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Radar data quality control - the VOLTAIRE software library

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1 Introduction

VOLTAIRE (Validation of multisensors precipitation fields and numerical modelling in Mediterranean test sites – EVK2-CT-2002-00155) has been an EU funded project running from November 2002 to April 2006. One of the objectives of VOLTAIRE was the analysis of recent data quality control schemes for radar (ground and space) and raingauges and their implementation in a software library. The gauge-adjusted and radar-derived precipitation fields should be used as ground validation for the TRMM radar in the Mediterranean area (around Cyprus). This is a basic condition for preparing the European participation in the future Global Precipitation Measurement (GPM) satellite mission, which will offer the possibility to measure precipitation by an onboard precipitation radar at higher latitudes than presently possible (35°N) using the TRMM radar.

Another objective of VOLTAIRE was to improve the data quality of ground radar and raingauge data by reducing or correcting the measurement errors e.g. in mountainous terrain. This is an important requirement for comparing precipitation fields as represented by numerical models, by adjusted ground-radar and by spaceborne radar.

The VOLTAIRE software library has now been completed and is available since end of April 2006.

2 Organisation of the radar data quality control procedures

The creation of the library started with a detailed literature review producing a literature pool in a data base. After the evaluation of the literature, a list of frequent radar data quality problems has been compiled. The most promising of the algorithms have been selected for further analysis on data from Cyprus, Switzerland and Spain. For some problems where no algorithms were available so far, suitable data check and correction procedures have been designed and implemented, e.g. for bright band detection on PPI data, or for negative speckle (i.e. pixels deleted by a clutter elimination procedure situated in a rain field).

A second important point in the preparation phase was the definition of a new VOLTAIRE HDF5 metadata format. It was necessary to create a standard data exchange format to simplify the exchange of radar data and its metadata between the different institutions and to be able to process data from different sources in a comparable way. This format was defined together with other project partners and complies with international standards and guidelines (OPERA and COST717). The exact description can be obtained as public document from the VOLTAIRE website.

Problem	2D-data	3D-data
Ground Clutter & Speckle	"clutter map" "texture-based algorithm" "segment size" "reverse speckle"	"vertical and horizontal substitution"
Attenuation	"cumulative gate-by-gate algorithm" "mountain return method"	-
Radial anomalies	"radial filter" "beamblock" "visibility map"	"EMITTER"
Classification convective / stratiform	"3 criteria"	"2 methods"
Vertical profile (VPR)	"climatological or idealised profile" "maximum method"	"MAVPR"
Anomalous propagation (ANAPROP)	-	"tilt-test"

Table 1. Overview of chosen QC algorithms

The developed data quality control (QC) software package is based on the new VOLTAIRE HDF5 metadata format. To transform the available radar data formats (e.g. IDIRISI, IRIS) into the uniform HDF5 metadata format specific software routines were developed and applied to the different data. This transformation offers the possibility to use one software package for various radar data formats. The

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reading and writing interfaces for the metadata format are public.

The software package includes 17 QC filters, which are treating the most common problems in radar measurements, e.g. ground clutter or bright band. Table 1 gives an overview of the chosen algorithms for cartesian PPI data, polar PPI data and polar volume data. More details can be found in Golz and Einfalt (2006).

The QC software library can be used in different ways. On the one hand, the graphical user interface “QCTool” has been created to demonstrate the capabilities of the library functions and offers the possibility to interactively analyse radar data in a very simple way. On the other hand, it is possible to link the developed C++ subroutine libraries to proprietary software and use the QC methods online. This has been done for the SCOUT radar data processing software, which has been used for a large part of the tests described in the following.

3 Applications of the QC algorithms

Correction results based on elements from the QC library to radar data in Germany (Jessen et al., 2005), Thailand (Chumchean et al., 2005) and the VOLTAIRE radar sites in Catalunya/Spain, Cyprus and Switzerland (Golz et al., 2006) have been published.

3.1 Results from Germany: beam blockage

Beam blockage arises from obstacles like towers, high buildings or single mountains. The detection and correction are important for rainfall estimation or forecast. A data-driven method to correct for beam blockage in polar radar PPI data has been developed, which does not require the existence of a DEM (Digital Elevation Model) or precise knowledge about the radar parameters as other methods do (e.g. BECH et al., 2003). It should be noted that DEM data may not be available in all countries, may not be of high resolution or may not be affordable for the radar data user. The proposed “beamblock” method is limited to narrow blockages, so that extended beam blockage like by mountain chains could not be corrected.

Although disregarding the physical properties of the radar beam, a careful analysis of the radar data leads to the determination of beam specific correction factors / values. It results in acceptable to good correction results. Visual tests support this statement as well as crosscomparisons with independent raingauges which have been performed on the combination of the two corrections described here, a bright band correction and the adjustment on a raingauge network.

The analysis of the PPI radar data (with a homogenous precipitation field) is performed for each angle radially: the sum of the reflectivity values along the ray is computed (for every radar image) and compared to the angle values which are not influenced by the beam blockage. This analysis resulted in potential values for correction of the different angles of the radar data. The corresponding correction value, applicable to the reflectivity values, is then determined for the full extent of the radar angle and can be applied to convective and stratiform precipitation events.

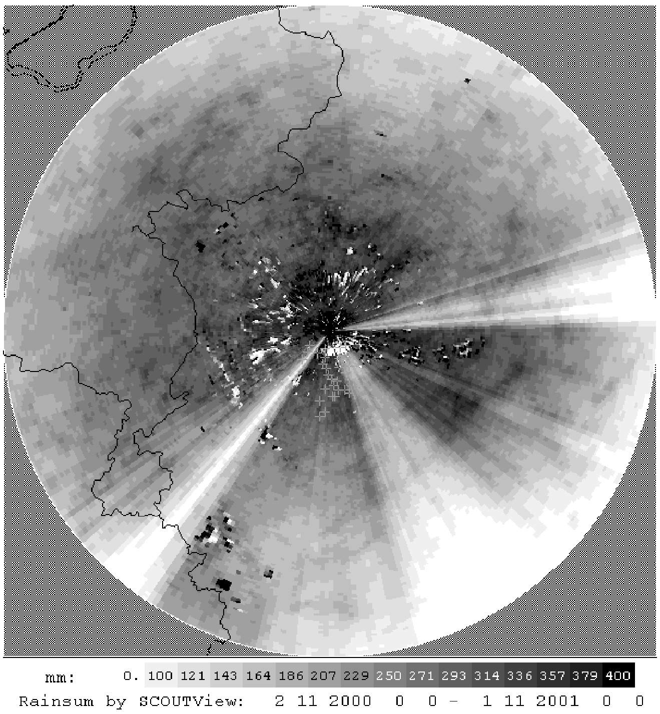

Fig. 1. Sum of one year of uncorrected and non-adjusted radar measurements

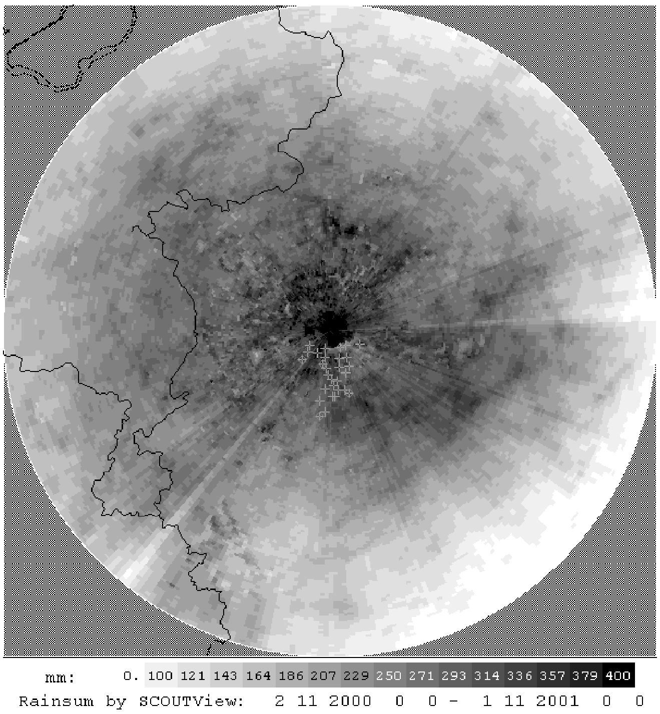

Fig. 2. Sum of one year of corrected and non-adjusted radar measurements

Figures 1 and 2 show an example of the radar Essen in Germany (run by German Weather Service, DWD, 6.97E /

51.41N). Fig. 1 displays the accumulated sum of uncorrected radar data of one year. In three areas (southwest, southeast and east) the problem of beam blockage can be observed. Fig. 2 presents the corresponding accumulated radar image after the correction. It can be seen that the corrected beam blockage areas have nearly disappeared (especially the southwestern beam blockage).

The developed approach appears to be useful where DEM data are not available, where partial beam blockage cannot be explained by DEM information or where the reason for partial beam blockage is unknown. The correction algorithm can also be used to correct for areas behind a known obstacle (e.g. ground clutter), treating only the part of the beam that is behind this known location. The location and the correction factors / values are parameters to the method.

3.2 Results from Thailand: clutter and online warning

Rainfall events that commonly occur in the Bangkok area are convective rain, therefore it was assumed that there is no bias caused by bright band. The effects of ground clutter have been removed from the data used in this study by using a map of known ground clutter locations and the radar measurement was discarded and interpolated in these areas. To avoid the effect of noise in the measured radar reflectivity, the reflectivity values that are less than 15 dBZ were excluded from the analysis. The singular pixels on the radar image which are normally not associated with rain have been eliminated using the Gabella texture based method (see Gabella et al., 1998 for details). Attenuation caused by rain may vary strongly according to the rain rates along the path, however this is not problem for radars transmitting at S-band (Hitschfeld, 1954). Hence, the effect of attenuation is considered to be insignificant.

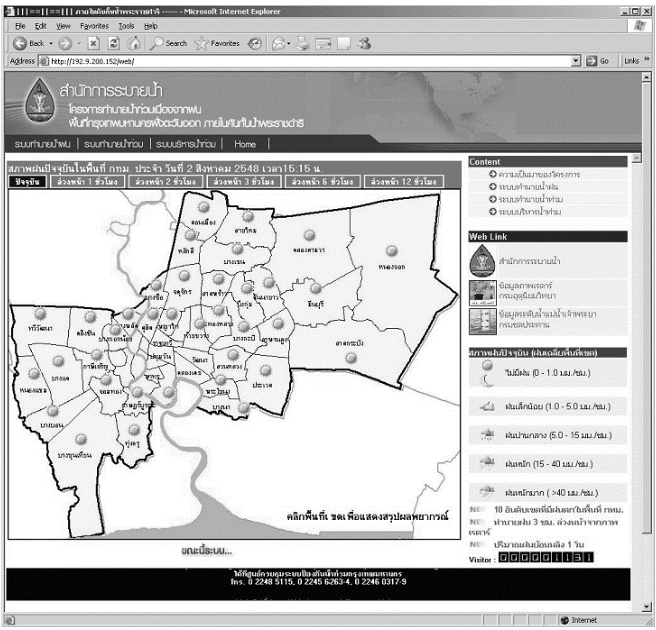

Fig. 3. Web presentation of the Bangkok rainfall forecasting system

Bangkok real-time rainfall forecasting system is producing a forecast for about hundred locations in Bangkok city for 12 hours ahead. Radar data from Don Muang radar (Thai Meteorological Department - TMD), from Phasicharoen radar (Bangkok Metropolitan Administration) and data from 111 raingauge stations are used to produce the 1st-3rd hour rainfall forecasts. Numerical weather prediction (NWP) data obtained from TMD provide the 4th – 12th hour rainfall prediction. A warning may be issued every hour when the system is running the hydrological model components.

The results are presented publicly on the web of the city of Bangkok (fig. 3).

The system has been operational since August 2005.

3.3 Results from the VOLTAIRE tests

The online tests have been conducted for Cyprus and Switzerland in the first quarter of 2006. Cyprus radar data have been available with four elevations in the time period 10th February – 6th March 2006. After this period the radar was not operating due to hardware problems. Switzerland radar data have been provided in a polar GIF format with up to 20 elevations for the time period 23rd January-1st April. Raingauge data have not been available as reference for Cyprus and Switzerland, what makes the evaluation difficult. For Switzerland it would have been interesting to have Italian raingauge data of the Piemont region, which was not possible in time. For Cyprus it was decided that the provision and analysis of raingauge data for one light rain event would have been too time-consuming. So it was only possible to compare single or cumulated radar images. Cumulated radar images are for most of the QC filters more significant than single radar images.

The Cyprus radar data have been tested with a clutter map and the ”texture-based” algorithm, because the offline tests have shown (Fig. 4), that the main problem in Cyprus is ground clutter. Swiss data have been tested with the “beamblock” and the ”texture-based” filter to correct for some mountain blockages.

All software modules were run in real time, which means that only a short time lag of a few minutes was present in the real time data flow between the data provision and the production of a single corrected HDF5 file. Cumulated images have been produced offline afterwards.

4 Discussion

Several of the algorithms have proven to be useful and performant for online applications. This is in particular the case for the beam blockage, radial anomalies, and texture based speckle filter.

Algorithms which require more testing are those based on volume data because during the project, only few volume data sets with interesting rainfall (e.g. where the anomalies to be corrected have been present) were available during the online testing period.

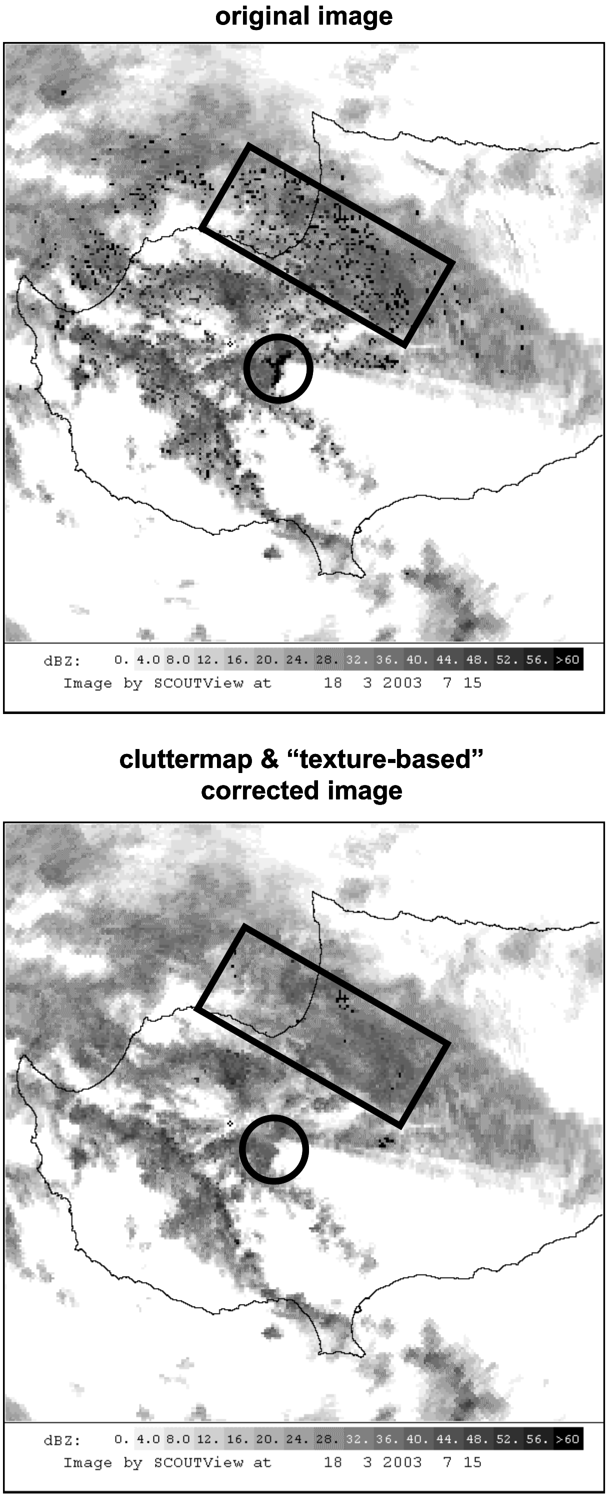

Fig. 4. Results from the corrections applied to the Cyprus data

5 Availability

The literature review, the metadata format and the demo version of the QCTool are completely free and available at http://www.voltaireproject.org, the official website of the VOLTAIRE project.

The algorithms have been produced as a C++-library, being available for Windows based systems, have been included in "QCTool", a free demonstration tool, included in "QCTool professional" for mass data correction, and have been included in the SCOUT radar data processing tool. Both versions of QCTool are based on the HDF5 radar data format developed in VOLTAIRE.

6 Outlook

This first library regrouping 17 radar data quality control algorithms and being largely available is a big step ahead for the general use of data quality control algorithms.

The algorithms will be further amended and refined, as function of the users' requirements.

New algorithms which shall be made available under this library are also welcome.

If this library approach is being accepted, other algorithms such as tracking algorithms may be bundled and distributed in the same way.

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