Date of Submission	04/08/2017

IPL Project Proposal Form 2017

1. Project Title:

   PS continuous streaming for landslide monitoring and mapping

2. Main Project Fields:

   (1) **Technology Development**

   A. Monitoring and Early Warning,

3. Name of Project leaders:

Federico Raspini, Silvia Bianchini, Andrea Ciampalini

Affiliation: Earth Sciences Department of the University of Firenze (DST-UNIFI)

Contact: Via La Pira, 4 50121, Firenze, (Italy) - Phone:+39 055 2757551;

Mobile: +39 3398929831 E-mail: federico.raspini@unifi.it

Core members of the Project:

Nicola Casagli, Full Professor, DST-UNIFI

Veronica Tofani, Researcher, DST-UNIFI

Lorenzo Solari, PhD student, DST-UNIFI

Matteo del Soldato, Researcher assistant, DST-UNIFI

4. Objectives:

   The main objective of this project is to perform the transition from historical analysis of radar satellite image archives to real time monitoring of ground deformation at regional scale using radar satellite scenes. To accomplish this objective the short revisiting time and regularity of acquisitions of Sentinel-1 constellation of SAR (Synthetic Aperture Radar) satellite sensors will be exploited.

5. Background Justification:

   Before the launch of the Sentinel-1 mission, the long revisiting time and the limited access to SAR data of orbiting satellites were the most serious limits for the extensive use of satellite SAR information as monitoring tool. So far, SAR data have been used only to map past ground displacement and to reconstruct the deformation history of the observed scene. This type of elaboration creates static maps, as they simple provide a synoptic, retrospective view of the main areas affected by ground motion. The launch of Sentinel-1 mission opened a new opportunity for InSAR (Interferometric SAR) applications: Sentinel-1 provides, on a regional scale, real-time deformation monitoring tools and response for geological processes. Sentinel-1 mission is composed of a constellation of two twin satellites, Sentinel-1A and Sentinel-1B. Launched in April 2014 and in April 2016 respectively, they share the same orbital plane and ensure a unique revisiting time of 6 days optimized for SAR interferometry applications. Sentinel-1 SAR products are freely accessible, providing the scientific community with consistent archives of openly available data, suitable for monitoring applications relying on the processing of long series of SAR images.

6. Study Area:

   The study area will be the Tuscany Region (Central Italy), specifically selected due to its peculiar geological setting prone to ground instability phenomena. Its territory, mainly hilly (66.5%) with mountainous areas (25.1%) and few plains (8.4%) results to be a very landslide-prone area.

7. Project Duration:

   The duration of the project is two years.

8. Resources necessary for the Project and their mobilization:

   The Geohazards research group, which is established at Earth Sciences Department of the University of Firenze it is one of the largest centers for scientific and technological services on geohazard in Italy, currently composed by more than 50 full-time employees. The group counts 5 professors, 4 researchers, 4 technicians, 18 post-doc fellows, 11 PhD students and several collaborators. The group has the necessary personnel, research infrastructure, field instrumentation, vehicles and administrative support essential for carrying out effective research in the framework of the proposed project, with a wide range of dedicated laboratory facilities supplying the most advanced technical support required for the many fields covered. The total budget of the group in 2016 related to international, European and national funding projects is about 2 Million of Euros. The required budget will be covered by DST-UNIFI for the research part. A contribution by ICL-IPL project budget might be required for dissemination purposes concerning the project results.

9. Project Description:

   For the initial implementation of the continuous monitoring of the Tuscan Region, the existing archives of the Sentinel-1A will be acquired and then processed by means of a multi-interferometric (MT-InSAR) approach, specifically designed to analyze long series of SAR scenes. For both ascending and descending geometries, reference ground deformation maps are thus generated, providing a synoptic, retrospective view of the main areas affected by ground motion. To accomplish the transition from historical analysis to real time monitoring program at regional scale based on Sentinel-1 images, a processing plan for both ascending and descending geometry will be set. Once a new Sentinel-1 image is available, it is automatically downloaded and added to the existing archive. The new data stack is then entirely reprocessed to generate new ground deformation maps and updated displacement time series (TS). A series of subsequent updating is created every six days using Sentinel-1A and Sentinel-1B images. Following the creation of updated ground deformation maps, displacement TS of each measurement point for both ascending and descending geometry will be systematically and automatically analyzed to identify, in the last part of the TS (i.e., in the last 150 days), any change in the deformation pattern. When this change occurred a breaking point (Tb) is identified and defined. The average deformation rates before and after the breaking point are recalculated; when their difference $|\Delta V|$ is higher than 10 mm/yr the points are highlighted as *anomalous points*. Changes in the deformation pattern are analyzed and interpreted, update by update, assigning them a driving triggering factor. To properly use, interpret and exploit the deformation TS and trend variation two important parameters have to be take into consideration:

   i) the spatial consistency: a single, scattered point with a change in the deformation pattern offers

no reliable information on the probability of movement. Only a group of neighbor points (i.e., cluster), sharing the similar TS trend variation and behaviour can be considered representative of a change in the kinematics of a given phenomenon (activation, acceleration, deceleration, etc.);

ii) the temporal persistency: only anomalies repeated in at least two updates are considered representative of an occurring change in the deformation TS. On the contrary, "ghost anomalies", i.e., anomalies identified only in one single update, are discarded from further interpretation because likely related to errors in the data processing (e.g., uncompensated orbital phase ramps, phase unwrapping errors, atmospheric artifacts, thermal effects on targets). It also worth recalling that TS are a zero-redundancy product, i.e., they contain one deformation measure per each SAR acquisition and for this reason, they are particularly sensitive to the phase noise.

10. Work Plan/Expected Results:

    The project includes two Work Packages (WP):

    WP1- Multi-interferometric analysis of archive of Sentinel-1 - which includes the analysis of historical archive of Sentinel-1 and the continuous elaboration of Sentinel-1 images for landslide monitoring and mapping with associated trend variation analysis (Month 1-12).

    WP2 - Analysis and interpretation of results derived from continuous elaboration of Sentinel-1 images- which includes the "radar-interpretation" activity, devoted to assign a geomorphological meaning to the scattered point-wise ground displacements measurements and to obtain an accurate analysis of the phenomenon (i.e. typology, spatial extension, causes). Due to the intrinsic characteristics of multi-interferometric techniques (e.g., the possibility to measure only the LOS component of ground movement and the scattered distribution of measurement points), the interpretation of the TS changes (i.e., anomalous points) requires a proper strategy of analysis based on traditional geomorphological thematic information (i.e. topographic, geomorphologic, geological and land use maps), optical images (both aerial and satellite data) and *in situ* data investigations. The necessary input data for the study area will be downloaded from the web portal of the Tuscany Region (http://www.regione.toscana.it/-/geoscopio) (Month 3-12).

    This monitoring system is designed to capture any changes in the deformation pattern occurring within the territory of the Tuscany Region, such as precursor movements related to major events (i.e., accelerations recorded before landslide failures). Advances in satellite technology, processing algorithms and computing power are now enabling scientists to expand the application fields of satellite SAR acquisition, providing a new tool to systematically track the evolution of landslide-induced ground deformation and for early warning purpose.

11. Deliverables/Time Frame:

    Information on persistent anomalies affecting elements at risk will be routinely delivered every 12 days to the Regional authorities in charge of the geohazard management practices, in the form of monitoring bulletin and implemented in a web-service. Field investigations will be performed in these areas at potential risk and, if necessary, they will be targets for detailed analysis with high resolution sensors (e.g., COSMO-SkyMed) to create a virtual constellation, where different satellite data sources are used in synergy to create a more effective and robust Earth observation system. Moreover, a geodatabase of

the anomalous points identified will be created and constantly updated. The database will be populated with anomalous points and relevant attributes (i.e., location coordinates, municipality, Province, cause, persistency, spatial consistency, land use, slope, etc.). A written report will be delivered at the end of the project (i.e., month 12).

12. Project Beneficiaries

    The main end user of this project is the Tuscany Region. Potential beneficiaries include Civil Protection Authorities, River basin Authorities, local authorities and any other entities in charge of management of risk posed by landslide.

Note: Please fill and submit this form by 1 September 2017 to ICL secretariat <secretariat@iclhq.org> and ICL network <ICL-network@iclhq.org>