The operational use of the Earth Observation satellites data within the Italian Civil Protection System : status and perspectives

G. Rum [a], L. Candela [a,], B. De Bernardinis [b], P. Soddu [b]

[a] Earth Observation Unit, ASI, Viale di Villa Grazioli, 23, 00198 Roma, Italy – (giovanni.rum, laura.candela)@asi.it
[b] DPC Dipartimento della Protezione Civile della Presidenza del Consiglio dei Ministri, – (bernardo.debernardinis, pierluigi.sddu)@protezionecivile.it

Abstract – After an introduction describing the architecture, the functions and the procedures of the Italian Civil Protection System, we focus on the use of satellite systems as the providers of key data to generate information that is essential to support decisions in all phases of the risk management.
For hydro geological and geophysical risks management in particular, after a brief description of how satellite data are currently used in an operational fashion, the paper will describe the main features of the implementation plan, jointly defined by ASI and DPC, that will progressively add new "modules" and capabilities to the Italian Civil Protection System by a continuous increase of the use of satellite data.
The role of ASI within the Italian Civil Protection System as Centre of Competence for Earth Observation, together with its associated functions and responsibilities, will be described.
A list of the existing and planned satellite systems, whose use is foreseen will be included, as well as final considerations on the scalability of Italian concepts and procedures into an European and a worldwide scenario

Keywords: Italian Civil Protection System, EO-based systems for civil protection.

1. INTRODUCTION

According to the approach of the Italian National Space Plan 2003-2005, the development and demonstration of EO-based Applications is implemented through Pilot Projects of duration 3 years, preceded by a 6 months definition study. The Italian Space Agency (ASI) is currently focusing on six national emergencies: floods, landslides, fires, marine oil spills, seismic and volcanic risk.
The development of Applications is carried out jointly by ASI and the reference institutional user, the Civil Protection Department (DPC). The partnership between Earth Observation (EO) Community and Users is finalized to enforce the role of satellite data in the National System of Civil Protection, developing EO-based systems and operational procedures.
The paper introduces the architecture and the operational principles of the Italian Civil Protection System and summarizes the results of the definition studies concluded by the Italian Space Agency in the fall 2004 for the development of Applications for the civil protection, focusing on hydro geological risk, i.e. floods and landslides emergencies.
The next phase, to be started in September 2005, is the activation of pilot projects for the implementation and the demonstration of EO-based functionalities in the framework of the national civil protection system.
In the Italian organizational structure, the Regional authorities are in charge of manage risk, and the Central Institution (DPC) has the role to coordinate, assist and, where necessary, to back-up and act for the local institutions: the Italian situation can be easily scaled up into an European and an worldwide scenario.

1.1 The institutional framework: the *Centri Funzionali* system

The Centri Funzionali (Functional Centres) system is being progressively implemented to realize the decision support network for Civil Protection actions. The system has been designed taking into account the present technical, legal and administrative issues. The structure of the *Centri Funzionali* network has been outlined in *the Direttiva del Presidente del Consiglio dei Ministri 27/02/04* and follows the legislative innovations regarding competences and duties contained in the various *Decreti Legislativi* following the Law 59/98.
The main task of the setting up of the *Centri Funzionali* is to systematically gather, both at national and regional scales, all the data, the information and to exploit modeling capabilities in the meteorological, hydrological and terrain analysis, in order to produce the information required to support the decisions to be taken in the different phases of an emergency.

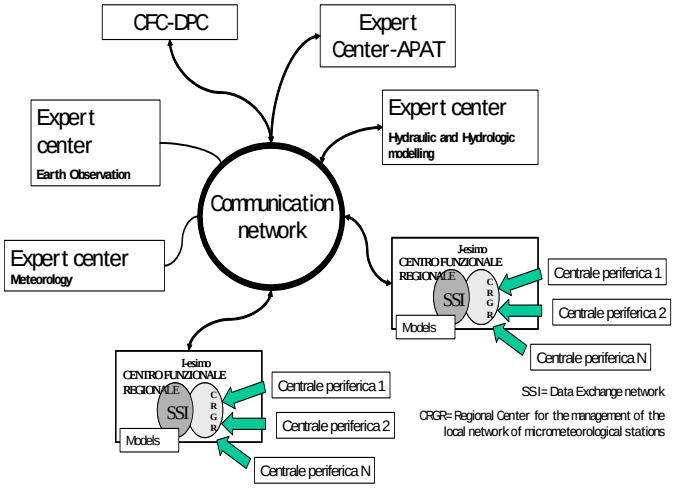

Figure 1. Scheme of the Centri Funzionali.

The structures involved, from local to central, can be defined as:

- *Centrali periferiche* (Pheripherical Centres) represented by the facilities that collect the data to be provided to the *Centri Funzionali*;
- *Centri Funzionali Decentrati/Regionali* (Regional Functional Centres), CFR, which will be constituted for each Region/Autonomous Province and structured into specific sectors. The Centri Funzionali Regionali receive and process with appropriate modeling techniques the data provided from the Centrali Periferiche and Centri di Competenza, and send the data and results of the elaborations to the Centri Funzionali Centrali;
- *Centri di Competenza* (Expert Centres), CC, that provide technical support and perform research and development

activities finalized to the National Civil portection system needs , using data from Centrali Periferiche or from their own sources. The Expert Centres can be structures on their own or coincident with a Centrale Periferica or a National or Regional Centro Funzionale;

- The *Centro Funzionale Centrale* (Central Functional Centre), CFC, at the Department of Civil Protection (DPC), that operates at national scale and receive and process all the data from the *Centri Funzionali Decentrati/Regionali* and *Centri di Competenza*.
  In the specific case of hydrogeological risk, it draws national meteorological forecast bulletins, supports CFRs during the forecasting and monitoring phase as well as in the evaluation of the risk level.

ASI has been recently designated as the *Centro di Competenza per l'Osservazione della Terra* (Centre of excellence for Earth Observation) at National level.

1.2 ASI Center of Competence for EO

The partnership between ASI and Civil Protection Department has been formalized through the ASI designation as *Centro di Competenza per l'Osservazione della Terra* (Centre of excellence for Earth Observation) for the Italian Civil Protection System.
The role of ASI can be summarized as follows :

- ASI has the function to develop applications, primarily based on EO data, for the National System of Civil Protection, interfacing other Space Agencies and transferring in the national scenario information, knowledge, technologies. This is to be implemented by the involvement of the needed scientific and industrial competences and through the coordination with various thematic Centres of Competence, thus, for the EO-based risk management, promoting R&D activities and the use of satellite data.
- ASI will produce and deliver products, services, information and data based on EO data intended for prevision, monitoring and surveillance.

The first point implies ASI leadership in application development programs involving EO community but also teams with multidisciplinary competences (as in pilot project phase).
The second point demands to ASI to develop service capabilities, building an infrastructure (the so called CC-EO) to support the delivery and to establish and maintain a network of EO competences.

1.3 The implementation logic

To respond to a request of the Italian Government, in July 2003 the Italian Space Agency (ASI) asked the Italian Scientific and Industrial Communities to identify possible solutions to best exploit remotely sensed satellite data (and derived information) available today and in the near future to support the National Civil Protection in managing various emergency phases (prevision, monitoring, surveillance) for natural risks: floods, landslides, fires, oil spill, seismic and volcanic risk.
The problem is complex and its solution requires multiple expertise including: a) understanding of the various kind of the phenomena, b) long standing experience on aspects related to natural risk management, c) practical experience on civil protection against hazards, d) consolidated understanding on the use of a wide range of remote sensing technologies for Earth Observation, and e) skills and experience in designing, building and maintaining complex systems.
In response to the call a number of a multidisciplinary teams with the requested skills worked from March to November 2004, in close contact with ASI and DPC, and formulated innovative and realistic proposals for the full exploitation of the available and forthcoming remote sensing technology and missions to manage natural risk.

To accomplish this ambitious task, the teams have: a) reviewed the use of remotely sensed imagery to support the management of each risk; b) analyzed the results of recent Italian and international projects aiming at using remote sensing technology to investigate phenomena in the framework of civil protection systems; c) identified the "end user" of the proposed system including his requirements and expectations, through a critical analysis of the existing phenomenological, practical and legislation constrains; d) critically reviewed the state-of-the-art of the available and the forthcoming remote sensing technology and products in the vast realm of the Earth Observation, with emphasis on the technologies and products most useful to the proposed goal (i.e., civil protection and/or deferred time objectives), including the identification of open scientific and technological problems that need to be addressed and solved.

The 6-month investigation resulted in detailed proposals, starting from which ASI has derived a set of 3-year pilot projects aimed at investigating and solving the identified scientific and technological problems, and at developing and demonstrate both working prototypes of a decision support system that can assist the Italian Civil Defense authorities in managing hazard problems and prototypes of EO products processing chains, to be integrated in the CC-EO infrastructure.
The aim of each pilot project is the implementation of a complete operational chain, maximizing the use of information derived from EO satellite data, for flood/landslide/fire/… forecast /monitoring /surveillance, able to give a real improvement to the CFR capabilities both in terms of phenomena modeling and risk management. The results of these developments, after validation, will be progressively included into the Civil Protection, by integration into different locations (selected number of Regional Centres, Central Facilities, Centers of Excellence) of the upgraded, EO-based systems.
The project is developed through different phases: consolidation – to define an executive project plan, where we foresee three system release, design and development – to realize each system release, support to integration - where the developed modules will be integrated by ASI in the CC-EO and by user in CFRs, demonstration - where the EO-based procedures are used operationally by the selected CFRs, supported by CC-EO, and feedback are collected to enhance the performance of the procedures themselves.

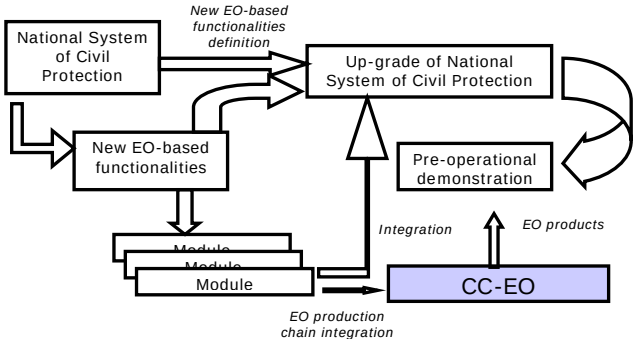

Figure 3. Implementation logic for Pilot projects

These pilot project can be considered as frame projects able to involve also the results and the products of others international projects involving Civil Protection User, specifically the GMES ones, and to test and validate them in the national context.

2. EO DATA for RISKS MANAGEMENT

2.1 The *"Centri Funzionali"* operational framework for hydrogeological risk

The real time operability of the CF network accounts for a series of subsequent steps from the synoptic scale meteorological forecast to the town-scale alert issuing and event monitoring.
Four steps can be identified in the framework. During each of them some questions must be answered:

1. synoptic-scale meteorological analysis: the models forecast rainfall in the target area?
2. analysis of the hazard related to the forecast rainfall: does the forecast rainfall exceed some pre-set hazard thresholds?
3. hydrological analysis: are the ground effects predicted by the hydrological models significant?
4. communication to decision makers: how transmit efficiently the information produced by the forecast procedure?
5. monitoring of the event: what is happening now?

Depending on the answers to the previous questions, the procedure follows different paths that can lead or not to the issue of warning messages.

In order to understand how EO-data positively affects the performance of the operational chain for flood and landslide risk management implemented at CFRs, a short, general description about how they currently operate is given here.
Every day meteorological forecast is provided by national and (selected) regional CCMeteo. Criticality of the current meteorological situation is evaluated from meteorological models output. Meteorological forecast is used both by CFC and CFRs to evaluate the hydrological effects of the forecasted rainfall. Some CFRs have their own hydrological models for flood prediction at regional scale, suitably coupled with meteorological outputs.
Both meteorological and hydrological forecasts are used for the redaction of national and regional meteorological and hydrological warning.
All the data needed for the meteorological and hydrological analysis and forecast are exchanged through the CF communication network.
It must be noticed that very little use of EO observations and products is currently made.

2.2 User needs and EO products

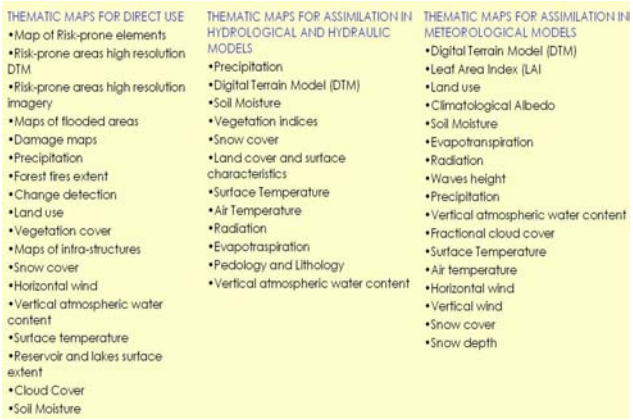

Figure 4. EO products identified for flood risk

The first phase of ASI programs was mainly devoted to evaluate for what kind of actions performed at each step of the scheme of forecasting-warning-monitoring procedure the satellite data can give some contribution, defining the requirements for EO products to be used.
A list of 'desired' EO products has been derived on the basis of the information gathered also through End-User involvement.
For each EO product, the specifics required by the users have been outlined in terms of spatial resolution, refresh rate, accuracy and latency with indication of minimal, optimal and 'threshold' values.
The feasibility of such requirements has then been investigated, evaluating the capabilities of the current and future EO missions and indicating the technological gaps and research necessities.

2.3 Satellite systems as information providers

The main objective of the pilot projects is to effectively improve the performances of the Civil Protection System, progressively increase the weight of satellites as routine providers of data.
In addition to the scientific and technical aspects, key criteria will be the sustainabilty of the proposed solution.
This important aspect will be jointly considered by SI and DPC with the aim to censure progressive operational use of EO derived information in accordance with progressive increase of the "space offer", by means of new satellite systems and availability of new products and services.
It is important to activate a sustainable approach that could start with quite few products and services and progressively improve the performances and the use of satellite EO data.

2.4 COSMO-SkyMed perspective

Concerning new satellite system sto come, there are high expectations for the COSMO-SyMed constellation (4 satellites with a X-band SAR as Payload, to be deployed in orbit between end of 2006 and end of 2008.
In general, the prevention and relief of natural disasters require the following characteristics:

- high spatial resolutions,
- high revisit time coupled with large spatial and spectral coverage, night/daylight and all-weather observations and
- the capability of very short response time and frequent revisit opportunities of a certain site.

Most of the user needs have to be carried-out through a correct mix of Optical and SAR sensor observations. The sensors should be based on multi-satellite Earth observation systems combined with a fast data reception capability. Such a provision of data on an operational basis with the associated implications of continuity and quality is an essential characteristic of the system.
COSMO – SkyMed, meet widely requirements of the risk management.

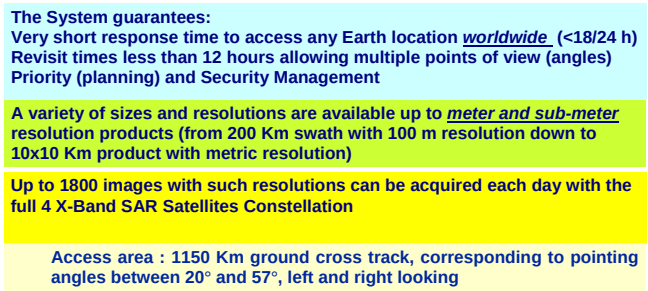

Figure 5. COSMO-SkyMed Overall performance

ASI aims to ensure the maximum use of COSMO-SkyMed, starting from the experience gained with already existents SAR missions (ERS, Envisat and Radarsat) and in the perspective to include other systems, whose access is ensured the cooperation

with France (the high resolution optical sensors of Pleiades) and Argentina (SAOCOM SAR L-band data).

3. DEVELOPMENTS FOR HYDROGEOLOGICAL RISKS MANAGEMENT

3.1 EO-based application for flood management

The pilot project for floods application foresees the development of following EO-based functionalities:

1. Emergency preparation (deferred time);
2. Monitoring and alert
3. Flood forecasting and local warning
4. Damage evaluation (early assessment and post crisis evaluation)

These main systems that integrate EO products and data into the existing operative procedures actually used by each CFR will be designed, developed and demonstrated, using EO products and data in the operative forecast chain.
The state of the art clearly highlights how, into the hydrological and hydraulic modeling system actually used by the CFRs, the EO data can fill the evident lacks of the processes representation and models initialization. As example we remind how at present hydrological modeling systems often lack of a suitable soil saturation conditions definition. This gap can adversely influence the flood forecast system taking the hydrological model to the wrong prediction. Real time updated maps of the vegetation index and of the soil moisture conditions like the ones produced from the EO data can strongly reduce this gap and the uncertainty of the prediction.
The hydraulic modeling systems need detailed surveys that can be expensive, not really updated and often not available. The high resolution images and the DTMs generated from the EO data can highly improve the availability of DTMs useful for the hydraulic modeling. The EO-products allow more frequent update of the products than the traditional techniques.
LAM forecast lead time is strongly affected by the quality of the initial and boundary conditions, derived by the analysis of observed data and GCMs outputs. Analyses based only on non-EO data, that are sparse in space and time, often are not as good as needed, enhancing the uncertainty associated to model forecasts. Assimilation of EO-based observations on LAMs introduces spatially distributed information that catch features of the meteorological patterns often missed by traditional observations. LAM forecasts with EO-data assimilation can have then longer lead-times and their use in CFRs operational chain can give operators longer lead time for warning issue
It is difficult for the CFR operators, to reliably evaluate what is going on during an event and how it'll be able to evolve, when the only information set available is represented by point values and traditional cartographic maps often not updated.
The high variability in space and time of the rainfall fields make the point-based estimates of the rainfall amount over a river basin and defined time interval affected by high uncertainties. Space and time rainfall observations both from satellite and ground-based rainfall radars can provide more reliable estimates of the rainfall field and then of the current and near-future hydrological conditions of river basins.
The synoptic point of view and the physical variables obtained from the EO-based thematic maps give the operators the possibility to improve their perception of the phenomena going on during the event and takes them to a more reliable prediction of the possible risks.

3.2 EO-based applications for landslide management

The pilot project for landslide application foresees the development of following EO-based functionalities:

5. Landslide identification and mapping;
6. Landslide monitoring
7. Susceptibility and risk modelling
8. Landslide warning, using operational models

These main systems that integrate EO products and data implements operative procedures in selected CFR, where at the moment a few landslides forecast and monitoring chains are operational.
The landslide phenomena represent a very complex problem that have to be analyzed in a multi-disciplinary scenario because of their diversity and variety of characteristics. In this context, the EO technologies can play a fundamental role because they may provide information and support the generation of algorithms and tools for the landslides identification, mapping and monitoring, which are essential steps for developing strategies for their prevention. However, we must also remark that, with the exception of the airborne photogrammetry, a full exploitation of the EO data is far to be achieved; in this case specific limitations and difficulties are represented by the available spatial and/or temporal resolutions of the actual sensors and by the limited expertise and EO data processing capability of the final users. In this sense a key effort is certainly needed in order to develop synergic actions between "EO technology developers" and the "end-users" community.

4. CONCLUSIONS

ASI and DPC have identified a clear approach to work together to develop and implement improved or new functionalities into the Italian Civil Protection System, exploiting opportunities and capabilities offered by satellite data and derived information.
The implementation will start within 2005, by progressive acivation of pilot projects relevant to different natural hazards, i.e. in the order they will be activated :

1. Hydrogeological – floods and landslides
2. Volcanic and seismic risks
3. Oil Spill
4. Forest fires.

In parallel ASI will develop its above mentioned Center of Competence for Earth Observation.
The temporal horizon for this first set of projects is 3 – years, however a stepped development and implementation of the new functions is being planned in order to achieve visible results as early as after one and a half year from the start. The latest steps will include what we think will be dramatic improvements tied to the entry into operation of the COSMO-SkyMed Constellation.

Building on what will be developed with DPC as reference User, ASI will progressively upgrade the Center of Competence in order to serve the needs of other Institutional Users,

We are strongly convinced that the approach selected is fully suitable to be scaled up at European and even at global level, mainly because of the applicability of its basic principles that are :

- Clear responsibilities at local and Central level, corresponding to respective tools and capabilities, with, during the actual emergency occurrence, a progressive shift towards the Center as quickly as the situation becomes so critical that is non longer manageable at local level
- Application of the Subsidiarity principle
- Presence of back-up capabilities at Central level
- Network of Competencies with shared products
- Modularity and growth potential of the System and easy implementation of new functions and competencies