DWDs new radar network and post-processing algorithm chain

Kathleen Helmert

Kathleen Helmert[1] , Patrick Tracksdorf[1] , Jörg Steinert[1] , Manuel Werner[1] , Michael Frech[2] , Nils Rathmann[1] , Thomas Hengstebeck[1] , Michael Mott[1] , Sybille Schumann[1] and Theodor Mammen[3]

[1]*Deutscher Wetterdienst, Frankfurter Str. 135, 63067 Offenbach am Main, Germany*
[2]*Deutscher Wetterdienst, Albin Schwaiger Weg 10, 82383 Hohenpeißenberg, Germany*
[3]*Deutscher Wetterdienst, Frahmredder 95, 22393 Hamburg, Germany*

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1 Introduction

The operational radar network of Deutscher Wetterdienst (DWD) with 16 radar systems was built up between 1987 and 2000. While the first systems delivered information about echo intensity, echo location and echo displacement only, the radar systems from 1994 onwards allowed the estimation of the mean Doppler velocity extending the range of meteorological applications. Since 2009 DWD is extending and modernizing its national weather radar network with new polarimetric C-Band Doppler radar systems. Additionally, a 5-minute volume scan strategy was successfully introduced in 2012. The enhanced system capabilities of the polarimetric radar systems in combination with the new volume scan strategy allow a mayor improvement of existing algorithms and the development of new procedures. The aim is an improvement of the quality of nowcasting algorithms and the warning management process as a whole. As a constraint, the results of the improved algorithms and procedures have to be available near real time with a minimal mean time between failures (run 24/7). Thus, the algorithms have to work with high performance in combination with an easy maintainability. To achieve this, a new software framework capable to unite all the stand alone radar algorithms was established in parallel to the exchange of the radar systems. This abstract will detail the current radar related developments within DWD.

2 DWDs new radar network

2.1 Radar system exchange

The DWD is currently replacing its operational Doppler radar network with new polarimetric C-Band Doppler radar systems (EEC DWSR-5001C/SDP-CE with an ENIGMA3+ signal processor). The radar systems are equipped with an AFC radome (20DSF17 6m stealth radome). The new systems are able to provide a peak power of 500 kW. Four pulse widths (0.4, 0.8, 2.0, 3.0 µs) are possible, from those 0.4µs and 0.8µs are used operational. The receiver may collect samples at 25m range steps with the antenna rotating at 8 rpm, leading to data with high spatial and temporal resolution. The beam width of the antenna is expected to be at least 1°. These technical facilities allow the identification of weak showers up to 250 km distance. Overall a preservation and improvement of data quality and quantity within the weather radar network is expected.

Along with the radar system exchange the network structure was optimized by the relocation of several sites (Frankfurt, Hamburg, Berlin, Munich, Hannover and Emden) and the installation of an additional 17th radar system in Memmingen. At the end of the radar system exchange in 2015 there will be 17 operational polarimetric radar systems and one research radar system at the Meteorological Observatory Hohenpeißenberg.

The research radar system was the first system replaced and is used for hard- and software tests, special measurements as well as the optimization of radar parameters like signal thresholds, filter settings, scan elevations etc. Additionally the system is extensively used for verification purposes.

The replacement of the operational radar systems is a logistical and technical challenge. In order to minimize gaps in the network coverage during the modernization of a system, special arrangements are taken. In a first step the range of the highly used precipitation scan (see section 2.2) was extended from 125 km to 150 km. For the radar stations near the German border the network coverage is ensured with a failover radar system (Essen, Feldberg, Rostock and Dresden). This is a Doppler radar mounted on top of an up to 30 m height mobile lattice tower. The failover radar is located temporary near the original radar station and delivers the established radar products with comparable quality. The Belgium and Czech weather service provide their radar data as failover for two radar stations (Neuheilenbach and Eisberg). For all radar stations which are relocated (Hamburg→Boostedt, Frankfurt→Offenthal, Berlin→Prötzel, Munich→Isen, Hannover→Hannover new, Emden→currently N/A) data are delivered from both stations during parallel operation. For all other stations a small gap remains in the network coverage or only information from higher altitudes is available. Therefore adjacent radar systems are not exchanged at the same time.

Figure 1 shows DWDs radar network on the basis of the precipitation scan before (left) and after (right) the introduction of polarimetric Doppler radar systems. Because of the range extension from 125 km to 150 km of the precipitation scan and the relocation of several sites, Germany is now completely covered by the highly used precipitation scan.

 kathleen.helmert@dwd.de

The polarimetric radar systems deliver differential power and phase moments, which may be used to estimate the size, shape and type of hydrometeors. Along with the radar system replacement the development of advanced algorithms has been started with the so called project “Radarmaßnahmen”. Results from the project are shown in the contributions by M. Frech, M. Werner, J. Steinert and P. Tracksdorf at this conference.

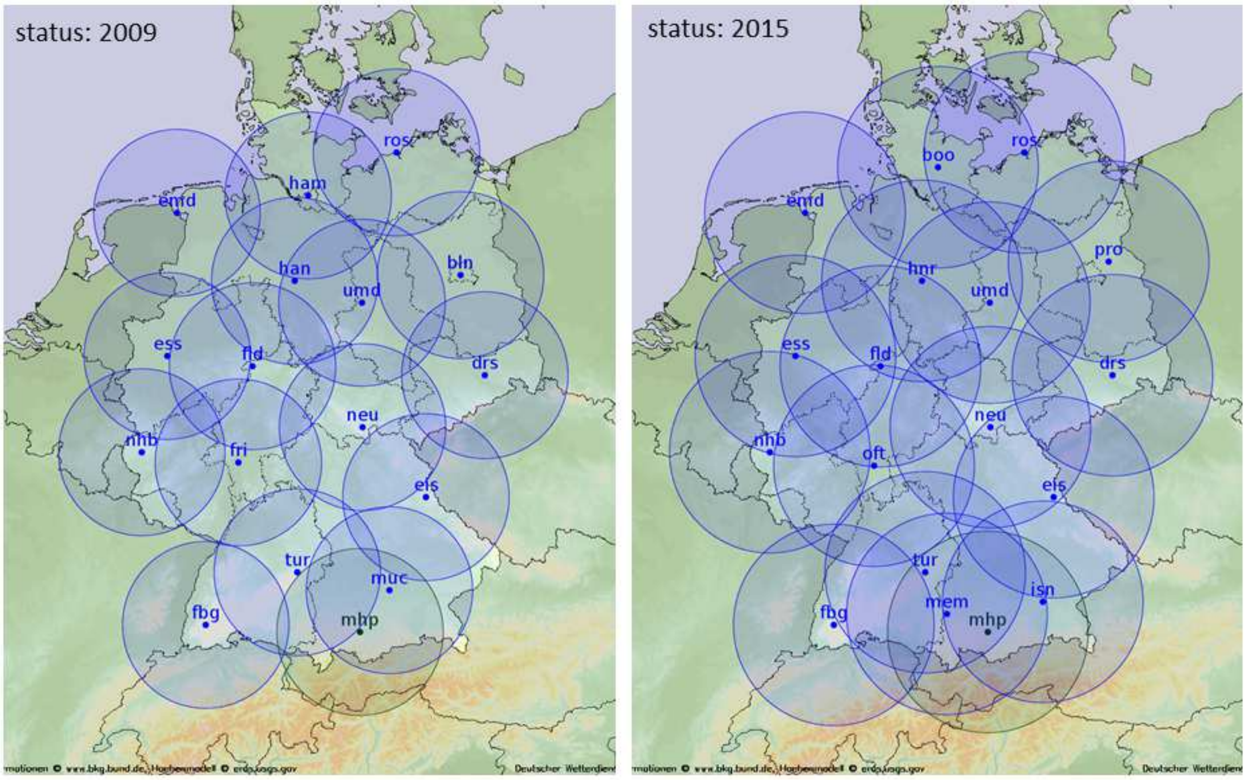

Figure 1: DWDs radar network on the basis of the precipitation scan before (left, 125 km range) and after (right, 150 km range) the introduction of polarimetric C-Band Doppler radar systems.

2.2 Scan strategy

In order to have a higher temporal resolution of the volume scan for the development of new and improved algorithms, a 5-minute volume scan strategy was successfully introduced at the end of 2012 (Seltmann, 2013) in parallel to the radar system exchange. The procedure of this scan strategy is described in the following paragraph and illustrated in Figure 2.

First, a horizon following precipitation scan (600 Hz, 150 km, lowest elevation angle possible following the horizon line) is performed. Here, the antenna elevation is a function of the azimuth and is individual for every site. The data has a range resolution of 250m and is used for many applications like algorithms related to the warn management and hydrological applications.

The volume scan consists of 10 elevation angles starting with the 5.5° elevation sweep. Going downwards in elevation with 3 rpm, the important data near the ground is available after 2.5 minutes. An unambiguous velocity interval of +/- 32 m/s and a radial range of 180 km is achieved by a 3:4 (600/800 Hz) dual PRF ratio. Then the upper four elevations are scanned combining an extended nyquist velocity of +/- 32 m/s with a maximal unambiguous range large enough to sample the troposphere up to a height of at least 12 km. No staggering is performed for the sweeps with the elevations 12°, 17° and 25°. The sweep with an elevation angle of 8° is recorded in a 2:3 staggering mode (1200/800 Hz, 125 km). This is the same setup as in the old scanning scheme upholding continuity for the VAD calculations, which are solely based on this sweep.

At the end of each 5 minute cycle a scan at 90° elevation is performed which is used for calibration and monitoring purposes (cf. M. Frech this conference).

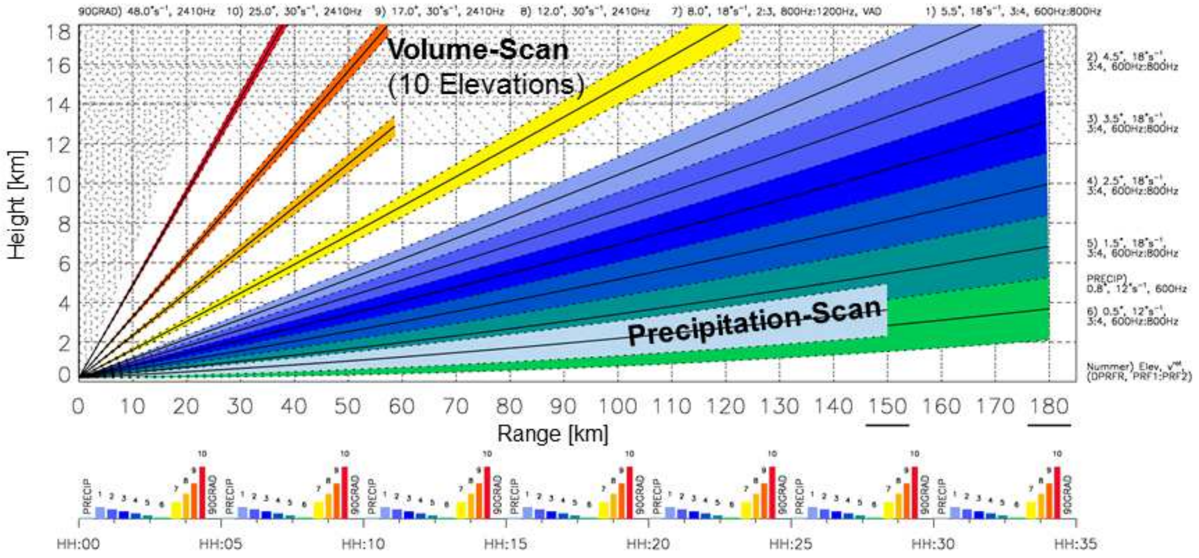

Figure 2: DWDs 5 minute scan strategy

3 DWDs new post-processing algorithm chain

The legacy post-processing algorithm chain at DWD consists of different tools (e.g. RadarQS, composite generation, KONRAD) to generate the various radar products. That increases the complexity for the maintenance, monitoring and controlling. Furthermore the integration of new algorithms and especially the combination of algorithms is difficult. Moreover it is time-consuming to transfer algorithms from the development (prototype) to the operational stage keeping in mind that the algorithms have to run 24/7 with efficient performance including extensive monitoring and easy error analysis.

Therefore, along with the replacement of the radar systems the post-processing algorithm chain is redesigned with the aim to create a development-, verification- and runtime environment, which supports and standardizes the implementation and operationalization process of radar- and future nowcasting algorithms. The further purpose is to avoid redundant work, standardize the look and the context of new algorithms and make continuous data processing as simple and stable as possible. The system is called POLARA (**POLA**rimetric **R**adar **A**lgorithms).

Figure 3 shows a schematic overview of DWDs new post-processing algorithm chain. Some standard radar products like CAPPIs or reflectivity-PPI's are directly generated at the radar sites with the quality control available there and are visualized in NinJo (DWD visualization system). More complex algorithms are developed and run operationally in POLARA.

POLARA is able to read, organize and process a huge amount of real-time (and verification) data simultaneously from all radar sites. This is an advantage compared to the legacy situation, because now in algorithms gaps in the vertical distribution may be closed with data from neighboring stations. The developed algorithms in POLARA are both comparable and connectable. They work in general in algorithm chains and the results are written to disk or may be used by other algorithms in POLARA. Each new developer benefits from the experience of preceding algorithm developments. Using the existing and consistent scheduling as well as logging and monitoring of POLARA, new algorithms can easily be transferred from development to operational stage. Details concerning the technical aspect of POLARA are shown in the contribution of N. Rathmann at this conference.

The quality of the input data is decisive for the results of automatic algorithms. In order to minimize the effects of non-meteorological phenomena each algorithm chain starts with a quality assurance at the radar station. Here, a Doppler filter is applied (Seltmann, 2000), cluttered raw range bins are excluded from range averaging, the data is checked against diverse thresholds and stand-alone range-averaged bins are discarded. Furthermore a monitoring is carried out at the radar sites, which consists of the following components:

- Monitoring of the polarimetric moments (quality, offsets)
- Monitoring of antenna position (offset, beam squint)
- Monitoring of system calibration (sun calibration, distrometer)
- Monitoring of system state

Details of this part are shown in the contribution of M. Frech at this conference. The results of the monitoring are immediately transferred to the DWD headquarter and are directly processed in the post-processing quality control of POLARA. The legacy post-processing quality control (Hengstebeck, 2010) was re-implemented in POLARA. It consists of a couple of algorithms to detect corrupt images, clutter, spokes, rings and aliasing. Using the polarimetric data the algorithms are improved and extended especially for the detection of bright band, clutter and attenuation (M. Werner, 2012 and M. Werner at this conference). Together with the information from the on-site-monitoring a quality flag product is generated. It contains the quality information for each range bin and meta-information concerning errors affecting the whole data set (Helmert et al, 2012). This enables a differentiated decision whether the pertaining range bins of the radar data are to be included or not for a follow-up algorithm or user application.

Up to now the following algorithms are implemented in POLARA:

- Hydrometeor classification (J. Steinert, at this conference)
- Quantitative precipitation estimation (P. Tracksdorf, at this conference)
- Mesocyclone detection and rotation tracks (T. Hengstebeck, at this conference)
- Vertical integrated liquid (VIL) and VIL track (T. Hengstebeck, at this conference)

Presently the verification and optimization phase is ongoing, which extends at least over a summer and winter period.

A great advantage of POLARA is that the output of each algorithm can be used as an input for each other algorithm. For instance the hydrometeor classification is an important input for the improved quantitative precipitation estimation, the planned cell detection algorithm and the nowcasting of winter events.

The results of the individual algorithm may be directly visualized in DWDs visualization system NinJo (Joe et al., 2005) or they may be used to generate radar network composites. To take into account the different user requirements for the overlapping areas several methods for the composite generation are implemented (e.g.: maximum method, smallest distance to the radar, value nearest to the ground or quality score method). Currently a method to generate a 3D-composite is developed (see M. Mott and M. Diederich at this conference).

The quality controlled composites will be used in further applications (DWD Radolan, DWD RadVor, data assimilation) and are visualized in NinJo.

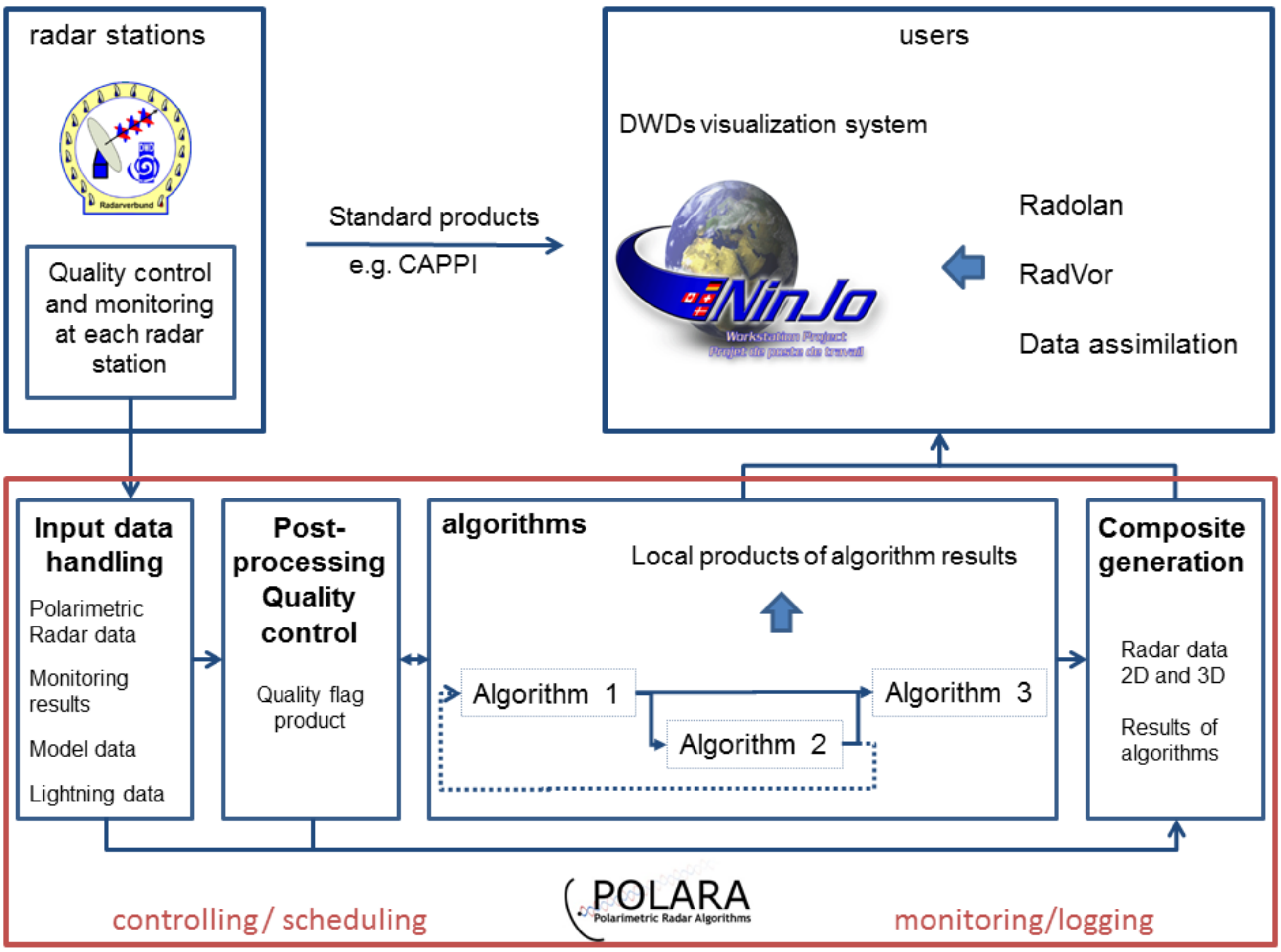

Figure 3: DWDs new post-processing algorithm chain

4 Summary and Outlook

Until 2015 DWD will exchange the 16 C-Band Doppler radar systems with modern dual-polarization C-Band Doppler radar systems. In order to ensure the operation only with small restrictions special arrangements are taken (range extension, failover radar, temporary foreign data, and parallel operation of relocated sites).

In order to use the new possibilities of the polarimetric radar systems efficiently a 5-minute volume scan strategy was introduced by the end of 2012. As basis for new and improved algorithm development the post-processing algorithm chain was redesigned.

In contrast to the existing stand-alone tools the new post-processing algorithm chain has the following advantages:

- Use POLARA as development- and run-time environment and for verification purposes
- Ability to read, organize and process a huge amount of real-time and verification data simultaneously from all radar sites
- Consistent and connectable algorithm development (Each new developer benefits from the experience of preceding algorithm developments)
- Small maintenance cost and easier transfer of new algorithms and prototypes from development stage to operational stage (consistent scheduling, logging and monitoring)

The actual implemented algorithms (Quality control, hydrometeor classification, quantitative precipitation estimation, Mesocyclone detection, rotation track, VIL and VIL track) will be verified and optimized using observations (e.g. from European severe weather database) or ground based measurements (ombrometer, present weather sensor). Beside these data also satellite and model data are to be considered to further improve existing algorithms and following the nowcasting and warning management. The data has to be organized additionally in the input data handling of POLARA. Then methods could be developed, which combine different measurements or algorithms. In addition it is possible to analyze the influence of different measurements on the algorithm results and to compare the nowcasting results with independent measurements and observations. In this manner a nowcasting tool can be build up step by step.

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