All. 1

Consiglio Nazionale delle Ricerche

NextData

un sistema nazionale per la raccolta, conservazione, accessibilità e diffusione dei dati ambientali e climatici in aree montane e marine

Project of Interest "NextData"

Proposal for a research project

Topic (number and title):
Topic 5, Reconstruction of ground surface deformation time series in test areas in mountain environments, and correlation to rainfall time series and implementation of the data and results in digital archives compatible with the NextData project archives.

TITLE OF THE PROPOSED PROJECT:
HAMMER - RelationsHips between meteo-climAtic paraMeters and ground surface deforMation time sEries in mountain enviRonments

Project duration: 21 months
start date (before 31 January 2014): 1 January 2014
end date (no later than 30 September 2015): 30 September 2015

Scientific coordinator of the proposed project:
Francesca ARDIZZONE

CNR Institute coordinating the proposed project:
Istituto di Ricerca per la Protezione Idrogeologica (IRPI)

Participating units, indicating the scientific responsible for each unit and the motivation for the inclusion in the proposal (in particular, illustrating whether and how the expertise of non-CNR partners is not available at CNR):
HAMMER will be executed by two research units, pertaining to two CNR research Institutes: (i) a research unit at the Istituto di Ricerca per la Protezione Idrogeologica, and (ii) a research unit at the Istituto per il Rilevamento Elettromagnetico dell'Ambiente.

Unit 1 (CNR coordinating Institute): Istituto di Ricerca per la Protezione Idrogeologica (IRPI)
Scientific responsible: Francesca ARDIZZONE
The mission of the *Istituto di Ricerca per la Protezione Idrogeologica* (IRPI) is to design and execute R&D activities on natural and human induced hazards and risks, with emphasis on geo-hydrological hazards, chiefly landslides and floods. Research activities are conducted at all geographical and temporal scales, in all physiographical and climatic environments, using a wide spectrum of techniques, methods, and tools. The institute is Centre of Competence of the Italian National Civil Protection Department. The activities proposed in HAMMER will be executed by two research groups: (i) the Geomorphology

research group in Perugia (http://geomoprhology.irpi.cnr.it/) and (ii) the Geohazard monitoring research group in Torino (http://gmg.irpi.cnr.it/). Collectively, the two groups have the knowledge and experience, the technical skills and capabilities, and the track record to execute successfully the proposed activities. The Geomorphology research group has extensive experience on landslide mapping, landslide hazard and risk assessment, and on landslide spatial and temporal modelling. The group lead the MORFEO national project funded by the Italian Space Agency (http://www.morfeoproject.it/), and two European FP7 projects – DORIS (http://www.doris-project.eu/) and LAMPRE (http://www.lampre-project.eu/) – for the exploitation of remote sensing data and technologies for landslide and ground deformation detection, mapping, monitoring, and forecasting. In these projects the group has exploited advanced Differential Interferometric Synthetic Aperture Radar (DInSAR) data combined with geological, geomorphological, and meteorological information to model slope instabilities and ground deformation time series. The Geohazard monitoring research group has extensive experience in slope monitoring, and operates a number of continuous landslide monitoring networks in the Alps, the Apennines, and the Pyrenees. The group has the facilities and the know-how to deploy and manage a wide spectrum of *in-situ* and remote instruments to monitor surface (GPS, RTS, LiDAR) and deep-seated (inclinometer) deformations, and to analyse and interpret the monitoring results. The group leads a Category-1 project of the European Space Agency (ESA) for the analysis of ground surface deformations caused by landslides in mountain areas exploiting the ESA ERS-1/2 and Envisat data archives for the period 1992-2010. The Category-1 project is part of the ESA Geohazard Supersites initiative (http://supersites.earthobservations.org/).

Unit 2:

Scientific responsible: Michele MANUNTA

The Institute for Electromagnetic Sensing of the Environment (IREA), founded in 2001, is part of the largest Italian public scientific and technological research institution, the National Research Council (CNR). The institute is Centre of Competence of the Italian National Civil Protection Department. IREA is fully inserted in the national and international research context and actively interacts with other CNR Institutes and Italian and foreign Universities and Research Institutes. This is witnessed by the high scientific production characterized by publications in the most prestigious journals and by the relevance of external funding. IREA staff consists of about 50 employees, mainly researchers, and 40 units of contract staff. The mission of IREA is the development of innovative methodologies and technologies for acquisition, processing, fusion and interpretation of data and images obtained through electromagnetic sensors (operating on satellite, aircraft and in situ). The activities of Remote Sensing group are mainly focused on Differential Synthetic Aperture Radar Interferometry, Airborne SAR interferometry techniques, and Satellite SAR Tomography. Recently, IREA has been involved in numerous national and

international projects dealing with exploitation of SAR data in natural and man-made hazard contexts (ASI-MORFEO, ASI-SRV, ASI-SIGRIS, FP7-DORIS, FP7-LAMPRE, ESA-TERRAFIRMA EXTENSION, FP7-MARSITE, FP7-MEDSUV, RITMARE). Numerous collaborations with companies and local authorities are in progress.

1. GENERAL INFORMATION

Abstract of the proposed project (max 1000 characters)

Landslides, present in all continents, play an important role in the evolution of landscapes. Main natural triggers include intense or prolonged rainfall, rapid snowmelt, freeze and thaw cycles, and the melting of permafrost. Climatic and environmental changes may affect the frequency and intensity of landslide-triggering events, and change the conditions that favour slope instability. Little is known on the past, present and future effects of the changing climate on the frequency and the intensity of the landslides. This is also due to a poor knowledge of how changes in meteorological and climatic parameters (temperature, rain/snow precipitations, pressure, etc.) are correlated with changes of ground deformation of instable slopes. HAMMER intends to close this gap by collecting accurate and long term time series of ground (surface and sub-surface) deformation, and analysing eventual changes of the deformation trend/style associated with meteorological and climatic variables over time.

Main goals of the project (max 1000 characters)

There is a lack of information on the effects of climate and environmental changes on the frequency and the intensity of landslides and their natural triggers. HAMMER intends to close this gap by collecting time series of ground deformations, and associated times series of meteorological and climatic measurements. Specifically, HAMMER will:

- **Collect time series of surface and sub-surface ground deformations in landslide areas in the Alps, the Apennines, the Pyrenees and the Andes.**
- **Collect time series of meteorological parameters for the same areas for which the ground deformations data will be collected.**
- **Demonstrate the capability of DInSAR techniques to provide multi-decadal time series of ground deformations in different physiographical and climatic environments.**
- **Attempt statistical correlations between time series of meteorological parameters and time series of the ground deformations, for selected test sites.**

Expected results of the project (max 2000 characters)

- **Analysis of the scientific and technical literature to determine where quantitative surface and sub-surface information on ground deformations in landslide areas is available, and for which periods. It includes the identification of landslide areas in the Alps and the Apennines where time series of deformations can be built using existing data.**
- **Combined time series of surface and/or sub-surface ground deformations and of meteorological parameters, for selected landslides in Europe and in South America. This will include time series obtained processing SAR data, and through surface topographical and/or sub-surface inclinometric measurements.**
- **Critical analysis of the possibility of using space-borne DInSAR techniques to prepare multi-decadal time series of ground deformations for landslide areas, and their correlation with meteorological and climatic variables. Emphasis will be given to DInSAR data obtained exploiting the ESA ERS-1/2 and ENVISAT SAR archives, and on results expected from the upcoming ESA SAR Sentinels.**
- **Preliminary results of the statistical cross-correlations of the time series available for the selected test sites. This will include an assessment of the reliability of the cross-correlations, and an interpretation of the results obtained, in view of their local and general significance.**
- **Assessment of the feasibility and costs for a systematic extension of the activities conducted in HAMMER in Italy (the Alps and the Apennines), and in other mountain areas in the World.**

Role of the different units (max 2000 characters)
Unit 1 (IRPI, coordinator) will:

- **Perform a literature review to determine where quantitative surface and sub-surface information on ground deformations in landslide areas is available, and for which periods, in the Alps and in the Apennines and in other mountain ranges.**
- **Provide ground displacement time series for selected test sites where *in situ* measurements are available and can be obtained during the lifetime of the project.**
- **Provide SAR images for two test sites acquired through the ESA Category-1 project, to be rocessed by Unit 2. Analyse the results of the DInSAR processing performed by Unit 2.**
- **Collect meteorological and climate data (rainfall, snow, temperature) for the areas for which the ground displacement time series are retrieved.**
- **Perform cross-correlations between the available time series of ground deformations and meteorological/climatic data. Assess the reliability of the cross-correlations, and interpret the obtained results.**

- **Design and populate a database with the collected time series of ground deformation and meteorological/climatic data. The database will be compliant to the specifications of the NextData Project.**
- **Produce intermediate and final scientific and economical reports.**

Unit 2 (IREA) will:

- **Provide existing ERS-1/2-ENVISAT deformation maps and associated time series for selected test areas.**
- **Process SAR images provided by IRPI for two test sites in order to produce deformation maps and associated time series.**
- **Produce intermediate and final technical-economical and scientific reports, related to the activity of Unit 2, to be included in the reports prepared by Unit 1.**

2. DETAILED PROJECT DESCRIPTION

State of the art and motivations (max 5000 characters)

There is a systematic lack of information on the effects of climate and environmental changes on the frequency and the intensity of landslides and their triggering phenomena (*Crozier, 2010, Huggel et al., 2012*). The problem is particularly severe in mountain areas, where natural and human-driven climatic and environmental changes may alter significantly the frequency and the intensity of the slope processes, with largely unknown short and long-term effects on the landscapes and the environment. In this context, the identification of ground (surface and sub-surface) displacements in mountain areas is a key issue for the correct analysis and forecasting of slope hazards. The analysis of surface movements aims to define the geomorphological evolution of single or multiple landslides. The short-term analysis of surface movements is obtained through quantitative or semi-quantitative analyses of three-dimensional topographic data and high accuracy measurements obtained exploiting different monitoring techniques (*Giordan et al., 2013*). The combined analysis of ground displacement time series and meteorological/climatic measurements may contribute to understand the response of unstable slopes to short-term meteorological triggers and long-term climatic forcing (e.g., *Lollino et al., 2006, Burda et al., 2013; Crosta et al., 2013*). In the last decades several *in situ* monitoring techniques were considered, including Total Stations, GPS receivers, Terrestrial LiDAR, Ground Based Radars, extensometers, and borehole inclinometers. These tools are essential to provide ground deformation time

series with very high temporal sampling, allowing for the reconstruction of the evolution of single landslide phenomena over time.

The relatively recent possibility to measure surface displacements from space using geodetic techniques, including Differential SAR Interferometry (DInSAR, *Rosen et al., 2000*), has significantly increased significantly the information available on surface movements, especially in terms of spatial density. Such techniques are particularly suitable to monitor ground surface at the regional scale, to recognize the areas presenting ground deformation anomalies where to focus for a better understanding of the on-going physical processes. Starting in 1990's, first ERS and then ENVISAT earth observation missions of ESA collected a very large number of SAR images, generating a huge archive of information relevant to the period 1992-2010 time period. Using this large archive with advanced processing techniques (*Ferretti et al. 2001; Berardino et al., 2002; Lanari et al., 2004*), SAR images can be exploited to obtain ground displacement time series for the most part of the World, allowing us to following the evolution of surface displacement over time, with a monthly temporal sampling.

The possibility of obtaining long time series of deformation relevant to several landslides in different physiographic and climatic regions of the World may open the possibility of understanding the complex, and largely unknown, relationships between climate and its variations, and to study the initiation and development of deep-seated landslides (*Calò et al., 2013*). As outlined above, DInSAR is an approach suitable to effectively monitor ground displacements in areas with limited and/or difficult access. However, in many cases the use of DInSAR for systematic landslide monitoring is hampered. This is mainly related to the intrinsic limitations of DInSAR monitoring (phase decorrelation on vegetated areas, coherence loss due to large revisit time, phase decorrelation due to large and/or rapid displacements, line-of-sight (LOS) measurements only, etc.). In these cases, the availability of ground displacement time series retrieved via *in situ* measurements is crucial in order to follow the evolution of landslide processes when DInSAR fails. In general, DInSAR as well as other remote sensing monitoring techniques are used to analyse and evaluate landslide hazard at regional scale. On the other hand, *in situ* monitoring is considered mainly when there is a need to focus on a single landslide, eventually with early warning purposes. Until now, the joint consideration of DInSAR and *in situ* deformation data was mainly aimed at evaluating and/or validating the accuracy of ground deformation measurements, thus confirming or not the effective activation or re-activation of a slope movement.

A more effective combination and integration of DInSAR and *in situ* measurements can be considered as a new and convenient approach to analyse landslide phenomena at a different spatial (regional vs. local) and temporal (month/weeks vs. days/hours) resolution, in order to better evaluate the behaviour of different instable slope areas, and also to find eventual relationship between meteorological and climatic variables and landslide movements.

Detailed description of the project, including the work plan, deliverables and milestones (explicitly indicating the activities of the different years) (max 8000 characters)

HAMMER will focus mainly on the following study areas: (i) Italian Western Alps, (ii) Apennines, (iii) Pyrenees, and (iv) Atacama desert, Andes.

In the Italian Western Alps active landslides are abundant. The Alpine territory is characterized by large instabilities that can be considered as predisposing factor for the activation of faster landslides, triggered by extreme meteorological events. HAMMER focuses on the investigation of the ground deformation time series processed within the project especially devoted to study the large and slow landslides, and to identify areas with higher velocities that could characterize smaller local landslides. The surface velocities of the activated/re-activated landslides during extreme meteorological events are in the order of several decimetres/month; in such cases in-situ data will be used to monitor the surface and subsurface displacements.

The Apennines are characterized by a very large density of landslides, a result of the lithological, morphological and meteorological settings. HAMMER focuses on the portion of the Apennines between the Umbria and the Marche regions where Unit 1 has prepared accurate landslide inventory maps, and Unit 2 has processed SAR images. Specifically, an area in central Umbria at the foothill of the Monte Subasio where a deep-seated landslide affects the town of Assisi, and for which an 18.5-year ground deformation time series obtained processing ERS-1/2 & ENVISAT is available, together with daily rainfall data for the same period.

The Upper Tena Valley, in the Central Spanish Pyrenees is characterized by hundreds landslides different in types and in particular by two deep-seated slides whose development is due to the destabilisation of the over steepened valley walls after the retreat of the glaciers (*Herrera et al., 2013*). This territory has been investigated by geomorphological investigation, in-situ geo-technical investigation and recently by the DinSAR technology. HAMMER focuses on the investigation of the portion of the area that is involved in the two deep-seated slides, to exploit the possibility to detect a relationship between change of the rate of the landslides displacement and climatic parameters.

The Atacama Desert is a plateau located in South America, where a ground surface deformation (uplift) was revealed by space-borne InSAR analysis on salt lakes (Salar, 4,000-5,000 m a.s.l.). This uplift is probably related to the regional decrease of the permafrost elevation, which may contribute to an increase in the annual volume of incoming groundwater. In that area several flanks of inactive volcanoes show gravitational processes, which might also be related to the decadal diminution of the permafrost elevation. HAMMER focuses to investigate the variation of the uplift trend and the variation of the velocity of

the gravitational slopes interesting the flanks of the volcanoes using the space-borne ground deformation time series already available.

Deep-seated landslides include large slope failure associated with translational, rotational, or complex movement. The relatively low surface velocities make these processes suitable to retrieve information on the long-term displacement via different monitoring techniques, and thus to investigate possible relationship between climatic parameters and past movements. On the other hand, the rapid velocity characterizing shallow landslides is difficult to monitor, mainly because movements usually involves a small portion of the soil cover without causing relevant displacements on the slope. Shallow landslides, e.g. debris flows, due to prolonged or intense meteorological events or to earthquakes, and rockfalls, are usually associated with impulsive processes, thus not suitable for the recognition of trends in the displacement time series, which are one of the main objectives of the proposed research.

HAMMER will collect ground deformation time series data, and rainfall time series not only for the mentioned study areas, but also intends investigate the existing information published in scientific literature to find out regions in the world for which surface or sub-surface displacement measured by in-situ techniques or by satellite techniques as been published. The *Piano di Straordinario Telerilevamento ambientale* (http://www.pcn.minambiente.it/viewer/) will be also examined as a technological tool that represents an interesting source of information.

HAMMER involves two parts. First it will develop an approach to analyse and compare displacement vs. meteo-climatic parameters using data already available for mountain areas. In particular, the project will exploit DInSAR deformation time series derived from satellite data already processed in different frameworks, not considered in terms of relationship between displacements and meteo-climatic parameters. Second HAMMER will produce ground displacement time series for two new sites, where the new methodological approach, developed in the first part of the project, will be applied.

The project is organized two Work Packages (WPs), for deformation time series collection and analysis (WP1), and for DInSAR processing in selected study areas (WP2). In the following, we describe the activities planned in the two WPs.

WP1: Deformation time series collection and analysis – The WP is organized in four main tasks, for (Task 1.1) the collection of ground deformation time series, (Task 1.2) the collection of meteorological/climate time series, (Task 1.3) for the cross-correlation of the time series, and (Task 1.4) for the implementation of a relational database for the storage of the collected time series.

Task 1.1 – Collection of ground deformation time series. Includes: (i) Collection and organization of surface and sub-surface deformation available to Unit 1 for test sites in the Alps and the Apennines (months: from 1 to 7), (ii) Collection and organization of ground deformation DInSAR time series already processed for test sites in the Apennines, the Andes and Pyrenees (months: from 1 tot 10) and inclusion of the new products obtained by the new acquired DInSAR images

(months: from 14 to 17): (iii) Systematic search of the surface deformation information available through the *Piano di Straordinario Telerilevamento ambientale* for selected study areas in the Alps and the Apennines and through a literature review (months: from 2 to 14).

Task 1.2 – Collection of meteorological/climate time series. Includes: (i) Selection of relevant meteorological stations (month 3), (ii) Collection and organization of the meteorological/climate time series (months from 3 to 10).

Task 1.3 – Cross-correlation of the time series. Consists of the statistical analysis of the correlation (or lack of correlation) between ground deformation and the meteorological/climatic time series, and their interpretation in view of their local and general significance (months from 13 to 19).

Task 1.4 – Implementation of a database for the storage of the collected time series. Includes the design and the implementation of the database using the open source object-relational database system PostgreSQL + PostGIS SW and the preparation and delivery of the collected information for the NextData main portal (months from 3 to 13).

WP2: DInSAR processing for selected study areas – The WP includes one task that develop two different activities: (i) Selection of the two test sites where the Unit 2 will produce new deformation velocity maps and associated time series using ERS1/2 and ENVISAT satellite images provided by the Unit 1 through a Category-1 project (months: from 10 to 11). (ii) Processing of the satellite images (months: from 12 to 15); the new products will be provide to the Unit 1 that will include the time series in the WP1, task 1.1.

Deliverables

The deliverables are (see table):

- **D.1. The deliverable is represented by the ground surface and sub-surface in-situ time series collected for the Alps territory (month 7).**
- **D.2. The deliverable is represented by the DInSAR ground surface deformation time series available for the Apennines, Pyrenees and Andes territory (month 10) and by the meteorological/climatic data collected for the test area of Alps, Apennines and Pyrenees.**
- **D.3. The deliverable is represented by the new DInSAR ground deformation map and associated time series realized by the Unit 2.**
- **D.4. The deliver is represented by a database for the storage of the collected time series will be completed at the month 12.**
- **D.5. The deliverable is represented by a report to carry out correlation analysis between correlation (or lack of correlation) between the ground deformation and the meteorological/climatic time series, and their interpretation with respect to their local and general significance.**

The activity will deliver two reports: an intermediate scientific report (IR) at 12 month and a final scientific report (FR) at 21 month.

Milestones

The milestones are (see table):

- **M.1. The first milestone is at month 11. Unit 1 and Unit 2 will decide the two test sites for the new satellite image processing and the acquisition plan.**
- **M.2. The second milestone is at 14 month. Unit 1 and Unit 2 will assess of the feasibility of a systematic extension of the activities conducted in HAMMER in Italy and in other mountain areas in the World.**

		Months																					
WP	Task	1	2	3	4	5	6	7	8	9	10	11	12		13	14	15	16	17	18	19	20	21
1	1.1							D1								M2			D3				
	1.2										D2												
	1.3																				D5		
	1.4												D4										
2	2.1											M1											
IR													IR										
FR																							FR

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List of Acronyms

ASI	***Agenzia Spaziale Italiana***
CNR	***Consiglio Nazionale delle Ricerche***
DInSAR	**Differential Interferometric Synthetic Aperture Radar**
DORIS	**Ground DefOrmation RIsk scenarios: an advanced assessment Service**
ERS	**European Remote Sensing**
ESA	**European Space Agency**

GPS	**Global Positioning System**
InSAR	**Interferometric Synthetic Aperture Radar**
IREA	***Istituto per il Rilevamento Elettromagnetico dell'Ambiente***
IRPI	***Istituto di Ricerca per la Protezione Idrogeologica***
LAMPRE	**Landslide Modelling and tools for vulnerability assessment Preparedness and Recovery management.**
LiDAR	**LIgth Detection And Ranging**
LOS	**Line of Sight**
PST	***Piano Straordinario di Telerilevamento***
RTS	**Robotized Total Stations**
SAR	**Synthetic Aperture Radar**
SBAS	**Small BAseline Subset**
SW	**Software**

Motivations for the required budget and budget on a unit and year-by-year basis (max 5000 characters)

The activity proposed by the two research units (CNR IRPI and CNR IREA), in the framework of the NextData project, assumes an innovative role in the context of the recent studies concerning the investigation of the relationships between climate change, and environmental changes and landslides.

The published literature deals with the analysis of these relationships in terms of the evolution of the landscape and assessment of the landslide erosion rate and in terms of correlation between landslide volume and sediment yield at catchment scale.

The interest generated by this topic has induced researchers of CNR IRPI and CNR IREA to investigate the role played by the landslide kinematics, by comparing slope displacements to rainfall data and other meteorological parameters.

The objectives of the proposal require an effort in terms of time in the phase of collecting and organizing available data and as well as to process the new ERS1/2 and ENVISAT datasets.

A review of the literature and a careful exploration of the PST maps represent a crucial point to identify the mountainous areas in Italy and in other part of the world where it will be possible to develop future investigations.

Finally the NextData archive will benefit from the inclusion of the deformation of surface and subsurface time series provided by HAMMER, and the resulting correlation analysis with rainfall and other meteorological parameters.

The two research Units ask for the budget indicated in the table. The budget (see table) was carefully calculated to reach the main goals of the project and to complete the expected results also considering the opportunity to keep a new research grant holder that will dedicate at the development of the described activities of the project. Budget details are provided in the following.

Cost details

a) The costs of the personnel are referred to five researchers, three from CNR IRPI (Unit 1) and two from CNR IREA (Unit 2), covering 40% of the total budget and corresponding to a total of 5 person-months per year. Each researcher will commit 2 person-months for the entire project. The Unit 1 researchers will work on the collection of the meteorological data, the collection of ground surface and subsurface deformation time series from space-borne and in-situ measurements, the organization of the digital database and the correlation analysis. The Unit 2 researcher will work at the production of the deformation map and associated time series from new satellite images.

b) The one research grant holder will be dedicated to work on this project. It will commit 10 months on the first year and 9 months in the second year. The research grant focus will be on the literature review, on the exploitation of the PST data, and on the implementation of the database. The research grant will co-operate with unit 2 in the production of the new DInSAR measurements and with unit 1 to analyse the correlation between ground deformation time series and rainfall or other meteorological measurements.

c) Travel and accommodation is required for personnel and research grant holder to support in the second year dissemination expenses.

	first year	second year
Unit 1 (coordinator)	33000	33000
Unit 2	17000	17000
TOTAL	50000	50000

Please attach the curricula and the list of relevant publications of the project coordinator and of the responsible of each participating unit, and the summary budget table in attachment.

Francesca Ardizzone Curriculum Vitae (Project coordinator and responsible of the Unit 1)

Francesca Ardizzone, geologist, is a research scientist of the Italian Consiglio Nazionale delle Ricerche (CNR), where she carries out her research activity in the landslide hazards and risk assessment research unit at the Institute for Geo-Hydrological Hazards Assessment (IRPI, www.irpi.cnr.it), in Perugia. After taking a degree in Geology at the University of Perugia in 1988, she started her

cooperation with the IRPI CNR in 1992. She worked in the framework of the AVI-GNDCI (Areas historically affected by hydrogeological disasters) national project from 1992 to 1994 and collected historical information about hydrogeological phenomena in Italy by reading newspapers, scientific literature and technical reports. From 1994 to 1996 she participated at the projects for the evaluation of the vulnerability areas of Appennines springs Bagnara, San Giovenale, and the San Cese in the town of Nocera Umbra (PG), in cooperation with the Perugia University and in 1997 she worked on the production of the Digital Terrain Model of the Umbria region for the CNR IRPI. In 1998 she obtained a temporary research position in the CNR IRPI and from 1998 to 2001 she worked in the framework of the CARG project for the implementation of the digital geo-database of the Geological Map of Italy at scale 1:50.000. She was and is still involved in several Italian regional project dedicated to the landslide mapping and evaluation of landslide susceptibility, hazard and risk. She developed several activities in the MORFEO project, a national project for the exploitation of Earth observation data and technology for improved landslide detection, monitoring and forecasting, funded by the Italian Space Agency and in this project she was the person in charge of two work packages: WP 1A-AAD DIVULGAZIONE SCIENTIFICA (Scientific dissemination) and WP 1A-ABF PIANO E ATTIVITA' DI FORMAZIONE (Training planning activity). She is involved in a national project funded by the Italian National Department of Civil Defence aimed at fostering the national capabilities to forecast rainfall induced landslides, and the associated risk, in Italy, in particular her contribution is devoted to the production of landslide inventory maps and the implementation of the landslide geo-database. In the period 2010 - 2013, she participated to the DORIS project "downstream service for the detection, mapping, monitoring and forecasting of ground deformations", European project FP 7. For DORIS she was the person in charge to coordinate the data and analysis for the Central Umbria test sites. In the period 2010-2013 she was involved in the national project entitled VIGOR "Valutazione del potenziale Geotermico delle regioni della Convergenza" (Evaluation of the geothermal heating capacity in four Regions in the South of Italy), a national project funded by the "Ministero dello Sviluppo Economico Dipartimento per l'Energia" (Ministry of Economic Development, Energy Department). For the VIGOR project she was the person in charge of the Work package 1 "Raccolta ed organizzazione dati" (Data collection and management). Since 2013 Francesca Ardizzone is working in the framework of LAMPRE " LAndslide Modelling and tools for vulnerability assessment Preparedness and REcovery management ", an European project and she is the person in charge of the task 5.2 "Event, seasonal and multi-temporal landslide mapping", of the task 6.5 "Impact assessment of landslides events on structures and infrastructures", and she is the person in charge of the activity in the Central Umbria study areas. She actively participated at the scientific and technical activities to support the Department of Civil Protection National in the emergency and post-emergence

actions, for the earthquake occurred in L'Aquila on the April 2009 and for the meteorological Messina event occurred in the October 2009. Her main recent scientific research topics are:

- **Production digital geographical databases of geological and environmental data.**
- **Production geomorphological inventory maps, event landslide inventory maps, and multi-temporal landslide inventory maps.**
- **Methods for landslide hazard exploiting GIS technology.**
- **Geological and geomorphological interpretation of very long ground deformation time series Produced by exploitation of multi-sensor SAR data.**
- **Evaluation of landslide mobilization volume and landslide mobilization rate.**
- **Production of Digital Elevation Model form different source of elevation data.**

List of Publications

JCR Scienific Journal

1. **Calò F., F. Ardizzone, R. Castaldo, P. Lollino, P. Tizzani, F. Guzzetti, R. Lanari, M. G. Angeli, F. Pontoni, Michele Manunta (2013) Enhanced landslide investigations through advanced DInSAR techniques: the Ivancich case study, Assisi, Italy. Remote Sensing of Environment (Accepted).**
2. **Del Ventisette C., A. Ciampalini, M. Manunta, F. Calò, L. Paglia, F. Ardizzone, A. C. Mondini, P. Reichenbach, R. M. Mateos, S. Bianchini, I. Garcia, B. Füsi, Z. V. Deák, K. Rádi, M. Graniczny, Z. Kowalski, A. Piatkowska, M. Przylucka, H. Retzo, T. Strozzi, D. Colombo, O. Mora, F. Sánchez, G. Herrera, S., N. Casagli and F. Guzzetti (2013) Exploitation of Large Archives of ERS and ENVISAT C-Band SAR Data to Characterize Ground Deformations. Remote Sens. 2013, 5, 3896-3917.**
3. **Ardizzone F., Basile G., Cardinali M., Casagli N., Del Conte S., Del Ventisette C., Fiorucci F., Garfagnoli F., Gigli G., Guzzetti F., Iovine G., Mondini A.C., Moretti S., Panebianco M., Raspini F., Reichenbach P., Rossi M., Tanteri L., Terranova O. (2012) Landslide inventory map for the Briga and the Giampilieri catchments, NE Sicily, Italy. Vol. 8 (2). (Paper and map). Journal of Maps.**
4. **Mondini A.C., Guzzetti F., Reichenbach P., Rossi M., Cardinali M., Ardizzone F. (2011) Semi-automatic recognition and mapping of rainfall induced shallow landslides using satellite optical images. Remote Sensing of Environment, Vol. 115, 1743–1757.**
5. **Fiorucci F., Cardinali M., Carlà R., Rossi M., Mondini A.C., Santurri L., Ardizzone F., Guzzetti F. (2011) Seasonal landslides mapping and**

estimation of landslide mobilization rates using aerial and satellite images. Geomorphology, 129(1-2), 59–70.

6. Guzzetti F., Manunta M., Ardizzone F., Pepe A., Cardinali M., Zeni G., Reichenbach P., Lanari R. (2009) Analysis of ground deformation detected using the SBAS-DInSAR technique in Umbria, Central Italy. Pure and Applied Geophysics, Vol. 166.
7. Guzzetti F., Ardizzone F., Cardinali M., Rossi M., Valigi D. (2009) Landslide volumes and landslide mobilization rates in Umbria, central Italy. Earth and Planetary Science Letters, Vol. 279, 222–229.
8. Guzzetti F., Reichenbach P., Ardizzone F., Cardinali M., Galli M. (2009) Landslide hazard assessment, vulnerability estimation and risk evaluation: an example from the Collazzone area (central Umbria, Italy) Geografia Fisica e Dinamica Quaternaria, Vol. 32:2, 183-192.
9. Galli M., Ardizzone F., Cardinali M., Guzzetti F., Reichenbach P. (2008) *Comparison of landslide inventory maps.* Geomorphology, Vol. 94, 268–289.
10. Ardizzone F., Cardinali M., Galli M., Guzzetti F., Reichenbach P. (2007). Identification and mapping of recent rainfall-induced landslides using elevation data collected by airborne lidar. Natural Hazards and Earth System Sciences, Vol. 7, 637–650.
11. Cardinali M., Galli M., Guzzetti F., Ardizzone F., Reichenbach P., Bartoccini, P. (2006) Rainfall induced landslides in December 2004 in South-Western Umbria, Central Italy. Natural Hazards and Earth System Sciences, Vol. 6, 237-260.
12. Guzzetti F., Galli M., Reichenbach P., Ardizzone F., Cardinali M. (2006) Landslide hazard assessment in the Collazzone area, Umbria, central Italy. Natural Hazards and Earth System Sciences, Vol. 6, 115-131.
13. Guzzetti F., Reichenbach P., Ardizzone F., Cardinali M., Galli M. (2006) Estimating the quality of landslide susceptibility models. Geomorphology, Vol. 81, 166-184.
14. Guzzetti F., Reichenbach P., Cardinali M., Galli M., Ardizzone F. (2005) Probabilistic landslide hazard assessment at the basin scale. Geomorphology, Vol. 72: 272-299.
15. Guzzetti F., Reichenbach P., Cardinali M., Ardizzone F., Galli M. (2003) The Impact of landslides in the Umbria Region, Central Italy. Natural Hazards and Earth System Sciences. Vol. 3: 5, 469 - 486.
16. Antonini G., Ardizzone F., Cardinali M., Galli M., Guzzetti F., Reichenbach P. (2002) Surface deposits and landslide inventory map of the area affected by the 1997 Umbria-Marche earthquakes. Bollettino Società Geologica Italiana, Volume Speciale 1, 843-853.
17. Ardizzone F., Cardinali M., Carrara A., Guzzetti F., Reichenbach P. (2002) Impact of mapping errors on the reliability of landslide hazard maps. Natural Hazards and Earth System Sciences, Vol. 2:1-2, 3-14.

Articles in peer reviewed international proceedings

18.Ardizzone F., F. Fiorucci, M. Santangelo, M. Cardinali, A. C. Mondini, M. Rossi, P. Reichenbach, and F. Guzzetti. (2013) Very-High Resolution Stereoscopic Satellite Images for Landslide Mapping. Landslide Science and Practice. Vol. 1 Landslide Inventory and Susceptibility and Hazard Zoning, 95-102. ISBN 978-3-642-31324-0

19.Ardizzone F., Bonano M., Giocoli A., Lanari R., Marsella M., Pepe A., Perrone A., Piscitelli S., Scifoni S., Scutti M., Solaro G. (2012) Analysis of ground deformation using SBAS-DInSAR technique applied to COSMO-SkyMed images, the test case of Roma urban area. SPIE Remote Sensing 2012.

20.Ardizzone F., Rossi M., Calò F., Paglia L., Manunta M., Mondini A.C., Zeni G., Reichenbach P., Lanari R., Guzzetti F. (2011) *Preliminary analysis of a correlation between ground deformations and rainfall: the Ivancich landslide, central Italy.* Proceedings SPIE Remote Sensing, 19-22 September 2011, Prague, Vol. 8179, CCC code: 0277- 786X/11/$18, doi: 10.1117/12.899453.

Michele Manunta Curriculum Vitae (Responsible of the Unit 2)

Michele Manunta received the Laurea degree in electronic engineering in 2001 and the Ph.D. degree in informatics and electronic engineering in 2009 from the University of Cagliari, Italy, with a thesis on Differential SAR Interferometry. From 2002 he has been with Istituto per il Rilevamento Elettromagnetico dell'Ambiente (IREA), an Institute of the Italian National Research Council (CNR), where he currently holds a Researcher Position.

He was a Visiting Scientific with the Institut Cartografic de Catalunya (Spain), in 2004, and the Rosenstiel School of Marine and Atmospheric Science of the University of Miami, in 2006.

His research interests are in the field of high resolution SAR and DInSAR data processing and application. He particularly works on DInSAR techniques for studying deformation affecting terrain surface (such as those produced by landslides, subsidence, volcano activity, and earthquakes) and man-made structures. More recently his research interests concern Cloud and GRID computing exploitation for SAR interferometry applications.

Michele Manunta has been collaborating in various national and international initiatives for the exploitation of satellite technologies, and in particular of SAR techniques, such as ASI-MORFEO, FP7-DORIS, FP7-LAMPRE, FP7-HELIX NEBULA and ESA-TERRAFIRMA.

List of Publications

1. Arangio, S., Calò, F., Di Mauro, M., Bonano, M., Marsella, M., & Manunta, M. (2013). An application of the SBAS-DInSAR technique for the assessment of structural damage in the city of Rome. *Structure and*

Infrastructure Engineering: Maintenance, Management, Life-Cycle Design and Performance, (October), 1–15. doi:10.1080/15732479.2013.833949

2. Atzori, S., Manunta, M., Fornaro, G., Ganas, A., & Salvi, S. (2008). Postseismic displacement of the 1999 Athens earthquake retrieved by the Differential Interferometry by Synthetic Aperture Radar time series. *Journal of Geophysical Research-Solid Earth*, *113*(B9), 1–14. doi:10.1029/2007JB005504
3. Bonano, M., Manunta, M., Marsella, M., & Lanari, R. (2012). Long-term ERS/ENVISAT deformation time-series generation at full spatial resolution via the extended SBAS technique. *International Journal of Remote Sensing, Vol. 33,* 4756–4783. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/01431161.2011.638340
4. Bonano, M., Manunta, M., Pepe, A., Paglia, L., & Lanari, R. (2013). From Previous C-Band to New X-Band SAR Systems: Assessment of the DInSAR Mapping Improvement for Deformation Time-Series Retrieval in Urban Areas. *IEEE Transactions on Geoscience and Remote Sensing*, *51*(4), 1973–1984. doi:10.1109/TGRS.2012.2232933
5. Castañeda, C., Gutiérrez, F., Manunta, M., & Galve, J. P. (2009). DInSAR measurements of ground deformation by sinkholes, mining subsidence, and landslides, Ebro River, Spain. *Earth Surface Processes and Landforms*, *34*(11), 1562–1574. doi:10.1002/esp
6. Calò F., Ardizzone F., Castaldo R., Lollino P., Tizzani P., Guzzetti F., Lanari R., M. G. Angeli, Pontoni F., Manunta M. (2013). Enhanced landslide investigations through advanced DInSAR techniques: the Ivancich case study, Assisi, Italy". *Remote Sensing of Environment* (in press). doi: 10.1016/j.rse.2013.11.003
7. Del Ventisette, C., Ciampalini, A., Manunta, M., Calò, F., Paglia, L., Ardizzone, F., … Guzzetti, F. (2013). Exploitation of Large Archives of ERS and ENVISAT C-Band SAR Data to Characterize Ground Deformations. *Remote Sensing*, *5*(8), 3896–3917. doi:10.3390/rs5083896
8. Guzzetti, F., Manunta, M., Ardizzone, F., Pepe, A., Cardinali, M., Zeni, G., … Lanari, R. (2009). Analysis of Ground Deformation Detected Using the SBAS-DInSAR Technique in Umbria, Central Italy. *Pure and Applied Geophysics*, *166*(8-9), 1425–1459. doi:10.1007/s00024-009-0491-4
9. Lanari, R., Casu, F., Manzo, M., Zeni, G., Berardino, P., Manunta, M., & Pepe, A. (2007). An Overview of the Small BAseline Subset Algorithm: a DInSAR Technique for Surface Deformation Analysis. *Pure and Applied Geophysics*, *164*(4), 637–661. doi:10.1007/s00024-007-0192-9
10. Lanari, R., Mora, O., Manunta, M., Mallorquí, J. J., Berardino, P., & Sansosti, E. (2004). A Small-Baseline Approach for Investigating Deformations on Full-Resolution Differential SAR Interferograms. *IEEE Transactions on Geoscience and Remote Sensing*, *42*(7), 1377–1386. doi:10.1109/TGRS.2004.828196

11. **Lanari, R., Zeni, G., Manunta, M., Guarino, S., Berardino, P., & Sansosti, E. (2004). An integrated SAR/GIS approach for investigating urban deformation phenomena: a case study of the city of Naples, Italy. *International Journal of Remote Sensing*, *25*(14), 2855–2867. doi:10.1080/0143116031000164775 0**
12. **Manunta, M., Marsella, M., Zeni, G., Sciotti, M., Atzori, S., & Lanari, R. (2008). Two-scale surface deformation analysis using the SBAS-DInSAR technique: a case study of the city of Rome, Italy. *International Journal of Remote Sensing*, *29*(6), 1665–1684. doi:10.1080/01431160701395278**
13. **Pepe, A., Euillades, L. D., Manunta, M., & Lanari, R. (2011). New Advances of the Extended Minimum Cost Flow Phase Unwrapping Algorithm for SBAS-DInSAR Analysis at Full Spatial Resolution. *IEEE Transactions on Geoscience and Remote Sensing*, *49*(10), 4062–4079.**
14. **Sansosti, E., Berardino, P., Manunta, M., Serafino, F., & Fornaro, G. (2006). Geometrical SAR image registration. *IEEE Transactions on Geoscience and Remote Sensing*, *44*(10), 2861–2870. doi:10.1109/TGRS.2006.875787**
15. **Tizzani, P., Castaldo, R., Solaro, G., Pepe, S., Bonano, M., Casu, F., M. Manunta, M. Manzo, A. Pepe, S. Samsonov, R. Lanari, Sansosti, E. (2013). New insights into the 2012 Emilia (Italy) seismic sequence through advanced numerical modeling of ground deformation InSAR measurements. *Geophysical Research Letters*, *40*, 1–7. doi:10.1002/GRL.50290**
16. **Zeni, G., Bonano, M., Casu, F., Manunta, M., Manzo, M., Marsella, M., Pepe, A., Lanari, R. (2011). Long-term deformation analysis of historical buildings through the advanced SBAS-DInSAR technique: the case study of the city of Rome, Italy. Journal of Geophysics and Engineering, 8(3), S1–S12. doi:10.1088/1742-2132/8/3/S01**

Signatures:

Project coordinator:

Director of the CNR Institute coordinating the proposal: