SAFER

Response to Eyjafjallajökull and Merapi Volcanic Eruptions

S. Barsotti, C. Bignami, M.F. Buongiorno, S. Corradin, F. Doumaz, L. Guerrier, L. Merucci, M. Musacchio, L. Nannipieri, A. Neri, A. Piscini, M. Silvestri, A. Spanu, C. Spinetti, S. Stramondo, U. Wegmuller

Istituto Nazionale di Geofisica e Vulcanologia, Università di Modena e Reggio Emilia, Gamma Remote Sensing

ABSTRACT

After PREVIEW FP6 Project's conclusion, the WP30210 within FP7 GMES SAFER (Services and Applications For Emergency Response) Project has the main objective to refine and consolidate the Earthquake & Volcanoes (E&V) services that were just tested in previous activities and to provide operative services to Users, the Civil Protection Authorities. Here we mainly report objectives and results for the specific tasks related to Eruptive volcanic parameters (WP30211). Four specific products related to the volcanic events which will contribute to the monitoring of the phenomena and mitigation of the eruption effects are expected within the end of the Project. They mainly concern: SAR displacement, high temperature events (HTE), Ash detection, SO_2 concentration and flux, and Ash dispersion models. In particular, here we mostly focus on the activity performed in the occasion of FP7 GMES SAFER activation during two major volcanic eruptions that occurred in 2010. The first activation was for the Eyjafjallajökull eruption in Iceland between April and May 2010, and the second one was solicited in the occasion of the eruption of Mount Merapi (Indonesia) in October-November 2010. Here we present the results of both remote sensing and modeling activities performed during these two events.

SAFER WORK PROGRAMME, METHODOLOGY, MILESTONES

The FP7 GMES Services and Applications for Emergency Response (SAFER) project aims at implementing preoperational versions of the Emergency Response Core Service.

SAFER is specifically addressed to reinforce European capacity to respond to emergency situations: fires, floods, earthquakes, volcanic eruptions, landslides, humanitarian crisis. The overall objectives of the activities in geophysical activities included in WP3 are to develop, upgrade, and validate thematic or crosscutting services and to qualify the most mature ones to be implemented in the pre-operational service provision.

The thematic products and services have been developed in line with the recommendations given by the Implementation Group Report.

They extend the core services (a) by specific expertise coming from the different thematic fields, or (b) by extending the service to cover the entire crisis cycle. These contributions will thus expand beyond the emergency response part of the disaster cycle and cover forecasts and early warning services as well as vulnerability analyses and assets mappings.

The geophysical WP3 activities to large degree take into account and further develop the products and services initiated and implemented in the EU FP6 project PREVIEW (Spinetti et al, 2009). The services previously developed are suited to be provided over large areas (e.g. pan-European), to be transferable from one region to another and to fulfill the criteria of Emergency Response "core" (vs. down-stream) services. The earthquake and volcanoes services provide forecasting of volcanic ash dispersion, the estimation of lava flow effusions rates, ash detection, SO_2 concentration and flux of volcanic eruptions, the mapping of surface deformations and sources in volcanic areas, and the mapping of damages under different earthquake scenarios.

PARTNERSHIPS AND COLLABORATIONS

The SAFER consortium brings together the main European actors involved in the emergency response (users, service providers, scientific teams). SAFER assembles a highly skilled and experienced European network of partners. The SAFER consortium includes key representatives of the main ongoing projects, either integrated projects for EC or GSE projects for ESA, ensuring thus the optimal capitalization of experience. In particular the Earthquakes and Volcanoes work is lead by INGV and supported by NILU and ENS for the generation of volcanoes related activity products and by GAMMA, Eucentre IGAR and Telespazio for the generation of earthquake related activity products. Moreover, the SAFER project has activated collaborations with the Tectonic platform of Terrafirma ESA Project. Indeed SAFER has focused the application of Advanced InSAR (A-InSAR) techniques to the Vrancea region (Romania) to make an analysis of slow movements in a high seismic risk area in Europe. This activity stems from SAFER service evolution as it is related to disaster preparedness efforts. As the Terrafirma project is specifically addressed to such topics this link with SAFER might be strengthened in the next years.

RESULTS

SAFER has been activated to perform activities to mitigate the risk and to support the emergency by satellite services and numerical simulations during two major volcanic eruptions occurred in 2010. The first activation was for the Eyjafjallajökull eruption that occurred in Iceland when explosive activity started on April and ended in May 2010. The second activation was for the eruption of Mount Merapi in Java Indonesia in October-November 2010. In the following the results of both remote sensing and modelling activities performed during these two events are described.

EYJAFJALLAJÖKULL ERUPTION PRODUCTS

The April-May 2010 Icelandic eruption has had a tremendous unprecedented impact on civil aviation in Europe and beyond resulting in billion Euro economic loss and large social impact, especially during the 14-20 April week. On 14th April at 8-9 GMT the eruption started to produce a sustained column reaching a maximum height of about 11 km a.s.l. and a volcanic ash cloud spreading all over Europe. Since the onset of the eruption the INGV staff was part of the permanent *coordination* group that was set up during the emergency by the Italian Civil Protection Department in order to monitor the air-space over the Italian territory.

SATELLITE RETRIEVAL MAPS

Satellite images, from which volcanic cloud quantitative parameters were estimated, came from polar satellite MODIS and MERIS acquired during different phase of the eruption.

MODIS data, free available from NASA, has been used during the week 14-20 April with approximately one day of delay to estimate the presence and the loading of volcanic ash in the North Europe area and the aerosol optical depth (AOT) over Italian territory (Figure 1 and Figure 2). The ash detection in the TIR spectral range is carried out by using the Brightness Temperature Difference (BTD) (Prata, 1989). To reduce the water vapour effects on BTD a correction procedure has also been applied (Corradini et al., 2008; 2010). The ash mass is computed using the formula suggested by Wen and Rose (1994). MERIS provide medium-spectral resolution of 300m of full spatial resolution data operating in the visible and near-infrared (VNIR) spectral range. The aerosol optical depth (AOT) over Iceland area has been calculated (Spinetti et al, 2007; 2008) showing the densely volcanic aerosol drifting S-SE direction on 11 May 2010 (Figure 3).

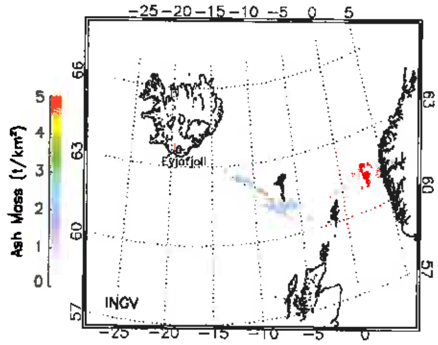

Figure 1: Terra-MODIS volcanic ash mass on 15th April 2010 11.35 GMT over North Europe. The figure shows the ash emitted on 14th April spreading from Iceland to Norway

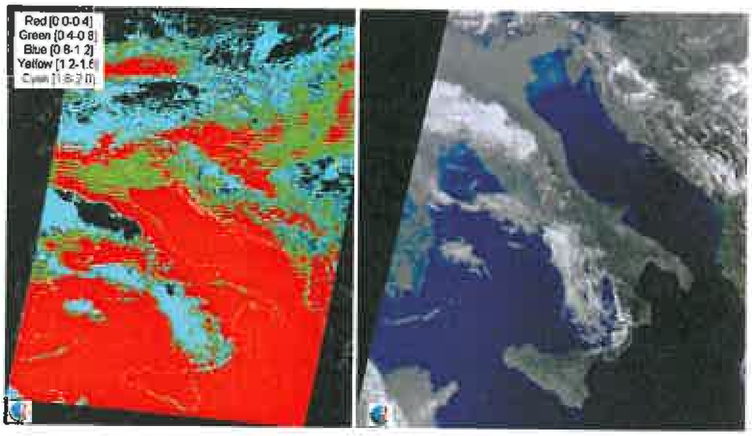

Figure 2: Terra-MODIS on 21th April 2010 9.35 GMT over Italian territory. Right panel shows the MODIS image in RGB composition. Left panel the corresponding AOT showing high values in the Pò Plane (Green color) where airspace was closed

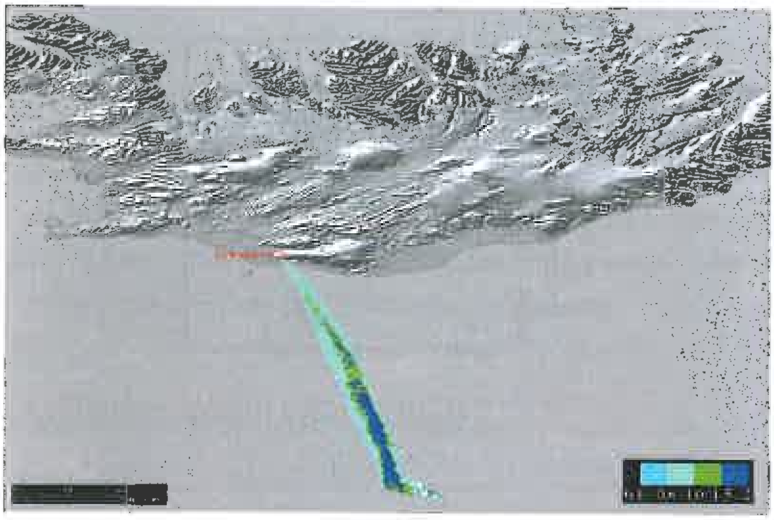

Figure 3: MERIS derived AOT map on 11th May 2010 12.55 GMT over South Iceland. The figure shows the volcanic plume traveling in S-SE direction

VOLCANIC ASH FORECASTING MAPS

The VOL-CALPUFF code (Barsotti et al., 2008) was used to simulate the ongoing activity and to provide forecasting maps of volcanic ash concentration at different atmospheric levels. During the volcanic crisis, as soon as the 72-hours weather forecasting data were downloaded from the NOAA website, the numerical procedure was executed once per day. Further in order to simulate a quite reliable activity and to update the model input data, each day an accurate check of all the available information regarding the eruption intensity and column height on the web was done. Due to the wide extension of the area interested by ash presence we choose to define a 6000X4000km domain extending from 35N to 65N. The standard map produced by the model shows areas interested by those concentration values adopted as new threshold for aviation security by VAACs at International level. They are 2x10-4 g/m^3 and 2x10-3 g/m^3, respectively (Figure 4).

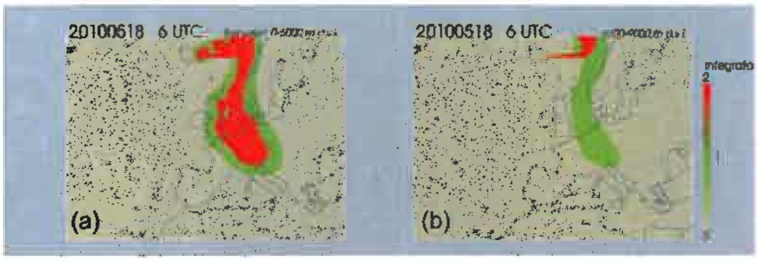

Figure 4: Forecasting maps produced with VOL-CALPUFF model for 18th May 2010 at a specific instant. They show ash presence at two different altitudes: (a) between 0-6000 m a.s.l. and (b) between 6000-9000 m a.s.l. The red area corresponds to ash concentration of 2x10-3 g/m³ and the green one to 2x10-4 g/m³

MERAPI ERUPTION PRODUCTS

On October 26th, 2010, Merapi Volcano (Indonesia) started its eruptive activity characterized by multiple pyroclastic flows that killed hundreds of people living in the surroundings.

SATELLITE RETRIEVAL MAPS

Thanks to the activation of a DAP (Data Access Portfolio), satellite images from the data basket of SAFER have been processed and analyzed applying DInSAR (Differential Interferometry SAR) to detect surface displacements (Massonet et al., 1994). Being the Merapi a case-study for another FP7 project named MIA VITA (MItigate and Assess risk from Volcanic Impact on Terrain and human Activities), the derived information have also been delivered to the Indonesian CVGHM (Center for Volcanology and Geological Hazard Mitigation). In particular, we have received Radarsat-2 scenes, pre and post-eruption images, and COSMO-SkyMed data. The analysis of the deformation has been performed in the period from March to October by using Radarsat-2 and COSMO-SkyMed.

Both results confirm a large movement up to 10 m of the Southern flank along SW direction and possibly a subsidence. The crater summit rupture and a new emerging dome have also been detected by exploiting the COSMO-SkyMed very high resolution images (Figure 5).

Figure 5: Left image: Multi-temporal analysis in RGB component: R= 1/5/2010, G=31/10/2010, B=8/11/2010. Evolution of the opening from 1st May 2010 (red line), 31th October 2010 (green line) and 8th November 2010 (blue line), after the big event on 5th November. Right picture: Onset of a new dome (yellow arrow)

Even considering the not ideal weather conditions, due to geographical position and season, a systematic analysis has been done based on infrared data MTSAT, AVHRR and MODIS, focused on the identification of the volcanic plume content.

Using MTSAT geostationary data, provided by "Earthquake Research Institute & Institute of Industrial Science U-Tokio", the presence of volcanic ash has been detected in the night between the 3rd and 4th November 2010 IR channels. The technique enables the discrimination of the weather clouds with respect to the ash clouds content (Figure 6). NOAA-AVHRR images, degraded 4 km of spatial resolution, between 24th October to 4th of November 2010 and MODIS images, 1 km of spatial resolution, between 29th October to 4th of November, have been processed for ash detection. A total of 31 images haven't revealed any evidence of ash, probably due to meteorological clouds higher than ash cloud and strong presence of water vapor. SO_2 has been reveled using MODIS bands as shown in Figure 7.

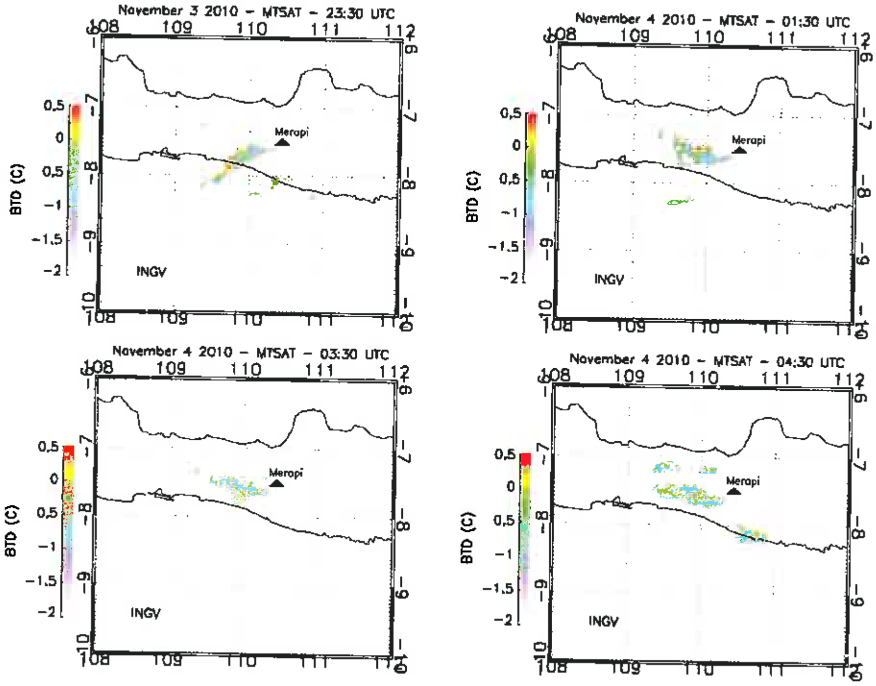

Figure 6: MTSAT elaboration for volcanic ash identification from 3rd November 23.30 GMT to 4th November 04.30 GMT

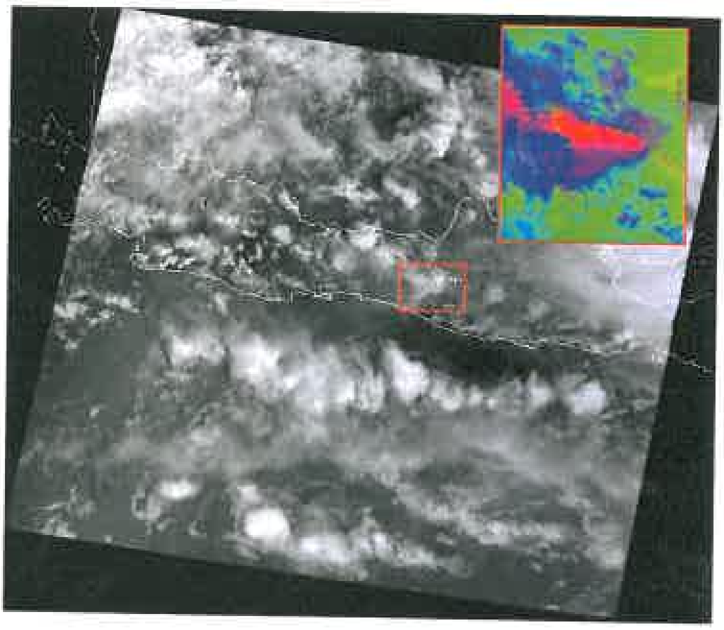

Figure 7: MODIS data on 4th November 2010 03.20 GMT on true colour showing the high presence of clouds in the Java region Insert panel de-correlation stretching zoom showing contaminated SO_2 release from Merapi

VOLCANIC ASH FORECASTING MAPS

As soon as the eruptive activity shifted to the generation of sustained plumes accompanied by an abundant release of ashes (this occurred since 5th November), the VOL-CALPUFF code was applied to produce forecasting maps of ash dispersal at regional scale. By using weather forecasting data available over Indonesian domain (GFS – dataset from NOAA/NCEP web server) the code was applied to simulate the impact on air and the ground of two plausible explosive events characterized by different eruptive intensities and defined on the basis of the volcano history. In particular we referred to Scenario1, characterized by a 15km column height and an estimated erupted mass equal to 0.26×10^8 m^3, and Scenario2 with 20km column height and 1.3×10^8 m^3 erupted volume, assuming a six hours emission duration for both of them. An almost uniform fine grain-size distribution was adopted as initial condition. Under these assumptions, the model produced maps of both aerial ash concentration (each six hours) and the cumulative ground deposition. Figure 8 shows forecasting ash concentrations in atmosphere at different altitudes a.g.l. as produced for Scenario 2 on November 8.

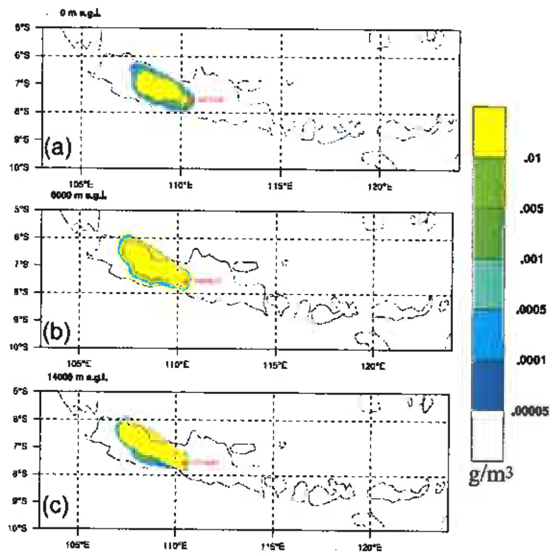

Figure 8: Ash concentration maps produced on 8th November 2010 for Scenario 2 (20km column height assumed). Three altitudes are reported: (a) at ground level, (b) at 6000 m a.g.l. and (c) at 14000 m a.g.l

CONCLUSION

The activation of SAFER for both the Eyjafjallajökull eruption in Iceland between April and May 2010, and Mount Merapi eruption in Indonesia between October and November 2010 has successfully demonstrated the possibility to react and provide products to Users. In the case of the Eyjafjallajökull eruption three newsletters were issued and the first one, issued on 15th April just the day after the explosive activity starts, has been published on the EC website. An official document (newsletter) compiled by the SAFER team was released also during the Merapi activity.

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