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Outline

The Earth Sciences Department of the University of Firenze has been recently recognized as National Centre of Excellence for scientific research and international relationship in the Geosciences field. The department has 42 units of academic staff, 21 units of administrative staff and 130 non permanent staff such as PhD students, assistant researchers. The Earth Sciences Department of the University of Firenze is, since 2004, the official Centre of Competence of the Italian Civil Protection for Remote Sensing and Geohazards (Directive of the Italian Prime Minister of 27 February 2004; Decree of the Head of the Italian National Civil Protection Department no. 252 of 25 January 2005).

In 2008 it was entitled "World Centre of Excellence on Landslide Risk Reduction 2008-2011" by International Programme on Landslide (IPL). This recognition was confirmed in 2011 and in 2014 for the third consecutive time.

The Geohazards research group, which is established at Earth Sciences Department of the University of Firenze it is one of the largest centres for scientific and technological services on geohazards in Italy, currently composed by 51 full-time employees (Figure 1). The group counts 4 professors, 3 researchers, 7 technicians, 19 post-doc fellows, 15 PhD students and 3 administratives. It is the biggest centre in Italy in the field of Geohazards and Engineering Geology.



Figure 1: DST-UNIFI Geohazards research group photo.

The research group has earned a firm reputation for its practical, problem solving approach to the geosciences, which has led to the establishment of solid ties with numerous governmental agencies and private enterprises alike. The research team actively participates in international research and technological development projects in many parts of the world, in collaboration with international, national and regional organizations and agencies, such as the Italian National Research Council (CNR), the European Union, the Italian and European and US Space Agencies (ASI, ESA), the UNESCO and many others. The group has the necessary personnel, research infrastructure, field instrumentation, vehicles and administrative support essential for carrying out effective research in the field of disaster risk reduction, with a wide range of dedicated laboratory facilities supplying the advanced technical support required for the many fields of investigation covered.

The facilities of the research group include:

Laboratories:

- GIS and thematic mapping laboratory
- Remote Sensing laboratory specialised on SAR interferometry, optical and hyperspectral remote sensing
- Rock and Soil mechanics laboratory

Relevant equipment (Figure 2):

- GBInSAR monitoring systems
- Compact submarine remotely controlled (NEMO-ROV)
- Drone (SATURN)
- Rock and soil mechanics field and laboratory equipment
- Advanced geotechnical and hydrogeological modelling software
- GPS and survey instrumentation (LEICA 530, LEICA 1200)
- 3D laser scanner (RIEGL LMS-Z420i)
- Airborne multi-sensor surveyor
- 3D printer
- Access to real-time meteorological services (EUMETSAT/EUMETCAST)
- Supercomputing facility with 70 parallel processors and data centre of 17 Tb of storage
- Fieldspec spectroradiometer
- Eco sounder Ocean Tools MA500
- Thermo camera FLIR
- Theodolite
- PASI geoelectrical and seismic integrated instrument
- Abem WADI to perform electromagnetic measurements in the very low frequency band
- Tromino, a 3G tromograph to perform seismic noise measurements



Figure 2: Available equipment of the DST-UNIFI Geohazards research group.

The group also operates a number of field instrumented test sites for environmental monitoring and slope instability, such as the Geophysical Laboratory in Stromboli.

The Earth Science Department of the University of Firenze (DST-UNIFI) is a member of the International Consortium on Landslides (ICL) since 2002. ICL is an International non-governmental and non-profit scientific organization, which is supported by UNESCO, WMO, FAO and UN/ISDR and other governmental bodies. IPL (International Programme on Landslides) is an ICL initiative that aims to conduct international cooperative research and capacity building on landslide risk mitigation, notably in developing countries. Since 2014 DST-UNIFI is also a member of the International Consortium on Geo-disaster Reduction (ICGdR) that wants to promote the reduction of disasters triggered by geological and geophysical phenomena on earth.

DST-UNIFI has carried out research international cooperation with 19 countries worldwide (Figure 3) and it has signed three bilateral agreements with eminent universities: Shimane University (Japan), Northeast Forestry University (China), Charles University (Czech Republic).



Figure 3: International cooperation. Stars indicate countries DST-UNIFI has cooperated with. Pictures refers to sites where recently has been carried out research activity.

Research Achievements and Challenges

The main objective of the group is to focus on landslide studies at all scales with an emphasis that in recent years moved towards the application and development of new technologies for landslide disaster prevention, monitoring and early warning with special emphasis on remote sensing. The work on these topics has produced several hundreds scientific publications relating upon landslide studies ranging from slope to regional scale.

Main research activities include:

1. Development of GIS-based quantitative models for landslide hazard and risk prediction at basin scale; investigations on landslide frequency-intensity relationships, definition of vulnerability functions, quantitative assessment of potential and expected damage.
2. Correlation analysis between rainfall and landslides, investigations on triggering thresholds for landslides in low permeability terrains; use of current rainfall forecasts from limited-area meteorological models to predict the spatial and temporal extent of landsliding.
3. Application of ground-based SAR interferometry and other new technologies for monitoring superficial displacement fields of slope movements; development of landslide early warning systems based on these technologies.
4. Application of spaceborne SAR interferometry and other remote sensing techniques, for updating landslide inventories and for gathering information on the reactivation frequency of mass movements.
5. Building of rapid mapping of natural disasters.
6. Integrated catchments' modeling and study of the interplay between fluvial dynamics and slope instability; assessment of riverbank stability and prediction of landslide dam hazards aimed at an integrated definition of risk scenarios.
7. Modeling of failure initiation mechanisms and landslide propagation areas through the use of numerical stress-deformation models and hydrological-hydraulic models.
8. Assessment of landslide impact on the built environment and on cultural heritage sites; vulnerability and potential damage evaluation.
9. Disaster management, definition of emergency plans and mitigation strategies for landslide risk.

In the last years the DST-UNIFI Geohazard research group has been involved in several european and international research projects. Among them we mention:

SAFER EC funded project (Services and Applications for emergency response) that aimed at implementing and validating a pre-operational version of the GMES Emergency Response Core Service (ERCS), with a

priority on rapid mapping during the response phase;

SAFELAND EC funded project, which aimed at developing generic quantitative risk assessment and management tools and strategies for landslides at local, regional, European and societal scales and establish the baseline for the risk associated with landslides in Europe, to improve our ability to forecast landslide hazard and detect hazard and risk zones;

ESA funded project TERRAFIRMA, targeted to the definition and quality assessment of multi-interferometric techniques to map and monitor slow surface displacements;

DORIS EC funded project, an advanced, national downstream service for the detection, mapping, monitoring and forecasting of ground deformations, that integrates traditional and innovative Earth Observation (EO) and ground based (non-EO) data and technologies;

LAMPRE EC-funded project proposes to execute innovative research and technological developments to increase GMES limited operational capacity to cope with triggered landslide events and their consequences, in Europe and elsewhere. The project improves the ability to detect/map landslides, assess/forecast the impact of triggered landslide events on vulnerable elements, and model landscape changes caused by slope failures.

As Centre of Competence the UNIFI has been appointed by the Italian Civil Protection Department to monitor several sites that were interested by different types of Geohazards producing an high level of risk to population. The sites that have recently monitored by the Department are 37 and they are reported in Figure 4. All these sites, which show different types of geohazards (Landslides, subsidence, volcanic hazard etc), have been equipped with innovative monitoring instrumentation such as ground-based synthetic aperture radar interferometer (GB-InSAR), laser scanner, satellite interferometry. Among them we should cite the Costa Concordia cruise ship that suffered the wreck on the night of January 13, 2012 along the eastern coast of the island of Giglio (GR). The monitoring activities were being carried in order to measure movements and internal deformations of the ship, using instruments and techniques usually applied to landslide study. The monitoring system was installed since January 18th 2012. It was completely functioning from the following day (19th January). The monitoring system was composed of a number of different technologies, namely: robotized total stations, global positioning system, onboard accelerometers, ground-based synthetic aperture radar interferometer, long ranging 3D terrestrial laser scanner, extensometer anchored at the sea bottom, seismic network, Cosmo-SkyMed satellite interferometry, Infrared thermal imaging, Multibeam bathymetric surveys, Submarine markers. DST-UNIFI has coordinated the monitoring activities until the removal occurred in July 2014.



Figure 4: Geohazard sites monitored in Italy. Pictures refer to some of the most recently monitored sites: Volterra, Castagnola, Costa Concordia, Stromboli, Montescaglioso, San Leo.

Recently the research group has patented two instruments (Figure 5):

- A Remotely operated underwater vehicle (NEMO)
- A Drone structure (SATURN)

NEMO is a remote-control submarine, commonly called ROV (Remotely Operated underwater Vehicle), is a mobile robot remotely piloted and used in underwater applications; these devices are widely used and suitable for different scenarios, e.g. for patrolling and monitoring but also for underwater interventions. A ROV allows investigating areas inaccessible to the human being or dangerous for himself. NEMO was originally designed for the exploration of the Costa Concordia wreck, Isola del Giglio, Italy.

SATURN is a drone developed by the research group, and is capable of autonomous flight, from take-off to landing, and emergency management. A new type of chassis structure has developed, overcoming some critical issues for scientific and heavy payload or long flight applications.

Saturn drone has onboard a complete and fully configurable acquisition system with frame grabber for scientific instruments. It is possible to plug in a multispectral camera, mini-lidar and various sensors through the most common connections and protocols (Usb, Firewire, LAN, wifi, RS-232). The drone is developed to be used and provide data in emergency and calamity areas. Saturn is designed to be water resistant to fly into rain and harsh conditions.



Figure 5: Left: Remotely operated underwater vehicle (NEMO). Right: Drone structure (SATURN).

The research group has also developed a web site called Multirisk Information Gateway (MIG) devoted to collect all the research activities carried out by the DST-UNIFI as Centre of Competence of National Civil Protection. MIG is divided into three sections: BLOG, MAPS and NEWS.

The section BLOG is devoted to collect all the monitoring reports that are produced with daily or weekly frequency for all the monitored sites (Figure 6). MAPS is the section devoted to the visualization through the software Google Maps V3 of geographical data (geomorphological maps, geological maps, hazard map, risk map and elements at risk) and PSI (Persistent Scatterers Interferometry) data available for the national territory. NEWS is a web data mining technique developed to compile and continually update a geohazard database with news on landslides, floods and earthquakes. The news are visualized on WebGIS management system specifically developed. The procedure is based on new technologies that publish news on the internet, i.e., the news is analyzed, georeferenced and attributed to a category of geohazards. A continuous flow of georeferenced events is established to populate and update the geodatabase automatically and in near-real time.

MIG (Multi-risk Information Gateway)



Figure 6: Different sections of the MIG georisk information gateway.

The major research challenges of DST-UNIFI Geohazards research group for the future are:

- Challenge 1:** Use of ground-based SAR interferometry for landslide monitoring and development of reliable procedures and technologies for early warning:
 The aim is the application of Ground-based SAR interferometry and other advanced landslide monitoring techniques in order to estimate the deformational evolution of the landslide masses and the successive operative implementation of Early Warning Systems (EWS) making alert warnings as much as possible robust, reliable in time, and tailored on specific scenarios, with the aim of providing threatened Communities with the appropriate instruments for self-protection against landslides.
- Challenge 2:** Use of EO (Earth Observation) data and technology to detect, map, monitor and forecast ground deformations:
 The aim is the exploitation of the large data archives for geo-hazards mapping: long-time series of archive data are available for C-band satellites, such as ERS-1, ERS-2, ENVISAT, RADARSAT-1 and the recently launched satellites such as COSMO SKY-MED and SENTINEL-1. They represent the baseline for the Emergency Core Service for Landslides. The aim is also the integrated use of EO and ground-based remote sensing data (GBInSAR) and eventually VHR and SAR data fusion.
- Challenge 3:** Application of the SATURN drone for geohazards mapping and monitoring:
 The aim is to further develop the drone security and automation and to test different types of sensors in selected test sites. The sensors used will be optical, thermal, LIDAR, iperspectral/multi spectral. The application will be rapid mapping, 3d surface reconstruction, monitoring and disaster recovery. Development of software for data interpretation is also foreseen.
- Challenge 4:** Shallow landslide prediction with statistical and physically based models:
 Development of a forecasting chain for shallow landslide prediction based on physically based distributed slope stability simulator for analyzing shallow landslide triggering in real time, on large areas, using parallel computational techniques. Refinement of statistical methods, already developed by DST-UNIFI, for the definition of rainfall thresholds for landslide initiation. Development of a devoted section (NOW-CAST) on the MIG portal for early warning at regional scale of shallow landslides, based on the above-mentioned methods.