NOWCASTING AND ASSESSING THUNDERSTORM RISK ON LOMBARDY REGION (ITALY)

Bonelli P.[1], Marcacci P.[1], Bertolotti E.[2], Collino E.[1], Stella G.[1]

[1] *ERSE S.p.A., ENEA Ricerca sul Sistema Elettrico (former CESI RICERCA), V Rubattino,54 Milan, ITALY,*
paolo.bonelli@erse-web.it, pietro.marcacci@erse-web.it, elena.collino@erse-web.it, giuseppe.stella@erse-web.it

[2] *Lombardy Region - Civil Protection Office Via Rosellini, 17 - 20124 Milan, ITALY,*
egidio_bertolotti@regione.lombardia.it

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I. INTRODUCTION

Severe thunderstorms in Lombardy (Italy) are a serious risk during warm seasons. The region between the Po valley and the Alps experiments one of the highest thunderstorms frequency in Italy. Most events are caused by high intensity convective cells that born and dissolve in few hours and that produce their effects in narrow area of about 10 km. The associated deep convection causes severe weather as: big hailstone, gust, tornado and heavy rain.

Due to the high urbanization of the Lombardy, almost every severe thunderstorm causes strong wind that damages house roofs, crashes scaffolds and old trees; often road signs flight away breaking down electric overhead lines (Bonelli et al., 2003). Furthermore short but heavy rain causes flooding of underpasses, flash flood or landslides.

In 2003, about 90 thunderstorms (TS) affected people's health, houses, cars, agriculture and electrical lines. Some tornadoes have been detected too. The 2003 summer was not particularly anomalous compared with others, concerning TS activity. In the 2007 summer a couple of tornadoes destroyed some houses in Guidizzolo, near Mantova. In these situations insurance companies and sometimes also local administration often appeal to the "exceptional phenomena" in order not to compensate injured people. They also hope the Central Government will declare "the state of natural disaster" in order to obtain public support. In this context an objective analysis would be requested to evaluate if the phenomena was really extraordinary.

In Lombardy the spare ground stations do not allow to evaluate severe weather associated to thunderstorms. Storms are however well monitored by some C-band radar, located at the border of the region, and by the Meteosat satellite. In particular, Mount Lema radar, operated by Switzerland Meteorological Service, provides useful data on quite the whole Lombardy region (Hering et al., 2007), (Joss et al., 1997).

Since 2006, ERSE (former CESI RICERCA), in the frame of its activity on interaction between severe weather and electrical grid, collaborates with Lombardy Authority of Civil Protection Office, developing and testing a severe thunderstorms detection and nowcasting system (Bonelli et al., 2008). In fact, despite the difficulty to forecast TS intensity and position less than one hour in advance (Wilson et al, 1998), a well designed alert system can be useful in preventing damages to people and to reduce the time of operations for the rescue teams.

Recently ERSE developed STAF (Storm Track Alert and Forecast), a nowcasting system based on Radar and MSG (Meteosat Second Generation) data that selects only severe TS, tracks them and sends alert messages to users, as described in chapter II.

II. PRESENTATION OF RESEARCH

It is well known that severe weather caused by a TS, as gust, hail, tornado, depends on the intensity of convection inside the cell and on the content of liquid or solid water inside it. For this reason two variables, detected by radar and Meteosat, could be well correlated with damages caused under the cell: the vertical profile of reflectivity inside the cumulonimbus cloud and its top temperature.

In STAF, radar reflectivity vertical profile is analysed on every pixel in order to calculate the number of vertical levels with reflectivity larger than 44 dBz, among the 12 ones. This is very important to evaluate the presence of deep convection.

In order to formulate the cause/effect relation a statistical regression between the probability of damage and radar/satellite variables, has been developed. For this goal a storm archive ST-AR has been built up. It contains both radar and satellite data together with damage reports, noted by local press. The database contains data for more than 300 TS cells, severe or not. (Collino et al., 2009).

The logistic regression has been used. The equation obtained has this formulation:

$$Y = a + bX_1 + cX_2$$

where X_i are the radar and satellite predictors, a,b,c are constant coefficients and Y is the logit of p:

$$Y = \text{logit}(p) = \ln\left(\frac{p}{1-p}\right)$$

where p is the probability of the severe event.

So, it is possible to calculate the probability like this:

$$p = \frac{1}{\left[1 + \exp\left(-\left(a + bX_1 + cX_2\right)\right)\right]}$$

In our case X_1 and X_2 are the normalized variables:

$$X_1 = \frac{N_{44}}{12} \qquad X_2 = \frac{T_{top} - (-75)}{(20.3 - (-75))}$$

N_{44} is the number of radar vertical layers with reflectivity higher than 44 dBz and T_{top} the brightness temperature of the cloud from Meteosat in °C.

a, b, and c are the coefficients of the regression, computed by means of the ST-AR data-set and with SYSTAT software:

a = -2.507; b = 7.388; c = -9.502
with $R^2 = 0.66$

The SYSTAT can also compute the improvement of the regression due to the introduction of a new independent variable. In this case the algorithm shows that T_{top} temperature adds a valid contribute to the regression compared to the one obtained using only radar data, despite of an evident correlation between the two variables.

The system STAF analyses every 5 minutes the full 3D radar reflectivity matrix, with a horizontal resolution of 2 km and 12 layers of 1 km in the vertical. STAF software processes radar data in order to:

- identify only the most intense cells, using a threshold of 36 dBz on the vertical maximum reflectivity (Hering et al., 2004) and compute their position;
- compute cell velocity by means of its two previous positions;
- attribute to every selected cell a damage probability based on radar reflectivity profile and top temperature from Meteosat data, as explained above;
- forecast cell position for 30 minutes ahead by means of its velocity;
- generate alert SMS messages, when a severe cell crosses a pre-defined alert area, and send them to selected users;
- display on-line and past situations on a WEB-GIS site.

Details about some features of the tracking algorithm can be found in Bonelli et al., 2008.

During the 2008 and 2009 summers about 15 alert areas of 10 km in radius over the Lombardy region were defined. In these areas the system STAF has been tested. Selected volunteers and Civil Protection personnel received the SMS alert from STAF and, after each received alert, they registered local observations about TS effects and the effectiveness of the message.

An important function of STAF is the possibility for the users to write down and upload a WEB form with own reports about the TS event. The information registered is: presence of strong gust, big hailstone, damages to houses, tree falling, electric blackout and the reception time of SMS.

A new important feature of 2009 STAF version, with respect to the 2008 one, is the WEB-GIS interface that allows the user to have a look on the TS cells with their velocity, intensity and probability of damage, over a standard geographic map with roads and cities, as shown in FIG 1. Optionally one can also display the overhead electric grid.

III. RESULTS AND CONCLUSION

The experimental activity concerning forecast and observations of severe thunderstorms in Lombardy, during the 2008 and 2009 summers allowed the collection of many data. These data will be used to better set up the STAF software.

An important goal of this effort is also to sensitize local Authority for Civil Protection. In fact these nowcasting practices will appear useful only if users are correctly trained on the thunderstorm risk and about the available monitoring instruments.

The challenge is due to the very short forecast time, in contrast with the common day to day weather forecast, that implicates a different management of the prevention and rescue activities.

An increase in the number of users and alert areas is expected in the future. Also new alert systems, as local radio broadcast, will be tested. The user feedback will be always very important to test the real effectiveness of the alert system.

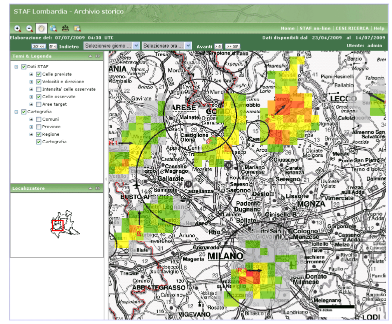

FIG 1: Example of the WEB-GIF interface developed for STAF.

IV. AKNOWLEDGMENTS

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