Proceedings of ERAD 2006

Combined use of meteorological radar and limited area model forecast in precipitation phase discrimination

Roberto Cremonini[1], Renzo Bechini[1], Valentina Campana[1], Luca Tomassone[1]

[1] ARPA Piemonte, Turin (Italy).

1 Introduction

The Piedmont region, in the North-Western part of Italy, is surrounded by Alps along the borders with France and Swiss, by Appennini along the border with Liguria region, and in the remaining area it's characterized by plans and hills with 700 – 800 meter a.s.l. altitude. The complex orography allows frequent and abundant snowfalls during winter, due to cold air pool trapped in the Po valley. This paper shows an algorithm, aimed at distinguishing between solid (snow, ice) and liquid (rain) precipitation at ground level during winter.

The basic idea of the algorithm is using the freezing level fields produced by a meteorological limited area model and the reflectivity radar data. Its performance is verified comparing the precipitation classification with 30' precipitation type classification, identified by 11 automatic present weather ground stations, during four snowfall events occurred in the 2005-2006 winter season.

Results of previous precipitation identification are used in a snow accumulation algorithm, which is also verified with manned snow depth measurements.

2 Precipitation type algorithm description

Several studies have shown the utility of polarimetric radar observables for discrimination of hydrometeor particle type (Ryzhkov 1998). Due to the polarimetric signature overlap for different particle types, the fuzzy logic is the most wide method, used to solve the problem. Membership functions are usually defined for all polarimetric observations available (Z, Zdr, Kdp, Ldr, ρ) and vertical profiler of temperature, which plays a key role in the classification process, and the hydrometeor type is assigned to every single cell.

As radar measurement always comes from some distance above ground, that increases over orographic complex terrain, without further elaborations few about precipitation type can be assessed at ground level.

As a matter of fact the precipitation type depends on lower-tropospheric air temperature, which is affected by horizontal and vertical advection, deep moist convection, vertical mixing/surface fluxes and different latent heating. When precipitation crosses the freezing level, before reaching ground, the latent heating, effect due to melting, causes a decrease in temperature, creating in some weather conditions a zero degree isothermal layer. The cooling by evaporation is an important cooling agent: this effect is one order greater than melting one.

Wishing to estimate the precipitation type at ground and considering the aforementioned importance of temperature profile in classification methods, a simple algorithm for liquid-solid precipitation discrimination, using radar reflectivity and temperature fields from numerical model, has been implemented. Input data used are:

- the north-west Italy composite lowest level reflectivity derived from two meteorological radar managed by ARPA Piemonte: Bric della Croce (TO) and Monte Settepani (SV);

- 7-km resolution freezing level analysis field (FL) derived by Italian version of the non-hydrostatic limited-area model Lokal Model (LAMI), developed by COSMO Consortium;

The algorithm estimates snow quote (SQ) from the model freezing level, applying a correction factor proportional to the precipitation intensity

Applying the common rule of thumb, used by weather forecasters in Piemonte region, the snow limit extends up to 300 m under the FL for weak intensity precipitation (about 20 dBZ) and up to 500 m under the FL for heavy precipitation (about 40 dBZ).

Then, according to the ground altitude above sea level (H) each reflectivity composite cell is classified in three classes:

$H > FL$	<u>Solid</u>
$SQ < H < FL$	<u>Mixed</u>
$H < SQ$	<u>Liquid</u>

3 The algorithm verification

In order to verify the performance of the presented algorithm a comparison between precipitation type identified using

Correspondence to: Valentina Campana

v.campana@arpa.piemonte.it

radar and LAMI model and the value given by 11 Vaisala FD12P automatic present weather sensors (fig. 1) has been carried on for four snowstorms cases, occurred in 2005-2006 winter, with diffuse snowfalls that interested Po valley.

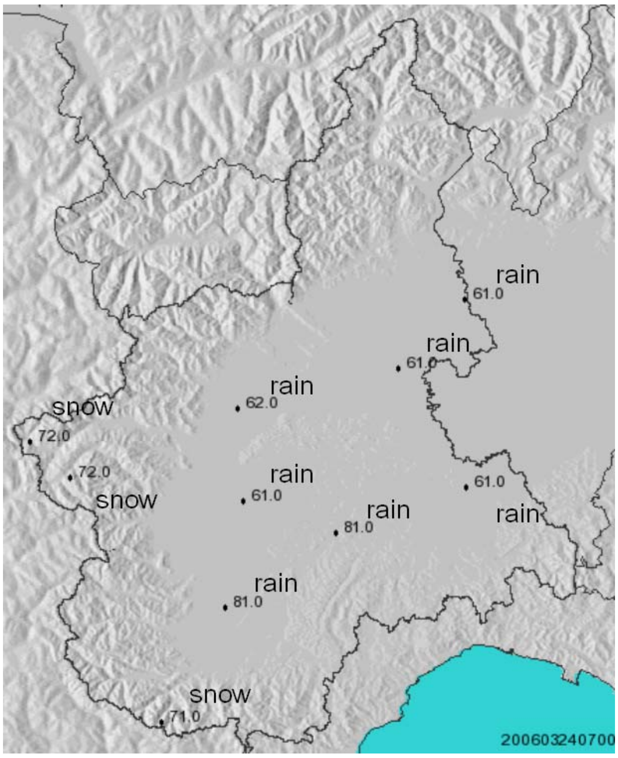

Fig. 1. Example of present weather observations (also displayed as WMO Synop codes).

For the comparison it has been used a *contingency table* (see Table 1), showing the relationship between known reference data (automatic present weather) and the corresponding results of the algorithm output.

Table 1. Contingency table showing the relationship between data collected by present weather sensors and algorithm output for four snowfall cases between November 2005 and March 2006.

		PRESENT WEATHER		
		no data/other	*liquid*	*solid*
RADAR+LAMI	*no data*	340	29	164
	liquid	37	117	38
	solid	39	30	461
		Accuracy	79.6%	92.4%
		Kappa coeff.		0.71
		Overall Accuracy		89.5%

The Accuracy of a class results from dividing the number of correctly classified observations in each category, by the total number of them in the corresponding column.

The Overall accuracy is computed by dividing the total number of correctly classified observations by the total number of reference data.

The Kappa coefficient is a measure of the difference between, the actual agreement between reference data (present weather) and an automated classifier (snow/rain model), and the chance agreement between the reference data and a random classifier. So a K = 0 suggests that the classification is only a random assignment of data; on the other side, a K = 0.7 (for example) is an indication that the observed classification is 70 percent better than one resulting from chance.

In the study ‘no data’, i.e. no precipitation observed by radar, were not considered, as they mainly depend on radar sensibility, and they are not related with the algorithm’s quality.

The results obtained (Table 1) show a general good agreement between automatic present weather sensors and algorithm output. In particular a good performance is obtained in identification of solid precipitation, having an accuracy of 92.4%, while less reliable results are obtained in identification of liquid precipitation.

4 The snow accumulation algorithm

A simple algorithm based on a modified Marshall Palmer equation obtained for snowy precipitation (See Doviak and Zrnic 1993) is used:

$$Z = 399\ R^{2.21} \qquad (1)$$

where Z is the radar reflectivity and R is the rainfall rate in snow water equivalent (mm/h).

The reflectivity of each composite cell flagged as dry snow is converted in snow water equivalent using [1] and then it’s cumulated for event duration.

A preliminary verification of the snow accumulation algorithm has been performed for the snowfall event occurred on 02nd and 03rd December 2005. The total accumulation of the snow water equivalent has been compared with 24-hours fresh snow accumulation, measured by 35 manned snow depths stations mainly located in mountainous areas. The figure 2 shows the location of snow depth stations and the relative height of the first radar beam free of orographic blocking. In order to compare data, the snow water equivalent accumulation at ground has been transformed in centimetres of snow depth, using the standard snow density 100 kg m^{-3} value.

Figure 3 shows scatter plot between radar and ground observations: white circles correspond to radar measurements taken under 4000 m above sea level, black ones measurements taken over 4000 m. The lines represent linear regressions, solid line for white circles and dashed line for black ones, with correlation coefficient (r) and bias superimposed.

A general underestimation of the algorithm can be seen, with better performance when radar measure is taken under 4000 m a.s.l., probably related to overshooting.

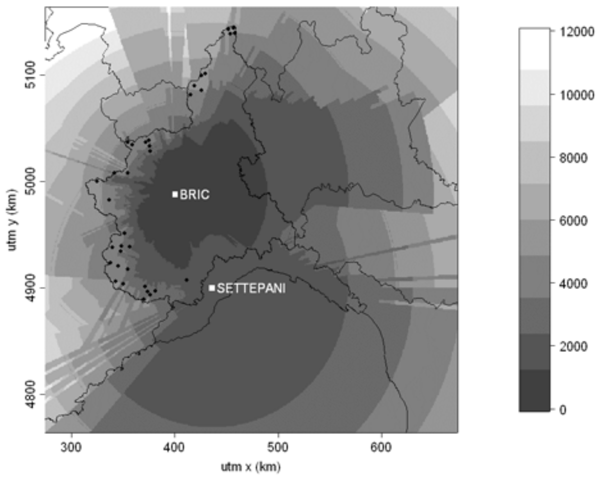

Fig. 2 Representation of the visibility map referred to the Piedmont radars composite. For each point and for each radar, comparing radar beam heights with a digital elevation model, we obtained the first beam free from blocking, then the height at which reflectivity is measured. The lowest height between Bric della Croce and Monte Settepani is chosen. The black points show the location of manual snow gauges.

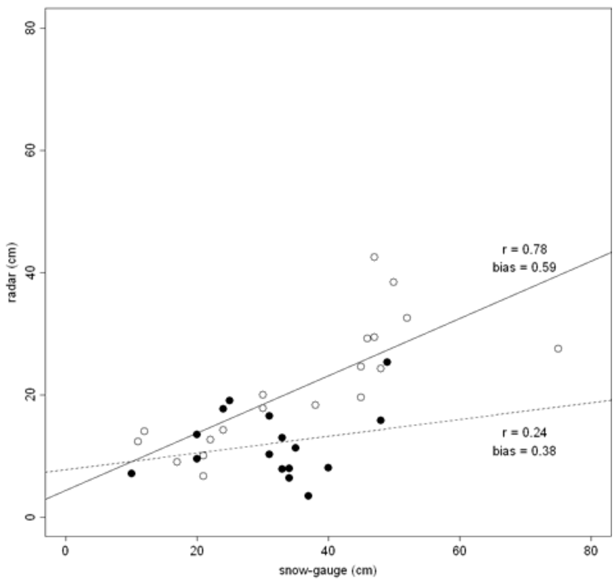

Fig. 3 2nd – 3rd Dec 2005: scatter plot of 24 hours snowfall cumulates by ground and radar observations (see text for details).

The observed mean underestimation of about 30-40% can be ascribed to several causes:

- The location of the snow depth stations, mostly situated in areas characterized by complex orography and far from radars, causing the radar beam overshooting the low tops of snow storms;
- The mis-classification of solid precipitation as mixed or liquid precipitation, which are not considered in the snow equivalent water accumulation;
- Snow density tends to vary greatly from one snow event to another, and it also varies within a single storm depending on its convective nature;
- The modified Marshall Palmer equation could be not optimal for Piemonte region, and the coefficients used should be different in case of solid precipitation other than snow (ice pellets, ice crystals, snow grains)

5 Conclusion and future improvements

First results seem to be encouraging but the solid-liquid identification algorithm should be verified analysing more snowfall events to obtain more significant statistics. Improvements of the algorithm performance could be obtained implementing precipitation type algorithms ensemble from standards algorithm (Ramer, Bourgouin, Czys).

Better identification of dry snow, wet snow and rain should bring to better snow water equivalent accumulations. Then improvements in snow accumulation could be reached using snow density fields varying in time and space, according to the interpolated field of temperature derived by ground stations (LaChapelle, 1961).

Finally, analysing new snowfall case studies and searching for a better tuning of the Marshall Palmer parameters, we hope to obtain more reliable snowfall maps.

Acknowledgements: This work have been partially supported by ALCOTRA within project 113 FRAMEA "Flood forecasting using Radar in Alpine and Mediterranean Areas" Interreg 3a Italia-Francia

References

Bourgouin, P., 2000: A method to determine precipitation types. Wea. Forecasting, 15, 583-592.

Czys, R. R., R. W. Scott, K. C. Tang, R. W.
Przybylinski, & M. E. Sabones: A physically based, nondimensional parameter for discriminating between locations of freezing rain and ice pellets. Wea. Forecasting, 11, 591-598.

Doviak, R. J., Zrnic D. S.: 1993 Doppler radar and weather observations, 228

La Chapelle E.: 1961. Snow Layer Densification. Alta Avalanche Study Center, Project F, Progress Report No. 1, US Department of Agriculture Forest Service, Wasatch National Forest.

Ryzhkov, A. V., Zrnic, D. S.
Discrimination between Rain and Snow with a Polarimetric Radar, Journal of Applied Meteorology 1998 37: 1228-1240