Meteorological and Climate Forecasting for Landslide Prediction

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Introduction and Motivation of Work

The aim of the presentation is to show the results obtained during the first two years of research activity of the work group 2 "Impacts on territory monitoring activity and hydrological risk prevention" of the Division "Impact on soil and coast" (I.S.C) in the framework of the project Euro-Mediterranean Centre for the Climate Change (C.M.C.C.).

The CMCC is a structure of scientific research with the aims to deepen knowledge on the climate variability, its causes and its consequences, this is done by providing models, simulations, middleware, application software and high quality personnel training, both in the specific field of climate dynamics and computer technology. The CMCC uses these simulations directly to effect studies of climate change impact on the economy, on agriculture, on sea and earth ecosystems, on coastal zones and health. All these research activities are developed by its six divisions, each one devoted to specific issues relating to the themes of climate change.

The work group 2 of the I.S.C. division has as its main goal the study and the development of models, algorithms and software for the analysis of landslides related to extreme meteorological events. Interest in these events occurs, especially in recent years, for a gradual increase in hydrogeological phenomena of failure. As shown in several studies, the causes of such disasters must be sought both in the changing climate and in an increasingly intensive exploitation of the territory (spreading urbanisation, funnel of rivers, intensive agriculture and so on).

The hydrogeological phenomena of interest are generally described (basin and/or slope scale) and so the tools for prediction and prevention require not only the development and the optimization of ad hoc numerical codes (accurate, robust, efficient), but also to couple the meteorological model with models evaluating impact of such phenomena on the soil (i.e. hydrological models), both at high resolution. The main result expected in this framework is a numerical simulation instrument to permit an early warning for hydrological instability phenomena (landslide, flood) connected to meteorological events. An innovative aspect of this activity is that the research work is developed by a multidisciplinary team; this permits to face the issues from different points of view and to introduce, through the integration and comparison between different skills, new methodologies producing optimums for simulating phenomena of a different nature (thunderstorm, landslide or floods).

This result has been obtained by realizing the "hydrometeorological simulation chain"; the numerical tool defined for the prediction and prevention of some type of hydrological disasters. All the tools defined in the chain are optimized to produce scenarios in less than half a day. In the future, then, this research tools will be available to the end users (civil protection and so on) to warn the people.

The Hydrometeorological Simulation Chain

Different components contribute to the definition of chain; a brief description of them follows.

The first simulation model of the "chain" is represented by the Numerical Weather Prediction (NWP); the code choice is essential for the weather forecasting quality and then for the evaluation of the hydrological calamities. The NWP model selected for this application is the COSMO-LM model [1] [2], this is the regional numerical model operatively used in Italy, and in many other European countries, to forecast mesoscale-phenomena; different numerical schemes and physical parameterization are available in the model and, depending on the application, different configurations can be defined. Two versions of the model are available: one with 7 km of horizontal resolution and forecast range up to 72 hours, running operatively all over the country, and a second one, pre-operative, with 2.8 km of horizontal resolution and up to 18 hours of forecast time range with a smaller spatial domain. Preliminary work has been done to find the optimal configuration to specialize the two COSMO-LM versions (7 km and 2.8 km) for the simulations of extreme meteorological events on the Mediterranean area. This last topic requires, in particular, a detailed study of precipitation, soil-atmosphere interaction and soil infiltration, runoff, and transpiration/evaporation. Different NWP models are used in the "chain": a limited area version model with a horizontal resolution of 2.8 km is nested on the one covering a bigger area with 7 km of horizontal resolution. This last one is nested on a global model, in our application this last one is represented by the IFS model running at ECMWF [3] [4], performing weather forecast all over the globe. This two-step nesting is necessary to guarantee the best quality of the forecast produced (in fact, a resolution of 2.8 km is more able to take into account the effect produced by a complex orography) but also to permit a smaller resolution jump among the NWP model and the others cascade simulation models; nevertheless this requires very long computational time; for this reason very efficient and powerful super computers are available to CMCC permitting to produce the scenarios for the different risks in less than half a day.

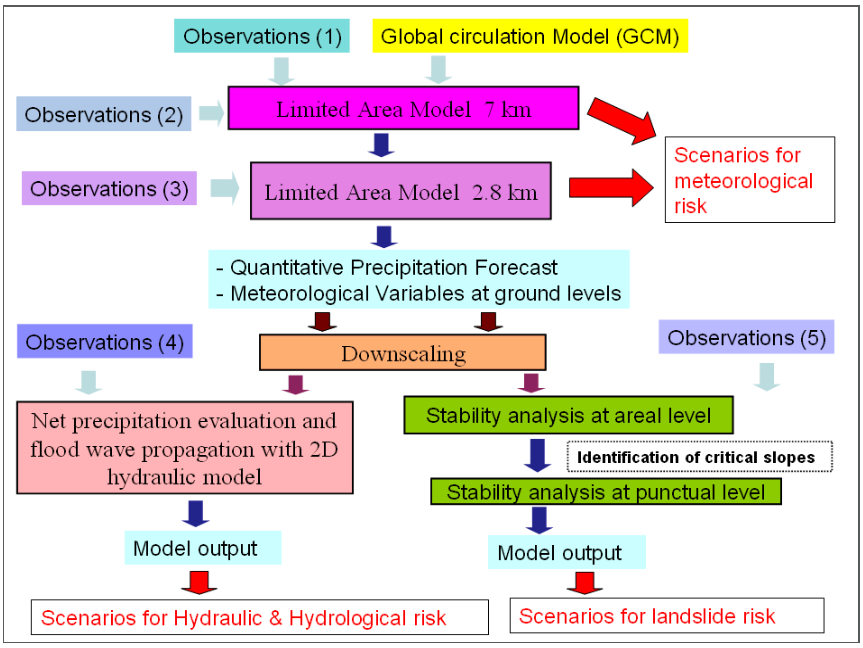

Fig. 1: Flow chart of the hydrometeorological simulation chain.

Taking into account the very high resolution required for the landslide simulation models and the impossibility to use higher resolution than 2.8 km for the limited NWP models, the opportunity has also been investigated to use statistical downscaling techniques to interface the models; this permit to have a smaller discontinuity and then more coherence in the results. It is important to emphasize that the coupling among the models is obtained through the precipitation fields and other soil properties; in particular, the precipitation is a discontinuous variable, depending strongly on orography and soil properties, then the downscaling algorithms also have to consider all these factors. About the landslide models, in order to produce risk scenarios on slopes, it has been decided that it is more useful to use a one-step nesting technique; this means that precipitation information are used to initialize a stability simulation model working on area level; this first step permits a preliminary individuation of the critical slopes, then, this information is used to perform a more precise investigation only on these last slopes through a more complex simulation model for the stability analysis at punctual level. The outputs of this study are scenarios for the landslide risks on areas affected by intense rainfall.

The Performed Test Cases

The hydrometeorological simulation chain has been tested on three test cases found in the Campania region, located in southern Italy. This area is frequently subject to landslides, some initialized by precipitation (this special type of landslide will be investigated). The first two test cases happened at the Camaldoli site, located near Naples. The first one occurred on 18^{th} of September, 2005, after a thunderstorm in which 70 mm of rain was observed in 30 minutes; the second one occurred on 13^{th} of October, 2004, after about 47.6 mm of rain in 24 hours. The third event occurred at Nocera site, located about 30 km south of Naples, on 4^{th} of March, 2005, in which about 200 mm of rain was measured in less than 1 day.

Conclusions

This work describes the results obtained by applying the hydrometeorological simulation chain, defined by a multidisciplinary team working in the CMCC, on some test cases, located in southern Italy, in which the landslides were initialized by intense precipitation. The test cases permit to compare the results (risks scenarios) predicted by the numerical simulations and those that were observed during the events. This activity is necessary to assess the predictive power of the defined simulation chain and to understand its limits and then make some improvements.

The same approach is under development applied to climate change. In this case a coupling between climate regional models together with landslide models will allow the evaluation of how it will change the landslide risk according to the increase of precipitation events foreseen in some specific areas according to the new climate scenario.

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