Forecast, observation and verification of severe thunderstorms in Lombardia

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Introduction

ARPA Lombardia provides weather data and forecasts to support Civil Protection in order to prevent and mitigate natural hazards. This work focuses on the forecast verification of severe thunderstorms. These forecasts are issued one day in advance, based on the **ECMWF** model among others, coded with respect to three levels of probability and referred to the so called "**alert areas**", subregions homogeneous to some degree in climate, orography and infrastructures.

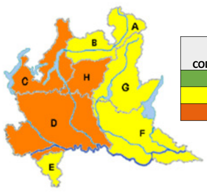
Traditional verifications are carried out comparing forecasted and observed rainfall accumulation in order to verify forecast against observed thunderstorms. This study introduces a method based on the Storm Severity Index (SSI) that summarizes all the phenomena related to severe weather (large hail, lighting, showers) and the potential damage.

The user request

The end-user is the Civil Protection. It requires:

- forecasts limited only to **severe storms**, i.e. those with the highest potential to make a widespread damage (it's not interested in «generic» storms);
- 24-hours lead time (**D+1**);
- a forecast for each of eight geographical "**alert areas**" (two in the flat Po valley, six in the Alps and the Apennines)

The severe storm forecast is issued by three levels of probability of severe storm (TF): unlikely, likely, and very likely.



CODE	PROBABILITY OF OCCURENCE OF SEVERE STORM
(green)	unlikely
(yellow)	likely
(orange)	very likely

These constraints are strong with respect to the low predictability of thunderstorms.

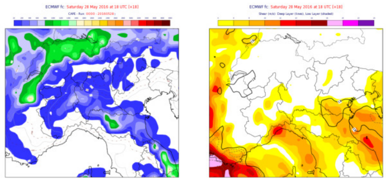
If the weather forecast code is "likely", Civil Protection informs local authorities issuing an advisory, but in case of code "very likely" a warning is issued which implies actions and then costs.

In this work we focus on the latter case so the object of the verification is "severe-storm occurrence over a large part of the alert area".

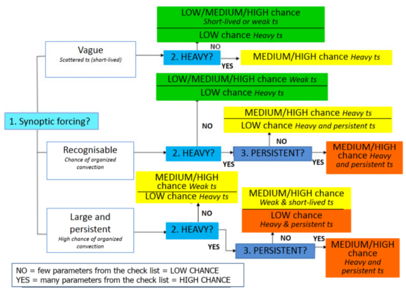
The forecast

The forecast is based on the **subjective analysis** of NWP models ECMWF and COSMO (2 nested limited area models, 7.5 km and 2.8 km grid). Many atmospheric instability indexes are available to the weather forecaster in addition to the standard meteorological fields maps.

In the figure below, an example of the CAPE - Shear plot from ECMWF IFS:



In order to assign a forecast code to each alert area, the forecaster is guided through a **decision tree** (see below). It considers first the synoptic forcing, then goes to a finer scale to get the possibility of **severe thunderstorms, that is, heavy and persistent storms**.



Observing thunderstorms

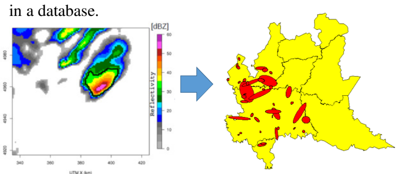
Thunderstorms are observed and identified by means of all the available networks and instruments: weather station network, lightning detection system, satellite, weather radar.

For this application, where the user is interested only in severe thunderstorms and the damage to people and properties (hazard), an algorithm is used that classifies storms on the basis of the Storm Severity Index:

$$SSI = mean + \sqrt{\frac{area}{\pi}} + \frac{\text{vil}}{top} + \text{poh}$$

Where: mean= mean reflectivity (dBZ) of the cell, area=area of 35dBZ (km²), vil= vertically integrated liquid (g/m²), top=height of the highest 10 dBZ (km), poh= probability of hail (%).

Each cell is thus schematized with an ellipse, with an SSI value assigned (ranging from 1 to 5) and stored in a database.

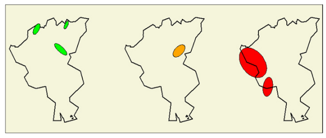


Verification

A basic method for verifying probabilistic forecasts is the Brier score. But in this application, the main interest of the user is in the correctness of the warnings issued. This means that the verification is better understood when reduced to the dichotomous case in which the forecast code "orange" (thunderstorm "very likely") is verified against severe thunderstorm occurrence on alert areas.

In order to define the occurrence of severe thunderstorms, for each area every detected cell (ellipse) is considered. Then, a weighted average is computed of the SSI, in which the weights are the percentages of the area covered by the ellipses of each SSI:

$$SSI_w = \Sigma_i SSI_i * C_i$$



Categorical statistics is computed from a 2 by 2 contingency table for the cases $SSI_w >= 3$, i.e severe thunderstorms occur over a large part of the area

ACC	0.68
POD	0.72
FAR	0.26
BIAS	0.97

Conclusions

A method to verify a **tailored forecast** of thunderstorms has been developed. The need to consider the constraint implied by in the user request has influenced all the forecasting service stages: subjective forecast on the basis of the ECMWF model, definition of "correct forecast" (observing thunderstorms), verification of the forecasts.

The occurrence of severe thunderstorms has been defined on the basis of a severity index (**SSI**, related to objective radar-parameters) as well as on the basis of the geographical extension of the phenomena, both of interest of the user.

The verification of the probabilistic forecast has been "**simplified**" as a categorical one in the attempt **to meet the user point of view**. A long lead time (24+ hours) in thunderstorm forecasting always implies a high degree of uncertainty, but the results are **satisfactory** so far.

The future work will be focused on the use of the new high resolution version of the ECMWF model in order to make the forecasting process more robust. Finally, the SSI index will be fine tuned in order to improve both the verification process and forecasting.

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