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The Italian radar network: current status and future developments

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Abstract. The primary justification for a weather radar network, in Italy, is for the detection and warning of severe weather and related hydro-geological risks. In the Mediterranean area floods, even in the form of flash floods, represent a recurrent problem, especially during the fall season. The damages associated to these events are very significant both in terms of human and social costs and losses of unique monuments and cultural heritage. The hydrological risk is further enhanced by the Italian orography, which is characterized by small catchments along most coastlines and by the Alpine and Apennine ranges. Early installations of Doppler Weather Radars by Regional Authorities date back to the middle of eighties. Major efforts have been carried out, indeed, by Northern Regions where so far there is fairly large number of technologically-advanced Weather Radars. The Dipartimento di Protezione Civile is entitled to implement a programme for the meteorological radar coverage over the national territory with the technical support of the National Research Group for the Prevention of Hydrogeological Disasters. A short presentation of the radar and the network will be given in the paper.

1 Introduction

In the Mediterranean area floods, even in the form of flash floods, represent a recurrent problem, especially during the fall season. The damages associated to these events are very significant both in terms of human and social costs and losses of unique architectural properties. In Italy the hydrological risk is further enhanced by the orography, which is characterized by small catchments along most coastlines and by the Alpine and Apennine ranges. Going from North to South, the Apennine divides Central and Southern Italy in two main geographical areas along the Tyrrenian, the Adriatic and Ionic seas.

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This scenario, characterized by such geographical constraints, some extreme rainfall events and the related hydrogeological disasters occurred in the recent years has highlighted the need of an up-to-date monitoring system. A number of actions have been undertaken to fill this ”monitoring” gap, one of this is the placing a new national Weather Radars network. Indeed, the primary justification for a weather radar network, in Italy, is for the detection and warning of severe weather and related hydro-geological risks. The actual Italian “network” configuration will be presented in Sect. 2, but we want just recall here that non- uniform radar coverage throughout the Italian peninsula is available up-to today. This network is mainly concentrate in the northern part of the country, with only few operational radar centers are present along the Apennine region. Besides, any operational radar monitoring does still not cover Italian islands, like Sicily and Sardinia.

To ensure a national framework for the new network and to give the adequate financial support the Law no. 365 of 11 December 2000 prescribes that the Italian Department of Civil Protection (DPC), with the technical support of the National Research Group for the Prevention of Hydro-geological Disasters (GNDCI), has to implement a program for the meteorological radar coverage over the national territory.

A short review of the present state of the Italian weather Radar Network, the plan of the new Network and the characteristics of the system will be described in the following sections.

2 Actual radar monitoring capacity

Early installations of operational Weather Radars in Italy date back to the middle of seventies. The first effort in this field was carried out by the Weather service of the Italian Air Force, while it is important to note that contemporary some efforts have been spent in early scientific investigation in the use of weather radar. This situation has prepared the first civil installation of weather radar. From the middle of eighties

Fig. 1. Status of the Italian radar coverage as classified at 31 December 2001 – The colored-symbol legend explains the owner institution (i.e., Regional Authority, Air Force, Research Institution) and the current status of each radar system (i.e., operational, not operational, to be installed).

some Regional Authorities start a pioneristic work in the use of radar for monitoring the evolution of the weather. Major efforts have been carried out, indeed, by Northern Regions where so far there is fairly large number of technologically-advanced Weather Radars.

This inhomogeneous distribution of Weather Radars in Italy can be appreciated by looking at Fig. 1. This figure shows the existing Weather Radar sites on the geographical map of Italy, derived from a high-resolution digital elevation model. The colored-symbol highlight the owner institution (i.e., Regional Authority or Air Force) and the current status of each radar system (i.e., operational, not operational, to be installed).

The systems that are present could be classified in term of management under three classes: Regional Authorities, Research Radar and Italian Air Force.

2.1 Regional authorities radar network

As evident from Fig. 1, the Northern Alpine regions and the Po-river valley present a relevant number of radar sites, able to ensure an excellent radar monitoring for surveillance and warning purposes. As a result of these efforts, at the beginning of the nineties a project called METEONET was started within the National Information System of Environment (SINA), funded by the Ministry of Environment and by the interested Regions. The aim of METEONET was to provide a radar composite of Northern Italy, that is a mosaic of rainfall products available from operational Weather Radars. The METEONET project was successfully concluded on 31 December 2000. For a further insight, Table 1 enumerates the main technical characteristics of the Weather Radars shown in Fig. 1 in terms of manufacturer, Doppler capability, operating frequency band, dual polarization option, beamwidth and radome presence. Radar current status, classified on 31 December 2001, is also given.

Another interesting feature coming from Table 1 is that almost all Weather Radars, managed by Regional Authorities, operate at C-band. The only exception is that of Spino d'Adda which operate at S band. It is worth mentioning that the Weather Radar of Italian National Council of Research (CNR) (not shown in Fig. 1) in Rome can operate with full polarimetric capabilities, besides having the Doppler mode. This CNR radar in Rome could be used to temporarily cover the Central Tyrrenian area of Italy corresponding to the Lazio region. Operational C-band radars, already foreseen and provided by other National Agencies, are envisaged to be installed in the Lazio region within the same temporal framework of DPC planned network.

If the Italian Air Force radars and the Research radars are excluded, from the analysis of Fig. 1 it emerges that in Central and Southern Italy only the Weather Radar of Preturo in Abruzzo is considered operational, being that one of Sicily (i.e., M. delle Rose) and of Sardinia (i.e., M. Rasu) still not used. Moreover, due its cumbersome location in the middle of Central Apennine, the Weather Radar of Preturo is on the way to be moved in a site with a wider radar visibility (i.e., M. Midia).

2.2 Italian Air Force radar network

The Italian Air Force has a long tradition within the history of national Meteorology. The Ufficio Generale di Meteorologia (UGM, General Office of Meteorology) represents Italy's interests within the international meteorological organizations.

Italian Air Force begun to install Weather Radars since the beginning of eighties. Figure 1 shows the UGM Weather Radar sites, while Table 2 lists the main technical characteristics of these Weather Radars in the same way of Table 1. It should be noted that Italian Air Force has other institutional duties inherent to military services and operations. As a matter of fact, all listed radar are located in military airports. This implies that the use of Weather Radar is very often shared with activities not directly related with the surveillance for hydro-geological defense purposes.

Table 2 shows that the majority of AMI Weather Radars is not technologically advanced, especially for what concerns Doppler capabilities and antenna directivity. The radar sites of San Giusto and Brindisi represent the exceptions; the latter is unfortunately not operational.

Table 1. Location of the existing Weather Radars in Italy belonging to Regional Authorities. "Site" names are those indicated in Fig. 1. Main specifications are also given in terms of manufacturer, Doppler capability, operating frequency band, dual polarization option, beamwidth and radome presence. Current status is classified on 31 December 2001. Membership to METEONET Italian network is also evidenced

Weather Radar Site	Main Characteristics	Current status
Name: **San Pietro Capofiume (BO)** Owner: ARPA Emilia Romagna Site: Lat. 44°39'22'', Lon. 11°37'26'' Altitude: 11 m	Manufacturer: **ALENIA-SMA** Doppler: **YES** - Band: : **C** Dual polarization: **YES** Beamwidth: **0.9° --** Radome: **NO**	Operational; member of the Italian METEONET network
Name: **Monte Grande - Teolo (PD)** Owner: ARPA Veneto Site: Lat. 45° 21' 46'', Lon. 11° 40' 25'' Altitude: 472 m	Manufacturer: **EEC-ERICSSON** Doppler: **YES** - Band: **C** Dual polarization: **NO** Beamwidth: **1°** - Radome: **YES**	Operational; member of the Italian METEONET network
Name: **Spino d'Adda (CR)** Owner: CNR Manager: PoliMI Site: Lat. 45° 24' 00'', Lon. 9° 30' 00'' Altitude: 80 m.	Manufacturer: **ALENIA** Doppler: **YES** - Band: **S** Dual polarization: **NO** Beamwidth: **2°** - Radome **NO**	Operational; member of the Italian METEONET network
Name: **Fossalon di Grado (GO)** Owner: ARPA Friuli Venezia Giulia Site : Lat. 45° 43' 40'', Lon. 13° 28' 00'' Altitude: 25 m.	Manufacturer: **ALENIA-SMA** Doppler: **YES** - Band: **C** Dual polarization: **YES** Beamwidth: **0.9°** - Radome: **NO**	Operational; member of the Italian METEONET network
Name: **Preturo (AQ)** Owner: Regione Abruzzo - CETEMPS Site: Lat. 42° 22' 48'', Lon. 13° 19' 12'' Altitude: 680 m.	Manufacturer: **EEC-ERICSSON** Doppler: **YES** - Band: **C** Dual polarization: **NO** Beamwidth: **1.6°** - Radome **YES**	Operational; External member of the Italian METEONET network; to be moved to M. Midia
Name: **Monte Macaion (BZ)** Owner: Autorità di bacino dell'Adige Manager: Province di Trento e Bolzano Site : Lat. 46° 29' 44'', Lon. 11° 12' 37'' Altitude: 1890 m.	Manufacturer: **EEC-ERICSSON** Doppler: **YES** - Band: **C** Dual polarization: **NO** Beamwidth: **1°** - Radome: **YES**	Operational; member of the Italian METEONET network
Name: **Bric della Croce (TO)** Owner: Regione Piemonte Site: Lat. 45°1'53'', Lon. 7°43'59'' Altitude: 720 m	Manufacturer: **ALENIA** Doppler: **YES** - Band: **C** Dual polarization: **NO** Beamwidth: **1°** - Radome: **YES**	Operational; member of the Italian METEONET network
Name: **Monte Rasu Bono (SS)** Owner: Regione Sardegna - SAR Site: Lat. 40° 25' 21'', Lon. 9° 00' 19'' Altitude: 1259 m.	Manufacturer: **ALENIA-ERICSSON** Doppler: **YES** - Band: **C** Dual polarization: **YES** Beamwidth: **0.95** - Radome: **YES**	To be tested; Not operational.
Name: **Monte delle Rose (PA)** Owner: Regione Sicilia Site: Lat. 37° 39' 14'', Lon. 13° 25' 06'' Altitude: 1436 m.	Manufacturer: **EEC-ERICSSON** Doppler: **YES** - Band: **C** Dual polarization: **NO** Beamwidth: **0.9°** - Radome: **YES**	Tested; Not operational.
Name: **Colle Settepani (SV)** Owner: Regioni Liguria e Piemonte Site: Lat. 44° 14' 57'', Lon. 8° 11' 55'' Altitude: 1387 m.	Manufacturer: **ALENIA-SMA** Doppler: **YES** - Band: **C** Dual polarization: **YES** Beamwidth: **1°** - Radome: **YES**	Testing phase; operational within the middle of 2002.
Name: **Gattatico (RE)** Owner: DSTN Manager: ARPA Emilia Romagna Site: Lat. 44° 47' 29'', Lon. 10° 29' 57'' Altitude: 34 m.	Manufacturer: **ALENIA-SMA** Doppler: **YES** - Band: **C** Dual polarization: **YES** Beamwidth: **0.9°** - Radome: **NO**	Testing phase; operational within the middle of 2002.
Name: **Loncon (VE)** Owner: ARPA Veneto Site: Lat. 45° 41' 12'', Lon. 12° 47' 12'' Altitude: 14 m.	Manufacturer: **EEC-ERICSSON** Doppler: **YES** - Band: **C** Dual polarization: **NO** Beamwidth: **0.9°** - Radome: **YES**	To be installed within the beginning of 2003

3 Planned radar network

A suitable location of new Weather Radars is essential to fulfill the need of a possibly uniform coverage of the Italian territory. From what previously argued, a priority has to be given to Central, Southern and Island regions. This requirement has to struggle with the difficulty due to the predominant mountainous characteristic of these Italian areas. An index of meteorological and hydro-geological risks, statistically affecting these areas, can be thought as a further constraint to the radar site choice.

Figure 2 shows the result of this cumbersome exercise, indicating the sites to be considered within this project. Table 3 lists the locations of the fourteen new Polarimetric Doppler Radar Systems (PDRS), planned by DPC. "Site" names are those pictured in Fig. 2 "Zone" indicates the geographical area, while "Region" is related to the respective regional Authority.

An indication of the complementarity of DPC-planned radar network with the existing one (shown in Fig. 1) can be derived comparing Fig. 1 and Fig. 2. It should be pointed out that, considering that C-band has been the general choice in Italy (and in most Europe) for Weather Radars, PDRS are thought to operate at C band. This can have several advantages; its major drawbacks will be soon discussed.

As anticipated, the planned radars shall exhibit both Doppler and polarimetric capabilities. These specifications emerge for two basic reasons. First, severe weather radars are connected to wind precursor activity so that Doppler option is essential for wind fields reconstruction (Sauvageot, 1992; Doviak and Zrnic, 1993). Secondly, at C band and during strong precipitation path attenuation can be significantly high and need to be accurately corrected (Gorgucci et al., 1996; Delrieu et al., 2000). To this aim it has been widely shown in literature that differential reflectivity and differential phase shift measurements can be successfully used to estimate rainfall, with an accuracy much higher that obtained by using single-polarization data even in extreme rain conditions (Zrnic and Ryzhkov, 1996; Gorgucci et al., 1999). Path attenuation correction procedures at C band have been recently proposed and successfully applied to polarimetric

Table 2. Location of the existing Weather Radars in Italy belonging to the Italian Air Force. "Site" names are those indicated in Fig. 1. Main specifications are also given in terms of manufacturer, Doppler capability, operating frequency band, dual polarization option, beamwidth and radome presence. Current status is classified on 31 December 2001

Weather Radar Site	Main Specifications	Current status
Name: Brindisi (BR) Owner: Aeronautica Militare Italiana Site: Lat. 40° 38' 00'', Lon. 17° 57' 00'' Altitude: 25 m.	Manufacturer: ALENIA Doppler: YES - Band: C Dual polarization: YES Beamwidth: 0.9° - Radome: NO	Not operational
Name: San Giusto (PI) Owner: Aeronautica Militare Italiana Site: Lat. 43° 40' 47'', Lon. 10° 38' 24'' Altitude: 25 m.	Manufacturer: ALENIA Doppler: YES - Band: C Dual polarization: YES Beamwidth: 0.9° - Radome: NO	Operational
Name: Grazzanise (NA) Owner: Aeronautica Militare Italiana Site: Lat. 41° 02' 59'', Lon. 14° 04' 12'' Altitude: 30 m.	Manufacturer: PLESSEY Doppler: NO - Band: C Dual polarization: NO Beamwidth: 1.5° - Radome: NO	Operational
Name: Istrana (VE) Owner: Aeronautica Militare Italiana Site: Lat. 45° 40' 47'', Lon. 12° 05' 59'' Altitude: 30 m.	Manufacturer: PLESSEY Doppler: NO - Band: C Dual polarization: NO Beamwidth: 1.5° - Radome: NO	Operational
Name: Trapani (TP) Owner: Aeronautica Militare Italiana Site: Lat. 37° 55' 12'', Lon. 12° 30' 00'' Altitude: 30 m.	Manufacturer: PLESSEY Doppler: NO - Band: C Dual polarization: NO Beamwidth: 1.5° - Radome: NO	To be installed
Name: Decimomannu (CA) Owner: Aeronautica Militare Italiana Site : Lat. 39° 21' 00'', Lon. 8° 58' 12'' Altitude: 30 m.	Manufacturer: PLESSEY Doppler: NO - Band: C Dual polarization: NO Beamwidth: 1.5° - Radome: NO	To be installed

Fig. 2. Geographical map of Italy illustrating new fourteen Polarimetric Doppler Radar System sites, planned by DPC.

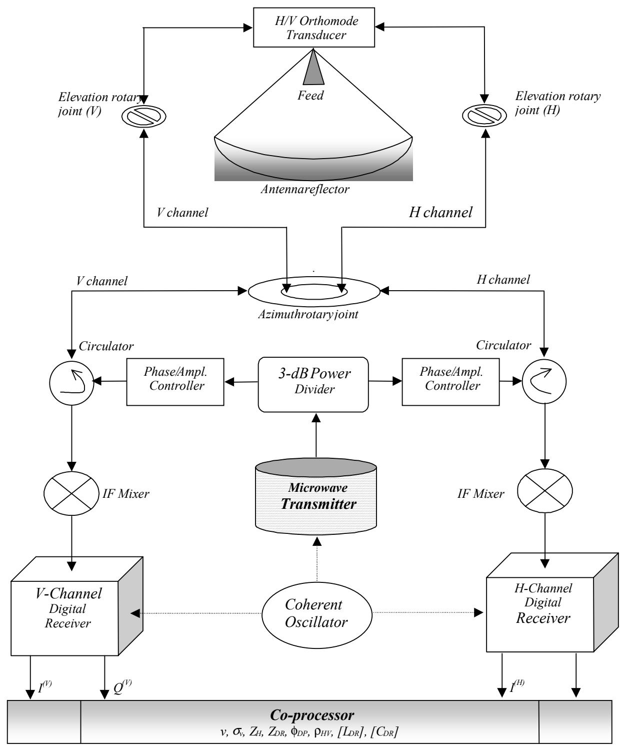

Fig. 3. Conceptual diagram of polarimetric configuration of the Polarimetric Doppler Radar System, referred as to dual-receiver simultaneous transmission.

radar data (Testud et al., 2000; Bringi et al., 2001).

In this respect, DPC-planned PDRS network can be seen as a technological challenge within the operational radar community. We believe that, if its goals are correctly achieved, the benefits in terms of accurate rainfall remote sensing will be much higher and durable than potential costs (Doviak et al., 1998; Doviak et al., 2000; Brandes, 2000). Indeed, the aim is to obtain at least 2 full PDRS, while ensuring the remaining radar systems to be easily upgradeable to a polarimetric capability.

The essential technical characteristics for the new radars are:

– C band

– Doppler capacity up to 125 km

Table 3. Location of the fourteen new Polarimetric Doppler Radar Systems, planned by DPC. “Site” names are those pictured in Fig. 2, “Zone” indicates the geographical area, while “Region” is related to the respective regional Authority

SITE	ZONE	REGION	LATITUDE	LONGITUDE	ALTITUDE (m)
Monte Matajur	Friuli/Slovenia	Friuli-Venezia Giulia	46°13’00’’	13°31’00’’	1641
Monte Le Pizzorne	Toscano/Ligure	Toscana	43°56’15’’	10°34’54’’	1023
Monte Paganuccio	Medio Adriatico	Marche	43°38’05’’	12°44’31’’	976
M. Poggio di Montieri	Toscana Litoranea	Toscana	43°07’36’’	11°01’29’’	1051
Monte Serano	Appennino Centrale	Umbria	42°51’36’’	12°47’59’’	1428
Il Monte	Abruzzo Adriatico	Abruzzo	41°56’22’’	14°37’16’’	692
Piana di Montenero	Puglia Settentrionale	Puglia	41° 70’	15°72’	1014
Monte Comune	Campania Penisola Sorrentina	Campania	40°37’46’’	14°26’57’’	877
Monte Li-Foy	Basilicata	Basilicata	40°38’59’’	15°49’48’’	1350
Località Casarano	Puglia Meridionale	Puglia	40°00’	18°16’	178
Monte Pettinascura	Calabria Ionica	Calabria	39°23’56’’	16°37’44’’	1705
Monte Pecoraro	Calabria Tirrenica	Calabria	38°31’58’’	16°19’58’’	1423
Monte Armidda	Sardegna Meridionale	Sardegna	39°52’59’’	09°29’41’’	1261
Monte Lauro	Sicilia Meridionale	Sicilia	37°06’57’’	14°48’00’’	986

– Operation (or possibility of) with polarimetric quantities (e.g. dual polarisation)

– Antenna with characteristics compatible with polarimetric observations

– Max angular width of the beam = 1°

– Radar system remotely controlled with 24-hour operability

A conceptual block diagram for the complete Doppler polarimetric system is shown in Fig. 3. The adopted polarimetric scheme is the so-called *hybrid scheme with simultaneous transmission*, that is the radar shall be capable of transmitting contemporary the horizontal (H) and vertical (V) linear polarization in a defined power ratio and phase shift and receiving both polarizations.

As a possible advanced polarization configuration will consider the capability to change the transmit polarization ratio in real time is required, being of peculiar interest the real-time switch between 45°-linear polarization (i.e., simultaneous transmission of H and V signal components) and horizontal linear polarization. The radar shall be capable of receiving in both planes simultaneously.

The main output variables of interest are: uncorrected Z_H, corrected Z_H, radial velocity v, spectrum width σ_v, differential reflectivity Z_{DR}, differential phase shift ϕ_{DP}, copolar correlation coefficient ρ_{HV} (at zero lag) and, when transmitting only horizontal polarization, linear depolarization ratio L_{DR}. Further the bidders should consider to calculate, in the RSP, from the co-polar quantity also the Circular Depolarisation Ration (CDR).

3.1 Radar system network

The distribution of PDRS over the entire Italian territory has as a consequence a careful analysis of the radar network topology and the interconnection between each node. The effort of DPC to complete the national radar network aimes, at the same time, to establish a common framework for the optimal use of all existing Weather Radars, belonging to both Regional Authorities and Italian Air Force. In this respect, an open and flexible network technology is of primary impor-

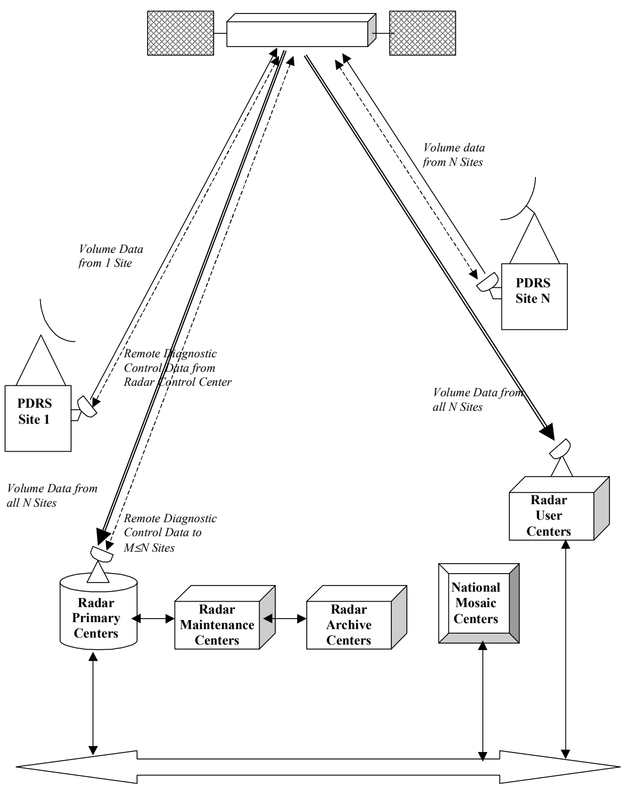

Fig. 4. Conceptual diagram of DPC Radar System Network connected through satellite up-links and down-links.

tance. The basic DPC choice to ensure the accomplishment of this mid-term goal is to resort to a satellite communication system both for transferring data and to remotely control the radar systems.

Figure 4 shows a conceptual scheme of the data communication network connecting each PDRS site to the Radar Primary Centers (RPC), Radar User Centers (RUC), National Mosaic Centers (NMC), Radar Archive Centers (RAC) and Radar Maintenance Centers (RMC). The service to be guaranteed shall consist of transferring information from remote Radar System Sites (hereinafter referred as Sources), distributed throughout Italy and located in difficult-to-access areas, to remote Radar Control Centers (hereinafter referred as Destinations) also throughout Italy and located within a easy-to-access area. Each Source shall pick the data, which flow without interruption, from a device dedicated to the memorization of the information. Before the memorization, the data shall be received from the Radar and elaborated.

The aim of the Radar System Network is to allow a transmission service performed at constant bit rate (e.g., equal to 512 kbit/s) from each Source 24 hours a day to each (or a part) Destination. Low-resolution data are supposed to be transmitted from PDRS in order to reduce the bit rate. Every Source must also receive a low-rate flow (e.g., 64 kbit/s), which must be sent to the radar for control and diagnostic information.

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References

Brandes E.A., ”Dual-polarization radar fundamentals and algorithm prospects”, Report on Next Generation Weather Radar Program – Operational Support Facility, WSR-88D Commerce-Defence-Transportation, May 2000.

Bringi V.N., T.D. Keenan and V. Chandrasekar, ”Correcting C-band radar reflectivity and differential reflectivity data for rain attenuation: a self-consistent method with constraints”, IEEE Trans. Geosci. Remote Sensing, 39, 1906–1916, 2001.

Delrieu G., H. Andrieu and J.D. Creutin, ”Quantification of path-integrated attenuation for X- and C-band weather radar systems operating in Mediterranean heavy rainfall”, J. Appl. Meteor., 39, 840–850, 2000.

Doviak R.J. and D.S. Zrnic, Doppler radar and weather observations, Second edition, Academic Press, San Diego (CA), 1993.

Doviak R.J., V. Bringi, A. Ryzhkov, A. Zahrai and D. Zrnic, ”Considerations for polarimetric upgrades to operational WSR-88D radars”, J. Atmos. Ocean. Tech., 17, 257–278, 1998.

Gorgucci E., G. Scarchilli and V. Chandrasekar, ”Error structure of radar rainfall measurement at C-band frequencies with dual polarization algorithm for attenuation correction”, J. Geophys. Res., 101, 26461–26471, 1996.

Gorgucci E., G. Scarchilli and V. Chandrasekar, ”Specific differential phase estimation in the presence of non-uniform rainfall medium along the path”, J. Atmos. Ocean. Tech., 16, 1690–1697, 1999.

Sauvageot H., Radar meteorology, Artech House, Boston (MA), 1992.

Testud J., E. Le Bouar, E. Obligis and M. Ali-Mehenni, ”The rain profiling algorithm applied to polarimetric weather radar”, J. Atmos. Oceanic Tech., vol. 17, pp. 322–356, 2000.

Zrnic D.S. and A. Ryzhkov, ”Advantages of rain measurements using specific differential phase”, J. Atm. Oceanic Tech., vol. 13, pp. 454–464, 1996.