Proceedings of ERAD 2006

Automatic and Visual Radar to Raingauge Quality Check - a Performance Comparison

Markus Jessen[1], Thomas Einfalt[1], Marco Gabella[2], Gianmario Galli[3]

[1] einfalt&hydrotec GbR, Breite Str. 6-8, D-23552 Lübeck (Germany).

[2] Politecnico di Torino, C.so Duca degli Abruzzi, 24, I-10129 Torino (Italy).

[3] MeteoSwiss, Via ai Monti della Trinità 146, CH-6500 Locarno-Monti (Switzerland).

1 Introduction

Three different methods to check raingauge and radar data have been compared:

- a visual data comparison based on qualified data screening and on the comparison of time series of the screened radar and raingauge data;

- a similar approach to the National Aeronautics and Space Administration (NASA) Tropical Raifall Measuring Mission (TRMM) Ground Validation (GV) program for the Automated Quality Check (AQC) of 7-minute radar-gauge data pairs.. In particular, the AQC procedure is used in the form presented during the VOLTAIRE project (Gabella and Notarpietro, 2004) and as it is implemented in the VOLTAIRE data quality control library (Einfalt and Golz, 2006);

- an automatic time series shape comparison procedure, comparing the similarity of the respective radar and raingauge time series.

Each of the procedures is working on detailed rainfall data (i.e. down to one minute resolution) and evaluating the results on a day by day basis. Such a procedure is a prerequisite before any thorough data comparison or adjustment excercise.

2 Methodology

2.1 Visual data comparison

The visual data comparison is a subjective method to evaluate raingauge and radar time series pairs. In this case only the shapes of both accumulated time series were compared to each other. Therefore the radar data are adjusted through a multiplicative factor in order to match his daily accumulation with the raingauge value.

Relevant characteristics for the visual comparison are on the one hand the agreement of the distribution of the precipation intensities and on the other hand the correlation of the precipitation peaks.

The evaluation occurred in three classes:

- Good agreement (see figure 1) between radar and raingauge (comparable intensity distribution, good agreement of the precipitation peaks, agreeing precipitation time periods)
- Moderate agreement between radar and raingauge
- Bad agreement (see figure 2) between radar and raingauge (different intensity distribution, no agreement of the main precipitation peaks, different precipitation time periods, no rainfall at one of the two time series)

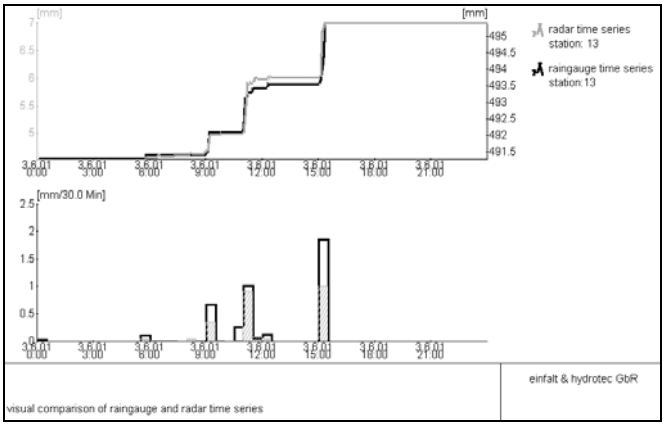

Fig. 1. Example for a good agreement of radar and raingauge time series (station 13 of the BRW)

The values of the daily precipitation volumes of radar and raingauge were not taken into account because of the varying Z-R factor between both measurement techniques. The proposed method therefore avoids any analysis where the difference between reflectivities and intensities is playing a major role.

Advantages of this method:

- Short time shifts between radar and raingauge are not relevant for the evalution
- Visual comparison is a holistic investigation

Disadvantages of this method are:

- Time consuming procedure
- Different evalution of different users
- Unreproducible results

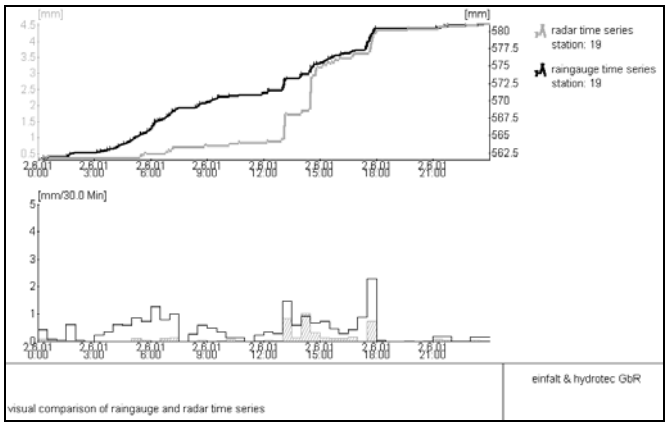

Fig. 2. Example for a bad agreement of radar and raingauge time series (station 19 of the BRW)

2.2 Automatic quality control (AQC) procedure

The reliability of radar-gauge couples was checked through an investigation of the following indices:

1) R_{only} - the total fraction of the rain depth [-], as measured by the radar, at times when the gauge measured no rain (for each 10-min data pair).

2) G_{only} - the total fraction of the rain depth [see above], as measured by the gauge, at times when the radar did not observe weather echoes above the gauge (again 10-min sampling).

3) F_n - daily normalized radar-to-gauge factor (or ratio). The normalization is performed at each raingauge location with respect to the daily gauge total.

4) $RG_{not\text{-}null}$ - the number of radar and gauge 10-min samples that are both different from zero.

5) r_{log} - the correlation coefficient of the 10-min radar-gauge data pairs of rainfall amounts transformed on a logarithmic scale (computed using only Radar-Gauge data pairs that are both different from zero).

The first two indices are used operationally in the NASA TRMM GV program at their GV sites with thresholds $R_{only}<0.4$ and $G_{only}<0.2$ (Amitai, 2000). In the Western Alps, Gabella and Notarpietro (2004) modified the threshold to 0.3 and were satisfied with their results.

The third index, F_n, is "static" in the VOLTAIRE implementation, while it is "dynamic" in the original AQC procedure of Amitai (2000). In complex orography or small scale convective rainfall, F_n can be comprised between 0.2 and 4, meaning that we allow a quite tolerant radar-to-gauge ratio, from –7 to +6 dB.

As far as criterion 4) is concerned, Gabella and Notarpietro (2004) opted for at least 6 simultaneous 10-min samples per day both different from zero. Criterion 5) was added based on the experience by Habib et al. (2001). In their paper, they explain why a Log-transformation is more suitable for more accurate and reliable correlation information

The current version is working on smaller time steps than the original AQC, using daily analysis steps on (interpolated) one-minute data. For the present data, the check criteria were slightly modified as compared to the original settings. The idea that at least 60 minutes of comparable data need to be present has been kept. Otherwise the series are not comparable.

Here, our objective is the systematic comparison of the two time series provided by raingauge and radar on similarity. Therefore, we include the notion of "good", "moderate" and "bad" agreement. We use similar thresholds as given above, considering data pairs as good where the radar part has less than 40% radar only data, the raingauge part has less than 40% of raingauge only data, the logarithmic correlation is higher than 0.15 and the raingauge to radar ratio for the daily sum is comprised between 0.2 and 5.0.

If one of the criteria is not met, the quality is moderate, with two or more "misses", the comparison quality is considered bad.

2.3 Automatic time series comparison (ATC) procedure

The ATC is a semi-empirical method to compare two time series, based on the temporal distribution of their relative shape.

The basic idea is to first transform each of the two time series to two relative series standardised by their daily sums. The choice of the comparison time step, here 30 minutes, is an important parameter for the determination of the thresholds for the comparison. The resulting time series will have values given in percent of the daily sum.

The ATC procedure then checks four attributes:

1. if both series only have values below a limit of 10%, they are considered to be nearly constant, therefore similar (Fig. 3). The suitable choice of the limit depends on the comparison time step;
2. if the part of concomitant time steps where one time series has values above 5% and the other one 0% is smaller or equal to one third, the series are considered similar;

3. if the squared difference, weighted by the selected time step, of the two series is always smaller than the maximum of the two function values for those time steps where the maximum is larger than 10%, the series are considered similar;

4. if the mean value of the squared difference for the time steps being not zero is below 7%, the series are considered similar.

To reach a good similarity, at least three of these conditions must be fulfilled – two will yield a moderate similarity, the rest is considered "bad".

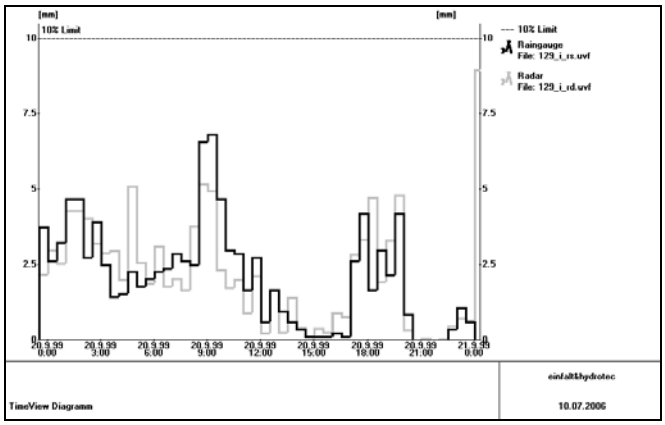

Fig. 3. Example for a nearly uniform agreement of radar and raingauge relative time series (station 129 of Piedmonte)

3 Results

The above methods have been applied to two sets of data:

1. One event (19 - 20 september 1999) of radar data of Monte Lema radar (Switzerland) have been compared to raingauge data from the Piedmonte region (Italy) in order to identify inconsistencies in the data and determine those data pairs which cannot be used for any further comparison.

2. One week (1 - 7 june 2001) of continuous radar data from the German Weather service (radar Essen) compared to 29 raingauges of the BRW water authority.

The results show that all procedures identify the same radar / raingauge time series pairs as unusable where one of the two data sources is heavily disturbed. These disturbances may be caused by radar beam shielding, by raingauge malfunctioning, time shift, clutter, attenuation or other causes. Differences between the methods arise in the assessment on the similarity of the time series pairs.

By comparing raingauges and radar observations it should be taken care that the precipitation field in vicinity of the gauge location is homogeneously distributed in space and inside the sampling interval of time – else the methods may result in (locally) bad comparison results. In addition, the radar observation should be placed not "too far" from the earth surface and below the bright band altitude, which ususally means within a radius of about hundred kilometres around the radar.

An example for the comparison of one day of the second data set is shown in the Table 1. Each raingauge location is evaluated by the three methods and in the last two columns the differences in the results between the methods are highlighted.

Table 1. Evaluation of 3rd June 2001

station number	visual comparison	AQC procedure	ATC procedure	Comparison visual-AQC	Comparison visual-ATC
1	bad	no comparison	bad	-	OK
2	good	good	moderate	OK	Partly
3	moderate	good	moderate	Partly	OK
5	moderate	moderate	moderate	OK	OK
6	good	good	moderate	OK	Partly
7	moderate	good	moderate	Partly	OK
8	moderate	moderate	moderate	OK	OK
9	no data	no data	no data	-	-
10	moderate	good	moderate	Partly	OK
11	moderate	good	moderate	Partly	OK
12	good	good	good	OK	OK
13	good	good	good	OK	OK
14	good	good	moderate	OK	Partly
15	moderate	good	moderate	Partly	OK
16	no data	no data	no data	-	-
17	moderate	good	moderate	Partly	OK
18	good	good	good	OK	OK
19	moderate	moderate	moderate	OK	OK
20	good	good	moderate	OK	Partly
21	bad	bad	bad	OK	OK
22	good	good	moderate	OK	Partly
23	moderate	good	moderate	Partly	OK
24	moderate	good	moderate	Partly	OK
25	moderate	good	moderate	Partly	OK
26	moderate	no comparison	moderate	-	OK
29	good	good	good	OK	OK
141	bad	moderate	bad	Partly	OK
142	bad	no comparison	bad	-	OK
143	bad	good	moderate	false	Partly

classification		Comparison visual-AQC	Comparison visual-ATC
identical classification	OK	13	21
one class difference	partly	10	6
two classes difference	wrong	1	0
no rainfall	no rain	0	0
no comparison possible	no comparison	5	2

The results of the first data set are summarised in Table 2 and for the second data set in Table 3.

An "identical classification" is reached when the visual method and the automatic procedure have produced the same classification (e.g.: "good" and "good").

"One class difference" is achievable when one method delivers as decision a "good" and the second a "moderate" or one "bad" and the other "moderate".

The difference of two classes (one method "good" and the other method "bad") is the problematic classification. In this case the evaluation is completely different.

As criteria for the classification "no rainfall" the measured rainfall must be less than 0,3 mm/day for the radar time series and for the raingauge less than 1,0 mm/day. Both limits depend on e.g. the aim of the investigation and on the factor between radar and raingauge and are adjustable for other cases.

The classification “No comparison possible” is necessary for the following cases:

- No data availability by radar or raingauge
- Gaps in (at least) one of the two time series
- The AQC-procedure needs as minimum a 60 minute intersection between radar and raingauge time series over a period of 24 hours.

Table 2. Results of the first data set (19 - 20 september 1999)

	Comparison visual-AQC	Comparison visual-ATC
OK	48	64
partly	29	23
wrong	0	1
no rain	1	1
no comparison	62	51

Table 3. Results of the second data set (1 - 7 june 2001)

	Comparison visual-AQC	Comparison visual-ATC
identical classification	62	94
one class difference	40	36
two classes difference	1	1
no rainfall	53	55
no comparison possible	47	17

Both data sets show a good agreement between the automatic procedures and the visual method. Only a few classifications have two classes difference.

4 Discussion

The procedures can be used for initial data quality check as well as for measuring the improvement of radar data after correction.

Both automatic procedures delivers results similar to the visual comparison.

Thus, the methods can be used for the selection of appropriate locations where raingauges and radar pixels can be used for adjustment. But there are more conclusions to be drawn from these analyses.

A good similarity of the radar and raingauge time series allows for the selected day and the selected radar pixel the following conclusions among other things:

- A relatively constant Z-R relationship over the day
- No relevant attenuation effects
- No clutter problems
- No bright band effects varying in time

In contrast, the detection of a bad similarity of the two series is useful for the indication of an insufficient correction of radar or raingauge data or to disapprove the data for radar data adjustment.

A quality check which is only based on the precipitation volume of radar and raingauge delivers not all information to evaluate the quality of the correspondence of the time series. But it can for example be useful for detecting and evaluating partial beam blockage before and after correction.

A combination of an investigation of the precipitation volume and the shape of the time series is necessary for a comprehensive sight on the data quality. Herefore the two investigated automatic methods deliver useful results.

The ATC method will be further developed in order to use it with different time steps and link it to a statistical test.

Acknowledgements: Part of the results has been produced in the VOLTAIRE project (EVK2-CT-2002-00155).

Also the support from the water authority of the BRW (Bergisch-Rheinischer Wasserverband) is gratefully acknowledged.

References

Amitai, E., 2000. Systematic variation of observed radar-reflectivity rainfall rate relations in the tropics, *J. Appl. Meteor.* (Special Issue on TRMM), 39, 2198-2208.

Einfalt T. and Golz, C., 2006. Radar data quality control - the VOLTAIRE software library, *ERAD 2006*, Barcelona.

Gabella, M., Notarpietro, P., 2004. Improving Operational Measurement of Precipitation Using Radar in Mountainous Terrain—Part I: Methods. IEEE Geoscience and Remote Sensing Letters, Vol. 1, No. 2,

E. Habib, W.F. Krajewski, and G.J. Ciach, 2001. Estimation of rainfall interstation correlation, *J. Hydrometeorol.*, vol. 2, pp. 621-629.