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Large sample evaluation of cumulative rainfall amounts in the Alps using a network of three radars

M. Gabella[a,*], M. Bolliger[b], U. Germann[b], G. Perona[a]

[a]*Dipartimento di Elettronica, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129, Torino, Italy*
[b]*Osservatorio Ticinese, Swiss Meteorological Institute, Switzerland*

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Abstract

Quantitative precipitation estimation in complex terrain is surely a challenge. Many papers have been published on the use of radar measurements to estimate surface rainfall during intense events lasting a few days, but little work has been dedicated to large data sets spanning several months and tens of thousands of km^2. This paper presents the analysis of 2 years of radar and gauge data measured in Switzerland (from December 2000 to November 2002). The analysis is based on the operational MeteoSwiss radar product RAIN, which combines radar measurements from a total of 20 elevations, to obtain the best estimate of surface precipitation in real time. The resolution is 5 min and 1 km. The data processing includes automatic calibration, 7-step clutter elimination, correction for partial shielding and profile effects, as well as long-term radar–gauge adjustment. The root mean square areal difference between the radar and in situ measurements, rms(AD), is of the order of 1700 mm (the average gauge total of the 2-year period is 3031 mm). This figure is an average of a 39,500 km^2 area (427 gauges) that includes mountainous areas with bad radar visibility. A bulk adjustment reduces the rms(AD) to ~900 mm. If an adjustment based on a non-linear weighted multiple regression (WMR) is used, the rms(AD) decreases to ~700 mm. A modified form of the WMR is able to further reduce the rms(AD) to ~400 mm. The results of this and other studies have been used to modify the RAIN algorithm in March 2003 and February 2004, and thus better radar–gauge agreement is expected for the year 2004.

Keywords: Meteorological radar; Large rainfall data set evaluation; The Alps; Rain gauge network

* Corresponding author. Tel.: +39 11 5644105; fax: +39 11 5647959.
E-mail address: gabella@polito.it (M. Gabella).

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1. Introduction

For more than five decades researchers have been trying to quantitatively assess rainfall amounts on the ground using radar echoes aloft. Literature is full of analyses on (intense) precipitation events observed by radar (several hours; several thousands of square kilometers). Analysis of larger data sets (weeks, months or even years) over spatial scales (tens of thousands of square kilometers) involving a network of radars are certainly much more unusual (Grecu and Krajewski, 2000; Krajewski and Vignal, 2001; Nelson et al., 2003; Vignal and Krajewski, 2001), especially in Europe (Michelson and Koistinen, 2000). This paper presents the results of an analysis of 2 years of data from the MeteoSwiss network of C-band Doppler radars. It is well known that rain gauge observations represent local effects and not areal quantities. Therefore, for hydrological applications, in which areal precipitation measurements are required, their main drawback is the lack of representativeness (Kitchen and Blackall, 1992) or under-sampling of the spatial variability, i.e. there are not enough observations to describe the variability of the precipitation field. Rain gauges are usually considered to provide accurate "point" measurements (a description of the main sources of errors that affect "high-resolution" rain gauges can be found e.g. in Nystuen et al., 1996; Nešpor and Sevruk, 1999; Steiner et al., 1999; Duchon and Essenberg, 2001; Habib et al., 2001; Ciach, 2003). In this context, "point" means a gauge cross-section that is usually 200 cm^2 (and a sampling volume of the order of ~30 m^3 every 5 min, assuming, for instance, 1 mm diameter raindrops). Because of the spatial variability of rainfall (especially during intense, convective events), it is obvious that "point" measurements could under-sample the precipitation fields, even though the measurements themselves were correct (Krajewski and Smith, 2002; Krajewski et al., 2003). Radar measurements can add the desired information on the areal distribution of precipitation fields. Several methods have been developed in recent years (e.g. Seo et al., 2000; Michelson and Koistinen, 2000) to operationally merge radar estimates with gauge measurements, so as to obtain quantitatively accurate and spatially continuous radar-derived precipitation fields. Many of these analyzed the Radar-to-Gauge ratio (e.g. Wilson, 1970; Brandes, 1975; Koistinen and Puhakka, 1981; Collier et al., 1983) while others applied optimal interpolation techniques (e.g. Krajewski, 1987; Smith and Krajewsky, 1991). The probability matching of radar reflectivity and the rain rate was first introduced on a long-term basis (of the order of a year) by Calheiros and Zawadzki (1987), and then proposed as an "after-the-fact" adjustment technique during observation periods of about 3 weeks by Rosenfeld et al. (1993).

A well-known technique that has been used in Europe to combine radar and gauge data, particularly in complex orography regions, is that of a non-linear Weighted Multiple Regression (Gabella et al., 2000), which was developed in cooperation with radar meteorologists from the Swiss Confederation and the Czech and Slovak Republics (Boscacci, 1999; Kracmar et al., 1999; Gabella et al., 1999). The WMR-adjustment was successfully applied to the most (severe/extreme) events that occurred in the 1994–2001 period on the southern side of the Western Alps (Gabella and Notarpietro, 2004; Gabella, 2004). This and other adjustment-techniques performances are here compared using a "large" (2-year long) data set. Section 2 presents the study area, the sensor locations, the instrumentation and the measurement characteristics. Section 3 introduces the WMR and