Proceedings of ERAD 2006

Improving the radar data mosaicking procedure by means of a quality descriptor

Anna Fornasiero, Pier Paolo Alberoni, Roberta Amorati, Chiara Marsigli.

Servizio IdroMeteorologico – ARPA Emilia Romagna, Bologna (Italy).

1 Introduction

A considerable advantage offered by the presence of two (or more) radar exploring the same area, is the possibility to improve the quality of the final product, by adopting procedures of data composition. Radar data mosaicking is normally performed using simply range-related or value related algorithms of selection and combination. Usually, the followed ways are: a-b) to attribute to the common cell the mean or the maximum value of reflectivity; c) to assign to the common cell the reflectivity value of the nearest radar; d) to combine the data through a weighted average, where the weight is inversely proportional to the second power of the distance from the radar. The first approach distributes equally the probability to fail to the two radars, the second one handles only the problem of attenuation (which could be produced by mountains or rain), the third and the fourth are based on the assumption that radar data reliability diminishes only with the distance. Hence, these methods take into account only a very small part of the problems that spoil radar data and this could limit the advantages offered by the network. The quality of the datum is in fact conditioned by a wide spectrum of error sources, like clutter, bad calibration, beam blockage, measure done far from the ground (when the goal is to convert the reflectivity in precipitation rate), wind drift, anomalous propagation, hail, inhomogeneous beam filling. Moreover it depends on the completeness and efficacy of the correction and elaboration procedures used to obtain the final product. The aim of the present work is the definition, testing and verification of a new methodology of reflectivity radar data mosaicking based on a quality descriptor and the reconstruction of the correspondent rainfall field. This last is obtained propagating quality information from the raw data to the final product: to achieve this, in each step of the correction procedure it is introduced a quality component, finally they are combined in a unique value. This value takes into account the initial condition of the data with respect to the various sources of errors and the efficacy of the applied corrections. Two quality-based composition methods, consisting, the first, on the selection of the highest quality measure and the second on a quality-weighted average, are finally compared toward the methods of the maximum reflectivity and of the minimum distance, using raingauges measures as 'true' reference.

Correspondence to: Anna Fornasiero.

afornasiero@arpa.emr.it

2 The radar data correction and the quality descriptor

In this work, radar data composition is applied to the reflectivity field which is corrected and elaborated with the final aim to retrieve the precipitation at the ground level. This field is defined using a method of combined correction of ground clutter beam blocking and anomalous propagation, which produces, at the end of the process, a quality indicator. The correction method (called hereinafter BDA) is described in Fornasiero (2006), Fornasiero et al. (2005), and is based on: i) doppler filter, to reduce clutter echoes; ii) choice of the minimum elevation that is not affected by clutter and with a beam blocking rate less than 50% iii) topographical beam blocking correction, based on a geometric optics approach, iv) anomalous propagation clutter detection by means of a test of the vertical coherency of the signal (Alberoni, 2001). The reconstruction of the reflectivity field at the ground is not yet implemented in the procedure. During the elaboration process, a set of indices is produced, which are useful to define the quality of the product. These indices, which can assume logical or numeric values, are a measure of 'problems' that affect the data, and are enumerated in Table 1. Respect to the method described in Fornasiero (2006) we have introduced also the PIA (Path Integrated Attenuation) among the quality indices. The quality Q is calculated as product of a set of quality components Q* each one relative to a 'contamination factor' (see Eq. 1) and obtained as function of the quality of the data before the correction Q^d and of the quality of the correction Q^c (see Eq. 2)

$$Q = \prod Q^* \quad (1)$$

$$Q^* = 1 - (1 - Q^d)(1 - Q^c) \quad (2)$$

Q^d and Q^c vary in the range [0,1]. In this way the following properties are respected: i) quality is positive and ranging from 0 to 1 (if Q^d is negative, data are rejected, if Q^c is negative, the correction is not applied), ii) a perfect initial state or perfect correction give a maximum quality, iii) quality after correction is higher or at least equal to the quality before the correction, iv) different quality components are comparable.

The component Q^d, is retrieved as function of the rain rate fractional error , err_{fract}, defined in Eq. 3

$$err_{fract} = \frac{R_{true} - R}{R_{true}} \quad (3)$$

where R is the estimated rainfall field and R_{true} is the unknown true precipitation field.

Eq. 4 and Eq. 5 show the Q^d function in case of underestimation and overestimation respectively.

$$Q^d = 1 - err_{fract} \quad (4)$$

$$Q^d = \frac{1}{1 - err_{fract}} \quad (5)$$

Considering an exponential relation between Z and R with exponent equal to 1.5 (Marshall and Palmer, 1948), Q^d can be defined as a function of the reflectivity error in dBZ unit (ΔZdB), as shown in Eq. 6.

$$Q^d = 10^{-\frac{|\Delta ZdB|}{15}} \quad (6)$$

The quality of the correction Q^c is obtained as function of the correction hypotheses; if the error is not corrected, Q^c is equal to 0 (refer to Fornasiero, 2006 and Fornasiero et al., 2005).

Table 1 Quality indices used to retrieve the final quality value

	Unit/ values	Description
AP	0,1,2	Anomalous propagation test output 0=anomalous propagation clutter test not applied 1=clutter detected 2=data ok
pBB	%	Rate of beam blockage in %
r	m	Distance from the radar site
Δvol	dB	Difference in dB between radar volume observed in standard propagation conditions and that, defined by a geometric approach using the previous radiosounding profile.
PIA	dB	Path integrated attenuation

3 Results

In order to evaluate the usefulness of the quality descriptor in the procedure of radar data mosaicking, a convective event occurred on 24th May 2006 has been taken into consideration.

The event was simultaneously observed by two radars located in the Po valley (northern Italy) in the sites of Gattatico (GAT) and S. Pietro Capofiume (SPC). Considering the short pulse acquisition mode (pulse width=0.5 μs, maximum range=125 km), the common area is approximately half of that inspected by each radar.

The reflectivity fields were obtained at first, by correcting the data of each radar, through BDA method and thereafter combining them by means of four different composition methods: maximum reflectivity (MAX_Z), maximum quality (MAX_Q), quality-weighted reflectivity average (AVE_Q), minimum distance (MIN_DIST).

An example of reflectivity field and of the relative quality field for the two radars are shown in Fig. 1a-b and Fig. 2a-b, respectively. In Fig. 3a-b-c is represented the weight *wspc* attributed to the datum of SPC, using the first three methods. The weight attributed to GAT datum is its complementary to 1.

Successively the reflectivity values were converted to rain rate, using an exponential relation $Z=aR^b$ where a=500 and b=1.5 (Joss et al., 1970) and the total precipitation was calculated supposing a single measure as representative of a quarter of hour. These fields have been finally compared with the cumulated rain measured by 168 raingauges during the event.

The performances of the four composition methods were evaluated filling the contingency tables respect to seven thresholds (0.2, 1, 2, 4, 6, 8, 10 mm) and calculating the following scores (Wilks, 1995): i) Probability of detection (POD), ii) False alarms (FA), iii) Bias score, iv) Threat score (TS), v) Hit rate (HR), vi) Heidke skill score (HSS). In addition they were considered the vii) Normalized root mean square error (rmseN) and the viii) Normalized bias (biasN). that are normalized with respect to the mean gauges cumulated rain. In Table 2 are shown the numbers of raingauges observations exceeding the chosen thresholds and also used to calculate the correspondent scores. In Fig. 4a-b-c-d-e-f is shown a comparison between the scores obtained using MAX_Z, MAX_Q, AVE_Q, MIN_DIST.

The method MAX_Z produces the highest POD and the highest number of false alarms, as could be easily expected, (except that for the last threshold, due probably to the poor sample population). Also, the bias score, the root mean square error and the bias are the highest using MAX_Z, which, hence, produces an evident overestimation that increases for high thresholds. Regarding HR, HSS and TS, we can observe that the MAX_Z method seems to work better for small thresholds, while for high thresholds the performance is poorer.

The two methods considering quality information produces lower POD and lower FA than MAX_Z, but the best indices are those relative to MAX_Q. It is important to evidence that, even if MAX_Q shows higher POD respect to AVE_Q, it gives lower FA for high thresholds. This means that the quality index reflects the reliability of the radar estimate.

Table 2. Number of raingauges observations exceeding the thresholds of total precipitation accumulation from 08 UTC to 18 UTC 24 of 24th May 2006.

threshold (mm)	0.2	1	2	4	6	8	10
observations	84	58	40	30	18	12	7

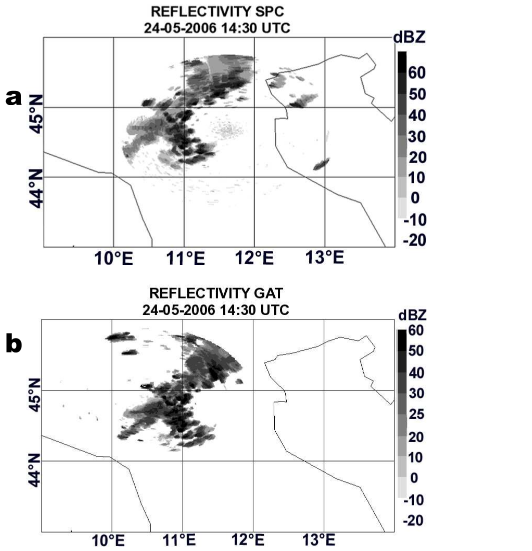

Fig. 1. Reflectivity map (retrieved by BDA correction method) measured by the radar of a) San Pietro Capofiume b) Gattatico. Time: 24th May 2006 14:30 UTC.

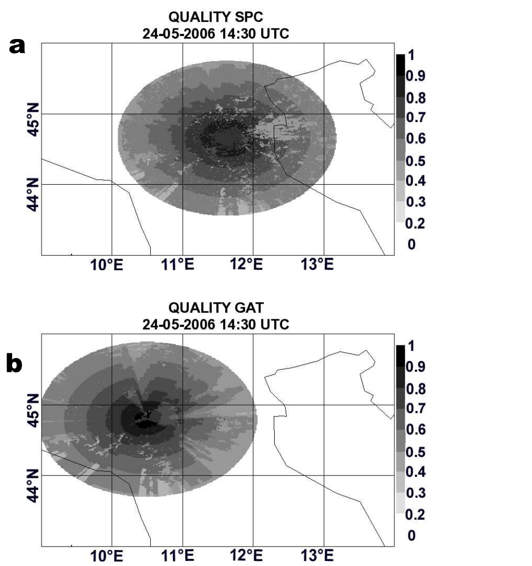

Fig. 2. Quality fields related to the maps shown in a) Fig. 2a b) Fig 2b.

This is confirmed also by the other scores, especially the biasN, the lowest value being obtained by MAX_Q. In general it works better than AVE_Q for high thresholds. The method of the minimum distance (MIN_DIST) shows the poorest indices except that for biasN and rmseN which are better only respect with MAX_Z.

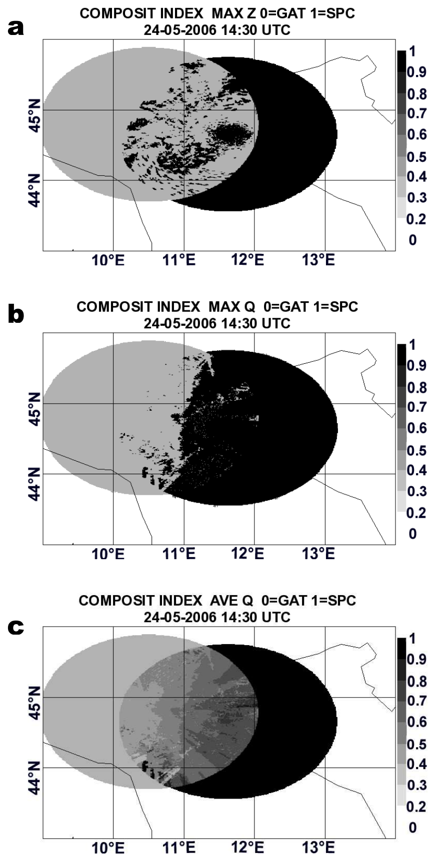

Fig. 3. Distribution of cells containig SPC and GAT measures in the radar composit obtained by method a) MAX_Z, b)MAX_Q c) AVE_Q. The color values represent the weight attributed to SPC data. Their complementary to 1 are the weights attributed to GAT data. Time: 24th May 2006 14:30 UTC.

Resuming, in terms of bias and root mean square error, the quality-based methods are the best, with a preference for AVE_Q with low thresholds, and for MAX_Q with high thresholds. This difference is probably due to the incompleteness of the quality functions which at the moment do not take into account every radar data problem. Regarding the other scores, the distance-based method seems to be the poorest, except that for FA and BS, (the poorest indices are produced by MAX_Z): otherwise MAX_Q shows in general better scores for medium-high thresholds than AVE_Q, and slightly poorer for low thresholds. The improvement in the scores of MAX_Q for medium-high thresholds is probably due to the presence of the PIA component into the quality function. In fact, if we consider (Fig. 5a-b) the rmseN and the biasN obtained without considering the PIA into the quality, we note that AVE_Q produces consistently better results than MAX_Q in terms of rmseN and comparable in term of biasN.

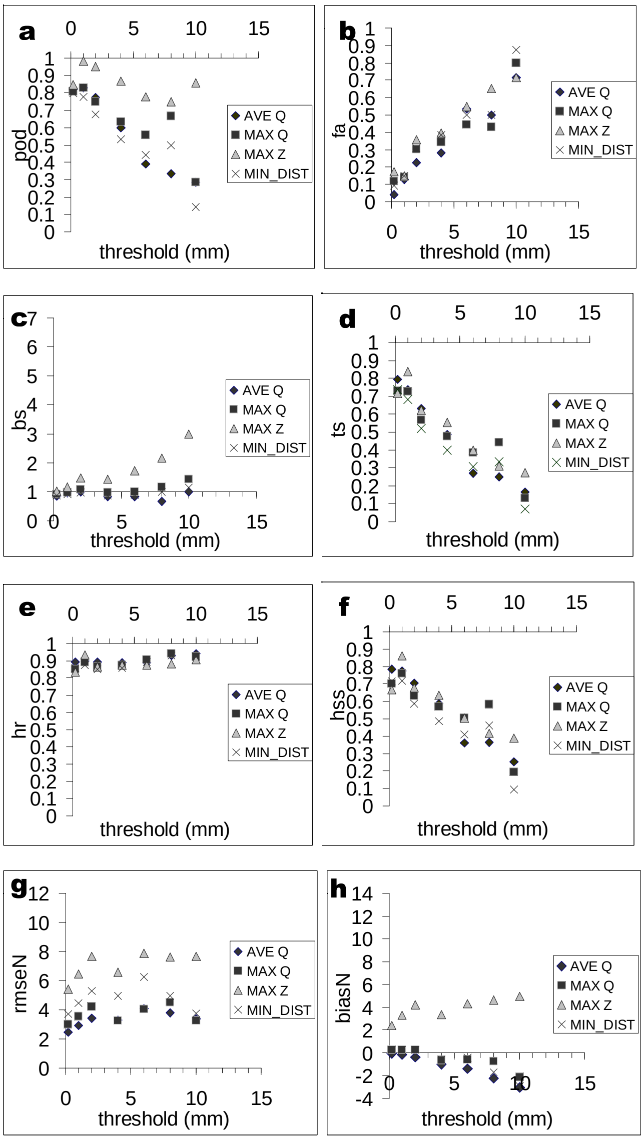

Fig. 4. a) POD, b) FA, c) BS, d) TS, e) HR, f) HSS, g) rmseN h) biasN calculated on radar data composed by means of MAX_Z, MAX_Q, AVE_Q, MIN_DIST methods. Time range: from 08 UTC to 18 UTC 24 of 24th May 2006.

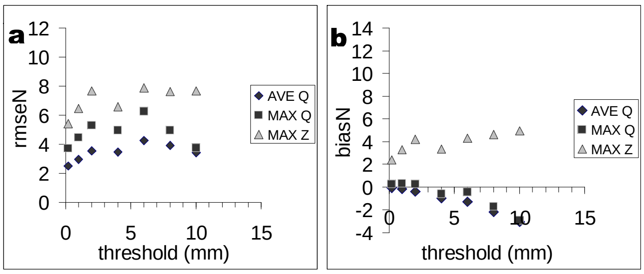

Fig. 5. a) rmseN b) biasN calculated on radar data composed by means of MAX_Z, MAX_Q, AVE_Q. The PIA is not considered into the quality function. Time range: from 08 UTC to 18 UTC 24 of 24th May 2006.

4 Conclusions

The quality information introduces an added value not only in terms of characterization of the datum as itself but in terms of estimate of the precipitation too, when this information is used into the composition of different radar data. In this work we have shown that, the more complete is the quality function, the more efficient is the composition method based on the maximum quality. The quality-averaged composition method seems to be preferable when there is a lack of information about the initial state of the data; in this case, it is better than both MAX_Q and MIN_DIST. The MAX_Z method is evidently biased towards overestimation, while MIN_DIST smoothes the errors, but works otherwise uncritically, because it attributes the same reliability to all the cells located at the same distance from the radar.

The case study is convective, and also the vertical variation of reflectivity is less evident than in case of a stratiform event. For the reason previously cited, we can not ensure that, in this type of event, a maximum-quality composition method works better than one based on the quality averaged value, if the information relative to the vertical reflectivity variation is absent into the quality function.

Concluding, the quality information is prone to be used into composition procedures especially when the quality function is comprehensive of the major problems affecting radar data.

Acknowledgements: This work is partially supported by the INTERREG IIIB programme through the RISK AWARE project (Contract N° 3B064) and was done within the framework of the EU-COST 717 action devoted to “Use of weather radar observations in NWP and hydrological models” and EU-COST - 731 Action devoted to “Propagation of uncertainty in advanced meteo-hydrological forecast systems". It is also supported by the Civil Protection Department through the PROSCENIO project.

References

Alberoni, P. P., T. Anderson, P. Mezzasalma, D. B. Michelson and S. Nanni, 2001: Use of the vertical reflectivity profile for identification of anomalous propagation. , Meteorological Applications, **8**, 257-266.

Fornasiero, A., 2006: On the uncertainty and quality of radar data. Phd Thesis. Università degli studi della Basilicata.

Fornasiero A., Alberoni P. P., Amorati R., Ferraris L., Taramasso A. C., 2005: Effects of propagation conditions on radar beam-ground interaction: impact on data quality. ADGEO, **2**, 201-208.

Joss, J., Schram, K., Thaus, J. C. and A. Waldvogel, 1970: On the quantitative determination of precipitation by radar. Wissenschaftliche Mitteilung Nr. 63. Eidgenössischen Kommission zum Studium der Heigenbildung und der Hagelabwehr, Locarno-Monti, Switzerland.

Marshall, J.S and W. McK. Palmer, 1948: The distribution of raindrops with size. J. Meteor. 5, 165–166.

Wilks, D. S., 1995: Statistical methods in the atmospheric sciences, Academic Press, San Diego, CA, USA.