HEURISTIC NOWCASTING OF OROGRAPHIC PRECIPITATION

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Abstract: Real-time radar wind and precipitation fields may be used for nowcasting the location and the time evolution of extreme orographic precipitation (EOP) events in the Alps. As a result of the strong orographic forcing heavy precipitation is often persistent over several hours and exhibits typical spatial patterns. These features are related to the meso-scale wind, whose direction and intensity determine the lifting of the air masses over the orography and then influence the spatial and temporal precipitation patterns. As a consequence of this relation, a significant variation in direction or intensity of the mesoscale wind field may constitute a short-term precursor of a change in the location and intensity of the heavy orographic precipitation.
The paper presents the concept and preliminary results of a novel heuristic system for nowcasting development and evolution of heavy orographic precipitation in the Southern Swiss Alps. The wind and precipitation estimates are performed using real-time measurements from the MeteoSwiss radar network.

Keywords: Nowcasting, Orographic Precipitation, Radar.

1. INTRODUCTION

The prediction of the location, the onset and the let-up time of extreme orographic precipitation (EOP) embedded in frontal passages is a difficult task, especially in an operational weather centre where high precision forecasts are needed and fast decisions have to be taken.

The atmospheric models are the main source of information in forecasting extreme precipitation. Due to constraints in resolution and time, they are used together with a number of observational systems if short range forecasting (3-9 hours) is required. During EOP events, however, there is often the need of forecasting the precipitation for very short time period, also less than 3 hours ahead. In fact, this is the typical time period for which specific predictions are asked to the forecaster by the institutions, which have to take concrete decisions for civil protection activities. In these cases the radar measurements constitute the main source of information, because they are available every few minutes with high spatial resolution. In particular, the recent improvements in radar rainfall estimation of the MeteoSwiss radar products (Germann *et al.*, 2006) enable their use for operational nowcasting.

In this paper we present a proof of concept of a novel heuristic system for nowcasting the development and the evolution of EOP in a mountainous region using real-time wind and precipitation measurements from the MeteoSwiss radar network. The heuristic approach allows us to train on a large set of past EOP events, and to optimize the system respect to one specific user defined parameter of particular importance in the hydro-geological risk management under consideration.

2. THE CONCEPT

In a mountainous region, such as the European Alps, simple extrapolation of radar precipitation maps for nowcasting heavy rain is not successful, because the mountains strongly influence the motion of air masses and then the development of precipitation. However, we may benefit from this strong orographic forcing, since EOP is often persistent over several hours and exhibits distinct spatial patterns. In fact, these particular features are strictly related not only to the thermodynamics conditions, but also to the mesoscale wind field. This is one of the major results of the Mesoscale Alpine Programme (MAP). Houze *et al.* (2001), for instance, show by means of a composite analysis of wind and precipitation measurements of Monte Lema radar relative to autumn 1998 and 1999 that the location of the maximum of orographic precipitation in the Lago Maggiore region is closely linked to the mesoscale wind, in particular to the strength and direction of the low-level flow from the Po valley towards the Alps. Moreover, Georgis *et al.* (2003) found that in this area the most of precipitation during the MAP IOP (Intensive Observing Period) 2b precipitation event occurred when the easterly component of the lower level wind was the strongest. This strong correlation is confirmed also by Asencio *et al.* (2003) and Medina and Houze (2003). However, also the upper level southerly winds play a fundamental role in determining the precipitation events in the Lago Maggiore region, as highlighted by Georgis *et al.* (2003) and Rotunno and Ferretti (2003).

Supported by these findings, which are organically resumed in Rotunno and Houze (2007), the intensity and direction of the mesoscale wind field can be used as short-term indicators for nowcasting the location, the intensity and the timing of the heavy orographic precipitation in an operational context.

As already mentioned, a typical configuration for heavy precipitation in the Lago Maggiore region in the Southern Alps is a moist low-level inflow from south to south-east and an upper-level flow from south-west to south. In order to detect the characteristic components of the meso-scale wind field, we estimate the wind intensity and direction at different vertical levels and in specific areas. In particular, we estimate the low-level flow (LLF) over the Po Valley between 1.5 and 2 Km in height, the cross-barrier flow (CBF) just south of the Alpine crest between 2.5 and 3.5 Km, and the upper-level flow (ULF) in a wide circle over the radar site between 5 and 6 Km. The location of these three areas in which the Doppler velocity data are considered and then these flows are estimated is shown in Fig. 1a, whereas their vertical extension is represented in Fig.1b.

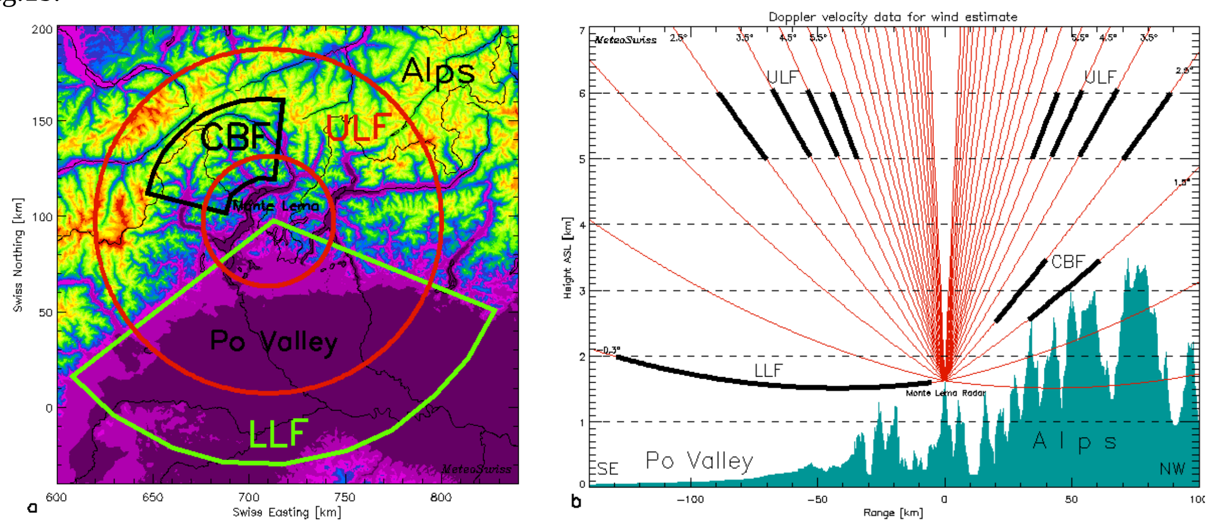

Figure 1: (a) Location of the three areas in which LLF, CBF and ULF are estimated; Monte Lema radar is at the centre of the picture. (b) Vertical cross section showing the 20 elevation angles of Monte Lema radar scan strategy (red lines) and the regions selected for the estimate of the three flows (thick lines).

3. DATA AND METHODS

The radar data are collected by the MeteoSwiss radar of Monte Lema, located on one of the southern-most mountains of the Alpine ridge in the Lago Maggiore region (see Fig. 1a). Information on precipitation is obtained by the operational radar product for quantitative precipitation estimation, which is the result of sophisticated data processing based on 40 years of experience in radar operation in the Alpine environment at MeteoSwiss (Germann *et al.*, 2006; Joss and Lee, 1995). It has 1Km×1Km spatial resolution and it is available every 5 minutes. The wind is estimated by the Doppler velocity measurements, which are performed over 20 elevation angles (see Fig. 1b) and are updated every 5 minutes with a spatial resolution of 1 degree in azimuth and 1 Km in range (Joss *et al.*, 1998). These data are dealiased using the four-dimensional Doppler dealiasing scheme developed by James and Houze (2001).

LLF, CBF and ULF intensity and direction are estimated by fitting a linear wind to all valid Doppler measurements within the pre-defined regions shown in Fig. 1a. Fitting is done with least-squares and Cholesky matrix decomposition. In some cases it is not possible to estimate these values for a number of reasons, which range from missing radar data to a small number of echoes for each azimuth or very narrow azimuthal arc with echoes which caused unsuccessful fitting.

The estimated precipitation data are averaged for various geographical areas of the Southern Alps, in order to detect the different spatial distribution of the rain which is typical of orographic precipitation.

4. PRELIMINARY RESULTS

In this section two events of EOP observed in the Lago Maggiore region (3 October 2006 and 1-2 August 2005) are briefly analysed with the methodology described in the previous paragraph. These are very first results and both the methodology and the interpretation will be refined in near future, and many more cases will be analysed.

In the first hours of 3 October 2006 a small low pressure system developed in the lower levels over the Bay of Biscay, and in the following period it moved north-eastwards. It was associated with an upper level trough over Western Europe and with a surface cold front which crossed the Alpine barrier in the afternoon. In the Lago Maggiore area precipitations were measured since the morning, for the lifting of the air mass over the Alpine slopes driven by southerly winds. The frontal passage caused in the afternoon the most of rain,

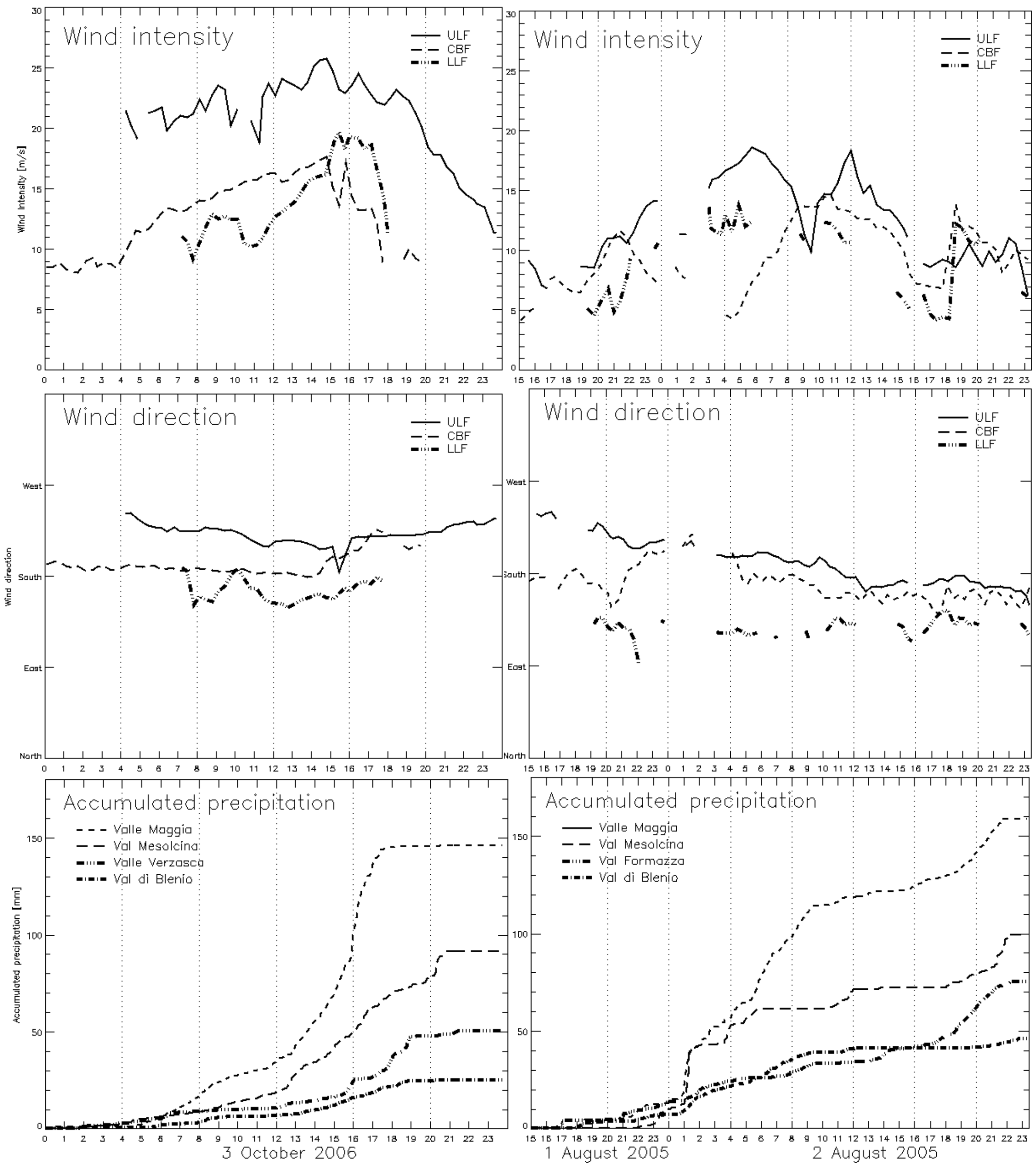

Figure 2: ULF, CBF and LLF intensity and direction and precipitation accumulated in four Alpine Valleys for 3 October 2006 (left column) and 1-2 August 2005 (right column) EOP events.

and some exceptional accumulations were measured as, for example, 78.4 mm/1h in Locarno-Monti (390 m asl) and 196.7 mm/24h in Brissago (200 m asl).

The left column of Fig. 2 shows the ULF, CBF and LLF intensities and direction, and the accumulated rain estimated for four Alpine Valleys near Lago Maggiore. Even though it was not possible to estimate the wind for long periods of time, due to missing or bad data, some significant features can be noticed. There appears to be a significant relation between LLF and CBF intensities and the rain rates: during the most intense phase of precipitation both these flows reached the largest intensity. The general diminution of the wind intensity, in particular of CBF, which anticipates the end of the rain is of particular interest for nowcasting purposes. On the other hand, the rain rate variations appear to be less related to the ULF intensity changes. Only the direction of the CBF changed significantly during the precipitation event, in particular from S to SW, in correspondence with its decrease of intensity.

On 1 August 2005 a cold front associated with a broad upper level trough over Western Europe was located in proximity of the Alps. It remained stationary for more than 24 hours and it left the Alpine region only in the evening of 2 August. In the Lago Maggiore region the most of precipitation was measured on 2 August, with total rainfall accumulation as large as 106 mm/24h (Locarno-Monti, 390 m asl). The right column of Fig. 2 shows the LLF, CBF and ULF intensity and direction and the accumulated precipitation for four Alpine Valleys. The most significant feature is the strong increase in the intensity of the flows measured at the beginning of the last phase of precipitation, between 18 an 19 of 2 August.

5. CONCLUSIONS

In this paper we described the concept and the methodology of a novel heuristic system for nowcasting heavy orographic precipitation in mountainous environment. We believe that the strong orographic forcing may be an help in forecasting extreme precipitation, because it determines the presence of typical spatial and temporal pattern in both precipitation and wind fields.

We showed preliminary results from the analysis of two historical cases, which prove that changes in rain rate are accompanied by significant variation in the mesoscale wind field.

However, our analysis has to be improved in the methodology and extended to a large set of past events, in order to identify typical signals in the meso-scale wind field and then to provide probabilistic information which can be operationally used for nowcasting.

We plan to consider in the future also thermodynamical aspects, in order to take into account also the stability of the air masses which may constitute a further help in forecasting EOP events.

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