GLOBVOLCANO PRE-OPERATIONAL SERVICES

M. L. Tampellini (*), R. Ratti (*), F. M. Seifert (**), S. Borgström (†), A. Peltier (‡), E. Kaminski (‡), M. Bianchi (††), W. Branson (‡‡), F. Ferrucci (***)(‡), B. Hirn (†††), P. van der Voet (‡‡‡), J.van Geffen (*‡)

(*) Carlo Gavazzi Space S.p.A., Via Gallarate 150 – 20151 Milano, Italia, e-mail ltampellini@cgspace.it.

(**) European Space Agency – ESRIN, Via Galileo Galilei, 64 – 00044 Frascati (Roma), Italia.

(†) INGV - Osservatorio Vesuviano, Via Diocleziano, 328 - 80124 Napoli, Italia

(‡) Institut de Physique du Globe de Paris, 4, Place Jussieu, B89, 75252 Cedex 05, Parigi Francia

(††) Tele-Rilevamento Europa – T.R.E. S.r.l.Via Vittoria Colonna, 7 – 20149 Milano, Italia

(‡‡) MDA Geospatial Services, 57 Auriga Drive, Suite 201 - Ottawa, Ontario K2E 8B2 Canada

(***) Università della Calabria, Via P. Bucci, Arcavacata di Rende , Cosenza (Italy)

(†††) IES Consulting SrL Via di San Valentino,34 Roma (Italy)

(‡‡‡) TerraSphere Imaging & GIS B.V. Keizersgracht 114 | 1015 CV Amsterdam (The Netherlands)

(*‡) Belgian Institute for Space Aeronomy Ringlaan-3-Avenue Circulaire B-1180 Brussels (Belgium)

1. INTRODUCTION

The GlobVolcano project (2007-2010) is part of the Data User Element programme of the European Space Agency (ESA). The project aims at demonstrating Earth Observation (EO) based integrated services to support the Volcano Observatories and other mandate users (e.g. Civil Protection) in their monitoring activities. The information services are assessed in close cooperation with the user organizations for different types of volcano, from various geographical areas in various climatic zones.

In a first phase, a complete information system has been designed, implemented and validated, involving a limited number of test areas and respective user organizations (Colima in Mexico, Merapi in Indonesia, Soufrière Hills in Montserrat Island, Piton de la Fournaise in La Reunion Island, Karthala in Comores Islands, Stromboli and Volcano in Italy) .

In the currently on-going second phase, Glob Volcano is delivering pre-operational services over 15 volcanic sites located in three continents and as many user organizations are involved and cooperating with the project team. The scope of this paper is to illustrate the main results of such pre-operational service provision .

2. GLOBVOLCANO PRODUCTS AND SERVICES

The set of GlobVolcano offered EO based information products is the following: Deformation Mapping, Surface Thermal Anomalies, Volcanic SO_2Emission and Volcanic Ash Emission.

2.1. Deformation Mapping

During the last decade DInSAR (Differential Synthetic Aperture Radar Interferometry) has been used to study a wide range of surface displacements related to seismic faults, volcanoes, landslides, aquifers, oil fields and glaciers, to name just a few, at a spatial resolution of less than 100 m and cm-level precision. Differential Interferometry (DInSAR) provides accurate deformation estimates covering large spatial areas and are derived based upon measured differences from a reference DEM of the area [1],[2]. Permanent Scatterers Synthetic Aperture Radar Interferometry method (PSInSAR™) [3],[4] has been introduced in the late nineties as an advanced InSAR technique capable of measuring millimetre scale displacements of individual radar targets on the ground by using large multi-temporal data-sets collected over the area of interest, estimating and removing the atmospheric components affecting the acquisitions. Other techniques (e.g. CTM, IPTA, SBAS) have followed similar strategies and have shown promising results in many different scenarios. Moreover Volcanic areas, characterized by debris and lava sediments as well as single outcrops, represent an interesting test case for a Distributed Scatterers (the SqueeSAR™ concept) approach. In the framework of GlobVolcano project different processing approaches have been adopted: Conventional DInSAR, PSInSAR™ and CTM (Coherent Target Monitoring); in addition the new SqueeSAR™ techniques will be experimented. The processing methodology has been selected according to SAR data availability, characteristics of monitored area and dynamic characteristics of the volcano. In order to generate GlobVolcano products either Envisat ASAR, Radarsat 1or ALOS PALSAR data have been used.

Tab. 1 summarises volcanoes analysed during the project and specifies for each volcano the processing approach adopted and the EO-data used for the study.

Table 1. Deformation mapping processing approach adopted for each volcano site.

Site / Volcano	Data Processing Approach	SAR Data
Areanal (Costa Rica)	DInSAR	ALOS -PALSAR
Colima (Mexico)	DInSAR EarthView®	Envisat ASAR
Cumbre Vieja (La Palma)	CTM (Coherent Target Monitoring)	Envisat ASAR
Hilo (Hawai)	PSInSAR™	Radarsat 1
Mt. St. Helens (US)	PSInSAR™	Radarsat 1
Nyiragongo (Comgo)	DInSAR EarthView®	Envisat ASAR
Pico (Azores)	DInSAR EarthView®	ALOS -PALSAR
Piton de la Fourmaise (La Reunion)	PSInSAR™	Envisat ASAR
Stomboli (Aeolie Islands)	PSInSAR™	Envisat ASAR
Vulcano (Aeolie Islands)	PSInSAR™	Envisat ASAR

2.2. Surface Thermal Anomalies

Volcanic hot-spots detection and radiant flux (and effusion rate where applicable) calculation of high temperature surface thermal anomalies such as active lava flow, strombolian activity, lava dome, pyroclastic flow and lava lake can be performed through MODIS (onboard Terra and Aqua platforms) MIR and TIR channels or through ASTER (aboard Terra), HRVIR/HRGT (SPOT4/5) and more commonly Landsat family SWIR channels analysis. In another hand, ASTER and Landsat TIR channels allow for relative radiant flux calculation of low temperature volcanic surface thermal anomalies such as lava and pyroclastic flow cooling, crater lake and low temperature fumarolic fields. In the framework of GlobVolcano project (Phases 1 and 2), MYMOD routine was used for MODIS data analysis [5],[6] and MYVOL for ASTER and SPOT data processing [7]. These two procedures have permit detection, mapping and activity level measurement of the following volcanic surface phenomena:

- effusive activity at Piton de la Fournaise (Reunion Island) (August-December 2006, 18-19 February 2007 and on November 5Th, 2009) and at Mt Etna (2006 and 2008-2009);
- lava dome growths, collapses and related pyroclastic flows at Soufrière Hills (Montserrat) (February-April and July-September, January-March 2007, December 2008-January 2009 and October-December 2009) and at Arenal (Costa Rica) (March -April 2009);
- permanent crater lake and ephemeral lava lake (November-December 2005, May-June 2006 and on January 13Th, 2007) at Karthala (Comores Islands);
- strombolian activity at Stromboli (Italy) (April-May 2009);
- Low temperature fumarolic fields at Nisyros (Greece), Vulcano(Italy) and Mauna Loa (Hawaii)

2.3. Volcanic Gas Emission (SO_2)

The Volcanic Gas Emission (SO2) Service is provided to the users by a link to GSE-PROMOTE – Support to Aviation Control Service (SACS). The aim of the service is to deliver in near-real-time data derived from satellite measurements regarding SO2 emissions (SO2 vertical column density - Dobson Unit [DU]) possibly related to volcanic eruptions. Global observations of SO2 derived from satellite measurements in near-real-time may provide useful complementary information to assess possible impacts of volcanic eruptions on public safety. Furthermore, the monitoring of SO2 volcanic emission is useful in the frame of early warning, as eruption precursor. The service is focused on the timely delivery of SO2 data derived from different satellite instruments, such as SCIAMACHY, OMI and GOME-2.

2.4. Volcanic Ash Emission

The Volcanic Ash Tracking Service is provided to the users by a link to GSE-PROMOTE – Support to Aviation Control Service (SACS). The aim of the service is to track the ash injected into the atmosphere during a volcanic eruption. The tracking of volcanic ash is accomplished by using SEVIRI-MSG data and in particular the following channels VIS 0.6 and IR 3.9, and along with IR8.7, IR 10.8 and IR 12.0. This service takes advantage of the MSG SEVIRI Scan cycle (15 minutes). Thus the provided product is an animated temporal sequence (i.e. animated GIF). The temporal resolution of the sequence is, at best, 15 minutes.

3. CONCLUSION

The GlobVolcano information system and its current experimentation represent a significant step ahead towards the implementation of an operational, global observatory of volcanoes by the synergetic use of data from available Earth Observation satellites.

4. REFERENCES

[1] Gabriel, A.K. Goldstein, R.M., Aebker, H.A. 1989. "Mapping Small Elevation Changes over Large Areas: Differential Radar Interferometry." Journal of Geophysical Research, Solid Earth and Planets, v 94, no B7, pp 9183-9191.

[2] J. Ehrismann, B. Hulshoff, M van der Kooij, "Commercial Applications of SAR Interferomtrey for Change Detection", Proceedings of International FRINGE99 Workshop, Liege Belgium, November 10-12 1999.

[3] Ferretti A., Prati C., Rocca F. "Permanent Scatterers in SAR Interferometry," IEEE Trans. on Geoscience and Remote Sensing, Vol. 39, no. 1, pp. 8-20, 2001.

[4] Ferretti A., Prati C., Rocca F. "Non-linear Subsidence Rate Estimation Using Permanent Scatterers in Differential SAR Interferometry," IEEE Trans. on Geoscience and Remote Sensing, Vol. 38, no. 5, pp.2202-2212, 2000.

[5] B. Hirn, C. Di Bartola and F. Ferrucci, "Spaceborne monitoring 2000-2005 of the Pu'u'O'o-Kupaianaha (hawaii) eruption by synergetic merge of multispectral payloads ASTER and MODIS", *IEEE Trans. Geosc. Rem. Sens.*, vol. 46, n. 10, pp 2848-2856, 2008.

[6] B. R. Hirn, C. Di Bartola and F. Ferrucci, "Combined use of SEVIRI and MODIS for detecting, measuring and monitoring active lava flows at erupting volcanoes", *IEEE Trans. Geosc. Rem. Sens.* Vol. 47, n. 8, Part 2, pp 2923 – 2930, 2009 .