CEOS Seismic Hazards Demonstrator Implementation Plan
Draft
1 March 2018

<table>
<tr><td>CEOS Seismic Hazards Demonstrator
Concept Phase: April 2017 – Q2 2018
Implementation Phase: Q3 2018 – Q2 2021
Theme area: earthquakes and tectonics</td><td rowspan="2">CEOS Implementation Lead:
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Main partners against objectives: I – COMET, II –COMET, HUA, III – HUA, INGV, IV & V – INGV, VI - ESA

Contributing projects:
Geohazard Supersites and Natural Laboratories (GSNL), Geohazards Exploitation Platform (GEP), LiCSAR, FP-7 Center of Excellence for EO-based Monitoring of Natural Disasters (BEYOND)

Potential Contributing Projects:
InSAR-based Global Strain Rate Model (iGSRM), WGCapD</td></tr>
<tr><td>Geographic areas of focus:
Worldwide</td></tr>
<tr><td>Partners:

<u>CEOS space agencies:</u>
ESA, CNES, ASI, DLR

<u>Other partners:</u>
INGV, COMET+, YachayTech, HUA, NASA JPL, NOA</td><td>Objectives:
Based on theme specific objectives that are directly derived from the ‘International Forum on Satellite EO & Geohazards’ the Seismic Hazards Demonstrator intends to support the following activities:

Concerning DRR activities not on an emergency basis:

I. Pursue and expand global tectonics mapping activity such as strain rate mapping (e.g. with the LiCSAR service of COMET);
II. Expand active faults mapping from regional to global level including also urban active faults and pursue reconnaissance mapping of active faults using stereo optical data and derived DEMs to ensure that a reference coverage is available in advance over priority areas and to provide fresh coverage in case of significant deformations. This is as per Objective A) of the seismic hazards community;
III. Support local capacity building in coordination with GSNL (by providing scientific and technical training) to broaden the use and acceptance of advanced EO products by geoscience centres and academia and facilitate end users with their interpretation.
IV. Develop a collaborative framework with geoscience centres to ensure a consensus methodology for product generation is adopted and to demonstrate relevance of advanced EO products to a broader base of users (see Collaboration with the Charter); concerning geoscience centres typically are End Users (e.g. recipient of the EO data in the Charter jargon) and they have a role to do science as experts and, in some instances, to advise DRM authorities.

Concerning DRR activities on an emergency basis:

V. Pursue science products based on terrain motion mapping e.g. advanced tectonics mapping using Sentinel-1 for earthquake response (deformation maps, source models, etc.) as per Objective C) of the seismic hazard community; expand this</td></tr>
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capability with VHR SAR missions (e.g. Cosmo-Skymed, TerraSAR-X, Radarsat) to provide interferograms and motion maps within a virtual constellation; expand this capability with VHR Optical based measurements such as stereo based DEMs and deformation maps.

VI. Collaborate with EO based disaster response capabilities such as the International Charter Space & Major Disasters, the Copernicus EMS and Sentinel Asia (see section 7): articulate with these initiatives to make sure users are aware and work with these capabilities; on a case by case and best effort basis, propose new products complementary to the damage mapping they provide (for instance InSAR based tectonic products such as earthquake source models as used in the context of the 2016 earthquakes in central Italy).

CEOS objectives:

- Demonstrate how satellite EO can be used to improve tectonics monitoring and earthquake response.
- Improve collaboration and sharing of EO products to maximise the benefit from CEOS contributions.
- Take advantage from the use of lessons learnt from the CEOS Seismic Hazards pilot.

Description:

The Seismic Hazards Demonstrator aims at addressing priorities of the *Sendai Framework for Disaster Risk Reduction 2015-2030* using Earth observations (EO) and in particular, *Priority 1 - Understanding disaster risk (hazard characteristics)* and *Priority 2 - Strengthening disaster risk governance at regional and global level*. At the 2016 GEO Plenary in Saint Petersburg the decision was made that Disaster Risk Reduction (DRR) is one of the three priority themes for the next few years. The main goal of the Seismic Hazards Demonstrator is to provide users with a mechanism to access to satellite EO data (e.g. based on yearly quota as typically done through CEOS Pilots),

The Seismic Hazards Demonstrator is an activity proposed as a follow-on of the Seismic Hazards Pilot within the CEOS WG Disasters to enable greater use of *observation data and derived products to assess seismic hazards and their impact*. The CEOS WG Disasters activities are focusing on Disaster Risk Management (DRM) with:

- DRR, addressing needs from both science users in geoscience centres and end users from mandated DRM organisations and workings directly with both types of users outside the disaster response phase,
- Disaster Response, addressing needs from science users in geoscience centres; as a baseline the Seismic Hazards Demonstrator fully articulates with operational initiatives such as the International Charter Space & Major Disasters, Sentinel-Asia and Europe's Copernicus Emergency Management Services; it is not interfering with them for data access in the crisis time; outreach to end users is possible based on the 2015 agreement between CEOS and the Charter that makes it possible to expose CEOS results in the disaster response phase to the Charter operational team (the so called Project Manager).

The Seismic Hazards Demonstrator is intended to expand the precursor Seismic Hazards pilot activities. The activity is addressing three challenges identified in the precursor CEOS Pilots:

- Accessing EO data in a cost-effective way, since it is costly to access large volumes of data in order to achieve the objectives of the seismic hazards community (regional to global scale coverage).

- Communicating results to decision makers, based on a consensus methodology for product generation to avoid confusing end-users (especially, those in regions with low quality internet access and no access to processing capabilities).
- Increasing the timeliness of hazard analysis, by pursuing the development and standardization of automated chains for the generation and distribution of hazard maps and preliminary models.

The Seismic Hazards Demonstrator aims to articulate in an orderly fashion with global, regional and national EO based disaster response capabilities. As an example, it is building on the agreement in place since July 2015 between the International Charter and the CEOS WG Disasters.

Philosophy of the Seismic Hazards Demonstrator:
The main contribution of CEOS agencies is access to EO data. The Seismic Hazards Demonstrator shall articulate with GSNL and the International Charter for the provision of EO data.

Key pilot outputs/deliverables:
The following describes targets associated to the Seismic Hazards community.

I) EO data to support global strain rate mapping (e.g. iGSRM) at regional and global scale:

- Wide extent and 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
- 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

II) EO data to support active fault mapping and fault reconnaissance mapping at regional and global scale:

- Wide extent and repeat InSAR and Optical ortho-rectified imagery to build regional or global maps of active visible fault (e.g. using Pléiades and other types of VHRO data ex archive) and to map deformations (combining with fresh acquisitions over hot spots)
- Fault mapping at a regional/global scale
- Risk assessment for urban faults over specific areas (mapping active urban faults)
- Ground displacement for historical events based on InSAR analysis and optical imagery when appropriate
- Study of past earthquakes during the satellite era using InSAR stacks and, when appropriate, optical data stacks
- Access to relevant Digital Elevation Models

III) Support local capacity building in coordination with GSNL (by providing scientific and technical training):

- Identify financing for training activities
- Identify the requirements of trainees and develop a training course based on their needs.
- Conduct training courses and showcase their benefit, when the opportunity is given.

IV) Collaboration and consensus methodology:

- Develop a collaborative framework with geoscience centres with or without EO expertise in order to ensure a consensus methodology for product generation is adopted and to demonstrate relevance of advanced EO products to a broader base of users (see Collaboration with the Charter); concerning geoscience centres typically are End Users and they have a role to do science as experts and, in some instances, to advise DRM authorities.
- Develop a procedure to exploit EO based data and derived products in accordance with the working practices of mandated users (in particular geoscience centres supporting End Users concerning geohazard risks).

V) EO data to support earthquake response:

- Ground displacement analysis using 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
- 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
- Maps of geological surface effects
- Post-seismic ground velocity maps

VI) Collaboration with EO based disaster response capabilities:

- Awareness and promotion: Present and explain the contribution of EO based disaster response solutions and their complementarity with EO based solutions to support tectonics
- Awareness and promotion: Take the opportunity of international presence activities (events, working groups, etc.) to promote complementary EO based capabilities
- Collaboration with the Charter about accessing Charter data packages based on the current Charter-CEOS WG Disasters agreement; establish communications links to make the Charter aware of activities conducted by the Seismic Hazards Demonstrator that might be relevant to them; provide feedback to the Charter about EO data supplied by the Charter to users of the CEOS WG Disasters.

Expected key outcomes:

- Increase the number of users that access EO data
- Increase satellite EO expertise from local geoscience centres and universities
- Achieve higher benefit of the use of satellite EO to local end users
- Raise awareness about the benefit of the use of EO data and advanced EO techniques

Key user communities and benefit:

The user base of the Seismic Hazards Demonstrator includes a range of users and practitioners of satellite EO with an interest in observing and measuring hazards and risks related to earthquakes. The views, needs and objectives of these users are captured in the Santorini report (available at: http://esamultimedia.esa.int/docs/EarthObservation/Geohazards/esa-geo-hzrd-2012.pdf) and further consultation and workshops.

The Seismic Hazards Demonstrator is aiming to provide advanced science products to different types of users:

- ***geoscience centres doing research or mandated to provide technical advice to national DRM authorities already contributing to the Seismic Hazards precursor activities***. Geoscience centers such as geological surveys, geophysics centres looking at seismic hazards are the first line users focused on the scientific use of data that aim to understand the physics of seismic hazards and better characterise, understand and model such risks. In many cases, they have an advisory role in decision making of DRM authorities. In some cases, EO experts, being part of these geoscience centres, process, analyse, validate, integrate the EO satellite data (using ground based data) to extract the maximum amount of information useful for DRM, and generate a simple, synthetic information product which can be understood and used by decision-makers to take effective decisions. Examples of geoscience centers already contributing to precursor seismic activities such as the GEP are INGV, CNR-IREA and CNR IRPI in Italy the ARIA center of NASA JPL and USGS in the USA, NOA in Greece, BGS and COMET/Univ. Leeds & Oxford in the UK, ENS, CNRS, IPGP, ISTerre and BRGM in France.

- ***national DRM authorities*** can be considered as second-line users.

As a baseline, the Seismic Hazards Demonstrator articulates with national disaster response activities and with international EO disaster response capabilities such as the International

Charter, Copernicus EMS, Sentinel Asia, etc. in order to make sure users are aware and use them. The Seismic Hazards Demonstrator will fully take into account the role of national and international initiatives with an operational mission. The main contribution of the Seismic Hazards Demonstrator will be to help develop or reinforce the ability of geoscience centres to support national DRM authorities.

- ***academia***: universities and institutes mainly focusing on research.

- ***other users that may benefit from the Seismic Hazards Demonstrator*** include national user organisations in the context of international development; beyond DRM authorities a range of national users have information needs related to natural hazard risk management such as for instance authorities in charge of basin for water resources management (reservoir monitoring against erosion and landslides, etc.), of transportation, energy and extractives, etc.

- in addition, ***users from industry*** may benefit from the capability (e.g. civil engineering, insurance/re-insurance, etc.) noting that the Seismic Hazards Demonstrator is focused both on science and end to end solutions to decision makers such as provided by Value Adding service providers. However, the link to industry users is mid-term rather than short term.

The user base of the Seismic Hazards Demonstrator is intended to expand thanks to Objectives III and IV: on capacity building and on a collaborative framework with geoscience centres to raise awareness and initiatives to achieve adoption of new methods.

The Seismic Hazards Demonstrator shall rely on pre-existing relations between geoscience centres and end users/decision makers to better understand the end users' expectations (e.g. there are end users with basic EO knowledge that could interpret EO results or others who prefer to receive analytic reports based on these results) and to ensure faster information exchange.

Although the research is complete for advanced EO products such as terrain motion maps (e.g. InSAR based tectonics product to support earthquake response), a consensus methodology for product generation and guidelines on interpretation by the users are required in order to avoid confusing the users about the content of advanced products such as those relating to co-seismic terrain deformations.

Milestones and schedule:

Concept Phase: April 2017- Q2 2018

Currently, there is a process of elaboration and discussion between CEOS agencies and other partners (that are contributing or shall potentially contribute) in order to better define the activities, key outcomes and the required data volumes.

Implementation Phase: Q3 2018 – Q2 2021

Year 1:

1. Document procedures to access and use processing chains.
2. Development of a procedure to make data available rapidly.
3. Monitor status of global strain rate mapping with LiCSAR (Obj. I) using Sentinel-1.
4. Continue active fault mapping (that started during the Seismic Hazards pilot activity) and identify more priority areas for reconnaissance mapping and possibly, urban fault mapping (Obj. II).
5. Launch capacity building activities (Obj. III)
6. Start discussions with partners on consensus methodology generation (Obj. IV) and define requirements.
7. Demonstration of the generation of different products for 10-12 earthquakes per year (Obj. V).

Year 2:

8. Monitor status of global strain rate mapping with LiCSAR (Obj. I) using Sentinel-1 and identify how end users can benefit from the results.
9. Continue capacity building activities (Obj. III) and demonstrate benefit of previous capacity building activities, if the opportunity is given.
10. Start elaborating on consensus methodology generation (Obj. IV).
11. Demonstration of the generation of different products for 10-12 earthquakes per year (Obj. V).

Year 3:

12. Complete active fault mapping analysis, including results in fault reconnaissance mapping and possibly, urban fault mapping (Obj. II).
13. Complete capacity building activities (Obj. III) and showcase results and benefit.
14. Propose procedure for consensus methodology generation (Obj. IV) to the tectonics community.
15. Demonstration of the generation of different products for 10-12 earthquakes per year (Obj. V).
16. Report on activities articulated with the International Charter and other EO response capabilities (Obj. VI).
17. Summarize lessons learnt and re-adapt based on user needs.
18. Identify ways forward.

EO data requirements:
Based on the Sustainability Report of the Seismic pilot, possible yearly volumes of data required for 3 years for are described below. This concerns data collections to be downloaded by users.

No areas of interest are specified as some of these objectives have a global basis, while for the objectives on an emergency basis, no area can be predefined. 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. The data requirements for seismic hazards can be summarized as follows:

(A) SAR data:

– HR and VHR C, L and X-band InSAR: (i) for hazard inventory purposes such as global strain mapping ;(ii) for hazard monitoring purposes (e.g. most critical faults showing shallow creep events or postseismic deformation); (iii) for rapid response to events, SAR acquisitions before and after the earthquake (primarily, for objectives I – Global tectonics mapping and V – Advanced tectonic products for earthquake response).

(B) HR Optical/VHR Optical:

– HR to be used as background reference imagery.
– VHR bi-stereo and tri-stereo optical for disaster response mapping and for surface fracture mapping (primarily, for objectives II - Active fault mapping and V - Advanced tectonic products for earthquake response).

Agency / Sensor	ASI Cosmo-Skymed	CNES Pleiades	CSA RADARSAT	DLR TerraSAR-X	ESA Sentinel-1 & 2
Number of Images per year	300	50	2	On request	open

Other EO data collections (SAR and Optical including VHRO) are intended to be exploited with processing without download (EO data are accessed by the processing environment but the user can only download the value adding product).

Main contributions by partner:
CEOS agencies that have expressed interest in joining the initiative include ESA, ASI, DLR and CNES. Contributing to the Seismic Hazards Demonstrator, primarily EO data.

Contribution from ESA:
i. Access to ESA missions data ex archive: ERS SAR and ENVISAT ASAR data will be made available over the areas of the Supersites (GSNL) and over extended areas for tectonic analysis e.g. strain rate assessment, active faults mapping, etc.

ii. Access to Sentinel-1A & 1B and Sentinel-2A data in line with the Copernicus Data Policy.
iii. Access to the Geohazards Exploitation Platform through the parallel Geohazards Lab initiative (this is a contribution of ESA, CNES, DLR and ASI), including in particular: data storage and ICT resources, including transparent access to other cloud providers processing resources; Query interface to select the data (GeoBrowser), interoperability with the data viewers, processing software to ease the use of EO data to support geohazard science including EO data preparation toolbox such as SNAP concerning ESA data, new software and workflows in particular InSAR and stereo-optical processing chains (for instance the MPIC-OPT processing chain developed by CNR EOST), etc.
iv. Support the coordination/supervision of the Seismic Hazards Demonstrator activities.

Contribution from DLR:
DLR shall contribute on the Seismic Hazards Demonstrator, on a voluntary basis by:
Supplying TerraSAR-X data at no cost for scientific use that can be organized by interfacing with DLR's existing data access platform established for the Geohazard Supersite initiative and used also for the CEOS Disaster pilots. Additional data support outside the quotas already approved for Supersites and AOIs of Disaster Pilot projects require a case-by-case decision in coordination with the commercial TerraSAR-X partner Airbus.

Contribution from ASI:
ASI will potentially provide COSMO-SkyMed data and shall make available CEOS and GSNL Cosmo-SkyMed collections through the GEP (already done for the Nepal event supersite).

Contribution from CNES:
Access to up to 20000 km2 of Pleiades data per year.

Examples of contributions from the seismic hazards community include, but are not limited to:

Contribution from INGV:

- INGV supports the Seismic Hazards Demonstrator and intends to coordinate with the existing national and international operational support schemes and frameworks. The INGV contributions will be defined in more detail later, however it is anticipated that INGV is interested in the EO data access provided by the Seismic Hazards Demonstrator to generate scientific products useful in the global context of DRR.

Contribution from CNRS IPGP :

- IPGP, in collaboration with IGN, is involved in developing an optical-images correlation tool, MicMac, and its preprocessing tools, in order to compute DEM from any optic satellite sensors providing simple or multi stereo images. This software package is open-source. The code, MicMac, following same methodologies, allows as well computing maps of displacement between two satellite acquisitions of the same scene. In the framework of the Geohazards Lab initiative IPGP will continue such developments to improve multi-sensor capabilities as well as correlation of diachronic images to measure changes. Result of application to earthquakes and volcanic events will be published on the platform. In addition, IPGP will continue its effort to compute high resolution DEM in active tectonic regions worldwide to build a body of data to be used to map active faults. This high-resolution topography will also serve as an archive in case of major event, such as earthquake or volcanic eruption, to allow quick re-tasking of satellite acquisitions to compute post-event DEM allowing 3D deformation measurements to be used in non-emergency studies, but potentially as well in emergency situations, assuming that technical capabilities and human resources would have been assigned to such task.

Contributions from COMET:

- Access to COMET-LiCSAR results from Sentinel-1. These will include interferograms, coherence maps and line of sight time series for the tectonic belts,
- Access to strain maps produced by COMET-LiCSAR from the integration of InSAR and GNSS results,
- Rapid access to interferograms and other EO data sets produced by COMET when we respond to Earthquakes,
- Links to COMET's modelling results for earthquakes,
- Access to COMET's InSAR training material and provision of training courses,

Contribution from CEO-YachayTech:

The recently created Earth Observation Center (EOC) in Yachay Tech University in Ecuador will conduct research in the field of remote sensing and geo-information sciences. Data from satellites, planes, drones and geophysical surveys contribute to understand our planet, secure our environment and manage our resources which clearly will transform and improve the understanding of Earth. The EOC will be applied to problems across a whole spectrum including among others, earthquake studies. The CEO will work together with other public institutions in charge of natural disaster management and monitoring.

- Access to EO products from visible data represented as disaster areas, vulnerability and risk maps.
- Access to EO products from earthquake monitoring using interferometry.
- Access to EO products and maps from areas affected by earthquakes.

Contribution from Harokopeion University of Athens (HUA):

Land motion has become increasing concerns in modern cities, affecting both population and infrastructure. Land deformation could lead to serious economic loss through damaged building, roads, gas/water pipes, utilities and telecommunication cables and in cases may indirectly threaten human live. The earthquake cycle of an active fault may include co-seismic rupture and inter-seismic deformation. During the inter-seismic stage that usually ranges from a few hundreds to thousands of years, crustal tectonic strain may be silently accumulated. The strain is released during the inter-seismic period, especially along creeping active faults. Understanding active tectonic processes and related energy release through monitoring of the transient deformation of strain accumulation process has become fundamental for several human activities. Additionally, local deformation type of a fault and the area near the fault may determine the extent of the seismic hazard as well. This allows taking into consideration measures and activities for seismic hazard mitigation.
Monitoring of active faults' inter-seismic behavior in urban areas is of great importance, as the local exposure (population, infrastructures etc.) increases the risks. Recently, inter-seismic crustal velocities and strains have been determined for a number of active areas, through repeated measurements using a Global Position System. In some cases, the terrain is remote and the accessibility is difficult and thus the density of GPS measurements is relatively sparse, or in the case of urban environments, the operation of GPS receivers may be interrupted due to the frequent blockage of signals. Also, other geophysics methods faced difficulties because of the continuous urban shell. Following SAR interferometry techniques the potential inter-seismic deformation could be detected and measured indirectly through the deformation effect on overlying structures.
Two main products could be derived following interferometric techniques, which can provide essential inputs both monitoring the movement of an urban fault collecting qualitative and quantitative data and the spatial dimension of the urban fault impact on overlying infra-structures contributing thus contributing to prevention tasks. The first one, "Synoptic view of urban deformations", provides a global monitoring of the deformation phenomena recognizing, based also on collateral data, potential active faults and spatial impact. The second one, "Single infrastructure: deformations" provides information on the stability of structures giving hints on the structural their health and, in particular, on the structure response to earthquakes. In general, structures are less affected by uniformly distributed ground displacements

compared to differential ground motion. A uniform displacement of a region may not be even noticeable in some cases. Similarly, uniform displacement of a structure does not damage the construction itself. It is mainly the differential displacements that might cause damages to structures. So, in this case appropriate data scale (high resolution SAR scenes) is the required condition.

Contribution from the National Observatory of Athens (NOA):
NOA shall process timely SAR data from missions like TerraSAR X and COSMO Skymed (e.g. the Cephalonia case), using the processing capacities in BEYOND and deliver valuable scientific results and papers/web-articles.

Capacity building and outreach activities:

- This activity is Obj. III. Additionally, the Seismic Hazards Demonstrator intends to use the Geohazards Lab to conduct e-collaboration, be promoted and raise awareness within the tectonics community.

Suggested evaluation criteria:

1. Quality of the output of the global tectonics mapping products and analysis.
2. Number of seismic events covered yearly (at least 10-12 events per year, when possible)
3. Number and quality of training courses performed to local institutions (at least 5 courses)
4. Number of local institutions using satellite EO (at least 10 institutions)
5. Number of end-users benefiting from the analysis of the work performed using CEOS EO data (at least 10 end users)
6. Number and quality of peer reviewed papers based on the work accomplished (at least 5 papers per year)

Governance
The Seismic Hazards Demonstrator activity shall be managed by a Steering Committee that oversees its implementation. The members of the Steering Committee and their responsibilities is described below:

- Stefano Salvi (INGV): Scientific Advisory, Supervision of the activity, Coordination with GSNL
- Philippe Bally (ESA): Supervision of the activity, Coordination with partners, Articulation with EO disaster response activities
- Theodora Papadopoulou (ARGANS c/ ESA): Coordination with partners and user communities, Reporting, Meetings/Teleconferences, Website, Promotion

In advance, 1 annual meeting with contributing partners, probably during the EGU conference (April) and 1 annual teleconference (October) are foreseen.

Seismci Hazards Demonstrator Contributors (as of 1 March 2018):
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