Forecast for the 1994 flood in Piedmont: performance of ensemble system at high resolution

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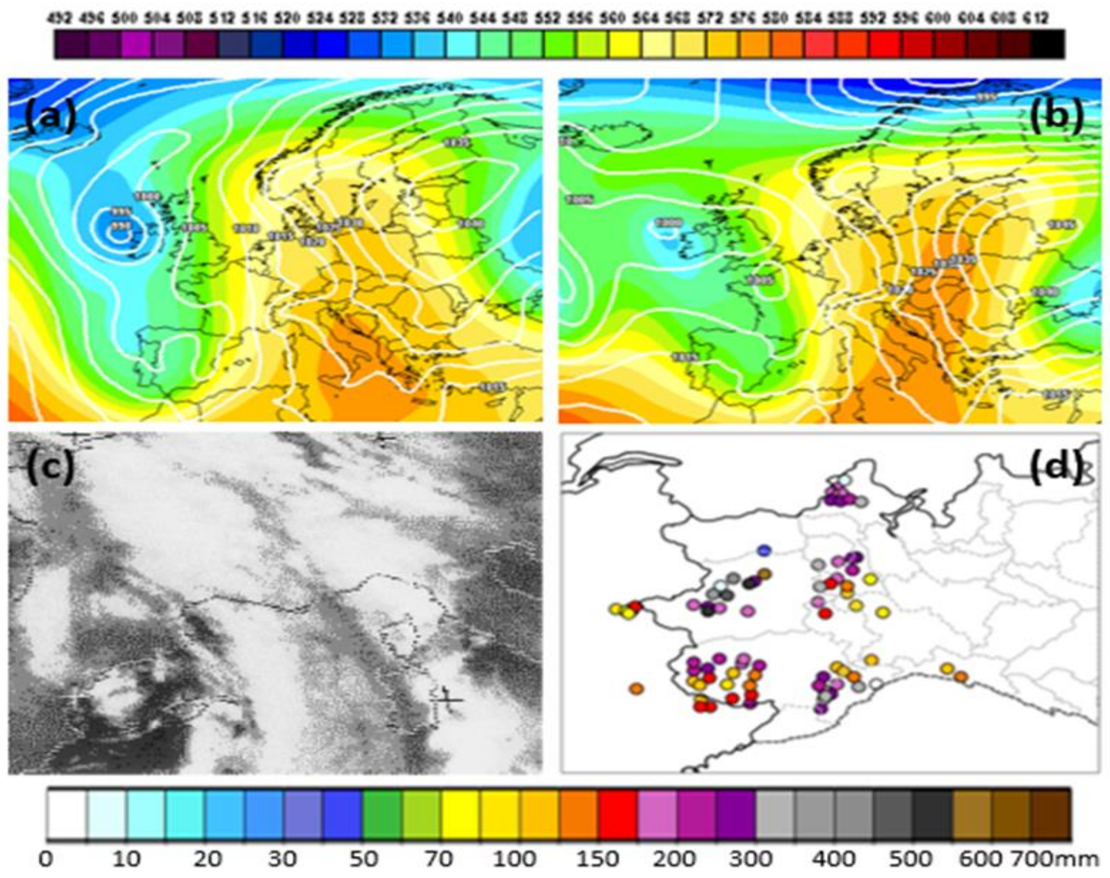
In the 1994 Piedmont flood in northwest Italy, 77 people lost their lives and the Piedmont region suffered 14.5 bn dollars in economic losses, making this the second costliest European extreme weather event between 1970 and 2012 as documented by World Meteorological Organization. Twenty-five years on, experts meeting in Italy used modern forecasting systems to reanalyse and re-forecast the rainfall that caused the event.

The 1994 Piedmont flood

A third of the precipitation falling in one year in Piedmont was observed in 72 hours between 4 and 6 November 1994. The large-scale circulation saw an Atlantic trough extending from The British Isles to the Iberian Peninsula and a blocking high over central Europe. The northward flux from the Mediterranean Sea provided moist air that sustained the precipitation over northern Italy.



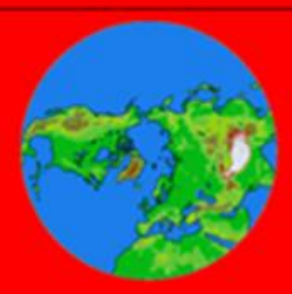
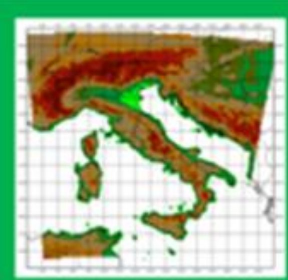
*Geopotential at 500hPa in colors and white isobars of MSLP for 4 November 1994 12UTC **(a)** and 5 November 1994 12UTC **(b)** from ERA Interim Reanalysis. Infrared Meteosat image for 5 November 1994 12UTC **(c)**. Total precipitation collected by the rain gauges network over the whole 1994 flood event from 3 November 00UTC to 8 November 00UTC **(d)**.*

ECMWF ENS and COSMO-2I-EPS

At the time…ECMWF have an experimental 32-member ensemble forecast with a grid spacing of 320km.

And now…thanks to the availability of ECMWF's new ERA5 climate reanalysis, a set of re-forecast for this major flood was produced using different forecasting systems, including:

- ECMWF's operational Integrated Forecasting System (IFS Cycle 46r1) at grid spacing of 18km for ensemble forecasts (ENS)
- COSMO-2I-EPS (Ensemble Prediction System over Italy) at 2.2km, with boundary conditions provided by ECMWF ENS.

MAIN TECHNICAL FEATURE / ENSEMBLE SYSTEM	ECMWF ENS	COSMO-2I-EPS
Integration domain:		
Hor/Vert resolution	18km /91 lev	2.2km/65lev
Initial Conditions	Hybrid-EnVar	KENDA
Boundary Conditions	-	AM ENS (nested on ENS)
Model Perturbation	Stochastic scheme	-
Forecast range (hours)	240	48
Type of model	Hydrostatic model	Non-hydrostatic model
Type of convection	Parameterized convection	Explicit convection
Ensemble size	51	20
Starting times (UTC)	00, 06, 12, 18	21

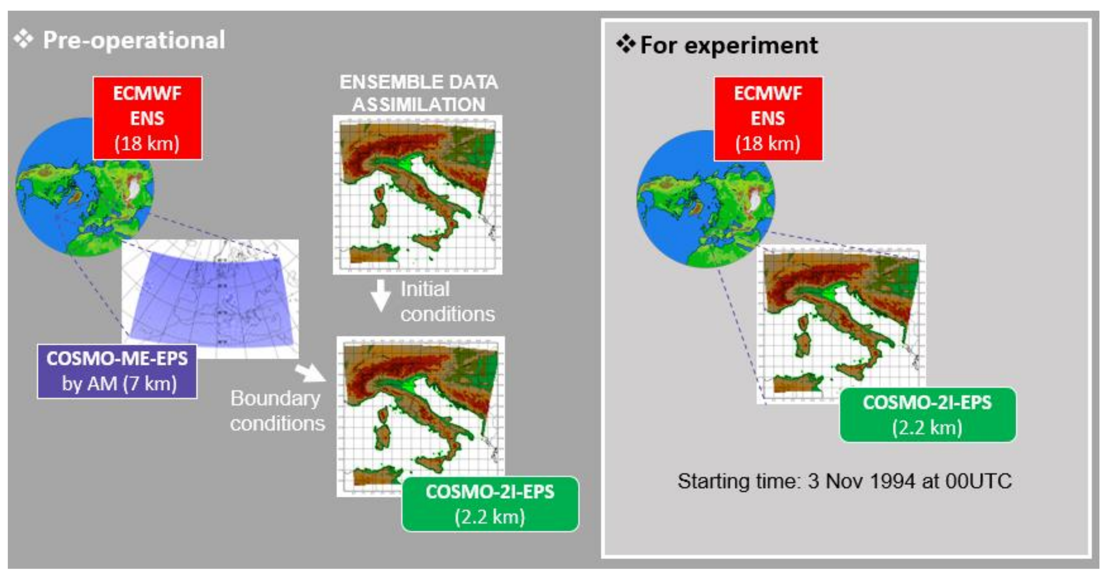
Summary table with the main technical characteristics of the operational ECMWF ENS and pre-operational COSMO-2I-EPS.

Description of experiment

For the experiment COSMO-2I-EPS was not run as in the preoperative version, but using a simplified configuration: a dynamic downscaling was done by ECMWF ENS, it is not an incast but a forecast anyway.

For the verification we used:

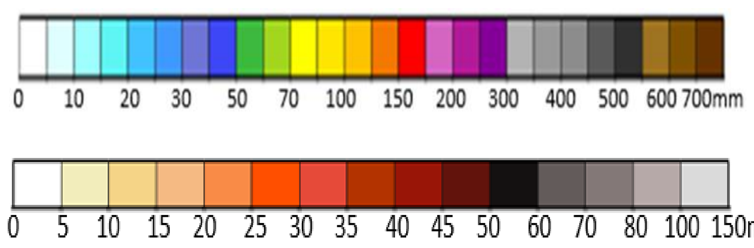
- A single ECMWF ENS and COSMO-2I-EPS re-forecast of 3 November 1994 00UTC with 50 members, and a 120 hour forecast range, so as to cover the entire flood event;
- The total precipitation data collected from approximately 80 stations distributed throughout Piedmont and neighboring areas, made available by Piedmont Arpa for the entire period considered (the location of the stations is visible on the maps with the observed data).

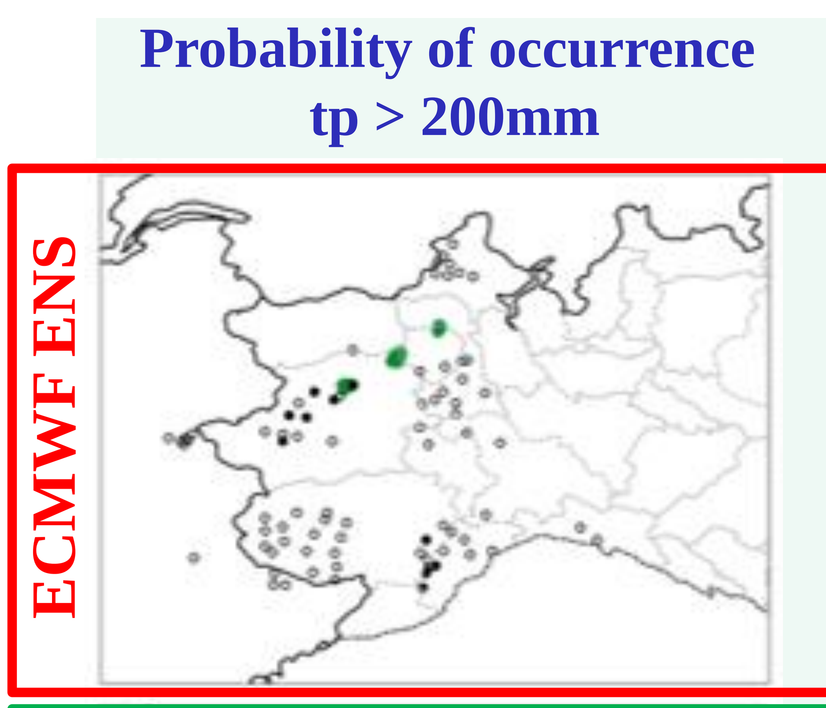


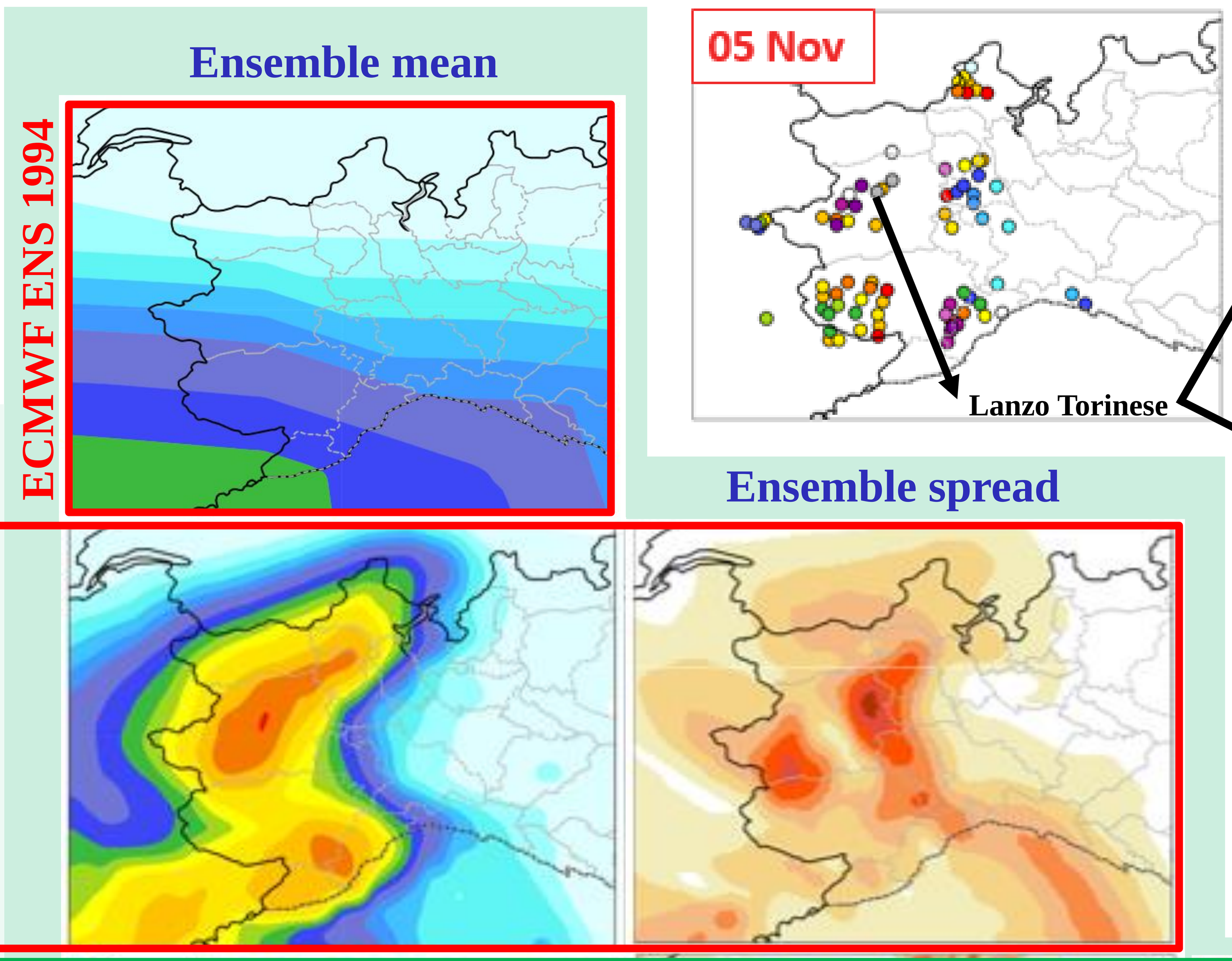
Overview on the functioning of the COSMO-2I-EPS modeling chain in the pre-operative case (left) and for the experiment (right).

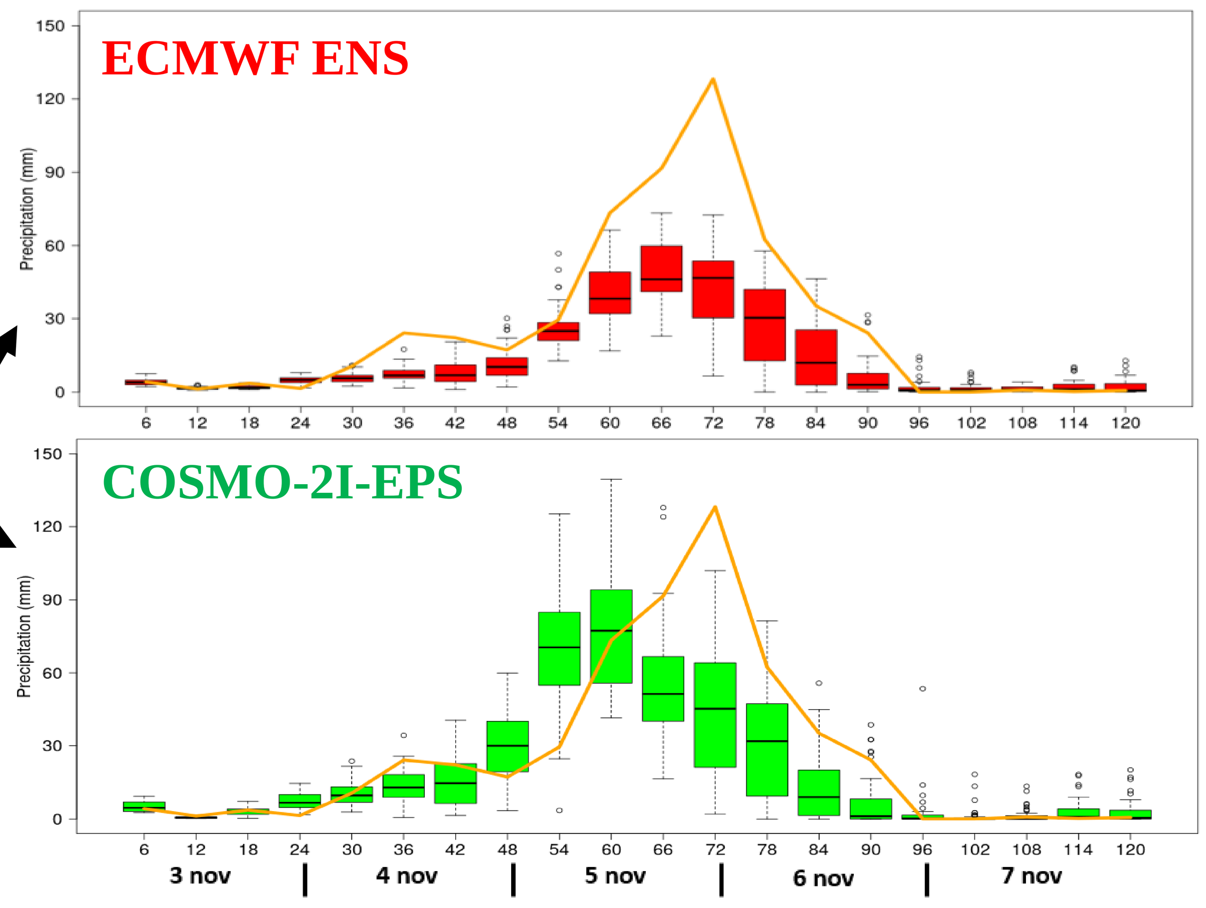
What information would we have had with today's probabilistic approach?

Here only the results for 5 November 1994 are shown: the rainiest day of the flooding event.



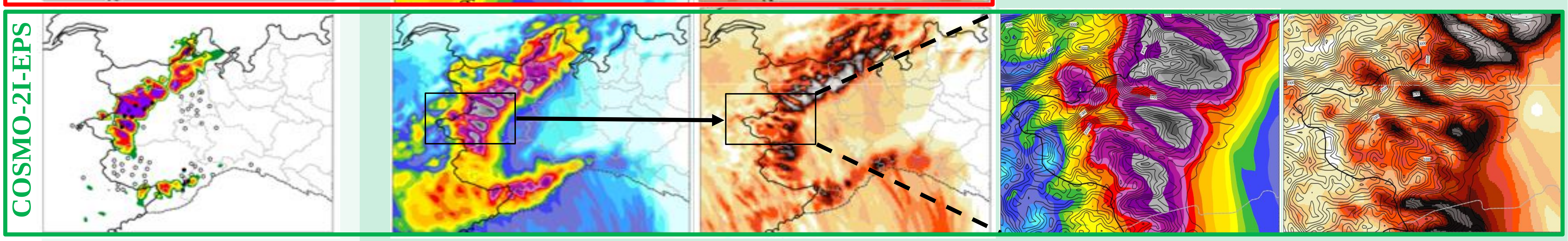




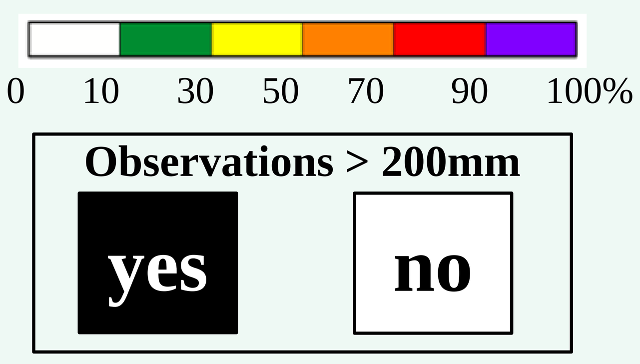


ECMWF ENS and COSMO-2I-EPS meteogram for Lanzo Torinese. The yellow line represents the values observed in the relevant station.

COSMO-2I-EPS represents better than ECMWF the precipitation peaks, although in some cases there is an advance compared to the observations.



Zoom on the ensemble mean and end ensemble spread of COSMO-2I-EPS with overlapping orography.



COSMO-2I-EPS forecast the exceeding of 200mm threshold with a probability greater than 90% on the Turin Prealps, where the rain gauges have recorded accumulations even over 300mm

Clear increase in forecasting capability compared to 1994.

ECMWF ENS: low uncertainty about the location of the most intense precipitation core. Uncertainty related to the intensity of the westward flow in the Po Valley. Uncertainty in the positioning and speed of the warm conveyor belt.

COSMO-2I-EPS: often the areas affected by greater precipitation corresponds to those with greater uncertainty. The area on the Ligurian sea is an exception due to the low predictability linked to the positioning and speed of the warm conveyor belt.

In some cases the areas of greatest uncertainty are not those where the greatest amounts of precipitation are expected, but those in the valleys and mountain sides. There is a high degree of unpredictability on the wet flow behaviour in relation to the orographic barrier and in relation to the interaction with thermal inversion in the valleys.

Conclusions

- Today's modelling capabilities make it possible to predict cases such as the 1994 Piedmont flood with satisfactory accuracy.
- High spatial resolution (explicit convection) is fundamental to predict convective situations in complex orography.
- Problems of small-scale predictability of intense phenomena (ensemble spread used as an indicator of areas of greater uncertainty).
- Improved forecasting capacity compared to 1994 due to increased resolution, improved model physics (e.g. explicit convection and microphysics) and analysis/model perturbation techniques.
- In the context of global warming, the fact that High Impact Weather events can be extremely localized and can develop over a short period of time represents new challenges for numerical weather prediction.

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