Monitoring snowfall events in Lombardia, Italy, by specialized observers network and advanced remote sensing systems.

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ABSTRACT: Real-time monitoring snowfall events in Po valley is often difficult due to fast temperature variations that change snow / rain limits. For this reason Arpa Lombardia is developing a network of volunteers and automatic weather sensors coupled with radar-based precipitation type products. Five automatic present weather sensors FD12P have been recently installed; they are able to discriminated solid and liquid precipitation combining temperature, humidity and optical measurements. An algorithm to discriminate the phase of precipitation at ground level, which involves radar and local area model data, has been developed several years ago by Arpa Piemonte. Wet bulb temperature derived from the nonhydrostatic limited-area atmospheric model COSMO and best precipitation estimations from polarimentric radar are ingredients of the precipitation type algorithm. Finally a dense network of specialized observers also provide snow depth and fresh snow measurements that are used both to improve monitoring of areas interested by snowfall and automatic algorithm to assess precipitation type. The present work describe the monitoring system set up in Lombardia to monitor snowfall and it shows results from heavy snowfall event occurred during winter season 2012 / 2013.

KEYWORDS: Instrumentation, monitoring and remote sensing.

1 INTRODUCTION

Snowstorms have strong impact on high-urbanized areas affecting transportation (highways, airports), commerce, communications, and energy (Rasmussen, 2003). For instance on December 2008 an heavy snow storm involved Piemonte, Italy, causing breaks in powerlines that involved more than 50,000 inhabitants (Bonelli, 2011). On 21st December 2009 a severe snowstorm struck the metropolitan area of Milano, bringing around 20 cm snow accumulation on the ground; the following day a temperature sudden rise caused wet snow and freezing rain. All metropolitan airports were closed, traffic were paralysed and several damages to powerlines were reported.

Therefore, real-time observation of snowstorms is crucial to manage promptly emergencies. This monitoring in Po valley is often challenging due to high variability in local conditions and sudden temperature variations that displaces the snow - rain limit (Kain, 2000; Lackmann, 2002; Marigo, 2008).

Merging weather radar observations and Numerical Weather Prediction (NWP) model, Arpa Piemonte has developed an algorithm to discriminate instantaneous precipitation type. Wet bulb temperature (T_{wb}) derived from the nonhydrostatic limited-area atmospheric model COSMO (Doms, 2011) and the best precipitation estimations from polarimentric radar are the ingredients of the algorithm.

The ground truth is necessary to validate remote sensing algorithms. Recently, the dense Arpa Lombardia ground weather network has been integrated with five automatic present weather sensors (AWS). Moreover a network of specialized observers has been set up to provide snow depth and fresh snow measurements that are used to improve monitoring.

The paper is organized as follows: section 2 describes the observing system managed by Arpa Lombardia; section 3 describes the algorithm of snow / rain discrimination. Section 4 analyses the late snowfall on 18th March 2013, then conclusions.

2 LOMBARDIA OBSERVING SYSTEM

Arpa Lombardia manages a dense ground weather network composed by more than 300 stations. The regional ground weather network has been recently integrated with five automatic present weather sensors FD12P (Vaisala, 2002). These sensors are automatically able to discriminated solid and liquid precipitation combining temperature, humidity and scatter light measurements. De Haij in 2007 has demonstrated that this sensor has a high level of detection for rain and snow and the detection of drizzle is good relative to other sensors; however, it has problems to identify freezing precipitation correctly.

Although strong the development of automatic ground network measurements during the past decades, dense and detailed observations are necessary for accurate monitoring and forecast. For this reason several experiences involving citizens and volunteers born in the past years. In USA, volunteers can post their daily observations on the Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS) Web site. Observations are immediately available on maps and reports for the public to view. By providing high quality, accurate measurement, the observers are able to supplement existing networks and provide useful results to scientists, resource managers, decision makers and other users (Cifelli, 2005; http://www.cocorahs.org). In 2011 the UK Weather Observation Website (WOW) was developed by the Met Office with support from the Royal Meteorological Society and the Department for Education. The aim was to provide a hub for UK weather observations, which can help educate children about weather and encourage further growth in the UK's amateur weather observing community (Bell, 2013; http://wow.metoffice.gov.uk/).

Following these successful experiences Arpa Lombardia has set up a network of trained volunteers to provide weather manned observations including snow depth and fresh snow measurements.

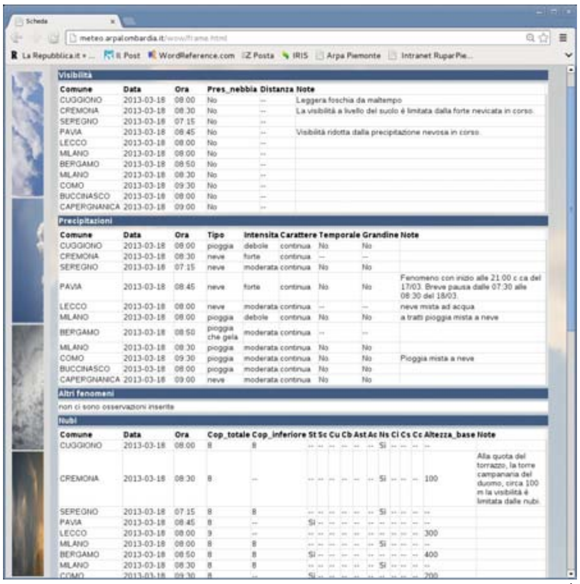

Figure 1. Weather reports relative to 18th March 2013 from Arpa Lombardia WOW system.

Their observations can be shared by a web interface, reporting several information including visibility, present weather and cloud reports. Figure 1 shows reports on 18th March 2013 morning.

3 RAIN SNOW DETECTION

As stated by Baumgardt in 1999, wet-bulb temperature (T_{wb}) is a key factor to find out the precipitation type at ground. Precipitation type is assessed merging reflectivity data and short-term forecast from limited area. T_{wb} is derived from short-term forecast by NWP COSMO model (Doms, 2011). According to values of T_{wb}, derived from specific humidity and dry temperature at model sigma level closest to the ground. Mixing ratio constant within 500 meters from the ground and standard atmosphere temperature profile are assumed to correct T_{wb} for differences between model and true ground altitude. The precipitation is classified as follow:

– $T_{wb} < 0$ °C snow
– 0 °C $< T_{wb} <$ 2 °C melting snow
– $T_{wb} >$ 2 °C rain

Precipitation classes are derived according to the intensities obtained from radar reflectivity as described below:

drizzle	0.1-0.5 mm/h
weak rain	0.5-1 mm/h
moderate rain	1-10 mm/h
heavy rain	10-50 mm/h
very heavy rain	> 50 mm/h
sleet	< 0.4 cm/h
weak snow	0.4-1 cm/h
moderate snow	1-20 cm/h
heavy snow	> 20 cm/h
moderate melting snow	< 20 cm/h
heavy melting snow	> 20 cm/h

The melting snow class includes also freezing rain and ice pellets precipitation. This product refers to the type of precipitation that is occurring over a specific area and not to snow accumulation. In fact the accumulation of snow at ground depends on other factors like ground temperature and surface type.

4 CASE STUDY: 17th - 18th March 2013

After a cold air-mass intrusion in the Po valley during previous days, on 17th March 2013 an Atlantic cold front reached northern Italy lowering temperature and causing widespread heavy precipitations for 48 hours.

Automatic snow depth sensors recorded up to 20 cm in the south-est Piemonte and in Lombardia. Weather volunteers observers reported on Lombardia WOW website heavy or moderate snow on 18th March 2013 between 07:00 and 08:00 UTC in Pavia, Crema, Cremona, and Lecco. At 07:30 UTC the automatic present weather sensors of the regional network recorded the following AWS codes:

Station name	**AWS code**
Cavenago d'Adda	72
Castello d'Agogna	67
Palidano di Gonzaga	62
Caiolo	72
Pieve S.Giacomo	67

Table 1. AWS codes recorded on 18th March 2013 at 07:30 UTC; see text for details.

These codes are defined in WMO SYNOP CODE 4680, W_a, W_b (WMO, 1998). Codes reported have the following meaning:

- 62 Rain, moderate
- 67 Rain, (or drizzle) and snow, light
- 72 Snow, moderate

Figure 2 shows automatic and WOW present weather observations in Lombardia recorded around 07:30 UTC. The green colour corresponds to rain, the blue one to snow and the purple one for melting snow.

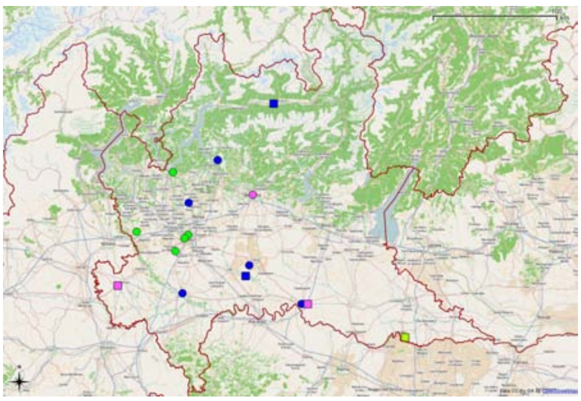

Figure 2. Automatic and manned present weather observation. See text for explanation.

The next Figure shows the precipitation type derived from Piemonte weather radar on 18th March 2013 at 07:30 UTC. It can be seen melting snow over Po valley and heavy snowfall in the Alps, the Appennines and the area of Pavese and Lodigiano with an excellent agreement to WOW observations.

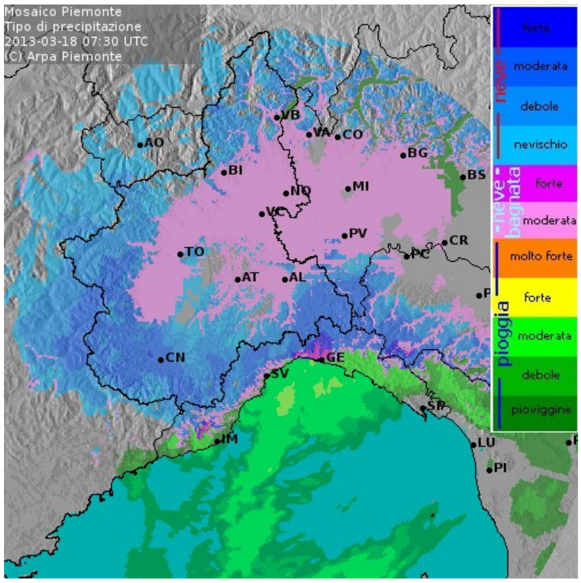

Figure 3. Precipitation type on northern Italy on 18th March 2013. Heavy snow is clearly visible over the Alps and in the area between Genova (GE), Alessandria (AL) e Piacenza (PC).

However manned WOW present weather reports in Milano area and close to Novara reported light rain while radar-based observation stated melting snow. Temperature close to ground ranged from 0 to +2 degrees.

Figure 4 shows the RGB composition of visible channels acquired by MODIS on 21th March 2013, few days later the snowstorm. Satellite data shows the accumulated snow by the snowstom at ground over the Alps, the Appennines and over the area between Piemonte, Lombardia and Emilia-Romagna.

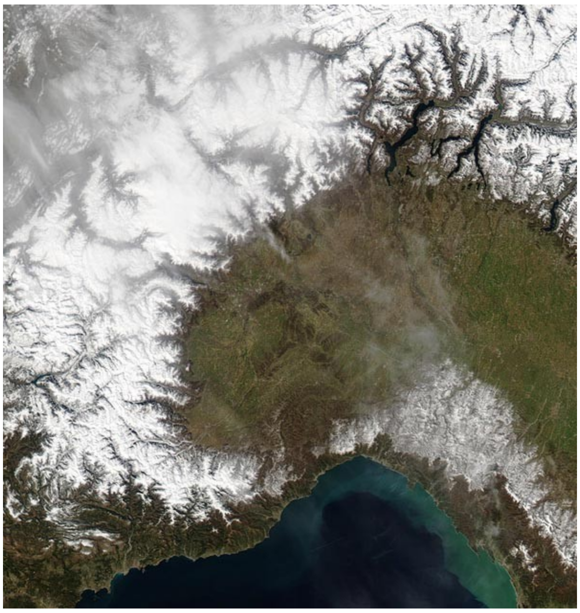

Figure 4. The visible channels of MODIS sensor on 21st March 2013 at 12.40 UTC show snow cover over the Alps and in south areas of Lombardia.

5 CONCLUSIONS

Assessing snow-rain limit is critical due to heavy impacts of snowstorms on human activities. Merging NWP model and radar observations a realtime discrimination from snow to rain has been developed. However due to strong influence of local conditions on temperature and humidity profiles, validation with ground truth is necessary. Volunteers observers and automatic weather sensors can be very useful. The case study briefly discussed in the paper has shown a good agreement between radar-based and ground observations. Nevertheless over Milano, Vercelli and Novara area the precipitation type was mainly light rain instead of melting snow as shown in Figure 2. Result is due to slightly lower temperature seen from COSMO NWP model over these areas. Next steps will be to assimilate real-time ground observations in the algorithm.

9 ACKNOWLEGMENTS

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