Umbria Region Forecasting/Decision Support for Hydraulic Risk Mitigation Purposes

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ABSTRACT: Within the Italian national hydrometeorological early warning system, 21 regional offices (called "Decentralized Functional Centres" - CFD) are planned to be operative in few years. CFDs are coordinated by the Central Functional Centre (CFC) at the National Civil Protection Department (DPC) in Rome. The CFD belong to Umbria Region, in central Italy, is here presented. The Umbria CFD provides technical tools able to support decisions when significant flood/landslide events occur, furnishing 24h support for the whole duration of the emergency period. The alert system is based on a hydrometric and rainfall thresholds set of three different increasing critical levels according to the expected ground effects, together with a detailed procedure for the management of critical events in which the different role of various authorities/institutions involved is defined. For the real time flood forecasting system, several hydrological and hydraulic models were developed. Recently, in December 2008, a significant flood event occurred in Upper-Medium Tiber River catchment represented a significant "testing tool" for the CFD and the whole activities set up is here detailed.

1 INTRODUCTION

The interest towards accurate methodology and modeling for the flood risk evaluation and management is continually increasing, due to the serious flood events occurring more frequently in European regions. Compared to other European countries, Italy is one of the most flood risk prone areas and, more in particular, the Umbria region, in central Italy, is almost yearly affected by landslide and flood events at different scales.
Following recent laws and regulations concerning extreme natural events management, such as the national directive DPCM 27 February 2004 concerning the "*Operating concepts for functional management of national and regional alert system during flooding and landslide events for civil protection activities purposes*", within the Italian national hydrometeorological early warning network of Decentralized Functional Centres (CFD), the one belong to Umbria Region was created in 2006.

Due to its "linking" role between Civil Protection "real time" activities and environmental/planning "deferred time" ones, the Umbria Region CFD is in charge to acquire and collect both real time and quasi-static data: quantitative data from monitoring networks (hydrometeorological stations, meteo radar, ...), meteorological forecasting models output, Earth Observation data, hydraulic and hydrological simulation models, cartographic and thematic GIS data (vectorial and raster type), planning studies related to flooding areas mapping, dam managing plans during flood events, non instrumental information from direct control of "territorial presidium" (Provinces of Perugia and Terni, Reclamation Bureaus, other intermunicipalities offices).

The paper purpose is to present the activity of CFD of Umbria in terms of real time operating procedures for the flood risk mitigation.

2 UMBRIA TERRITORY

The Umbria Region (8500 km^2) is crossed from the Upper-Medium Tiber River. The Tiber River is one of the most important Italian river (the third for length and the second for watershed extension) getting the capital city, Rome. The Upper-Medium Tiber basin (12700 km^2) presents a complex topography, mainly hilly/mountainous with elevation ranging from 50 to 2500 m a.s.l.. It is mainly characterized by terrigeneous facies and flysch deposits consisting of clayeyschistose and clayey-marly sediments; the 53.6% of the total watershed area is covered by agriculture/arable land, the remaining area is 39.2% forest and 4.7% urban.

The Tiber River basin's precipitation regime, based on monthly rainfall distribution for year, can

be classified as a sub-coastal precipitation regime. Higher monthly precipitation values generally occur during the autumn-winter period and floods, caused by widespread rainfall, normally occurred.

Mean annual precipitation is about 1000 mm; mean annual temperature is 11°C; snowfalls at altitude below 500 m are unusual.

The territory is covered by a real time hydrometeorological network (1 station every 150 km^2) operating for more than 20 years. Nowadays the system is made up by 120 stations (72 hydrometers, 85 rain gauges, 74 weather stations, 12 Radio repeaters, 1 Meteoradar).

3 SYSTEM DESCRIPTION AND PURPOSES

The Umbria Region CFD alert system is based on hydrometric and rainfall thresholds of three different critical levels according to the expected ground effects (ordinary, moderate and high), along with with a detailed procedure for the management of critical events in which the different role of various authorities/institutions involved has been defined. The alert system is referred to 6 different warning areas in which the territory has been divided as shown in Figure 1.

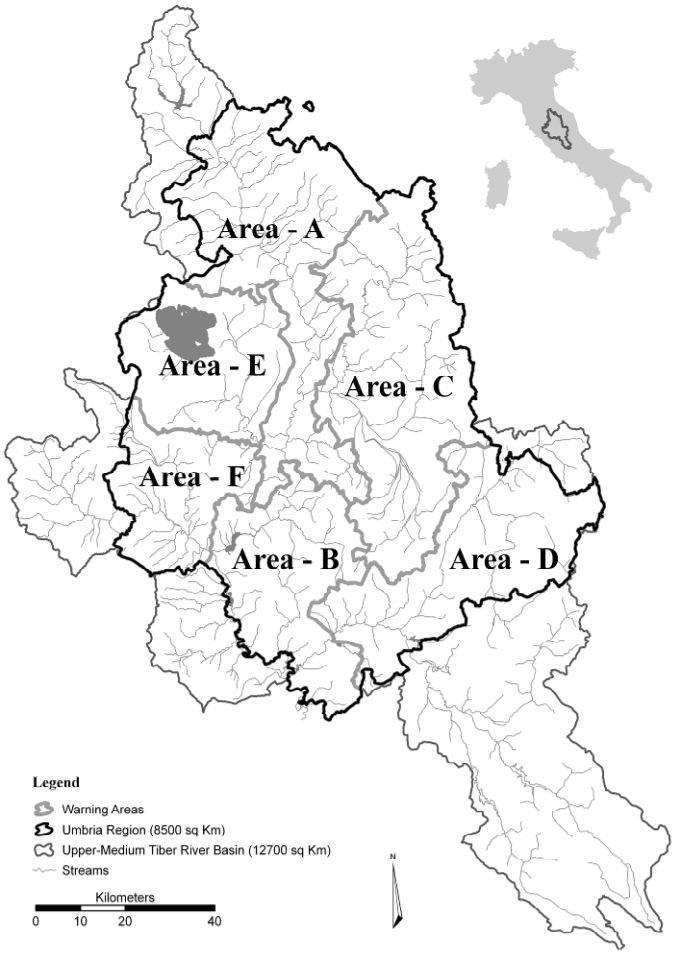

Figure 1. Umbria Region: Upper-Medium Tiber River basin and warning areas.

The Upper-Medium Tiber River basin includes also regional trans-boundary areas with issues very important to cope, especially in terms of large dams behaviour and their management during heavy rainfall.

A pre-adopted *Flood attenuation plan by dams* was defined in order to assess the best conditions of upstream water storage for flood attenuation purposes (through the surplus disposal works management), both in a static way (fixed volume) and dynamic way (releases from outlets in according to the real time upstream conditions) preserving downstream areas. This plan involves the National Civil Protection Department along with the Tiber River Basin Authority, the Umbria, Toscana and Lazio Regions involved, dams management companies, National Dams Service.

3.1 *Alerting thresholds*

As previously mentioned, hydrometric and rainfall thresholds for floods and landslides alarms were assessed.

For water levels a simplified procedure was developed in order to estimate three increasing values for hydrometric thresholds (considering catchments with spatial extension wider than 400 km^2):

- *Attention*: corresponding to a ordinary critical level useful to the “warm up” period of the emergency office (evaluated through a statistical regression of ordinary events with 1 year recurrence interval);
- *Pre-Alarm*: corresponding to a moderate critical level and it allows a mean period of at least 1 hour before arriving to the successive critical level, also in case of minor streams;
- *Alarm*: corresponding to an high critical level (effective high risk situation) which requires to undertake civil protection actions. The monitoring network shows high intensity rainfall in the same river basin of the automatic hydrometrical station where this threshold is exceeded. This water level allows almost 3 hours before the real flooding.

Previous values were assessed from the hydrometric thresholds corresponding to over-bank flow to flood prone areas.

For the rainfall both local and areal thresholds are defined, for landslide and flooding risks respectively. Values were established considering the regional rainfall frequency analysis procedure proposed in the VAPI Project (CNR-GNDCI 2000a, b). The three rainfall threshold levels are evaluated considering different return period (2, 5 and 10 years).

The defined hydrometric and rainfall threshold values require continuous updating based on new data acquisition and on the improvement of the scientific/technical knowledge.

Based on these thresholds, at the Umbria Region CFD an automatic phone-call and SMS alert system is operating.

3.2 *Alerting procedures*

Based on previous mentioned thresholds CFD forecasts and management activities for a severe event are organized into three different phases:

1. *Forecasting (Pre-event)*
2. *Event*
3. *Post-event*

During the Forecasting period three conditions are possible depending on the weather forecast and the expected ground effects: Normality (no expected ground effects), Pre-Alert (expected ordinary ground effects) and Attention (expected moderate/high ground effects) states. In these phases a continuous monitoring is guaranteed by the 9h/day office activities and a 24h remote controller (laptop and pda devices with VPN links).

During the Event phase, if moderate or high rainfall/hydrometric thresholds are exceeded, Pre-Alarm and Alarm conditions are respectively formally adopted and CFD office starts 24h opening.

Finally, during the Post-event phase CFD guarantees support until the end of critical condition is reached.

Each phase has detailed subdivisions of roles among different authorities and subjects involved and is defined by bulletins/advices emanation and adoption; CFD provides continuous decision support for national/regional Civil Protection offices and territorial presidium.

In Figure 2 the CFD synthetic procedures flowchart for the Pre-event and Event phases is shown.

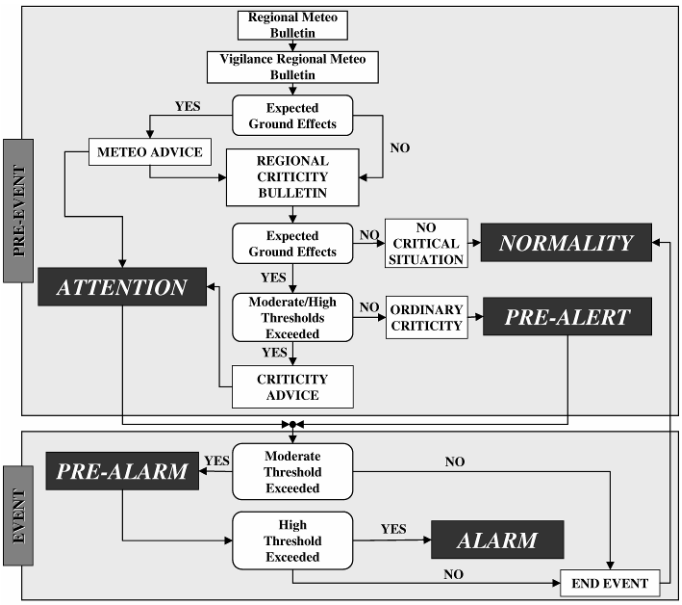

Figure 2. CFD procedures flowchart for the Pre-event and Event phases.

3.3 *Hydrological and hydraulic models*

For the real time flood forecasting system, at the CFD several hydrological and hydraulic models are operating.

Three rainfall-runoff hydrological models, using different quantitative meteorological forecasts (QPF), are available: the event based models *X-Nash* and *Mike-DRiFt* (DHI, 2001), the latter coupled with the hydraulic model *Mike-11* (DHI, 2001); and the physically-based continuous model *MOBIDIC* (Distributed and Continuous Model for the Hydrological Balance) developed by the Florence University in cooperation with the CFD of Tuscany Region (Campo et al. 2006, Castelli et al. 2006).

The X-Nash and Mike-DRiFt models were performed for the Upper-Medium Tiber River catchment (1800 km^2), instead the MOBIDIC model was developed for the three basins covering almost the whole Umbria territory.

Two further hydrological models, using observed data by the real time hydrometeorological network, were implemented; the first one is an event based semi-distributed rainfall-runoff hydrological model developed using the freely available platform *Hec-HMS* (USACE, 2000) chosen because of its flexibility and it was developed for the three basins. For a more accurate evaluation of the antecedent moisture condition of sub-basins, which is a key factor for a correct runoff volume evaluation (Brocca et al. 2009, Brocca et al. 2008), a continuous soil moisture model was developed. The Hec-HMS model is also coupled with the hydraulic model *Hec-RAS* (USACE, 2008) performed for the Upper-Medium Tiber River branch (Berni et al. 2008, Berni et al. 2009). The second model is the routing hydrological model *STAFOM* (STAge FOrecasting Model) developed by the Italian Research Institute for Geo-Hydrological Protection of the National Research Council (IRPI-CNR) (Barbetta et al. 2008, Moramarco et al. 2006). This model is an adaptive model for on-line stage forecasting for river branches where significant lateral inflow contributions occur based on Muskingum method. Up to now, it is implemented for the main Tiber River branch and it allows a forecasting lead time up to 10 hours for the downstream river section.

The hydrological - 2D hydraulic model *FLO-2D* is also used at the Umbrian CFD for “off line” flood mapping where risk assessment studies are not available.

In Figure 3 the scheme of the hydrological and hydraulic models implemented at the Umbria CFD is shown.

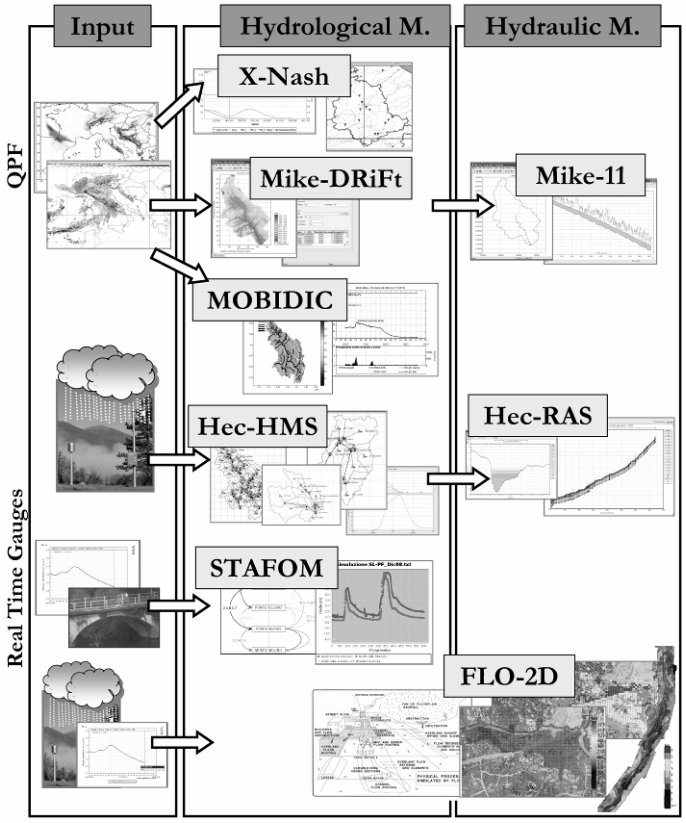

Figure 3. Hydrological and hydraulic models implemented at the Umbria CFD.

3.4 *Web-based operational decision support tool: www.cfumbria.it*

Umbria Region CFD was able to set up, in cooperation with Tuscan CFD, an entirely "open source" web platform (PHP and MySQL codes), for real time data and information exchange with all the administrations and subjects involved (different levels of policies through user id and password), bulletin/advices dissemination, modeling predictions, etc. Website (Fig. 4) is accessible from PC, Laptop, PDA devices and all the equipment able to connect to the internet.

www.cfumbria.it website is able to publish the following sections (for advanced users/institutional subjects):

- Meteorological qualitative and quantitative predictions (QPF) for next 72 hours;
- Updated Bulletins/Advices and formal documents;
- Meteosat Second Generation images;
- Lightening maps;
- Real time hydrometeorological data (rainfall, hydrometric levels, computed discharges, winds direction and velocity, barometric values, etc.) compared to thresholds;
- Statistics and reports of passed extreme events;
- Soil moisture punctual/areal values and maps (soon);
- Meteo radar maps;
- Hydrological and hydraulic modeling outputs;
- Alarm zones interactive description;
- Monitoring network details;
- Links to Umbria Region web-GIS tools;
- Etc..

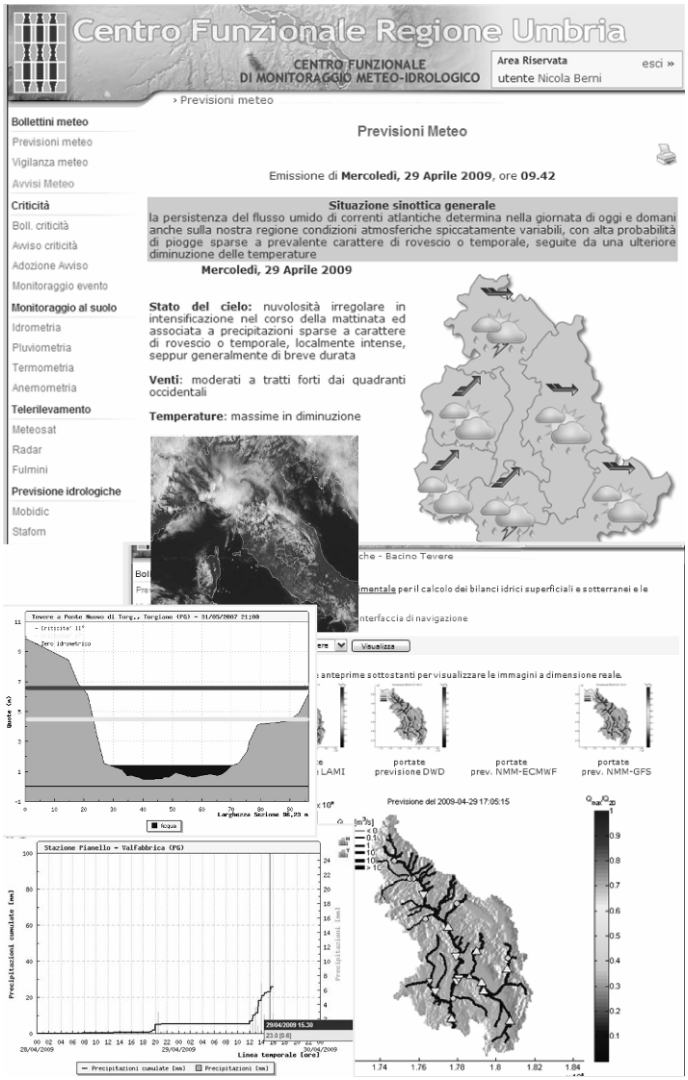

Figure 4. Website www.cfumbria.it: main Umbrian CFD operating platform for decision support activities.

4 CASE STUDY

Recently, during the period on 4th to 16th December 2008, Umbria territory was interested by a significant rainfall event causing many floods and landslides. The mean areal recorded rainfall depth was over 100 mm all over the major-minor Tiber River catchments (10 years return time period) (Fig. 4) and almost every branch of Umbria hydrographic network was involved, especially the Tiber River (Fig. 5), Sovara and Cerfone Streams (2-10 years return time period approximately).

A day before the intense rainfall Attention state was formally adopted and during the event the Pre-Alarm and Alarm conditions were also declared.

Analogously for the major flood event occurred on 2005, dams played a very important attenuation role also for interregional trasboundary issues: Montedoglio dam (Tuscany) stored all inflows, Casanuova dam (Umbria) stored part of inflows with its controlled bottom outlets, Corbara dam (Umbria,

close to Lazio administrative border) avoided Rome flooding, especially thanks to a real time application of STAFOM hydrological model and HEC-HMS+RAS model system (Fig. 6).

During the mainly critical phases CFD furnished 24h decision support for the national/regional Civil Protection offices. The official web site (www.cfumbria.it) represented a very useful device furnishing good performances for the monitoring and data dissemination to all the subjects involved.

Hydrometric and rainfall thresholds were finally "tested" presenting good accordance with surveys and automatic alerting system was very effective.

Real time hydrological and hydraulic models produced preliminary but encouraging results, allowing also a better understating about their main performances and limits.

During the flooding event a continuous contact with the National Department, regional Civil Protection offices, territorial presidium and local public services, along with real time monitoring and nowcasting hydrological activities performed by available models, represented a suitable link between practice and science in CFD operational forecasting system at local, regional and national scale.

No casualties were registered during the emergency period. After the post-event recognitions economical losses around 100 millions of euros were estimated.

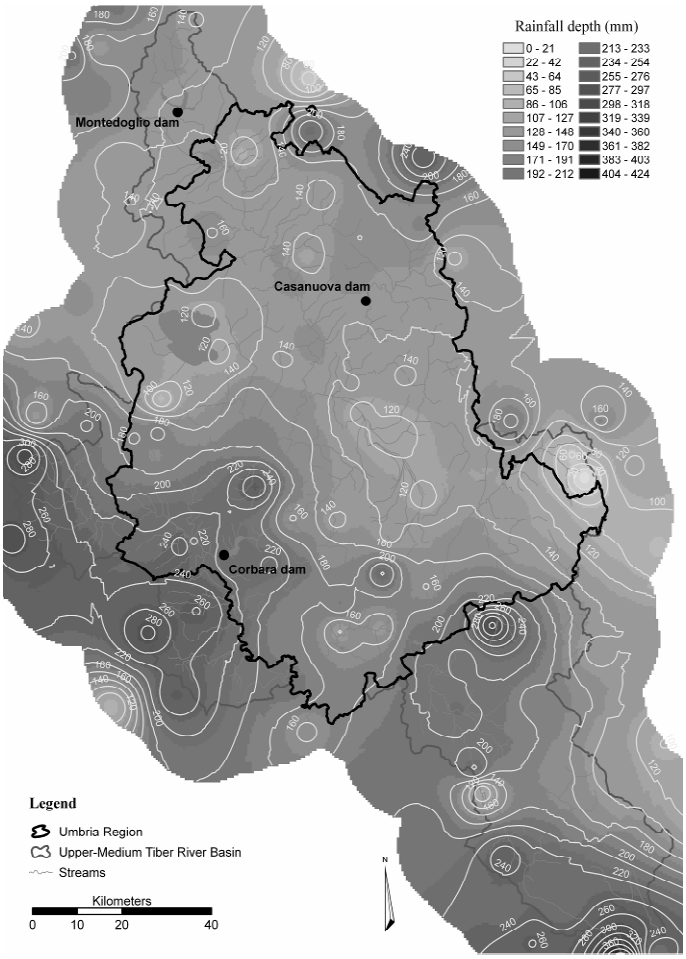

Figure 4. December 2008 event: rainfall depth for the Upper-Medium Tiber River basin, also the dams location is shown.

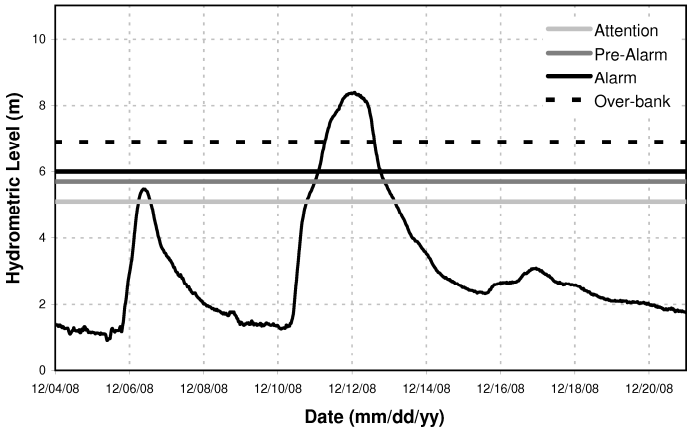

Figure 5. December 2008 event: hydrometric level and thresholds at Monte Molino section.

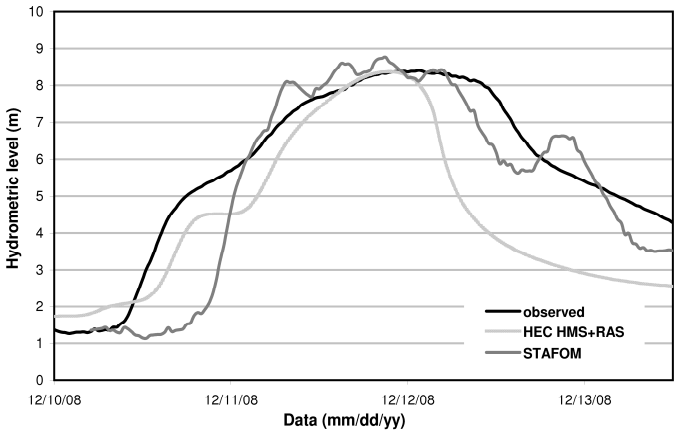

Figure 6. December 2008 event: observed and simulated hydrometric levels with Hec-HMS+RAS and STAFOM models at Monte Molino section.

5 CONCLUSIONS AND CHALLENGES

The December 2008 event showed that the Umbria Region Functional Centre was able to provide a reliable decision support to Civil Protection activities at local, regional, interregional and national scales.

Open source www.cfumbria.it website represented a very good operational tool as first source of information for all the administrations/subjects involved. For this reason, all the available models outputs (also for a remote control of ground effects prediction) are going to be implemented inside the website.

Territorial presidium played a fundamental role providing non instrumental/on-site direct information; although they need to raise funds for empowering their contribution.

However, some overlapping of competencies of different administrations are still going on; this situation can generate confusion and conflicts about different subjects roles: for example, local government offices still need to clear their role during emergency phases.

In spite of the hydrological and hydraulic models produced preliminary good results, predictions uncertainty assessment procedures, coupled with real time dynamic risk scenario definition and visualiza-

tion (possibly coupled with Web-GIS tools) would add extra value to the whole alerting and decision support system.

REFERENCES

Autorità di Bacino del Fiume Tevere (ABT) 2005. *Tevere, pilot river basin article 5 report*. Gangemi Editore, Roma, 17-39.

Barbetta, S., Brocca, L., Melone, F. & Moramarco, T. 2008. On the lateral inflows assessment within a real-time stage monitoring addressed to flood forecasting. In M. Sànchez-Marrè, J. Béjar, J. Comas, A.E. Rizzoli, G. Guariso (Eds.), *Proceedings of the iEMSs Fourth Biennial Meeting: International Congress on Environmental Modelling and Software (iEMSs 2008)* International Environmental Modelling and Software Society, Barcelona, Catalonia: 438-445.

Berni, N., Viterbo, A., Pandolfo, C., Stelluti, M., Barbetta, S. & Brocca, L. 2008. Effects of rainfall and soil/land use spatial distribution on hydrological response at different scales. In: M. Sànchez-Marrè, J. Béjar, J. Comas, A.E. Rizzoli, G. Guariso (Eds.), *Proceedings of the iEMSs Fourth Biennial Meeting: International Congress on Environmental Modelling and Software (iEMSs 2008)*, International Environmental Modelling and Software Society, Barcelona, Catalonia: 470-477.

Berni, N., Brocca, L., Giustarini, L., Pandolfo, C., Stelluti, M., Melone, F. & Moramarco, T. 2009. Coupling hydrologic and hydraulic modelling for reliable flood risk mitigation activities in the Upper-Medium Tiber River basin. Geophysical Research Abstracts vol. 11, *European Geosciences Union General Assembly 2009, Vienna, Austria, 19–24 April 2009*.

Brocca, L., Melone, F. & Moramarco, T. 2009. Assimilation of observed soil moisture data in storm rainfall-runoff modelling. *J. Hydrol. Eng.* 13 (2): 153-165.

Brocca, L., Melone, F. & Moramarco, T. 2008. On the estimation of antecedent wetness condition in rainfall-runoff modelling. *Hydr. Proc.* 22 (5): 629-642.

Campo, L., Caparrini, F. & Castelli, F. 2006. Use of multi-platform, multi-temporal remote-sensing data for calibration of a distributed hydrological model: an application in the Arno basin, Italy. *Hydr. Proc.* 20 (13): 2693-2712.

Castelli, F., Menduni, G., Caparrini, F. &. Campo, L. 2006. A distributed package for sustainable water managment: A case study in the Arno basin. In: *XXX Convegno di Idraulica e Costruzioni Idrauliche IDRA2006; Proc. intern. symp., Rome, 10-15September 2006*.

Danish Hydraulic Institute (DHI) Water & Environment MIKE11 2001. *A Modeling System for Rivers and Channels Reference Manual*. Horsholm, Denmark.

Moramarco, T., Barbetta, S., Melone, F. & Singh, V.P. 2006. A real-time stage Muskingum forecasting model for a site without rating curve. *Hydrol. Sci. J.* 51(1): 66–82.

National Research Council – Gruppo Nazionale per la Difesa dalle Catastrofi Idrogeologiche (CNR-GNDCI) 2000a. Sintesi del rapporto regionale nei bacini delle sezioni idrografiche di Roma e Pescara, In: Rapporto di sintesi sulla valutazione delle piene in Italia. Available at http://www.idrologia.polito.it/~GNDCI/Vapi.htm

National Research Council – Gruppo Nazionale per la Difesa dalle Catastrofi Idrogeologiche (CNR-GNDCI) 2000b. Sintesi del rapporto regionale per i compartimenti di Bologna, Pisa, Roma e zona emiliana del bacino del Po. In: Rapporto di sintesi sulla valutazione delle piene in Italia. Available at http://www.idrologia.polito.it/~GNDCI/Vapi.htm

U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC) 2000. *Hydrologic Modeling System HEC-HMS: Technical Reference Manual*. CPD-74B. U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, CA. Available at http://www.hec.usace.army.mil/software/hec-hms/documentation/CPD-74B_2000Mar.pdf

U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center 2008. *HEC-RAS River Analysis System Hydraulic Reference Manual*. CPD-69. U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, CA. Available at http://www.hec.usace.army.mil/software/hec-ras/documents/HEC-RAS_4.0_Reference_Manual.pdf