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The weather radar system of north-western Italy: an advanced tool for meteorological surveillance

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Abstract. North-Western Italy is a geographical region characterized by complex orography with many river catchments. Severe meteorological conditions frequently leads to flood situations due to very high rainfall amounts. In addition to a quite dense net of rain gauges, in the last three years two Doppler radar systems have been installed to provide a continuous monitoring of the region.

The *Bric della Croce* radar, with a magnetron transmitter, was installed in 1999 above the Turin hill, at 736 m height, and is now fully operational with real-time data transmission to the regional weather service in Turin via a radio link. It has been recently updated to dual polarization. The second radar was installed at the end of 2001 on the top of the *Settepani* mountain, at about 1400 m height in the Ligurian Apennines. It is a klystron equipped system, with dual polarization capabilities and a full digital receiver. The radar sends real-time data to the regional weather service via a satellite link.

In this paper a general description of both radar systems is given, with a special emphasis on the issues related to the surrounding mountainous environment. Due to a distance of about 90 km between the two radar sites, combining their measurements offers a chance to face problems due to beam blocking and allows to derive a detailed wind field over a wide area, in one of the most meteorologically interesting regions in Europe.

1 Introduction

During the last decades severe flood events repetitively hit North-Western Italy at 2–3 years intervals. Those floods may cause large amounts of economic damages and in the worst case human losses as well. The strong impulse given to the development of the meteorological service within the "Settore Meteoidrografico e Reti di Monitoraggio" of the Piedmont region in the second part of the nineties lead to an effective alert system in case of flood warning. This system proved its effectiveness especially during the last severe flood of October 2000, when the accuracy of the forecast and the early warnings to the regional and sub-regional authorities limited the amount of material damages. During this event, despite its severity, no human losses were registered.

In 1999, in connection with the meteorological monitoring network reinforcement, the old analog radar operational since 1978 in *Bric della Croce*, over the Turin hill, was replaced with a digital Doppler and dual polarization system. Two years later, in 2001, a second Doppler and polarimetric radar was installed over the *Settepani* mountain, in the Ligurian Apennines. This new radar meets the main goal of extending the surveillance area to the Northern Tyrrhenian Sea and in particular the Gulf of Genoa, where important convective activity, often associated with lee cyclogenesis, take place. Figure 1 shows the location and range coverage at 125 km of both radars.

2 The *Bric della Croce* radar

The radar is located above the Turin hill at 736 m above mean sea level, on the top of a 25 m high tower. The position, central and free from obstacles in the near surroundings, is especially suitable for monitoring the region: Fig. 2 shows a visibility map, which emphasizes the good regional coverage with the best performance in East direction. Toward West the radar beam at low elevation angles is completely or partially blocked by Alps and the first useful elevation is generally between 2.0° and 3.0°.

The elevation set of the operational volume scan at 125 km has been calculated using the standard model for beam propagation (Doviak and Zrnic, 1993), 1 km resolution DEM model and following few simple rules:

– determination of a minimum elevation angle tangent to the ground in East direction to adequately cover Po valley floor (Wood and Brown, 2001);

– determination of the elevations between the minimum

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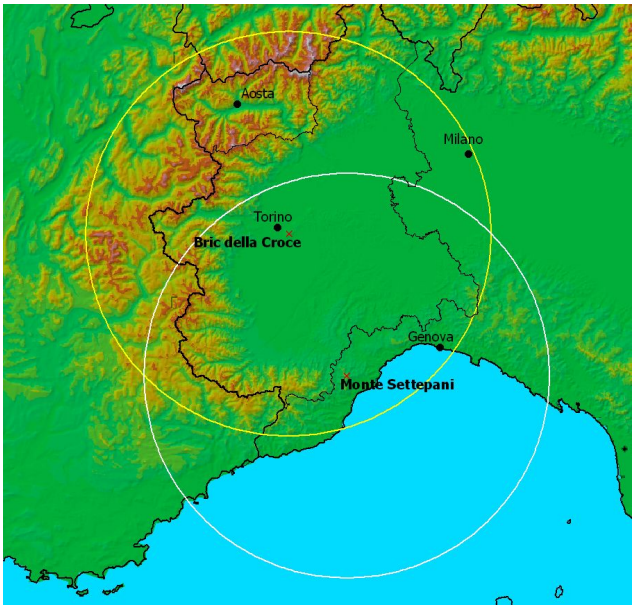

Fig. 1. *Bric della Croce* and *Monte Settepani* locations with range ring at 125 km.

(in our case $-0.1°$) and the first one completely unblocked (3.0°): this is calculated by maximising the increment in the overall visibility between successive elevations and oversampling the lowest layers for better rainfall estimation;

– determination of equivolumetric spaced elevations above the first completely unblocked elevation (3.0°), given a maximum number of elevations (11) and maximum height (15 km).

The set of the 11 elevations obtained with this method is: -0.1, 0.5, 1.2, 2.0, 3.0, 4.4, 5.8, 7.4, 10.0, 15.0, 28.5. Figure 3 shows the elevation set for different azimuth directions. It is worth noting the best visibility along the Po valley (East direction), while the Alps limit the coverage of the lower atmospheric layers in the Western section.

The operational schedule consists of a volume scan at 125 km range with the complete set of 11 elevations and a second volume scan for qualitative monitoring at 250 km with just the first 5 elevations: this schedule is repeated every 10 min in case of significant weather conditions, otherwise the same schedule is executed with a lower frequency (30 min). The 125 km volume scan is currently performed to acquire reflectivity and Doppler data only: the PRF is 1100 Hz and the number of integrated short pulses (0.5 μs) is 55. For the 250 km range volume scan the PRF is 500 Hz and the number of integrated long pulses (2.0 μs) is 33. Until now Z_{DR} is only acquired experimentally: to measure operationally Z_{DR} the operational schedule will have to be revised.

The main technical characteristics of the *Bric della Croce* radar are listed in Table 1. The transmitter is a magnetron type and the 4.2 m diameter antenna is covered by a radome. The accuracy of the polarimetric measurements with this

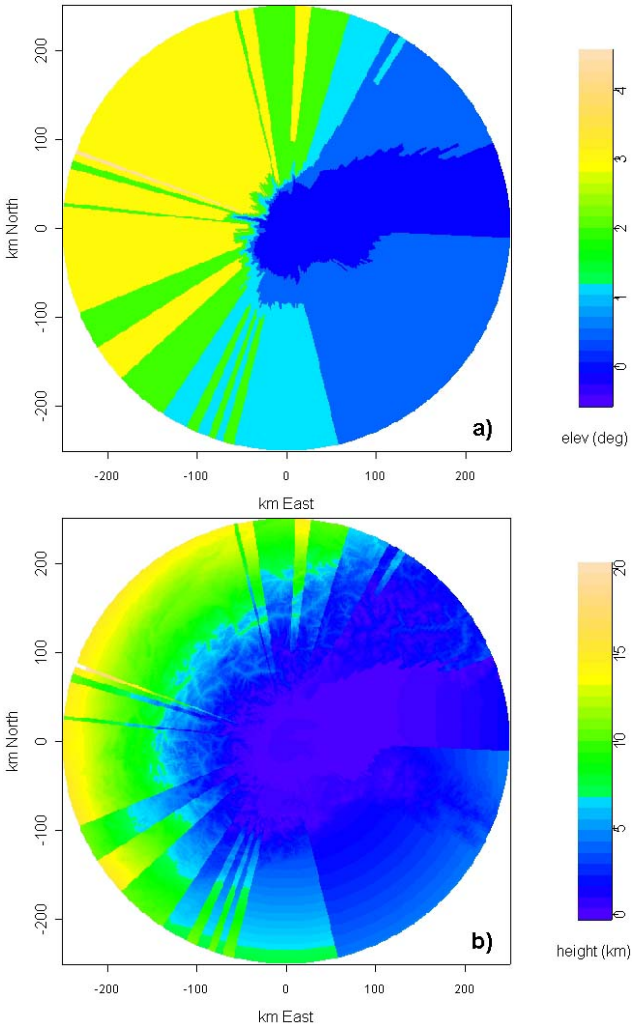

Fig. 2. Visibility map up to 250 km for the *Bric della Croce* radar: elevation angle of the first beam not blocked, considering the beam centre **(a)**; height above the ground of the first beam not blocked **(b)**.

hardware configuration is currently under evaluation. Polarimetry is still not much used for operational radars, due to limitations such as the longer scan period or the presence of radome covering the antenna, which may actually cause unpredicted results. Nevertheless, the very first measurements performed after the installation of the polar switch at the *Bric della Croce* radar are quite encouraging and allow to think about employing Z_{DR} measurements for:

– improving the clutter subtraction algorithms;

– microphysical discrimination between different hydrometeors such as rain, snow, hail;

– rainfall estimation.

A speciality of the radar system is the presence of two identical analog receivers: this hardware configuration allows the use of one receiver channel for research purposes

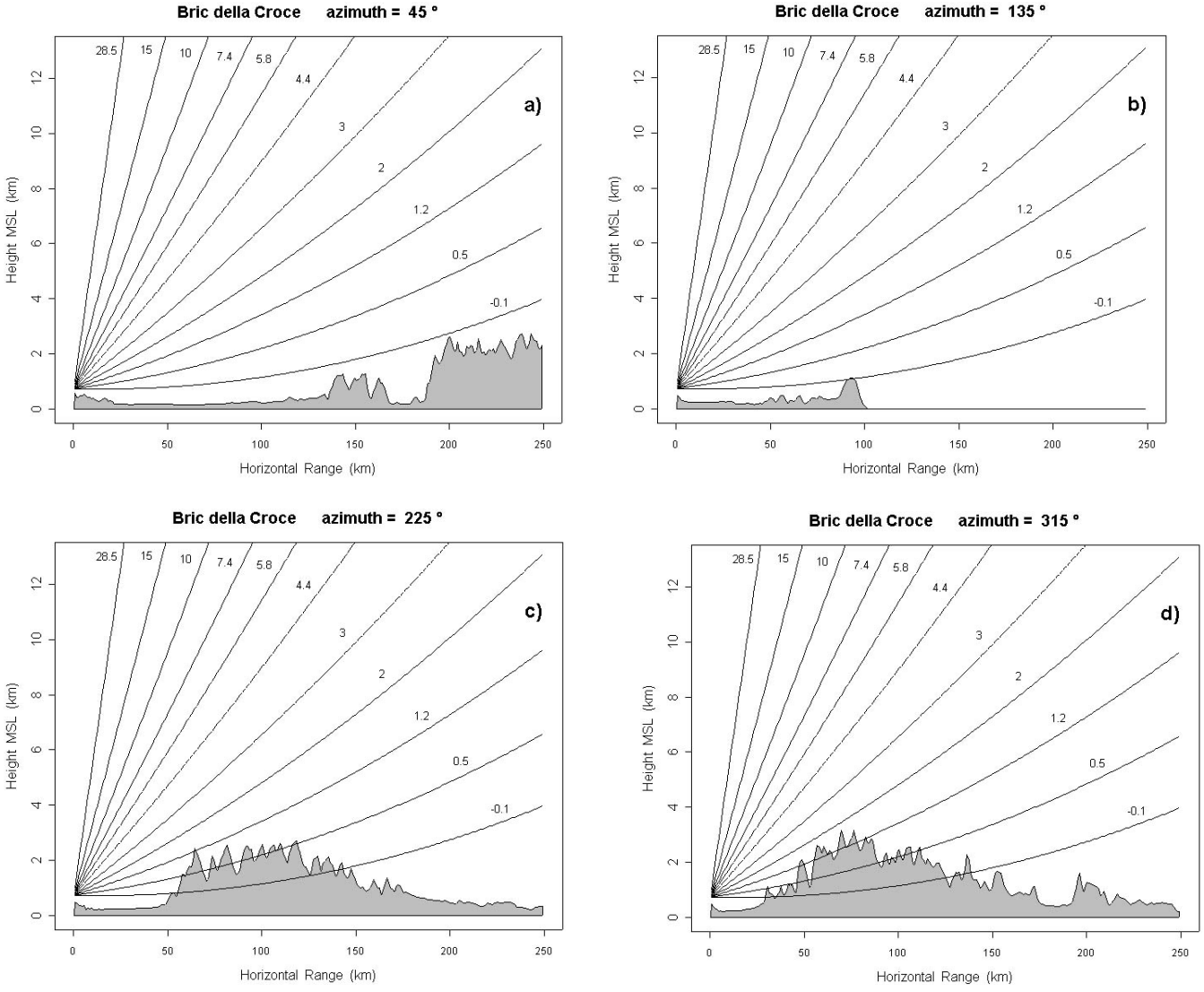

Fig. 3. *Bric della Croce* vertical cross-sections of topography with beam heights for 11 elevation angles and different azimuth directions: 45° **(a)**, 135° **(b)**, 225° **(c)**, 315° **(d)**.

only. In this way it is possible to test and optimise new processing algorithms without interfere with the operational acquisition mode.

The data are real-time transmitted to the operational centre in Turin: besides the 128 kbit/s CDN line a 2 Mbit/s radio link allows heavier data transfer for research purposes and prevents from data losses in case of fault of the CDN line.

The power supply to the whole radar and data transmission system is guarantee even in case of power fault thanks to an UPS system and a 20 kVA generator with a 72 h autonomy.

The system is remotely controlled from the regional meteorological centre in Turin, 14 km far from the radar site: messages about the system status are continuously sent to regional centre to allow a constant monitoring of the system.

3 The *Settepani* radar

The installation of the Ligurian radar began in autumn 2001 and it is now completed: the system is currently in a pre-operational phase. The radar is located at 1386 m height, above one of the higher peak in the Ligurian Apennines chain. This dominant position makes the system very attractive for extended monitoring capabilities in South direction over the Ligurian sea and in North-North-East direction over the Po valley.

During the Autumn season depressions in the Ligurian sea are frequent, causing large amounts of precipitation along the coast and in the Po valley due to strong Southerly wet flow above the sea.

The new radar system looking over the sea will improve monitoring and nowcasting in North-Western Italy.

Some special features distinguish this system from the

Table 1. *Bric della Crove* site and system specifications

Site	
Location	Pecetto Torinese (TO)
Height	736 m
Latitude	45.03
Longitude	7.73
Main technical data of the radar system	
Radar type	Meteor 400C
Polarization type	Linear H and V
Measured parameters	Z_H, Z_{DR}, V, σV
Antenna diameter	4.2 m
Beam width	1.0° max. w/o radome
Maximum sidelobe level	-28 dB
Maximum cross polar discrimination	-25 dB
Antenna gain	44.5 dB
Radome type	sandwich
Radome transmission loss	0.2 dB max., one way
Transmitter type	Magnetron
Frequency	5450 ÷ 5825 MHz
Peak Power	$\geq$ 250 kW
Pulse length	0.5, 2.0 μs
PRF	250 ÷ 1200 Hz
Receiver noise figure	$\leq$ 3.0 dB
MDS	≤ -110 dBm
Effective dynamic range	90 dB

Table 2. *Settepani* site and system specifications

Site	
Location	Calizzano (SV)
Height	1390 m
Latitude	44.25
Longitude	8.20
Main technical data of the radar system	
Radar type	GPM 250C
Polarization type	Linear H and V
Measured parameters	Z_H, Z_{DR}, V, σV
Antenna diameter	4.2 m
Beam width	1.0° max. w/o radome
Maximum sidelobe level	-28 dB
Maximum cross polar discrimination	-25 dB
Antenna gain	44.5 dB
Radome type	sandwich
Radome transmission loss	0.2 dB max., one way
Transmitter type	Klystron
Frequency	5600 ÷ 5650 MHz
Peak Power	$\geq$ 250 kW
Pulse length	0.5, 1.5, 3.0 μs
PRF	300 ÷ 1200 Hz
Receiver noise figure	$\leq$ 2.5 dB
MDS	≤ -110 dBm
Effective dynamic range	$\geq$ 95 dB

Bric della Croce radar. Among the technical characteristics listed in Table 2, it is worth noting the klystron transmitter, which allows very stable phase measurements, and the full digital receiver, with better clutter suppression capabilities and more stable calibration. The 4.2 m antenna covered by a radome is the same type as that installed at *Bric della Croce*.

Since the radar is located at about 1400 m height in a complex orography terrain, a considerable amount of the measurements, especially during winter season, will be in the ice or ice mixed with water phase. From this point of view polarimetry will be of great help to distinguish the type of meteorological target, allowing the choice of appropriate algorithms for rainfall estimation. Using polarimetric measurements, improvements in clutter suppression are expected as well.

Using the same scan schedule as the *Bric della Croce* one, visibility maps for the Ligurian radar have been calculated: these are shown in Fig. 4. Due to the high location of the radar and the use of negative elevation angle, the system is able to catch precipitation close to the ground even in the North direction, where the highest mountains restrict the *Bric della Croce* visibility. The presence of two mountain peaks (Mt. Carmo: 1389 m and Mt. Grosso: 1268 m) close to the site in West direction causes poor visibility for about a 15° sector.

As in the *Bric della Croce* site, the whole system is remotely controlled by Piedmont regional centre and it is equipped with a power supply generator. The data acquired are simultaneously transmitted by a satellite link to the Piedmont weather regional centre in Turin and to the Ligurian civil protection centre in Savona. Ground links are also available for backup.

Reflectivity data coming from both radars are merged in a mosaic which extends from Northern Alps to the Corsica. The merging can be performed using different techniques in the overlap area:

- choose data from the closest radar;
- choose the maximum value;
- choose from a priority map.

As seen from visibility maps of the two radars, the major problems comes from the Maritime Alps region, South-West from Turin and West from Monte Settepani, close to the French borderline: in this area an improvement is expected by merging with French radars.

4 Conclusions

This paper has shown new radar installations in North-Western Italy: both instruments are C-band Doppler radars

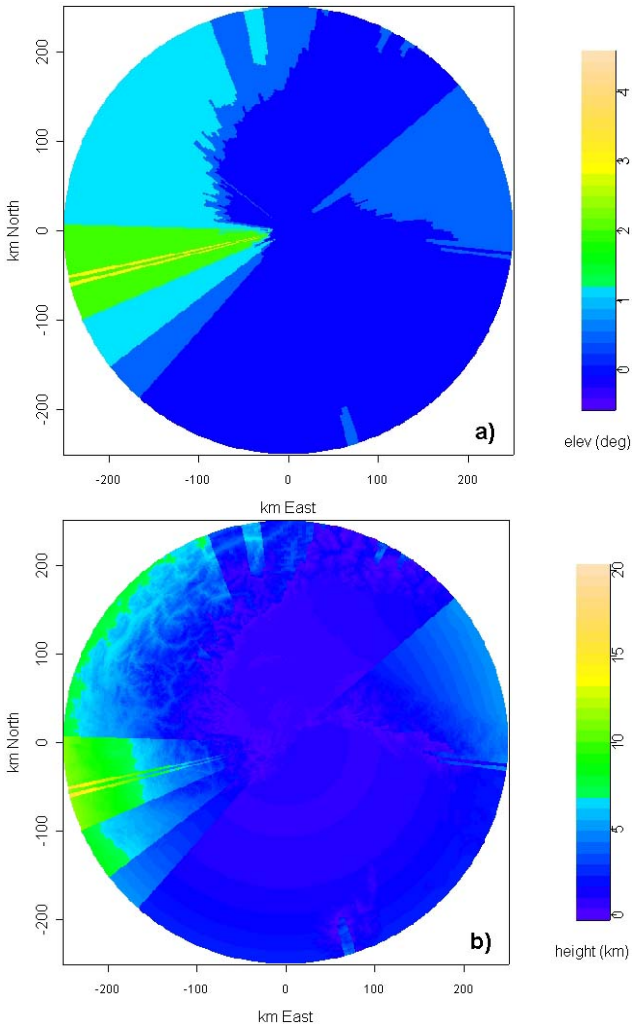

Fig. 4. Same as Fig. 2, but for the Settepani radar.

with polarimetric capabilities and fully remotely controlled. The first one is located close to Turin in a central position within Piedmont region; the second one is located in the Ligurian Apennines, having a good visibility over the Po valley and the Ligurian sea. This radar network allows the monitoring of the Western Mediterranean area, where deep troughs associated with heavy rainfall cause frequent floods over the North- Western Italian region. Moreover the system responds to the requirements for the development of the next Italian national radar network. The operational use of the two radar systems with the 350 real-time ground stations network of the Piedmont region will improve monitoring and nowcasting of extreme weather conditions that affects North-Western Italy.

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