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REQUIREMENTS FOR WEATHER RADAR DATA

Review of the climate requirements for Weather Radar data

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SUMMARY AND PURPOSE OF DOCUMENT

This document provides the current status and future climate requirements on weather radar data derived from current gaps in global and regional monitoring for purposes of hydro-climatology. The requirements are prerequisites for the supplementary use of radar data in the fields of quantification of the global water cycle, assessment of geo-temporal small scale precipitation variability and global detection and assessment of extreme precipitation events world-wide.

ACTION PROPOSED

Review document in preparation for workshop on weather radar data exchange to be discussed

WORKSHOP ON RADAR DATA EXCHANGE – REQUIREMENTS FOR WEATHER RADAR DATA (EXETER, UK, 24-26 APRIL 2013)

1. Introduction

Which application area(s) is being reflected in this report?

- Flood protection and sizing of adaptation measures in the field of water management, food and agriculture in the national and regional scale
- Flood and Flash Flood risk assessments for the most recent decade(s)
- Re-Analysis of extreme precipitation in the past decade
- Assessment of land erosion in the field of agro-meteorology in the past decade
- (Potential) adjustment and enhancement of station based extreme precipitation statistics including intensity duration curves and duration specific return periods of extreme events
- Improvement of observational (reference) data sets for reanalysis
- Calibration of hydrological models

Apart from the author, were others consulted in the generation of this report?
Radar experts in-house DWD have been consulted. Tanja Winterrath and Elmar Weigl have provided core input but also Kathleen Helmert, Patrick Tracksdorf, and Thomas Hohmann have been consulted. Moreover discussions with climate experts of GCOS AOPC, EUMETSAT P-SAG, University of Bonn (on a joint project on HR precipitation re-analysis and on data homogenization), Météo-France (Philippe Dandin), ECMWF (Dick Dee on ERA-CLIM2) and colleagues of the Weather Radar Centre of the Korean Meteorological Agency (Seong-Heon Kim, Jeong-Hee Kim, Sun-Ki Choi) have provided inspirations to this report.

2. Current requirements and use of the data

What is the data being used for by the application area? Both directly (eg assimilation of Doppler winds by regional NWP) and indirectly (eg contributes to the forecast skill in severe weather forecasting)?
The use of weather radar data to address "climate" or long-term assessment requirements is at its infancy and has so far not left the national scale. However, use of weather radar data and generation of local and composite quantitative precipitation estimation (QPE) products for purposes of customers coming from the field of hydrology, water management and flood and flash flood protection has reached an operational and high availability status at a number of countries based on the accordingly advanced capabilities of their National Meteorological and Hydrological Services. However, so far only the real-time application and warning purposes (excellently reviewed in INF.2.3) have governed the requirements list.

Nevertheless the growing demand on consulting and guidance in context of adaptation to climate change for the various sectors including the water and food and agriculture sector in particular (see also the GFCS Implementation Plan) and the entrance of radar data coverage length into the decadal time scale are setting the opportunity to explore the use of weather radar data for hydro-climate applications provided geo-temporal homogenized re-processed decadal radar data sets can be generated. Successful efforts in this field by Météo-France (Tabary et al., 2011[1]), KNMI (Oevereem, 2009[2]) and the Bureau of Meteorology (see INF.2.3) demonstrate the feasibility of such re-analysis.

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1 Pierre Tabary, Pascale Dupuy, Guy L'Henaff, Claudine Gueguen, Laetitia Moulin, Olivier Laurantin, Christophe Merlier & Jean-Michel Soubeyroux, 2011: A 10-year (1997–2006) reanalysis of Quantitative Precipitation Estimation over France: methodology and first results. *Weather Radar and Hydrology* (Proceedings of a symposium held in Exeter, UK, April 2011) (IAHS Publ. 351, 2012), 255- 260 http://iahs.info/redbooks/a351/abs_351_0255.pdf
2 Overeem, A., Holleman, I., Buishand, A., 2009. Derivation of a 10-year radar-based climatology of rainfall. *J. Appl. Meteor. Climatol.* 48, 1448–1463.

The Deutscher Wetterdienst is in the particular fortunate situation to operate a network of 17 C-band radar systems with similar specifications and a harmonized scan strategy covering the entire territory of Germany at still reasonable radar ranges.

But even at these excellent observational conditions it has turned out that a reliable quantitative precipitation measurements is absolutely dependent on the calibration against a sufficiently dense network of automated rain gauges (~1300 Ombrometers).

DWD is in the middle of a transition phase enhancing all its radar systems by the additional measurement of the polarized moments (in fact the doppler-systems are replaced by dual-pol ones). Five of 17 replacements have been completed already. The new network will ultimately allow for a number of improvements towards a substantially improved absolute calibration of its QPE products. For each location running already a dual-pol system DWD can

- calibrate the radar against the known irradiance of the sun in the C-band allowing for absolute and cross-calibration of the radar network members, yielding ultimately an enhanced spatial homogeneity of composite (mosaic) products
- evaluate the polarized moments to feed the Z-R relationship with a directly measured (so not assumed) drop-size distribution of the volume scanned (yielding absolutely calibrated PHR and PYR products enhancing the non-calibrated PH and PY ones)
- include an exact vertical scan to utilize the radar as a quasi-distrometer to operationally calibrate LHN distrometer systems running at each radar location.

To what extend these absolute calibrations can reduce the above mentioned dependency on the gauge network needs to be investigated in course of the completion of the dual-pol network in the upcoming 2-3 years and the years thereafter.

So far extreme precipitation statistics, serving the core information in the field of hydrological engineering applicable for the sizing of sewer systems, run-off projection, flood risk assessment etc., solely utilized rain gauge in-situ observations. While some of them actually feature the requirements on temporal data homogeneity and length of time period they have their limitations in geo-temporal resolution of the analysis to an extend that leaves hydrological customers in Germany – for example – sticking to their own gauge networks operated in the catchment, which is unfortunate given the nominal lower spatial resolution and capability of gauge networks to fetch and quantify small scale extreme events.

What level of pre-processing of the data is preferred by the application area? Is this currently either insufficient or too much?

The automated pre-processing is substantial to remove to the best possible extend artefacts and false echoes (clutter) leading to severe errors in the QPE products generated down the processing workflow. While these procedures have reached a certain maturity to enhance the quality of the qualitative precipitation analysis, the QPE for the climatological application demands for additional QC in order to warrant a higher geo-temporal homogeneity and the generation of self-consistent mosaic (composite) products.

In the real-time warning mode where aggregations are normally not longer than 24 hours, these inhomogeneities are easily overlooked. However weekly or monthly aggregated composite products feature all kinds of additional artefacts like inhomogeneity's at the edges of the radar ranges, negative and positive spikes that have been tolerated in the real-time application.

So the level of pre-processing is certainly insufficient. On the other hand, concatenation of national QPE products will not yield a homogeneous regional, continental or global product. So the requirement is two-fold at the current pre-mature stage:

- Exchange of best precipitation estimates (also composite products) for the time being to get started.
- Development of a global radar reflectivity data base that contains level0 data to allow for a homogeneous re-processing across data sets from different suppliers and radar networks

In doing so, the Deutscher Wetterdienst has stored since 1st January 2001 the reflectivity data of its precipitation scans (the scan with the lowest possible elevation following the orography potentially blocking the radar beam across the azimuths in BUFR sweaps. These data in company with the required meta information is sufficient to regenerate the majority of the 2D QPE and adjusted precipitation analysis products generated once in online mode.

- Finally, 3D (Volume) data come at a too high cost benefit ratio for hydro-climatological applications, so that their storage for future re-processing appears too cumbersome at this early stage.

What is the use of quality indicators in the processing of the data from weather radars?

Permanent generation of quality indicators along with the radar based QPE products is absolutely mandatory to allow for a quantitative precipitation estimate and assessment of the uncertainty of the method to adjust against rain gauge measurements. Again, for the climate application the hydrological requirements can be regarded as the lower boundary.

What are the major constraints in the use of the data by the application area?

- Very little experience yet. Many problems not even known yet
- Too short data coverage yet (10-20 years; but it's time to enter into the R&D now to have proper algorithms and post-processing ready in 10 years when the first data sets reach at the magic 30 years)
- If 3D data is not excluded, the data storage effort is substantial to unbearable for many NMHS's operating radar networks. Therefore 2D precipitation scans should be the major target for weather radar data storage.
- No proper algorithm to post-process and correct artefacts that had not been detected and removed during the real-time application and processing of the data
- Availability of a sufficiently dense and reliable network of automated gauges to for the adjustment procedure, although this constraint is even stronger in the real-time application when the data gathering and processing can lead to truncated gauge data usage.

Is consistency of availability of the data important o the application area?

Again the climate application is most demanding here, so the answer is YES, but:

- The relaxed time constraint for the climate applications that rather run in the re-analysis mode can be helpful here, provided local copies of data measurements (radar and gauges) are made available off-line later.
- A proper storage and buffer strategy for the data can alleviate the problem, in contrast to the real-time application were data drop-outs simply cannot be compensated anymore

Is it understood where these data have the biggest impact on the application area?

There is more expectation than understanding on the impact issue at this infancy stage. Obviously there is a big potential in the field of (flood) risk assessment and adaptation to CC in the fields of water management and agriculture through higher resolving intensity duration curves and extreme precipitation statistics.

Moreover if a high-resolution radar based precipitation analysis is used as reference data set to verify climate models and to improve re-analysis schemes utilizing limited area models that manage to resolve at least convective precipitation (alike the COSMO_DE model of the Deutscher Wetterdienst) while assimilating radar data. On the down-side data assimilation works best with the cumbersome volume weather radar data.

A very personal view is that a global re-processing of 2D weather radar data might serve the clue to solve the current paradoxon of the statistical significant global trend in the station based temperature measurements vs. a yet insignificant trend in the precipitation data also diagnosed by the Global Precipitation Climatology Centre. Under the hypothesis, that an accelerated hydrological cycle in connection with CC is manifested rather through small-scale and extreme precipitation events, rain gauges only might be the wrong data for such assessments, while the quality of satellite measurements is still too questionable at least across land-surfaces, leaving radar data as the remaining opportunity.

Is the relative value of weather radar data to other sources of data well understood in the application area?
Not at all! The wide spread understanding (not at Deutscher Wetterdienst!) so far is, that radar data is too scarce, spotty and unreliable in the global scale, and too inaccurate in the regional scale for the climate application. But at some aforementioned weather services this attitude is changing. Anyway the challenges are huge.

Is there a strong or critical dependency on other observational data to support the use of weather radar data in your application area?
In contrast to the hydrological requirements (INF.2.3) there is only strong but not critical dependency on rain gauge data to adjust the QPE product, because the relaxed time constraint opens opportunities to cover the adjustment requirement through smart gauge data storage and exchange schemes in offline mode.

3. Known future requirements for use of the data

For the climate requirements the outlook into future requirements is tricky, as NHMS's are busy enough to get started with addressing climate requirements at all. So this section can be kept short, unfortunately.

Is there any general trend in these requirements (eg more demanding in terms of availability or spatial coverage)?
Not yet assessable, in the absence of any world-wide agreed requirements. But common sense is allowed, so the spatial resolutions already utilized for the hydrological applications (in Germany this is 1 km) should be a baseline. For the temporal resolution the rain gauge adjustment procedure determines the resolution (for example 1h at DWD).

Data coverage and availability are a core requirement for climatological application. While a global (land-surface) coverage is impossible even in the far future, it would be excellent to yield coverages for characteristic climate zones to allow for representative global studies.

Have these future requirements been published or communicated widely with the weather radar operator community?
No, like any climate requirement so far. For the weather operator community it would be already a great deal to reach at a global understanding that level0 2D precipitation scan data should be stored an made ready for offline re-processing at any later time.

Of the parameters currently measured by weather radars which are likely to be the most important or more greatly used in the future?
Precipitation is and will be the most important one for climate. Wind data might become important for a while if the move towards renewable (wind) energy – made by Germany for example - becomes really a global effort.

4. Possible future requirements for use of the data

Will the temporal and spatial requirement for data change significantly in the future?
No. The current resolution of up to 1x1 km is a stable requirement. The hydrological community will always demand for higher resolution, but even the nominal resolution of X-band radars hardly copes with their requirements. Therefore, there will always be a gap, and methods required to fill this gap. For example mapping of (flood) risk maps derived from static high resolution data to be folded with the precipitation analysis is the more feasible approach.

Is it likely there will be a reduction in the requirement for weather radar platform based observational data?
No, it is very unlikely.

Will new forms of quality data be required, especially to better exploit the data?
Yes. The statements of INF.2.3 are fully valid also for the climate requirements.

Will less or more pre-processing of the data be required (the raw data or refined products question)?
Raw 2D data should be maintained as the most efficient storage of the complete information. However, this is only useful if sufficient meta information is also stored to allow for generation of QPE and adjusted QPE products in offline mode.

To get started, there should also be institutionalize scientific exchange on the R&D required to generate (multi-) decadal re-processing products and extreme precipitation statistics. Many, many person years of R&D still required to come up with solid methods.

5. Further points to consider

For the climate application it needs in the mid-term future a data centre function. The let’s say GRCC (Global Radar Climatology Centre) should be charged to collect and quality control 2D radar data, ideally at the raw data level. With regard to rain gauge data, DWD supplies such a function while operating the Global Precipitation Climatology Centre and is ready to share experience also in context of copyright issues.

But the effort of running and maintaining a GRCC would be substantially bigger, comparable to a EUMETSAT CM-RAF being charged to explore radar data for climate applications.

6. Summary

The key points discussed are as follows:

1. In the climate context only the precipitation parameter of weather radar data is of sustained importance.
2. Weather radar data coverage enters into the (multi-)decadal scale. In another decade it is ready to address climate requirements, provided methodologies and data exchange have matured to do so.
3. A number of NMHS’s has conducted promising proto-type studies and is ready to invest into the development and generation of multi-decadal radar bases to support climate requirements
4. Raw 2D radar data taken from precipitation scans (or lowest elevation scans) is target data. Volume (3D) data is currently two cumbersome
5. Target applications are extreme precipitation statistics, long-term aggregations and re-analysis
6. Quality control of radar data mandatory for climate application. Demands even higher than for hydrological purposes as data homogeneity in space and time comes as an additional requirement (on top of clutter and artefact corrections also required for hydrological applications)
7. Quantitative radar based precipitation analysis most reliable through adjustment against gauge data. This implies an additional requirement on gauge data. New absolute calibration methods based on dual-pol radar measurements might alleviate the gauge requirement.
8. On the global scale the effort to address climate requirement is huge and should be addressed by an international data centre that is charged to world-wide collect and quality assure radar data.