PROJECT TITLE

DEVELOPMENT AND APPLICATION OF REMOTE SENSING METHODS FOR THE MONITORING OF ACTIVE ITALIAN VOLCANOES

Scientific Coordinator
Mauro COLTELLI – Senior Researcher
Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania

ACTIVITY REPORT –2° YEAR

PROJECT PARTICIPANTS

UR#	AFFILIATION	RESPONSIBLE
1- IGG (ex CSGSDA)	CNR- Istituto Geoscenze e Georisorse, Pisa	Francesco Mazzarini
2- INGV-CT	Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania	Giuseppe Puglisi
3- INGV-CNT (ex CNMS)	Istituto Nazionale di Geofisica e Vulcanologia, Centro Nazionale Terremoti, Roma	Maria Fabrizia Buongiorno
4- IPGP	Institut de Physique du Globe de Paris	Pierre Briole
5- IREA	CNR- Istituto per il Rilevamento Elettromagnetico dell'Ambiente, Napoli	Riccardo Lanari
6- JPL	Jet Propulsion Laboratory, California Institute of Technology Pasadena, California	Paul Lundgren
7- OPGC	Observatorie de Physique du Globe de Clermont-Fd	Frank Donnadieu
8- INGV-OV	Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Napoli	Sven Borgstrom
9- POLIMI	Dip. di Elettronica e Informazione, Politecnico di Milano	Claudio Prati
10- UNIBO	Dip. di Fisica, Università di Bologna	Paolo Baldi
11- UNICAL	Dip. Di Elettronica, Informatica e Sistemistica, Università della Calabria, Rende CS	Giuseppe Di Massa
12- UNICT	Dip. Elettrico, Elettronico e Sistemistico, Università di Catania	Giuseppe Nunnari
13- UNIMO	Dip. Ingegneria Materiali e Ambiente, Università di Modena e Reggio Emilia	Sergio Pugnaghi
14- UNIPD	Dip. di Costruzioni e Trasporti, Università di Padova	Vladimiro Achilli
15- UNIRM	Dip. Idraulica, Trasporti e Strade, Università La Sapienza di Roma	Maria Marsella

GENERAL OBJECTIVES

Task 1: SAR Interferometry applications on ground deformation studies

Task 2: Application of Digital Terrain Models (DTM) to volcanology

Task 3: Remote sensing of thermal anomalies from active volcanoes

Task 4: Monitoring of eruptive clouds

Task 5: Study of volcanic-plume's gas by mean of remote sensing techniques

TASK 1 - SAR Interferometry applications on ground deformation studies

UR PARTICIPANTS: INGV-CT; INGV-OV; IREA; IPGP; JPL; POLIMI; UNICAL; UNICT

I YEAR OBJECTIVES

1) Ground deformation measurements using DInSAR commercial software and development of phase unwrapping algorithm in experimental software.
2) Study of permanent scatterers on selected test areas.
3) Set up for back -scattering measurement of microwaves on volcanic terrain.
4) Carrying out measurements to calibrate interferometric measurement and for validating the results.
5) Study and set up of advanced filtering techniques based on multi-scale approaches and on the availability of information on atmospheric delay on the SAR signal.
6) Study and set up of analytic direct and inverse models.
7) Analysis of application both of the simple analytic models and the filtering techniques to the available data for the Etnean area.

I YEAR RESULTS

- *Methodology*
  Commercial software has been used to process the data bought in the previous year at both INGV-CT and INGV-OV URs. Software allowed to focus the RAW data into SLC format and produce interferograms form SLC data relevant to the Mt. Etna and Neapolitan areas. The IREA-CNR developped a phase unwrapping algorithm based on an appropriate combination of interferograms (by using Singular Value Decomposition (SVD) method) produced by subsequently acquisitions characterized by small baselines. This algorithm increases the number of data available for the analysis of an area of interest.
  INGV-CT and UNI-CT URs are developping an algoritm to invert the interferograms by using a numerical optimization approach (Simulated annealing) and an appropriate dislocation mode (Okada). The first test are currently running on recent activity of Mt. Etna.

- *Data acquisition*
  The bought data are relevant to the Mt. Etna and Neapolitan area, according the paln of the project.

- *Processing and interpretation*
  Studies on specific volcanic events occurred on Mt. Etna (1998 summit crater explosive activity and the July-August 2001 eruption) are currently performed, by using interferograms produced by commercial software.
  Validation on phase unwrapping algorithms developed at IREA-CNR has been carried out in cooperation with INGV-OV, by comparing interferometric data with the data from the geodetic networks in Campi Flegrei area, related to the uplift event recorded from March to August, 2000.
  The PST has been used to monitor Mt. Etna deformations during the 5 years period of relative low volcanic activity from April 1995 to December 2000. 40 ERS images have been used with normal baselines larger than +/- 1000 m. The accuracy of the velocity values (computed independently one from the other). The results of this study clearly show the presence of many active faults splitting the Etna eastern flank in blocks with different slipping velocities. The URs POLIMI, INGV-CT, IPGP are studying these results in the framwork of the volcanic activty of Mt. Etna
  The activity of Mt. Etna from 1993 to 1995 has been studied by inverting ascending and descending interferograms produced by using a two-pass approach. The use of two different line-of-sight directions (ascending and descending) allows to constraint a complex set of deformations source that result in an ellipsoid and near horizontal dislocation. This set of sourc allow the eastward movement of the eastern flank of the volcano

TASK 2 - Application of Digital Elevation Model (DTM) to volcanology

UR PARTICIPANTS : UNIBO, UNIPD, UNIRO, INGV-CT

1° YEAR OBJECTIVES

1) Set up of methodologies for acquisition and processing of the GPS data for Ground and Aerial Control.
2) Digital Photogrammetry Processing
3) Differential Digital Photogrammety (DDP) (Vulcano and Stromboli)
4) Extraction and Comparisons of SAR DTM

5) DTM Validation
6) Validation of morphological variation maps

1° YEAR RESULTS

– *Methodology*
Comparisons between DEMs derived from 1993, 1996 and 2001 photogrammetric flights on Vulcano island have been performed, using also coordinates of natural points measured on the models. Least square surface matching procedure has been tested in order to obtain the registration of different (multitemporal) sets of 3D coordinates of the same area, by the detection of the parameters for a rigid transformation in a common reference system of the data sets, without the aid of control points.
A morphometric study of the digital terrain model (DTM) of "La Fossa" Cone of Vulcano Island (Aeolian Arc, Italy) has been performed in order to define morphological features and classify main landforms.

- *Data acquisition*
GPS and classical surveys on Vulcano Island to collect data for DTM validation.

- *Processing and interpretation*
The digital photogrammetric processing of the 2001 photogrammetric data (1:5000 scale) of the Stromboli island was performed. A 5x5 m grid DEM of the entire Island was extracted.
Morphometric maps, a Terrain Units Map and a Morphometric Units Map were compiled for the Vulcano Island.

- *Other*
Updating of the laboratory for digital photogrammetry processing, activated in Bologna in 2001: installation of the latest version of Helawa software, O.S. upgrade, RAM and Hard Disk expansion.
A GIS software has been configured and partially implemented with the aim to obtain a tool for the distribution, visualization and analysis of 3D and 2D mapping products obtained for the Vulcano Island from the 1996 photogrammetric data.

TASK 3- Remote sensing of thermal anomalies from active volcanoes

UR PARTICIPANTS: INGV-CNT (ex INGV-CNMS)

I YEAR OBJECTIVES

1) Time-series analysis (1984-1993 eruptive events) of data from LANDSAT (series from JPL and GNV), AVHHR, ATSR and validation of the dual band algorithm. Data-fusion of deferent image datasets to compare the potentialities of distinct sensors in volcano monitoring.
2) ASTER data analysis

I YEAR RESULTS

- *Data acquisition*
On July 29th an airborne campaign equipped with an image spectrometer was performed over Mt. Etna to acquire image data of the eruption. This campaign, funded by the ASI, was organized to permit a simultaneous acquisition with the TERRA (ASTER sensor), EO-1 and LANDSAT 7 satellites. This multi-sensor acquisition over an active lava flow represented a unique opportunity to study the temperature distribution and at the same time to compare the different sensors capabilities for this type of volcanic events. The preliminary observations of the different data sets enlighten the importance of the data quantification and of the gain setting of the instrument.

- *Processing and interpretation*
Surface temperature analysis was performed on distinct lava flows by using dual-band and triple-band techniques. Hot-cracks fractional area frequency distribution is peculiar for each different lava flow and appears to be related to the topographic slope gradient and to the flux rate of the flows. This means that the monitoring of the lava thermal status may be used as powerful tool for volcanic hazard prediction especially if combined with an detailed study of the topography through Digital Elevation Model analyses.
The airborne high-spatial resolution images allow for the creation of a mathematical and physical model of the temperature distribution. This model must be subsequently tested on satellite data characterized by a lower spatial resolution but a higher time frequency of acquisition.

TASK 4 - Monitoring of Eruptive Clouds

UR PARTICIPANTS: INGV-CT, OPGC, UNICAL

I YEAR OBJECTIVES

1) Development of the radar Voldorad II for remotely controlled fixed position monitoring of volcanic eruptions.
2) Laboratory measurement of the backscattering properties of volcanic ashes
3) Ddevelopment of complex models for the simulation and measurement of the field scattered by volcanic ash.
4) Study and devising algorithms able to evaluate the atmospheric delay related to the azimuth direction and elevation of each GPS satellite.

I YEAR RESULTS

- *Methodology*
  The development of the prototype of Voldorad-2, a medium-power UHF Doppler radar specially designed for remote sounding of explosive volcanic eruptions in a permanent remote-controlled station is ongoing. The construction of the radar is on its way but has been interrupted when funds of the 1st year ran out. The major part of the receiver has been built and tested and the low level part of the transmitter built too.
  The research activity has been also addressed to the design of a microstrip antenna array for Voldorad-2. The correct operation of the radar as well as its target sensitivity depend both on the beam shape and on the matching properties of the antenna used to transmit and receive the radar power. In order to satisfy the prescribed requirements, a radiation pattern with a total beamwidth equal to 9 degrees has been imposed in both planes. Two configurations have been proposed for the array, working at a center frequency f = 1274 MHz. The first configuration uses an array of 8x8 aperture coupled patches, while the second consists of an array of shorted annular patch antennas. This latter solution presents the same appealing features of standard patches in terms of size, weight and cost but, in addition, it offers the possibility to control the radiation pattern by varying the inner and outer radii of the ring. As a further characteristic, the proposed array can be designed to avoid surface wave emission, so reducing the mutual coupling effects between elements and increasing the overall antenna efficiency.

- *Data acquisition*
  Backscattering measurements on controlled environments have been used for calibrating the scatterometer of UNICAL, and results have been compared with simple electromagnetic models on homogeneous material with known dielectric properties
  In order to characterize the scattering properties of volcanic particles, a cylindrical structure has been realized to encapsulate volcanic particles of selected size. Material of dielectric properties similar to vacuum has been used for the cylinder. These measures will allow to know backscatter properties of the volcanic ash in a wide range of wavelength using different sets of volcanic particles dispersed in the cylindrical structures of inert material. Presently scattering measurements have been performed into the anechoic chamber of the Microwave Laboratory of UNICAL for different frequencies on the X-band. Experimental results have been validated by a simple model of electromagnetic scattering by dielectric particles of known properties.

- *Processing and interpretation*
  Efforts have been made by OPGP to improve the data processing programs of the radar signal in order to retrieve and visualize easily velocity and power values as a function of time.
  A numerical code has been developed by UNICAL to compute the field scattered by volcanic particles assumed as dielectric spheres of assigned radius. Permittivity values obtained during the activity of the first year have been included in the model.
  At INGV-CT we are presently studying the dispersion of the volcanic particles in both eruptive column and umbrella cloud to define particle's grain-size and density in air at different distance from the vent. A this aim we are running available PDMs (particle dispersal model) and comparing their results with well know deposit of recent Etna's explosive eruptions.
  The processing of GPS data relevant to the recent volcanic activity, which produced important and continuous ash clouds, is currently in progress at INGV-CT.

TASK 5 - Study of volcanic-plume's gas by mean of remote sensing techniques

UR PARTICIPANTS: INGV-CNT (INGV-CNMS), IGG (ex CSGSDA), UMIMO

I YEAR OBJECTIVES

1) Developing Remote Sensing techniques applied to the atmospheric volcanic emissions to retrieve the tropospheric volcanic plume aerosols optical characteristics and gases (H2O and CO2) abundance.
2) Development of an airborne Fourier spectrometer (FTIR)
3) Application of the procedure to evaluate the SO_2 flux emitted from Mt. Etna using real ASTER data remotely sensed during ground truth measurements
4) Field campaign in order to collect radiometric samples of natural surfaces at Mount Etna (vegetation, rocks, soils, human artefacts by using the FIELD-SPEC spectroradiometer

I YEAR RESULTS

- Methodology
  1)Plume optical characteristics and aerosol loading:
  2) algorithms to retrieval columnar abundances of gases
  3)A semi-automatic procedure to retrieve SO2 columnar abundances, based on a series of Look-Up Tables (LUTs) containing the simulations performed using MODTRAN code.
  4)A new inversion procedure to retrieve SO2 columnar abundances, based on the split-window technique
  the FIELD-SPEC spectroradiometer calibration. This task took about three month, we prepare an operative procedure to follow in the field to collect spectral signature of natural surfaces at Mount Etna. Some sites for the spectral sampling have been defined through the analysis of Landsat ETM 7 satellite images.
- Data acquisition
  LANDSAT IMAGES 2001 and 1993
  ASTER DATA 2000-2002
  HYPERION DATA
  AVIRIS data of HAWAII
  FIELD SPECTRA OF ETNEAN LAVAS
  METEOROLOGICAL DATA OF PERMANET STATION
  TRAPANI PROFILES
- Processing and interpretation
  Data processing and interpretation. New Landsat ETM of the volcano have been geocoded in order to identify potential sites for in situ spectral sampling.
  Image processing of MIVIS, AVIRIS data for to determine reflectance and emissivity images.
  Up today was possible to analyse only one daily ASTER image (July 29, 2001) of Mt. Etna. The SO2 estimated flux is comparable with the COSPEC data, at least close to the summit area.
- Other
  Acquisition of the sun photometer (CIMEL)
  Development of the FASA project which will fly in 2003 a Fourier spectrometer (FTIR) to analyse the gas content of Etna (project partially funded by ASI)

- RESEARCH PRODUCTS OF THE PROJECT
  - n° of articles published on international journals: **14**
  - n° of articles published on national journals, proceedings, technical reports: **21**
  - invited papers and talks: **2**
  - Presentation at international meetings: **16**
  - Presentation at national meetings: **16**
  - Data base: **3**
  - Computation codes: **7**

PUBLICATIONS LIST

Achilli V., Baldi P., Fabris M., Marsella M., Monticelli R., Salemi G., (2002) Application Of Digital Elevation Model To Volcanology , Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in print.

Baldi P., Bonvalot S., Briole P., Coltelli M., Gwinner K., Marsella M., Puglisi G., Rémy D., (2002).Validation and comparison of different techniques for the derivation of digital elevation models and volcanic monitoring(Vulcano island, Italy), International Journal of Remote Sensing, 22, 4783-4800.

Baldi P., Marsella M., Signoretto V. (2002) Analysis of High Resolution Digital Elevation Models for Morphometric Parameters Extraction and Classification. Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in print..

Berardino P., Bequignon J., Borgstrom S., De Natale G., Capuano P., Fornaro G., Lanari R., Pingue F., Ricciardi G.P., Sansosti E., Troise C. (2002) Evidence for a peculiar style of ground deformation at Vesuvius volcano revealed by 10 years of ERS mission. Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS), Toronto (Canada), 24-28 June 2002, VI: 3614-3616.

Berardino P., Borgstrom S., Cecere G., Del Gaudio C., De Martino P., Fornaro G., Lanari R., Ricciardi G.P., Ricco C., Sansosti E., Sepe V., Siniscalchi V. (2002) Un approccio multimetodologico per il controllo delle deformazioni nell'area flegrea. Proceedings of the 6th National Conference of ASITA, Perugia, 5-8 November 2002, 1: 409-416.

Berardino P., G. Fornaro, R. Lanari, E. Sansosti, "A new Algorithm for Surface Deformation Monitoring based on Small Baseline Differential SAR Interferograms ",IEEE Transactions on Geoscience and Remote Sensing, in print, Dicembre 2002.

Berardino P., Borgstrom S., Del Gaudio C., De Martino P., Fornaro G., Guarino S., Lanari R., Ricciardi G.P., Sansosti E. (2002) Geodetic/SAR monitoring of Campi Flegrei caldera: the 2000 uplift event. Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in print.

Chaabane F., A. Avallone, F. Tupin, P. Briole, E Trouvé, J.M. Nicolas and H. Maître, (2002) Improvement of the tropospheric correction by adapted phase filtering. Proceedings of the European Conference on Synthetic Aperture Radar, Cologne, Germany, 4-6 June 2002, in press.

Coltelli M., Puglisi G., Guglielmino F.,Palano M. (2002) Application of Differential Sar Interferometry for studying the eruptive event of 22 July 1998 at Mt. Etna. Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in print.

Costanzo S., Di Massa G. (2002) Electromagnetic Characterization of Volcanic Ash, Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in print.

Costanzo S., Di Massa G. (2002) An Integrated Probe for Phaseless Near-Field Measurements. Measurements, vol.31, pp.123-129.

Donnadieu F., Dubosclard G., Allard P., Cordesses R., Hervier C, Lénat J.-F. (2002). Sondages des jets volcaniques par radar Doppler : applications à l'Etna. Rapport quadriennal 1999-2003, XXIII Ass. Gén. C.N.F.G.G., Sapporo, Japon. Submitted.

Donnadieu F., Dubosclard G., Allard P., Cordesses R., Hervier C, Coltelli M., Lénat J.-F. (2002). Monitoring of Strombolian eruptions of Etna by UHF Doppler radar. Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in print.

Dubosclard G., Allard P., Cordesses R., Donnadieu F., Hervier C., Coltelli M., Privitera E., Kornprobst, J. (2002). Doppler radar sounding of volcanic eruption dynamics at Mount Etna. Bull. Volcanol., accepted.

Ferretti A., Colombo D., Savio G., Prati C., Rocca F. (2002) Monitoring the surface deformation of Mt. Etna with ERS-SAR images. Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in print.

Lanari R., De Natale G., Berardino P., Sansosti E., Ricciardi G.P., Borgstrom S., Capuano P., Pingue F., Troise C. (2002) Evidence for a peculiar style of ground deformation inferred at Vesuvius volcano. Geophysical Research Letters, Vol. 29, No. 9, 10.1029/2001GL014571.

Lanari R., Berardino P., Sansosti E., Fornaro G., De Natale G., Ricciardi G.P., Borgstrom S., Capuano P., Pingue F., Troise C., Bequignon J. (2002) Deformation of Vesuvius revealed by 10 years of ERS mission. Proceedings of the 22nd EARSeL (European Association of Remote Sensing Laboratories) Symposium, Prague (Czech Republic), 4-6 June 2002, in print.

Lanari R., Berardino P., Borgstrom S., Del Gaudio C., De Martino P., Fornaro G., Guarino S., Ricciardi G.P., Sansosti E., Lundgren P. (2003) The use of IFSAR and classical geodetic techniques in civil protection scenarios: Application to the Campi Flegrei uplift event of 2000. Submitted to Journal of Volcanology and Geothermal Research.

Lombardo V., M.F. Buongiorno, S. Amici (2002), Characterization of a volcanic hot-spot source by means of sub-pixel temperature distribution analysis: a case from the 1996 Mount Etna eruption using airborne imaging spectrometer data, submitted on 31/09/2002 to Bulletin of Volcanology

Lombardo V., M.F. Buongiorno, L. Merucci, D. Pieri (2001), difference in the hot-cracks frequency distribution between Summit and flunk eruptions of Mount Etna lava flows, observed by Landsat Thematic Mapper, submitted on 18/05/2001 al Journal of Volcanology and Geothermal Research

Lombardo V. , Buongiorno M.F. (2002) Etnean lava flows thermal analysis by using short wavelength infrared data acquired by spaceborne and airborne sensors. Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in print.

Lundgren, P., P. Berardino, M. Coltelli, G, Fornaro, R. Lanari, G. Puglisi, E. Sansosti, and M. Tesauro (2002) Coupled magma chamber inflation and sector collapse slip observed with syntheic aperture radar interferometry on Mt. Etna volcano, J. Geophys. Res., in press, 2002.

Lundgren P. and Rosen P. (2003) Source model for the 2001 flank eruption of Mt. Etna volcano", submitted to Geophys. Res. Lett.

Lundgren P., Berardino P., Coltelli M., Fornaro G., Lanari R., Puglisi G., Sansosti E., Tesauro M. (2002) Report on observations and modeling of coupled magma chamber inflation and flank motion on mt. etna volcano. Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in print.

Marsella M., F. Volpe (2002) Analisi delle potenzialità dei dati satellitari ad alta risoluzione per la generazione di ortofoto Proceedings of the 6th National Conference of ASITA, Perugia, 5-8 November 2002, 2: 1485-1490.

Mora P., Baldi P., Casula G., Fabris M., Ghirotti M., Mazzini E., Pesci A., (2003). Monitoring landslide movements using GPS and Digital Photogrammetry. Engineering Geology (in press).

Nunnari G., Puglisi G., Guglielmino F., Coltelli M. (2002) Modelling Ground Deformations in Volcanic Areas By Using SAR Interferograms, Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in print.

Pingue F., Berrino G., Capuano P., Del Gaudio C., Obrizzo F., Ricciardi G.P., Ricco C., Sepe V., Borgstrom S., Cecere G., De Martino P., D'Errico V., La Rocca A., Malaspina S., Pinto S., Russo A., Serio C., Siniscalchi V., Tammaro U., Aquino I. (2002) Sistema integrato di monitoraggio geodetico dell'area vulcanica attiva napoletana: reti permanenti e rilevamenti periodici. Proceedings of the 6th National Conference of ASITA, Perugia, 5-8 November 2002, 2: 1751-1764.

Pugnaghi S, Teggi S, Corradini S, Buongiorno MF, Merucci L, Bugliolo MP, (2002) Estimation of SO2 abundance in the eruption plume of Mt. Etna using two MIVIS thermal infrared channels: A case study from the Sicily 1997 Campaign. Bulletin of Volcanology, 64, 328-337.

Pugnaghi S., Teggi S., Corradini S., Medici P., Lombroso L. (2003); Estimation of the SO2 flux of the eruption plume of the Mt. Etna volcano using MIVIS and ASTER data. Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in print.

Remitti M., Pugnaghi S., Teggi S., Parmiggiani F. (2003); Retrieval of tropospheric ash clouds of Mt. Etna from AVHRR data. Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in print.

Riguzzi F., Anzidei M., Baldi P., Casula G., Galvani A., Pesci A., Pietrantonio G. (2002): Rilievi GPS per il controllo delle deformazioni nell'area dei Colli Albani (Roma). Atti della 6° Conferenza Nazionale ASITA: Geomatica per l'ambiente, il territorio e il patrimonio culturale, 5-8 Novembre 2001, Perugia, 1797-1802.

Spinetti C., M.F. Buongiorno, V. Lombardo, and L. Merucci (2002). Retrieval Aerosol Optical Thickness of Volcanic Plumes by means of the Airborne Multispectral Image Spectrometer (MIVIS): a case study from Mt. Etna Sicily, June 1997. Special issue of Annali di Geofisica (in press).

Spinetti C., M.F. Buongiorno (2002). Aerosol Optical Characteristics of Volcanic Plume Retrieval by Means of Remote Sensing Techniques: the Case of Mt. Etna Studied Using the MIVIS Airborne Multispectral Image Spectrometer. Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in print.

Venneri F., Costanzo S., Di Massa G., Angiulli G. (2003) Investigation of Printed Reflectarrays as Permanent Scatterers in SAR Interferometry. Microwave & Optical Technology Letters, in print.

Development and application of remote sensing methods for the monitoring of active Italian volcanoes

GNV Co-ordinated Project

Scientific co-ordinator : Dr. Mauro Coltelli
(INGV – Sezione di Catania)

Files of the activities of the Research Units

Second year report

(January 2003)

DEVELOPMENT AND APPLICATION OF REMOTE SENSING METHODS FOR THE MONITORING OF ACTIVE ITALIAN VOLCANOES

RU Responsible
Name-Francesco Mazzarini - Research
Affiliation CNR IGG-Pisa

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Francesco Mazzarini - Research	CNR-IGG-Pisa	5
Massimiliano Favalli- Research	CNR-IGG-Pisa	5
Ruggero Casacchia - Research	CNR-IIA-Roma	4
Rosamaria Salvatori - Research	CNR-IIA-Roma	4
Giovanni Graziani - Research	Centro EC ISPRA (VA)	4
Maria Ranci - Research	Centro EC ISPRA (VA)	5

- 2nd YEAR OBJECTIVES

Field campaign in order to collect radiometric samples of natural surfaces at Mount Etna (vegetation, rocks, soils, human artefact) by using the FIELD-SPEC spectro-radiometer.

- 2nd YEAR RESULTS **(max 1 page)**
  - methodologies: the FIELD-SPEC spectro-radiometer operates in the optical field of the electromagnetic spectrum (from visible to near infrared, wavelenth ranging from 0.3 to 2.5 microns). The calibration of the instrument took about three month, we prepare an operative procedure to follow in the field to collect spectral signature of natural surfaces at Mount Etna. Some sites for the spectral sampling have been defined through the analysis of Landsat ETM 7 satellite images.
  - Data acquisition, Since the optimal period (meteorologi conditions) is in June early July, a seven to ten days campaign (two-three persons) has been scheduled for the June 2003.
  - Data processing and interpretation. New Landsat ETM of the volcano have been georeferenced in order to identify potential sites for in situ spectral sampling.

DEVELOPMENT AND APPLICATION OF REMOTE SENSING METHODS FOR THE MONITORING OF ACTIVE ITALIAN VOLCANOES

RU Responsible
Giuseppe Puglisi – Senior Researcher
Istituto Nazionale di Geofisica e Vulcanologia – Sezione di Catania

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Mauro Coltelli – senior researcher	INGV - CT	6
Giuseppe Puglisi –senior researcher	INGV - CT	6
Francesco Guglielmino – researcher in charge to the project	INGV - CT	12
Mario Mattia – technical researcher	INGV - CT	1
Biagio Puglisi – qualified technician	INGV - CT	2
Orazio Campisi - qualified technician	INGV - CT	2
Massimo Rossi - qualified technician	INGV - CT	1
Alessandro Bonforte - PhD student	UNICT / INGV-CT	3
Mimmo Palano – PhD student	UNICT / INGV-CT	3
Simona Scollo – fellowship in charge to the project	INGV - CT	5

- 2nd YEAR OBJECTIVES

During the first year the UR co-ordinated the following activities:

- Ground deformation measurements using DInSAR commercial software at Etna (Task 1).
- GPS measurements for atmosphere probing during the ERS1/2 satellite passes (Task 1) and devising algorithms able to evaluate the atmospheric delay related to the azimuth direction and elevation of each GPS satellite (Task 4).

Furthermore, the UR cooperate with other UR to achieve the following activities

- To process and to interpret DInSAR (Task 1, activity 5 and 7)
- Development of the Voldorad-2 (Task 4)
- Measurement of the backscattering properties of volcanic ashes (Task 4)

- 2nd YEAR RESULTS **(max 1 page)**

In the frame of the Task 1, the UR was deeply involved in the set-up of Remote Sensing Laboratory of the Catania Dept. of INGV. The results of the tests of commercial software performed in the previous year, allowed to identify a product ideal for the routinely use in the monitoring system (Atlantis software). It was implemented in the Laboratory and specific training courses was followed by personnel involved in the Laboratory. This software was used to process the data set bought in the previous year by the GNV. In particular all raw data set was converted in SLC format, in order to create an archive for speeding up the processing; this facility is particularly useful for monitoring purposes. Specific analysis were carried out for two relevant periods of Mt. Etna: the July 1998 summit explosive activity and the July-August 2001 eruption. The first results of these processing are in agreement with the available volcanological and geophysical information relevant to the specific volcanic activities. In order to increase the experience of the personnel

involved in the laboratory, data relevant to the January 2001 eruption of Nyiragongo (an other volcano that had volcanic activity in the period of the project), provided in the framework of an ESA project, were processed. Beside the obvious interests from the volcanological point of view (but far from the objective of this project), the importance of this last data set concerns to test the capability of the software to process data in unfavourable environmental conditions (e.g. forested area, etc.). The good results obtained confirm the adequate choice of the software.

Always in the frame of the Task 1 activities, the UR collaborate with other UR involved in the project. In particular, with the POLIMI and IPGP, it investigate the dynamic of the eastern flank of Mt. Etna by using PS technique, with the JPL and IREA, studied the ground deformations measured by InSAR from 1993 to 1995 on Mt. Etna, and with UNICT itis developing an algorithm to invert ground deformation source parameters from interferograms by using SA techniques. With respect to the plan of the activities, the UR cannot continue the experiences in installing target point on the volcano due to the anomalies occurred on ERS2 sensor during the last years.

Within the Task 4 activities we are collaborating with the UR OPGC and UR UNICAL to the development of the prototype of Voldorad-2 for mobile uses and for a permanent remote-controlled station. In particular we support the developing of a new micro-strip antenna that UR UNICAL are building and it location in a shelter at La Montagnola on Mt Etna, including the remote controlled pan/tilt operations and wireless data transmission to INGV in Catania.

After the first study and measure of the electric properties of the volcanic ashes in collaboration with UR UNICAL, we are involved in the backscatter measures of the volcanic ash that UNICAL staff is performing in the anechoic chamber of their Microwave Laboratory. These measures will allow to know backscatter properties of the volcanic ash in a wide range of wavelength using different sets of volcanic particles dispersed in a cylindrical structures of inert material. To this aim we are studying the dispersion of the volcanic particles in both eruptive column and umbrella cloud to define particle's grain-size and density in air at different distance from the vent. A this aim we are running available PDMs (particle dispersal model) and comparing their results with well know deposit of recent Etna's explosive eruptions.

The processing of GPS data relevant to the recent volcanic activity, which produced important and continuous ash clouds, is currently in progress.

- RESEARCH PRODUCTS
  - n° 3 of articles published on international journals
  - n° 3 of articles published on national journals, proceedings, technical reports
  - n° 2 presentations at international meetings
  - n° 2 presentations at national meetings;

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

1. Baldi P., Bonvalot S., Briole P., Coltelli M., Gwinner K., Marsella M., Puglisi G., Rémy D., (2002).Validation and comparison of different techniques for the derivation of digital elevation models and volcanic monitoring(Vulcano island, Italy), International Journal of Remote Sensing, 22, 4783-4800.
2. Coltelli M., Puglisi G., Guglielmino F.,Palano M., Application of Differential Sar Interferometry for studying the eruptive event of 22 July 1998 at Mt. Etna, Quaderni di Geofisica, in press, 2002
3. Dubosclard G., Allard P., Cordesses R., Donnadieu F., Hervier C., Coltelli M., Privitera E., Kornprobst, J., 2002. Doppler radar sounding of volcanic eruption dynamics at Mount Etna. *Bull. Volcanol.*, accepted.
4. Donnadieu F., Dubosclard G., Allard P., Cordesses R., Hervier C, Coltelli M., Lénat J.-F., 2002. Monitoring of Strombolian eruptions of Etna by UHF Doppler radar. Quaderni di Geofisica. (in press).
5. Lundgren, P., P. Berardino, M. Coltelli, G, Fornaro, R. Lanari, G. Puglisi, E. Sansosti, and M. Tesauro, Coupled magma chamber inflation and sector collapse slip observed with syntheic aperture radar interferometry on Mt. Etna volcano, J. Geophys. Res., in press, 2002.
6. Nunnari G., Puglisi G., Guglielmino F., Coltelli M., Modelling Ground Deformations in Volcanic Areas By Using SAR Interferograms, Quaderni di Geofisica, in press, 2002

DEVELOPMENT AND APPLICATION OF REMOTE SENSING METHODS FOR THE MONITORING OF ACTIVE ITALIAN VOLCANOES

Responsible
M.Fabrizia Buongiorno - Senior Researcher
Istituto Nazionale di Geofisica e Vulcanologia, Centro nazionale Terremoti

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Title	From	Months/Person
Buongiorno M.F/ Senior Researcher	INGV-CNT, Roma	6
Lombardo V,/ Researcher	INGV-CNT, Roma	6
Colini L./ Researcher	INGV-CNT, Roma	3
Claudia Spinetti / fellowship in charge to the project	INGV-CNT, Roma	6
Luca Merucci./ Researcher	INGV-CNT, Roma	3
Wooster M./ Researcher	Kings College London	1
David C. Pieri./ Senior Researcher	Jet Propulsion Laboratory	1

- 2nd YEAR OBJECTIVES

Developing Remote Sensing techniques applied to the atmospheric volcanic emissions to retrieve the tropospheric volcanic plume aerosols optical characteristics and gases abundance (Task 5).
Time-series analysis (1984-1993 eruptive events) of data from LANDSAT (series from JPL and GNV), AVHHR, ATSR and validation of the dual band algorithm. Data-fusion of different image datasets to compare the potentialities of distinct sensors in volcano monitoring (Task 3).
ASTER data analysis (Task 3)

2nd YEAR RESULTS **(max 1 page)**

1)Plume optical characteristics and aerosol loading:

Inversion algorithm has been developed and applied to the available Mt. Etna images data set: MIVIS sensor, 'Sicily 1997' MVRRS campaign and '2001 MIVIS mission ' to retrieve the aerosol optical characteristics of the Etna volcanic plume in the visible channels . The 6S (Second Simulation of the Satellite Signal in the Solar Spectrum) radiative transfer model has been used to model the atmosphere parameters for the MIVIS images and to retrieve the volcanic aerosol optical thickness distribution. In order to furnish reliable results the inversion procedure had to take into account the spectral albedo of the surfaces under the plume and the topographic effects on the reflected radiance, due to the surface orientation and elevation. For this purpose a DTM (digital terrain model) was co-registered with the MIVIS images. The spectral reflectances of the ground were estimated both by field spectra-radiometers measurements, made during the 1997 campaign, and by laboratory measurements made on samples collected in the field. The obtained results were compared with the available optical thickness measurements obtained independently during the MVRRS campaigns to validate the developed retrieval algorithm.

2) algorithms to retrieval columnar abundances of gases

The CIBR techniques to calculate water vapour column abundance has been implemented during the 6 months stage of Dr. Spinetti at the "Maison de la Recherche en Environment Naturel" ULCO – CNRS. The technique has been applied to the following data set: Mt. Etna, MIVIS sensor, campagna di misura "MVRSS" 1994, 1997 and AVIRIS 1991; Kilauea Volcano, AVIRIS sensor 2000 campaign.

Is still in progress to applied The CIBR technique to calculate CO2 concentration from remote sensing images in the infrared wavelength range.

3) Development of the FASA project which will fly in 2003 a fourier spectrometer (FTIR) to analyze the gas content of Etna (project partially funded by ASI)

4) Image spectrometer airborne campaign on Mt Etna

On July 29th an airborne campaign equipped with an image spectrometer was performed over Mt. Etna to acquire image data of the eruption. This campaign, funded by the ASI, was organized to permit a simultaneous acquisition with the TERRA , EO-1 and LANDSAT 7 satellites. This multi-sensor acquisition over an active lava flow represented a unique opportunity to study the temperature distribution and at the same time to compare the different sensors capabilities for this type of volcanic events. The preliminary observations of the different data sets enlighten the importance of the data quantification and of the gain setting of the instrument.

Surface temperature analysis was performed on distinct lava flows by using dual-band and triple-band techniques. Hot-cracks fractional area frequency distribution is peculiar for each different lava flow and appears to be related to the topographic slope gradient and to the flux rate of the flows. This means that the monitoring of the lava thermal status may be used as powerful tool for volcanic hazard prediction especially if combined with an detailed study of the topography through Digital Elevation Model analyses.

The airborne high-spatial resolution images allow for the creation of a mathematical and physical model of the temperature distribution. This model must be subsequently tested on satellite data characterized by a lower spatial resolution but a higher time frequency of acquisition.

- RESEARCH PRODUCTS
  - 4 of articles published on international journals
  - 2 of articles published on national journals, proceedings, technical reports
  - presentations at international meetings:

    Abstract and Presentation to the international conference EGS-2002 organized by European Geophysical Society "Natural Hazard" Section (Nizza, Aprile 2002).

    Abstract and Presentation to the international conference " Prof G. Fiocco 70th birthday: an international conference in atmospheric research progress and more", organized by IFA-CNR (Istituto per la Fisica dell'Ambiente) and Physics' Department of Università degli Studi di Roma "La Sapienza" (Roma, Settembre 2001).

  - presentations at national meetings:

    Presentation to the "Journée de rencontre ULCO: la Recherche en Environnement" organized by Universite' du Littoral "Cote d'opale" and Universite' de Scienze et Tecniques de Lille (Wimereux, October 2002).

    Presentation to the Workshop of GNV "Mitigation of volcanic Risk by remote sensing thecniques", organized by INGV Catania Section (Catania, Gennaio 2002).

    "La componente terrestre del sistema terra" organized by the CNR/GOST (Gruppo Osservazione e Studio della Terra)

  - Computation codes:

    IDL program has been developed to invert the MIVIS images applying the alghoritm and to retrieve the aerosols optical thickness spatial distribution.
    Specific script unix and program on IDL and Fortran has been developed to have a procedure to cacluate the water vapour colunnar aboundance including the Modtran radiative transfer code.
    Triple-band technique codes for sub-pixel temperature retrieval ; geometrical correction routine for MIVIS images.

PUBLICATIONS LIST(inclusive of papers in prints and accepted)

- Lombardo V., M.F. Buongiorno, S. Amici (2002), Characterization of a volcanic hot-spot source by means of sub-pixel temperature distribution analysis: a case from the 1996 Mount Etna eruption using airborne imaging spectrometer data, submitted on 31/09/2002 to *Bulletin of Volcanology*
- Lombardo V., M.F. Buongiorno, L. Merucci, D. Pieri (2001), difference in the hot-cracks frequency distribution between Summit and flunk eruptions of Mount Etna lava flows, observed

by Landsat Thematic Mapper, submitted on 18/05/2001 al *Journal of Volcanology and Geothermal Research*

- Lombardo V. , Buongiorno M.F. (2002) Etnean lava flows thermal analysis by using short wavelength infrared data acquired by spaceborne and airborne sensors. *Quaderni di Geofisica*(in press).
- Spinetti C., M.F. Buongiorno, V. Lombardo, and L. Merucci, 2002. Retrieval Aerosol Optical Thickness of Volcanic Plumes by means of the Airborne Multispectral Image Spectrometer (MIVIS): a case study from Mt. Etna Sicily, June 1997. Special issue of *Annali di Geofisica* (in press).
- Spinetti C., M.F. Buongiorno, 2002. Aerosol Optical Characteristics of Volcanic Plume Retrieval by Means of Remote Sensing Techniques: the Case of Mt. Etna Studied Using the MIVIS Airborne Multispectral Image Spectrometer. *Quaderni di Geofisica*(in press).
- Pugnaghi S, Teggi S, Corradini S, Buongiorno MF, Merucci L, Bugliolo MP, (2002) Estimation of SO2 abundance in the eruption plume of Mt. Etna using two MIVIS thermal infrared channels: A case study from the Sicily 1997 Campaign. *Bulletin of Volcanology*, 64, 328-337.

DEVELOPMENT AND APPLICATION OF REMOTE SENSING METHODS FOR THE MONITORING OF ACTIVE ITALIAN VOLCANOES

RU Responsible
Pierre Briole - Researcher
Institut de Physique du Globe de Paris (IPGP)

ACTIVITY REPORT – 2nd YEAR

RU PARTICIPANTS

Name - Position	Affiliation	man/month
Pierre Briole – researcher	IPGP	2
Yvan Trembley – Engineer	IPGP	0.5
Nicolas Houlié – PhD student partially in charge to the project	IPGP	7
Yvan Trembley – Engineer	IPGP	0.5

- **2nd YEAR OBJECTIVES**

The objective planned of the second year was to pass from analytic to numeric models.

- **2nd YEAR RESULTS (max 1 page)**
  - methodologies : the general methodology is still to progressively introduce complexity in the modelling models (data permitting).
  - data acquisition : no data was acquired by RU IPGP in 2002
  - data processing and interpretation : the data used for modelling are the same interferograms that were used in the previous years. They mostly concern the periods 1992-93 and 1995-1999. More recent interferograms corresponding to the July 2001 eruption exist. RU IPGP has not directly been working on them yet, but the software code developed by RU IPGP in 2002 aims at a better introduction of the topography in the analytic (forward and inverse) modelling of those interferograms. Refinement of simple codes assuming flat topography is indeed mandatory in the case of eruption occurring close to large slopes, as it has been the case in July 2001 at Etna (vicinity of the Valle del Bove). With respect to using a flat surface, the introduction of the topography allows to better infer the tilt of the dykes. The models without topography often suggest non vertical dykes (with dip angle typically of 65-75%), where models with topography can more easily predict quasi vertical dykes. In the case of the July 2001 eruption, the model proposed by P. Lundgren (fall AGU 2002) suggests that there could be two feeding dykes for the eruption with opposite orientations, instead of only one as commonly assumed. Because several researchers think that the two-dykes model is hardly supported by the current knowledge of the structure of Etna, we decided to study in more detail the effects of the topography on the predicted surface motions on Etna. Several works already exist on that problem, and we currently work on the adaptation of this to Etna. The planned work for the next work is to finalise this study. Therefore, the passage to numeric models (initially planned for 2002) will start in 2003.
  - others :

- RESEARCH PRODUCTS
  - n° of articles published on national journals, proceedings, technical reports: 1
  - invited papers and talks: 1 (a)
  - presentations at international meetings: 1
  - computation codes : 1 (b)

[b] Briole P., Applications of SAR interferometry in volcano monitoring, Symposium “New Technologies for Land Monitoring: from Digital Elevation Models to Subsidence Estimation”, Florence 2002, 64th EAGE (European Association of Geoscientists and Engineers) Annual Conference, Florence 27 - 30 May 2002. Invited talk.
[c] inverse6.f: fortran code to invert geodetic data in areas with topography, presently under development within the project team.

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Chaabane F., A. Avallone, F. Tupin, P. Briole, E Trouvé, J.M. Nicolas and H. Maître, Improvement of the tropospheric correction by adapted phase filtering, Proceedings of the European Conference on Synthetic Aperture Radar, Cologne, Germany, 4-6 June 2002.

DEVELOPMENT AND APPLICATION OF REMOTE SENSING METHODS FOR THE MONITORING OF ACTIVE ITALIAN VOLCANOES

RU Responsible
Riccardo Lanari – Senior Researcher
CNR IREA, Napoli

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Riccardo Lanari - Senior Researcher	CNR IREA	4
Paolo Berardino - Researcher	CNR IREA	3
Eugenio Sansosti - Researcher	CNR IREA	2
Gianfranco Fornaro - Senior Researcher	CNR IREA	1
Simone Guarino - Technician	CNR IREA	2

- 2nd YEAR OBJECTIVES

Reference Task: Task 1

Support to the Ground deformations surveying by DInSAR techniques on Campi Flegrei with commercial software (participation)

Interferometric algorithm development and validation experiments on real data relevant to Campi Flegrei (coordination); in this context, the developed interferomtric approach has been also applied to investigate Mt. Vesuvius and Mt. Etna deformations

- 2nd YEAR RESULTS **(max 1 page)**

The activities carried out by the IREA research unit have been focused on the generation of displacement maps and deformation time series via a differential SAR interferometry (DIFSAR) approach; in particular, we have applied a new DIFSAR algorithm, recently proposed in (1), which is based on an appropriate combination of interferograms produced by subsequently acquired data sets. Key points of the applied technique are the following:

- the data pairs used to generate the interferograms are characterized by a small spatial separation between the orbits (baseline) in order to limit both spatial decorrelation and topography;
- the application of the Singular Value Decomposition (SVD) method allows to “link” independent SAR acquisition data sets, separated by large baselines, thus increasing the number of data available for the analysis of an area of interest.

As consequence, we can produce spatially dense deformation maps and, at the same time, deformation time-series for each investigate pixel of the imaged scene; this allows to detect and follow the temporal evolution of the surface displacements in the analyzed zone. We further remark that the availability of both spatial and temporal information is crucial to identify and filter atmospheric phase artifacts which can be present in the interferograms (due to changes of the atmospheric conditions between the acquisitions) and that represent a key limitation of the conventional DIFSAR approach.

The above mentioned approach has been successfully applied to investigate the deformations affecting, in time interval 1992/2000, the Somma/Vesuvious volcano complex (2) and the Campi Flegrei Caldera (3-4); in particular, in the latter case, we have compared the DIFSAR results obtained form the ERS-2 acquisitions with the continuous GPS measurements (projected on the radar line of site) provided by the Osservatorio Vesuviano researchers and available in the year

2000. These results, achieved via the collaboration with the Osservatorio Vesuviano, show a very good agreement between the DIFSAR and the GPS measurements (3). In addition to the above mentioned actions two more research activities are in progress. In particular the IREA group is collaborating on the modeling activities relevant to the Campi Flegrei caldera and the Mount Etna volcanic systems (5). For what concerns the Campi Flegrei area two complete data sets have been already processed, which are related to ascending and descending tracks of the ERS-1 and ERS-2 sensors; preliminary results of the inversions on descending data have already been presented in (4). For what concerns the Mt. Etna test site, an entire data set of ERS data acquired on ascending orbits have already been processed and the interpretation and modeling of the data is in progress.

- RESEARCH PRODUCTS
  - 5 papers submitted/published on international journals (see publications list)
  - Computation codes

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

(1) Berardino P., G. Fornaro, R. Lanari, E. Sansosti, "A new Algorithm for Surface Deformation Monitoring based on Small Baseline Differential SAR Interferograms ", in stampa su *IEEE Transactions on Geoscience and Remote Sensing*, pag. 000-000, Dicembre 2002.

(2) R. Lanari, G. De Natale, P. Berardino, E. Sansosti, G. P. Ricciardi, S. Borgstrom, P. Capuano, F. Pingue, C. Troise, "Evidence for a peculiar style of ground deformation inferred at Vesuvius volcano", *Geophysical Research Letters*, vol. 29, n.9, 2002.

(3) Berardino P., Borgstrom S., Del Gaudio C., De Martino P., Fornaro G., Guarino S., Lanari R., Ricciardi G.P., Sansosti E. "*Geodetic/SAR monitoring of Campi Flegrei caldera: the 2000 uplift event*", Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, *Quaderni di Geofisica* in print.

(4) Lanari R., Berardino P., Borgstrom S., Del Gaudio C., De Martino P., Fornaro G., Guarino S., Ricciardi G.P., Sansosti E., Lundgren P,*"The use of IFSAR and classical geodetic techniques in civil protection scenarios: Application to the Campi Flegrei uplift event of 2000*", submitted to *Journal of Volcanology and Geothermal Research.*

(5) Lundgren P., Berardino P., Coltelli M., Fornaro G., Lanari R., Puglisi G., Sansosti E., Tesauro M., "*Report on observations and modeling of coupled magma chamber inflation and flank motion on Mt Etna volcano"*, Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, *Quaderni di Geofisica* in print.

DEVELOPMENT AND APPLICATION OF REMOTE SENSING METHODS FOR THE MONITORING OF ACTIVE ITALIAN VOLCANOES

RU Responsible
Name-Position: Dr. Paul Lundgren, Research Scientist
Affiliation: Jet Propulsion Laboratory, California Institute of Technology

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Paul Lundgren- Researcher	JPL	2

- 2nd YEAR OBJECTIVES

The objectives of the RU continue to be the processing of ERS SAR data to understand the sources of deformation of Mt. Etna through source deformation models. One of the primary objectives was to get additional ERS data to complete the ERS record for SAR data covering the entire time of ERS data acquisitions (1992-2001). By doing so our objective was to develop a nearly complete time series of deformation for 1992-2001 and to study the 2001 flank eruption.

- 2nd YEAR RESULTS **(max 1 page)**

- To that end we acquired 80 additional ERS SAR raw data images for the 1992-2001 time period.
- We computed a preliminary InSAR time series for 1992-2000 (see animation of surface deformation at the ESA website: http//www.projects.esa-ao.org/bin/nav/results/
- We developed a preliminary source model for the 2001 flank eruption of Mt. Etna that shows how the volcano spread symmetrically over shallowly dipping normal faults (Lundgren and Rosen, Geophys. Res. Lett., submitted, 2002)
- We used the time series inversion algorithm of Lundgren et al. [2001] and Berardino et al. [2002] to solve for the time series of interferograms for 1992-2000.
- The InSAR processing was computed using the ROI_PAC software developed at JPL.
- Modeling of the 2001 flank eruption was done through forward modeling of the sources using both analytic and finite element solutions.

- RESEARCH PRODUCTS
  - One presentations at national meetings: "A new mode of volcanic dike-fault interaction observed with SAR interferometry for the 2001 flank eruption of Mt. Etna", by P. Lundgren, EOS Trans. Am. Geophys. Un., AGU Fall Meeting, 2002.

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Lundgren, P., P. Berardino, M. Coltelli, G, Fornaro, R. Lanari, G. Puglisi, E. Sansosti, and M. Tesauro, Coupled magma chamber inflation and sector collapse slip observed with syntheic aperture radar interferometry on Mt. Etna volcano, *J. Geophys. Res.*, in press, 2002.

Lundgren P. and Rosen P. Source model for the 2001 flank eruption of Mt. Etna volcano", submitted to Geophys. Res. Lett

Lundgren P., Berardino P., Coltelli M., Fornaro G., Lanari R., Puglisi G., Sansosti E., Tesauro M., Report on observations and modeling of coupled magma chamber inflation and flank motion on mt. etna volcano. Proceedings of the Mid Term Meeting of the GNV Project on Remote Sensing, Catania, 24-25 January 2002, Quaderni di Geofisica, in press.

DEVELOPMENT AND APPLICATION OF REMOTE SENSING METHODS FOR THE MONITORING OF ACTIVE ITALIAN VOLCANOES

RU Responsible:
Name-Position : **Frank Donnadieu** Physicien adjoint OPGC
Affiliation : Observatoire de Physique du Globe de Clermont-Ferrand (OPGC)
Université Blaise Pascal, Campus des Cézeaux
24 avenue des Landais
63177 Aubière, FRANCE

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
F. Donnadieu, researcher (Physicien adjoint)	OPGP	
R. Cordesses, Engineer	OPGC	

- 2nd YEAR OBJECTIVES
  Continuation of the radar construction.

- 2nd YEAR RESULTS **(max 1 page)**
  - Data acquisition

  The construction of the radar is on its way but has been interrupted when funds of the 1st year ran out. The major part of the receiver has been built and tested and the low level part of the transmitter built too.
  - Data processing and interpretation

  Efforts have been made to improve the data processing programs (going with the radar) in order to retrieve and visualize easily velocity and power values as a function of time.

  - **Other comments**:

  The initial budget asked for the radar construction (after the 30% cost reduction imposed by the GNV in April 2000) was 94 Mlires (52 for 1st year + 21 for 2d year +21 for 3d year) and was accepted as so. Then, we had a significant reduction of the radar construction funding (49 ML for 1st year + 16 ML for 2d year + ??? for 3d year). As the radar construction cost has not obviously decreased, we will need a significant increase of the 3d year funding (with respect to the 2d year amount) in order to achieve the radar construction. Moreover, due to the delay of the 2d year funds transfer, we had to stop the radar construction and, meanwhile, some electronic components had their price increased by as much as 30%. Accordingly, the amount necessary to complete the radar construction during **the 3d year is estimated as 14500 euros**. This amount would bring the total funding of the radar to the initial (incompressible) budget asked to the GNV. Note that no budget is included anymore in the amount asked for the last year.

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

7. Donnadieu F., Dubosclard G., Allard P., Cordesses R., Hervier C, Lénat J.-F., 2002. Sondages des jets volcaniques par radar Doppler : applications à l'Etna. Rapport quadriennal 1999-2003, *XXIII Ass. Gén. C.N.F.G.G.*, Sapporo, Japon. *Submitted*.
8. Donnadieu F., Dubosclard G., Allard P., Cordesses R., Hervier C, Coltelli M., Lénat J.-F., 2002. Monitoring of Strombolian eruptions of Etna by UHF Doppler radar. *Quaderni di Geofisica. (in press)*.

9. Dubosclard G., Allard P., Cordesses R., Donnadieu F., Hervier C., Coltelli M., Privitera E., Kornprobst, J., 2002. Doppler radar sounding of volcanic eruption dynamics at Mount Etna. *Bull. Volcanol*., accepted.
10. Dubosclard, G., R. Cordesses, P. Allard, C. Hervier, M. Coltelli and J. Kornprobst, First testing of a volcano Doppler radar (Voldorad) at Mount Etna, Italy, *Geophys. Res. Lett*., 26, 3389-3392, 1999.

Communications in international meetings:

1. *Donnadieu F., Dubosclard G., Cordesses R., Allard P., Hervier C, Lénat J.-F., Kornprobst J., 2002. Sondage des éruptions volcaniques explosives par radar Doppler (Voldorad).* Journée scientifique de la C.R.V., *Clermont-Ferrand, p.30.*
2. Donnadieu F., Dubosclard G., Cordesses R., Allard P., 2002. Dynamique des gaz volcaniques lors des éruptions explosives : investigations par radar Doppler. Réunion spécialisée *Section Volcanol. Soc. Géol. France*, Paris, p.34.
3. *Donnadieu F., Dubosclard G., Allard P., Cordesses R., Hervier C, Lénat J.-F., Coltelli M., Privitera E., Kornprobst J., 2001. Doppler radar sounding of volcanic eruption dynamics: a possible application to dust plumes,* IAVCEI General Assembly*, Martinique.*
4. *Dubosclard G., Donnadieu F., P. Allard, R. Cordesses, C. Hervier, J. Kornprobst, J.-F. Lénat, M. Coltelli, E. Privitera, 2001. Doppler radar sounding of volcanic eruption dynamics at Mount Etna,* AGU Fall meeting*, San Fransisco, p.1367.*
5. *G. Dubosclard, R. Cordesses, P. Allard, C. Hervier, F . Donnadieu, 2001. Doppler radar recording of eruption dynamics at Etna.* Assemblea 1° Anno del GNV, *Roma, p.127-128.*

DEVELOPMENT AND APPLICATION OF REMOTE SENSING METHODS FOR THE MONITORING OF ACTIVE ITALIAN VOLCANOES

RU Responsible
Dr. Sven Borgstrom - Graduated Technician
Istituto Nazionale di Geofisica e Vulcanologia - Osservatorio Vesuviano, Naples - Italy

ACTIVITY REPORT - 2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	Man/month
Dr. S. Borgstrom - Graduated Technician	I.N.G.V. - O.V.	8
Dr. G. P. Ricciardi - Researcher	I.N.G.V. - O.V.	3
Dr. C. Del Gaudio - Researcher	I.N.G.V. - O.V.	2
Dr. C. Ricco - Researcher	I.N.G.V. - O.V.	2
Dr. V. Sepe - Researcher	I.N.G.V. - O.V.	2
Dr. P. De Martino - Graduated Technician	I.N.G.V. - O.V.	2

2nd YEAR OBJECTIVES

Reference Task:

Task 1;

Ground deformations surveying by DInSAR techniques on Campi Flegrei with commercial software (participating Research Unit);

Carrying out of validation experiments on real data relevant to Campi Flegrei for the unwrapping algorithm produced in the project (participating Research Unit).

2nd YEAR RESULTS

During the second year of activity also the interferometric modulus (InSAR of Atlantis Scientific Inc.) has been acquired, in addition to the raw data focusing modulus already bought during the first year (APP, of the same company). The modulus for Envisat data processing will be taken in a short time. The software acquisition period lasted two years, depending on the high costs of each single modulus and, consequently, on the difficulties to get money for purchase.

At present the focusing modulus has been successfully tested on a series of ERS1/2 raw data (from both ascending and descending orbits) acquired in the frame of a CAT-1 project on the Neapolitan volcanic area. Recently, also a test phase on focused data began using the interferometric modulus, in order to produce interferograms and deformation maps.

For Envisat data processing, besides the above mentioned modulus, the use of a scientific software is planned, developed in the frame of another project (DUP, Data User Program from ESA) on Linux platform. With regard to this project, the acquisition of Envisat data is also foreseen, in addition to new CAT-1 data that will be likely requested.

During the second year of activity, a strict validation on phase unwrapping algorithms developed at IREA-CNR has been carried out, comparing interferometric data from descending orbits (time-series from June, 1992 to February, 2001, Berardino et al., 2001 and 2002) with the data from the geodetic networks of the INGV-Osservatorio Vesuviano in Campi Flegrei area. The considered data

are those related to the period from March to August, 2000, during which an uplift event of a few centimetres took place.
In order to eliminate the discrepancies due to the different components of ground deformation measured by the different techniques, GPS data have been projected into the radar line of sight, using as a reference point for both the techniques a stable site of Campi Flegrei located outside the maximum deformation area. The differences in the final results are in the order of a few millimetres. Purely qualitative comparisons with levelling data have been also carried out, indicating a good agreement between the two techniques.
A comparison between interferometric and classical geodetic data has been also carried out for Vesuvio area.
From a methodological point of view, it is important to highlight that the main limitations toward achieving a more precise comparison between interferometric and geodetic data recorded by monitoring networks are due to both the poorer *temporal* sampling of the complete "periodical" networks (i.e. levelling and GPS), and the poor *spatial* coverage of the "continuous" GPS sites versus the space-temporal coverage of SAR data, available only in the radar line of sight. The availability, in a next future, of deformation maps from also ascending interferograms should reduce such a discrepancy. This will allow also a better definition of the deformation field acting in the Neapolitan volcanic area and, more specifically, in Campi Flegrei area, characterized by continuous ground motions.

RESEARCH PRODUCTS

- 1 article published on an international journal *(Geophysical Research Letters, 2002);*
- 1 article published on the proceedings of an international meeting *(IGARSS 2002);*
- 2 articles published on the proceedings of a national meeting *(ASITA 2002);*
- 1 article in print on the proceedings of the mid term meeting of the triennial GNV project on remote sensing;
- 1 article in print on the proceedings of an international meeting *(EARSeL 2002);*
- 1 article submitted to an international journal *(Journal of Volcanology and Geothermal Research);*
- 2 presentations at international meetings *(IGARSS 2002, EARSeL 2002);*
- 2 presentations at national meetings *(ASITA 2002);*
- 1 presentation at the mid term meeting of the triennial GNV project on remote sensing.

PUBLICATIONS LIST

1) Lanari R., De Natale G., Berardino P., Sansosti E., Ricciardi G.P., Borgstrom S., Capuano P., Pingue F., Troise C. Evidence for a peculiar style of ground deformation inferred at Vesuvius volcano. *Geophysical Research Letters, Vol. 29, No. 9, 10.1029/2001GL014571, 2002.*
2) Berardino P., Bequignon J., Borgstrom S., De Natale G., Capuano P., Fornaro G., Lanari R., Pingue F., Ricciardi G.P., Sansosti E., Troise C. Evidence for a peculiar style of ground deformation at Vesuvius volcano revealed by 10 years of ERS mission. *Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS),* Toronto (Canada), 24-28 June 2002, **VI**: 3614-3616.
3) Berardino P., Borgstrom S., Cecere G., Del Gaudio C., De Martino P., Fornaro G., Lanari R., Ricciardi G.P., Ricco C., Sansosti E., Sepe V., Siniscalchi V. Un approccio multimetodologico per il controllo delle deformazioni nell'area flegrea. *Proceedings of the 6th National Conference of ASITA,* Perugia, 5-8 November 2002, **1**: 409-416.
4) Pingue F., Berrino G., Capuano P., Del Gaudio C., Obrizzo F., Ricciardi G.P., Ricco C., Sepe V., Borgstrom S., Cecere G., De Martino P., D'Errico V., La Rocca A., Malaspina S., Pinto S., Russo A., Serio C., Siniscalchi V., Tammaro U., Aquino I. Sistema integrato di monitoraggio geodetico dell'area vulcanica attiva napoletana: reti permanenti e rilevamenti

periodici. *Proceedings of the 6th National Conference of ASITA,* Perugia, 5-8 November 2002, **2:** 1751-1764.

5) Berardino P., Borgstrom S., Del Gaudio C., De Martino P., Fornaro G., Guarino S., Lanari R., Ricciardi G.P., Sansosti E. Geodetic/SAR monitoring of Campi Flegrei caldera: the 2000 uplift event. *Proceedings of the Mid Term Meeting of the Triennial GNV Project on Remote Sensing,* Catania, 24-25 January 2002, in print on Quaderni di Geofisica.

6) Lanari R., Berardino P., Sansosti E., Fornaro G., De Natale G., Ricciardi G.P., Borgstrom S., Capuano P., Pingue F., Troise C., Bequignon J. Deformation of Vesuvius revealed by 10 years of ERS mission. *Proceedings of the 22nd EARSeL (European Association of Remote Sensing Laboratories) Symposium,* Prague (Czech Republic), 4-6 June 2002, in print.

7) Lanari R., Berardino P., Borgstrom S., Del Gaudio C., De Martino P., Fornaro G., Guarino S., Ricciardi G.P., Sansosti E., Lundgren P. The use of IFSAR and classical geodetic techniques in civil protection scenarios: Application to the Campi Flegrei uplift event of 2000. *Submitted to Journal of Volcanology and Geothermal Research.*

DEVELOPMENT AND APPLICATION OF REMOTE SENSING METHODS FOR THE MONITORING OF ACTIVE ITALIAN VOLCANOES

RU Responsible
Claudio Prati – Full professor
POLIMI – Dipartimento di Elettronica e Informazione (DEI)

ACTIVITY REPORT –2° YEAR

UR PARTICIPANTS

Name-Position	Affiliation	man/month
Claudio Prati – Full professor	POLIMI/DEI	2
Fabio Rocca – Full professor	POLIMI/DEI	2
Carlo Colesanti – PhD student	POLIMI/DEI	3

- II YEAR OBJECTIVES

Use of the Permanent Scatterers Technique developed and patented by POLIMI in order to identify surface deformation of Mt. Etna during the time period covered by ERS-1 and ERS-2 SAR observations.

- II YEAR RESULTS

The PST has been used to monitor Mt. Etna deformations during the 5 years period of relative low volcanic activity from April 1995 to December 2000. 40 ERS images have been used with normal baselines ranging from -1056 to +1109 meters with respect to the reference orbit.

The following steps have been carried out:

1 - Isolated targets that maintain their coherence during the monitoring time interval (Permanent Scatterers) have been identified from a statistical analysis of the 40 complex ERS SAR images

2 - The relative elevation of the PSs has been measured with accuracy better than 1 meter thanks to the large baseline dispersion. As a consequence no reference DEM has been used.

3 - Finally, isolated target motion and atmospheric artifacts have been separated by means of a joint space-time data analysis.

The quality of the information of this data set is shown in the following examples. In figure 1 two profiles AA' and BB' crossing the eastern flank of Mt. Etna from South to North are shown. Figures 2 and 3 show the average Line of Sight velocity of more than 300 PS identified along the two profiles AA' and BB'. The accuracy of the velocity values (computed independently one from the other) can be appreciated from these plots where the vertical scale is expressed in millimeters per year. From a geophysical point of view, these plots clearly show the presence of many active faults splitting the Etna eastern flank in blocks with different slipping velocities. The PS results are currently object of analysis by volcalogists in Catania (GNV) and Paris (IPGP).

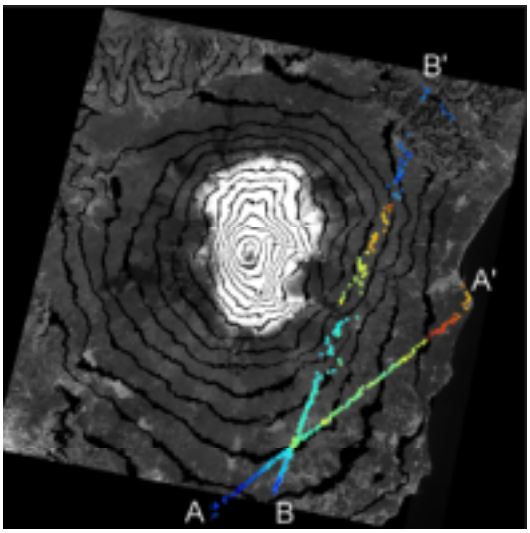

Figure 1: Profiles AA' and BB' crossing the eastern flank of Mt. Etna from South to North along which the average PS velocity has been computed.

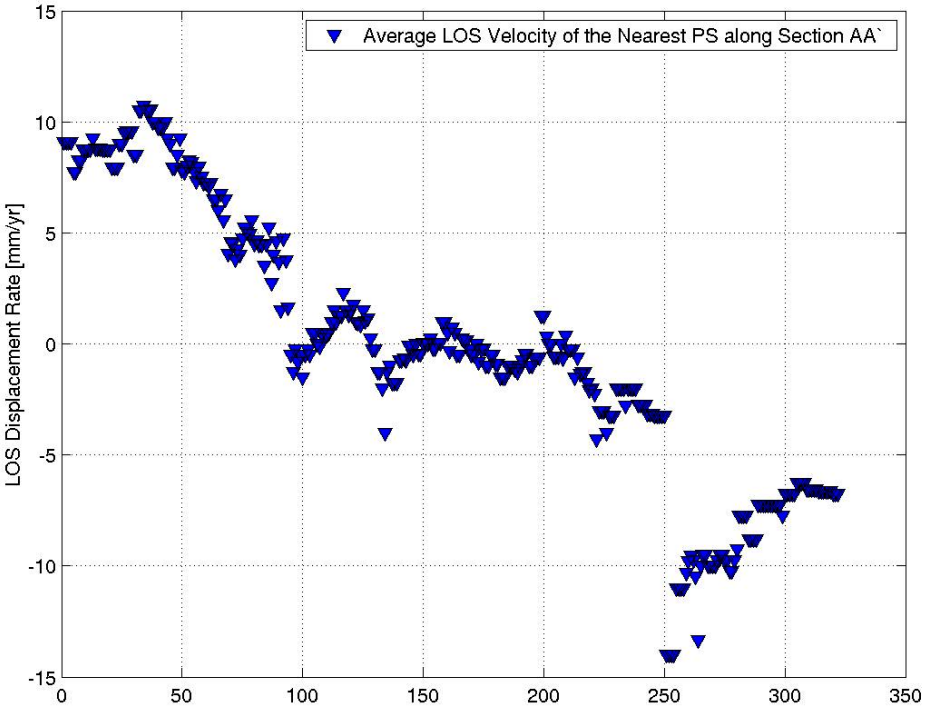

Figure 2: Average LOS PS velocities along the profile AA'. The dispersion of LOS velocities is in the order of 1 mm/year; no averaging of neighboring PS has been carried out. The effects of the non uniform distribution of the PS along the transept contribute to the residual dispersion. Rapid ground velocity variations identify several active faults.

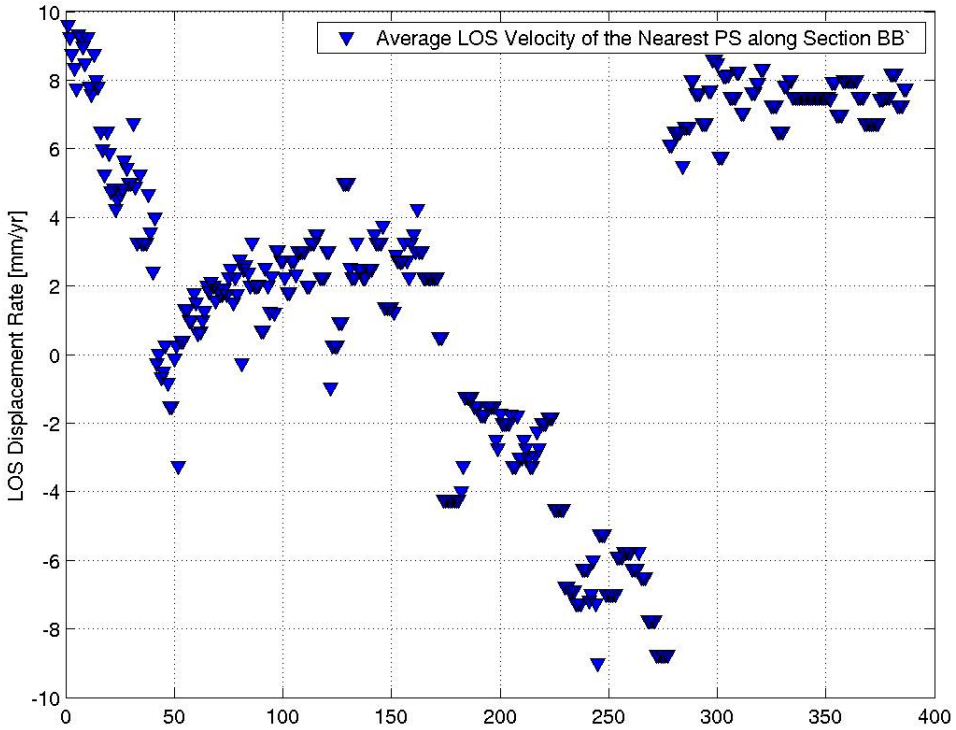

Figure 3: Average LOS PS velocities along the profile BB'. The large ground velocity variation on the right part of the profile corresponds to the slipping of the Pernicana fault. The dispersion of LOS velocities along the profile BB' looks higher than in profile AA'. This is just a visual impression connected to the position of the PS as clearly shown in figure 1; again, no averaging of neighboring PS has been carried out.

PUBLICATIONS

Alessandro Ferretti, Davide Colombo, Giuliano Savio, Claudio Prati, Fabio Rocca:" ***Monitoring the surface deformation of Mt. Etna with ERS-SAR images",*** Proceedings of the GNV meeting Catania, 24-25 January 2002, in press, 2002.

DEVELOPMENT AND APPLICATION OF REMOTE SENSING METHODS FOR THE MONITORING OF ACTIVE VOLCANOES

RU Responsible
Paolo Baldi - Full Professor
Università degli Studi di Bologna – Dipartimento di Fisica

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Anzide Marco - Senior Researcher	INGV(Roma)	0.5
Casula Giuseppe - Researcher	INGV(Bologna)	0.5
Serpelloni Enrico - Researcher	INGV(Bologna)	0.5
Fabris Massimo - Researcher	Univ. di Padova	3.0
Mora Paolo - Technician	Univ. di Bologna	1,0
Loddo Fabiana - Fellowship	Univ. di Bologna	0.5
Bacchetti Massimo - Technician	Univ. di Bologna	1,0

- 2nd YEAR OBJECTIVES

-Set up of methodologies for acquisition and processing of the GPS data for Ground and Aerial Control.
-Digital PhotogrammetryProcessing
-Differential Digital Photogrammety (DDP) (Vulcano and Stromboli)
-Extraction and Comparisons of SAR DTM
-DTM Validation
-Validation of morphological variation maps

- 2nd YEAR RESULTS **(max 1 page)**

Data processing and interpretatiom:
Updating of the laboratory for digital photogrammetry processing, activated in Bologna in 2001: installation of the latest version of Helawa software, O.S. upgrade, RAM and Hard Disk expansion.

The photos of the 2001 photogrammetric survey (1:5000 scale) of the Stromboli island have been digitized at 1000dpi; using the image automatic correlation module, a 5 m grid DEM of the Island has been generated, together with the ortophoto.

Comparisons between DEMs derived from 1993, 1996 and 2001 photogrammetric flights on Vulcano island have been performed, using also coordinates of natural points measured on the models. Least square surface matching procedure has been tested in order to obtain the registration of different (multitemporal) sets of 3D coordinates of the same area, by the detection of the parameters for a rigid transformation in a common reference system of the data sets, without the aid of control points.

- RESEARCH PRODUCTS
  - n° of articles published on international journals: 2
  - n° of articles published on national journals, proceedings, technical reports:3
  - presentations at international meetings:1
  - presentations at national meetings:2
  - Data bases : DEM of Vulcano ; DEM of Stromboli

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Achilli V., Baldi P., Fabris M., Marsella M., Monticelli R., Salemi G., (2002) Application Of Digital Elevation Model To Volcanology , Quaderni di Geofisica , in press.

Baldi P., Marsella M., Signoretto V. (2002) Analysis of High Resolution Digital Elevation Models for Morphometric Parameters Extraction and Classification, Quaderni di Geofisica, in press.

Baldi P., Bonvalot S., Briole P., Coltelli M., Gwinner K., Marsella M., Puglisi G., Rémy D., (2002).Validation and comparison of different techniques for the derivation of digital elevation models and volcanic monitoring(Vulcano island, Italy), International Journal of Remote Sensing, 22, 4783-4800.

Riguzzi F., Anzidei M., Baldi P., Casula G., Galvani A., Pesci A., Pietrantonio G. (2002): Rilievi GPS per il controllo delle deformazioni nell'area dei Colli Albani (Roma). *Atti della 6° Conferenza Nazionale ASITA: Geomatica per l'ambiente, il territorio e il patrimonio culturale*, 5-8 Novembre 2001, Perugia, 1797-1802.

Mora P., Baldi P., Casula G., , Fabris M., Ghirotti M., Mazzini E., Pesci A., (2003). Monitoring landslide movements using GPS and Digital Photogrammetry. Engineering Geology (in press).

DEVELOPMENT AND APPLICATION OF REMOTE SENSING TECHNIQUES FOR THE MONITORING OF ITALIAN ACTIVE VOLCANOS

RU Responsible:
Name-Position: Giuseppe Di Massa - Full Professor
Affiliation: Dipartimento di Elettronica, Informatica e Sistemistica, Università della Calabria, Rende (CS)

ACTIVITY REPORT –2° YEAR

UR PARTICIPANTS

Name-Position	Affiliation	man/month
Giuseppe Di Massa- Full Professor	D.E.I.S – Università della Calabria	
Giandomenico Amendola – Associate Professor	D.E.I.S – Università della Calabria	
Giovanni Angiulli - Researcher	D.I.M.E.T – Università di Reggio Calabria	
Sandra Costanzo – Researcher	D.E.I.S – Università della Calabria	
Francesca Venneri – PhD	D.E.I.S – Università della Calabria	
Luigi Boccia – PhD	D.E.I.S – Università della Calabria	

- I YEAR OBJECTIVES

  Development of complex models for the simulation and measurement of the field scattered by volcanic ash.
  Laboratory and in-situ Scatterometer Calibration.

- II YEAR RESULTS

The research activity of the second year has been addressed to two principal tasks:

1. Laboratory and in-situ Scatterometer Calibration (Objective 1.3.II.b).
2. Development of complex models for the simulation and measurement of the field scattered by volcanic ash (Objective 1.3.II.a).

Concerning the first task, backscattering measurements on controlled environments have been used for calibrating the scatterometer, and results have been compared with simple electromagnetic models on homogeneous material with known dielectric properties.
In order to characterize the scattering properties of volcanic materials, a cylindrical structure has been realized to encapsulate volcanic particles of selected size. Material of dielectric properties similar to vacuum has been used for the cylinder. Scattering measurements have been performed into the anechoic chamber of the Microwave Laboratory for different frequencies on the X-band. Experimental results have been validated by a simple model of electromagnetic scattering by dielectric particles of known properties.
The research activity has been also addressed to the design of a microstrip antenna array for VOLDORAD, a medium-power UHF Doppler radar specially designed for remote sounding of explosive volcanic eruptions. The correct operation of the radar as well as its target sensitivity depend both on the beam shape and on the matching properties of the antenna used to transmit and receive the radar power. In order to satisfy the prescribed requirements, a radiation pattern with a total beamwidth equal to 9 degrees has been imposed in both planes. Two configurations have been

proposed for the array, working at a center frequency f = 1274 MHz. The first configuration uses an array of 8x8 aperture coupled patches, while the second consists of an array of shorted anular patch antennas. This latter solution presents the same appealing features of standard patches in terms of size, weight and cost but, in addition, it offers the possibility to control the radiation pattern by varying the inner and outer radii of the ring. As a further characteristic, the proposed array can be designed to avoid surface wave emission, so reducing the mutual coupling effects between elements and increasing the overall antenna efficiency.

- RESEARCH PRODUCTS
  A numerical code has been developed to compute the field scattered by volcanic particles assumed as dielectric spheres of assigned radius. Permittivity values obtained during the activity of the first year have been included in the model. Research activity results have been collected into a paper entitled "Electromagnetic characterization of volcanic ash", authors S. Costanzo and G. Di Massa, which is part of the Proceedings of the GNV Project Meeting: "*Development and application of remote sensing methods for the monitoring of active Italian volcanoes*".

PUBLICATIONS LIST

1. S. Costanzo, G. Di Massa **Electromagnetic Characterization of Volcanic Ash** Quaderni di Geofisica 2002 (in press).
2. S. Costanzo, G. Di Massa, ***"An Integrated Probe for Phaseless Near-Field Measurements ",*** Measurements, vol.31, pp.123-129, 2002.
3. F. Venneri, S. Costanzo, G. Di Massa, G. Angiulli, ***"Investigation of Printed Reflectarrays as Permanent Scatterers in SAR Interferometry ",*** Microwave & Optical Technology Letters, to be published in April 2003.

Communications in international and national meetings:

4. S. Costanzo, G. Di Massa, M. D. Migliore, "***A X-band Probe for Phaseless Near-Field Measurements*** ", IEEE AP-S Intern. Symposium, June 16-21, 2002 – San Antonio (Texas).
5. S. Costanzo, G. Di Massa, "***Improved Spectral Iteration Technique for solution of first kind integral equations in diffraction problems*** ", SIMAI 2002 , VI Congresso Nazionale della Società Italiana di Matematica Applicata e Industriale , May 27-31, 2002, Chia (Cagliari), Italy.
6. S. Costanzo, G. Di Massa, M. D. Migliore, ***"Un sensore in banda X per misure di sola intensità in campo vicino"***, XIV RiNEm, September 16-19, 2002 – Ancona, Italy.
7. S. Costanzo, G. Di Massa, ***"Near-Field Phase Retrieval from Intensity-Only Measurements on a Cylindrical Helix",*** JINA 2002, Journées Internationales de Nice sur les Antennes, Nice (France),

DEVELOPMENT AND APPLICATION OF REMOTE SENSING TECHNIQUES FOR THE MONITORING OF ITALIAN ACTIVE VOLCANOS

RU Responsible
Giuseppe Nunnari- Full Professor
Dipartimento di Ingegneria Elettrica, Elettronica e dei Sistemi, University of Catania

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Giuseppe Nunnari Full Professor	DEES – University of Catania	2
Saraceno Salvatore External research collaborator	DEES – University of Catania	6
Bosco Salvatore External research collaborator	DEES – University of Catania	2
Accetta Fabio External research collaborator	DEES – University of Catania	2

- 2nd YEAR OBJECTIVES

To develop a tool for synthetic generation of synthetic SAR interferometric data in volcanic areas and inverse modelling.

- 2nd YEAR RESULTS **(max 1 page)**

During the 2nd year of activity both the direct and inverse modelling problem of interferometric data in volcanic areas were considered. The implementation of tools for the generation of synthetic data (direct modelling) is of capital importance for studying the inverse-modelling problem. The direct modelling was addressed by considering the Okada type source that seems the most realistic to interpret eruptive phenomena in volcanic areas such as the Mt. Etna, where eruptions have their origin in dikes opening from a certain depth toward the surface. The basic expressions considered for solving the direct problem are those provided by Okada, who solved the problem of computing ground deformation generated in a isotropic, homogeneous and elastic half-space. The original formulas were appropriately adapted in the framework of the present project to generate SAR interferograms. Investigations into the structural analysis of the direct mathematical model show that the problem is an extremely non-linear one. Hence, the solution of the inverse modelling was formulated in terms of an optimisation problem and solved by using the Simulated Annealing optimisation approach in order to avoid the problem of local minima.
The experimental framework was formulated as follows. A regular observation grid of 21 by 21 stations, spaced at a distance of 1 Km, covering a region of 20 by 20 Km. The origin of the reference system is centred on the summit volcano area. The inverse model solution for some three hundred models, uniformly chosen in order to represent the whole space of model parameters, were computed. In order to assess the accuracy of the inverse problem solution, appropriate performance indexes were computed (such as the Mean Error, the Mean Absolute Error etc). The results obtained shows that the model parameter are estimated with an average error E% that is lower that 10% in case of free-noise data. In more detail the source coordinates Xa and Xb are obtained with E% lower that 3% while for Zb the average error reaches 7%. The L, W and U3 parameters are estimated with E% around 7% while the Strike and Deep angles are both estimated with E% of about 5%. Moreover, it has been estimated that when the test data are corrupted with a gaussian type noise up to 30%, the coordinates Xa and Xb are obtained with E% lower that 5% while for Zb, L and W the average error reaches about 10%. Finally the Strike and Deep angles are both

estimated with E% of about 15%. The solution of the inversion modelling problem by using a Multi-layer Perceptron neural networks approach was also studied during the 2nd year of activity and the accuracy compared with the SA based one. The results of the comparison, that is still undergoing, will be the object of a future report. Moreover, the robustness of the inverse solution in a more realistic framework, in order to take into accounts the effects of poor quality SAR images, is under testing. To this purpose, the filtering procedure implemented during the 1st year of activity will be considered. Finally the inversion of real SAR interferograms, presumably recorded in the area of Mt. Etna during the most recent eruptive events, will be studied.

- RESEARCH PRODUCTS

Software Codes

Computation codes were implemented to generate SAR Synthetic Interferograms and to solve the inverse modelling problem. The software was coded in MATLAB language.

- PUBLICATIONS LIST

Nunnari G., Puglisi G., Guglielmino F., Coltelli M., Modelling Ground Deformations in Volcanic Areas By Using SAR Interferograms, Quaderni di Geofisica (to appear)

DEVELOPMENT AND APPLICATION OF REMOTE SENSING TECHNIQUES FOR THE MONITORING OF ITALIAN ACTIVE VOLCANOS

RU Responsible
Name-Position: Sergio PUGNAGHI - Researcher
Affiliation: Università di Modena e Reggio Emilia – Dipartimento Ingegneria Materiali e Ambiente

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Sergio PUGNAGHI - Researcher	Università di Modena e Reggio Emilia Dipartimento Ingegneria Materiali e Ambiente	4
Sergio TEGGI - Researcher	Università di Modena e Reggio Emilia Dipartimento Ingegneria Meccanica e Civile	2
Luca LOMBROSO - Technician	Università di Modena e Reggio Emilia Dipartimento Ingegneria Materiali e Ambiente	1
Stefano CORRADINI - PhD Student	Università di Modena e Reggio Emilia Dipartimento Ingegneria Materiali e Ambiente	1

- 2nd YEAR OBJECTIVES
  Application of the procedure to evaluate the SO_2 flux emitted from Mt. Etna using real ASTER data remotely sensed during ground truth measurements.

- 2nd YEAR RESULTS **(max 1 page)**
  - methodologies
    A semi-automatic procedure to invert the radiative transfer equation has been developed. It is based on a series of Look-Up Tables (LUTs) containing the simulations performed using MODTRAN code. Each LUT contains the simulated values of the three atmospheric terms of the radiative transfer equation: atmospheric transmittance, down-welling radiance and up-welling radiance. These tables may be derived only knowing the experimental atmospheric vertical profiles. The simulations performed to compute the values of the atmospheric terms of the LUTs take also into account different plume geometries, different SO_2 abundances and all the possible geometric configurations between the pixel at the surface and the radiometer. In particular three plume geometries: laminar, ground based and ground based with the top at constant altitude and 31 SO_2 abundances in the range 0-15 (g m^{-2}) at steps of 0.5 (g m^{-2}) were considered. The pixel-radiometer geometries incorporate 23 pixel altitudes (1000-3200 m asl, step 100 m) and 9 viewing angles (0-40 degrees, at steps of 5 degrees). The *LUT-procedure* determines the SO_2 abundance at each pixel performing the following steps. 1) A spectral emissivity map is obtained from the image itself using SNM (Spectrum Normalization Method; Realmuto, 1990); map refined with the method suggested by Gillespie et al. (1998). Since the spectral emissivity cannot be estimated under the plume (due to SO_2) a mean spectral emissivity is manually derived. 2) A Digital Elevation Model (DEM) registered to the image is used. 3) Using the channels not affected by SO_2 the surface temperature of each pixel is derived with the aforementioned emissivity. 4) Finally, a weighted least-squares fit between the remotely sensed data and the simulated radiances at the sensor is done. The best result indicates the SO_2 abundance.
    A new inversion procedure, based on the split-window technique, has been developed to be used both with MIVIS and ASTER radiometers. The advantages of this procedure is its

speed, respect LUT procedure, and that pixel altitude is not requested (using radiances from pixel at 2000-3000 m asl). Three of the four parameters of the split-window algorithm developed have a seasonal trend. Part of the research is related to the comprehension of the possible use of climatologic and in situ data to prepare an automatic procedure.

- Data acquisition
  The described procedures should be used to analyse satellite remotely sensed data. Nowadays only Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data may be used; ASTER is aboard Terra satellite, launched in December 1999. During the first two years this scientific instrument, which may be switched on only eight minutes per orbit, took about only ten good images, mainly during night time. To test the aforementioned procedure it was carried out a campaign on Mt Etna the first week of October 2002. On 4 October, on the basis of contacts with NASA and GDS, ASTER was switched on over passing Mt. Etna. Unfortunately the fourth of October was cloudy.
- Data processing and interpretation
  Up today was possible to analyse only one daily ASTER image (July 29, 2001) of Mt. Etna. The SO_2 estimated flux is comparable with the COSPEC data, at least close to the summit area.
- Others
  To estimate mean monthly atmospheric profiles four years of radio-soundings, carried out at Trapani, were collected. Now fourteen years (1989-2002; that is about 16500 profiles) have been collected. A lot of work is requested before to use this data base.

- RESEARCH PRODUCTS
  - n° of articles published on international journal: 1
  - n° of articles published on national journals, proceedings, technical reports: 2
  - Data bases (trapani profiles; to be finished): 1

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Pugnaghi S, Teggi S, Corradini S, Buongiorno MF, Merucci L, Bugliolo MP, (2002) Estimation of SO_2 abundance in the eruption plume of Mt. Etna using two MIVIS thermal infrared channels: A case study from the Sicily 1997 Campaign. Bulletin of Volcanology, 64, 328-337.

Pugnaghi Sergio, Teggi Sergio, Corradini Stefano, Medici Pietro, Lombroso Luca (2003); Estimation of the SO_2 flux of the eruption plume of the Mt. Etna volcano using MIVIS and ASTER data. Proceedings of the Annual Meeting GNV – Catania, January 24-25 2002.

Remitti Matteo, Pugnaghi Sergio, Teggi Sergio, Parmiggiani Flavio (2003); Retrieval of tropospheric ash clouds of Mt. Etna from AVHRR data. Proceedings of the Annual Meeting GNV – Catania, January 24-25 2002.

DEVELOPMENT AND APPLICATION OF REMOTE SENSING METHODS
FOR THE ACTIVE VOLCANOES MONITORING

RU Responsible
Vladimiro Achilli - Prof. Ordinario
Università degli Studi di Padova – Dipartimento di Architettura, Urbanistica e Rilevamento

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Massimo Fabris – Dottorando	Università Padova	3
Alessandro Bedin – Borsista CNR	Università Padova	1
Andrea Menin – Tecnico	Università di Padova	2
Gabriele Targa – Ricercatore	Università di Padova	1
Giuseppe Salemi – Ricercatore	Università Udine	2

- 2nd YEAR OBJECTIVES
  - Processing of Digital Photogrammetric Data
  - Validation of Digital Terrain Models
  - Set up of Differential Digital Photogrammetry applied to Vulcano and Stromboli
  - Extraction of 5x5 m grid DTM of the Stromboli island

- 2nd YEAR RESULTS **(max 1 page)**
  - Methodologies
    - Digital Elevation Models (DEM) comparisons among the 1993, 1996 and 2001 data set derived from the photogrammetric flights on Vulcano island. The coordinates of natural points measured on the models were also used.
    - Morphometric study of the "La Fossa" cone of Vulcano, in order to extract the morphological features and to study the landforms.
    - Usage of the image automatic correlation module coming from the last version of the DPW 770 Helava software Socet Set in order to extract a 5m DEM.
  - Data acquisition
    - Gps surveys on Vulcano to acquire data for the DTM validation.
    - 1000 dpi digitalization of the 1:5000 scale photogrammetric photos acquired with the 2001 Stromboli photogrammetric flight.
  - Data processing and interpretation
    - 2001 photogrammetric data processing of the Stromboli island.
    - Digital Elevation Model of the Stromboli island based on 5x5 m grid.
    - Ortophoto (mean scale 1:5000) of the intere Stromboli island
  - .Others
    - Upgrading of the digital photogrammetric facilities in the Bologna laboratory:
      - Hardware updating in order to process up to 1 Gb images (ram memory expansion and hard disk addition)
      - Operating system updating (last version of Solaris)
      - Socet Set software updating

- RESEARCH PRODUCTS
  - n° of articles published on international journals : 1

- invited papers and talks: 1 (ESC Lanzarote workshop)
- presentations at international meetings: 2
- presentations at national meetings: 1 (GNV Congress, Rome)
- Data bases :Vulcano and Stromboli DEM

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

ACHILLI V., BALDI P., FABRIS M., MARSELLA M., MONTICELLI R., SALEMI G., 2002. Application of digital elevation model to volcanology. Quaderni di Geofisica (in press)

Communications in international meetings:

ACHILLI V., BALDI P., COLTELLI M., FABRIS M., MARSELLA M., PUGLISI G., 2001. Comparison of different techniques for the derivation of digital elevation models and volcanic monitoring (Vulcano island, Italy). Proceedings of the GNV Congress on "Programma quadro per l'attività di sorveglianza e ricerca sui vulcani italiani 2000-2002", October 9-11, 2001, Rome, Italy, 131-132.

ACHILLI V., BALDI P., FABRIS M., MARSELLA M., MELIS F., SIGNORETTO V., 2002. High resolution techniques for morphological studies in volcanic areas. EGS, XXVII General Assembly, April 22-26, 2002, Nice, France. (poster)

DEVELOPMENT AND APPLICATION OF REMOTE SENSING METHODS FOR THE MONITORING OF ACTIVE VOLCANOES

RU Responsible
Maria Marsella Associate Professor
Università degli Studi di Roma "La Sapienza" - DITS

ACTIVITY REPORT–2nd YEAR

RU PARTICIPANTS

Name-Position	Affiliation	man/month
Maria Marsella - Associate Professor	DITS-Università "La Sapienza"	6
Vanessa Signorotto - felloship	INGV Università di Bologna "	10
Roberto Monticelli	DITS-Università "La Sapienza"	6
Flavio Belloli	DITS-Università "La Sapienza"	4

- 2nd YEAR OBJECTIVES

-Set up of methodologies for acquisition and processing of the GPS data for Ground and Aerial Control.
-Digital PhotogrammetryProcessing
-Differential Digital Photogrammety (DDP) (Vulcano and Stromboli)
-Extraction and Comparisons of SAR DTM
-DTM Validation
-Validation of morphological variation maps

- 2nd YEAR RESULTS **(max 1 page)**

Data processing and interpretatiom:
In collaboration with the University of Bologna and Padova, the digital photogrammetric processing of the 2001 photogrammetric data (1:5000 scale) of the Stromboli island was performed. A 5x5 m grid DEM of the entire Island was extracted.

A morphometric study of the digital terrain model (DTM) of "La Fossa" Cone of Vulcano Island (Aeolian Arc, Italy) has been performed in order to define morphological features and classify main landforms; Morphometric maps, a Terrain Units Map and a Morphometric Units Map were compiled.

A GIS software has been configured and partially implemented with the aim to obtain a tool for the distribution, visualization and analysis of 3D and 2D mapping products obtained for the Vulcano Island from the 1996 photogrammetric data.

- RESEARCH PRODUCTS
  - n° of articles published on international journals: 1
  - n° of articles published on national journals, proceedings, technical reports: 3
  - presentations at international meetings:1
  - presentations at national meetings:1
  - Data bases: DEM of Vulcano and Stromboli Island

PUBLICATIONS LIST (inclusive of papers in prints and accepted)

Achilli V., Baldi P., Fabris M., Marsella M., Monticelli R., Salemi G., (2002) *Application Of Digital Elevation Model*

To Volcanology , Quaderni di Geofisica , in press.

Baldi P., Bonvalot S., Briole P., Coltelli M., Gwinner K., Marsella M., Puglisi G., Rémy D., (2002).*Validation and comparison of different techniques for the derivation of digital elevation models and volcanic monitoring(Vulcano island, Italy),* International Journal of Remote Sensing, 22, 4783-4800.

Baldi P., Marsella M., Signoretto V. (2002) *Analysis of High Resolution Digital Elevation Models for Morphometric Parameters Extraction and Classification*, Quaderni di Geofisica, in press.

Marsella M., F. Volpe *Analisi delle potenzialità dei dati satellitari ad alta risoluzione per la generazione di ortofoto* - Proceedings of the 6th National Conference of ASITA, Perugia, 5-8 November 2002, 1: 1485-1490.

Communications in international meetings:

Achilli V., Baldi P., Fabris M., Marsella M.,Melis F., Signoretto V. *High resolution techniques for morphological studies in volcanic areas* Poster presentato al EGS XXVII General Assembly, Nice, France, April 2002

Atzori S., Baldi P., Marsella M., Signoretto V. *Analysis of high resolution digital elevation model of vulcano island for morphometric relief classification* Poster presentato al Convegno Nazionale GNV, Roma 2001