GROUP ON
EARTH OBSERVATIONS

GEO Geohazards Supersites and Natural Laboratories

Geohazard Supersites and Natural Laboratories - GEO Initiative

2020-2022 GSNL Implementation plan

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GEO Initiative

Overview

The Geohazard Supersites and Natural Laboratory initiative (GSNL) is a voluntary international partnership aiming to improve, through an Open Science approach, geophysical scientific research and geohazard assessment in support of Disaster Risk Reduction.

The GSNL goal is pursued promoting broad international scientific collaboration and open access to a variety of space- and ground-based data, focusing on areas with high geohazard and risk levels, the Supersites and the Natural Laboratories. For these areas a joint effort is carried out: the space agencies provide satellite imagery at no cost for scientific use, the monitoring agencies provide access to ground-based data, the international scientific community employs these data to generate new scientific results which are eventually delivered to decision makers.

The decision-making processes which are functional to achieve effective DRR occur at national and local scales and involve a variety of public bodies. To be well received and effectively support decisions, the scientific information generated at the international scale must reach the appropriate stakeholders in the proper way and form. For this reason, the Supersites are coordinated by local geohazard scientific institutions which have a mandate, in the respective national risk management frameworks, to provide authoritative information to public decision makers and the population. This ensures a rapid uptake of the information by stakeholders, benefiting hazard assessment, disaster monitoring and response actions.

The specific objectives of GSNL are:

1. to empower the international scientific community with open, full and easy access to space- and ground-based data, knowledge, capacities and resources, over selected, high risk areas of the world: the Supersites and Natural Laboratories;
2. to demonstrate over the selected sites how the Open Science approach and international collaboration can generate actionable geohazard scientific information;
3. to communicate the information to public agencies and other stakeholders, supporting informed decision making in risk reduction and management;
4. to promote innovation in technologies, processes, and communication models, to enhance data sharing, global scientific collaboration, knowledge transfer and capacity building in geohazard science and risk management applications.

To reach these goals, in the period 2020-2022 the GSNL initiative will expand the network partnership, increasing the number of Supersites from 11 to 14, with a focus on less developed countries. We will also improve data access, management and capacity building support, strengthening the way the Supersite scientific community cooperates to generate new science, and enabling the coordinators to provide better services to the Supersite end-users.

Planned activities

Reform of the governance structure. Review biennial Supersite progress reports. Work with the CEOS WG Disasters to coordinate GSNL with other CEOS initiatives on Disaster. Manage with the CEOS the EO data access for Supersite scientists. Review and approve Event and Permanent Supersite proposals. Organize at least two annual meetings of the GSNL community at main geophysical conferences, as AGU and EGU. Manage the data licensing process, and ensure ordering of satellite image acquisition. Pursue the establishment of the SE Asia Natural Laboratory (or another Supersite in SE Asia). Coordinate the communication and the provision of data/processing services to the scientific community. Enlarge the community, improve the knowledge exchange and the sharing of research results in digital format, ensure the proper attribution of IPRs, promote the Supersite activities and seek national resources for sustainability of the Supersite infrastructures.

Improve communication and collaboration with other international initiatives on DRR and open data/processing infrastructures. Strengthen relationships with providers of data processing services, as the ESA Geohazard Platform, UNAVCO Plug & Play GPS project,the EVER-EST VRE, to improve the processing capacities of the Supersites. Contact development funding agencies to explore the possibility to support Supersite in less developed countries. Improve collaboration with other scientific, user-oriented initiatives as the Global Earthquake Model and the Global Volcano Model.

Carry out capacity building in collaboration with Supersite partners and existing initiatives in GEO and in the CEOS. Promote sharing of scientific codes for data processing and provide remote processing services. Student support programs will be requested to national and international funding agencies, with the help and coordination of the GSNL governance bodies.

Collect EO data needs from the Supersite scientific community and request image quota allocation to the CEOS space agencies. Pursue JAXA support for the initiative. Promote within the Supersite community the data access services developed by existing data sharing infrastructures as EPOS, IRIS, UNAVCO GSAC/SSARA, GEP. Promote the use of GEOSS for data and product dissemination.

Carry out continuous monitoring activities, early warning and research at each Supersite, using the in situ and satellite data. Generate new scientific results and monitoring products, and disseminate them to the Supersite national end-users. Exchange and disseminate scientific information.

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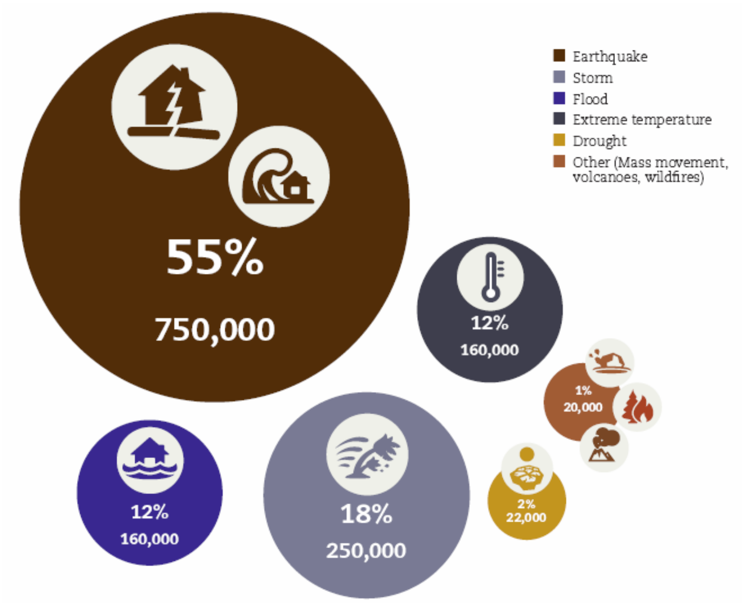
2. Purpose

Earthquakes, volcanic eruptions and landslides become disasters only if they meet with vulnerability of the human environment. When this happens they have the deadliest consequences: in the last 20 years they claimed over 770.000 lives (56% of the total disaster deaths), causing economic damages in excess of 785 B$/year and affecting over 135 million people and 25 million homes, most of which in lower-income countries (CRED, 2015).



Number of deaths by disaster type in the period 1994-2013, CRED, 2015

The basic requirement for an effective prevention of these disasters is the accurate knowledge of the hazard (i.e. the probability of occurrence of the adverse effect in a certain area over a given time period). The assessment of seismic and volcanic hazards requires continuous scientific investigations, since their causative processes are still not completely understood (Rundle et al., 2003). The scale at which these phenomena and their preparatory processes are best studied is the regional scale (100s of km).

As stressed in the the [Sendai Framework for Disaster Risk Reduction 2015-2030](), there are still many areas of the world where the knowledge of the hazard sources, their magnitude, frequency of occurrence, cascading effects, and dimension of possible impacts, are poorly known due to three main reasons: lack of data and monitoring, limited local capacities (scientific and/or technical), limited resources.

The aim of the Geohazard Supersites and Natural Laboratories initiative (GSNL) is to demonstrate how international scientific collaboration can contribute to solve these knowledge gaps and benefit Disaster Risk Reduction, focusing on providing better access to data, capacities and resources at the local scale.

The specific objectives of GSNL are:

1. to empower the international scientific community with open, full and easy access to space- and ground-based data, knowledge, capacities and resources, over selected, high risk areas of the world: the Supersites and Natural Laboratories;
2. to demonstrate over the selected sites how the Open Science approach and international collaboration can generate actionable geohazard scientific information;
3. to communicate the information to public agencies and other stakeholders, supporting informed decision making in risk reduction and management;

4. to promote innovation in technologies, processes, and communication models, to enhance data sharing, global scientific collaboration, knowledge transfer and capacity building in geohazard science and risk management applications.

GSNL does not have a formal policy mandate from international organisations, however the scientific and monitoring institutes acting as Supersites Coordinators (see later) do have a mandate defined by national laws or agreements, to provide operational scientific support to government agencies for DRM.

In most cases, the main reason for committing to establish and maintain a Supersite on a given area is to improve access to data and resources, and eventually provide better services to local DRM stakeholders.

In all cases, the role of the Supersite coordinating institution is truly operational, involving normally 24/7 multi-parametric monitoring, early warning, provision of information services during the DRM Response phase, and production of hazard maps during the Mitigation phase.

The table below shows the most common information products provided to the end-users.

Science products to support Hazard Assessment and Risk Mitigation	***Science products to support Response***
Ground deformation maps for seismic and volcanic areas (mean ground velocity over many years)	Ground deformation maps for earthquakes and volcanic eruptions and associated gravitational mass movements (ground displacement related to a single event, or displacement time series during or after the crisis)
Strain rate maps	Precise earthquake locations
Identification of active faults and characterization of their kinematics	Regional Moment Tensor solutions
Models of active faults and estimates of fault slip rates, maximum expected event, recurrence intervals, and other parameters of fault activity	Maps and parameters of earthquake effects on the built environment: classification of building and infrastructure damage at different resolutions
Earthquake hazard and damage scenarios	Maps and parameters of phenomena induced by earthquakes on the natural environment: fault scarps, soil liquefactions, ground fractures, triggered landslides, drainage network changes, etc.
Models and estimates of parameters for volcano plumbing systems	Coulomb stress transfer analysis maps
Volcanic hazard scenarios, for lava flows, flank collapses, lahars, ash fall, ash clouds, etc.	Identification and characterization of magma chambers and plumbing systems during eruptions
Topographic maps (periodical updates)	Models of maximum deviatoric shear stress caused by ground deformation episodes during volcano unrest.
Land use and exposure maps (periodical updates)	Maps and parameters of volcanic hazards, as fractures, collapses, pyroclastic/lava flows, lahars, lava domes, ash fall, etc.
	Near real time scenarios for mass eruption rate, plume height, ash fall, ash cloud paths, etc.

At each Supersite, the authoritative role of the Coordinator in the national DRM value chain is expressed in an end to end relationship with a number of public agencies to which the above information products are provided within established agreements. The main end-users for each Supersite are listed in Table 1.

Table 1 – Supersite coordinators and end users.

Permanent Supersite	Coordinators	End-user
Hawaiian volcanoes	Michael Poland, Ingrid Johanson, USGS, USA	Hawai'I County Civil Defense, Hawai'I Volcanoes National Park
Icelandic volcanoes	Freysteinn Sigmundsson, Kristin Vogfjord, University of Iceland and IMO, Iceland	Icelandic Police - Dep.t of Civil Protection and Emergency Management, Environmental Agency of Iceland, Directorate of Health
Mt.Etna volcano	Giuseppe Puglisi, INGV, Italy	National Department of Civil Protection, Regional Civil Defense
Campi Flegrei & Vesuvius volcano	Sven Borgstrom, INGV, Italy	National Department of Civil Protection, Regional Civil Defense
Marmara Fault	Semih Ergintav, KOERI, Turkey	Istanbul municipality
Ecuadorian volcanoes	Patricia Mothes, IGEPN, Ecuador	National Secretariat for Risk Management, Regional governments, Municipalities
Taupo volcanic zone, NZ	Nico Fournier, Ian Hamling, GNS Science, New Zealand	Ministry of Civil Defence and Emergency Management, Department of Conservation, Regional councils, MetService
Gulf of Corinth-Ionian Islands	Spyros Lalechos, ITSAK , Greece	EPPO, Greek Civil Defense
San Andreas Fault Natural Laboratory	Charles Wicks, USGS, USA	California Office of Emergency Services, Federal Emergency Management Agency, plus many other local stakeholders
Southern Andes Volcanoes	Luis Lara, SERNAGEOMIN, Chile	ONEMI (Oficina Nacional de Emergencias), under the Ministry of Interior and Public Safety
Virunga volcanoes	Charles Balagizi, Goma Volcano Observatory, D.R. of Congo	DRC Civil Protection, NGOs for Emergency and Disaster Management, also in Rwanda, Virunga National Park offices

The information support provided by each Supersite to its end-users results in:

- Outcomes: informed decisions by national/local government agencies on operational mitigation and response measures, as risk-aware territorial planning, engineering/structural measures and codes, evacuation plans, alert level change, evacuation decisions, event scenarios, situational awareness, etc.
- Impacts: the above decisions might result in: reduction of casualties and economic/environmental damage, increase of resilience at community to national levels, increased public awareness of risk, etc.
- Beneficiaries: the direct beneficiaries are the population at risk (also in neighbouring countries for cross-border impacts), but given the far reaching economic consequences of a disaster, the entire population in the country will benefit of more effective mitigation and response measures.

Moreover, since the Supersites, albeit limited in size, have also the role to experiment and demonstrate the advantages of new technological and collaboration models (as Open Science), their example is able to promote the application of the same successful approach at national and even regional scales, eventually producing a much wider benefit on DRR.

3. Background and previous achievements

The most important achievements of the initiative during 2017-2019 have been:

Main achievements

- provision of open access to in-situ geophysical data for the Supersites;
- CEOS support for the provision of thousands of satellite images to the Supersite scientific communities;
- generation of new scientific results over the Supersites, based on the open data;
- approval of the GSNL Data Policy Principles;
- establishment of the Geohazard Exploitation Platform as the reference portal for EO data access;
- establishment of the EVER-EST Virtual Research Environment (from an EC H20202 project) as provider of data processing services for Supersites in developing countries;
- provision of scientific monitoring information to DRM decision makers at several Supersites;
- capacity building by training, collaboration, and provision of resources.

Challenges for 2020-2022

- identify a way to ensure that EO data from public space agencies are made fully open for risk management use, at least in developing countries;
- establish a Supersite or Natural Laboratory in Asia;
- establish further Supersites in regions with high geohazard and risk levels;
- improve open sharing of further data types, research products and software;
- promote international collaboration and capacity building;
- fully implement an Open Science approach in the GSNL initiative.

Progress with respect to Tables 5.1 and 5.2 (p.13-14) of the Implementation plan 2017-2019

Task	Task (% completion)	Task progress summary
1.1	Management (85%)	A draft for the new governance structure has been submitted to the Scientific Advisory Committee and is under discussion. Eight biennial progress reports have been received and evaluated by the SAC and the CEOS, and are available on our website. Three more are under evaluation. Constant collaboration with the CEOS space agencies within the WG Disasters has resulted in their support to three new Supersites and a Natural Laboratory. Full coordination with the CEOS Disaster Pilots and Demonstrators is in place. Six meetings of the GSNL community have been organized at the AGU and EGU conferences.
1.2	Networking activities (70%)	We have established the San Andreas Fault Natural Laboratory and three new Supersites: multihazard Supersite in the Southern Andes of Chile, Virunga volcanoes in D.R. Congo, Gulf of Corinth in Greece, all supporting local end users. We coordinated with EPOS, UNAVCO, ESA, for the provision of data and processing services to the Supersites. We have established contacts with WB and UNISDR to explore the possibility to fund activities of Supersites in developing countries, however no result has been obtained. We have established an agreement with the Charter on sharing scientific products during crises. We have presented the initiative to researchers and stakeholders in 14 different countries, stimulating the participation in the initiative. A few new Supersite proposals are now in preparation. One for Peru was submitted in February 2019.
1.3	Data provision (80%)	We analyzed the various Supersite contexts and issued the GSNL Data Policy Principles, to promote the adoption of the GEO Data Sharing Principles in the long term. We have implemented e-collaboration, processing and information services through the GEP and

		the EVER-EST VRE, promoting an Open Science approach for GSNL. We obtained further support from the CEOS, with access to over 5000 new images. We have established new procedures for satellite data access using specialized data infrastructures as the UNAVCO SSARA, EVER-EST and the GEP. We have documented the new procedures on our website. We have set up an agreement with ESA to provide access to over 10,000 Supersite COSMO-SkyMed satellite images through the GEP portal. Part of the images are already available.
1.4	Disseminatio n& Outreach (85%)	We have created and populated a new website and prepared new material for dissemination, as a GSNL brochure and a 4-page summary. We placed all the Supersite reports on the website, and we are gradually extracting success stories from each report for more immediate communication of results. We have started to use the Research Object Hub (ROHUB) to implement a repository for the scientific results and other information generated within the Supersites.

Task	Task (% completion)	Task progress summary
2.1	Supersite management (70%)	Comprehensive reports are submitted and evaluated by the SAC and the CEOS every two years from the date of establishment of the Supersite. Coordinators have been instructed by the GSNL Chair on the satellite tasking and data request procedures. Coordinators report on the scientific achievements and provide the relevant information to their national end users. A few Supersites are now supported, at least in part, by national or regional projects. The new Open Science approach has started to be implemented at some Supersites; technological resources are available to support this step (e.g. the EVER-EST platform), but the community still needs to be fully engaged. Supersite coordinators report periodically on the Supersite achievements to their end users, and deliver the information support products according to independently established agreements.
2.2	Supersite community building (70%)	Community building around Supersites has been promoted mainly through dissemination at scientific meetings. Capacity building at some Supersites has been provided supported by in kind resources and EC projects (EVER-EST, FUTUREVOLC), and has focused on short stages at the coordinating institutions (4), and ad hoc technical courses on the use of platforms and software for EO data processing (2 on EVER-EST in Colombia and Peru, 4 on the GEP at AGU and EGU meetings).
2.3	Supersite infrastructure maintenance & development (60%)	A few Supersites have developed their own data infrastructures to share in situ data. Others use community infrastructures provided by IRIS, UNAVCO, and EPOS services. Most satellite data are now provided through specific portals, and most data become available in few hours to 8 days from acquisition. The Virunga Supersite has elaborated a specific Data Policy to promote the engagement of the international scientific community in local activities, while maintaining a fair level of collaboration, to develop local resources.
2.4	Supersite dissemination /outreach (60%)	Supersite coordinators have provided to CEOS and GEO material showcasing the results of their Supersites. These have been published in public reports. Update of the website proceeds, although not very frequently.

All the volcano and seismic monitoring products based on Supersite in situ and EO data are constantly delivered to the reference end-users shown in Table 1. Several micro-decisions based on this information are constantly taken at various levels but are difficult to describe singularly. Some prominent examples are summarised below.

The ground motions associated with the 2018 Kilauea (Hawai' i Supersite) earthquakes and eruption were constantly monitored using S-1, CSK, TSX, and Pleiades data. The repeated deformation products were used for tracking the migration of subsurface magma and for mapping the collapse of the summit (over 700 m at places) and the emplacement of lava flows. These data were used in combination with in situ data to draft multiple public documents about the potential hazards of continued eruptive activity. They were released to the public and formed the basis for the response by both Hawaiʻi Volcanoes National Park and the County of Hawaiʻi. Results were published on HVO's website, so that the general public could track the evolution of activity in amplitude imagery and SAR interferograms.

In 2018, the Copernicus EMS services were activated by the Virunga Supersite to generate hazard and exposure maps for Goma City and a HR DEM to simulate the lava flow pathways and identify the affected areas. These maps were validated by the scientists of the Goma Volcano Observatory and delivered to the Conseil Provincial de prévention des catastrophes au Nord-Kivu, in D.R.C., which includes the national Civil Protection, Red Cross, Ministries of Interior, Urbanism, research. They were also delivered to similar institutions in Rwanda, where the risk from a Nyragongo eruption is also very high.

The 2017, Mw 3.9 earthquake in the Campi Flegrei Supersite (Ischia Island). The INGV data inversion based on S-1 and CSK InSAR results allowed to identify a seismic source due to gravitational deformation mechanisms, not due to volcanic origin.

An actively deforming slide was mapped following the 2016 eruption along the inner slope of the White Island volcano (Taupo Supersite, NZ). Continuous monitoring using stripmap TerraSAR X data showed slope motions up to 20 cm/yr, and this information was provided to the local authorities which used it to ban access to this popular touristic area for a number of months.

The Bardabunga volcano in the Iceland Supersite started erupting in August 2014, under a 800 m-thick ice cap. The worst scenario was magma-water interaction and strong ash emissions, possibly replicating the Eyjafjallajokull eruption in 2010, with risk of strong impacts on aviation across Europe. This caused issuing a red alert level, blocking overflight by commercial airlines. Seismic, geodetic, InSAR, and field geological data were shared and jointly analysed by a large scientific community under an EC Supersite project. The scientists constantly provided evolutionary models for the eruption to the Iceland Civil Protection, and the latter used this information to lower the alert level and let airlines resume flights.

Effectiveness of the Initiative's governance structure and resourcing strategy

Presently GSNL is managed by a Scientific Advisory Committee (SAC) which is composed by prominent researchers and practitioners in seismic/volcanic/geodetic science or data infrastructures. However much of the burden of the governance lies on the SAC Chair (including the website update, reporting to GEO, etc.), whom is not supported by a secretariat. To improve the governance structure of GSNL was decided in 2017 to identify an operational team to support the SAC Chair, and the best way to do this would be to obtain support from the single Supersites. However this has not yet been agreed within the initiative. It is an objective for 2019.

The initiative is reviewed by GEO and by the CEOS Working Group on Disasters (WGD). The CEOS Data Coordination Team (a subset of the WGD) has the task of examining and approving the GSNL requests for satellite data support to the Supersites. The CEOS WGD receives updates every 6 months from the GSNL SAC Chair on general issues, and reviews every two years detailed reports from each Supersite. If the accomplishments are in line with objectives, the CEOS confirms the attribution of image quotas for the next two years. Until now all the 15 Supersite biennial reports examined by the WGD since 2014 have passed the reviews. In some cases, appreciating the successes of the Supersite, the CEOS has granted an increase of the yearly satellite data quotas.

Lesson learned

The main lessons learned from the 2017-2019 Implementation period have been the need for more consistent funding sources, for the Supersites and for the initiative management, and the need to ensure more active contribution for the outreach and dissemination of the Supersite results.

The reform of the management should help reach the latter objective, while for the funding issue we would need to develop a sponsoring scheme. GEO support would be much welcome in this subject.

4. Relationship to the Sendai Framework for Disaster Risk Reduction and other Work Programme Activities

GSNL is contributing to reach the SDGs expressed in the table below:

11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations
11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels

This is actively done at the Supersites. In particular for the Supersites in Iceland, D.R. Congo and Ecuador, the improved volcano monitoring capacities established with the satellite data support to the Supersites, has already provided benefits on the hazard assessment and early warning of rural areas and major cities as Quito and Goma. The actual use of this improved information for the implementation of effective risk mitigation measures is the responsibility of local and national governments.

The most direct contribution of GSNL to the Sendai Framework targets is related to:

G. Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.

This is accomplished at each Supersite by the increased use of EO data by the Coordinating Institutions and through the collaboration with the international scientific community. It is clear that without GSNL, the countries which host Supersites would have a much more limited access to EO data that are extremely useful (and in some cases fundamental) for an effective monitoring of volcanic activity and fault-induced deformation.
Moreover GSNL contributes to the enhancement of international collaboration on disaster topics, and to the development of better disaster risk management capacities by the national authorities in charge, and thus it provides partial contributions to most of the other Sendai targets.

GSNL does not have relationships to other Disaster initiatives in the GEO WP. The closest initiative would be GEO-DARMA, which however is focused on other risk types (flooding) and on the provision of EO data to international initiatives/programmes, with limited involvement of local scientists and monitoring institutions.

5. Stakeholder Engagement and Capacity Building

There are three main categories of stakeholders involved in the GSNL initiative:

1. **The data providers** (for in situ and EO data). They are mostly contributors to the initiative, however they also use GSNL to promote their activities, demonstrating the societal benefits of the data they produce, in DRR (e.g. space agencies). The in situ data providers (which are also the Supersite coordinating institutions) are listed in Table 1. The EO data providers are the following CEOS space agencies: ESA, NASA, ASI, DLR, CNES, CSA.
2. **The global geohazard scientific community**. Scientists use the initiative to obtain easier and open access to a large quantity of EO data, plus in situ data which may not be easily accessible outside of the Supersite framework. They are motivated by the scientific research, by the possibility to improve their capacities through a focused collaboration, and by the possibility to contribute with their work to generate direct societal benefits in DRR. The number of scientists involved in research at each Supersite varies, and it is not easy to ascertain, since the EO data are open access and, while we recommend coordination with the local Supersite teams, there is no obligation to provide feedback on data use. A list of known scientists is provided in Table A1.
3. **The final users of the geohazard scientific information (end-users)**. This category includes risk managers and decision makers at international/national/regional scales, the industry sector, the responders, the general public. As mentioned above, each Supersite coordinating institution has formal agreements to provide scientific and monitoring information to some reference end-users (Table 1). However, other end-users interested in specific subjects and information may become engaged on an occasional basis.

End-user engagement

In nearly all Supersite countries, the national, state or federal agencies in charge of disaster risk management are already receiving scientific and monitoring information produced thanks to the Supersite data and its international scientific community. While there might be differences in the roles, capacities, and powers of the DRM agencies of the different countries, they have a well structured relationship with the Supersite coordinating institutions (in some cases defined by law), and the information support products are defined together, as well as the levels of service provision.

In case new information products for the end users are developed (e.g. high resolution ground deformation maps) some individual capacity building is carried out, to explain what is the meaning of the information and how to best use it for DRM. Some organizational capacity building is also needed, for instance when the Supersite coordinating institutions develop dissemination services for providing direct online access to the scientific and monitoring information (see for instance http://futurevolc.vedur.is/), to explain how to exploit the data for decision making.

Capacity building

Capacity development is increasingly a strong theme for GSNL. As the number of Supersites continues to grow (increasing by 60% in the 2017-2019 period), and more developing countries are involved (3 at present), the need to support the improvement of capacities for EO-data exploitation and for the effective use of the new information in DRM, increases constantly.

In fact, the success of any Supersite implementation depends on the attainment of good levels of local expertise and resources in two main fields: monitoring, i.e. capacity to generate enough observations to follow the seismic and volcanic phenomena, their evolution and the associated hazards, and scientific capacity of the Supersite community to use those data to generate new science and useful information for decision making and risk reduction.

The monitoring capacity can be highly variable, especially in terms of quantity and density of instruments and collected data, and depends from local constraints (mainly funding) for what concerns the ground networks development, and from the space agencies' collaboration for what concerns satellite image use.

In the ideal conditions the Supersites should have already well developed in situ monitoring networks which are upgraded and maintained on national funding. However, in less developed countries the situation is often far from ideal, and resources for the optimal development of the in situ monitoring networks should be sought at international level, leveraging on the GEO framework. For the satellite data the GSNL partnership is instead able to obtain a good areal coverage, mobilizing large quantities of in-kind resources from the CEOS space agencies.

The development of improved scientific capacities is also in the scope of GSNL, and is composed of several actions, as: knowledge sharing, higher education, mobility, networking, dissemination, provision of data and processing infrastructures, etc. We believe that these actions can be carried out through transnational scientific collaboration finalized to ensure that the local scientific community becomes completely independent in providing effective support to local DRM.

In GSNL the partners obtain the necessary resources through shared in-kind support (satellite data, data processing infrastructures, training, stages, etc.), and also through competitive calls or institutional funding (e.g. from the Supersite Coordinating institutions). In the 2017-2019 period, capacity building at five Supersites (Mt Etna, Campi Flegrei-Vesuvius, Iceland, Ecuador, Azgeleh Event Supersite) was supported using funding from the EC EVER-EST project, which developed a Virtual Research Environment (VRE) designed to provide a variety of collaboration and remote data processing services. Some of these services will be active until 2020, and possibly beyond if funding is obtained under other EC projects.

The ESA's Geohazards Exploitation Platform has also supported several Supersite scientists and will continue to do so for the next three years, providing data storage, access, and processing services. The long term sustainability of the GEP and of its support to GSNL is envisioned through new approaches based on virtualization and federation of the services, and linking them to research infrastructures as the European Plate Observing System – EPOS (a GEO supporting organization). The EPOS infrastructure is developing a large set of interoperable data and product services to the Earth Science community, and fully supports the European Supersites.

The USA consortium UNAVCO is also expected to continue providing important in-kind resources to GSNL, consisting mainly of Supersite data storage and data/processing services, as the Seamless Geodetic and SAR archives (GSAC/SSARA) and the Plug & Play GPS project. UNAVCO will also continue to provide technical and management support.

6. Governance

The GSNL initiative is managed at central level by the Scientific Advisory Committee (SAC), which works in close collaboration with the CEOS Data Coordination Team (DCT).

The SAC receives the proposals for new Supersites, and evaluates them with the help of two external reviewers. It proposes to the CEOS DCT to establish or discontinue a Supersite. It evaluates possible changes to the GSNL mission, and proposes them to the other partners. It provides scientific advice to Supersites where needed. It reviews the Supersite biennial reports and recommends their approval or rejection.

The CEOS DCT receives from the SAC the proposals for new Supersites, then each space agency decides whether to support the Supersite with the requested satellite image quotas. It reviews the Supersite biennial reports and, based on the accomplishments, it may recommend to renew the image quotas for two more years, or withdraw them. It proposes to the SAC possible changes to the GSNL mission.

The activities of the SAC members are supported by their respective organizations as in-kind contributions.

The composition of the Scientific Advisory Committee is:

Name	Role	Affiliation
Stefano Salvi	Chair	Istituto Nazionale di Geofisica e Vulcanologia (INGV), Italy
Falk Amelung	Member	Division of Marine Geology and Geophysics, Univ. of Miami, USA
Massimo Cocco	Member	INGV and European Plate Observing System (EPOS)
Florian Haslinger	Member	Swiss Seismological Service (SED) at Zurich ETH, Switzerland
Chuck Meertens	Member	UNAVCO, USA
Susanna Zerbini	Member	WEGENER, EU

The activities of the DCT members are supported by their respective space agencies.

The composition of the CEOS Data Coordination Team is:

Name	Role	Affiliation
Pierric Ferrier	Chair	Centre national d'études spatiales - CNES, France
Simona Zoffoli	Member	Agenzia Spaziale Italiana - ASI, Italy
Thomas Cecere	Member	United States Geological Survey – USGS, USA
Yves Crevier	Member	Canadian Space Agency - CSA, Canada
Jens Danzeglocke	Member	Deutsches Zentrum für Luft- und Raumfahrt - DLR, Germany
Henri Laur	Member	European Space Agency - ESA, Europe
Yabe Shizu	Member	Japan Aerospace eXploration Agency - JAXA, Japan
David Borges	Member	National Aeronautics and Space Administration - NASA, USA
Michael Pavolonis	Member	National Oceanic and Atmospheric Administration - NOAA, USA

Each Supersite is managed by one or two Coordinators (Table 1). In the Supersite proposal they have to indicate a Core Team, including some international scientists, that should support the Coordinators. The participation to the Core Team is open to all, but not all researchers who are part of the Supersite scientific community will be part of the Core Team.

The Coordinators are autonomous in managing the Supersite but they have to respect the Open Science commitments declared in the initial proposals, the GSNL Data Policy principles, and the general rules of the initiative. This is demonstrated through detailed reports submitted every two years, which document the scientific achievements, the societal benefits and the end user interactions. The reports are evaluated by the SAC and the DCT, and if the stated objectives are not met, the Supersite may be discontinued.

All the Supersite reports are published on the geo-gsnl.org website, as well as other information on data access, how to propose a Supersite, management documents, etc.

In addition to the Supersite reports, the SAC Chair presents the general accomplishments of the initiative to the governing bodies of GSNL during SAC meetings, and during meetings of the CEOS Working Group on Disasters, twice per year.

Communication with the wider GSNL community is carried out through the GSNL website, through mailing lists, and at face to face meetings organized at least once a year, during large geoscience conferences (AGU meeting in the USA and EGU meeting in EU). Several presentations per year on the initiative and its accomplishments are made mostly by the SAC Chair or the Supersite Coordinators, at scientific or stakeholder meetings, and at the GEO WP Symposium and GEO Plenary side events.

A reform of the governance model is planned, and should be implemented by 2020. A new Terms of Reference is also needed given the important changes implemented since 2015, and is an objective of 2020.

Risks and present issues in the initiative are mainly related to the uncertainty and scarcity of the resources (see next section).

The list of participants to the Scientific Community of each Supersite is provided in Table A1.

7. Resources

The majority of the resources supporting the GSNL initiative are provided in-kind by the participants. It is difficult to provide an accurate value assessment of in-kind resources provided by such a complex partnership, but we attempt to provide a reasonable estimate in Table B.

The contribution by the CEOS agencies is mainly expressed as in kind provision of satellite images, and in Table B we provide figures considering the total market value of the satellite data to be acquired on demand for the Supersite needs. The operation of the existing in-situ instrument networks occurs for the most part independently of Supersite existence, and is not considered here.

In GSNL there are specific resources used for Supersite management, data infrastructures, service provision and dissemination. Only European Supersites have benefited in the recent years from direct EC funding, and have been able to develop instrumental and data dissemination infrastructures. Most of the other Supersites are supported by in kind resources of the Coordinating institutions. Unfortunately, in some cases the local economic situation prevents the development of even the minimum ground networks for effective monitoring and early warning (e.g. for the Virunga volcano Supersite in D.R.Congo), and external funding is urgently needed. The GSNL management is seeking international funding sources to develop local capacities, and one of the actions is promoting joint participation of Supersites in research or development projects. We recommend that GEO Secretariat provides support to GSNL in the identification of possible funding sources.

Table B shows the estimated resources available to GSNL for 2020-2022. There is an inherent uncertainty in the in-kind resources allocation, given the voluntary nature of the initiative, and because these resources are often identified on a yearly basis. Moreover we expect to establish new Supersites in the period and this will change the picture..

The annual planned income from in-kind resources is 7600 KEuro. Annual planned income from financial resources (intended as funding directly assigned to GSNL activities identified in this IP): 770 KEuro. The latter includes funding estimates from running projects (H2020 EUROVOLC project) and from known EC project proposals presently under evaluation. During the IP period further smaller scale projects may be activated, providing financial support to Supersites.

8. Technical Synopsis

The core datasets available for each GSNL Supersite are satellite EO data and in-situ data.

To date the main satellite EO data used by the community are:

Type of data	Data provider	How to access	Type of access
ENVISAT	*ESA*	*http://eo-virtual-archive4.esa.int*	*Registered public*
RADARSAT-1	*CSA*	*FTP access from Supersite Coordinators*	*GSNL scientists upon license acceptance*
TerraSAR-X	*DLR*	*https://supersites.eoc.dlr.de/ and UNAVCO*	*Public access upon license acceptance*
Cosmo-SkyMed	*ASI*	*Via the ESA-GEP portal or UNAVCO SSARA*	*GSNL scientists upon license acceptance*
RADARSAT-2	*CSA*	*Via UNAVCO, ESA-GEP or FTP access*	*GSNL scientists upon license acceptance*
Sentinel-1	*ESA*	*https://scihub.esa.int/dhus/*	*Registered public*
Pleiades/SPOT 5	*CNES*	*Tbd*	*GSNL scientists upon license acceptance*
Landsat	*USGS*	*http://hddsexplorer.usgs.gov*	*Registered public*

The main in situ data used by the community are (not all data types are available for each Supersite):

Type of data	Data provider	How to access	Type of access
GPS/GNSS	*Supersite communities*	*UNAVCO, Iceland catalogue, Mt.Etna catalogue, FTP in some cases*	*Registered public or through email request*
Seismic	*Supersite communities*	*IRIS, EIDA, FTP access in some cases*	*Unregistered public or through email request*
Gas Emission analysis	*Supersite communities*	*Text Reports, FTP access*	*GSNL scientists through email request*
Gravity	*Supersite communities*	*Text Reports, FTP access*	*GSNL scientists through email request*
Tilt, levelling	*Supersite communities*	*Text Reports, FTP access*	*GSNL scientists through email request*
Camera	*Supersite communities*	*Web links or Text Reports, FTP access*	*GSNL scientists through email request*
Strain	*Supersite communities*	*Text Reports, FTP access*	*GSNL scientists through email request*
Geological data	*Supersite communities*	*Text Reports, FTP access*	*GSNL scientists through email request*
Ground-based radar	*Supersite communities*	*Iceland catalogue, FTP access*	*GSNL scientists through email request*
Infrasonic data	*Supersite*	*Iceland catalogue, FTP access*	*GSNL scientists through*

	communities		*email request*
VNIR/TIR video camera data	*Supersite communities*	*Iceland catalogue, FTP access*	*GSNL scientists through email request*

Data are provided by the owners, i.e. the CEOS space agencies, and the Supersite coordinators. Some in situ data may be provided by the international scientific community (e.g. those acquired during temporary experiments).

Data are processed using scientific software or commercial packages. Most scientific software is open and can be obtained from Github or through institutional websites; some workflows are available on Rohub (e.g. http://www.rohub.org/rodetails/vsm_campi_flegrei_20112013-release/overview). Commercial software is mainly used for the satellite data. Three platform are available to the community for data processing: UNAVCO Plug & Play GPS, the Geohazard Exploitation Platform by ESA, and the EVER-EST VRE.

Existing issues concern the provision of direct web access to some datasets, especially some in situ data types (see table above). There is no easy solution to this problem. The data owners are in general aware of this need but they not always have the capacities to build data infrastructures. For some data the metadata are also missing or non-standard. However in Europe the EPOS research infrastructure is developing data services for a variety of datasets, and may be open to support data provision also for the non-European Supersites, at least on a temporary basis.

For some Supersites there is also the issue of accessing data processing capacities. At present this is guaranteed with the mentioned platforms, but none of them is permanent, and their sustainability depends on project funding. We will investigate, during the IP period, if a business model can be applied to these platforms (e.g. pay per use), to ensure a long term sustainability.

9. Data Policy

GSNL promotes Open Science and the adoption of the GEOSS Data Sharing Principles for all the Supersite communities.

For the satellite data the fully open access is limited by the space agencies (other than NASA and ESA), and the users need to sign specific license agreements which accept only scientific use. The management of satellite data is streamlined and well organised (through the GEP, DLR Supersite portal, and UNAVCO services, in addition to the public access data infrastructures). Although at the moment GSNL scientists still need to user different interfaces for data access, all platforms provide also web services for automated access.

For in situ data the situation is more fragmentary. In July 2017, noting that the actual implementation of in situ data sharing was not fully satisfactory, we published the GSNL Data Policy Principles, which set the minimum standard to which the Supersites should be compliant. The Supersites established after that date are requested to publish their own Data Policy compliant with those principles, while those established earlier should progressively align to it. During the next three years we expect to progress in this field. In the Annex D to the IP 2017-19 we described the status of adherence of the GSNL data management practices to the GEO Data Management Principles. That status has not changed much. Seismic data are fully compliant to the GEO DMP, and geodetic data for the most part. We could not dedicate resources to investigate in more detail which alignment actions could be requested to the Supersites for the other data types.

The SAC continues to press the Supersites to make all of their data accessible through web services, however as mentioned earlier, many of them do not have the resources to implement such services, beyond the fact that in some cases particular data types do not even have standardized metadata (e.g. geochemical data). Between 2019 and 2020 the EPOS European research infrastructure should start distributing a number of datasets relevant to the European Supersites (Etna, Campi Flegrei-Vesuvius, Iceland, Marmara and Enceladus), and these will be fully compliant with the GEO DMP principles. The same for seismic and geodetic data from the US Supersites (Hawaii and San Andreas Fault). For the other Supersites we hope to be able to support the implementation of data management practices and ensure their dissemination and preservation using one of the available infrastructures.

Concerning the outputs, during 2017-2019 we have tested the use of Research Objects (RO, see http://www.rohub.org) as a means to exchange scientific information and knowledge. Within an EC project in which three Supersites have participated (and two more were involved as demonstrators), a Virtual Research Environment was developed and used to support the collaborative work of the GSNL community (https://vre.ever-est.eu/). A number of ROs have been created, containing scientific results or volcano bulletins, and in some cases also executable workflows (e.g. models), which have been shared within the community and executed using the VRE web platform. The ROs can be assigned a DOI to facilitate the sharing of the scientific results even before publishing. The final report of this VRE demonstration for the GSNL community is available at: https://ever-est.eu/wp-content/uploads/EVER-EST-DEL-WP3-D3.6.pdf. The EVER-EST project ended in December 2018, but the partnership agreed to maintain the VRE operational at least until the end of 2019; in the meantime other options for sustainability are investigated.

GPS data accessible through UNAVCO web services were discoverable on the GEOSS platform until 2016, but they are not any more. The Sentinel satellite data are discoverable, but not the other CEOS data; they could be harvested from the GEP web services. Seismic data could be harvested and made discoverable, however the usefulness of this is not clear, since the use of seismic waveforms is normally limited to scientists or experts who know already where to download the data from, and how to use the specialised web services. The same for other datasets, as GPS or SAR, which require high levels of expertise to be processed.

Placing research results on the GEOSS platform would require to have some standard metadata (which do not exist for some of the results), and that the results be available through web services, which at the moment is rather limited. Both UNAVCO and EPOS are progressively loading scientific products in their platforms, so this picture might change considerably in the next three years.

We do not implement direct long term preservation methods for the Supersite data and scientific products. The preservation should be ensured by the data owners through their infrastructures. In some cases this is guaranteed.

10. WBS in separate tables

The Tables are in an external excel file. For easiness of compilation the Table A layout has been redesigned in Table A1. The data have been inserted in there.

11. ANNEXES

ANNEX I - ACRONYMS

Acronym	Meaning
CEOS	Committee on Earth Observation Satellites
DCT	Data Coordination Team (of the CEOS)
DMP	GEO Data Management Principles
DP	Data Policy
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EPOS	European Plate Observing System
FDSN	Federation of Digital Seismic Network
GEOSS GCI	GEOSS Common Infrastructure
GEP	Geohazards Exploitation Platform
GFDRR	Global Facility for Disaster Reduction and Recovery
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSAC	Geodetic Seamless Archive Centers
HDDS	Hazard Data Distribution System (of USGS)
InSAR	SAR interferometry
IPRs	Intellectual Property Rights
IRIS	Incorporated Research Institutions for Seismology
IT	Information Technology
OpenDRI	Open Data for Resilience Initiative
RDA	Research Data Alliance
SAC	Scientific Advisory Committee of GSNL
SAR	Synthetic Aperture Radar
SB	Small Baseline
SSARA	Seamless SAR Archive
TBC	To Be Confirmed
TBD	To Be Defined
UNAVCO	University NAVSTAR Consortium
UNISDR	United Nations office for Disaster Risk Reduction
UN-SPIDER	United Nations Platform for Space-based Information for Disaster Management and Emergency Response
VRE	Virtual Research Environment
WG	Working Group
WOVO	World Organization of Volcano Observatories
WP	Work Package

ANNEX II - Most recent publications extracted from the Supersite reports

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ANNEX III - CV of GSNL SAC Chair

Stefano Salvi is technological director at the Istituto Nazionale di Geofisica e Vulcanologia (INGV), Osservatorio Nazionale Terremoti (ONT), Rome, Italy. In 1999 he founded the ING Remote Sensing Laboratory, and in 2001 the INGV Geodesy and Remote Sensing Laboratory. He now coordinates a research group including engineers, geophysicists and geologists experienced in the use of space geodetic data for the study of ground deformation due to various phenomena, earthquakes, volcanoes, tectonics, gravitational mass movements, sinkholes, anthropogenic subsidence. He has authored over 60 papers on peer reviewed journals on these subjects. He has been PI or co-PI for several research projects funded by EC, ESA, ASI, NASA, Italian Antarctic program, national and bilateral research programs, on the use of remote sensing data and techniques for geophysical applications and geohazard assessment. He is a member of the CEOS Working Group on Disasters and co-lead of the CEOS Seismic Demonstrator. He was elected Chair of the GEO GSNL Scientific Advisory Committee in 2014.