GROUP ON EARTH OBSERVATIONS

GEO DI-01 Disasters Task Team

GSNL - Geohazard Supersites and Natural Laboratories

Biennial report for Candidate/Permanent Supersite - October 2015

Icelandic Volcanoes

Status	*Candidate Supersite*
Proposal documents	*http://futurevolc.hi.is/sites/futurevolc.hi.is/files/Pdf/iceland_ceos_proposal.pdf*
Acceptance letter(s)	*http://futurevolc.hi.is/sites/futurevolc.hi.is/files/Pdf/acceptance_letter.pdf*
Previous reviews	*No previous report*
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Science team issues

During the initial two years of the Icelandic Volcanoes permanent supersite, its science team has overlapped with the deformation team of the FutureVolc research project (http://futurevolc.hi.is), funded by 7th Framework Programme for Scientific Research of the European Commission. FutureVolc is a 26-partner project funded by FP7 Environment Programme of the European Commission, addressing topic “Long-term monitoring experiment in geologically active regions of Europe prone to natural hazards: the Supersite concept”. The project started on 1 October 2012 and has a duration of 3.5 years. The supersite concept implies integration of space and ground based observations for improved monitoring and evaluation of volcanic hazards, and an open data policy. The project is led by University of Iceland together with the Icelandic Meteorological Office. All the scientists-in-charge of institutions involved in the FutureVolc project were listed in the proposal for the Icelandic Volcanoes as the “Core

Supersite Team". The proposal also defined "Other Supersite Research Teams", including scientists with extensive experience in InSAR studies of volcanic processes in Iceland and elsewhere.

The Science team as listed in the table above includes the researchers (individuals) that have been actively working with satellite data provided by CEOS partners to the supersite and have signed appropriate agreements with the space agencies involved. It also includes scientists at the Icelandic Meteorological Office, which leads the operation and implementation of the FutureVolc data hub that holds in situ data for interpretation with the satellite images (see section on In situ data).

The two main institutions involved in the scientific exploration of the satellite data provided by the supersite are the University of Iceland and University of Leeds. The point-of-contact (Freysteinn Sigmundsson) has coordinated extensively with the head of the Icelandic Volcanoes supersite team at University of Leeds (Andy Hooper). Their research teams have worked in close collaboration on data acquisition issues in coordination with space agencies and InSAR analysis of the data acquired; including extensive time series analysis, interpretation of satellite and in situ data with new novel models for magma propagation, and publication of results in a high level journal (Nature, see publications).

Data has been delivered to other institutions as requested by other scientists, following the procedures imposed by space agencies. Some researchers have worked independently on the SAR data provided, advancing science. This shows the supersite has worked as planned, with data being delivered to other research groups after contact with the point-of-contact.

We report no major obstacles in the organization of scientific research. Collaboration on the leadership between University of Iceland and University of Leeds has been very successful. The organization has benefitted from the FutureVolc project and funds from this project have allowed interaction between the different science teams. A potential issue in the coming years is how the organization of the supersite research will continue after the end of FutureVolc (spring 2016). The University of Iceland and University of Leeds are ready and willing to continue their close collaboration and lead further research, based on use of the SAR data provided, as well as distributing data to other researchers.

In situ data

The most important data sets used in joint interpretation of data are the following:

Type of data	Data provider	How to access	Type of access
GPS	*IMO*	Data can be downloaded from the FutureVolc data hub: http://futurevolc.vedur.is/	Registered scientists
Seismicity	*IMO*	www.vedur.is http://hraun.vedur.is/ja/viku/ http://drifandi.vedur.is/skjalftavefsja/index2.html	Unregistered public

In situ data issues

In situ data is available by direct contact with a number of researchers. The aim is to provide access to a large body of such data via the "FutureVolc data hub", intended for sharing of volcanological data. This FutureVolc data hub on Icelandic Volcanoes is accessible at:
http://futurevolc.vedur.is/
The initial version of the system has been developed and tested, and preliminary data sets are available. Work is ongoing to populate the underlying databases.

The web interface of the data hub provides two types of access: i) Scientific users will be able to download data and upload theirs studies and analyses. ii) All users, including Operational users, Airlines and Civil protection will be able find information about the Icelandic volcanoes (The catalogue of Icelandic Volcanoes, CIV) and download data and studies they require for their analysis and decision making. At Icelandic Volcanoes the users have a single point of access for near real-time data, processed data and historical data related to Icelandic Volcanoes. The data should be easy to find and recognised users can download the data and use according to the stipulated terms, free of charge.

The Catalogue of Icelandic Volcanoes (CIV) is an open web resource in English and is composed of individual chapters on each of the volcanic systems. It is an official publication intended to serve as an accurate and up to date source of information about active volcanoes in Iceland and their characteristics. Data on the most active volcanoes are already available. A web interface is shared with the Futurevolc database for scientific data.

At present the following data sets that are streamed to IMO are available at the data portal; Global Positioning System data (GPS), Optical Particle Counter data (OPC) and data from X-band and C-band radars. Predefined users can also upload their own data sets in a free file format. For other data sets there is ongoing work among FutureVolc members to import their data to the IMO IT data systems, so they can be made available through the FutureVolc system.

It is important to remember, that at the Icelandic Volcanoes website the user can, as initially defined, search for data sets by location of instruments, date range and data type (category). The user will then be prompted with several data packages for possible download. The user can also view the basic Metadata for the selected data sets before he/she downloads them. No viewing or analysis of the data is available at the present website.

Work on enabling user access to earthquake catalogue data at the Futurevolc data hub is near completion and preparation of station metadata and seismic waveforms for access through the data hub is also in the final stages. Waveform data from stations installed during the Futurevolc project will be made available with a 2-year delay from the time of recording.

Until the seismic data services are completed, earthquake catalogue data is available at the Icelandic Metorological Office (IMO) website (see table above).

Satellite data

Type of data	Data provider	How to access	Type of access
ERS-1/ERS-2	ESA	http://eo-virtual-archive4.esa.int/?q=Iceland	registered public
ENVISAT	ESA	http://eo-virtual-archive4.esa.int/?q=Iceland	registered public
TerraSAR-X	DLR	Available after proposal submission to and acceptance by DLR	GSNL scientists
Cosmo-SkyMed	ASI	POC requests access from ASI for individual users, data then accessible via secure ftpsite: sftp://askja.rhi.hi.is	GSNL scientists
RADARSAT-2	CSA	POC requests access from CSA for individual users, data then made accessible by POC	GSNL scientists
Sentinel-1	ESA	https://scihub.esa.int/	registered public
ALOS-2	JAXA	https://auig2.jaxa.jp/ips/home	successful proposers

Satellite data issues

The following satellite data has been provided through the supersite project:

- ERS1: 145 images
- ERS2: 1160 images
- Envisat: 339 images
- Radarsat-2: 125 images
- Cosmo-Skymed: 840 images (54 of them are in SCS_U format, the remainder are SCS_B)
- TerraSAR-X: 451 images

Handling and use of satellite data has been in agreement with guidelines provided by each of the space agencies providing data.

Cosmo-SkyMed data was invaluable during the recent Bárðarbunga eruption, although there were some delays receiving data during the first few weeks of the eruption, following this the bulk of the data was received in near real-time – 6 hours after the acquisition – which enabled near real-time processing and results that could also be presented in monitoring meetings with the Icelandic Civil Protection, to facilitate the assessment of potential hazards. There was some confusion when placing initial orders as

to what was considered as an individual scene or multiple scenes (e.g. the thumbnail display on the e-GEOS website appears as a single image but actually counts as 3 images from the quota). This fact was clarified by ASI staff.

Regarding TerraSAR-X data, a temporary Supersite account was initially provided (prior to the set-up of the official Supersite account) enabling us to place orders for future acquisitions. This implied that we would have to systematically reorder this data once acquired, as archive data, once the official Supersite account was delivered in July 2014. However, DLR automatically transferred the data to their own Supersite website, making this process much easier for us, which was greatly appreciated! At the start of 2014 we saw an increase in our number of TSX acquisitions over Icelandic volcanoes (more orders accepted), however this was not the case during the end of 2014 and throughout 2015 due to clashes with the TanDEM-X science mission. As a result only a few images have been acquired on key tracks during this period. An issue is therefore the number of TerraSAR-X images available over Iceland.

Radarsat-2 data has been very useful as a complement to other data sets. An initial problem was that it took several months between our proposal application and its acceptance by the Canadian Space Agency, which delayed our ordering of archive images and made us miss the possibility of near real-time monitoring of the Holuhraun eruption with these data. Concerning the ordering itself, the APT software only works on Windows operating systems. It would be beneficial to have the possibility to run it on Linux or Mac. The APT software has an awkward user interface, which made the first order quite complicated. It is also quite slow when undertaking a search through all the archives. Implementation of a web based ordering tool would be a great improvement.

Managing large satellite based data sets takes a significant amount of time to order, download and organize, so unfortunately delays are inevitable uploading data to secure sites and filing the required space agency contracts during periods of volcanic unrest/eruption. This could be improved by assigning a dedicated IT person at the home institute of the point-of-contact, who would be responsible for this task rather than research/monitoring staff. Proposals have been written to contribute to such support.

Research results

FutureVolc Project

The European FutureVolc project, which commenced in October 2012 has benefited substantially from the award of SAR data made available through the Icelandic Volcanoes Supersite. The FutureVolc project is concerned with establishing an integrated volcanological monitoring procedure, through a collaboration of 26 partner institutions across Europe. A primary goal of this project is to combine ground-based and satellite measurements to be able to track magma movements over extended time periods (covering both pre-eruptive and co-eruptive activity). FutureVolc combined with the Icelandic Supersite offers a unique opportunity to provide insight into the inner workings of Icelandic volcanoes via multi-disciplinary studies, by gaining an improved understanding of the magmatic processes involved and the internal structuring of volcanic edifices. See http://www.futurevolc.hi.is.

Bárðarbunga (FutureVolc Deformation Team)
Supersite SAR data was invaluable during the recent unrest and eruption within the Bárðarbunga volcanic system. This data was utilized to provide a very quick response to the unrest that began on August 16, 2014. It was used to track the propagation of a 48 km long dyke from the central volcano to eventual eruption site in the Holuhraun plain and also used during the eruption to monitor the subsidence (slow caldera collapse) that was occurring within the Bárðarbunga caldera. The combination of InSAR and GPS data sets was key to interpreting the source of the deformation – both the initial lateral propagation of a dyke intrusion and the caldera collapse. Furthermore, this was the first time that SAR data were able to capture co-eruptive deformation on an ice-capped volcano using 1-day interferograms. Initial paper with deformation results has been published in Nature.

Gro Pedersen, I Jonsdóttir and V Drouin used TSX and CSK SAR data to map the temporal development of the Holuhraun lava field (outline, channel, lobes). This has been presented at both EGU and IUGG this year and will be a part of a paper in preparation.

I Jonsdóttir mapped the extent of the lava field in real time during the eruption to send to scientists in the field, as well as the relevant authorities. This was undertaken mainly by using the amplitude images. Radar images show surface topography very well, which was very useful because the team (comprising Þ Þórðarson, Á Höskuldsson and I Jonsdóttir) could monitor the evolution of lava channels, make comparisons with thermal satellite images (LANDSAT 8, EO-1 ALI and HYPERION) to map regions of highest activity within the lava field, and on 2-3 occasions predict changes in lava channel structure and direction, based on how the active channel was terminating and lava was stacking up, just prior to a new outbreak or change in the channel network. This combination of thermal and radar imagery is very exciting and promising for monitoring future effusive eruptions. They also investigated (and will undertake more research on) how effusion rates were related to the type of lava being formed at the same time (e.g. A'a or Pahoehoe) and plan to further investigate how this data can assist us in estimating lava volumes.

KAUST scientists (Crustal Deformation and InSAR group leaded by S. Jónsson) have used both COSMO-SkyMed and TerraSAR-X data to study the deformation associated with the 2014-2015 Bárðarbunga intrusion. They used pixel-offset tracking and focused on the near-field deformation in the graben between the eruption site and the glacier. Combined with seismicity and fieldwork, the results provide information about the graben formation and its evolution. Along with the meter-scale extension, they observe significant left-lateral shear across the graben.
Joël Ruch has presented these results twice; at EGU in Vienna (April 2015) and at the ILP conference in Potsdam in Germany (Sept. 2015). He will also present this at AGU in December and has recently submitted a manuscript on the topic.

The vast amount of high quality data provided during this event via the Icelandic Supersite will support numerous multidisciplinary research projects for many years to come and allow further in-depth investigation of magmatic processes and shed light on the complexities of the volcanic plumbing system and magma migration. This data set is truly unique and of exceptional quality, and would not have been acquired without the award of the Icelandic Supersite.

The increase in satellite SAR data acquired since 2014 has also enabled new research to be undertaken in the following areas:

Hekla volcano (S Dumont, M Bagnardi and W Wittmann)
Hekla is one of the most frequently erupting volcanoes in Iceland with 18 summit eruptions during the past 900 years, the last one in February-March 2000. Before 1970 the average repose period between eruptions was of ~60 years but since then Hekla has erupted four times, approximately every 10 years (in 1970, 1980-81, 1991 and 2000).

While this volcano is one of the most active in Iceland, the structure of its plumbing system is still debated. Fifteen years have now passed since the last eruption, but no signs of unrest have yet been recorded. It is therefore of crucial importance to determine the ongoing state of the volcano from ground deformation and complimentary field based measurements.

To track magma movement beneath this volcano and investigate the evolution of its plumbing system/possible changes since the 2000 eruption, an extensive archive of SAR data is required. To compliment the few TSX images collected since 2009, CSK images acquired on both ascending and descending tracks with good temporal coverage have allowed the generation of long-time PS-InSAR timeseries, since 2010. Some RADARSAT-2 data spanning the same period were also processed. This ongoing work was presented at EGU in 2015. Envisat (T324) and ERS (T52, T359) SAR data are also being used to study historic lava cooling and contraction rates and also to revisit deformation models of the plumbing system of Hekla volcano as part of an investigation on the mechanisms controlling the eruptive frequency of the volcano.

Eyjafjallajökull and Katla volcanoes (M Parks)
PS-InSAR techniques have been used to generate a time series of high-resolution deformation measurements, in the vicinity of Eyjafjallajökull and Katla volcanoes using both TSX and CSK images. This study exploits the combination of InSAR and GPS derived ground deformation measurements, in order to advance our understanding of sub-volcanic processes at these neighbouring volcanoes. Both GPS and InSAR measurements undertaken since the Eyjafjallajökull 2010 eruption reveal an inflation signal near the summit of the volcano. The location corresponds with the region of deflation identified during the explosive April 2010 eruption. The recent inflation is likely associated with renewed magma recharge to the shallow chamber that was tapped during the explosive phase of the eruption. InSAR and GPS observations at Katla volcano prior to 2010 suggest no magma induced deformation (Spaans et al., 2015). However, a signal was detected on InSAR observations during the summer of 2011, possibly associated with a small flood originating from Mýrdalsjökull. This event was followed by an increase in micro-seismic earthquakes and could well be related to magma movements. In addition, recent PS-InSAR results suggest deformation on the eastern flank of Katla during 2014. Further analysis of both historic and future deformation measurements at this volcano is key to understanding whether the recent signals are related to seasonal variations in crustal loading, stress changes induced during the

Bárðarbunga eruption or indeed magma migration beneath the volcano, which may be precursory to the next eruption. This work will be presented at the AGU meeting in December.

Reykjanes, Krisuvik and Hengill, (South Iceland) (K Michalczewska and D Juncu)
This work involves monitoring the subsidence at geothermal sites and interpreting the observed ground deformation in terms of both man-made and volcano-tectonic processes. The numerous data acquired over these areas are currently being studied by 2 PhD students (K. Michalczewska, D. Juncu) and provides an excellent opportunity for improved understanding of ground deformation in geothermal areas, including temporal variations and its potential impact.

Northern Volcanic Zone (NVZ) (V Drouin and J Giniaux)
The Northern Volcanic Zone (NVZ) of Iceland is a subaerial part of the divergent boundary between the North-American and Eurasian Plates. It is thus subject to deformation from plate spreading and volcanic activity. The NVZ is divided into a series of volcanic systems, the two main active ones being Krafla and Askja. For Askja, the ongoing subsidence in the caldera, the landslide of July 2014 and the influence of the 2014-2015 Holuhraun eruption could all be observed thanks to the Cosmo-Skymed images and TerraSAR-X images acquired over that period of time.

For Krafla, **V Drouin** has used TerraSAR-X satellite images since 2009 to monitor the deformation around two geothermal powerplants and the Icelandic Volcanoes Supersite quota of images allowed him to continue this study. In addition, the large footprint of Radarsat-2 images has enabled him to monitor the entire NVZ in one single process.

J Giniaux is a PhD student studying deformation at Askja volcano. To date she has used ENVISAT data from 2004 to 2010 (track 273). Her aim is to cover the entire period from 2002-present (using ERS, CSK, ENVISAT and Sentinel-1 data) and combine InSAR observations with microgravity data to determine the potential physical processes responsible for the on-going subsidence.

Publications

The following publication and conference presentations all acknowledge the support from CEOS to the Icelandic Volcanoes Supersite. For publications on in situ data and complementary projects, see the publication list of the FutureVolc project: http://futurevolc.hi.is/publications

Peer reviewed journal articles

Sigmundsson, F., A. Hooper, S. Hreinsdóttir, K. Vogfjord, B. Ófeigsson, E. R. Heimisson, S. Dumont, M. Parks, K. Spaans, G. B. Guðmundsson, V. Drouin, Th. Árnadóttir, K. Jónsdóttir, M.T. Gudmundsson, Th. Högnadóttir, H. M. Friðriksdóttir, M. Hensch, P. Einarsson, E. Magnússon, S. Samsonov, B. Brandsdóttir, R. S. White, Th. Agustsdottir, T. Greenfield, R. G. Green, Á. R. Hjartardóttir, R.

Pedersen, R. Bennett, Halldór Geirsson7, P. LaFemina, H. Björnsson, F. Pálsson, E. Sturkell, C. J. Bean, M. Möllhoff, A. Braiden, and E. P.S. Eibl, 2015. Segmented lateral dyke growth in a rifting event at Bárðarbunga volcanic system, Iceland, Nature, 191-195. doi:10.1038/nature14111 (online December 15, 2014).

Conference presentations/proceedings

2013, ESA Symposium (Edinburgh, UK): FUTUREVOLC: A European Volcanological Supersite in Iceland, a Monitoring System and Network for the Future (presented by F. Sigmundsson)

2013, ESA Symposium (Edinburgh, UK): Tracking Magma Migration in Near-Real Time using Radar Interferometry - the FUTUREVOLC Supersite Approach (presented by A. Hooper)

2013, AGU Fall meeting (San Francisco, USA): FUTUREVOLC: A European volcanological supersite in Iceland, a monitoring system and network for the future (presented by F. Sigmundsson)

2014, EGU meeting (Vienna, Austria): Icelandic Volcanoes Geohazard supersite and FUTUREVOLC: Role of interferometric synthetic aperture radar to identify renewed unrest and track magma movement beneath the most active volcanoes in Iceland (presented by M. Parks)

2014, EGU meeting (Vienna, Austria): The FUTUREVOLC Supersite's e-Infrastructure - A multidisciplinary data hub and data service for Icelandic Volcanoes (presented by K. Vogfjörd)

2014, EGU meeting (Vienna, Austria): Modelling of thermal contraction of emplaced lava flows at Hekla volcano (presented by W. Wittmann)

2014, EGU General Assembly, (Vienna, Austria): European collaboration for improved monitoring of Icelandic volcanoes: Status of the FUTUREVOLC project after the initial 18 months (presented by S. Dumont)

2014, EGU General Assembly, (Vienna, Austria): Crustal movements at a divergent plate boundary: interplay between volcano deformation, geothermal processes, and plate spreading in the Northern Volcanic Zone, Iceland since 2008. (presented by V. Drouin)

2014, IGARSS (Québec, Canada): InSAR for near real-time deformation monitoring (presented by A. Hooper)

2014, MeMoVolc workshop (Pisa, Italy): Constraints on eruption dynamics and volcanic conduit processes inferred from volcano geodesy (presented by F. Sigmundsson)

2014, MeMoVolc workshop (Pisa, Italy): Geophysical features of recent volcanic eruptions in Iceland (presented by K. Vogfjörd)

2014, COST Action workshop IS1304 (Rome, Italy): Monitoring, hazard assessment and decision-making during the on-going crisis at Bárðarbunga volcano (Iceland) (presented by S. Barsotti)

2014, Iceland Geoscience Society (Reykjavík, Iceland): Interpretation of deformation captured by GPS and InSAR geodesy during the 2014 rifting event in the Bárðarbunga volcanic system (presented by F. Sigmundsson)

2014, Iceland Geoscience Society (Reykjavík, Iceland): SAR satellite monitoring of the 2014 dyke intrusion and eruption within the Bárðarbunga volcanic system (presented by V. Drouin)

2014, Iceland Geoscience Society (Reykjavík, Iceland): Öskjusig í Bárðarbungu (Caldera collapse in Bárðarbunga) (presented by F. Sigmundsson)

2014, Iceland Geoscience Society (Reykjavík, Iceland): Comparison of the Bárðarbunga 2014-2015 rifting event, slow caldera collapse and the eruption in Holuhraun with the 1975-1984 Krafla and

2005-2010 Dabbahu, Afar, rifting episodes (presented by F. Sigmundsson)

2014, Iceland Geoscience Society (Reykjavík, Iceland): Deformation derived from GPS geodesy associated with the 2014-2015 Bárðarbunga rifting event (presented by H. M. Friðriksdóttir)

2014, AGU fall meeting (San Francisco, USA): Seismicity and deformation of Krafla volcano, Iceland. Intervals of low seismicity rate during rapid inflation explained by the Kaiser effect. (presented by E. R. Heimisson)

2014, AGU fall meeting (San Francisco, USA): Long-Term Geodetic Measurements at the Most Active Volcanoes in Iceland: Role of Interferometric Synthetic Aperture Radar and GPS in Hazard Monitoring at Hekla, Katla, Eyjafjallajökull and Askja Volcanoes. (presented by M. Parks)

2014, AGU fall meeting (San Francisco, USA): Deflation and Deformation of the Askja Caldera Complex, Iceland, Since 1983: Strain and Stress Development on Caldera Boundaries Prior to Tsunami Generating Rockslide in 2014 at Lake Öskjuvatn. (presented by F. Sigmundsson)

2015, Fringe, ESA (Frascati, Italy): Satellite Monitoring of the 2014 Dyke Intrusion and Eruption within the Bárðarbunga Volcanic System, facilitated by the CEOS Icelandic SUPERSITE (presented by M. Parks)

2015, Fringe, ESA (Frascati, Italy): PS-InSAR Measurements at the Most Active Volcanoes in Iceland: Role of Interferometric Synthetic Aperture Radar in Deformation Monitoring at Bárðarbunga, Askja, Hekla, Katla and Eyjafjallajökull Volcanoes (presented by M. Parks)

2015, Fringe, ESA (Frascati, Italy): Rapid InSAR processing as a volcano monitoring tool (presented by K. Spaans)

2015, Fringe, ESA (Frascati, Italy): Deformation models for the 2014 Bárðarbunga dyke intrusion and caldera collapse in Iceland (presented by A. Hooper)

2015, Fringe, ESA (Frascati, Italy): Constraints from satellite radar interferometry on the plumbing system feeding the 2014 fissure eruption at Holuhraun, Bárðarbunga volcanic system, Iceland (presented by S.Dumont)

2015, EGU General Assembly, (Vienna, Austria): The rockslide in the Askja caldera on the 21st of July 2014 (presented by F. Sigmundsson)

2015, EGU General Assembly, (Vienna, Austria): Segmented lateral dyke growth in a rifting event at Bárðarbunga volcanic system, Iceland (presented by F. Sigmundsson)

2015, EGU General Assembly, (Vienna, Austria): Deformation derived from GPS geodesy associated with Bárðarbunga 2014 rifting event in Iceland (presented by B. G. Ofeigsson)

2015, EGU General Assembly, (Vienna, Austria): Deformation monitoring of the 2014 dyke intrusion and eruption within the Bárðarbunga volcanic system, and associated stress triggering at neighbouring volcanoes (presented by M. Parks)

2015, EGU General Assembly, (Vienna, Austria): Deformation modelling of the 2014 Bárðarbunga rifting event in Iceland (presented by A. Hooper)

2015, EGU General Assembly, (Vienna, Austria): Prediction of Dyke Propagation using the Minimum Potential Energy Principle (presented by E. R. Heimisson)

2015, EGU General Assembly, (Vienna, Austria): The feeder system for the 2014 fissure eruption at Holuhraun, Bárðarbunga volcanic system, Iceland: Geodetic and seismic constraints on subsurface activity in the area north of the Vatnajökull ice cap (presented by S. Dumont)

2015, EGU General Assembly, (Vienna, Austria): Graben formation during the Bárðarbunga rifting

event in central Iceland (presented by J. Ruch)

2015, EGU General Assembly, (Vienna, Austria): Constraints on deformation of Hekla volcano, Iceland, 2011-2014, from time-series interferometric analysis of COSMO-SkyMed SAR data and Singular Spectrum Analysis (SSA) (presented by S. Dumont)

2015, EGU General Assembly, (Vienna, Austria): Influences of Topography and Strain on the Segmented Nature of the 2014 Bárðarbunga Dyke (presented by E. H. Heimisson)

2015, EGU General Assembly, (Vienna, Austria): Contribution of the FUTUREVOLC project to the study of segmented lateral dyke growth in the 2014 rifting event at Bárðarbunga volcanic system, Iceland (presented by F. Sigmundsson)

2015, EGU General Assembly, (Vienna, Austria): PS-InSAR measurements at the most active volcanoes in Iceland: role of the GEO supersite initiative in deformation monitoring at Bárðarbunga, Askja, Hekla, Katla and Eyjafjallajökull volcanoes (presented by M. Parks)

2015, EGU General Assembly, (Vienna, Austria): Magma discharge and lava flow field growth in the Nornahraun/Bardarbunga eruption Iceland. (presented by Á. Hoskuldsson)

2015, EGU General Assembly, (Vienna, Austria): Real-time satellite monitoring of Nornahraun lava flow NE Iceland (presented by I. Jónsdóttir)

2015, EGU General Assembly, (Vienna, Austria): Nornahraun lava morphology and mode of emplacement (presented by G. Pedersen)

2015, EGU General Assembly, (Vienna, Austria): Investigating the mechanisms controlling the eruptive frequency at Hekla volcano (presented by M. Bagnardi)

2015, IUGG, 26th General Assembly, (Prague, Czech Republic): Segmented lateral dyke growth in a rifting event at Bárdarbunga volcanic system, Iceland (presented by F. Sigmundsson)

2015, IUGG, 26th General Assembly, (Prague, Czech Republic): Contribution of geodetic observations towards a multi-disciplinary approach for studying the plumbing system feeding the 2014 fissure eruption at Holuhraun (presented by S. Dumont)

2015, IUGG, 26th General Assembly, (Prague, Czech Republic): Nornahraun lava morphology and mode of emplacement (presented by G. Pedersen)

2015, IGARSS (Milan, Italy): COSMO-SkyMed data and the Icelandic volcanoes Supersite: Understanding magma movements in the Bárðarbunga volcanic system (presented by F. Sigmundsson)

2015, ILP conference (Potsdam, Germany). Oblique rift opening revealed by reoccurring magma intrusions in Central Iceland (presented by J. Ruch)

Research products

There are no formally complete, publically available research products; therefore, the table below has been left blank. Supersite data have been used to make a variety of non-publically-available products, however, and have assisted some software development.

<In this subsection please list all research products available for the Supersite in the table below>

Type of product	Product provider	How to access	Type of access
e.g. ground deformation time series, source model, etc.	*Name of scientist(s)*	*Link to publication, research product repository or description of procedure for access*	*E.g. public, registered, limited to GSNL scientists, etc.*
…	*…*	*…*	*…*
…	*…*	*…*	*…*

Dissemination and outreach

During the recent 6 month long eruption within the Bárðarbunga volcanic system, both Icelandic and international institutions benefited from the Supersite award and FutureVolc project. The Icelandic Meteorological Office and University of Iceland (who were highly active in the monitoring this rifting event), along with the majority of the 26 partners of FutureVolc project, were involved in the dissemination of information during this event. This information was delivered to a wide public audience through social media, interviews and conference presentations.

An exhaustive list of the dissemination and outreach led by FutureVolc partners is available on the FutureVolc website (http://futurevolc.hi.is/publications).

Funding

The Icelandic Volcanoes Supersite did not provide any funding resources.
The Icelandic Volcanoes Supersite benefits from the financial support of FutureVolc project which is a FP7 program funded by European Commission since October 2012. The open access data sharing policy is central to this project. The creation of a data hub is an independent WorkPackage of the project where FutureVolc data and the Catalog of Icelandic volcanoes will be accessible through a unique web interface. The researchers, Post-Doc and PhD students working on the FutureVolc data are mostly funded by FutureVolc project. NERC COMET (UK) cofunds one postdoc, and funding for some PhD students based at the University of Leeds also comes from the Portuguese Science Funding Agency and the University of Leeds.

New project proposals have been submitted to both European and Icelandic funding bodies, by members of the Icelandic Supersite team, which if successful will commence after the end of the Futurevolc project (March 2016). These projects would benefit significantly from the continuation of the Iceland Volcanoes Supersite.

Societal benefits

SAR data have constituted a critical resource for monitoring natural phenomena in Iceland, especially because of the harsh climate and ever changing weather conditions, which often hamper the deployment of instruments or aerial surveys. Implementation of such a vast resource would not be possible without the Supersite support.

One of the primary beneficiaries of remote sensing data, especially SAR data, has been the Icelandic Civil Protection. The large amount of data collected thanks to the Icelandic Supersite has provided a significant contribution to monitoring the most active volcanoes in Iceland and assessing their current state of activity. This data were particularly helpful during the recent Bárðarbunga eruption to monitor the temporal changes in ground deformation in the vicinity of both the central volcano and the eruption site. Enabling tracking of the propagation of the dike during the rifting event and the contemporaneous subsidence occurring at Bárðarbunga caldera. These results were shared and discussed at regular Civil Protection meetings to provide updates on the rates of deformation and possible scenarios/associated hazard. In addition to the Holuhraun eruption, this vast amount of data has been used to produce an unprecedented timeseries of the ground deformation measurements at the most active volcano-tectonic areas in Iceland. These results were regularly presented to the IMO monitoring team in order to compare with other data sets and interpret the current state/changes in activity at these volcanoes.

During the Bárðarbunga unrest and Holuhraun eruption, IMO and IES did their best to keep the public and scientific community informed by regularly posting information, processed data and pictures on their own websites to help both local and international communities understand the nature of the volcanic crisis:

http://en.vedur.is/earthquakes-and-volcanism/articles/nr/2947
http://earthice.hi.is/bardarbunga_2014#29.08.2014

In communicating regularly to the public through websites, weekly TV programs, radio interviews and newspaper articles, IES and IMO have demonstrated how new technologies and datasets can improve the monitoring procedure by delivering a clear message to both the population and decision makers in charge of operations during a volcanic crisis. Such an approach was beneficial at multiple levels; by drawing attention to this exceptional event, promoting the wealth of data obtained through the Supersite and informing stakeholders at both a national and international level. These varied forms of communication have increased the visibility of and promoted both the Icelandic Volcanoes Supersite and the FutureVolc project within Iceland and the international community.

Conclusive remarks and suggestions for improvement

The achievements of this GSNL initiative are considerable. They include joint interpretation of satellite and in situ data, leading to important new understandings of magma propagation in the subsurface, published in a high level journal (Nature). A group of researchers, postdocs and graduate students at a number of research institutions are working on the SAR data provided by CEOS, creating times series of deformation at the most active volcanoes of Iceland, and these data are being interpreted together with in situ data. A wealth of ongoing research has been presented at international meetings, and research papers are in preparation.

The SAR data provided by CEOS has allowed detailed studies of the largest effusive lava eruption in Iceland since 1783, which occurred in the Bárðarbunga volcanic system from 31 August 2014 – 27 February 2015. At the same time a slow collapse of the Bárðarbunga caldera occurred throughout the eruption, resulting in a caldera collapse volume of about 2 cubic kilometers. These events have influenced the Icelandic Volcanoes Supersite project, and have put focus on this volcanic area. Satellite and in situ data has been used jointly to provide advice to Civil Protection authorities.

There has been important synergy between the Icelandic Volcanoes Supersite and the FutureVolc project. In particular, the FutureVolc data hub with open access to in situ data and information on the Icelandic volcanoes is an important element. The Icelandic Meteorological Office is interested in securing funding to continue the operation of this data hub after the end of the FutureVolc project; an important aspect for the continuation of the GSNL initiative. However, work is still in progress for the partners forming the FutureVolc consortium to upload data to the data hub.

The collaboration and interaction with space agencies contributing data to the supersite has been effective, but some issues regarding the number of actual acquisitions of images requested, and ordering of images have been raised above.

A continuation of the Icelandic Volcanoes Supersite initiative, with commitment from space agencies and researchers involved at a minimum of similar level as before, including those contributing in situ data, has the potential to provide important new findings within the next two year period. In light of the considerable scientific achievements and societal benefits made to date, utilizing data provided through the Icelandic Volcanoes Supersite, the point-of-contact requests the continuation of this initiative, on behalf of the science teams involved in the Icelandic Volcanoes Supersite.