
Credits: Fa. Ilv im Auftrag von LMBV mbH.

CEOS
Disaster Risk Management Observation Strategy

Issue 2.1

CEOS ad hoc Disasters Team
November 1, 2013

Table of Contents

CEOS
Disaster Risk Management Observation Strategy

Executive Summary

The Disaster Risk Management (DRM) Observation Strategy is a response to a collection of observation requirements from the user community to enable the delivery of three coordinated pilots to be implemented in 2014-2016 in three thematic areas: floods, seismic hazards and volcanoes. Each of these thematic pilots aims to serve as a showcase for the international DRM community, in particular demonstrating a) the added value and uniqueness of increased CEOS coordination in this area; b) benefits of closer ties to users and ease of access to data; c) potential for increased roles of space agencies in DRM beyond the current Hyogo Framework for Action, for the following 10-year period starting in 2015. In addition, the Observation Strategy proposes the establishment of a Recovery Observatory, which would coordinate the reaction of volunteer CEOS agencies to a massive disaster on a scale similar to the Haiti Earthquake of 2010 or Japanese Tohoku tsunami of 2011.

The current document provides a detailed definition of the three thematic pilots together with their respective Earth observation (EO) remote sensing data requirements. In addition, it includes a draft proposal for the Recovery Observatory. The final Recovery Observatory proposal will be presented to the next CEOS SIT meeting (Spring 2014). The response to the pilots' EO data requirements by the CEOS Agencies (i.e. acquisition plans of relevant satellite missions & instruments) will be consolidated following the 2013 CEOS Plenary and will be presented at the next CEOS SIT meeting; potential satellite missions to address requirements included in this document are only given on an indicative basis.

The main goals that led CEOS agencies to propose the current activities are threefold:

- To support the protection of lives and safeguarding of property;
- To foster increased use of EO in support of DRM; and
- To raise the awareness of politicians, decision-makers and major stakeholders of the benefits of using satellite EO in all phases of DRM.

Successful contribution from space agencies to DRM will:

- Increase the awareness of decision-makers of the critical role of satellite EO; and
- Reinforce the need for enhanced satellite EO programs to better address DRM needs.

The long-term vision for CEOS' enlarged actions for DRM is a contribution that is:

- Global in scope, but building on strong partnerships at local/national or regional levels;
- User-driven (i.e. defined against user information needs and based on the engagement of the diverse user communities involved in DRM);
- Full-cycle (i.e. address mitigation/preparedness, warning, response/recovery, etc.);
- Addressing several hazard types;
- Taking account of all relevant EO based capabilities available (such as for instance the International Charter Space & Major Disasters, Sentinel Asia, etc.) or under development; and
- Sustainable through partnerships.

About 35 Experts from CEOS Agencies and 25 from non-CEOS organisations representing the user community (user and practitioner community at local/national or regional levels) have worked together to establish for each pilot a list of real and prioritized user needs translated then into EO data requirements. Particular attention has been dedicated to ensuring that the EO data to be provided by the CEOS Agencies will be processed or used by a well-identified community. The three pilots and the Recovery Observatory have been defined with the goal to produce significant outcomes already at the time of 2015 World Conference on Disaster Risk Reduction – WCDRR organized by the United Nations in Japan (Sendai, 2015). The positive feedback expected in the coming months from the user community is therefore key to the success of the CEOS Disaster initiative. While the main role of CEOS Agencies is to deliver EO data to support each pilot, the intermediate and final users of this data have been closely involved in the definition of the three pilots and in particular to agree on a detailed list of outcomes and deliverables to be generated by CEOS Agencies and by the user community engaged in the pilots.

With the CEOS DRM Observation Strategy, CEOS sets targets for the three thematic pilots and the Recovery Observatory.

Floods:

Demonstrating the effective application of satellite EO to the full cycle of flood management at global and regional/local scales:

- Integrating existing near-real time global flood monitoring and modeling systems.
- Linking global systems to regional end-to-end pilots that produce high-resolution flood mitigation, warning and response products and deliver flood and flash flood related services in:
  - The Caribbean (with particular focus on Haiti);
  - Southern Africa, including Namibia, South Africa, Zambia, Zimbabwe, Mozambique and Malawi;
  - Southeast Asia (with particular focus on the lower Mekong Basin and Western Java, Indonesia).
- Developing new end products and services to better deliver flood related information and to validate satellite EO data and products with end users, including retrospective products working from archived EO flood extent data;
- Encouraging regional in-country capacity building to access EO data and integrate into operational systems and flood management practices.

Benefits of CEOS activity:

There are a large number of flood related initiatives underway around the world, in every region of the world, and on a global basis, working with different data sets and sensors and developing different products. While the advent of rapid mapping using satellite EO has led to some degree of standardization in the context of EO based response capabilities (such as the International Charter Space & Major Disasters, Sentinel-Asia, etc.), there is a need for greater cooperation across existing projects to develop common approaches on how to collect data for flood monitoring and the prevention of flood damage, and how to exploit data and derived information from them. Furthermore, there is a strong need for comparison of results across local, national and global efforts to enable global systems to become more accurate and to chart a path for sustained local and national monitoring on an on-going basis across the world. Only CEOS offers the breadth of membership and sensor platforms to provide the full range of necessary data to support an effort that groups end-users, practitioners, and satellite operators. CEOS offers a unique venue to improve the efficiency of satellite observations through coordination of observing strategies across multiple agencies and comparison of products to improve the standardization of observing practices in support of flood monitoring products. The pilot will generate new products as a result of the combination of several satellite sources, which enables a higher degree of accuracy. In some areas, the use of more than one mission with similar instrument type over a specific geographical zone can be harmonized to eliminate redundant data collects and allow new areas to be imaged.

Recommendations:

In considering the needs for a CEOS pilot, the ad hoc Team recommends focusing on integrating existing products and services so that they are easier for users to access, and on demonstrating how global and regional observations can work together enabling EO-based flood monitoring products and services to be delivered. The products and services operate at separate scales, with global observations based on low spatial and high-temporal resolution observations, and regional pilots based on high spatial and lower temporal resolution observations. The flood thematic team has developed regional work components for Southern Africa, the Caribbean/Central America and Southeast Asia (Lower Mekong Delta and Western Java). The innovative approach of the CEOS flood pilot, using both a global and a regional approach, allows for the validation of improved global monitoring through regional efforts, establishing a baseline for future global monitoring and developing advanced regional products in coordination with regional and national end users.

Seismic hazards:

- Supporting the generation of globally self-consistent strain rate estimates and the mapping of active faults at the global scale by providing EO InSAR and optical data and processing capacities to existing initiatives, such as the iGSRM *[Wide extent satellite observations]*
- Supporting and continuing the Geohazard Supersites and Natural Laboratories (GSNL) for seismic hazards and volcanoes *[Satellite observations focused on supersites]*
- Developing and demonstrating advanced science products for rapid earthquake response *[>Magnitude 5.8]*

Benefits of CEOS activity:

While the CEOS activity build on some major, existing initiatives, the involvement of CEOS offers clear added value. For wide area observations, CEOS offers a coordinated approach to observations, eliminating overlap and duplication, allowing the gathering of data necessary for large-scale ground motion and fault mapping. These high-resolution, continuous coverage, strain rate and fault maps will in turn become an essential input to probabilistic seismic hazard estimation, today based only on seismicity models and historical earthquake catalogues (as in the Global Earthquake Model project); CEOS also offers a framework in which users and practitioners can be federated; finally CEOS offers new tools developed through contributions of CEOS pilot partners to enable the generation of advanced products, through the development of an exploitation platform. The involvement of a range of CEOS agencies allows more satellites to be used to collect data for rapid product generation, and allows satellite agencies to work together to establish standard collection protocols to support the generation of such products in the aftermath of earthquakes.

Recommendations:

In considering the needs for a CEOS pilot, the ad hoc Team recommends demonstrating on a regional scale how a global EO-based strain model would improve strain measurements for a better understanding of seismic hazards, developing the existing GEO Geohazard Supersites and Natural Laboratories and showcasing EO-based science products for rapid response to earthquake events. This challenge involves selecting a subset of the global 15% of terrestrial landmass (in Turkey, the Himalayas and the Andes) in which to validate the global modelling work.

Volcanoes:

- Demonstrating comprehensive monitoring of Holocene era volcanoes in the Latin American volcanic arc
- Developing new protocols and products over active volcanoes where EO data collects are already taking place (GSNL – Hawaii, Iceland)
- Demonstrating operational monitoring over a large scale eruption (e.g. Merapi 2010) during 2014-2016

Benefits of CEOS activity:

This pilot represents a stepping-stone towards the long-term goals of the Santorini Report ("Scientific and Technical Memorandum of The International Forum on Satellite EO and Geohazards", cf. reference documents) with respect to volcanic activity, namely: 1) global background observations at all Holocene volcanoes; 2) weekly observations at restless volcanoes; 3) daily observations at erupting volcanoes; 4) development of novel measurements; 5) 20-year sustainability; and 6) capacity-building. By completing a regional study of volcanic activity in Latin America (sustained regional monitoring over time), the CEOS pilot will demonstrate the feasibility of a global monitoring programme over all Holocene volcanoes. The development of a comprehensive monitoring programme that includes all potentially active volcanoes and works in close cooperation with local and national end-users will serve as a showcase to demonstrate the value of EO-based monitoring, especially in areas where volcano observatories have fewer resources. Such an ambitious monitoring programme is only possible through the collective effort of many agencies working together under an umbrella such as CEOS to achieve a mutually sought-after goal. In-depth monitoring using EO at established volcanic hotspots (the GSNL supersites) will enable the improvement of operational protocols for monitoring of active volcanoes. Data contributions from different agencies enable a truly multi-platform approach to be developed. These protocols and new products can be demonstrated in the event of a major eruption during the lifetime of the pilot.

Recommendations:
In considering the needs for a CEOS pilot, the ad hoc Team recommends focussing on demonstrating how in a single region— Latin America—comprehensive use of satellite-based EO could significantly improve volcano monitoring practices, especially before and during eruptions. The pilot will also take advantage of existing agreements in the context of the Geohazard Supersites and Natural Laboratories (e.g. Hawaii, Iceland), to develop new EO-based monitoring techniques to be applied in other areas. In the event of a large-scale volcanic eruption in the 2014-2016 timeframe, such as the Merapi eruption of 2010, the pilot will apply existing and newly-developed methodologies and protocols to demonstrate how satellite EO can save lives and protect property through improved warning and response.

Recovery Observatory:

Coordinating sustained access to EO data by non-profit organisations and local end-users, to support reconstruction and recovery efforts after a major catastrophic event.

Benefits of CEOS activity:
A Recovery Observatory will make available as much geospatial data as possible that may be of use in the aftermath of a major disaster and for a period of a number of years after the event. Such an observatory can be considered as a central resource, providing non-profit users' communities concerned by the event with all the data they need for supporting their activity in the longer-term response and recovery phases. CEOS offers access to a range of different satellites that collectively can provide a unique database to support recovery after a major disaster like that of Haiti in 2010 or the Japanese tsunami in 2011. A single space agency working alone cannot provide the necessary coverage and volume of data to properly support a major international effort on this scale. This is also a unique opportunity for CEOS to showcase how useful EO can be when properly coordinated and applied efficiently to address DRM concerns. In the first instance, CEOS agencies and partners will work on precisely defining the Recovery Observatory concept and establishing all necessary conditions and mechanisms. The following figures from the Haiti experience show that the contribution requested to the Space Agencies is marginal with respect to the efforts deployed following the Charter activation: approximately 3Tb of data

(69000 files) have been collected in the frame of the Charter while less than 150 images have been generated and distributed during Recovery period.

Recommendations:

In considering the needs for a CEOS pilot, the ad hoc Team recommends establishing a demonstration Observatory to allow international and local users to support multi-year recovery through:

- Built area damage assessment (initial and later detailed)
- Natural resource and environment assessment
- Reconstruction planning support
- Reconstruction monitoring; and
- Change monitoring.

A Recovery Observatory would collect varying information depending on the type of disaster and the length of the recovery period. However, it is possible to make some generalizations on the type of data information products required, which include:

1) Baseline data from before the disaster to establish impact of disaster;
2) Updated exposure data to establish the impact of the disaster and track progress towards recovery;
3) Data collected during and immediately after the event;
4) Regular updates to maps (derived from satellite EO) showing condition of critical infrastructure (e.g. transportation networks, hospitals, energy networks, etc) and building stock (built-up areas and extent of damage);
5) Change detection products showing the evolution of the natural and built environment.

CEOS Disaster Risk Management Pilots in the Global Context - introduction

The CEOS Disaster Risk Management (DRM) Observation Strategy is the product of work by the CEOS ad hoc Disasters Team (ad hoc Team) since the presentation of the 2012 Consensus Report to the 26th CEOS Plenary (October 2012). The Consensus Report aimed to define 'enlarged actions' to support DRM. This Observation Strategy should be read in conjunction with the 2012 Consensus Report, as well as the three CEOS thematic pilot proposals (floods, seismic hazards and volcanoes) and the proposal for the Recovery Observatory, which are included in annex. The ad hoc Disasters WG currently includes representatives from nine CEOS agencies (ASI, CNES, CSA, DLR, ESA, JAXA, NASA, NOAA, and USGS), the CEOS Executive Officer, a representative of the GEO Secretariat and numerous experts from non-CEOS agencies that have contributed to the Observation Strategy through active participation on the three thematic teams on floods, volcanoes and seismic hazards. The ad hoc Team members are listed in annex to the report.

The purpose of this document is to address the action assigned to the CEOS ad hoc Disasters Team at the 26th Plenary meeting in 2012, namely, the development of a comprehensive, coordinated observation strategy to support disaster risk management efforts. It is submitted to the 27th CEOS plenary meeting in Montreal in November 2013 for approval. The first part of this document summarizes the global needs analysis of the ad hoc Disasters Team Consensus Report and extends it to new areas not covered by the report. The second part of this document focuses on the specific needs of the three pilots and Recovery Observatory and explains the EO data requirements to meet the objectives of the proposed pilots. Collectively, the document articulates a CEOS DRM Observation Strategy for the 2014-2016 period that if approved will be implemented through a Strategic Data Acquisition Plan to be developed and approved at the spring 2014 SIT meeting.

This strategy implements the first recommendation of the Consensus Report, namely, the development of a comprehensive, coordinated observation strategy to support disaster risk management efforts. The Observation Strategy covers the 2014-2016 period, in support of three thematic pilots developed to demonstrate to the global DRM stakeholder community how satellite-based EO can better contribute to risk and disaster management.

After the 2014-2016 period, at the 2016 Plenary, CEOS will assess the results achieved through its DRM Observation Strategy and consider approaches for sustained support from satellite-based EO for the DRM community.

The main goals that led CEOS agencies to propose the current activities are threefold:

- To support the protection of lives and safeguarding of property;
- To foster increased use of Earth observation (EO) in support of DRM; and
- To raise the awareness of politicians, decision-makers and major stakeholders of the benefits of using satellite EO in all phases of DRM.

Successful contribution from space agencies to DRM will:

- Increase the awareness of decision-makers of the critical role of satellite EO; and
- Reinforce the need for enhanced satellite EO programs to better address DRM needs.

The long-term vision for CEOS' enlarged actions for DRM is a contribution that is:

- Global in scope, but building on strong partnerships at local/national or regional levels;
- User-driven (i.e. defined against user information needs and based on the engagement of the diverse user communities involved in DRM);
- Full-cycle (i.e. address mitigation/preparedness, warning, response and recovery);
- Multi-hazard; and
- Sustainable through partnerships.

The DRM Observation Strategy is a response to a collection of observation requirements from the user community to enable the delivery of three coordinated pilots to be rolled out over 2014-2016 in three thematic areas: floods, seismic hazards and volcanoes. Each of these thematic pilots aims to serve as a showcase for the international DRM community, in particular demonstrating a) the added value and uniqueness of increased CEOS coordination in this area; b) benefits of closer ties to users and ease of access to data; c) potential for increased roles of space agencies in DRM beyond the current Hyogo Framework for Action, for the following 10-year period starting in 2015. In addition, the Observation Strategy proposes the establishment of a Recovery Observatory, which would coordinate the reaction of volunteer CEOS agencies to a massive disaster on a scale similar to the Haiti Earthquake of 2010 or Japanese Tohoku tsunami of 2011.

In developing the pilots, CEOS worked in a progressive manner, beginning with contributions that highlight the benefit that satellite Earth Observations can provide and that aim at filling identified gaps. The thematic teams worked from existing projects, developing a vision and proposals for new pilots that will achieve CEOS objectives. These coordinated pilots, at their mid-term review, will allow CEOS to make a visible and concrete contribution to the post-2015 Hyogo Framework for Action 2. The pilots require strong user involvement to be successful, as users are the best champions for EO integration. Each thematic team has worked closely with practitioners and end users to define the objectives, activities and products of each pilot. The three thematic teams have conceived, defined and proposed pilots that underpin the Observation Strategy. Thematic experts both from within CEOS agencies and from non-CEOS bodies expert in the three areas of activity have joined the thematic teams to participate in the definition of the proposed pilots, review existing projects for possible synergies, identify key outputs and benefits and support the development of strong ties to user communities.

I. Pilot Priority Themes & Hazard Occurrence Maps

In December 2012, the ad hoc Disasters Team selected three priority themes that the pilots would address over the 2014-2016 period. These priorities were selected on the basis of the extent of their impact through loss of life and economic loss, their potential for catastrophic impact and the value brought by integrating satellite-based EO into existing and new DRM solutions. The three priority themes selected are floods, seismic hazards and volcanoes. This does not preclude that other themes may be added to the CEOS activities on a voluntary basis if the resources necessary for their implementation are available, but the Team recommended to the CEOS Plenary to initially focus on a small number of disaster types and to undertake a limited number of activities to be able to clearly demonstrate already by 2015, the relevance and added value of satellite-based EO to DRM. The section below summarizes the global need perceived for each of these areas, while the thematic pilots aim to address a subset of that need for demonstration purposes and to develop a vision for global implementation beyond 2016.

Global Flood Needs

Global flood management needs involve a wide range of users, practitioners and stakeholders. As a general statement, users interested in flood monitoring and modeling at a global level generally work at much coarser resolution than those at the regional, national or local level. The needs reflected below aim to address both types of flood monitoring. At the global level, several teams are currently working on systems that aim to model and predict flooding globally on a daily basis. Other efforts focus on local and national flooding with a view to providing high spatial resolution information (typically 10-50m for rural areas and 1m for urban areas). The CEOS effort aims to combine both approaches and demonstrate the value of integrating information collected at both levels.

Flooding is important as it is the most common hazard on a frequency and area-affected basis, and affects the largest number of people, though large earthquakes and tsunamis are generally responsible for more fatalities over time. Flood risk is dynamic, changing over time based on land use practice changes or subsidence for example. This means that tracking flood risk requires information on both water and the areas that may potentially be flooded. DRM users are concerned by all emergencies, not just large-scale disasters. In this regard, support to global flood risk monitoring is much more ambitious than responding to single large-scale events. On a daily basis, small-scale floods occur in many different countries with real impact on populations and property. Satellite EO can play a meaningful role in reducing flood risk when integrated into a

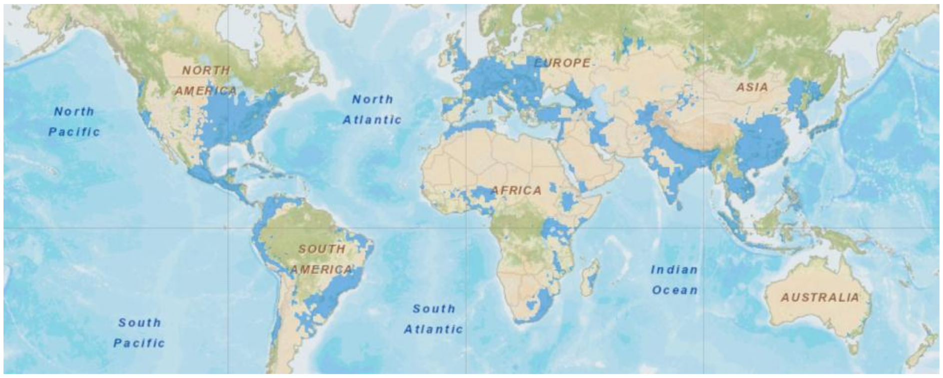


Figure 1. Example of global priority area map concerning the flood hazard used by European RESPOND and SAFER risk management projects

broader approach. Compared to other hazard types, global risk maps concerning flooding are subject to controversy. It is difficult to gather the required underlying data and information. There are 33 major river basins in the world, covering huge areas. In addition, there are many areas outside of major river basins that are subject to flooding on a regular or irregular basis. For comprehensive monitoring, all these areas need to be imaged several times weekly during the flooding season, and at least once during the dry season, in order to build up a database of flood levels that can be used to properly evaluate flood risk on an on-going basis. While some of these areas are already imaged, a systematic approach is required to complement existing imaging efforts with missing data and effectively use the data collected. Many flood modellers argue that in order to properly monitor and model flood events, daily monitoring of water systems on a global scale is necessary. Flood risk areas are immense as illustrated in figure 2, above. The map, generated in the framework of the GMES RESPOND and SAFER projects to indicate priority areas worldwide, illustrates some of the areas of the world most vulnerable to flooding and where a coordinated strategy for regular data collects could make a significant difference. It should be noted that while the map was generated by the RESPOND programme, the volume of required observations was such that the need remains unanswered today. Ensuring satellite EO data are acquired is a challenge due to the vast areas considered and large volumes of data required.

In considering the needs for a CEOS pilot, the ad hoc Team recommends focussing on integrating existing products and services so that they are easier for users to access, and on demonstrating how global and regional observations can work together enabling EO-based flood monitoring products and services to be delivered. The products and services operate at separate scales, with global observations focussed on low spatial and high-temporal resolution observations, and regional pilots focussed on high spatial and lower temporal resolution observations. The flood thematic team has developed regional work components for Southern Africa, the Caribbean/Central America and Southeast Asia (Lower Mekong Delta and Western Java). The innovative approach of the CEOS flood pilot, using both a global and a regional approach, allows for the validation of improved global monitoring through regional efforts, establishing a baseline for future global monitoring and developing advanced regional products in coordination with regional and national end users.

Global Seismic Needs

Earthquakes represent one of the world's most significant hazards in terms both of loss of life and damages, and are also responsible for many other related fatalities and damages through tsunamis, which are triggered by earthquakes. In the first decade of the 21st century (2000-2010) earthquakes accounted for 60 percent of deaths from natural disasters, according to the United Nations International Strategy for Disaster Reduction (UNISDR). In 2010, more than 225,000 people were killed.[1] Even when loss of life is reduced, the economic impact can be devastating. The M9.0 Tohoku Japanese earthquake in 2011 killed 100 people, but nearly 20,000 lost their lives in the subsequent tsunami, and losses of the overall event are

[1] http://disasterphilanthropy.org/where/issue-insights/earthquakes/#sthash.ONRw6yCe.dpuf

estimated at over $360 billion.[2] National and Regional Civil Protection authorities, Seismological centers, and National and Local authorities in charge of seismic risk management activities are concerned with the phases of prevention, preparedness, early warning, response, recovery, rehabilitation and reconstruction. Beyond operational users with a mandate in seismic risk management, there is a range of geoscience users focused on the scientific use of data with the main goal of understanding the physics that drive earthquakes, thereby improving our ability to characterize, understand, and model seismic risk.

The science users of seismic risk management require satellite EO to support mitigation activities designed to reduce risk. They are carried out before the earthquake occurs, and are presently the only effective way to reduce the impact of earthquakes on society –short term earthquake prediction today offers little promise of concrete results. The assessment of seismic hazard requires gathering geo-information for several aspects: the parameterization of the seismic sources, knowledge of historical and instrumental rates of seismicity, the measurement of present deformation rates, the partitioning of strain among different faults, paleo-seismological data from faults, and the improvement of tectonic models in seismogenic areas.

Operational users of seismic risk management do have needs for geo-information to support mitigation, although the need for situational awareness during response often receives more attention. Satellite EO can contribute by providing geo-information concerning crustal block boundaries to better map active faults, maps of strain to assess how rapidly faults are deforming, and geo-information concerning soil vulnerability to help estimate how the soil is behaving in reaction to seismic phenomena. On an emergency basis, the first information needed after a large earthquake occurs is an assessment of the extent and intensity of the earthquake impact on man-made structures, immediately after which it becomes important to formulate assumptions on the evolution of the seismic sequence, i.e. where local aftershocks or future main shocks (on nearby faults) are most likely to occur.

Based on the priorities defined at the 2012 International Forum on Satellite EO and Geohazards, the seismic community has set out a vision of the EO contribution to an operational global seismic risk program. In 5 to 10 years' time, EO could provide fundamental new observations of the seismic belts - around 15% of the land surface – and improved understanding of seismic events through the work of the GSNL.

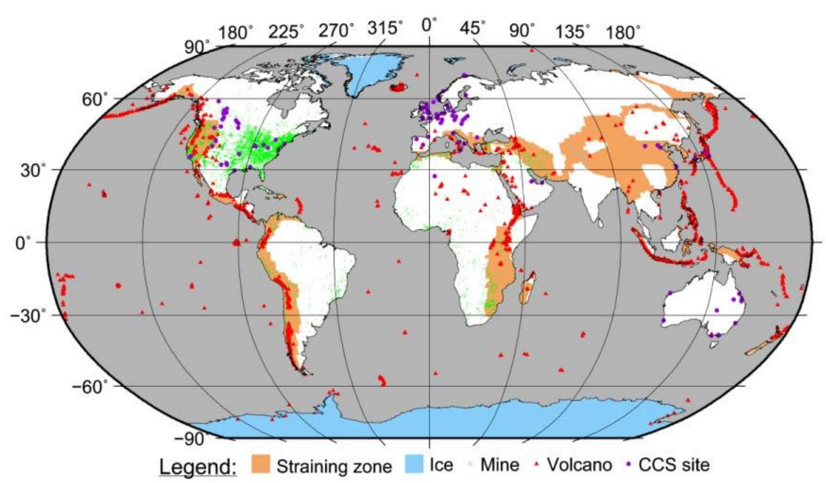


Figure 2. Straining areas (seismic belts) and volcanoes of the world. (Kreemer et al., 2003). Figure from the GSNL Strategic Plan 2012.

As proposed by the seismic community, a satellite EO-based programme will enable:

1. *Development of a high resolution global strain rate model (GSRM) at high spatial resolution incorporating*

deformation constraints from GNSS and InSAR. InSAR allows essentially continuous observations of the seismic belts worldwide with near-uniform quality.

2. *New regional or global maps of active visible faults*, incorporating the latest results from the geomorphological analysis of high resolution optical imagery and digital topography data.

3. *The creation of a new global seismic hazard map* based on 1 and 2.

4. *To continue the GSNL* and provide precise measurements, including frequent acquisitions with multiple SAR sensors, over geographically focused areas to ensure strain rate measurements of unprecedented accuracy. The GSNL are supported by numerous partners including GEO, ESA, JAXA, NASA, DLR, ASI, CSA, NSF, UNAVCO and EPOS.

5. *Rapid response to earthquakes*, including:

(a) Automatic rapid estimation of earthquake damage using high-resolution optical and radar imagery, and InSAR coherence using available capacities.
(b) Automatic rapid creation and web-publication of co-seismic interferograms (wrapped and unwrapped) from all available sensors.
(c) For non-specialist end users, products derived from the interferograms, such as phase gradient maps, combined with critical infrastructure data, could be produced.
(d) (Semi-) automatic fault modelling – rapid production and web-publication of fault parameters using simple, consistent techniques.
(e) Prediction of damage distribution using this fault model.
(f) Rapid calculation of Coulomb Stress changes on neighbouring faults to assess likely locations of aftershocks or triggered earthquakes. The fault model in (d) would be used initially, along with any data on historical seismicity (e.g. from USGS archives).
(g) Collection of InSAR data to support fundamental research on earthquake fault mechanics using observations of the early post-seismic phase. These observations (hours to days after the event) are now possible thanks to the multiple sensors available to the GSNL.

6. *A long-term response to earthquakes* that involves acquiring radar data for years to decades after an earthquake in order to measure post-seismic deformation.

> In considering the needs for a CEOS pilot, the ad hoc Team recommends demonstrating on a regional scale how a global EO-based strain model would improve strain measurement, developing the existing GEO Geohazard Supersites and Natural Laboratories and showcasing near-real time EO-based science products in response to earthquake events. This challenge involves selecting a subset of the global 15% of terrestrial landmass (in Turkey, the Himalayas and the Andes) in which to validate the global modelling work.

Global Volcano Needs

Global volcano monitoring needs involve a wide range of users, practitioners and stakeholders. This document includes the needs relating to monitoring of both the ground and the atmosphere. The starting point for the analysis was the Santorini Report[3], with modifications brought by the expert members of the volcano team.

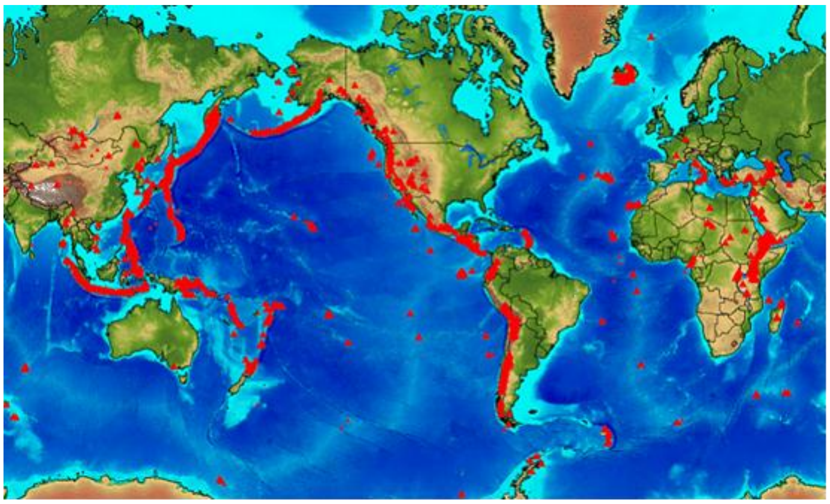


Figure 3. Holocene active volcanoes (Global Volcanism Program of the Smithsonian Institution, www.volcano.si.edu/world/find_regions.cfm)

About 1,500 volcanoes are known to have erupted in the last 12,000 years (the Holocene Era); about 700 of these, mostly subaerial, have erupted at least once in historical times (Siebert et al., 2010). Worldwide, about 100 episodes of volcanic unrest are observed yearly, about half of which evolve into some sort of eruption. It is estimated that less than 10% of active volcanoes are monitored on an on-going basis (by ground-, air-, and/or space-based sensors), meaning that about 90% of potential volcanic hazards are either monitored occasionally or not at all. There is a greater number of active submarine volcanoes than subaerial ones, but the precise number is unknown. Almost all active volcanoes are associated with plate boundaries or hotspots, with particularly large numbers around the Pacific Rim (figure 3). The conversion of hazard to risk depends on the location of people and assets at risk, and their dependence on time. This leads to two risk terms, one related to geographically permanent exposures, such as cities and mega-cities at the feet of active volcanoes[4], and one that is transboundary, most often related to the emissions of volcanic ash and gases into the atmosphere.

The dramatic impact of transboundary emissions is well known to travellers. On April 14, 2010, a moderate effusive eruption of the Icelandic volcano Eyjafjallajökull - which began one month earlier - suddenly transitioned into phreato-magmatic explosive activity. The resulting closure of north and central European airspace between April 14 and 20 led to the cancellation of ~100,000 flights and the stranding of ~10 million passengers (about half of the world's air traffic). Oxford Economics (2010) estimated that the 2010 Eyjafjallajökull eruption had a total global economic impact of ~5bn€, and the International Air Transport Association (IATA) stated that the total loss for the airline industry was close to 1.5bn€. The

[3] Perspectives Concerning Satellite EO and Geohazard Risk Management: volcanic hazards, from the Santorini Conference, Fabrizio Ferrucci (IPGP), Fred Prata (NILU) et al.

[4] In Italy, Japan, Iceland, western central and southern Americas, northern-western USA and Alaska, Kamchatka, Indonesia, Philippines, Hawaii, Lesser Antilles, Azores, Canarias, Congo, etc.

driving force for explosive eruptions, the products of which are ash and gas (including SO_2), is provided by dissolved gas in viscous magmas. The resulting clouds can disperse in the troposphere and stratosphere, travelling very large distances (~1000's km) from the eruption source.

Three additional hazardous elements related to volcanoes are the expected length and path of volcanic flows (including lava, lahars, and pyroclastic density currents), the duration of unrest, and the impact of both on the management of territory and air space. Forecasting the direction and extent of volcanic flows is important to preparing the operational response to an eruption, including the time, location, type and extent of civil protection activities. For lava flows, the hazard is usually slow to develop (over days to weeks, except in some spectacular cases, as in the Congo in 1977 and 2002), and civil defense responses can evolve over time as the area to be affected by the hazard becomes better constrained. In explosive eruptions, however, ultrafast development of climaxes do not allow a timely response and all prevention measures –mostly involving evacuation of people from areas that are likely to be affected– should be taken well in advance of the hazard manifestation (the 2010 eruption of Merapi, which was anticipated far enough ahead of time that evacuations could be made, thus saving thousands of lives, is a good example). In general, however, the ability to take decisions is affected by a lack of knowledge concerning two crucial questions: when the first hazardous activity will be manifested, and when the eruption –or the eruptive cycle– will come to an end. Recent major worldwide crises illustrate that we can often only address the first question, and even then only with large uncertainty (a condition that is unacceptable when large numbers of people are affected).

In considering the needs for a CEOS pilot, the ad hoc Team recommends focussing on demonstrating how in a single region— Latin America—comprehensive use of satellite-based EO could significantly improve volcano monitoring practices, especially before and during eruptions. The pilot will also take advantage of existing agreements in the context of the Geohazard Supersites and Natural Laboratories (e.g. Hawaii, Iceland), to develop new EO-based monitoring techniques to be applied in other areas. In the event of a large-scale volcanic eruption in the 2014-2016 timeframe, such as the Merapi eruption of 2010, the pilot will apply existing and newly-developed methodologies and protocols to demonstrate how satellite EO can save lives and protect property through improved warning and response.

II. Users

There has been significant discussion within the ad hoc WG on the definition of the end user. The end users for DRM services are local and national authorities. They are the first to be concerned by disasters affecting populations, and have a mandate to protect them. These end users are the final users of information generated with EO satellite data integrated into information systems. A second category of users concerns intermediate users who generate information using satellite data and redistribute this information either to another intermediate user or to the end users. These intermediary users or practitioners may be either research institutes, other branches of government or private sector companies such as value-adding companies.

A global initiative requires international or regional champions that consolidate the needs of the users and serve as an intermediary for organisations such as CEOS. These organisations are not users, but rather stakeholders with a recognised interest in DRM and risk reduction in particular. Examples of such organisations include the Global Facility for Disaster Reduction and Recovery (GFDRR, hosted by the World Bank), the United Nations International Strategy for Disaster Reduction (UNISDR), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP) and the United Nations Science, Education and Culture Organisation (UNESCO). Other relevant organisations that may serve as relays or partners include United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER), United Nations Institute for Training and Research (UNITAR)/ Operational Satellite Applications Programme (UNOSAT) the World Meteorological Organisation (WMO), and the Group on Earth Observations (GEO).

The end users and intermediary users for the various themes addressed in the pilots are not always the same. While civil protection agencies and local and national governments are always concerned with disasters, thematic experts vary according to hazard type and are often involved in the front-line management of risk analysis and disaster warning, response and recovery.

The end user includes affected or to be affected people, in addition to local and national authorities and intermediary users. From experience of the International Charter and Sentinel Asia, it is clear that delivering data and information to the local and national authorities is not enough. The pilots need to ensure data and information will be correctly understood and used for early warning and decision making by local and national authorities. In the context of the pilots, scenarios or value chains for the DRM data and information distribution from the pilot to the people will be developed.

The following list of user categories is segmented by hazard type:

- Floods:

National and Regional Civil Protection Agencies, Meteorological services, Hydrological centres, National and Local authorities concerned with the phases of prevention, preparedness, early warning, response, recovery, rehabilitation and reconstruction. Beyond operational users with a mandate in flood risk management there is a range of science users focused on the water cycle.

There are three main user communities practicing flood risk and disaster management:

1. Emergency Response – this community is concerned with operational response to floods, and needs data and information products geared towards damage analysis and situational awareness.
2. Flood Risk Management – this group uses applied science, advanced imagery analysis and models before events, considering 100-year flood cycles to predict worst case flood scenarios and propose mitigation strategies to local and regional authorities.
3. Meteorological Users – this group is concerned hydro-meteorological events and forecasting precipitation and its impacts locally and nationally.

- Seismic hazards:

National and Regional Civil Protection Agencies, Seismological centres, National and Local authorities in charge of seismic risk management activities are concerned with the phases of prevention, preparedness, early warning, response, recovery, rehabilitation and reconstruction. Beyond operational users with a mandate in seismic risk management there is a range of geoscience users focused on the scientific use of data with the main goal of understanding the physics the drive earthquakes thereby improving our ability to characterize, understand, and model seismic risk.

There are four main user communities involved in seismic hazard activity:

1. Emergency Response – this community is concerned with operational response to major seismic events, and needs data and information products geared towards damage analysis and situational awareness.
2. Hazard Science Response – this group uses applied science, advanced imagery analysis and models during events to help develop the situational awareness needed to help facilitate the Emergency Response Community, bringing the science into an operational context.
3. Operation Science – this group is concerned with the mechanisms triggering events.
4. Hazard Science Research – this group is focused on pure science research.

- Volcanic risk:

Conceptually, the monitoring of volcano dynamics is dealt with by volcano observatories, which run arrays of instruments and carry out multi-parameter measurements for constraining geological, geochemical, and geophysical changes in time and space. While many of these measurements are collected by automated or remote instruments, all such data mush be interpreted by experts to better inform volcano hazards assessment and forecasting.

By nature, a volcanic eruption is a locally-relevant event that may turn into a trans-boundary event. Consequently, there are two categories of users of geo-information on volcanic activity (monitoring) and hazards (risk exposure assessment and mapping):

1. National Users: should be selected case by case from those responsible for disaster and risk management, or for giving scientific advice to those who make decisions to protect lives and property. Typically, the former is a Ministry or a mandated National Agency, whereas the latter is a volcano observatory, a geological survey or its equivalent.
2. Transnational Users: no ruling nor advising powers on the territory hosting the volcano. Typically represented by the Volcanic Ash Advisory Centres (VAACs), it is an intermediate link between the WMO, the International Civil Aviation Organisation (ICAO) and individual airlines,. While VAACs and similar agencies gather data from local volcano observatories (where they exist), they also independently monitor remote sensing data for signs of major ash and gas emissions.

- Recovery Observatory:

There are many types of users for satellite data and products involved in the reconstruction and recovery efforts after major disasters, including:

1. International users (or stakeholders): international organizations (either governmental like World Bank or Non Governmental Organisations like the Red Cross) with a mandate tied to the recovery of major disasters and a major stake in supporting recovery efforts. Identifying one or several such users that adopt the idea of a Recovery Observatory and are prepared to work with CEOS to have one implemented is critical to success. This organization would be the lead interface with other users immediately after the response phase, and would assist in defining the initial acquisition plan to be adapted form the generic plan prepared before the disaster
2. National users:for major disasters, the national body responsible for civil protection is typically the sole interface for the outside community (hence the idea of privileging a dialogue through an established DRM stakeholder which will have the requisite privileged access - necessary to be able to get people's attention after a major disaster). This body will authorize NGOs and other to work in the recovery area and is responsible for the coordination of recovery efforts. Their buy-in is essential as to be successful the Observatory must address their needs and the needs of their partners.
3. Local users: the local end user is the most affected, and may have no resources at all after a major disaster. However, ultimately, the local end user will be the key long-term partner for a recovery observatory. There needs to be some sort of transition so that as the Observatory is established, it develops a direct relationship with the local end user to ensure the Observatory is meeting needs and to adjust if desired and possible.
4. Practitioners or intermediary users: CEOS agencies will essentially provide data to the Observatory. Mechanisms must be established to allow participation of partners who can provide value-added products and services. These partners may be universities, government organizations or private companies. These intermediary users often include science or research users who work on data for scientific interest but with outputs that are used by civil protection authorities. In some cases, CEOS contributions may include some value adding or training and capacity development. This needs to be set up in a single comprehensive framework where the roles of partners are made clear before the Recovery Observatory is triggered. Intermediate users should be able to:
    - understand user requirements;
    - from the user requirements identify and generate high level products;
    - help to identify EO data acquisition plan;
    - train the users in the use and interpretation of the derived products and, when possible;
    - try to transfer EO-based methodologies and practices to ensure sustainability EO.

III. Information Needs and Satellite EO Abilities

III.1 Views from users & experts of the thematic teams

Flood Information Needs in the context of the CEOS DRM Pilot

1) Global flood modelling: comprehensive mapping/modelling (using EO and information technology) of daily global surface water extent using EO-based data to show changes and predict floods

Today, LEO SAR missions are not systematically used for alert. A 'constellation' approach of SAR missions, coordinating distributed capacity, would allow alert/warning using this approach. EO data is also provided by meteorological missions and satellite rainfall data (e.g. GPM/TRMM) to complement (or replace if unavailable) rainfall gauge measurement; would include flood simulations and flood forecasts using meteorological and hydrological forecasts.

2) Regional flood monitoring and modelling: rapid daily flood extent maps during flood seasons beginning before flood onset and continuing throughout flood period (weeks or months), high resolution regional and local flood models for frequently flooded areas

This is a reactive effort primarily based on redundant LEO mission data (SAR and optical used in combination) to obtain rapid access to imagery to map observable flooding traces. This includes rapid damage assessment and mapping of the maximum flood extent and helps Post Disaster Needs Assessment in recovery.

3) Integrated information systems: a flood dashboard for each of the regional pilots showcasing key products and recapping main data inputs, and a global flood dashboard that offers a global overview

4) Historical EO-based flood mapping (10-year archive) on global scale to address future flood risk based on past flood extent

Seismic Information Needs in the context of the CEOS DRM Pilot

1) Terrain motion mapping for seismic risk estimation (to support global strain mapping): crustal block boundaries mapping to support seismic fault investigations, earthquake cycle investigations and investigations of vertical deformation sources in urban areas; precise terrain deformation to support soil vulnerability mapping.

This is based on conventional INSAR and PSI techniques and is primarily based on space-borne SAR (HR or VHR). It requires repeat observations (typically multi-year). The specific aim is to deliver information on crustal faults, including their slip rates and locking depths.

Geoscience users recommend the creation of a new global strain rate model at high spatial resolution (a new seismic hazard map) that would incorporate InSAR- and GPS-based measurements. Current initiatives are only GPS-based. This would include the provision of satellite interferometric data for continuous observations of the seismic belts worldwide. To understand earthquake physics a long-term response involves acquiring radar data for years to decades after an earthquake in order to measure post-seismic deformation. This model would improve with time as new EO mission data become available but accuracies should be sufficient for a first release after 3-5 years of regular acquisitions. The primary model would show the average deformation rates during the observation period; areas showing significant deviations from steady-state deformation could also be identified.

Geoscientists require access to space-borne InSAR and *in-situ* geophysical data concerning earthquake risk areas and earthquake events. Users from the Santorini Conference identified the following needs:

- Development of a global strain map based on InSAR data, as well as access to pre- and post-event InSAR data;
- Automatic rapid creation and web publication of co-seismic product derived interferograms (wrapped and unwrapped) from all available sensors
- Simple identification of fault breaks combined with information about earthquake mechanisms to derive estimated surface offsets;
- (Semi-) automatic fault modelling – rapid production and web-publication of fault parameters using simple techniques;
- Rapid calculation of Coulomb Stress changes on neighbouring faults, a calculation used to assess likely locations of aftershocks or triggered earthquakes;
- Prediction of damage location based on fault models; and,
- Rapid estimation of earthquake damage using high resolution optical and radar imagery, and InSAR coherence.

2) Rapid mapping and related products in response to earthquakes to support earthquake science

This is a reactive effort primarily based on InSAR data, to obtain rapid access to value added products to support evaluation of earthquakes. Efforts will focus on co-seismic and post-seismic mapping. Co-seismic deformation mapping is the mapping of the ground displacements generated by the fault dislocation, associated to the mainshock and modified by successive large aftershocks. This is usually carried out using two-pass InSAR. In this case, timeliness is an important requirement. Post-seismic deformation mapping consists instead in the measurement of the slow ground movements which start right after the mainshock, and which need to be measured using time-series InSAR techniques (e.g. SBAS, PS) over multitemporal data sets of at least 15-20 images (depending on SAR band). For post-seismic deformation, the displacement time series for at least 1 year after the mainshock is required. For post-seismic deformation mapping with HR SAR, the requested area is the same as for the co-seismic case: 400 x 200 km, although these values may vary depending on magnitude and tectonic setting, as specified in the table, figure 8, below.

Sample products include:

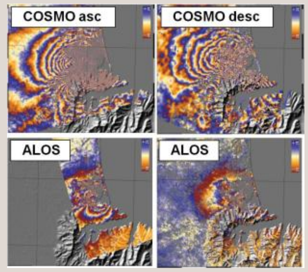
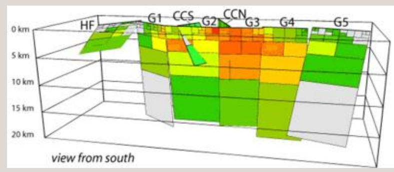
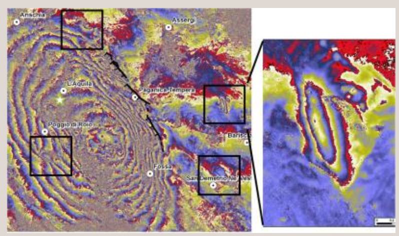
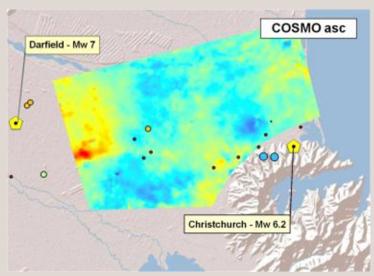
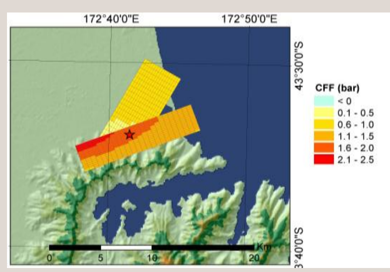
Co-seismic ground displacement maps	
Seismic source models	
Maps of geological surface effects (landslides, liquefactions, fault scarps, etc.)	
Post-seismic ground velocity maps	
Coulomb stress change models on neighboring faults	

Figure 4. Sample rapid co and post-seismic science products to be produced by the seismic pilot (through INGV).

3) Advanced information products requiring collocation of large amounts of data and tools for advanced processing (through an exploitation platform)

While technically not an information need, there is a clear need for an exploitation platform that would bring advanced technology (e.g. cloud computing, advanced processing tools) to bear on seismological problems, given that typically science users working on seismological data from satellites use very large volumes of data and need to process these data with tools that require advanced computing capabilities. Collocating these data and tools on a joint exploitation platform would enable new products and services to be developed.

Volcano Information Needs in the context of the CEOS DRM Pilot

1) Sustained monitoring of all Holocene era volcanoes.

To effectively use EO to monitor volcanoes requires a multi-parameter observation strategy in both real-time and delayed time. This strategy has six points:

- Establish regularly refreshed baseline observations concerning ground deformation, thermal energy release and gas release at all 1500 Holocene Volcanoes, independently of the state of unrest.
- Measure ground deformation and thermal, ash and gas emissions (where appropriate) weekly at all volcanoes that show signs of unrest (approximately 100 episodes yearly).
- Detect, measure and track ash, thermal and gas parameters for any eruption worldwide and at the appropriate spatial and temporal resolution at least daily; complemented with ground deformation measurements, morphology changes and topography (DEM) as appropriate; improve the scientific understanding of eruption initiation and dynamics by frequent ground deformation measurements at volcanoes in severe unrest (for example, InSAR observations of summit deformation before, during, and between explosive eruption phases, and of the initiation and propagation of dikes).
- Improve and/or develop the capability to carry out systematic measurements of gas ratios, ash particle distribution, ash plume height, minor gases and ratios for gases in low quantities (HCL, H2S, e.g.); extend the current capacity of measuring thermal and gas parameters to shallow submarine eruptions.
- Secure continuity and sustainability of all the above for the next 20 years.
- Improve uptake of EO by providing training for end users.

Most monitoring relies on visual observation and terrain inspection. Less than a hundred observatories worldwide follow activity in the 10% of volcanoes that are monitored. A key for EO data is at volcanoes where little or no ground-based monitoring exists. This includes (a) large-scale InSAR surveys that look for deformation, especially at volcanoes without any seismic monitoring stations, (b) imagery to detect surface change (visual or SAR) to identify, for example, dome growth and pyroclastic flows (e.g. SAR backscatter imagery spanning the 2010 eruption of Merapi), (c) thermal studies that look for the first sign of magma close to the surface and active lava flows on the surface, (d) gas emissions before, during, and after an eruption, and (e) tracking large ash clouds during and following eruptions.

Given the transboundary nature of ash and gas emissions, those hazards constitute one of the most critical in terms of global volcano monitoring. Current needs for tracking gas and ash emissions include the timely provision (refresh rates in the order of minutes, both day and night) of: (i) detection, location and quantitative characterization of the active volcanic source on ground; (ii) detection, accurate 3-D location and concentration imaging of the volcanic ash cloud, and (iii) forecast of cloud dynamics in terms of concentration over space and time. The end users for these data are essentially the airline industry, but the data pass through several filters, including third-party EO data-product providers, advisory and warning centres (e.g. VAACs), and official channels (e.g. MWOs) before arriving at aviation stakeholders, such as airport authorities, airlines, air-freight companies, private and commercial business jet operators and defence agencies.

In the near term, there is a growing need for quantitative integration of ground-based and space-borne information for improving the constraint on crucial parameters which might be affected in a 'multi-parametric noisy' environment such as that of an erupting volcano. This concept, launched in 1990s as the « EU Laboratory Volcanoes» undertaking, is currently in practice as the GSNL initiative, and is worth consideration as a global, systematic exercise. However, demonstrations and short-duration actions related to major eruptions have not provided a complete picture of volcanic behaviour. Instead, it is necessary to also monitor pre- and post-eruptive phases of activity with the same frequency, quality, and resolution as co-eruptive activity, to improve understanding of all aspects of the eruption cycle. This holds true for thermal features, ground deformation, and gas and ash emissions at a number of volcanoes large enough to embody the variety of eruptive styles.

2) New protocols for EO-based measurement of volcanoes

Given that some volcano observatories, especially in developing nations, do not have the resources nor the capacity to effectively use satellite-based EO to monitor volcanoes on an on-going basis, development of standard protocols for use of EO data would allow users to understand what data would be required and what capacity needs to be developed to increase monitoring and effectively exploit data.

The table below summarizes volcano observation needs where EO is relevant.

Feature	Need	Resolution	Observable	Required
Magma at surface	Detection and Location	High temporal	Radiance	TIR, MIR, SWIR
Lava flows	Flow mapping (topography and volume) Effusion rate monitoring	High spatial High temporal	Radiance ** Amplitude, phase ** Radiance **	SWIR, NIR SAR TIR, MIR, SWIR
Pyroclastic flows	Flow mapping	High spatial	Radiance	TIR
Active domes	Detection, Mapping	Moderate temporal High spatial	Radiance	TIR, MIR TIR, SWIR, NIR
Fumarole fields	Detection, Monitoring	High spatial	Radiance	TIR
Eruptive columns, Ash	Detection, Location	High temporal	Radiance	TIR, MIR, SWIR, NIR, Visible
Ash dispersal (atmosphere)	Monitoring	High temporal	Radiance **	MIR, TIR, LiDAR
SO2 concentrations	Detection, Monitoring	Low spatial, High temporal	Radiance **	UV, TIR, MIR
CO2 concentrations	Detection, Mapping	Low spatial, Low temporal	Radiance **	UV to TIR
Topography	DEM	High spatial	Interferometric phase ** Stereoscopy **	SAR Visible, NIR
Ground deformation	Detection, Location, Monitoring	High spatial, Low temporal	Interferometric phase change **	SAR
Ash dispersal (ground)	Mapping	High spatial, Low temporal	(Reflectance) Radiance **	Visible, NIR, SWIR
Morphology changes	Detection, Location, Mapping	High spatial	Amplitude, phase (coherence, reflectivity) Radiance (Reflectance) changes)	SAR Visible, NIR, SWIR

Figure 5. Volcano pilot observation needs

Most major observational needs can be satisfied using remote-sensing data. In 2012, only 4 passive geostationary payloads, 12 passive polar orbiting payloads and 7 SAR payloads were systematically exploited for the provision of volcanic observation services at various levels of timeliness (and generally for research only, as opposed to research and monitoring) worldwide.

Recovery Observatory Information Needs

While it is impossible to determine the exact needs of a Recovery Observatory before an event takes place, there are a large number of requirements that are common to all recovery situations after major disasters. What is required is to establish what the baseline data requirements would be both for EO data and for derived products. These data and products support several different types of activity that change as the observatory period evolves. A draft categorization of these activities might include:

- Built area damage assessment (initial and later detailed)
- Natural resource and environment assessment
- Reconstruction planning support
- Reconstruction monitoring; and
- Change monitoring.

A Recovery Observatory would collect varying information depending on the type of disaster and the length of the recovery period. However, it is possible to make some generalizations on the type of data information products required, which include:

1. Baseline data from before the disaster to establish impact of disaster;
2. Updated exposure data to establish the impact of the disaster and track progress towards recovery;
3. Data collected during and immediately after the event;
4. Regular updates to maps (derived from satellite EO) showing condition of critical infrastructure (e.g. transportation networks, hospitals, energy networks, etc) and building stock (built-up areas and extent of damage);
5. Change detection products showing the evolution of the natural and built environment.

III.2 Targets for CEOS

Within the broader, long-term information needs identified for each thematic area, CEOS has chosen to focus its efforts to limit the scope of its activities and chose a few clear examples where satellite-based EO makes a compelling contribution to DRM. These demonstrators are undertaken in partnership with practitioners and users with a view to ensuring that a sustainable vision for the application of satellite EO be developed over the coming three years. In this way, CEOS pilots showcase what is possible and prepare the way for durable contributions of satellites from both CEOS agencies and other satellite data providers.

With the CEOS DRM Observation Strategy, CEOS sets the following targets for the three thematic pilots and the Recovery Observatory:

Collection of satellite-based EO data and targeted value-added contributions to support…

… Floods… by demonstrating the effective application of satellite EO to the full cycle of flood management at global and regional/local scales:

- Integrating existing near-real time global flood monitoring and modeling systems.
- Linking global systems to regional end-to-end pilots that produce high-resolution flood mitigation, warning and response products and deliver flood and flash flood related services in:
  - The Caribbean (with particular focus on Haiti);
  - Southern Africa, including Namibia, South Africa, Zambia, Zimbabwe, Mozambique and Malawi;
  - Southeast Asia (with particular focus on the lower Mekong Basin and Western Java, Indonesia).
- Developing new end products and services to better deliver flood related information and to validate satellite EO data and products with end users, including retrospective products working from archived EO flood extent data;
- Encouraging regional in-country capacity to access EO data and integrate into operational systems and flood management practices.

<u>Benefits of CEOS activity:</u>
There are a large number of flood related initiatives underway around the world, in every region of the world, and on a global basis, working with different data sets and sensors and developing different products. While the advent of rapid mapping using satellite EO has led to some degree of standardization in the context of the International Charter and its activations, there is a need for greater cooperation across existing projects to develop common approaches on how to collect data for flood monitoring and the prevention of flood damage, and how to display this information. Furthermore, there is a strong need for comparison of results across local, national and global efforts to enable global systems to become more accurate and to chart a path for sustained local and national monitoring on an on-going basis across the world. Only CEOS offers the breadth of membership and sensor platforms to provide the full range of necessary data to support an effort that groups together end-users, practitioners, and satellite operators. CEOS offers a unique venue to improve the efficiency of satellite observations through coordination of observing strategies across multiple agencies and comparison of products to improve the standardization of observing practices in support of flood monitoring products. The pilot will generate new products as a result of the combination of several satellite sources, which enables a higher degree of accuracy. In some areas, the use of more than one mission with similar instrument type over a specific geographical zone can be harmonized to eliminate redundant data collects and allow new areas to be imaged.

… Seismic hazards… by:

- Supporting the generation of globally self-consistent strain rate estimates and the mapping of active faults at the global scale by providing EO InSAR and optical data and processing capacities to existing initiatives, such as the iGSRM *[Wide extent satellite observations]*
- Supporting and continuing the GSNL for seismic hazards and volcanoes *[Satellite observations focused on supersites]*
- Developing and demonstrating advanced science products for rapid earthquake response *[M>5.8]*

Benefits of CEOS activity:

While the CEOS activity build on some major, existing initiatives, the involvement of CEOS offers clear added value. For wide area observations, CEOS offers a coordinated approach to observations, eliminating overlap and duplication, allowing to gather the data necessary for large-scale ground motion and fault mapping. These high resolution, continuous coverage, strain rate and fault maps will in turn become an essential input to probabilistic seismic hazard estimation, today based only on seismicity models and historical earthquake catalogues (as in the Global Earthquake Model project) ; CEOS also offers a framework in which users and practitioners can be federated; finally CEOS offers new tools developed through contributions of CEOS pilot partners to enable the generation of advanced products, through the development of an exploitation platform. With regard to rapid science product generation. The involvement of a range of CEOS agencies allows more satellites to be used to collect data for rapid product generation, and allows satellite agencies to work together to establish standard collection protocols to support the generation of such products in the aftermath of earthquakes.

… Volcanoes…by:

- Demonstrating comprehensive monitoring of Holocene era volcanoes in the Latin American volcanic arc
- Developing new protocols and products over active volcanoes where EO data collects are already taking place (GSNL – Hawaii, Iceland)
- Demonstrating operational monitoring over a large scale eruption (e.g. Merapi 2010) during 2014-2016

Benefits of CEOS activity:

By completing a regional study of volcanic activity in Latin America (sustained regional monitoring over time), the CEOS pilot will demonstrate the feasibility of a global monitoring programme over all Holocene volcanoes. The development of a comprehensive monitoring programme that includes all potentially active volcanoes and works in close cooperation with local and national end-users will serve as a showcase to demonstrate the value of EO-based monitoring, especially in areas where volcano observatories have fewer resources. Such an ambitious monitoring programme is only possible through the collective effort of many agencies working together under an umbrella such as CEOS to achieve a mutually sought-after goal. In-depth monitoring using EO at established volcanic hotspots (the GSNL supersites) will enable the improvement of operational protocols for monitoring of active volcanoes. Data contributions from different agencies enables a truly multi-platform approach to be developed. These protocols and new products can be demonstrated in the event of a major eruption during the lifetime of the pilot

… a Recovery Observatory… by coordinating sustained access to EO data to support reconstruction and recovery efforts after a major, catastrophic event.

Benefits of CEOS activity:
Beyond the limited scope of the International Charter, which covers the immediate response phase only, CEOS offers access to a range of different satellites that collectively can provide a unique database to support longer-term response and recovery after a major disaster like that of Haiti in 2010 or the Japanese tsunami in 2011. A single space agency working alone cannot provide the necessary coverage and volume of data to properly support a major international effort on this scale. This is also a unique opportunity for CEOS to showcase how useful EO can be when properly coordinated and applied efficiently to address DRM concerns.
Past experience of CNES in Haiti has demonstrated that the volume of data collected during the whole duration of the Kal-Haiti project months was marginal with respect to the volume of data collected following the Charter activation.

IV. Contributing Capabilities, Gaps and Priorities

The information needs listed above lead to EO data requirements and observation strategies, which can be stated at varying levels of detail. Section V, below, provides detailed requirements flowing from the information needs. These needs span three disaster types, the various phases of the disaster cycle and many types of satellite data, including:

- medium and high resolution optical data;
- medium and high resolution microwave radar data;
- interferometric SAR data products;
- infrared and thermal data;
- meteorological data sets and models.[5]

This section also identifies gaps between existing capabilities and the identified CEOS targets, and provides the rationale for why the pilots were structured as proposed.

A complete list of satellites operated by CEOS agencies is available on-line in the MIM database at www.ceos.org (“EO Handbook” in upper banner) or directly at http://www.eohandbook.com/ .

The CEOS pilots will be delivered through a combination of CEOS agency resources (principally through data and data processing contributions, although in some cases other contributions such as capacity building support or information technology development are envisaged) and contributions relating to value-added products and services through partnering institutions and companies.

The detailed EO data acquisitions are planned in each of the thematic pilots and in the description of the Recovery Observatory. These requirements are detailed in section V below.

Floods

A review of the key observations currently made or planned in support of flood management was undertaken by the Disasters SBA Team in 2011-2013. That gap analysis focused on which satellite missions were ‘workhorse’ missions for global flood monitors, what observations they made and what likelihood there is for a gap in those observations over the coming years. The results of this gap analysis

[5] From CEOS EO Handbook 2012.

were captured in the **CEOS Strategic Gap Analysis for Earth Remote Sensing in Support of Flood-related Disasters (March 2013**), and can be found at:

http://ceos.org/images/Floods_Analysis_030713.pdf

There are many key missions that provide flood information products and services. These include all types of synthetic aperture radar (SAR) instruments for monitoring topography and water levels and providing imaging products. In addition, low to high resolution multispectral and panchromatic (PAN) imagers are critical for monitoring everything from land use and housing in the mitigation phase to coastal erosion in the warning phase and flood extent and damage assessment in the response and recovery phases. Key sensors of these types, which would be most useful for flood observations, have been included in the CEOS gap assessment.

Necessary Earth observational measurements provided by various instrument types are detailed in Tables 2 through 5 of the study and have been derived from the product requirements referenced above. Optical, Radar, Microwave, and Thermal Infrared instruments were considered the primary sources of measurements to supply flood data product inputs. The observational needs are categorized by instrument type, spatial resolution, repeat frequency, and data availability to determine which instruments could supply the needed measurement inputs to generate flood data products and are summarized as follows:

- VHR Pan or Multispectral (less than 2m) and HR Multispectral (2-15m) for detailed damage assessments
- M/LR Multispectral (15-30m) for moderate resolution flood extent mapping
- Low resolution Multispectral for wider area views of large events at more frequent acquisition rates
- Hyperspectral for water quality assessments
- VHR SAR, HR SAR, and M/LR SAR for flood extent mapping during cloudy conditions and for topography
- Passive microwave for long term trending of normal surface reflectance to infer increased presence of water
- Precipitation sensors – tracking actual accumulations and predictions

Main gaps concerning EO capacity for the flood pilot:

1) Global Systems

There were no identified gaps in data for near-real time global systems, which operate at a very high temporal resolution but very low spatial resolution. Missions are operating that meet the need of these systems and these observations are expected to continue and are typically available without restriction. There is a data gap for the 10-year archive of SAR data to be addressed by this pilot, which would enable a comparative 10-year review of past events using both optical and SAR data. The main gap for global systems is with regard to the validation of the data products, either with end-users directly or through cross-referencing with other global observations. There is also a gap in terms of presenting the available information in a single place so that users can quickly understand what data is available where.

2) Regional systems

The main gap for regional flood monitoring systems is the availability of high resolution and very high resolution optical and SAR data on a daily or near daily basis during floods and immediately before and after. This gap is to some extent addressed by the International Charter, but only for data during and after the flood, and only for major flood events where the Charter is activated. The pilots intend to work directly with Charter authorised users. The pilot will also coordinate with agencies providing data for Charter activations to ensure Charter data are integrated in the pilot. The Charter authorized users receive value-added products. The data therefore reside with each participating agency and data requests must be addressed to these agencies, which will decide whether or not the data can be shared (according to their data policy). Charter value-added products when available will also be integrated into the pilot. The pilot builds on existing regional end-to-end pilots in two of three regional areas, but the agreements in place for these pilots did not guarantee access to a sufficient range of satellites to ensure that comprehensive products can be developed, offering near daily coverage in extreme flood situations.

3) Local capacity

There are significant gaps in local capacity to be able to work on satellite data to develop EO-based flood products to support the flood management cycle. These gaps include both technical infrastructure (computing capacity) and training for human resources.

Seismic Hazards

Main gaps concerning EO capacity for seismic hazards pilot:

1) Terrain motion mapping for global strain modelling

Many users are not aware of the potential benefits from satellite EO. EO techniques to support seismic risk assessment have been delivered to DRM users in a few countries only (for instance, in Europe: Italy, Greece, and Turkey).

A global strategy (coordinated amongst major SAR data providers) is needed to ensure HR SAR and VHR SAR acquisitions fit for InSAR exploitation are performed and data are made available. New missions such as Sentinel-1 will allow EO to be much more widely used in estimating seismic hazard and risk. Planned radar missions should acquire data as often as possible in the world’s seismic belts (the entire belts, including the lower straining areas, cover ~15% of the imageable surface). Radar missions could build uniform catalogues in single modes of acquisition for long periods of time. Data should be made freely available to all, or widely licensable to the community, allowing multiple users to work on this task. A long-term response to earthquake elements that involves acquiring radar data for years to decades after an earthquake in order to measure post-seismic deformation. Mapping tectonic strain with the required accuracy to be useful for seismic hazard estimation requires regular repeated radar acquisitions over long time periods, ideally in several different viewing geometries. No single planned mission meets all the requirements, but upcoming missions (e.g. Sentinel-1A/B, ALOS-2 and the Radarsat Constellation Mission) have the potential to collectively fulfil the objective. (Main beneficiary: scientific seismic community)

2) Geohazard risk science

Gaps remain in the collection of scientific data for geohazard risk assessment, though the GSNL initiative is an important step forward. Science users feel that the areas covered remain too limited, either in coverage or in density of observations. A clearer definition of the science objectives of the GSNL and their selection criteria is needed.

A data repository for this subset of data is a key aspect and the principal identified gap, after access to large data sets in InSAR mode, along with the support of an exploitation platform to allow large data volume processing. On demand processing and cloud computing could make possible the exploitation of large datastacks to support this. An exploitation platform providing rapid and automated processing capacity could be used to improve the accuracy of predicted damage distributions, and for forecasting the likely distribution of aftershocks and triggered earthquakes. Much progress has been made possible by the decision of space agencies to task their radar satellites to have “background missions” (e.g. 15+ years of ERS and Envisat SAR data).

3) Advanced science products in response to earthquakes to support relief actions

An operational EO capacity is in place to deliver rapid earthquake damage mapping, though users would like it to be more rapid, and quality could be improved through the use of VHRO imagery with oblique views (oblique sensors not common in current Charter stable of satellites). There is no service in place today to develop rapid science products such as those proposed in the pilot, and these require specific data collects in specific modes (e.g. interferometry) not currently offered on a systematic basis after major events; for instance the International Charter does not deliver interferometric time series. (Main beneficiaries: civil protection agencies, science communities advising civil protection agencies)

Volcanoes

Main gaps concerning EO capacity for volcano pilot:

1) Monitoring of Holocene era volcanoes in Latin America

The main identified data gaps for sustained volcanic monitoring in Latin America are the availability of L-band (and to some extent C-band) SAR data in large volumes to monitor terrain motion near potentially active volcanoes, and nighttime acquisitions of SPOT-5/Sentinel-2 (and similar) data. With regard to other data sets, the main “gap” is not in relation to satellite missions to monitor volcanoes, but in the use of these missions. Improved coordination in the application of existing satellite assets and a comprehensive strategy to exploit the acquired data are both required. The CEOS volcano pilot will demonstrate how an application of existing satellite EO assets over Latin America can significantly improve volcanic monitoring there by both volcanic observatories and VAACS.

2) Development of new protocols and products over GSNL volcanic supersites

No identified gaps

3) Response to a major eruption 2014-2016

In the event of a major eruption during the pilot period, there will be data gaps to meet the established need for daily information about the eruption.

Recovery Observatory

Main gaps concerning EO capacity for Recovery Observatory:

A CEOS commitment for the Recovery Observatory requires a commitment from a collection of CEOS agencies to provide regular data collects over a given area (that of the disaster) for a long period of time (typically ranging from three to five years. The area is however limited and the rate of data collects after the initial crisis has settled will be relatively infrequent.

Local capacity to assimilate data and data products will vary widely according to the area affected. CEOS will work with a supranational partner to establish a generic requirement related to capacity, and adapt this to the area affected.

V. Data Requirements for the CEOS Pilots and Proposed Observation Strategy

EO data requirements have been generated for each of the three thematic pilots and for the Recovery Observatory. They are summarized in the text below, but also exist as shape files for specific geographic areas and excel tables summarizing specific data types. These tools will be sued to support the generation of a data acquisition plan in response to the requirements should the Observation Strategy be approved.

Floods

The flood pilot operates at both global and regional levels, generating products at each level and using these to compare products across the two levels.

For global flood products, the flood pilot will use low and medium spatial resolution (1km, 250m) optical imagery to produce daily estimations of flood extent on the global landmass (excluding Antarctica and the far north).

A ten-year archive of low spatial resolution (250m), high temporal resolution (daily) optical and SAR data will allow comparison of flood area analysis between data types and allow for summary risk analysis of future flooding based on past flood extent.

On a regional basis, medium and high resolution optical and SAR imagery will allow much more detailed flood monitoring, and this will be used to validate global products in these regions:

- In Southern Africa, where flood risk is from slow onset flooding in river basins, the pilot requires a single dry season acquisition (per year) using high resolution optical and SAR data (approximately 50 scenes each). During the wet season (November-March), the pilot will image affected areas on a daily basis in the days preceding a flood and throughout the flooding period, for an approximate period of six weeks. This will happen in several affected areas, resulting in total acquisitions of 150 scenes each of optical (HR) and SAR (fine beam C-band and X-band; L-band) imagery per year.

- In the Caribbean and in Southeast Asia (Mekong and Western Java), flooding is caused by intense rain events, usually during hurricanes or typhoons (but not always). A single dry season acquisition using HR optical and SAR data is required (approximately 30 scenes for each region), and then daily acquisitions are required immediately before, during and immediately after events, for an approximate period of one week, representing approximately 150 images for each region.

The table below provides a summary of the data needs for the pilot.

Objective	Type	Observation requirement	Other requirements
A (Global Flood Dashboard)	Low resolution optical (250m, 500m, 1000m)	Daily observations globally to establish daily flood extent. Ten-year archive for event-based flood risk analysis	
	High resolution optical (20-50m)	Daily observations where they are available from survey mode assets	Used to supplement and provide finer detail to low resolution daily coverage on an as available basis
	Low resolution SAR (10-100m)	Daily observations globally to validate/complete daily flood extent (above) Ten-year archive to validate optical data and improve event-based flood risk	
	Soil moisture (10km active, 40 km passive)	Daily, global	Combined with rainfall rate and flow models for flood prediction
	Rainfall rate (derived from multiple MW and IR instruments and merged into a single field)	Daily, global	Combined with soil moisture and flow models for flood prediction
B (Regional Flood Monitoring)	High resolution optical (5-30m)	Background data collects over regional polygons during dry season; Daily or near daily data collects over affected areas before, during and after events (approximately six weeks) during wet season;	Combination of optical and radar data to achieve daily collects would be feasible. Level 2 co-registered products.
	Very high resolution optical (less than 5m)	Targeted data collects over most affected areas during wet season	
	High resolution SAR (10-100m)	Background data collects over regional polygons during dry season; Daily or near daily data collects over affected areas before, during and after events (approximately six weeks) during wet season;	Multiple bands: X, C and L. Some combination of above preferred. Combination of optical and radar data to achieve daily collects would be feasible. Level 2 ortho-rectified.
	Very high resolution SAR (less than 5m)	Targeted data collects over most affected areas during wet season	Multiple bands: X and C. Some combination of above preferred. Level 2 ortho-rectified.

Figure 6. Summary flood pilot data needs

The figure below provides a summary of the geographic areas to be imaged for the pilot.

Figure 7. Overview of flood pilot EO data polygons.

Seismic Hazards

The integration of InSAR/optical geodetic measurements in probabilistic seismic hazard models require a complete time and space mapping of all deformable continental areas for: (1) constraining spatial variations of seismic loading along faults at depth, (2) detecting strain on silent or hidden active faults, (3) deciphering which fault is being seismically loaded where there are ambiguities, (4) integrating transient deformation in the seismic loading budget and susceptibility. In addition, large-scale optical and DEM data are required for global fault mapping and past-earthquake quantification. Furthermore, the rapid or longer term response to earthquake occurrence requires a global background SAR or optical imagery, and a quick re-acquisition after each earthquake occurrence. All these EO data requirements should be fulfilled in tectonic areas, including low strain rate continental areas. As this tectonic area is large, the burden of EO acquisition can be split by different space agencies based on instrument characteristics and ground and seismo-tectonic properties.

The observational requirements for InSAR applications for seismic hazards can be summarized as follows:

(A) SAR data:

- High Resolution InSAR: (i) for hazard inventory purposes (*e.g.* seismic loading mapping): continuous observations of descending and ascending mode repeat coverage (maximum images per year, C and L-band in stripmap mode. The focus is to extend and guarantee observations of the priority seismic belts); (ii) for hazard monitoring purposes (eg. Coseismic or postseismic deformation measurement or monitoring transient fault behavior before and after an earthquake):: descending and ascending repeat coverage of hotspots (*e.g.* most critical faults) with more than 3 images per month C- or L-band; (iii) for rapid response to events, before and after earthquakes in InSAR mode.

- Very High Resolution X-band InSAR: (i) for hazard inventory purposes such as global strain mapping the smaller swath width and cost limits VHR utility; (ii) for hazard monitoring purposes on hotspots (*e.g.* most critical faults showing shallow creep events or postseismic deformation): descending and ascending repeat coverage in X-band; (iii) for rapid response to events, one requires SAR acquisition before and after the earthquake in X-band InSAR mode.

(B) HR Optical/VHR Optical:

(i) To provide background reference imagery: archive images (no more than one year old), bi-stereo panchromatic or true colour composite. (ii) VHR bi-stereo optical for disaster response mapping and for surface fracture mapping, this data should be better than 5m resolution panchromatic or multispectral and delivered in near-real-time.

For Objective A, mapping global strain:

Mapping tectonic strain with the required accuracy to be useful for seismic hazard estimation requires regular repeated radar acquisitions over long time periods, ideally in several different viewing geometries. No single planned mission meets all the requirements, but upcoming missions, notably Sentinel-1A/B, ALOS-2 and the RCM, have the potential to collectively fulfil the objective. In order to achieve this:

- Planned radar missions should acquire data as often as possible in the world's seismic belts. The surface area with strain rates higher than 10-8 yr-1 is ~3.55% of the imageable Earth surface (between +/-80 degrees). The entire seismic belts, including the lower straining areas, cover ~15% of the earth's land surface.

- Radar missions should acquire data with multiple viewing geometries (ascending and descending). To ensure that faults with all geometries can be viewed, single missions (e.g. Sentinel-1A/B) should acquire data in ascending and descending modes. Space agencies should coordinate efforts to ensure a range of viewing geometries are acquired in the future.

- Highly vegetated areas with large deformation rate should be covered in priority by L-band data (the areas to be processed first are the Himalayas, the eastern border of the Andes, and the South

Chile subduction zone, but Indonesia and the eastern part of the Himalayas are also key areas for L-band ground motion monitoring)

- Tectonic areas showing strongly transient deformation should be monitored with a repeat cycle as short as possible using C-Band SAR data (East African Rift, Central and South American subduction zones, Kunlun and Haiyuan faults in the northern part of the Tibetan plateau)

- We must acquire EO C-band SAR data on all other tectonic areas, but, if necessary, with a longer repeat cycle (~a month). The areas processed in priority for feasibility assessment will be the part of the Himalayan belt between Turkey until Iran and the whole Tibetan plateau.

For Objective A, global fault mapping:

Mapping faults using EO data requires high-resolution optical imagery and digital topography. Specifically:

- High-resolution (1 m or better) optical imagery should be made available at reasonable cost for all tectonic zones of the pilot for the purposes of seismic hazard investigation. Currently the costs for finding faults across large regions using tectonic geomorphology from EO data are prohibitive for individual scientists or civil protection agencies.

- High-resolution (10 m or better) digital topography should be made available at reasonable cost for all tectonic zones for the purposes of seismic hazard investigation. New missions are capable of producing high-resolution topographic models using optical stereo matching or InSAR. Space agencies should consider making these available at reasonable cost for large regions for investigations into seismic hazard.

For Objective B, support to supersites:

No new data beyond those already committed to supersites are required.

For Objective C, rapid science response to earthquakes:

The rapid acquisition of post-event data is critical. The impact of EO data for damage assessment is highest in the immediate aftermath of an earthquake, and its use would be facilitated by:

- Immediate tasking of radar and optical satellites for acquisition of post-event data. In some cases this will require special intervention to ensure SAR imagery is acquired in modes compatible with pre-event imagery. In others, with suitable background missions, this objective should be straightforward to meet.

- Opening of archive data for the area of the earthquake. For change detection work and surface deformation measurements using optical or radar data, pre-event imagery is as critical as post-event imagery.

The table below provides a summary of the data needs for the pilot.

Objective	Sensor	Observation requirement	Other requirements	Area expected to be covered	Approximate frames per year
A (interseismic strain mapping)	HR SAR (L-band, ALOS-2)	Continuous observations in ascending and descending mode (9 acquisitions/year). In priority in vegetated areas showing strong deformation rate.	InSAR mode	Himalayan belt, eastern border of the Andes, South Chile subduction zone (South of -33S). To be extended to the eastern Himalayan syntaxis.	Descending ScanSAR mode: Himalaya: 200 frames Andes: 200 frames South Chile: 100 frames Ascending stripmap: Himalaya: 1500 frames Andes: 1500 frames South Chile: 1000 frames
A (interseismic strain mapping)	HR SAR (Radarsat, Sentinel-1)	Continuous observations of descending and ascending modes, repeat coverage (30 acquisition/yr). Intensive observations in areas showing strong transients.		East African rift area, Central and South America subduction zones (only Mexico, Peru), North Tibet	East African rift : 800 frames Central Am.: 600 frames South America: 1500 frames
A (interseismic strain mapping)	HR SAR (Sentinel-1)	Continuous observations of descending and ascending modes, repeat coverage (30 acquisitions/yr). The goal is to extend and guarantee observations to all seismic belts.		Turkey to Iran seismic belt, Tibet, South American subduction zone	Turkey to Iran: 1000 frames Tibet : 800 frames South America : 800 frames
A (transient deformation and creep on focused areas)	VHR SAR (TerraSAR X, COSMO-SkyMed	For this objective, the smaller swath width limits VHR usage in situation where HR data cannot be acquired or where further viewing geometries are needed to better resolve the deformation field.	1-3 images/ month, depending on temporal decorrelation InSAR mode	Max ~100 x 300km for each test site. ~100 x 300km for each test site: two in Turkey, one in Tibet	Tibet : 500 frames Turkey : 1500 frames
A (transient deformation and creep on focused areas)	VHR optical (Pleiades)	High revisit time in ascending and descending mode, focused on main creeping segments of faults. Strain measurement on fault creep segments by image correlation.	1 coverage per year	Two test sites in Turkey along the North Anatolian Fault	400km by 100km wide area
A (fault mapping)	HR/VHR Optical (SPOT-5, Pleiades)	Archive images (no more than one year old), panchromatic or true colour composite. HR for fault recognition VHR for detailed offsets mapping, historic earthquake recognition.	VHR Stereo coverage along faults HR: coverage of wide areas	VHR only on 20 km wide strips elongated along faults Turkey to Iran Andes Tibet	TBD

B, C (post-seismic deformation mapping)	HR SAR (Radarsat, Sentinel-1, ALOS-2)	Descending and ascending repeat coverage of critical faults surrounding the mainshock epicentral area.	More than 3 images/month, NRT delivery, InSAR mode	Max ~400 x 200km for each test site (depends also on mainshock magnitude and tectonic setting)	Varies with satellite, maximum around few tens of frames (per revisit time)
	VHR SAR (TerraSAR X, COSMO-SkyMed)	Used to cover smaller faults than HR SAR. Descending and ascending repeat coverage of critical faults surrounding the mainshock epicentral area.	Shortest possible revisit time, up to 5 images/month, NRT delivery, InSAR mode	Max ~400 x 200km for each test site (depends also on mainshock magnitude and tectonic setting)	Max ~24 frames, average ~8 frames (per revisit time)
B, C (co-seismic deformation mapping)	HR SAR (Radarsat, Sentinel-1, ALOS-2)	Descending and ascending coverage of the mainshock epicentral area. All archive images younger than one year, and 4-6 acquisitions following the event.	NRT delivery, InSAR mode	Max ~400 x 200km for each test site (depends also on mainshock magnitude and tectonic setting)	Varies with satellite, on average around ten frames (per revisit time)
	VHR SAR (TerraSAR X, COSMO-SkyMed)	Used to cover smaller faults than HR SAR. Descending and ascending coverage of the mainshock epicentral area. All archive images younger than one year, and 4-6 acquisitions following the event.	NRT delivery, InSAR mode	Max ~400 x 200km for each test site (depends also on mainshock magnitude and tectonic setting)	Max ~24 frames, average ~8 frames (per revisit time)
B, C (surface fracture mapping)	VHR Optical	Pre- and post-event imagery at resolutions better than 1m. No later than 4 days after the event.	NRT delivery. Stereo coverage is preferred.	Max ~150 x 20km for each test site (depends also on mainshock magnitude and tectonic setting)	Varies with satellite, on average around ten scenes

Figure 8. Summary of seismic pilot data needs

Images must be acquired in both ascending and descending modes. For VHR SAR data, only stripmap coverage is required. InSAR require same polarization throughout the time series. In the table, for SAR acquisition for objective B, C, the last column states requirements only for each date, thus the number of dates in the time series must be considered, a time series for post-seismic deformation lasting typically 6-12 months, depending on earthquake size.

The figure below provides a summary of the geographic areas to be imaged for the pilot.

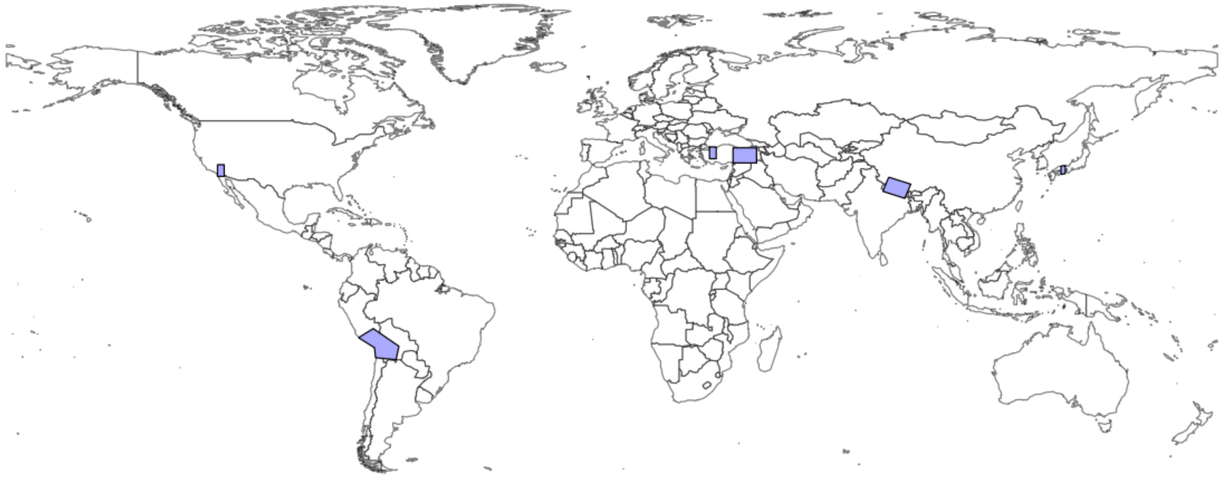


Figure 9. Overview of seismic pilot EO data polygons.

Volcanoes

The volcano pilot aims to demonstrate how global monitoring of all Holocene volcanoes could be achieved on a regular basis using EO-based techniques. As a regional demonstration, the pilot focuses on a single volcanic arc, in Latin America, to explore the benefits of broad-scale monitoring in locating and characterizing volcanic unrest before eruption. By demonstrating how EO-based monitoring would work in a single region, the pilot aims to refine and finalize the estimated effort required for a global monitoring program beyond 2016. In addition, the pilot will focus on detailed studies of a few highly active volcanoes (in Hawaii and Iceland, as well as other volcanoes that may become active over the course of the project), which builds synergy with the Supersites and Geoscience Natural Laboratories initiative of the Group on Earth Observations and will focus on characterizing short-term changes in active volcanism. Overall, the pilot will establish a comprehensive monitoring strategy for volcanoes that are dormant, experiencing unrest, or in eruption.

For regional monitoring purposes, in Latin America (Objective A), the pilot will require the following observations:

Over volcanoes at rest (quiescent):

Archived high-resolution (10-50m) SAR data and new acquisitions four times yearly for three years will be used to measure surface deformation—a frequent sign of unrest. In the central Andes, this requires C-band SAR; in other pilot areas, this requires L-band SAR. Monthly visible and NIR-SWIR will also be used to look for surface changes and thermal anomalies.

Over volcanoes showing unrest or in eruption:

Archived and new acquisitions of high-resolution (10-50m) L- and C-band SAR data monthly, and very-high-resolution (less than 10m) X-band SAR data weekly, will be used to characterize surface deformation. Weekly visible and TIR-SWIR optical data will be used to assess surface change and thermal anomalies, especially at erupting volcanoes; nighttime acquisitions would be particularly valuable (using SPOT-5 and Landsat-8, for example). Very-high-resolution optical data would also be used to map fine-scale changes in topography (e.g., Pleiades) and thermal features (e.g., SPOT-5). To assess ash clouds and other major changes in volcanism that are hazardous on a broad scale, freely available resources will be used (e.g. GOES, MODIS).

For focused study of a few very active volcanic systems (in Hawaii and Iceland; Objective B), the pilot will require the following observations:

To measure deformation, monthly acquisitions of L- and C-band SAR imagery, and weekly X-band SAR data takes (in Iceland or other areas with heavy snow over, these acquisitions would be summer only), are required. Weekly visible and NIR-SWIR acquisitions are necessary to map changes in thermal anomalies and surface characteristics (i.e., due to lava flows); this would include nighttime acquisitions (especially on Landsat-8 and SPOT-5). Very-high-resolution optical data would provide detailed maps of surface change caused by thermal features (e.g., SPOT-5) and deformation (e.g. Pleiades).

During the most active periods of volcanic activity (for example, dike intrusions, explosive eruptions, precursory energetic seismic swarms, etc.), daily acquisitions of all data types are needed.

For response to a major volcanic event during the course of the project (Objective C), the pilot will require the following observations:

If a major volcanic event occurs during the course of the pilot, remote sensing data will be used to track changes in eruptive activity, including the development and dispersion of ash clouds that may be hazardous to aircraft. Daily to weekly L-, C-, and X-band SAR acquisitions, and daily visible and NIR-SWIR-TIR optical data (including nighttime imagery), are needed to detect changes in deformation, thermal anomalies, and surface change. Archive data would be useful for assessing whether or not any measureable precursory activity occurred.

The table below provides a summary of the data needs for the pilot.

Objective	Type	Observation requirement
A (regional demonstration – Latin America and Caribbean)	HR SAR (Radarsat, Sentinel-1, ALOS-2)	**At quiescent volcanoes**: - Mexico, Central America, and northern Andes: quarterly L-band - Central Andes: quarterly L- and C-band - Southern Andes: monthly summer (October-March) L-band - Galapagos: quarterly L- and C-band - Caribbean: quarterly L-band **At active volcanoes**: - Mexico, Central America, and northern Andes: monthly L- and C-band - Central Andes: monthly L- and C-band - Southern Andes: monthly summer (October-March) L- and C-band - Galapagos: monthly L- and C-band - Caribbean: monthly L- and C-band
	VHR SAR (TerraSAR-X, COSMO-SkyMed	**At quiescent volcanoes**: - Mexico, Central America, and northern Andes: none - Central Andes: quarterly X-band - Southern Andes: none - Galapagos: none - Caribbean: none **At active volcanoes**: - Mexico, Central America, and northern Andes: monthly X-band - Central Andes: monthly X-band - Southern Andes: monthly summer (October-March) X-band - Galapagos: monthly X-band - Caribbean: monthly X-band
	VHR Optical (SPOT-5, Pléiades)	Nightime VIR, SWIR, and TIR acquisitions over active volcanoes to characterize thermal anomalies. Monthly stereo optical data over erupting volcanoes to measure terrain changes.
B (detailed study of frequently active volcanoes – Iceland and Hawaii)	HR SAR (Radarsat, Sentinel-1, ALOS-2)	Monthly L- and C-band data on as many tracks as possible, year-round in Hawaii and summer only (April-October) in Iceland.
	VHR SAR (TerraSAR-X, COSMO-SkyMed	Weekly X-band data on as many tracks as possible, year-round in Hawaii and summer only (April-October) in Iceland. Daily acquisitions during the most critical periods of unrest and eruption
	VHR Optical (SPOT-5, Pléiades)	Weekly nighttime VIR, SWIR, and TIR acquisitions for detecting changes in thermal anomalies. Monthly stereo optical data for detecting terrain changes. Daily acquisitions of all types during the most critical periods of unrest and eruption.
C (response to major volcanic event)	SAR and Optical	Daily (if possible) to weekly HR SAR, VHR SAR, and VHR optical data to track short-term changes in eruptive activity (including deformation, thermal anomalies, and surface changes). Archive data, if available, would be helpful in identifying (in hindsight) any precursory activity.

Figure 10. Summary of volcano pilot data needs.

The figure below provides a summary of the geographic areas to be imaged for the pilot.

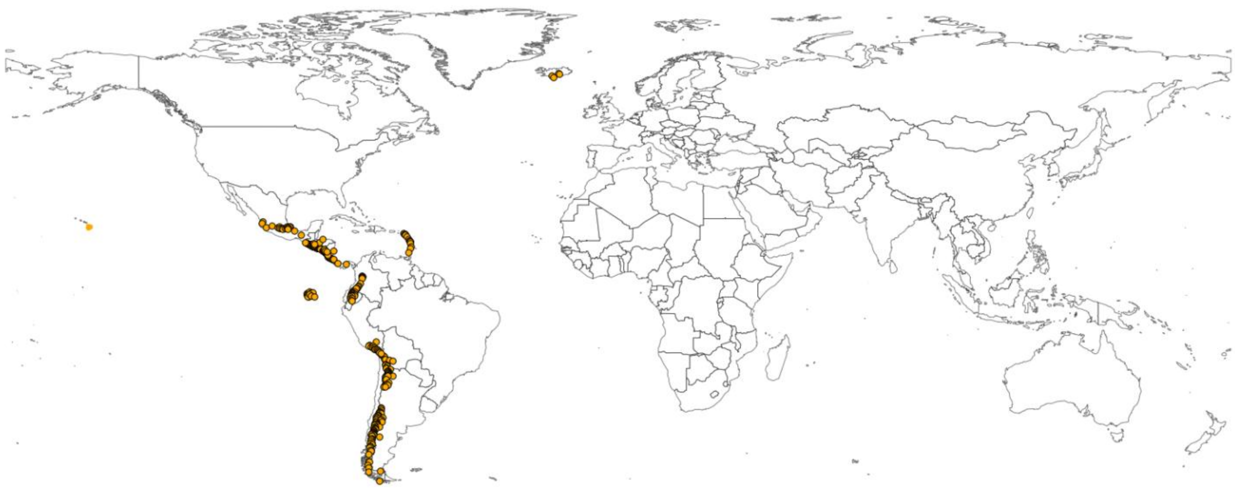


Figure 11. Overview of volcano pilot EO data polygons (NB includes by reference GSNL sites in Hawaii and Iceland).

Recovery Observatory

The content of the Recovery Observatory needs to be defined by the CEOS partners. It can range from a simple repository of available data to a pro-active acquisition strategy and the development of key value-added products that would support recovery.

Data

It is clear that the volume of data collected during the response phase is in fact likely to be much larger than the volume of data collected in the following three to five years. Examples of EO data would include high resolution and very high resolution optical imagery; high and very high resolution radar imagery (X, C and L-bands). Examples of revisit might include once a week for a two or three months and once a month for a period of several years, over a given target area. For some disasters such as earthquakes, InSAR imagery would be required to develop products such as interferograms. For other disasters, InSAR applications may be limited to change detection over built-up areas.

There is a need for data from before and after the event, and if this data is organized as a mosaic coverage of the area for example, with easy access for multiple users, this would allow both large and small users to access data without large capacity needs.

Products

Many end users need products rather than data. It is clear that the Observatory can only be successful if relationships are established to enable the generation of products from the contributed data. The baseline scenarios will determine not only the volume of data but representative products for each type of catastrophe. This allows CEOS to engage in discussions with multilateral stakeholders before an event and establish a framework within which different partners bring different contributions.

Infrastructure

In the event that CEOS decides to set up an exploitation platform for the Observatory, part of the preparation phase should be dedicated to establishing the generic capability to host the Observatory, determining the appropriate informatic tools to include and ensuring standards are in place to receive the data in an easily searchable format. Many CEOS agencies already have plans for exploitation platforms and synergies could be sought between existing projects.

While there is no need for detailed acquisition plans before the triggering of the Observatory, the preparation phase should include the development of detailed EO data requirements for different types of Observatories: one for a major earthquake, one for a major volcanic eruption, one for a major flood and/or hurricane, perhaps a tsunami. The exact number of scenarios developed will be decided during the detailed analysis phase. Some elements are quite common and involve situational awareness immediately after the event and for the damage assessment period, or involve baselining pre event and post event imagery in a single database. Other products might be specific to the disaster type - historical flood analysis for future flood events, InSAR analysis for strain estimates after earthquake, etc. The proposal would include a few such scenarios and scope out the types of data required for each, without identifying specific satellite missions. After the SIT in April 2014, volunteer agencies can indicate a willingness to further contribute specific data sets in the event of a triggering.

VI. Enlarged Actions and New Partnerships

The CEOS DRM Observation Strategy builds on the analysis work produced by CEOS in the Consensus Report (October 2012) and focuses effort in three distinct areas selected as priority themes by the ad hoc Disasters Working Group: floods, seismic hazards and volcanoes. The Strategy proposes to support three thematic pilots for three years, one in each of these three thematic areas. In addition, the Strategy proposes as an option the development of a Recovery Observatory. These actions are limited in scope but serve as a showcase for how sustained EO in support of DRM might significantly enhance the effectiveness of DRM efforts by users on a global basis. Through this pilot or demonstrator process, CEOS aims to engage major DRM stakeholders and raise the awareness of the value of EO for meeting DRM needs. The objectives of the pilots are summarized below. These pilots are undertaken in close cooperation with a range of partners from outside CEOS, partners that are committed to using EO and generating value-added products with CEOS observations through their own efforts and resources. Ultimately, these intermediary and end users are the best champions for the use of EO within DRM globally, and the success of the pilots can serve to herald much broader, sustained use of EO beyond 2016.

This Strategy includes a description of the three proposed thematic pilots and Recovery Observatory. This section provides the detailed requirements for each component of the pilots. These requirements explain how optical, SAR and thermal satellite observations will be used on both a global and regional scales to address the specific objectives of each pilot. Once the CEOS Plenary has endorsed the three pilots and the approach outlined in this Strategy, the ad hoc Disasters Team will work with individual agencies on an implementation plan to secure commitments for data acquisitions and other contributions from both CEOS agencies and non-CEOS partners to enable the delivery of the pilots.

The figure below provides an overview of the combined imaging requirements of the thematic pilots.

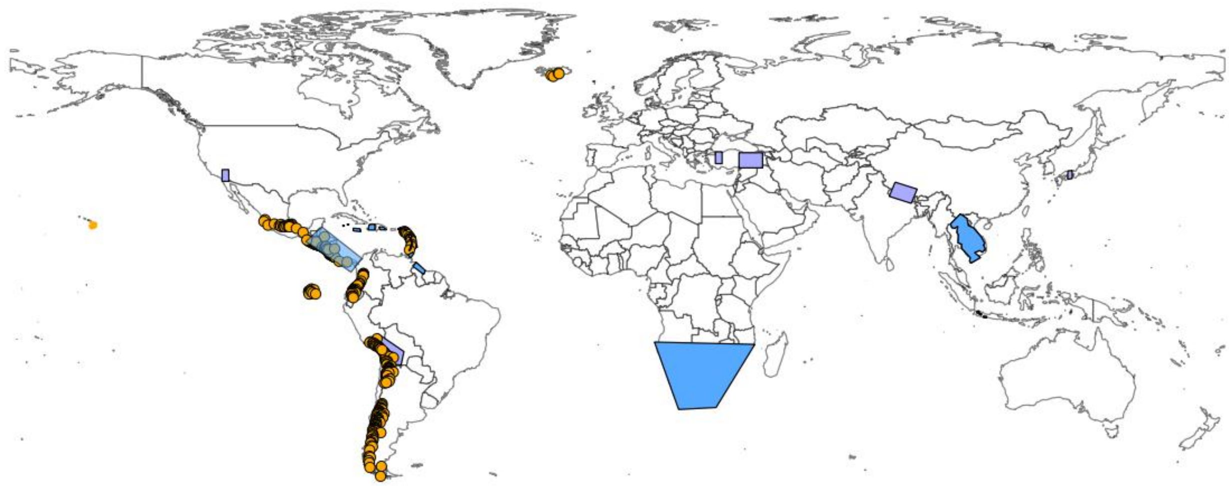


Figure 12. Overview of combined EO data polygons for three thematic pilots. Floods in blue, seismic hazards in purple, volcanoes in sierra. Areas not to scale and for indicative purposes only.

These pilots are demonstrators. They offer a vision for sustained application of EO to DRM beyond 2016, once they have successfully shown the positive impact of coordinated and effective EO use. At the World Conference on Disaster Risk Reduction in Sendai, Japan in 2015, CEOS will showcase the early results of the pilots. At the November 2016 Plenary of CEOS, CEOS principals will consider what steps to take to ensure sustained observations for DRM users on a global basis.

The section below summarizes the objectives of each pilot and offers a vision for how the pilot will lead to enlarged actions within a specific community during and beyond the 2014-2016 timeframe.

Flood Pilot

The flood pilot's objectives are to:

- Provide a linkage among existing global flood modeling, prediction and mapping projects to facilitate data comparison;
- Demonstrate how higher spatial resolution observations can provide enhanced flood mitigation, warning and response on a regional basis and improve the validation of existing global efforts (with linkages to global models);

- Initiate development of needed flood mapping infrastructure (including archived data regarding previous mapped flooding).

The CEOS Flood Pilot aims to demonstrate the effective application of satellite EO to the full cycle of flood management at global and regional/local scales by:

- Integrating existing near-real time global flood monitoring and modeling systems.
- Linking global systems to regional end-to-end pilots that produce high-resolution flood mitigation, warning and response products and deliver flood and flash flood related services in:
  - The Caribbean (with particular focus on Haiti);
  - Southern Africa, including Namibia, South Africa, Zambia, Zimbabwe, Mozambique and Malawi;
  - Southeast Asia (with particular focus on the lower Mekong Basin and Java, Indonesia).
- Developing new end products and services to better deliver flood related information and to validate satellite EO data and products with end users;
- Encouraging regional in-country capacity to access EO data and integrate into operational systems and flood management practices.

<u>Component 1</u> – Global Overview and Regional Linkages: the capabilities of existing global flood systems will be combined in a "Global Flood Dashboard" that will provide users with a single point of entry for relevant data covering the full cycle of flood monitoring. The three regional pilots will be linked to one or several global systems, allowing for higher spatial resolution but lower temporal resolution information to be displayed in the three areas of interest;

<u>Component 2</u> – The flood aspects of the existing regional end-to-end disaster pilots in the Caribbean/Central America and Southern Africa and the new flood component in Southeast Asia will provide full-cycle flood monitoring products and develop a common presentation for flood related information, based on the "flood dashboard" developed in Namibia (http://matsu.opencloudconsortium.org/namibiaflood). This dashboard will display information in a standard format based on requests from users who determine polygons of interest through a standard query interface. This will be linked to one or several global systems (see component 1). Standard new end products will be developed based on expertise of partners, building on Charter and rapid mapping experience, extending beyond the Charter two-to-four week cut-off (activation) period. CEOS agencies will contribute data in each region to enable product generation and demonstration; some CEOS agencies will develop products on best efforts basis; some non-CEOS partners will develop products/services as well.

Component 3 – CEOS agencies will sponsor local organizations in capacity building initiatives tied to the project, in cooperation with donor agencies such as World Bank, UNDP and national donors (USAID, CIDA, EC's ECHO, etc).

Outlook for enlarged action:

Successful development of the flood pilot offers strong potential for broader application on a global scale. The global efforts will be better showcased when viewed collectively through a single Global Flood Dashboard; the work of global flood modellers will greatly benefit from validation with regional data in three different regions. Improved accuracy of global flood extent modeling would open its use to a broader range of end users. On a regional level, the existing pilots will be greatly reinforced by increased data access and standardization of products across regions allowing end users to benefit from improved timeliness and accuracy, critical aspects to establishing sustainable, on-going services beyond the pilots. Furthermore, success at the regional level in the pilots could lead to a more generalized approach for other regions through interest generated with donor agencies working with CEOS on the pilots.

Seismic Pilot

The pilot set its objectives based on priorities elaborated through an open review process in the framework of the International Forum on Satellite EO and Geohazards (Santorini Conference). The three objectives are:

A. **Support the generation of globally self-consistent strain rate estimates and the mapping of active faults at the global scale by providing EO InSAR and optical data and processing capacities to existing initiatives, such as the iGSRM**

[Wide extent satellite observations]

B. **Support and continue the GSNL for seismic hazards and volcanoes**

[Satellite observations focused on supersites]

C. **Develop and demonstrate advanced science products for rapid earthquake response.**

[Observation of earthquakes with M>5.8]

The pilot activity envisages the following steps:

1) *identify space agencies engaged to share the task of gathering observations;* requires definition of the observational requirements for A) B) C) (see Santorini report). Objective A requires large volumes of archived and new data; C-band and L-band SAR data (such as those provided by Sentinel-1 and ALOS-2) would be of great value to the project;

2) *define geographic priorities for observations & allocate sensors against areas (strategic datasets);* the priorities defined in Santorini, those of the iGSRM and the GSNL are described in the Annex.

3) *acquire data;*

4) *provide data storage and dissemination;* the data repository is concerning EO missions permitting open supply at no cost and other EO missions data provided an appropriate protocol for supply is in place.

5) *provide access to processing for seismic hazard assessment;* assumes access to all EO missions contributing to CEOS DRM on geohazards; processing can be conducted independently of whether data are downloaded or not.

6) *define a protocol for access to the exploitation platform allowing various forms of access for the processing used and for the data utilised, including in some cases limited access to data (use but not download)* .

Regional strain maps, then enlarged to global strain rate maps, with unprecedented spatial resolution and coverage (objective A), will be used by a large community of science users to define worldwide the rate of seismic loading on all (or most) active faults, at the surface and at depth. It will lead to the recognition of seismic loading variations, laterally and at depth, of possible transient strain accumulation or relaxation events, and of interaction between earthquakes, all essential inputs to seismic hazard.

The earthquake response activity will be partly covered by the GSNL through the event sites concerning very severe events, however, Objective C) has a broader scope (4 to 6 earthquakes of interest above M5.8). Objective B integrates GSNL objectives under the pilot. Activities focus on cross-linkages with additional activities bringing benefit. For instance, to address objectives B) & C) the CEOS DRM pilot will both rely on the GSNL and conduct other activities. While the GSNL are providing freely available EO data for scientific analysis of geohazards, to address objective B) the pilot will coordinate different demonstration activities some following a similar approach (making use of data and data infrastructure of the GSNL) and others following different approaches (e.g. data access to a limited user group) in other activities.

Outlook for enlarged action:

Successful modelling of the global strain belt using an EO-based technique allows for much more accurate modeling of global strain, given the difficulty of identifying measurement points using other techniques in areas such as the Himalayas. Better understanding of strain will lead to improved preparedness for earthquakes, especially in regions where strain is not well understood today. Recognition of the need of geodetic data into probabilistic seismic hazard assessment (PSHA) is now widely recognized (in particular in Global Earthquake Model), however modalities must still be defined. The measurements developed in this pilot will allow scientists to test new PSHA models that include seismic loading estimates from InSAR. This is of particular importance in areas with active faults but little or unknown seismicity or in subduction areas (for accurate tsunamis risk evaluation). New products developed in the pilot and made available after earthquakes will position EO data providers to work more closely with civil protection agencies on improved information in the immediate aftermath of major earthquakes.

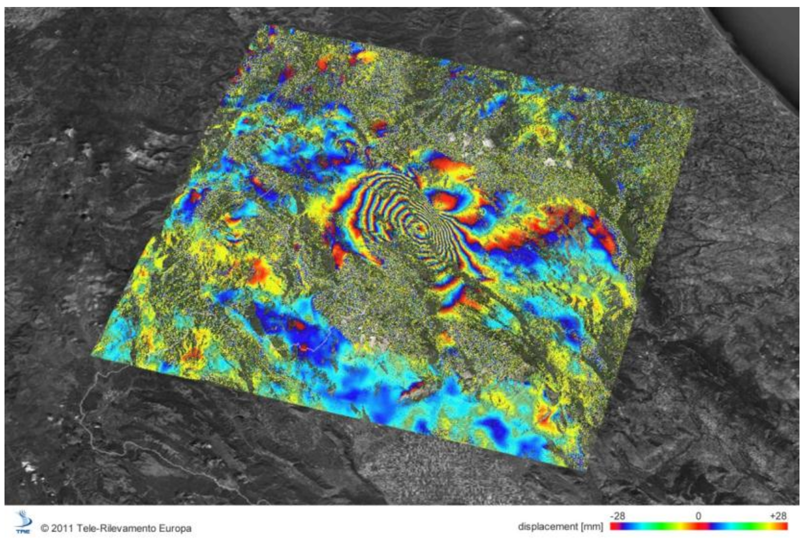


Figure 13. Envisat-based co-seismic interferogram, earthquake in L'Aquila (Italy), April 6, 2009 (M 6.3). Source: TRE Europe.

Volcano Pilot

This pilot represents a stepping-stone towards the long-term goals of the Santorini Report on satellite EO and geohazards with respect to volcanic activity, namely: 1) global background observations at all Holocene volcanoes; 2) weekly observations at restless volcanoes; 3) daily observations at erupting volcanoes; 4) development of novel measurements; 5) 20-year sustainability; and 6) capacity-building. Specifically, the pilot aims to:

A. Demonstrate the utility of integrated, systematic space-based EO as a volcano monitoring tool on a regional basis and for specific case studies

B. Provide space-based EO products to the existing operational community (such as volcano observatories and VAACs) that can be used for better understanding volcanic activity and reducing impact and risk from eruptions

C. Build the capacity for use of EO data at the majority of the world's volcanoes (particularly those that are not monitored by other means)

The pilot will consist of two components: a regional study of volcanic activity in Latin America, and focused studies of a few individual volcanic systems. Both components have obvious synergy with the GSNL initiative. The pilot will showcase how a wide range of sensors can produce valuable information for use by volcano observatories, civil protection agencies, and other organizations responsible for volcano hazard mitigation and response.

<u>Regional Component</u>

CEOS plans to initiate regional monitoring of volcanic arcs in Latin America, stretching from Mexico to southern Chile and including the Lesser Antilles, using satellite EO data to track deformation as well as gas, ash, and thermal emissions. Emissions will be targeted over the entire region by utilizing existing tools—for example, data processing and display interfaces developed by NOAA, EVOSS, and other agencies—and adding new data sources made available by contributing space agencies. Deformation and surface change will be examined using different types of data across the region, including:

- L- and C-band SAR data from Central America, the Northern, Central, and Southern Andes, the Galapagos, and the Lesser Antilles

- X-band SAR data for a few individual volcanoes that are persistently active or restless (e.g., Galeras, Tungurahua, Fernandina) to assess how shorter repeat times may counter the decreased coherence that is associated with shorter wavelength SAR data

- SPOT-5 and Sentinel-2 nighttime acquisitions for mapping thermal anomalies

- Pleiades data for select volcanoes to assess topographic changes

Latin America was chosen for the regional component because: 1) the volcanoes are situated in a diversity of environments (from rain forest to high-altitude desert), providing a good test of the capabilities of different types of satellite data in different settings, 2) volcanic activity is abundant, including deformation with no eruption (e.g., Lazufre) as well as persistent eruptive activity (e.g., Tungarahua, Arenal, Reventador, Villarica), 3) explosive eruptions that disrupt air travel are likely over the course of the three-year pilot and have occurred frequently in the past (e.g., Cordon Caulle, Chaiten, Guagua Pinchincha), and 4) volcano observatories and monitoring agencies in Latin American countries would directly benefit from the additional resources that this pilot will make available. It is hoped that the regional study will demonstrate that EO data can help to identify volcanoes that may become active in the future (i.e., provide a forecasting ability) as well as track eruptive activity that may impact populations and infrastructure on the ground and in the air, ultimately leading to improved targeting for permanent EO-based observations and in-situ volcanic monitoring efforts.

In the Latin American volcanic arc, the pilot will provide access to derived products from optical satellite data that will allow for easy recognition of thermal, gas, and ash emissions. SAR data will be analyzed to assess deformation of volcanoes across the region, providing insights on the types of data and repeat times best suited to monitoring volcanoes in different environments and supplying deformation information to operational users.

Intensive Site-specific Monitoring at Supersites

In addition to demonstrating the viability of sustained monitoring in Latin America, CEOS will conduct multi-disciplinary, multi-platform monitoring over volcano supersites. The goal of the site-specific component is to develop new methodologies and protocols for intensive monitoring of known, active volcanoes, demonstrating the importance of EO data (including SAR, VHR, and visual/near/short-wave/thermal IR scenes) for both operational monitoring and for scientific investigation of eruptive processes and unrest. The sites include:

- Hawaii: location of persistent eruptive activity at Kilauea Volcano. InSAR and thermal data are used for operational volcano monitoring by the USGS Hawaiian Volcano Observatory.

- Iceland: home to numerous deforming volcanoes and site of frequent eruptions. Ash emissions have demonstrated their potential to impact air travel across Europe.

Optical and SAR data will be combined to demonstrate the benefit of operational volcano monitoring during pre-, co-, and post-eruption periods, with specific benefit to on-site volcano-monitoring agencies and general benefit to the scientific community attempting to better understand how volcanoes work. This component will directly support the GSNL initiative.

Major Eruption

In the event of a major eruption in a populated area during the 2014-2016 timeframe, the CEOS pilot will use the eruption to demonstrate the potential of intensive, regular monitoring during and after an eruption, generating products similar to those produced in the other two components of the project.

Outlook for enlarged action:

The volcano pilot is a clear pre-cursor for global monitoring of all Holocene era volcanoes using EO. The current estimate of monitored volcanoes is 10%, and the geographic distribution of monitoring is in relation to resources rather than risk. As the Icelandic explosion of 2010 demonstrated, volcanoes are an international concern with huge potential detrimental impact. CEOS is leading the way towards establishing an affordable and comprehensive monitoring system that will highlight how satellite EO can enable global volcanic monitoring for societal benefit.

Recovery Observatory

Over the course of the past decade, the world has seen an unprecedented number of disasters, which are growing both in number and severity. Large populations living in more vulnerable areas has led to record damages and large losses of life. The last decade has also been witness to a series of catastrophic events that has each marked us: the deadly Indian Ocean tsunami and Haiti earthquake of 2004 and 2010; the catastrophic flood damages of Hurricane Katrina in 2005 and the Tohoku tsunami of 2011, and the astonishing extent of the environmental impact of the Deepwater Horizon explosion in 2009. These catastrophes are on an impressive scale and have widespread and long-lasting impacts. Recovery after such disasters costs billions of dollars and lasts years, even as long as a decade. While satellite imagery is used on an ad hoc basis after many disasters to support damage assessment and track recovery efforts, there is currently no system to support the coordinated acquisition of data and its easy access. After catastrophic events of this magnitude, a coordinated approach would maximise the effectiveness of efforts and promote more widespread use of satellite data after smaller events by increasing the awareness of the benefits to be obtained through its use.

The concept of a “Recovery Observatory” was initially born from seeing huge quantities of Earth observation data that are made freely available following major disasters to many different users. These data are made available in an ad hoc manner and through a large variety of platforms, which means that their use both during and after the disaster (when this is authorised) is not optimised. Seeking to optimise the use of collected data, and understanding the value of implementing systematic observations for several years, CNES led the creation of a platform to gather and continue to make available Earth observation data following the devastating Haiti earthquake of January 2010. This project, the KalHaiti project, has made great progress over the past three years, and has allowed CNES to identify lessons learned that underscore the importance of working before a catastrophic event takes place, and of working collectively, as a community of agencies, rather than in isolation. A single, coordinated approach supported by advance planning and identified mechanisms to trigger the creation of an Observatory will greatly increase the efficiency and impact of actions taken following major events. These lessons have led to the creation of the Recovery Observatory Oversight Team and this proposal.

The Recovery Observatory concept offers a clear complement to the Charter, firstly because it will offer a well-organised repository for data collected during the Charter activation, and secondly because it will continue to support recovery for several eyars, whereas Charter activations must be closed after a few weeks.

A CEOS-led Recovery Observatory, a one-time demonstration in the 2014-2016 period, would allow the development of specific tools tailored to provide easy access to data over affected areas (pre-event data, response data and coordinated post event acquisitions). An organised repository, combined with an effective exploitation platform would allow disaster managers to work in a known environment with advanced satellite products and promote their use to key user communities. Currently, research shows that EO can be a valuable tool for recovery, DRM stakeholders do not have a clear example of how EO can be used to support Recovery efforts and an optimal scenario for data collection and sharing has not been put forward for any major catastrophes.

The main objective of the proposed Recovery Observatory is to facilitate access to data and products that support recovery from a catastrophic event. A subsidiary benefit for CEOS and satellite data providers will be the development of specific approaches and protocols for using satellite data to support disaster recovery, and raising the awareness with the Disaster Risk Management community of the benefits of a satellite-based approach.

Outlook for enlarged action:

While only one Recovery observatory is planned in the 2014-2016 timeframe, the Observatory offers a showcase into how EO can effectively be used for disaster recovery, even on smaller scales. It will also enable the development of protocols of observation and new reconstruction products. For CEOS member agencies, improved understanding by the international community of the value of EO in supporting disaster recovery is of great benefit.

The Recovery Observatory has been conceived from the outset as a partnership between CEOS and DRM stakeholders, especially large international organisations involved in supporting local and national recovery efforts during the aftermath of major events.

Annex I. CEOS ad hoc Disasters Team and Expert Teams

ASI	Laura Candela, Simona Zoffoli
CNES	Steven Hosford
CSA	Christine Giguere (team Co-Chair)
DLR	Jens Danzeglocke, Joern Hoffmann
ESA	Philippe Bally, Maurice Borgeaud, Stephen Briggs, Simonetta Cheli, Ivan Petiteville (team Co-Chair)
JAXA	Takao Akutsu, Chu Ishida
NASA	Brian Killough, Frank Lindsay, Stu Frye, Shelley Stover, Karen Moe, John Evans, Guy Seguin
NOAA	Yana Gevorgyan, Bob Kuligowski
USGS	Brenda Jones, Michael Poland
CEOS ex officio	Kerry Sawyer (and previously Tim Stryker)

The *ad hoc* Disasters Team recognises the contribution of Andrew Eddy of Athena Global, under contract to ESA, who provided extensive input and drafting support for the Observation Strategy and thematic pilot proposals, as well as secretarial support during Team meetings and teleconferences, and for all three thematic teams.

Floods Experts Team:

Expert Name	Organisation
Stu Frye	NASA. Team co-Chair
Bob Kuligowski	NOAA Team co-Chair
Bob Adler	UM
John Bolten	NASA
Giorgio Boni	CIMA
Bob Brakenridge	UC
Laura Candela	ASI
Pat Cappelaere	NASA
Andrew Eddy	Athena Global
David Farrell	CIMH
Delphine Fontannaz	CNES
Kosta Georgakakos	HRC
Christine Giguere	CSA
Alain Giros	CNES
Tom de Groeve	JRC
Brenda Jones	USGS
Bob Jubach	HRC
Benjamin Koetz	ESA
Christophe Lerebourg	ACRI
Pauline Mufeti	Dept. of Hydrology/Namibia
Patrick Matgen	Lippmann Institute
Shelley Stover	NASA
Nicki Villars	Deltares
Albrecht Weertz	Deltares
Hessel Winsemius	Deltares

Seismic Hazards Expert Team:

Philippe Bally	ESA. Team co-Chair
Joern Hoffmann	DLR. Team co-Chair
Steven Hosford	CNES
Eric Fielding	NASA
Falk Amelung	GSNL
Stefano Salvi	INGV
Tim Wright	Comet+
Chuck Meertens	UNAVCO
Laura Candela	ASI
Fabio dell'Acqua	EUCENTRE
Marie-Pierre Doin	ISTerre/IPGP
Cecile Lasserre	ISTerre/IPGP
William Barnhart	USGS
Andrew Eddy	Athena Global

Volcanoes Expert Team:

Expert Name	**Organisation**
Michael Poland	USGS. Team co-Chair
Simona Zoffoli	ASI. Team co-Chair
Juliet Biggs	University of Bristol
Matthew Pritchard	Cornell University
Chiara Cardaci	DPC
Fabrizio Ferrucci	IPGP
Sue Loughlin	BGS/Global Volcano Model
Michael Pavolonis	NOAA
Antonio Ricciardi	DPC
Rick Wessels	USGS
Steven Hosford	CNES
Christine Giguere	CSA
Freysteinn Sigmundsson	University of Iceland
Andrew Eddy	Athena Global

Annex II. CEOS Flood Pilot Proposal

<table>
<tr><td>CEOS Flood Pilot

2014-2016

Theme area: floods</td><td rowspan="2">CEOS Proposal Development Lead:

Stu Frye, National Aeronautics and Space Administration (NASA)

Bob Kuligowski, National Oceanic and Atmospheric Administration (NOAA)

User Implementation Lead:
Global: NASA Goddard Space Flight Center (GSFC)
Caribbean: Caribbean Institute for Meteorology and Hydrology (CIMH)
Southern Africa: Namibia Dept. of Hydrology
Southeast Asia: Mekong - Mekong River Commission (MRC Technical Support Division), Java - Indonesian Ministry of Public Works (Research Center for Water Resources)
CEOS Implementation Lead: NASA and NOAA</td></tr>
<tr><td>Geographic areas of focus:

Global, with regional pilots in
Caribbean (focus on Haiti)
Southern Africa (focus on Kavango/Okavango and Zambezi basins)
Southeast Asia (Mekong basin and Java)</td></tr>
<tr><td rowspan="2">Partners:

CEOS agencies: NASA, NOAA, Agenzia Spaziale Italiana (ASI), Canadian Space Agency (CSA), European Space Agency (ESA), Centre National d'Etudes Spatiales (CNES), South African National Space Agency (SANSA), United States Geological Survey (USGS).

Other partners: CIMA, Hydrologic Research Center (HRC), Lippmann Institute, Deltares, Service Régional de Traitement d'Image at de</td><td>Contributing projects:
NASA SensorWeb
Group on Earth Observations (GEO) Caribbean Satellite Disaster Pilot
GEO Southern African Flood and Health Pilot
Lower Mekong River Basin Project (NASA, USGS)
ESA TIGER Initiative
RASOR (CIMA, SERTIT, CIMH, Deltares, Indonesian Govt., AG)
KAL-Haiti (CNES)
Dartmouth Flood Observatory (Univ. Of Colorado)
NASA near-real-time (NRT) Global Moderate resolution Imaging Spectro-radiometer (MODIS) Flood Mapping
Global Flood Monitoring System (U. of Maryland; Tropical Rainfall Measuring Mission (TRMM) and Global Precipitation Measurement (GPM))
Global Flash Flood Guidance (HRC)
Other relevant projects: International Charter, SERVIR, GDACS</td></tr>
<tr><td>Pilot objectives:

The CEOS Flood Pilot aims to demonstrate the effective application of satellite earth observations (EO) to the full cycle of flood management at</td></tr>
</table>

Télédétection (SERTIT), University of Colorado, University of Maryland, Joint Research Centre (JRC), CIMH, ACRI, Global Facility for Disaster Reduction and Recovery (GFDRR), MRC-Technical Support Division, Government of Namibia, Kavango/Okavango River Commission, Government of Indonesia (Research Center for Water Resources - RCWC), UNESCO.	global and regional/local scales by:
	
	• **Objective A** – Integrating information from existing near-real time global flood monitoring and modeling systems in a Global Flood Dashboard for hydro-meteorological modeling by science users, for flood monitoring by DRM practitioners, disaster managers, other end users, and for the general public;
	(higher temporal and lower spatial resolution)
	• **Objective B** – Delivering EO-based flood mitigation, warning and response products and services through regional end-to-end pilots in:
	  o The Caribbean (with particular focus on Haiti);
	  o Southern Africa, including Namibia, South Africa, Zambia, Zimbabwe, Mozambique and Malawi;
	  o Southeast Asia (with particular focus on the lower Mekong Basin and Java, Indonesia).
	(higher spatial and lower temporal resolution)
	• **Objective C** – Encouraging at least base-level in-country capacity to access EO data and integrate into operational systems and flood management practices.
	CEOS objectives:
	
	• Improve coordination of satellite data acquisitions in support of flood management;
	• Demonstrate the value of satellite EO in the context of integrated flood management practices (and including flood hazard mapping).

Description:

Component 1 – Global Overview and Regional Linkages: the capabilities of existing global flood systems will be combined in a "Global Flood Dashboard" that will provide users with a single point of entry for relevant data covering the full cycle of flood monitoring. Users will be able to evaluate larger-scale flood risk via archive flood and related products at moderate resolution (e.g., MODIS flood maps, flood vectors from UNOSAT). Current or predicted flooding (based on observed and/or predicted rainfall) will be depicted on a global map with moderate-resolution satellite flood products and forecasts (e.g., Sensor Web, U. of Maryland Global Flood Monitoring System), and particular regions of interest will be indicated (e.g., based on information from the Dartmouth Flood Observatory, Europe Media Monitor, and International Red Cross). Users will also be able to focus on specific regions of interest—the three regional Pilots (Caribbean/Central America, Southern Africa, or Southeast Asia) and any other regions where Charter products can be freely obtained—to view close-ups and overlays of estimated and predicted rainfall, predicted severity of flooding, available flood images (if flooding is in progress), and links to the relevant datasets. The portals of the three regional components of the Flood Pilot will be linked to and coordinated with the Global Flood Dashboard, allowing users to view the higher-resolution data sets available to the regional components. This capability will significantly facilitate validation of the coarser-resolution global flood products via the linkages with the regional Pilots and high-resolution Charter products. New end products developed at a regional scale will also be incorporated into the Global Flood Dashboard on a demonstration basis.

Component 2 – The flood aspects of the existing regional end-to-end disaster pilots in the Caribbean/Central America and Southern Africa and the new flood component in Southeast Asia will provide full-cycle flood monitoring products and develop a common presentation for flood related information, based on the "flood dashboard" developed in Namibia (http://matsu.opencloudconsortium.org/namibiaflood). These regional dashboards will provide information in a standard format from various high resolution assets and in-situ data sources based on requests from users who determine polygons of interest through a standard query interface. Each flood component "dashboard" will be linked to the global systems (see component 1). New end products will be developed based on the expertise of partners, building on the Charter (the concept, not the actual Charter data but rather freely accessible products) and rapid mapping experience and extending beyond the Charter two-week cut-off (activation) period. CEOS agencies will contribute data in each region to enable product generation and demonstration; some CEOS agencies will also develop products on a best-efforts basis. Some non-CEOS partners will develop products/services as well that will be linked through the common interface for each regional component.

Component 3 – CEOS agencies will sponsor local organizations in capacity building initiatives tied to the project, in cooperation with donor agencies such as the World Bank, UNDP and national donors (USAID, CIDA, EC's ECHO, etc).

In the Caribbean, CIMA will work with the RASOR end users (Haiti, CIMH) to develop specific training tied to the CEOS Pilot activities (RASOR multi-hazard risk analysis and management). Annual Donor meetings sponsored by regional authorities will be tracked and attended by CEOS Flood pilot representatives to influx remote sensing thrusts into the planning activities of that body. Similar approaches will be pursued at the regional level of World Bank donor conferences working through national representatives that attend the regional WB conference.

In Southern Africa, ESA's TIGER initiative will make specific linkages between the pilot activities and local capacity building including training in Namibia, Zambia and possibly South Africa (2014-15).

In the Mekong, NASA will develop specific training tied to CEOS Pilot activities and provide end users with EO data products that complement existing Mekong River Commission (MRC) flood management efforts in the Lower Mekong River Basin. In Indonesia, end users will receive training for RASOR platform use and integration of satellite EO for flood risk management.

CEOS contribution to pilot: CEOS will act as the coordinating body to ensure the support and participation of member agencies in executing this project. The main contribution of CEOS agencies is:

a) maintenance and improvements to existing global-scale efforts;
b) coordinated higher spatial resolution satellite observations before, during and after floods in the three regions of interest.

In some cases, agencies are providing value-added products and services, as well as modeling support and product validation work. CEOS agencies are providing project management support to oversee the implementation of the pilot.

Key pilot outputs/deliverables:

Component 1 – Global Flood Dashboard providing a single point of entry that links existing global initiatives and three regional components;

Component 2 – Three regional flood dashboards; standard new end products building on Charter and rapid mapping experience, extending beyond the Charter two-week cut-off (activation) period.

Component 3 – Capacity building initiatives tied to the project, in cooperation with local organizations and donor agencies such as the World Bank, UNDP and national donors (USAID, CIDA, EC's ECHO, etc).

CEOS outputs/deliverables:

- Coordinated satellite EO data acquisitions to support integrated flood management in three regions, and to reinforce global flood monitoring efforts
- Plan for satellite data acquisitions to support global flood monitoring beyond 2016

Key user communities:

- Users: local governments, civil protection agencies, river basin authorities, meteorological services, land use planning decision makers, disaster risk reduction specialists with NGOs and international organisations, insurance sector
- Practitioners: flood modelers, scientists and hydrological engineers in hydrology, water and environment ministries, meteorological services, satellite data providers, value added service companies
- Institutional bodies responsible for communication of risk to communities (gap between technical level and shared information with communities): research institutions with operational responsibilities.
- General public: some information will be made available to the general public, although the main focus of the pilot is on specialized users.

The pilot recognizes that users of the pilot outputs and products may be different according to global or regional interests, and will endeavor to build stronger relationships with both categories of users through outreach activities.

Key outcomes:

1. Simplified access to existing global flood modeling and monitoring systems for users;

2. Improved understanding of how satellite EO can be used to support integrated flood management;

3. Increased local capacity to adopt satellite EO solutions;

3. Best practices and lessons learned for regional flood management using EO.

Milestones and schedule:

Global systems

2014: initial pilot Global Flood Dashboard website with linkages to major global projects and systems (e.g., Sensor Web, U. of Maryland Global Flood Mapping System, Dartmouth Flood Observatory) and archive flood products (e.g., MODIS, UNOSAT flood vectors);

2015: functional linkages between the Global Flood Dashboard and the three regional flood component areas; indication of regions of interest based on reports of flooding (e.g., International Red Cross, Europe Media Monitor); showcase at World Conference on Disaster Risk Reduction

2016: continue 2015 services and draft a plan for longer-term sustainability for beyond 2016 for satellite products to support global flood monitoring, if Charter data availability supports it, functional linkages to additional user-selected polygons of interest beyond the three regional pilot areas

Caribbean

2014: flood dashboard based on Namibia pilot adapted to Caribbean users; flood monitoring (i.e., targeted EO data acquisitions); contributions of data to KAL Haiti data base;

2015: flood monitoring during 2015 season; RASOR risk management platform operational for flood risk and landslide risk analysis in Haiti; 10-year flood archive over region based on Deltares Flood Monitoring Programme;

2016: continue 2015 services and draft a plan for longer-term sustainability.

Southern Africa

2014: flood monitoring during early 2014; training and capacity development; Windhoek workshop; updates to flood dashboard;

2015: flood monitoring during early 2015; 10-year flood archive over region based on Deltares Flood Monitoring Programme;

2016: continue 2015 services and draft a plan for longer-term sustainability.

Southeast Asia

2014: user consultations on new pilot products; establishment of regional GEO pilot; test TRMM/GPM-based high resolution flood monitoring product over the Lower Mekong Basin (contingent on river gauge data being obtained); flood dashboard development based on Namibia pilot adapted to SE Asia users;

2015: operational test bed for RASOR risk management system for test sites in Java; integration of flood dashboard; initial services for Mekong River Commission; 10-year flood archive over region based on Deltares Flood Monitoring Programme; 1st new TRMM/GPM and other flood monitoring products;

2016: continue 2015 services and draft a plan for longer-term sustainability.

EO data requirements:

The CEOS flood thematic team has developed detailed EO data requirements, which identify specific polygons of interest and frequency of observations for various satellite types and specific satellite sensors. Data provided must be ortho-rectified and geolocated for integration into user systems and products, which in turn are designed with open standards to encourage transmission and sharing across regions. The EO data requirements were presented in draft form to the CEOS SIT in fall 2013. The EO data requirements include both archived data from past and existing missions (Envisat MERIS and ASAR, MODIS, TRMM, Radarsat-1 and 2, ALOS-1, COSMO-Skymed, TerraSAR-X, Proba-V, Landsat-8, EO-1, Pleiades, SPOT-5, AMSR-E, GRACE,etc) and new data from upcoming missions (Sentinel-1 and 2, GPM, SMAP).

Main contribution by partner:

- NASA: support the DRM Flood effort by funding the implementation of the prototype Global Flood Dashboard and its linkage to the three regional systems (Component 1)
- NOAA: provide real-time rainfall rate estimates to support the HRC flash flood system and any other pilot efforts as needed
- CSA: RSAT-2 data over some regional pilot areas (exact areas TBC).
- ESA: The TIGER initiative will provide capacity building/training in Namibia, Zambia and South Africa; Sentinel-1 and 2 data will be available over regional pilot areas, and ESA will work internally to facilitate early access to Sentinel data during the early mission's lifetime in the three regions of interest.

- CNES: KAL Haiti data base can receive data over Haiti and be linked to regional pilot in Caribbean; SPOT and Pleiades data over regional pilot areas.
- ASI: COSMO-Skymed data over some regional pilot areas (exact areas TBC).
- SANSA: data over Southern African test area; training.
- CIMA and SERTIT: RASOR platform for test sites in Haiti and Java by mid 2015; integration of data from several satellite sensors including TanDEM-X, COSMO-Skymed, ALOS-2, Radarsat (through this pilot) and Pleiades, and flood modeling.
- CIMA: algorithms to support EO-based flash flood monitoring and forecast over RASOR test sites; expertise on practices for operational flash flood forecast.
- CIMH: capacity building tied to EO data exploitation in Caribbean.
- Deltares: development of Envisat radar archive over three test areas – linkages to global activities – through Global Flood Monitoring program (10-year Global Flood Archive based on Envisat SAR imagery and a global flood detection algorithm) – regional case studies over Southern Africa, Java and Haiti.
- HRC: Flash flood system running operationally from HRC in Dominican Republic and Haiti (build bridges to KAL Haiti and CSDP). Flash flood systems provided by HRC in Southern Africa and Mekong. HRC will incorporate selected EOS products into the operational flash flood warning systems and evaluate effectiveness.
- Dartmouth Flood Observatory/University of Colorado: Completion of global coverage for "Surface Water Record" displays and supporting GIS data and associated public data distribution portals. Includes previous maximum flood extent data and current surface water from NASA NRT Global MODIS Flood Mapping
- University of Maryland: Global Flood Monitoring System (GFMS) continued development, improvement and testing using TRMM/GPM rainfall into hydrological model with routing at 12 km and 1 km resolutions. Continued routine real-time product generation (www.flood.umd.edu). U of Maryland will work with pilot to provide through the global model regional cut-outs tailored by users, so that a user can define a specific polygon of interest and receive flood bulletins and products only for this area.
- Lippmann Institute (with TU Wien and JPL): test water-related EO products (Envisat based flood map) for data-assimilation in hydraulic models with a number of case study flood events, generate flood hazard maps of the Lower Zambezi area using the archive of ENVISAT ASAR WSM imagery.
- ACRI: MERIS archive for historical flood events; development of Sentinel 2/3 use in regional pilots.
- MRC and RCWC: in-situ data for product calibration and validation.

Capacity building:

- U. of Maryland: capacity building with global users and in regional pilot regions using global real-time results.
- ESA: TIGER activities in Namibia and Zambia will link with the CEOS Flood Pilot in Southern Africa. The activities include the development and installation of a Water Observation Information System (open source software) and—most important—intensive training of the local stakeholders. Interfaces will be established to the existing global systems (Component 1 above) to improve local capacity. Finally, the WOIS as open source software can be disseminated further in the Southern African region, possibly in South Africa (already included in TIGER).
- RASOR project (CIMA, AG, SERTIT and Deltares): the FP7 RASOR project will work closely with local users in the Caribbean, especially with CIMH, to develop capacity working with satellite EO data on flood management; RASOR will also work in Indonesia (Java) with local users to develop uptake of EO-based products.
- Lower Mekong Basin and Indonesia: The Project Mekong activities will link existing flood monitoring and management activities to the CEOS Flood Pilot. Partners will develop a methodology and application strategy for efficiently integrating EO data products with the FMMP flood monitoring network and forecasting system. The utility of these activities for improving flood management capacity will be demonstrated and improved through the engagement of the stakeholders and linking

the EO data products, global systems and local gauge data. In Indonesia, capacity building activities will be centered on training end users in RASOR platform use as a tool to integrate EO data into prototype risk assessment systems. Involvement with the Global Earth Observation System of Systems Architecture Implementation Pilot: The NASA-led initiatives through the GEOSS AIP continue development of Sensor Web tools/techniques that are demonstrated and adopted by regional flood component practitioners for improved uptake of CEOS provided EO data.
Outreach activities: • The pilot will use a registered user system where anyone can register as an organization or individual and offer constructive feedback to validate and improve the system (allows metrics); users will be encouraged to evaluate pros and cons of various global systems and linkages to regional products, to allow feedback and improvement of existing systems. • The flood pilot activity will provide (through its website) an "index" of who is doing what, where and how they are linked with regard to global and regional flood management efforts in the areas covered by the pilot (to be maintained by the flood team leads and automated when possible). • CEOS Flood Pilot will design specific products that will be made publicly available through social media, including work using Open Street Map as a tool to validate satellite EO flood extent data and products in several of the test areas. These links to social media will also provide tools for metrics gathering through inherent tracking mechanisms to assess uptake. • The pilot will use structured multi-channel communication to ensure broad public outreach while respecting confidentiality and targeted communication where appropriate.
Suggested evaluation criteria: 1. Increased use of global flood monitoring and modeling tools/sites (pilot will track metrics from 2014 to 2016, and categorize the user communities) 2. Successful integration of archived and near-real time satellite EO into operational flood monitoring systems in the three pilot areas 3. Quantitative evaluation of the effectiveness of modeling and observational products for warning and response for the three pilot areas.
Proposal Contributors: Bob Adler (UM), John Bolten (NASA), Giorgio Boni (CIMA), Bob Brakenridge (UC), Laura Candela (ASI), Pat Cappelaere, (NASA), Andrew Eddy, (Athena Global), David Farrell (CIMH), Delphine Fontannaz (CNES), Stu Frye (NASA), Kosta Georgakakos (HRC), Christine Giguere (CSA), Alain Giros (CNES), Tom de Groeve (JRC), Brenda Jones (USGS), Bob Jubach (HRC), Benjamin Koetz (ESA), Bob Kuligowski (NOAA), Christophe Lerebourg (ACRI), Pauline Mufeti (Dept. of Hydrology/Namibia), Patrick Matgen (Lippmann Institute), Shelley Stover (NASA), Nicki Villars (Deltares), Albrecht Weertz (Deltares), Hessel Winsemius (Deltares).

Annex III. CEOS Seismic Pilot Proposal

<table>
<tr><td>International Coordination on Satellite EO & Seismic Science

Theme area: seismic risk</td><td rowspan="2">CEOS Proposal Lead:

Philippe Bally, ESA (philippe.bally@esa.int)

Joern Hoffmann, DLR (joern.hoffmann@dle.de)

User Implementation Leads: A – COMET+, ISTerre; B – GSNL; C - INGV

CEOS Implementation Lead: ESA & DLR</td></tr>
<tr><td>Geographic areas of focus:

A: representative portions of the global seismic belt (Alpine-Himalayan Belt, East African Rift and subduction zones of Central America and South America) demonstration areas to be selected from these zones (NAFZ through to Iran; Himalayan uplift China/India; other TBD); validation sites in Turkey, California and Japan.

B: areas covered by GSNL

C: 4 to 6 earthquakes of interest (>M5.8) per year 2014-2016</td></tr>
<tr><td rowspan="2">Partners:

CEOS partners:

ESA, NASA, CNES, ASI, DLR.

Other partners:

INGV, UNAVCO, COMET+, University of Miami, EU Centre,</td><td>Contributing projects:

Geohazard Supersites and Natural Laboratories (GSNL), InSAR-based Global Strain Rate Model (iGSRM), SSARA, ESA SuperSites Exploitation platform (SSEP), ASI SIGRIS, FP-7 Rapid Analysis and Spatialisation of Risk (RASOR), JPL Advanced Rapid Image Analysis (ARIA)

Other relevant projects: International Charter, European Plate Observing System (EPOS), FP-7 “Connecting EU-US Research Infrastructure” (COOPEUS)</td></tr>
<tr><td>Pilot objectives:</td></tr>
</table>

<table>
<tr>
<td>ISTerre/IPGP</td>
<td>The pilot set its objectives based on priorities elaborated through an open review process in the framework of the International Forum on Satellite EO and Geohazards (Santorini Conference). The three objectives are:

A. Support the generation of globally self-consistent strain rate estimates and the mapping of active faults at the global scale by providing EO InSAR and optical data and processing capacities to existing initiatives, such as the iGSRM
[Wide extent satellite observations]

B. Support and continue the GSNL for seismic hazards and volcanoes
[Satellite observations focused on supersites]

C. Develop and demonstrate advanced science products for rapid earthquake response.
[Observation of earthquakes with M>5.8]

CEOS objectives:

Demonstrate how satellite EO can be used to improve seismic monitoring and response to seismic events.</td>
</tr>
<tr>
<td colspan="2">Description:

The pilot activity envisages the following steps:

1) identify space agencies engaged to share the task of gathering observations; requires definition of the observational requirements for A) B) C) (see Santorini report). Objective A requires large volumes of archived and new data; C-band and L-band SAR data (such as those provided by Sentinel-1 and ALOS-2) would be of great value to the project;
2) define geographic priorities for observations & allocate sensors against areas (strategic datasets); the priorities defined in Santorini, those of the iGSRM and the GSNL are described in the Annex.
3) acquire data;
4) provide data storage and dissemination; the data repository is concerning EO missions permitting open supply at no cost and other EO missions data provided an appropriate protocol for supply is in place.
5) provide access to processing for seismic hazard assessment; assumes access to all EO missions contributing to CEOS DRM on geohazards; processing can be conducted independently of whether data are downloaded or not.
6) define a protocol for access to the exploitation platform allowing various forms of access for the processing used and for the data utilised, including in some cases limited access to data (use but not download).
The earthquake response activity will be partly covered by the GSNL through the event sites concerning very severe events, however, Objective C) has a broader scope (4 to 6 earthquakes of interest above M5.8 per year). Objective B integrates GSNL objectives under the pilot. Activities focus on cross-linkages with additional activities bringing benefit. For instance, to address objectives B) & C) the CEOS DRM pilot will both rely on the GSNL and conduct other activities. While the GSNL are providing freely available</td>
</tr>
</table>

EO data for scientific analysis of geohazards, to address objective B) the pilot will coordinate different demonstration activities, with some following a similar approach (making use of data and data infrastructure of the GSNL) and others following different approaches (e.g. data access to a limited user group) in other activities.

CEOS contribution to pilot:

The main contribution of CEOS agencies is access to data. However, certain agencies (ESA, NASA) have agreed to contribute work relating to system architecture to develop geohazard services for the global user community.

Key pilot outputs/deliverables:

The pilot activities will result in both *data provision* and *information products.*

A.1) EO data to support global strain rate estimates (e.g. iGSRM) and regional/global mapping of active visible faults:

- Wide extent & repeat InSAR data to build the global strain model (continuous observations over large areas using SAR data such as Sentinel-1, ALOS-2 and RCM). Coordination and sharing of data acquisition burden among SAR data providers.
- Optical ortho-rectified imagery to build regional or global maps of active visible fault (e.g. wide extent mapping using data from the SPOT archive).

A.2) Derived geo-information and outputs/products generated under objective A:

- Fault mapping at a regional/global scale
- Ground displacement for historical events based on InSAR analysis and optical imagery when appropriate
- On-going wide extent & repeat ground displacement mapping to contribute to the global strain model (continuous observations over large areas using SAR data such as Sentinel-1, ALOS-2 and RCM).
- Demonstration of EO-based strain rate measurements (over representative sites)
- Demonstration of methodologies and tools to produce large-area to global strain rate estimates
- Validation of these techniques to measure strain rates
- Study of past earthquakes during the satellite era using InSAR stacks and, when appropriate, optical data stacks
- Access to relevant Digital Elevation Models

B.1) EO data to support the GSNL:

- Repeat InSAR data over supersites (SAR data stacks from several missions).
- Optical satellite data, requested by users to support geohazard research at supersites and natural laboratories.

B.2) Derived geo-information and outputs/products generated under objective B:

- Repeat InSAR measurements over supersites (multi-mission).
- Access to relevant Digital Elevation Models

C.1) EO data to support earthquake response:

- Rapid supply of co-seismic data for event sites (SAR stacks and optical pre and post-event images).
- Collection of InSAR data to support fundamental research on earthquake fault mechanics using observations of the early post-seismic phase. These observations (up to months after the event) are now possible thanks to the multiple sensors available through event supersites under the GSNL.

C.2) Derived geo-information and outputs/products generated under objective C:

- Rapid supply of co-seismic ground displacement from analysis of SAR and optical imagery.
- (Semi-) automatic fault modelling, prediction of damage distribution, rapid calculation of Coulomb Stress changes on neighbouring faults (derived from above).
- Seismic source models
- Maps of geological surface effects.
- Post-seismic ground velocity maps.

In addition, the pilot will deliver a data exploitation platform, described under capacity building and outreach below.

CEOS outputs/deliverables:

Data contributions

Data exploitation platform and associated tools

Key outcomes:

A: demonstration of the effectiveness and utility of a global strain model based on EO data observations, particularly relevant in areas where few other measures (GPS) exist (e.g. Himalayas)

B: provide GSNL with exploitation platform to develop value-added contributions made by GSNL users

C: rapid availability of science products (e.g. interferograms) to assist international scientific community in interpretation of major seismic events

Key users communities:

Objectives A) & B):

- Geo-science community incl. Universities (PIs) worldwide
- Organisations with a national mandate concerning risk assessment (incl. seismological centres)
- Specialists of geohazard risks in other sectors (pre-commercial research affecting insurance/re-insurance sector, civil engineering companies, energy, etc.)
- *Longer term: National & regional civil protection agencies and national & local authorities with a risk management mandate*

Objective C):

- Geo-science community
- Organisations with a national mandate concerning risk assessment (incl. seismological centres)
- Longer term: National & regional civil protection agencies and national & local authorities with a risk management mandate (response)

Milestones and schedule:

Objective A):

Q1 2014 - required data and data acquisition plans in place

End 2014 - results of test areas using archived data, initial results for main areas; established beta methodology for processing over large areas (see target for end 2016); preliminary results for validation sites on ERS/Envisat, COSMO SkyMed and TerraSAR-X data in Eastern Turkey and California

End 2015 - partial results of validation - Turkey, California, Japan, other selected areas

End 2016 - strain rate measurement results over pilot areas of focus (see EO data requirements)

Objective B):

see GSNL Planning, e.g. Action DI-01-C2_4 under http://ceos-actions.com/CEOS/ceos?_dm_flow=user2&_dm_event=actions.

Objective C):

Q3 2013 Examine the gaps in existing acquisition plans over the major cities of the world in areas at high seismic risk (COSMO SkyMed,TerraSAR-X, Radarsat).

Q1 2014 Example data for past earthquakes put on the SSEP (L'Aquila, Van, Emilia, New Zealand)

Q3 2014 Implementation of processing algorithms for rapid response products on the SSEP

Q3 2014 Demonstration of the generation of different products (see C2) for 1-2 earthquakes.

Q1 2015 Comparison of results obtained by different groups/algorithms/approaches; consensus report.

Q3 2015 Demonstration of the generation of different products (see C2) for 1-2 earthquakes.

Q3 2015 Product assessment by the final users

Q3 2016 Demonstration of the generation of different products (see C2) for 1-2 earthquakes.

For A, B & C):

Coordination activities (CEOS) such for e.g. web site for sharing the results of the three objectives.

Q1 2014 Development of the Web site.

Q1 2014 Development of procedures (for each agency) to ensure optimal data acquisition in case of earthquakes over a certain threshold. (same for volcanoes)

Q1 2014 Development of a procedure to list EO data acquisitions as they are acquired. Development of a procedure to make data available rapidly.

EO data requirements:

The geographic focus of value-adding product providers & users (e.g. COMET+, LICS and EwF funded projects in the UK and the ISTerre/IPGP group in France) are the Alpine-Himalayan Belt (including for instance Turkey, Iran, Tibet, etc.), the East African Rift and the subduction zones of Central and South America. These regions are part of the priority areas illustrated in Annex 13. In the time frame of the pilot users seek both access to large collections of data ex archive (SAR & Optical) and to assist CEOS in developing a strategy for new acquisitions (e.g. Sentinel-1, ALOS-2, TerraSAR-X) for global seismic belt monitoring. A subset of the areas of interest under Objective A is being considered as a demonstration area to showcase benefits of the work on EO-based global strain models.

A table summarizing the Observation modes and areas is included in the main strategy document and in annex 15.

Main contributions by partner:

ESA

The ESA originated SSEP capability can be used as a critical building block of a distributed global e-infrastructure for Geohazards. Following the SSEP v1.0, 2.0 & 3.0 demonstrators (see Annex 5) and leveraging their concept and architecture, ESA is proposing a User Exploitation Platform for the CEOS DRM community concerning Geohazards (primarily seismic hazards): the GSEP 1.0 (2014-2016). In the medium- to long-term ESA plans to provide a component solution to the Geohazard user communities based on the CEOS DRM requirements. The GSEP will provide a prototype Exploitation Platform that will address objectives A) B) and C) described in section 2.1) of this document. The prototype will be a platform providing functions concerning the space assets from several space agencies and satellite owners and developed in collaboration with them. Concerning the GSNL portal, following objectives B) and C), based on an appropriate assessment of the benefit with partners and users, the intention is to evaluate whether the portal associated to the exploitation platform might offer the services of the GSNL portal. The aim is to provide the following:

- Access to ESA missions data ex archive: ERS SAR and ENVISAT ASAR data will be made available over the areas of the GSNL and over extended areas for tectonic analysis e.g. strain rate assessment, active faults mapping, etc. provided the data collections have been defined and approved (e.g. through project proposals to ESA).

- Access to EO data using Sentinel-1: specific data sets are foreseen to gradually be made available over selected areas of the GSNL and over specific areas for tectonic analysis such as strain rate assessment. This is provided that it is in line with the Copernicus Data Policy under preparation by the European Union and corresponding relevant data policy.

- Multi-mission data storage and data dissemination e.g. ERS & ENVISAT (A)SAR data ex archive, SPOT, TerraSAR-X, Cosmo-SKYMED, Sentinel-1, etc. The data repository is concerning EO missions permitting open supply at no cost and other EO missions data (e.g. commercial) provided an appropriate protocol for supply is in place; the data repository concerns extended coverage (larger than for the GSNL) as described in Annex 13 (figure 7). TPM mission data provided if in line with the various relevant data policies, and pending agreement with data owners.

- Query interface to select the data, interoperability with the data viewers, post-processing software for ease use of EO data to support geohazard science (e.g. precise co-registration of large data stacks of radar data to support INSAR including PSinSAR), including EO data preparation toolbox such as NEST concerning ESA data, new software and workflows (e.g. new InSAR commercial software) in particular INSAR processing such as PSinSAR (for instance the Wide Area Processing developed by DLR) processing, etc.

- Scientific animation of the data, information and results provided by the CEOS DRM pilot as part of outreach and promotion actions. This would be based on moderators organising and commenting the content of the pilot projects for objectives A) B) and C) when the CEOS pilot has clear commitments regarding the content of the GSNL.

- Access to ICT resources, including transparent access to other cloud providers.

- Other domain specific capabilities required by the Geohazards community, still to be formulated.

The above targets are indicative and detailed targets will be provided later, based both on a refinement of the requirements raised by the communities, and constrained by available funding.

While the exact scope and schedule of GSEP still needs be defined in detail, the target is to have an operational User Exploitation Platform with basic capabilities available in 2014 and a version meeting the principal requirements by end 2016. As a minimum, in 2014 the GSEP will provide data storage and dissemination concerning SAR data ex archive from ERS and ENVISAT over sites of interest identified in the CEOS DRM thematic group, including the GSNL and those sites with large data volumes concerning tectonics such as for studies concerning strain rate estimates and regional/global mapping of active faults. For instance ESA already manages project proposals from user communities concerning wide extent tectonic analysis where very large data stacks (typically 1000+ and 5000+ scenes) are required in areas such as: the Western North America region, Italy, Turkey, Iran, China, etc.

The SSEP demonstrators are precursor to the GSEP as described in Annex 4.a) of the Annexes document. In particular the SSEP v3.0 evolves the SSEP for GSNL adding some general platform functions, and implements some new requirements (modelling, feasibility/consistency analysis, GMTSAR integration; GUI reworked). The general capabilities of SSEP v3.0 (and some of the specific) are applicable both to the GSEP and the SSEP for GSNL, and will be fed into GSEP. It also addresses some of the CEOS DRM requirements and will be operated for one year as a pilot.

CNES

Through the proposed SPOT World Heritage programme, CNES plans to provide access for the science community to the 25-year SPOT archive. As a contribution to the CEOS DRM seismic pilot, SPOT scenes covering objective A would be processed and made available for fault mapping and the study of historical earthquakes. It is estimated that all the needs of this community for optical data will be met through the SPOT World Heritage Programme, when approved. To address objective C ("EO data or derived geo-information to support earthquake response"), when scientifically relevant, CNES will make pre and post event imagery from the SPOT 5 and Pleiades satellites available to the science community. This data will be made available via CNES's thematic data centres and will require science users to be pre-registered.

INGV

In the framework of the SIGRIS project (activities funded by ASI under the MUSA project) INGV will generate rapid response, value added products relevant to moderate/large earthquakes worldwide.

The products will be generated, validated with any available in-situ information, then published on the project website. Full public access will be granted to most of the products. Scientific and operational users will use a registered access to obtain additional value on the products.

The products foreseen are:

- Co-seismic displacement maps
- Seismic source models
- Maps of geological surface effects (landslides, liquefactions, fault scarps, etc.)
- Post seismic ground velocity maps
- Coulomb stress change models on neighboring faults

In the SIGRIS framework INGV will contribute to the pilot with value added demonstration products generated for 4 to 6 moderate/large earthquakes each year (Objectives B and C), whenever useful pre-event data are available. INGV will also engage in outreach activities aimed at promoting the use of EO data in the seismic risk management chain (especially emergency management). SIGRIS could also implement some of its algorithms in the GSEP exploitation platform, although for some of them permission from ASI must be obtained first.

SIGRIS requests to the pilot will be X, C and L-band SAR data acquired over the test areas for a period of 3 years (routine monitoring for pre-event archive maintenance). Actual needs are still being quantified, and will be clearly laid out in the EO data requirements document.

In the framework of the RASOR project INGV will define, develop, demonstrate and pursue final exploitation, of VA information products relative to earthquake risk management both before and during an event (Objectives B and C). The RASOR Users will be public managers, international organisations, private companies involved in the risk management chain.

INGV will define a set of procedures, standards, and benchmarks to define the various application scenarios for the geohazard products within a multi-hazard perspective, taking into account the diversity of operational modes of the different users. INGV will demonstrate the RASOR platform integrating EO and in-situ data to generate and validate VA seismic products for three main test cases: the Caribbean region (mainly focused on Haiti), the Northern Italy region (mainly focused on the lower Po Plain) and parts of Java in Indonesia (Bandung and/or Jakarta, South Java Coast).

In the RASOR framework INGV will contribute to the pilot with value added demonstration products generated over the RASOR test areas, and with outreach activities aimed at promoting the use of EO data in the seismic risk management chain.

RASOR requests to the pilot will be InSAR time-series and optical EO data acquired over the test areas for a period of 3 years.

DLR

The DLR contribution to the DRM seismic pilot will be

Objective A:

- (Prospective contribution) Availability of TANDEM-X DEM consultation to registered science users through a “viewer” that does not allow download of the data.

Objective B:

- Data contributions to the GSNL including TerraSAR-X SAR data, TanDEM-X DEM data. Data will be made available for Permanent Supersites, Event Supersites and selected Natural Laboratories.

- Digital Elevation data from the SRTM-X mission at 1 arc-second resolution (<30m). This data is available free-of-charge at http://eoweb.dlr.de.

- The Global Urban Footprint (GUF) product for the GNSL sites and other sites covered under this pilot (tbc after definition of the regions). The GUF is a global dataset of built-up land surface derived from Tandem-X SAR data. It’ll be available at 12m resolution for GNSL sites and at reduced resolution (50m, tbc) globally. The product will be available at the end of 2013.

Objective C:

- TerraSAR-X and TanDEM-X data contributed to the GSNL Event Supersites.

- Global Urban Footprint product.

ASI

ASI will contribute with COSMO-SKyMed data to:

- objective B) through the GSNL project over selected supersites;

- objective C) providing COSMO-SkyMed data for some selected earthquakes to allow the production of value-added products listed in the INGV annex.

The ASI contribution will be confirmed during the internal ‘upward’ briefings to CEOS agencies on data requirements.

CSA

CSA will contribute data made available through the GSNL project over supersites and natural laboratories.

(Prospective contribution) will provide near-real time imagery in support of Objective C when value added providers have identified a target event to provide products, in cooperation with either INGV or JPL/ARIA. The target number of events over which data would be required (pre-event archived imagery and near-real time acquisitions) is 4 to 6 times a year.

NASA

NASA provides a large number of EO datasets through its Distributed Active Archive Centers (DAACs). Data acquired by NASA satellite sensors and airborne platforms are available for free download by all. The datasets most useful for earthquake studies are the Shuttle Radar Topography Mission (SRTM) digital elevation models (DEMs) for most of the world and the UAVSAR repeat-pass interferometry data acquired by a NASA piloted airplane. The ASTER optical images from the NASA Terra satellite have also been used to study large earthquakes, and the new Landsat 8 satellite provides excellent wide area coverage using high-resolution optical data. The SRTM DEMs have recently been upgraded with a new release V3 that has the voids filled, which will make it more useful for InSAR processing to study earthquakes in areas of high relief. The airborne UAVSAR data is available for the San Andreas Fault and its continuation into northern Mexico, with repeat-pass interferometry acquired 2-4 times per year. There is also UAVSAR data for Hawaii and a number of volcanoes in Alaska, Japan, Central America and South America.

NASA is supporting three projects closely related to the Pilot: ARIA Monitoring Hazards, REPAIR and SSARA. The Jet Propulsion Laboratory (JPL)-Caltech Advanced Rapid Imaging and Analysis (ARIA) team the ARIA Monitoring Hazards project is supported under the NASA AIST program and is focused on time series analysis of InSAR and GPS data for monitoring ground deformation due to faults and volcanoes. ARIA Monitoring Hazards is developing improvements to the Generic InSAR Analysis

Toolbox (GIAnT) that is designed to facilitate the comparison of InSAR time series, which can be used for Objective A.

The ARIA Rapid Earthquake Products from Analysis & Imaging for Response (REPAIR) project is a joint project between JPL, Caltech and the USGS NEIC, supported under the Earth Science Applications Disasters program. The REPAIR project is planning to produce rapid processing of InSAR and GPS measurements of coseismic deformation and automated or semi-automated finite fault slip models, which will benefit Objective C.

NASA is also supporting the Seamless SAR Access (SSARA) project that is a joint effort of UNAVCO, Alaska Satellite Facility (ASF) DAAC, JPL and University of California, San Diego, under the NASA ACCESS program. The SSARA project has already built a federated query Applications Programming Interface (API) and related graphical user interface that can search the combined SAR archives at the ASF DAAC, UNAVCO (WInSAR), and GSNL virtual archive. SSARA is working on additional development of an archive for interferograms that are contributed by users or produced by a future version of the ASF DAAC on-demand InSAR system

NASA will use pilot supplied data from satellites such as RADARSAT-2 to image events and provide rapid seismological products for the science community through the ARIA project and related efforts.

EU CENTRE

The EUCENTRE can contribute expertise in building vulnerability/exposure mapping from EO and ancillary data, facilitating linkages between seismic hazard extent and potential impact on populations and infrastructure.

COMET + (Universities of Leeds, Oxford, Cambridge, Glasgow, Reading, Bristol and UCL)

COMET+ will contribute the following aspects to the pilot

- Demonstration of EO-based strain rate measurements for the validation sites and focus areas in Turkey, Tibet and California

- Development of methodologies and tools to produce strain rate estimates

  - Implementation of an automated processing chain to process all Sentinel-1 data acquired in the Alpine-Himalayan Belt and East African Rift. This will be delivered at CEMS in Harwell and linked to the ESA SSEP.

- Validation of techniques to measure strain rates, using multiple extended sites with varying strain rates, which are well mapped and known through alternative techniques such as GPS)

  - Delivery of new fault maps derived from optical and DEM data in selected parts of the Alpine-Himalayan Belt
  - Development of InSAR fault plane solutions for selected earthquakes (Objective C).

COMET+ is the UK Natural Environment Research Council's Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics. The work described here is co-funded by COMET+ and two NERC consortia grants – Earthquakes without Frontiers (EwF), and Looking Inside the Continents from Space (LICS). Together, these represent more than £4M of UK investment in the scientific exploitation of SAR data that will be available from Sentinel-1 and other future radar missions.

U of Miami

University of Miami will develop techniques to validate the methodologies used to obtain strain rate measurement, in particular focussing on possible errors introduced through the use of different types of data over different areas.

ISTerre/IPGP

- Software optimisation, and methodological contribution for automated InSAR time series analysis (in particular: development of NSBAS software and adaptation to SSEP, cluster and cloud infrastructures)
- Validation of techniques to generate velocity maps, through inter-software comparisons (we will participate to software benchmarking that shall help define errors in LOS velocity maps.)
- Generation of LOS velocity maps over wide areas (e.g. Tibet, Himalaya, Central and South America, Turkey, Middle East and Afar depression) to incorporate into iGRSM
- Development of an automated, end-to-end, open-source image correlation software dedicated to the processing of SAR and optical data for the measurement of large ground deformation
- Computation of pre- and post-event DEMs using high-resolution optical imagery
- Methodologies and tools for the assimilation of ground displacement maps (InSAR, SAR correlation, optical imagery correlation) into rapid source models for all major earthquakes (M>7 for continental events ; M>7.5 for subduction earthquake) and significant volcanic eruptions
- Methodologies and tools to produce strain rate estimates

Capacity building and outreach activities:

As far as systematic *data exploitation* is concerned, the pilot will:

- *Develop communities*: pro-actively develop and manage the international community of geohazard users. Conduct outreach and capacity development concerning EO based techniques within user communities (geoscience centres, observatories, end users);
- *Conduct e-science:* accelerate the science use of satellite EO & promote research through new mechanisms using the web;
- *Create an exploitation platform*: address the goals of the geohazard risks community with dedicated tools (such as atmospheric correction or crustal deformation modelling, etc.) in a cloud-based computing environment. An

exploitation platform (e-infrastructure, incl. cloud computing capability) will provide users with data, software and computation to support i) data storage and access ii) processing tools and Value Adding (SaaS and PaaS) iii) virtual machines (IaaS). The added value of CEOS DRM will be to reinforce the capacity of the GSNL with the functionalities of an exploitation platform (for instance data storage, dissemination, scientific animation, etc.) which will apply to both GSNL and other regions. On the issue of exploitation platforms, it was agreed that the pilot will propose several prototypes developed in parallel by ESA and UNAVCO, and that a joint evaluation process would be established to present lessons learned and chart a path forward for sustainable services beyond the pilot timeframe.
Suggested evaluation criteria: A: accuracy of measurements of iGSRM region completed under the project; ability to use output of work for other regions (validation methodologies for example) B: number of end users and practioners using data exploitation platform; number and quality of peer reviewed papers based on work done on the platform; C: rapid delivery of science products; linkages made between rapid delivery and advancement of seismic understanding of given area
Proposal Contributors: Philippe Bally (ESA), Joern Hoffmann (DLR), Steven Hosford (CNES), Eric Fielding (NASA), Falk Amelung (University of Miami), Stefano Salvi (INGV), Tim Wright (COMET+), Marie-Pierre Doin (ISTerre/IPGP), Cecile Lasserre (ISTerre/IPGP), Chuck Meertens (UNAVCO), Laura Candela (ASI), Fabio dell'Acqua (EUCENTRE), Andrew Eddy (Athena Global).

Annex IV. CEOS Volcano Pilot Proposal

Volcano Pilot **2014-2016** Theme area: Volcanoes	**CEOS Proposal Development Lead:** Michael Poland, USGS Simona Zoffoli, ASI **User Implementation Lead**: USGS **CEOS Implementation Lead:** ASI
Geographic areas of focus: A. The Latin American volcanic arc (Mexico through southern Chile, including the Antilles) for regional monitoring B. Supersites of the GSNL C. Site of major volcanic event 2014-2016	
Partners: CEOS partners: USGS, ASI, CSA, ESA, NOAA, JAXA*, NASA*, DLR*, CNES* Other partners: University of Bristol, Cornell University, University of Iceland, British Geological Survey, Italian Department of Civil Protection	**Contributing projects:** Geohazards Supersites and Natural Laboratories CSA Volcano Watch NOAA Volcanic Cloud Monitoring Global Volcano Model STREVA Other relevant projects: EVOSS

(DPC), Institut de Physique du Globe of Paris (IPGP), VAACs (Buenos Aires and Washington)*, volcano observatories (several with confirmed interest in Latin America), VDAP, civil defense agencies* Research Consortia: IAVCEI*, STREVA (University of Bristol), Global Volcano Model (BGS), WOVO*, VHUB*, COMET+(University of Leeds), ALVO* * Denotes unconfirmed commitment	**Pilot objectives:** This pilot represents a stepping-stone towards the long-term goals of the Santorini Report on satellite EO and geohazards with respect to volcanic activity, namely: 1) global background observations at all Holocene volcanoes; 2) weekly observations at restless volcanoes; 3) daily observations at erupting volcanoes; 4) development of novel measurements; 5) 20-year sustainability; and 6) capacity-building. Specifically, the pilot aims to: D. Demonstrate the feasibility of integrated, systematic and sustained monitoring of Holocene volcanoes using space-based EO; E. Demonstrate applicability and superior timeliness of space-based EO products to the operational community (such as volcano observatories and VAACs) for better understanding volcanic activity and reducing impact and risk from eruptions; F. Build the capacity for use of EO data in volcanic observatories in Latin America as a showcase for global capacity development opportunities. **CEOS objectives:** Improve coordination of satellite data acquisition over volcanoes, demonstrate efficiency of EO-based monitoring methodologies as a complement to in-situ measurements, and support and continue the GSNL initiative
Description: The pilot will consist of three components: a regional study to demonstrate the feasibility of global volcanic monitoring, focused on Latin America; detailed studies of a few frequently active volcanic systems (namely the Hawai‘i and Iceland volcano Supersites); and a third component to address a major volcanic event anywhere in the world if such an eruption takes place during the course of the pilot. The pilot will showcase how a wide range of sensors can produce valuable information for use by volcano observatories, civil protection agencies, and other organizations responsible for volcano hazard mitigation and response.	

Regional Demonstration

CEOS will demonstrate the feasibility of global volcano monitoring of Holocene volcanoes by undertaking regional monitoring of volcanic arcs in Latin America, stretching from Mexico to southern Chile, and including the Lesser Antilles, using satellite EO data to track deformation as well as gas, ash, and thermal emissions. Emissions will be targeted over the entire region by utilizing existing tools—for example, data processing and display interfaces developed by NOAA, interfaces developed through the EVOSS project, and those developed by other agencies—and adding new data sources made available by contributing space agencies. Deformation and surface change will be examined using different types of data across the region, including:

- L-band SAR data from Central America, the Lesser Antilles, and the Northern, Central, and Southern Andes
- C-band SAR data from the Central and Southern Andes
- X-band SAR data for a few individual volcanoes that are persistently active or restless (e.g., Galeras, Tungurahua) to assess how shorter repeat times may counter the decreased coherence that is associated with shorter wavelength SAR data
- Landsat-8, SPOT-5, IRS-P6/LISS-III and Sentinel-2 HR data (Visible-NIR-SWIR) to assess surface changes at volcanoes showing unrest
- SPOT-5 and Sentinel-2 (NIR-SWIR) day and nighttime acquisitions for computing and mapping High-Temperature thermal anomalies at erupting volcanoes
- Landsat-8 (TIR) nighttime acquisitions with strategic revisit, to assess thermal anomalies
- Pleiades VHR 3-D data to assess ground deformation (volume changes, dome growth) at selected volcanoes
- A wide range of publicly available NASA, NOAA and ESA data and products to detect, assess and track volcanic ash plumes
- VIIRS and MODIS data and products to detect, assess and monitor surface, high-temperature thermal anomalies at moderate spatial and temporal resolution
- GOES-East, GOES-West data and products – where appropriate – to detect, assess and monitor surface, High-Temperature thermal anomalies at very-high temporal resolution

Latin America was chosen for the regional component because: 1) the volcanoes are situated in a diversity of environments (from rain forest to high-altitude desert), providing a good test of the capabilities of different types of satellite data in different settings, 2) volcanic activity is abundant, including persistent eruptive activity (e.g., Tungarahua, Arenal, Reventador, Villarica, Soufriere Hills) and deformation with no eruption (e.g., Lazufre), 3) explosive eruptions that disrupt air travel are likely to occur over the course of the three-year pilot, based on experience over the past decade (e.g., Cordon Caulle, Chaiten, Guagua Pinchincha, Popocatèpel), and 4) volcano observatories and monitoring agencies in Latin American countries would directly benefit from the additional resources that this pilot will make available. It is hoped that the regional study will demonstrate that EO data can help to identify volcanoes that may become active in the future (i.e., provide a forecasting ability) as well as track eruptive activity that may impact populations and infrastructure on the ground and in the air, ultimately leading to improved targeting for permanent EO-based observations and in-situ volcanic monitoring efforts.

Supersite activity

In addition to regional studies, we will conduct multi-disciplinary, multi-platform monitoring of a few volcanoes that represent a diverse cross section of eruptive activity and unrest. The exact sites will coincide with the volcanic supersites (Hawai‘i and Iceland). The goal of the Supersite component is to establish the importance of EO data (including SAR, VHR, and visual/near/short-wave/thermal IR scenes) for both operational monitoring and for scientific investigation of eruptive processes and unrest. The Supersite locales offer the following benefits for demonstrating the value of EO monitoring and research:

- Hawai‘i: location of persistent eruptive activity at Kīlauea Volcano. Hawai‘i is already a GSNL Supersite, and InSAR and thermal data are used for operational volcano monitoring by the USGS Hawaiian Volcano Observatory.
- Iceland: home to numerous deforming volcanoes and site of frequent eruptions. Ash emissions have demonstrated their potential to impact air travel in Europe. Also a GSNL Supersite.

Significant Global Event

If, during the course of the pilot, there is a major eruption with significant regional or global impact, the volcano will be the object of specific study, and a range of pre-event (if possible), event, and post-event products will be developed by the partners. The 2010 “100-year” eruption of Merapi, Indonesia, provides an example of an event that would qualify for intensive study as part of the pilot because of the level of risk to a large population and the need for EO data by local agencies tasked with volcano monitoring and civil defense. Although the space charter may also be activated for such an important volcanic eruption (as it was for Merapi in 2010), the pilot will go beyond the space charter mission by providing data for a comprehensive analysis of all aspects of the eruption cycle, including local (e.g., mass flows on the volcanic slopes), regional (e.g., ash emissions that may be hazardous to aircrafts), and global (e.g., volatile and aerosol emissions that may influence climate) impacts.

CEOS contribution to pilot:

The main CEOS contribution is satellite data, which will be used by partners to demonstrate viability of volcanic risk reduction/mitigation and support to operational monitoring of volcanic eruptions and unrest. In some cases. CEOS agencies will provide value-added support and/or training to operational users and other partners.

Key pilot outputs/deliverables:

In the Latin American volcanic arc, the pilot will provide access to derived products from optical satellite data that will allow for easy recognition of thermal, gas, and ash emissions. SAR data will be analyzed to assess deformation of volcanoes across the region, providing insights on the types of data and repeat times best suited to monitoring volcanoes in different environments and supplying deformation information to operational users. The Latin American demonstration is a precursor demonstration to showcase how monitoring Holocene volcanoes would work on a global scale beyond 2016.

At the supersites, optical and SAR data will be combined to demonstrate the benefit of operational volcano monitoring during pre-, syn-, and post-eruption periods, with specific benefit to on-site volcano-monitoring agencies and general benefit to the scientific community attempting to better understand how volcanoes work. This component will directly support the GSNL initiative

CEOS outputs/deliverables:

Collection of L, C and X-band data over Latin America and at certain specific volcanic sites outside this area; VHR data collects over select volcanoes.

Coordinated observation strategy 2014-2016 for pilot volcanoes, in coordination with the GSNL;

Draft plan for global observation strategy beyond 2016.

Key user communities:

Washington and Buenos Aires VAACs; Operational volcano-monitoring agencies in Latin American countries (Chile, Bolivia, Peru, Ecuador, Columbia, Panama, Costa Rica, Nicaragua, El Salvador, Guatemala, and Mexico); Operational volcano monitoring agencies for Supersites (USGS, Iceland Meteorological Office, United Nations, etc.); Civil Protection agencies in Latin America and at Supersite locales; and volcano eruption response and capacity-building agencies (e.g., VDAP).

Key outcomes:

- identification of volcanoes that are in a state of unrest in Latin America and the Lesser Antilles
- demonstration of the feasibility of operational volcanic monitoring of Holocene volcanoes using EO
- comprehensive tracking of unrest and eruptive activity using satellite data in support of hazards mitigation activities
- validation of EO-based methodology for improved monitoring of surface deformation
- improved EO-based monitoring of key parameters for volcanoes that are about to erupt, are erupting, or have just erupted, especially in the developing world (where in-situ resources may be scarce)
- capacity-building in countries that do not currently have access to abundant EO data and/or the ability to process and interpret such data

Milestones and schedule:

2014: Begin studies at Supersite volcanoes. Begin collection of data over Latin America data and development of derived products. Establish ties with users and work with them to define procedures for delivering products.

2015: Provide derived products to appropriate users in Latin America (e.g., VAAC, Observatories) and agencies working on Supersite volcanoes. Collect feedback from users about the data and derived products, and use the feedback to refine monitoring strategies. Provide initial evaluation of pilot results to the World Conference on Disaster Risk Reduction.

2016: Receive reports from Latin American users on derived products and adjust as needed. Evaluate results from Supersite studies. Develop broader space-based EO strategy using insights from pilot in a formal report.
EO data requirements: The volcano thematic team has developed a detailed set of EO data requirements, including the designation of specific polygons of interest and identification of specific satellite data types and satellites that may provide support to the pilot. These requirements will be considered by CEOS and addressed in the Acquisition Plan that implements the Observation Strategy.
Main contribution by partner: USGS: support to volcano observatories in Latin America through VDAP; conduct Supersite studies in Hawai‘i and process regional data from the Galapagos ASI: access to COSMO-Skymed data on selected volcanoes DPC: methodologies and practices for EO-based operational volcanic monitoring ; support (training, capacity development) CSA: access to Volcano Watch data archive; possible modification of Volcano Watch data acquisition plan to support pilot objectives, and provision of Radarsat-2 data over Central and Southern Andes and at Supersites; processing of some data from the Volcano Watch archive. ESA: Sentinel-1 data collects over areas of interest; access to exploitation platform (seismic pilot) and integration of volcanic studies into data repository; scientific animation for volcanic community, along the same lines as that described by the seismic pilot. IPGP: access to EVOSS joint venture for tracking thermal emissions and volcanic aerosols at Latin American and Supersite volcanoes CNES: Optical data (SPOT, Pleiades) to support HR lava flow and dome deformation studies and monitoring of ash extent University of Bristol: contribution of effort of doctoral student to perform analysis of SAR data over Latin America, and capacity building in Latin American through STREVA Cornell University: contribution of effort of doctoral student to perform analysis of SAR data over Latin America NOAA: satellite-based information on airborne volcanic clouds as well as thermal and gas emissions, from volcanoes in Latin America and that are the subject of Supersite studies, along with real-time access to GOES-West and GOES–East crude data – and future ABI’s – for the high temporal resolution thermal monitoring of the geographic area of focus.

EVOSS: real-time quantitative thermal and SO2 monitoring over the whole of Europe, of Africa, the Middle-East, the Lesser Antilles, the centre-western South America, the Atlantic and the northwestern Indian Ocean (includes any erupting volcano in this region of focus). EVOSS' stretching to all erupting/severely unresting volcanoes in Latin America is feasible under ad-hoc data provision agreement

BGS: contribution through Supersite studies in Iceland, Post-doctoral effort in the Futurevolc project and contributions to EVOSS

Global Volcano Model network (GVM): will work alongside the CEOS initiative, as GVM produces a section on volcanoes for the UNISDR 2015 Global Assessment Report (GAR15) and we will continue to work alongside CEOS in response to global post-2015 developments.

Latin American volcanic observatories: use of EO-generated products, validation with in-situ data, use of prototype products and provision of feedback.

Capacity building:

The CEOS pilot will work with designated developing-world volcano observatories and VAACs to identify EO-based methodologies that complement existing monitoring efforts and provide a more robust monitoring capacity. Where possible, EO-based methodologies and practices will be transferred with training to ensure sustainability. STREVA will be an important venue for this work.

Outreach activities:

Training in the use and interpretation of EO data will be provided to volcanologists in the developing world (Latin America in particular) through research consortia (e.g., STREVA) and VDAP. Results will be highlighted at research conferences (e.g., AGU, EGU) and workshops (especially those organized by CEOS agencies).

Suggested evaluation criteria:

- Identification of new areas of unrest through regional InSAR monitoring

- Uptake by Latin American volcano monitoring agencies of EO-based methodologies for tracking deformation, as well as gas, thermal, and ash emissions

- Utilization of EO data for operational monitoring by volcano observatories at Supersite targets

- Interest expressed by volcano community to broaden approaches adopted in pilot (especially regional monitoring and new methodologies for EO-based monitoring) through representative bodies such as IAVCEI, WOVO or GVM

Proposal Contributors:

Michael Poland (USGS), Simona Zoffoli (ASI), Juliet Biggs (University of Bristol), Matthew Pritchard

(Cornell University), Chiara Cardaci (DPC), Fabrizio Ferrucci (IPGP/EVOSS), Sue Loughlin (BGS/Global Volcano Model), Michael Pavolonis (NOAA), Antonio Ricciardi (DPC), Rick Wessels (USGS), Steven Hosford (CNES), Christine Giguere (CSA), Freysteinn Sigmundsson (University of Iceland), Andrew Eddy (Athena Global).

Annex V.   Recovery Observatory Proposal

Proposal to Establish a Recovery Observatory

Draft as of 27 October, 2013 (not final)

Developed by the Recovery Observatory Oversight Team:

Takao Akutsu (JAXA), Andrew Eddy (Athena Global), Stuart Frye (NASA), Alain Giros (CNES), Steven Hosford (CNES), Chu Ishida (JAXA), Ivan Petiteville (ESA), Guy Seguin (ISC Consulting), Simona Zoffoli (ASI).

Introduction

Over the course of the past decade, the world has seen an unprecedented number of disasters, which are growing both in number and severity. Large populations living in more vulnerable areas has led to record damages and large losses of life. The last decade has also been witness to a series of catastrophic events that has each marked us: the deadly Indian Ocean tsunami and Haiti earthquake of 2004 and 2010; the catastrophic flood damages of Hurricane Katrina in 2005 and the Tohoku tsunami of 2011, and the astonishing extent of the environmental impact of the Deepwater Horizon explosion in 2009. These catastrophes are on an impressive scale and have widespread and long-lasting impacts. Recovery after such disasters costs billions of dollars and lasts years, even as long as a decade. While satellite imagery is used on an ad hoc basis after many disasters to support damage assessment and track recovery efforts, there is currently no system to support the coordinated acquisition of data and its easy access. After catastrophic events of this magnitude, a coordinated approach would maximise the effectiveness of efforts and promote more widespread use of satellite data after smaller events by increasing the awareness of the benefits to be obtained through its use.

The concept of a "Recovery Observatory" was initially born from seeing huge quantities of Earth observation data that are made freely available following major disasters to many different users. These data are made available in an ad hoc manner and through a large variety of platforms, which means that their use both during and after the disaster (when this is authorised) is not optimised. Seeking to optimise the use of collected data, and understanding the value of implementing systematic observations for several years, CNES led the creation of a platform to gather and continue to make available Earth observation data following the devastating Haiti earthquake of January 2010. This project, the Kal Haiti project, has made great progress over the past three years, and has allowed CNES to identify lessons learned that underscore the importance of working before a catastrophic event takes place, and of working collectively, as a communutiy of agencies, rather than in isolation. A single, coordinated approach supported by advance planning and identified mechanisms to trigger the creation of an Observatory will greatly increase the efficiency and impact of actions taken following major events. These lessons have led to the creation of the Recovery Observatory Oversight Team and this proposal.

This document seeks to describe a “generic” Recovery Observatory and the schedule for establishing such a platform. It then highlights some of the major issues that must be addressed during the development of this project if it is to be successfully implemented.

1. Rationale

A CEOS-led Recovery Observatory, a one-time demonstration in the 2014-2016 period, would allow the development of specific tools tailored to provide easy access to data over affected areas (pre-event data, response data and coordinated post event acquisitions). An organised repository, combined with an effective exploitation platform would allow disaster managers to work in a known environment with advanced satellite products and promote their use to key user communities. Currently, research shows that EO can be a valuable tool for recovery, DRM stakeholders do not have a clear example of how EO can be used to support Recovery efforts and an optimal scenario for data collection and sharing has not been put forward for any major catastrophes.

2. Outcomes and Benefits

The main objective of the proposed Recovery Observatory is to facilitate access to data and products that support recovery from a catastrophic event. A subsidiary benefit for CEOS and satellite data providers will be the development of specific approaches and protocols for using satellite data to support disaster recovery, and raising the awareness with the Disaster Risk Management community of the benefits of a satellite-based approach.

3. Challenges

A number of major challenges to the establishment of an Observatory have been identified:

3.1 Triggering the Observatory

Defining the type of disaster for which the RO could be triggered. Such a disaster should have a sufficient impact to ensure a long term involvement of the national governments or international institutions, the scientific communities, NGOs, etc. This impact can be estimated through different parameters such as its location, its geographical extent, the number of victims, affected infrastructures, impact on natural or economic resources, and also the estimated time to recovery. Beyond its impact, the institutional and social context is also an important parameter to be considered. All these conditions must be identified and carefully analyzed in order to be ready to select the most reasonable opportunity for triggering the RO with the highest possible outcome in terms of demonstrating the benefits of remote sensing for risk management and recovery monitoring.

Finding an appropriate “supranational” partner. Being able to quickly establish links to national and local users is of critical importance for the RO to have maximum impact. Clearly it is not possible to prepare this aspect in advance in all countries. Having an appropriate partner, most probably from within the UN family of organisations, who can provide a formal link to the affected country in the aftermath of a disaster is one way of addressing this issue.

3.2 Mobilising User Communities

Identifying and mobilizing users’ communities. Ensuring the involvement of end-users in the RO is a key for success but also one of the most difficult challenges because they cannot be precisely known in advance. Our analysis leads us to identify different users categories such as rescue teams, national institutions, scientific communities, NGOs, international bodies, urban planners or even citizens. Some of them are well coordinated at the international level and the dialog for involvement, promotion and operations could be made as that level. Others are more independent and their mobilization around the RO cannot be prepared for every country. A solution for each of these categories must be found and implies the identification of the right partners for each of them (see below for instance).

3.3 Developing Generic Acquisition Plans

Building a data acquisition plan. Depending on the kind of catastrophe, its extent, its impact and other parameters, the data types which could be needed for the response and recovery phase may extend over a wide range. Identifying the data sources and the way to get them is of great importance prior the triggering of the RO. The Observatory will define pre-determined scenarios to estimate requirements for EO before the disaster occurs.

3.4 Funding Infrastructure

There are useful investments to be made in generic infrastructure before the event occurs, but it can be difficult to obtain funding for a generic platform. Efforts will be made to find synergies with existing projects within CEOS agencies and to attract interest form major DRM stakeholders. The generic platform will be upgraded and adapted after the event occurs.

4. Proposed Scope and Organisation

4.1 A demonstrator

The proposed Observatory would be triggered only once in the 2014-2016 period, as a demonstrator to validate the concept of Recovery Observatories and to showcase how EO can be effectively used to increase the effectiveness of recovery efforts.

A Recovery Observatory such as the one established for Haiti aims to gather and make available as much geospatial data as possible that may be of use in the immediate aftermath of a major disaster and for a period of a number of years after the event. Such an observatory can be considered as a central resource (possibly collaborative), providing users' communities concerned by the event with all the data they need for supporting their activity in the response and recovery phases. Users of the Recovery Observatory belong to rescue teams, NGOs, national ministries, international organizations, urban planning, scientific teams, etc. Even if the Recovery Observatory emphasizes remote sensing data, diverse types of data may be made available ranging from Earth Observation data and derived information products on the event itself and its impact, to socio-economic data on the affected populations. The common theme should be that this data is geospatial (i.e. the data is associated with a position) and that it is of use in helping the response and recovery phase following the disaster. In order to have greatest impact, the Recovery Observatory should be established within weeks after the disaster and should provide a focus for data gathering over and above the Earth Observation community.

The development of the Recovery Observaotry would take place in two phases: first, a preparation phase that includes planning and early development, and then an operations phase that covers the Life-cycle of the Observatory.

4.2 Preparation Phase

Initial Analysis – until November 2013

The initial analysis of the problem has been completed and is contained in this document.

Detailed Analysis – until April 2014

<u>Overview of User Needs</u>

There are many types of users, including…

- International users (or stakeholders): international organizations (either governmental like WB or NGOs like the Red Cross) with a mandate tied to the recovery of major disasters and a major stake in supporting recovery efforts. Identifying one or several such users that adopt the idea of a Recovery Observatory and are prepared to work with CEOS to have one implemented is critical to success. This organization would be the lead interface with other users immediately after the response phase, and would assist in defining the initial acquisition plan to be adapted form the generic plan prepared before the disaster.

- National users: for major disasters, the national body responsible for civil protection is typically the sole interface for the outside community (hence the idea of privileging a dialogue through an established DRM stakeholder which will have the requisite privileged access - necessary to be able to get people's attention after a major disaster). This body will authorize NGOs and other to work in the recovery area and is responsible for the coordination of recovery efforts. Their buy-in is essential as to be successful the Observatory must address their needs and the needs of their partners.

- Local users: the local end user is the most affected, and may have no resources at all after a major disaster. However, ultimately, the local end user will be the key long-term partner for a recovery observatory. There needs to be some sort of transition so that as the Observatory is established, it develops a direct relationship with the local end user to ensure the Observatory is meeting needs and to adjust if desired and possible.

- Practitioners or intermediary users: CEOS agencies will essentially provide data to the Observatory. Mechanisms must be established to allow participation of partners who can provide value-added products and services. These partners may be universities, government organizations or private companies. These intermediary users often include science or research users who work on data for scientific interest but with outputs that are used by civil protection authorities. In some cases, CEOS contributions may include some value adding or training and capacity development. This needs to be set up in a single comprehensive framework where the roles of partners are made clear before the Recovery Observatory is triggered. Intermediate users should be able to:

- understand user requirements;
- from the user requirements identify and generate high level products;
- help to identify EO data acquisition plan;
- train the users in the use and interpretation of the derived products and, when possible;
- try to transfer EO-based methodologies and practices to ensure sustainability EO.

While it is impossible to determine the exact needs of a Recovery Observatory before an event takes place, there are a large number of requirements that are common to all recovery situations after major disasters. What is required is to establish what the baseline data requirements would be both for EO data and for derived products. These data and products support several different types of activity that change as the observatory period evolves. A draft categorization of these activities might include:

- Built area damage assessment (initial and later detailed)
- Natural resource and environment assessment
- Reconstruction planning support
- Reconstruction monitoring; and
- Change monitoring.

While there is no need detailed acquisition plans before the triggering of the Observatory, the preparation phase should include the development of detailed EO data requirements for different types of Observatories: one for a major earthquake, one for a major volcanic eruption, one for a major flood and/or hurricane, perhaps a tsunami. The exact number of scenarios developed will be decided during the detailed analysis phase. Some elements are quite common and involve situational awareness immediately after the event and for the damage assessment period, or involve baselining pre event and post event imagery in a single database. Other products might be specific to the disaster type - historical flood analysis for future flood events, InSAR analysis for strain estimates after earthquake, etc etc. The proposal would include a few such scenarios and scope out the types of data required for each, without identifying specific satellite missions. After the SIT in April 2014, volunteer agencies can indicate a willingness to contribute specific data sets in the event of a triggering.

Overview of Technical Components

The content of the Recovery Observatory needs to be defined by the CEOS partners. It can range from a simple repository of available data to a pro-active acquisition strategy and the development of key value-added products that would support recovery.

Data

It is clear that the volume of data collected during the response phase is in fact likely to be much larger than the volume of data collected in the following three to five years. Examples of EO data would include high resolution and very high resolution optical imagery; high and very high resolution radar imagery (X, C and L-bands). Examples of revisit might include once a week for a two or three months and once a month for a period of several years, over a given target area. For some disasters such as earthquakes, InSAR imagery would be required to develop products such as interferograms. For other disasters, InSAR applications may be limited to change detection over built-up areas.

There is a need for data from before and after the event, and if this data is organized as a mosaic coverage of the area for example, with easy access for multiple users, this would allow both large and small users to access data without large capacity needs.

Products

Many end users need products rather than data. It is clear that the Observatory can only be successful if relationships are established to enable the generation of products from the contributed data. The baseline scenarios will determine not only the volume of data but representative products for each type of catastrophe. This allows CEOS to engage in discussions with multilateral stakeholders before an event and establish a framework within which different partners bring different contributions.

Infrastructure

In the event that CEOS decides to set up an exploitation platform for the Observatory, part of the preparation phase should be dedicated to establishing the generic capability to host the Observatory, determining the appropriate informatics tools to include and ensuring standards are in place to received the data in an easily searchable format. Many CEOS agencies already have plans for exploitation platforms and synergies could be sought between existing projects.

International partner

A critical aspect of the analysis phase is identifying a single or several suitable "supranational" partners who will play an important role as a RO user in themselves but also in establishing links to the national user community. This role is particularly important as, given that the national users will not be known until the RO is to be established, they will provide necessary feedback to CEOS through the development phases.

During the detailed analysis, the following issues wil be settled:

- Conditions for triggering an Observatory
- Responsibilities, organization and procedures for triggering and running the Observatory
- Users communities (Engagement, Needs identification, etc)
- Content of preparation phase and commitments in principle from partners

Preparation – April-October 2014

The goal is to prepare the creation of a Recovery Observatory by working on all the required components in order to have all of them ready before entering "cold storage" and the beginning of the Observatory life-cycle. Numerous aspects have been identified:

- Technical components (website, database(s), processing chains)
- Data provision flows (data types, providers, licenses)
- Agreements with Users communities and partners (intermediary users, science users)

This phase should be closed after a "dry-run" formal exercise has been implemented successfully.

4.3 Observatory life-cycle

Cold-storage – from October 2014 until triggering

During this phase we await the occurrence of a disaster corresponding to the defined criteria. As, intrinsically, the components (new sensors, computing technologies, web technologies, communities, international situations, risk management procedures …) evolve, this time period should be limited and defined in advance.

The duration of the waiting phase cannot be predicted, as it depends on an "appropriate" disaster happening, however CEOS should be prepared to support the "Cold-storage phase" for at least 5 years.

Triggering – in the 10 days following the catastrophe

The CEOS agencies supporting the Observatory are in many cases also members of the International Charter. It is clear that the Observatory is a useful complement to the Charter, and that for a disaster of the scope envisaged for the Observatory, it is highly unlikely that the Charter would not be activated. For this reason, Charter activation should be a pre-condition for the creation of an Observatory (no Recovery Observatory if no Charter activation). There will however be only one Observatory created in the 2014-2016 period, whereas there is on average one Charter activation per week. Other criteria are necessary to determine when an Observatory is triggered.

The magnitude characteristic (exceptional event with far reaching impact in human and/or material terms) should be the first filter. The Observatory should be triggered when the catastrophic nature of the disaster and the scale of the anticipated recovery effort warrant it. This may be a CEOS assessment, or may be the result of a request to CEOS from an outside organisation that agrees to serve as a "filter" to assess which disasters may be the best candidates. Any of the members of the Oversight Team who choose to commit to the preparation of the Observatory could also suggest that the Observatory be triggered and call a teleconference to discuss why, according to predetermined criteria. One of these criteria could (and should) be advice/request from a designated international DRM body. The Oversight Team would review the triggering scenarios, consider the main 'standard' requirements for the triggering, and establish whether there is critical mass within CEOS for the triggering.

A CEOS management level participation in the activation discussions is a good idea at the very least to associate this level with the decision. The CEO (CEOS Executive Officer) is the right person to manage this interface, however it should be clear that this representative is acting as a conduit for CEOS management (CEOS Chair/ CEOS SIT Chair) and has consulted with them bringing a CEOS management point of view to the RO activation decision.

With this in mind, the triggering mechanism might function as follows:

1. Charter activation - Oversight Team members or international DRM stakeholder/partner consider whether or not event is catastrophic and warrants Observatory.

2. One Oversight Team member or international DRM stakeholder calls teleconference to propose triggering.

3. Oversight Team examines predetermined scenarios (that were defined during analysis and preparation phase) and looks at triggering criteria, which would include considering advice from DRM stakeholder (and commitment in kind or resources for value added support), looking at scale and scope of disaster, looking at benefit to be derived from establishment of Observatory.

4. Three Oversight Team members, with the agreement of the CEOS Executive Officer in consultation with the CEOS Chair and SIT Chair, representing critical mass/varied contributions of data (according to what was deemed to be required in the preparation scenario) decide they would like to trigger the creation of the Observatory.

5. The Observatory is announced within CEOS with a call for participation.

6. The Observatory is announced publicly, jointly with a DRM partner.

Operations – for a period of 3 to 5 years

The operational phase of the Recovery Observatory should be of a reasonable length, which may depend on the impact of the catastrophe, and would probably range from 3 to 5 years.

Closing – six months before end

This phase involves closing the Observoatory or arranging for its operation by a local partner or international organisation with storng local presence, who might continue to operate the historical data base or suply it with new data to support risk management initiatives.

The review of the activities and outcomes will be presented to CEOS but it should also involve Users Communities and International bodies at the highest possible level.

5. Responsibilities of CEOS Members

The main contribution sought from CEOS members is satellite EO data. Observations will include archived data over the affected area from before the event, data acquired during the response period and dedicated observations to support recovery during the duration of the Observatory.

On a voluntary basis, some CEOS agencies may also contribute value-added products (or support for industry to develop such products), hosting services for the repository, tools to support generation of products or other related services.

Building a data acquisition plan

Depending on the kind of catastrophe, its extent, its impact and other parameters, the data types which could be needed for the response and recovery phase may extend over a wide range. Identifying the data sources and the way to get them is of great importance prior the triggering of the Observatory. From the spatial side, the most suited remote sensing data depend on the sensor type, resolution, swath, acquisition period and also on the targeted applications. The definition of the remote sensing acquisition plan could start with the ECO procedure used in the International Charter which identifies the most suited sensors for a given type of disaster. However since the applications in the framework of the Observatory can be very different, the option of systematically acquiring data from most of the current flying sensors might also be chosen.

Aside the acquisition of new remote sensing data, gathering archive data on the affected area as well as the possibly acquiring in-situ data deserve also a special consideration. One aim of drafting these acquisition plans as precisely as possible would be to provide the CEOS agencies with a precise view of their commitments in terms of amount of images they should provide to the Observatory.

6. Partners (international organisations, DRM stakeholders)

The Recovery Observatory has been conceived from the outset as a partnership between CEOS and DRM stakeholders, especially large international organisations involved in supporting local and national recovery efforts during the aftermath of major events.

As one element of the outside partnership, it is of great importance that the proposed Observatory include some mechanisms to constantly measure benefits in order to be able to communicate and demonstrate the achieved results to the international community.

7. Conclusions

This document has introduced the concept of a Recovery Observatory for helping the response and recovery phase following a disaster and proposed a tentative plan for its implementation. The most important challenges identified so far have also been listed, even though their solutions have only been drafted. Analysing the problem in depth and proposing possible options and solutions to these challenges in order to better shape this pilot is still an on-going task. However, considering the unpredictable occurrence of the disaster on which the Recovery Observatory would be operated, this pilot is proposed with three main phases: preparation, waiting and operations. This is because a rapid response after a catastrophe with the expected characteristics has occurred is of utmost importance. Establishing and moving to the operations phase of the Observatory should be a matter of a few weeks after the event. The only answer to this challenge is 'be prepared'. Otherwise there is no chance of launching a useful Recovery Observatory when it is most needed and will have the greatest impact.

Annex VI. Acronyms

ALI	Advanced Land Imager (NASA's EO-1)
ALOS	Advanced Land Observing Satellite (Japan)
ASAR	Advanced SAR (ENVISAT)
ASI	Italian Space Agency
CEOS	Committee on Earth Observing Satellites
CIESIN	Center for International Earth Science Information Network
CNES	Centre National d'Etudes Spatiales
Copernicus	The European Earth Observation Programme (formerly called GMES)
CSA	Canadian Space Agency
CSDP	Caribbean Satellite Disaster Pilot
DEM	Digital Elevation Model
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
DMSG	Disaster Management Support Group (CEOS)
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EO	Earth Observation or Earth Observations
EPOS	European Plate Observing System
ERS	European Remote Sensing Satellite
ESA	European Space Agency

ETM	Enhanced Thematic Mapper (Landsat)
EU	European Union
FAO	UN Food and Agriculture Organisation
FCT	Forest Carbon Tracking
FEMA	Federal Emergency Management Agency (FEMA)
FP7	7th Framework Programme (EU)
GDLND	Global Landslide Hazard Distribution
GDP	Gross Domestic Product
GEM	Global Earthquake Model
GEO	Group on Earth Observations
GEOSS	Global Earth Observing System of Systems
GFDRR	Global Facility for Disaster Reduction and Recovery
GFOI	Global Forest Observation Initiative
GHCP	Geohazards Community of Practice
GIO EMS	GMES Initial Operations Emergency Management Services
GMES	Global Monitoring for Environment and Security (now called Copernicus)
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
GRIP	Global Risk Identification Programme (UNDP)
GSE	GMES Service Element
GSNL	Geohazard Supersites and Natural Laboratories
GSRM	Global Strain Rate Model
HDDS	Hazards Data Distribution System

HFA	Hyogo Framework for Action
HH	Horizontal/Horizontal – polarizations for SAR
HV	Horizontal/Vertical – polarizations for SAR
IADB	Inter-American Development Bank
ICAO	International Civil Aviation Organisation
ICL	International Consortium for Landslides
ICSU	International Council for Science
ICT	Information and Communication Technologies
IFM	Integrated Flood Monitoring (WMO)
IFRC	International Federation of Red Cross and Red Crescent Societies
IGOS	International Global Observing Strategies
INGV	Istituto Nazionale di Geofisica e Vulcanologia (Italy)
InSAR	Interferometric Synthetic Aperture Radar
IPL	International Programme for Landslides
HR	High Resolution
JAXA	Japan Aerospace Exploration Agency
JRC	Joint Research Centre (EU)
LDCM	Landsat Data Continuity Mission (Landsat-8)
MDA	Macdonald, Dettwiler Associates
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration (USA)
NGO	Non Governmental Organisation
NOAA	National Oceanographic and Atmospheric Administration (USA)

OECD Organisation for Economic Cooperation and Development

PDNA Post Disaster Needs Assessment

PSI Persistent Scatterer Interferometry

RCM Radarsat Constellation Mission (Canada)

SAFER Service and Applications For Emergency Response

SAR Synthetic Aperture Radar

SBA Societal Benefit Area

SPOT Satellite Pour l'Observation de la Terre

SRTM Shuttle Radar Topography Mission

SSEP SuperSites Exploitation Platform (ESA)

UN United Nations

UNAVCO University Navstar Consortium (Boulder, Colorado)

UNDP United Nations Development Programme

UNEP United Nations Environment Programme

UNFCCC United Nations Framework Convention on Climate Change

UNITAR UN Institute for Training and Research

UNOSAT UNITAR'S Operational Satellite Applications Programme

UN-SPIDER United Nations Platform for Space-based Information for Disaster Management and Emergency Response

UNU UN University

USGS United States Geological Survey

VAACs Volcanic Ash Advisory Centres

VHR Very High Resolution

VV	Vertical/Vertical – polarizations for SAR
WFEO	World Federation of Engineering Organisations
WOVO	World Organisation of Volcanic Observatories
WGCapD	Working Group on Capacity Building and Data Democracy
WMO	World Meteorological Organisation

Reference Documents

BALLY, Ph., Ed. (2012), *Scientific and Technical Memorandum of The International Forum on Satellite EO and Geohazards*, 21-23 May 2012, Santorini Greece. doi:10.5270/esa-geo-hzrd-2012

CEOS ad hoc Disasters Team, *Consensus Report on Disaster Risk Management*, Issue 2, October 2012, CEOS.

www.ceos.org : to find updated versions of this strategy, updated versions of the three thematic pilot overviews and their annexes, and updated versions of the Recovery Observatory proposal.