUTSIDE THE VILLAGE OF ISDORTO IN THE SOUTHERN BAKOL REGION. PICTURE CREDITS: UNICEF/HQ06-0029/BRENDAN BANNON

Drought is a disaster very different in nature from the previous set of catastrophes examined. Firstly, it is a slow onset disaster. It can be detected and predicted many weeks and even months in advance. Secondly, while its human impacts are real, it does not offer the dramatic physical devastation of a flood or windstorm. The usefulness of situational awareness immediately after a drought is limited. Similarly, while the environment suffers, infrastructure such as roads, bridges or other critical transportation and energy corridors are unaffected. The most useful type of Earth observation to better mitigate drought is a comprehensive agricultural monitoring program that includes monitoring of soil moisture from space over large growing areas, and also monitoring of agricultural practices. Land use can be critical to understanding the underlying causes of drought. For example, the existence of large numbers of farm dams that trap water above the ground and lead to increased evaporation and lower water tables is a useful data point. Finally, meteorological information about likelihood of rainfall is most important.

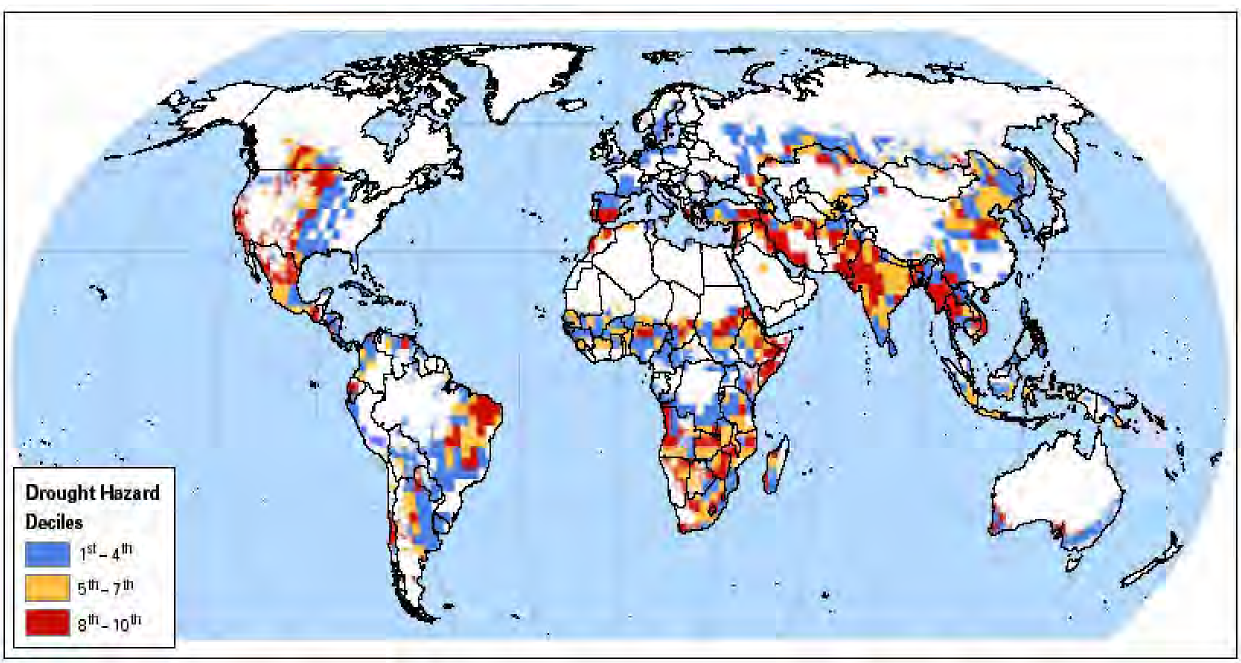

FIGURE 19: GLOBAL DISTRIBUTION OF CATASTROPHIC DROUGHT RISK (SOURCE: THE WORLD BANK – NATURAL DISASTER HOTSPOTS: A GLOBAL RISK ANALYSIS)

Phase Requirements	Mitigation	Warning	Response	Recovery
Target	Soil moisture AVHRR 'drought' products (indices)	Soil moisture AVHRR 'drought' products (indices)	Crop health indicators Weather forecast	None identified
Revisit	Weekly, or	Weekly	Daily	None identified
Timeliness/ latency	1 day	1 day	hours	None identified
End use	Decision to issue warnings	Decision to issue warmings	Crop damage maps for initial insurance damage assessment	None identified

TABLE 5: EO REQUIREMENTS FOR DROUGHT

vii.Wildfires

"These violent infernos occur around the world and in most of the 50 states, but they are most common in the U.S. West, where heat, drought, and frequent thunderstorms create perfect wildfire conditions… On average, more than 100,000 wildfires, also called wildland fires or forest fires, clear 4 million to 5 million acres (1.6 million to 2 million hectares) of land in the U.S. every year. In recent years, wildfires have burned up to 9 million acres (3.6 million hectares) of land." (National Geographic)

FIGURE 20: FOREST FIRE PHOTO CREDIT: JOHN MCCOLGAN OF THE BUREAU OF LAND MANAGEMENT, ALASKA FIRE SERVICE

Wildfires are large scale events that are readily tracked from space, even using low resolution imagery. Wildfires that approach urban areas can be devastating, causing loss of life and significant property damage. Tracking fire risk in the interface between urban and rural areas can be a challenge that space offers excellent tools for. This type of fire risk mitigation involves land cover mapping medium to high resolution optical data that is used to determine types and density of vegetation in and around the urban/rural interface.

Fighting wildfires is a dangerous and time critical activity. It has been demonstrated that rapid response to emerging fires can ensure fires are not allowed to grow into a threat that cannot be effectively managed. Today, geostationary weather satellites are used to detect fire hotspots in real time as they are created, and this information is made available on an operational basis to disaster managers. A separate GEO task, DI-06-13, is currently examining ways to better use geostationary data in the fight against fires. However, the resolution of these sensors cannot provide any useful information on the extent and severity of the fire. Different types of sensors are required to offer information about fires that are known to firefighters, and are being fought over several days. These data typically come from polar orbiting satellites, meaning they are more expensive to acquire over large areas at frequent time intervals. No comprehensive system has been designed to integrate polar orbiting satellite data into operational fire response. The MODIS sensor however is widely used to support a small subset of operations – new fire detection and burn scar mapping. This sensor is somewhere between geostationary and other polar orbiting sensors in that it offers 1000 and 250m imagery once a day, rather than a resolution of several kilometers every ten minutes, like geostationary weather satellites, or as little as 60cm, but only every few days, such as Quickbird imagery. Other low resolution sensors of great importance included AVHRR data collected globally to assess vegetation dryness for fire risk indices.

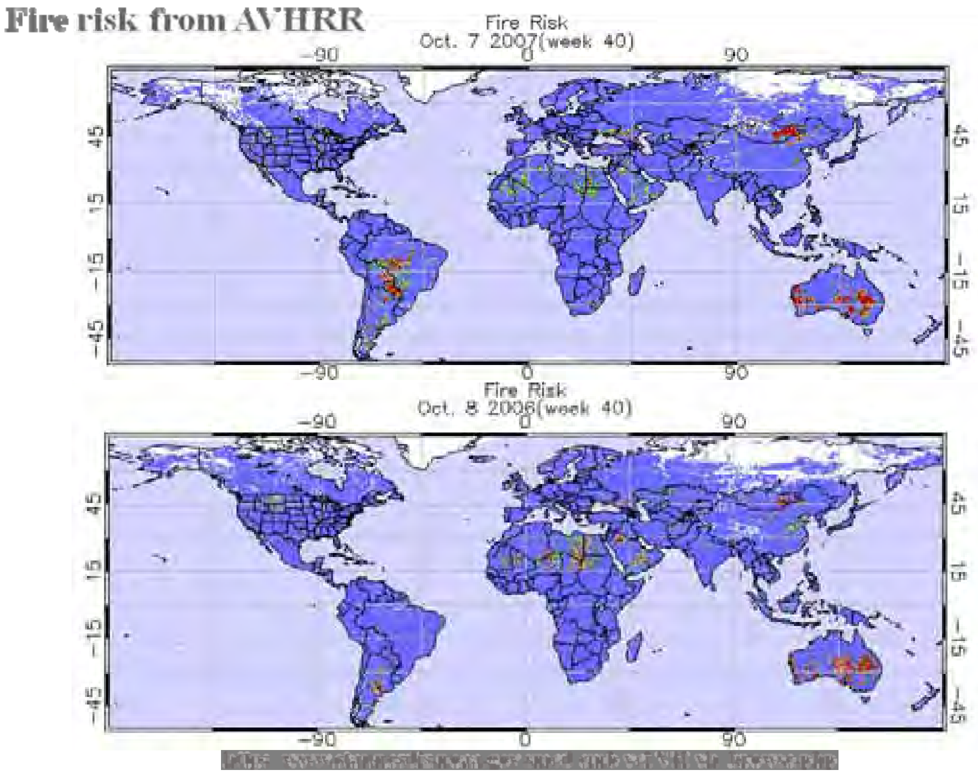

FIGURE 21: ANALYSIS OF FIRE RISK BY SATELLITE

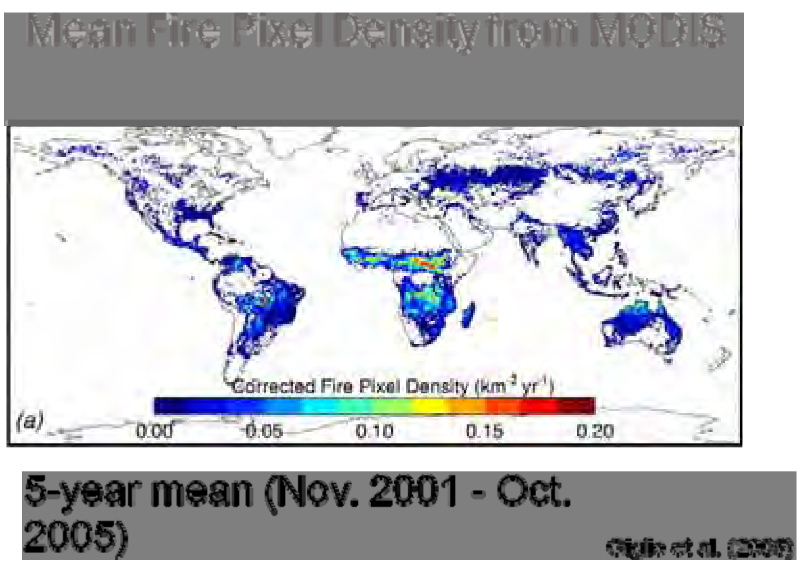

FIGURE 22: FIRE DENSITY FROM SPACE

Phase Requirements	Mitigation	Warning	Response	Recovery
Target	Location and extent of fires (routine monitoring) Soil moisture Fuel condition (characteristics, amount and distribution of dead and live fuels) Vegetation stress / fuel condition (fuel moisture) Topography Emissions (trace gases, aerosol)	Fire weather forecast (includes precipitation, surface winds) Soil moisture Early fire detection Monitoring of development of already ongoing fires Smoke transport	Precise location, extent and spread of fires Current fire danger / fire weather Smoke transport / dispersion and quality Land-use information	Burnt area Vegetation cover damage assessment Status of critical infrastructure Post-fire threats (land- and mudslides) Post-fire regeneration / rehabilitation
Revisit	Weekly to daily (topography: long-term revisit)	6 hours	6 hours	Monthly for the first year, then annually
Timeliness / latency	Days	Hours	Hours (2-4 max)	Weeks
End use	Long-term time series of fire observation allowing production of consolidated datasets on vegetation fire occurrence and long-term trend analysis Identification of regions at greatest risk Integration in land use planning / zoning Baseline for response planning and preparedness Determination of the contribution of vegetation fire emissions to the atmosphere and anthropogenic climate change	Decision support for preparedness, warnings & evacuation	Decision support for initial attack and extended situations Resource allocation support Initial damage assessment	Tracking affected assets Charting progress

TABLE 6: EO REQUIREMENTS FOR WILDFIRES

viii. Tsunamis

"Tsunami waves can be very long (as much as 60 miles, or 100 kilometers) and be as far as one hour apart. They are able to cross entire oceans without great loss of energy. The Indian Ocean tsunami traveled as much as 3,000 miles (nearly 5,000 kilometers) to Africa, arriving with sufficient force to kill people and destroy property." National Geographic News, Jan 14, 2005

FIGURE 23: INDIAN OCEAN TSUNAMI: DAMAGE, GLEEBRUK, INDONESIA © DIGITALGLOBE

It is widely believed that remote sensing data cannot be readily used for tsunami disaster management because of the quick onset of the disaster and because of the speed with which the wave moves across the ocean. In fact during the Indian Ocean tsunami, the wave from the initial earthquake zone was tracked by operational ocean altimeters but could not be used effectively for disaster warning purposes because of the time delay in processing and distributing the imagery. In any event, a tsunami wave before it approaches the coastal zone, even in the case of devastating tsunamis, may be only a few inches high, much smaller in fact than regular ocean swells. In-situ buoys are without a doubt the best means of detecting tsunamis and warning coastal populations. However, as effectively demonstrated during the Indian Ocean tsunami of 2004, high resolution optical imagery can be very useful for determining the extent and severity of damage, through the use of before and after assessment and critical infrastructure mapping. In a broad sense, land cover mapping applied to coastal areas can determine the extent to which a given area is likely to suffer from a tsunami, depending on the extent of traditional vegetation as opposed to exposed beachfront. It should be stated however that some of the most useful information even during the mitigation phase, such as mapping of ocean bathymetry along the coastal zone, is not practicable from space.

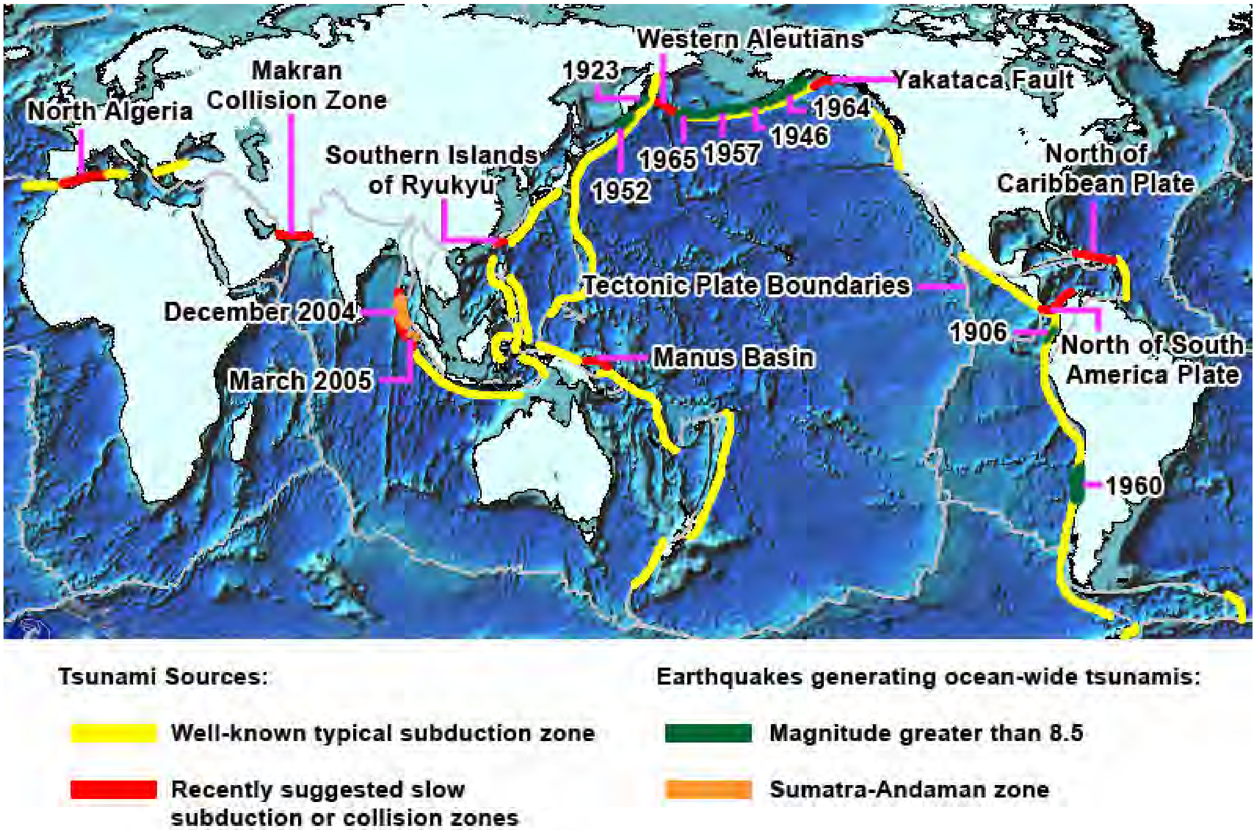

FIGURE 24: MAP OF GLOBAL FAULT ZONES THAT MAY CAUSE TSUNAMIS

Phase Requirements	Mitigation	Warning	Response	Recovery
Target	Land cover and elevation maps of coastal areas Bathymetric mapping in coastal waters	n/a	Affected areas	Affected areas
Revisit	Annual or multi-annual	n/a	Daily	Weekly for several months
Timeliness/ latency	Weeks	n/a	Within 2 hours	A few hours
End use	Baseline for response Mapping if high risk areas	n/a	Update to response operations centre	Logistics tracking, land cover rehabilitation

FIGURE 25: EO REQUIREMENTS FOR TSUNAMIS

IV. Issues

The analysis of the user requirements raises a large number of issues that must be addressed in parallel to the development of system architecture. These issues go well beyond the identification of data gaps, and address questions such as capacity development needs and the inexistence of service providers in relation to some core needs.

At a high level, some of the issues identified include:

- Disaster managers in most cases cannot use raw satellite data
- Often no clear vision of how to integrate data into existing systems, and little or no capacity in disaster management community to develop GIS and integrate data
- Operational turn-key products and services are expensive for large areas and outside mandates of space agencies to produce
- User requirements for data will depend on which systems are operational – varies by region and even by country
- User requirements depend on means to address them – users want inexpensive or free data, and will try to these before paying for "better" data (e.g. MODIS and Landsat vs. RADARSAT for flooding – RADARSAT often offers better flooding information but at a much greater cost)
- Very large number of case studies performed to demonstrate how satellite data can be used to support disaster management
- Many systems focus on free data, but as consequence do not maximize potential impact
- No clear vision for operational system that capitalizes on established cases studies
- Operations require sustained commitment (financial, programmatic, capacity development)
- Operational disaster management community not familiar with satellite data and its potential applications
- Capacity building in developing countries and capacity development in other countries
- Data access in near-real time and data access more generally
- Funding for mitigation and warning activities
- Forms of public-private partnership to access private sector capacity and infrastructure

V. Next Steps

A similar methodology to that used for compiling user needs will be used to match those needs with prospective architectures. The architecture requirements are to be derived from each set of user requirements. This process has begun, but still requires validation by user communities and a roll-up across all disaster types and phases. This process will also include a gap analysis, beginning with systems already in orbit or planned to be in orbit, and a prioritization process based on the maximum value brought by new systems to fill existing needs.

The areas covered by type and by phase will be:

- What type of satellite data? (SAR, optical, altimetry, etc)
- Number of satellites and coverage mode?
- Ground segment
- Application

Subsequently, the group will undertake the consolidation of the validated requirements and examine options for system development and implementation, using the following steps:

- Roll-up across all disaster types to establish overall architecture requirements for Earth observation satellites
- Simulation of satellite systems to respond to the requirements
- Gap analysis for existing and planned satellite systems
- Recommendations for future satellite systems

These aspects will be developed in the second volume of this report, designed to address architecture requirements.

It is clear from initial work in this area that the greatest challenge is to prioritize the observations required to support disaster mitigation activity. Most satellites observations are useful to disaster managers if properly packaged and adapted to meet their needs. Identifying which satellites observations may make a critical difference to the way in which risk is managed is a more challenging feat, and one that may not meet with universal consensus, given conflicting interests and geographic disparities.

The table below is an initial lay-out of how critical requirements will be rolled up by disaster phase across all disaster types on a global basis, in an effort to establish which mission architectures could best meet the wide array of needs laid out in the earlier sections of this report.

Phase Requirements	Mitigation	Warning	Response	Recovery
Data type				
Coverage and revisit				
Potential data source				
Ground segment				
Application				

VI. Sources

UN-SPIDER Report to UN General Assembly (2005)

UN-SPIDER Bonn Conference Report (unpublished – 2007)

Geohazards Earth Observation Requirements (BRGM/RP 55719-FR) August 2007

CEOS Disaster Management Working Group Report (2004)

GMES Emergency Response Core Service Strategic Implementation Plan (2007)

RADARSAT Constellation User Requirements Document (2006)

Athena Global Disaster Report (2006)

Global Fire Monitoring Center (GFMC) repository of unpublished feasibility studies for operational wildland fire observation systems; GOFC/GOLD Fire Monitoring and Mapping Implementation Team 2nd Workshop on Geostationary Fire Monitoring and Applications Report (2006)

Living with Risk: a global review of disaster reduction initiatives, ISDR (2004)

ISDR website

International Charter Space and Major Disasters website

The World Bank - Natural Disaster Hotspots: A Global Risk Analysis (2005)
http://www.proventionconsortium.org/themes/default/pdfs/Hotspots.pdf

UNDP – Reducing Disaster Risk – A Challenge for Development
http://www.undp.org/cpr/whats_new/rdr_english.pdf

The following people and groups have been involved in the development of this report:

CEOS Disaster SBA team:
Steve Ambrose (NASA), Pakorn Apaphant (GISTDA), Philippe Bally (ESA), Bryan Bailey (USGS), Jerome Béquignon (ESA), Selma Cherchali (CNES), Ivan Csiszar (NOAA), Craig Dobson (NASA), Andrew Eddy (Athena Global), Ernest Hilsenrath (NASA), Steven Hosford (CNES), Jerome Lafeuille (WMO), Shimada Masanobu (JAXA), Steven Neeck (NASA), Marc Paganini (ESA), Elaine Prins (University of Wisconsin – SSEC), Chris Schmidt (University of Wisconsin – SSEC), Guy Seguin (Canadian Space Agency), Giovanni Valentini (Italian Space Agency), Marian Werner (DLR-HR), Stan Wilson (NOAA), Claus Zehner (ESA).

DI-06-09 GEO Task Group:
Irene Acevedo (UN Mission), Porrames Amatayakul (TMD), Steve Ambrose (NASA), Pakorn Apaphant (GISTDA), Robert Backhaus (UN-SPIDER), Somchai Baimoung (TMD), Philippe Bally (ESA), Jerome Béquignon (ESA), Michael Bittner (DLR DFD-KA), Alider Cragnolini (INTA), Ivan Csiszar (NOAA), Ian Downey (BNSC), Andrew Eddy (Athena Global), P. Fourlas (GSCP General Secretariat for Civil Protection), Paolo Gasparini (INFN), Evangelos Gerassopoulos (National Observatory of Athens – Institute of Environment Research and Sustainable Development),

Thomas Glade (Vienna University), Johannes Goldammer (Freibourg University), Bassam Habib (General Organization of Remote Sensing), Joachim Hill (Universität Trier), Steven Hosford (CNES), Ulrich Huth (DLR-ST-IZ), Chin-Young Hwang (Korea Aerospace Research Institute), Chu Ishida (JAXA), Ioannis Kaloghros (National Observatory of Athens – Institute of Environment Research and Sustainable Development (IERSD), Srisaang Kaojarern (GISTDA), Laura Kong (UNESCO), Manwan Koudmani (General Organization of Remote Sensing), Jerome Lafeuille (WMO), Gonéri Le Cozannet (Geohazards), Rosa Loizzo (Italian Space Agency), Georg Magerl (UNOOSA), Mark Majodina (South African Weather Service), N. Manalis (Ministry of Environment and Public Works), Sérgio Marques Barbedo (Skysoft Portugal - Software e Tecnologias, SA), Shimada Masanobu (JAXA), Shoji Matsubura (JAXA), Harald Mehl (DFD-UG), Robert Missotten (UNESCO), John Morrisroe (NOAA), Pete Mouginis-Mark (Hawaii Institute of Geophysics and Planetology), Mmboneni Muofhe (National Disaster Management Centre), Mbangiseni Nepfumbada (Department of Water Affairs and Forestry), David Nyomo (NASRDA/NCRS), Dr. Obrusnik (CHMI), J. Funso Olorunfemi (NASRDA/NCRS), Luciano Parodi (Foreign Ministry), Ivan Petiteville (ESA), Francesco Pisano (United Nations Institute for Training and Research Operational Satellite Applications Programme), Elaine Prins (GOFC-GOLD), K. Radhakrishnan (National Remote Sensing Agency), Shanti Reddy (ACRES), Andrianos Retalis (National Observatory of Athens – Institute of Environment Research and Sustainable Development), Alain Retiere (United Nations Institute for Training and Research Operational Satellite Applications Programme), David Richardson (ECMWF), Giovanni Rum (GEO Secretariat), Dr. Schau (GFZ Potsdam), Guy Seguin (Canadian Space Agency), Pierluigi Soddu (Italian Civil Protection Department), Gheorghe Stancalie (National Meteorological Adminstration), David Stevens (UNOOSA), Mohamed Tarabzouni (KACST), Prasong Thammapala (Department of Disaster Prevention and Mitigation), Larry Tieszen (USGS/EROS), Eikichi Tsukuda (AIST), Giovanni Valentini (Italian Space Agency), Igor Veselov (EMERCOM), Marian Werner (DLR-HR), Hideyuki Yamada (Ministry of Education, Science and Technology), Peter Zeil (Z.GIS), C. Zerefos (National Observatory of Athens), Nataliya Zubach (NSAU).

UN-SPIDER Bonn Workshop attendees:

Yousif Al Yah Madi (AD Police GHQ, UAE), Patricia Alarcón (Civil Defense of Michoacán, Mexico), Nicole Alleyne (CDERA), Khalfan Al-Noaimy (AD Police GHQ, UAE), Sandra Amlang (UNISDR), Michael Angermann (DLR), Thanwarat Annan (GISTDA), Robert Backhaus (DLR), Suzanne Baltay (Infoterra), Jean-Luc Bessis (CNES), Jörn Birkmann (UN-EHS), Janos Bogardi (UNU-EHS), Ralf Busskamp (German Federal Institute of Hydrology), Sergio Camacho (UNOOSA), Alider Cragnolini (INTA), Lorant Czaran (UN/OCHA), Stefanie Dannemann (UNISDR), Bernd Domres (DGKM), Andrew Eddy (Athena Global), Marcel Endejan (GWSP/IPO), S.H.M. Fakhruddin (ADPC), Monika Gaehler (DLR / DFD), Vladimir Gershenzon (ScanEx), Mohsen Ghafory-Ashtiany (IIEES & IASPEI), Shaba Ahmad Halilu (NEMA), Martin Hellmann (DLR), Nicolas Heyer (RapidEye), David Hodgson (DMCII), Ulrich Huth (DLR), Saman Jalayerian (ISA), Franz Jaskolla (Infoterra), Norman Kerle (ITC), Nikolay Khabarov (IIASA), Ian King (UNDP), Marc Kleemann (LogicaGMC), Kenpei Kojica (ADRC), Rüdiger Koppe (Astrium), Algis Kucinskas (San Diego Super Computer Center), Niyazi Kerem Kuterdem (Earthquake Research Department), Jonatan Lassa (ZEF University of Bonn), Guido Lemoine (EC / JRC), Chuanrong Li (CAS), Georg Magerl (UN/SPIDER), Joseph Otieno Malo (Kenya National Academy of Science), Harald Mehl (DLR), Milorad Miloradov (Academy of Science and Arts of Vojvodina), Mirjana Miloradov (University of Novi Sad), Rogerio Mobilia (UN/OCHA), Rithy Moeun (UNISDR), Mario Giovanni Molina Masferrer (SNET), Michael Mundt (ESRI Geoinformatik), Richard Munz (IFHV), Takayuki Nakamura (JAXA), Juergen Nolte (LogicaGMC), Naceur Omrane (INCT), Douglas Pattie (UNISDR), Oleg Pinskyy (EADRCC), Francesco Pisano (UNITAR/UNOSAT), Serge Plattard (UN-OOSA), Roland Pleger (DLR), Jean Marc Racine (OAS), Lubna Rafiq (SUPARCO), Fabrice Renaud

(UNU-EHS), Torsten Riedlinger (DLR/DFD), Antonio Rogmann (University of Bonn), Michael Rose (BNSC), Giovanni Rum (GEO Secretariat), Dusan Sakulski (UNU-CUSA), Tania Maria Sausen (INPE), Bernd Michael Schneider (WADEM), Manfred Schroeder (bavAIRia e.V.), Holger Sdunnus (etamax space), Nate Smith (USAID/OFDA), Peter Stamm (WhereGroup), David Stevens (UN/SPIDER), Luc St-Pierre (UNHCR), Günter Strunz (DLR/DFD), Jörg Szarzynski (DLR/DFD), Micheline Tabache (ESA), Bekir Murat Tekin (Earthquake Research Department), M. Abdelhak Trache (CRASTE-LF), Hans-Jürgen Tscheulin (Tscheulin-TeleConsulting), Jan Ulrich (EC), Irma Velazquez (WHO), Juan Carlos Villagran De Leon (UNU-EHS), Stefan Voigt (DLR/DFD), Walter Wintzer (CEPREDENAC), Tsehaie Woldai (ITC), Ismail Adam M. Zain (Remote Sensing Authority), Karl-Otto Zentel (Katastrophenvorsorge).

UN-SPIDER Working Group:

Irene Acevedo (Chile/Permanent Mission to UN), Robert Backhaus (DLR), Alider Cragnolini (INTA), Ian Downey (BNSC), Andrew Eddy (Athena Global), Bassam Habib (GORS), Chin-Young Hwang (Aerospace Research Institute), Srisaang Kaojarern (GISTDA), Manwan Koudmani (GORS), Georg Magerl (UN/SPIDER), Mardianis (National Institute of Aeronautic and Space), Harald Mehl (DLR), John Morrisoe (USA/NOAA/NESDIS), David Nyomo (NCRS/NASRDA), J. Funso Olorunfemi (NCRS/NASRDA), Luciano Parodi (Foreign Ministry Chile), Francesco Pisano (UNITAR/UNOSAT), K. Radhakrishnan (NRSA/ISRO), Shanti Reddy (Geoscience Australia), Giovanni Rum (GEO Secretariat), Gheorghe Stancalie (National Meteorological Administration), David Stevens (UN/SPIDER), Mohamed A. Tarabzouni (KACST), Harry L. Tieszen (USGS/EROS), Igor Veselov (EMERCOM), Hideyuki Yamada (Ministry for Education, Science and Technology), Peter Zeil (Z-GIS), Nataliya Zubach (NSAU).

Special thanks to the team of international reviewers who examined requirements and architecture for each disaster type and provided valuable comment:

Flooding: Canadian Space Agency

Windstorms: David Richardson, ECMWF

Earthquakes: Craig Dobson, NASA

Landslides: Craig Dobson, NASA

Volcanoes: Craig Dobson, NASA

Drought: Ivan Czisar, NOAA

Wildfires: Johann Goldammer, Uni Freiburg; Ivan Czisar, NOAA

Tsunamis: Laura Kong, UNESCO