Winter and summer weather studies using high resolution radar data

Tim Böhme[1]

[1]*Deutscher Wetterdienst, Frankfurter Str. 135, 63067 Offenbach am Main, Germany*
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Tim Böhme

1. Introduction

Using the latest radar products of DWD helps analysing and nowcasting severe weather events both in winter and summer season. Temporally and spatially high-resolution Doppler radar data of 5 min intervals and up to 250 m in range in combination with new dual-polarimetric information of the renewed radar network give additional information and also help to classify precipitation events and to warn adequately and in real-time. In winter, the additional phase information of the new dual-polarimetric radar products is very valuable to nowcast snow and black ice, whereas in summer the high-resolution radar data in space and in time are a precondition in order to nowcast the fast and variable development of convective cells. This includes heavy precipitation events like hail and mesocyclones which are responsible for heavy damage to infrastructure and can be life threatening. The new products are still under development as so far the precipitation phase classification is done on radar beam level only. A new project is in preparation to determine the precipitation phase at the ground but also at distinct flight levels for aviation purposes as weather radar information is also necessary for the safety and regularity of international air navigation (e.g. oral presentation of Wetter and Zinkhan (2014), APP 9a.1). With the new algorithms, also new visualisation methods will be introduced.

For the detection and tracking of convective cells, the variable terrain-following precipitation scan products and the elevation volume scan products are used. Both scans are the basis for the automatic warning products which are currently used at DWD, e.g. the thunderstorm warning algorithm KONRAD and the mesocyclone detection algorithm (e.g. poster presentation of Hengstebeck et al. (2014), NOW.P11). For these products, a further development in order to determine the life cycle phase is planned. In addition, the use of radar data of neighbouring radar networks is necessary to extend the nowcasting time range of operationally used products.

Weather studies for two winter events of 21 January 2014 and 05 February 2014 and for one summer event of 09 July 2014 will be presented in order to show the currently available data sets.

2. Radar data

DWD is operationally using radar data of high spatial and temporal resolution. In fall 2012, the new radar scan strategy has become operational. Since then the radar products are produced in 5 min intervals. Two different scans are used: The so-called volume scan and the terrain following precicipation scan. The volume scan consists of 10 different elevations with fixed elevation angles between 0.5° and 25°. While in the lower troposphere six neighbouring beams between 0.5° and 5.5° are used, the upper troposphere is scanned with beams between 8° and 25° (see oral presentation of Helmert et al. (2014), NET 4.4).

Figure 1 shows the current DWD radar network configuration. Currently, the single-polarimetric C-band Doppler radars are replaced by dual-polarimetric C-band Doppler radars (project RadSys-E). In order to minimise clutter effects and extend the radar coverage new locations have been established. Instead in metropoles, three dual-polarimetric radars have been installed in the countryside: The new sites are Boostedt (formerly Hamburg), Isen (formerly Munich), Offenthal (formerly Frankfurt) and Prötzel (formerly Berlin). In order to receive a better coverage of some valleys of the Alps an additional dual-polarimetric radar in Memmingen was operationalised in 2013. So far, already 12 out of 16 single-polarimetric radars have been replaced by dual-polarimetric radars. Three more radars (Eisberg, Dresden and Flechtdorf) will follow until spring 2015. The renewal will be finished with the replacement of the Doppler radar in Emden. With this altogether 17 dual-polarimetric Doppler radars will have become operational.

For the use of radar and nowcasting products both data quality and availability have to meet high requirements. For warning and aviation purposes, operational data sets have to be available in near real-time, that means within 2-3 minutes. Furthermore, raw data quality is an important issue. Already the measurements should consist of homogenous and undisturbed data sets. Therefore, it is very important to monitor the radar data as well as to avoid non-meteorological influences (e.g. frequency interferences or wind turbines clutter, see also oral presentation of Böhme (2014), DAC 13.4).

 Tim.Boehme@dwd.de

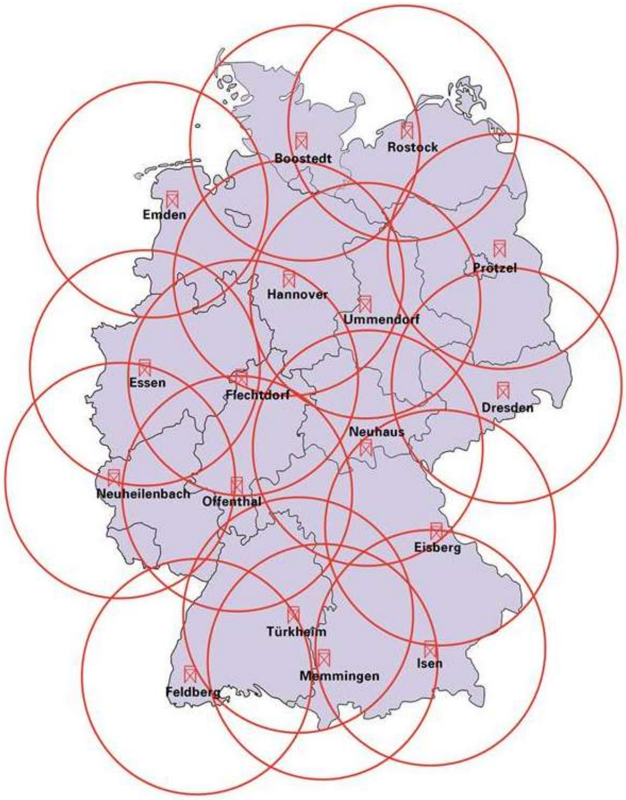

Figure 1: Current sites of DWD radar network.

3. Weather studies

Since the quasi-operational supply of high-resolution data sets with dual-polarimetric information some months ago, it is possible to evaluate the additional precipitation phase information. The quality assured dual-polarimetric radar data give valuable information for precipitation estimation products (e.g. poster presentation of Tracksdorf (2014), QPE.P34), but also for new products which indicate the precipitation phase (e.g. poster presentation of Steinert (2014), MIC.P11). This will indirectly also affect nowcasting products. So far, only case studies have been analysed. Some of these case studies (of 21 January, 05 February and 09 July 2014) will be presented in the following subsections.

3.1. Winter case - 21 January 2014

The focus on the winterly case studies is in the identification of black ice and conditions of snow-cover. The previous winter was characterised by relatively high temperatures in large parts of Germany. This caused often ground temperatures around the freezing level. Therefore, it was important to know, if precipitation which reached the ground was still in solid or liquid form. The new quality assured dual-polarimetric radar data could help to provide this information. As currently hydrometeor data are only available at radar beam height, case studies have been limited to areas in the vicinity of dual-polarimetric radar sites. Two cases will be referred: a precipitation case in the region of Lower Saxony in the vicinity of the radar Hannover radar on 21 January 2014 and a precipitation case in the Rhine-Main area in the vicinity of the radar Offenthal on 05 February 2014.

Figure 2 shows the height composite of the operational radars over Northern Germany in areas with precipitation on 21 January 2014, 11.30 UTC, when a zone of low pressure separated warm air masses in the West of Germany from cold air masses in the North-East of Germany. The zones were separated by a precipitation band of low intensity in between. Precipitation phase information can only directly used in the areas depicted in dark green colour as the radar beams were only there close to the ground. Figure 3 shows important differences between the hydrometeor algorithm without dual-polarimetric data input and the new hydrometeor algorithm with dual-polarimetric data input. Around the radar Hannover precipitation is mostly marked as liquid (blue) instead of solid (yellow). As the temperatures at the ground were still below 0°C black-ice occured there. For the analysis also the precipitation amount was very important: In some areas precipitation evaporated on the way to the ground. The radar observations and in particular the dual-polarimetric hydrometeor classification data were confirmed by synoptic observations at 11.30 UTC and 12.00 UTC (see Fig. 4). This case shows already that an important improvement in data observation could be expected with operationally available hydrometeor classification data. The users need this information both at the ground but also at special height levels for aviation purposes.

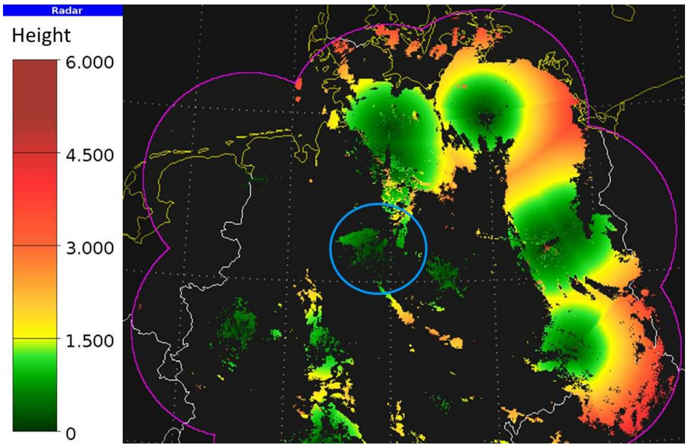

Figure 2: Composite of height of the used radar beam for the hydrometeor classification over Northern Germany on 21 January 2014. The blue circle shows the area of interest next to the radar in Hannover.

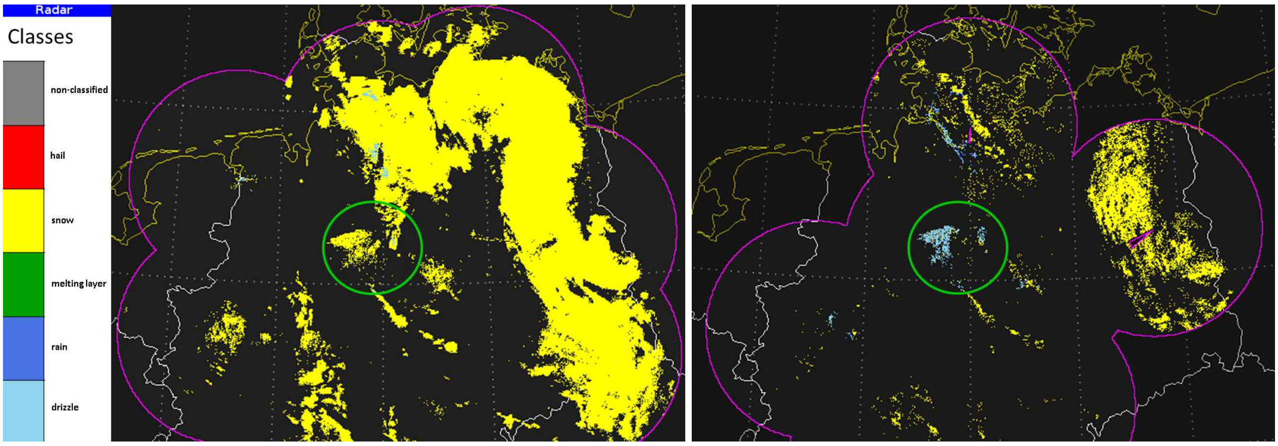

Figure 3: Composites of hydrometeor classical classification over Northern Germany on 21 January 2014 of all operational radar stations (left) in comparison to the hydrometeor algorithm with dual-polarimetric data input (right). The green circle shows the area next to the radar Hannover. For both images the same legend is applied, i.e. the same hydrometeor classes are visualised. The algorithm without dual-polarimetric data input shows snow next to the radar Hannover while the algorithm with dual-polarimetric data input shows drizzling rain.

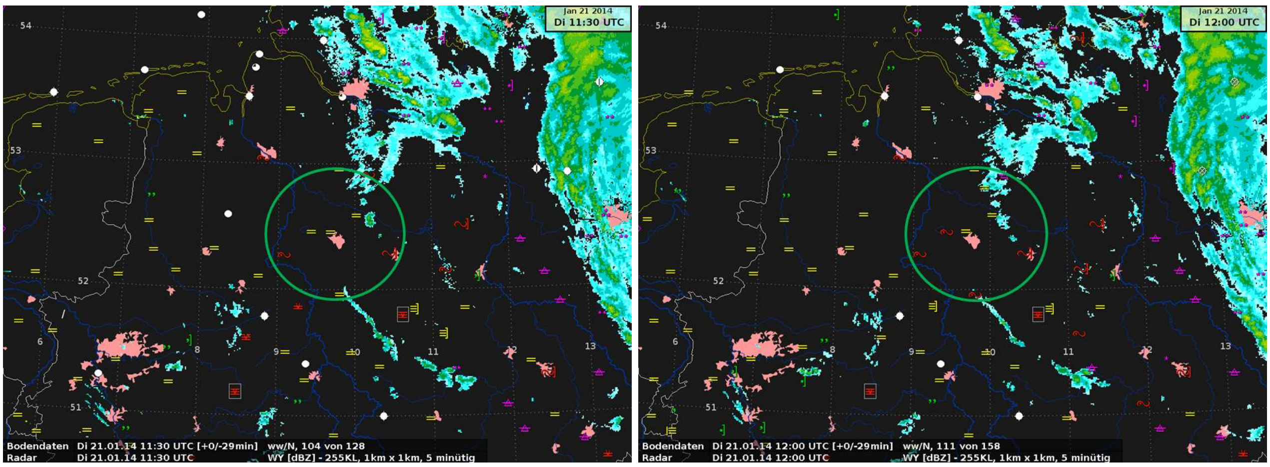

Figure 4: Radar reflectivities over Northern Germany on 21 January 2014, 11.30 UTC (left) and 12.00 UTC (right). Over Lower Saxony only signals of light precipitation intensity can be observed. In addition, synoptic observation data are displayed. The case shows that the dual-polarimetric hydrometeor classification result is plausible.

3.2. Winter case - 05 February 2014

Another example of a winterly weather situation over the Rhine-Main area around Frankfurt of 05 February 2014 shows the situation when in front of an occlusion which approached the Rhine-Main area from the West slippery conditions occured on the streets. In this case the fine and detailed structure of the hydrometeor classification product becomes apparent. On the one hand, this helps a lot as precipitation phase can vary on small scale significantly. On the other hand, data interpretation becomes difficult as the visualisation of small-scale variances is difficult. Figure 5 shows that precipitation of moderate intensity fell down in the Rhine-Main area at 10.00 UTC. At Frankfurt airport rain was observed. Radar data confirmed this. Some few kilometers away at around 800m msl in the Taunus mountains freezing rain was observed. This information agrees with the dual-polarimetric hydrometeor classification product of Offenthal radar while the non-dual-polarimetric radar data showed a melting layer signal (see Fig. 6 which shows that radar data height and Figure 7 which shows the precipitation phase). Also this case indicates that the new dual-polarimetric radar data can improve nowcasting.

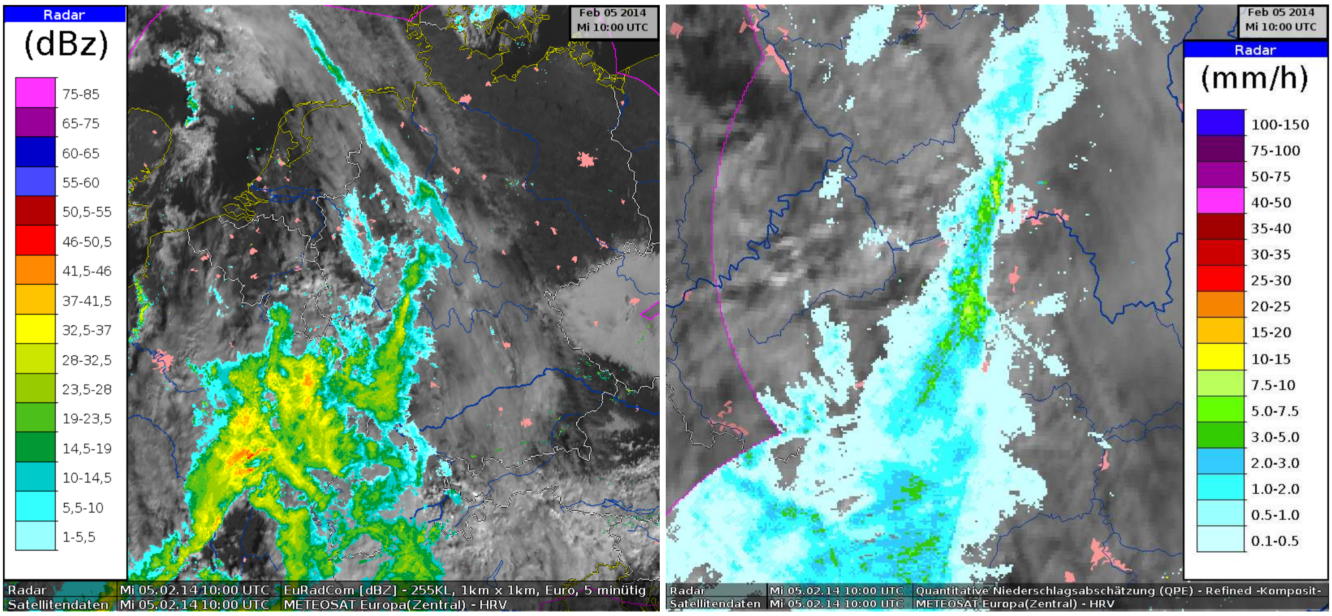

Figure 5: Composites of reflectivity over western Central Europe and quantitative precipitation estimation (refined Z-R relationship) over the Rhine-Main area on 05 February 2014.

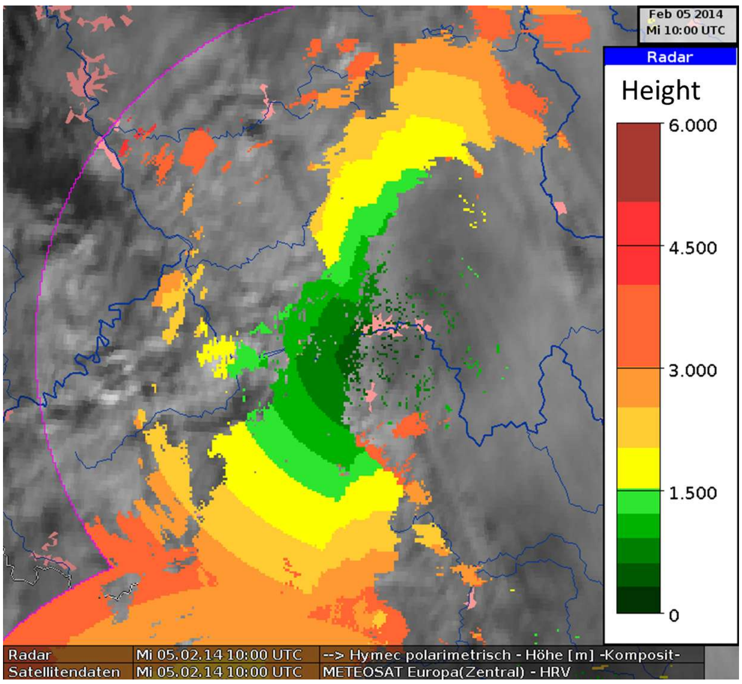

Figure 6: Composite of the height of the used radar beam for the hydrometeor classification over the Rhine-Main area on 05 February 2014.

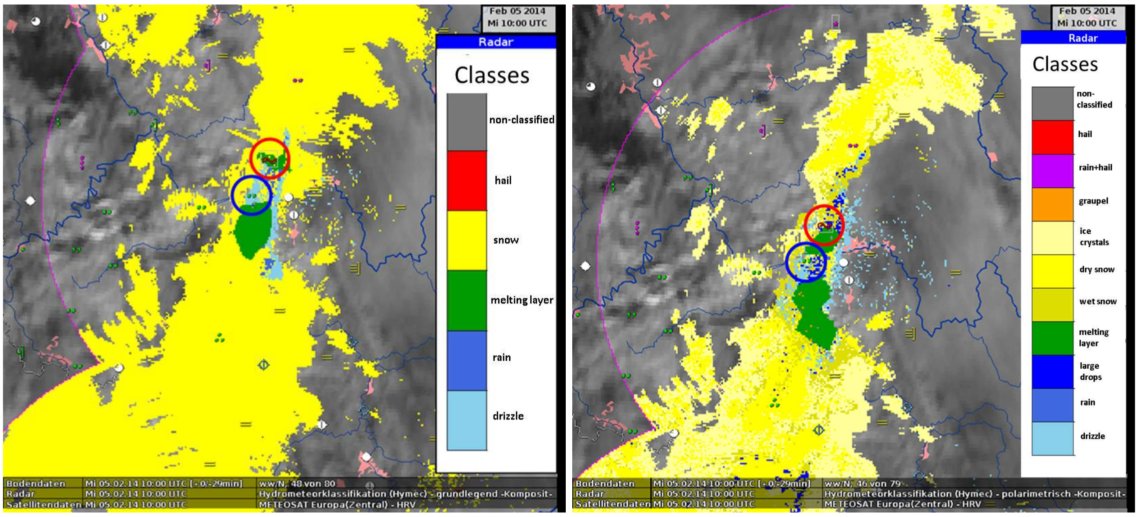

Figure 7: Composites of hydrometeor classification product over the Rhine-Main area on 05 February 2014 based on the algorithm without dual-polarimetric data input (left) in comparison to the algorithm with dual-polarimetric data input (right). In addition, the synoptic observations are displayed as symbols: The blue circle represents Frankfurt airport and the red circle the Kleiner Feldberg *station at $\approx$ 800 m above mean sea level in the Taunus mountains. The occurence of liquid precipitation as indicated by the dual-polarimetric classification scheme is confirmed there.*

3.3. Summer case - 09 July 2014

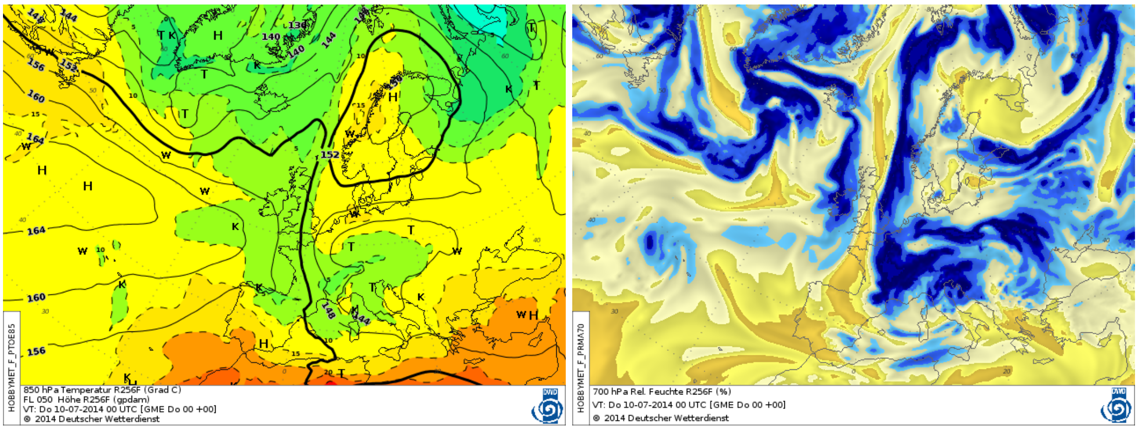

Figure 8: Weather situation in Europe on 10 July 2014, 00.00 UTC. Above and in the north of the Alps a low pressure zone can be identified in 850 hPa level (left) which is influencing the southern and central regions of Germany. The 700 hPa relative humidity image (right) shows a significant borderline which separates dry air masses in the North from humid air masses in the Centre and South of Germany. At this borderline strong convective events (thunderstorms, heavy precipitation) occurred.

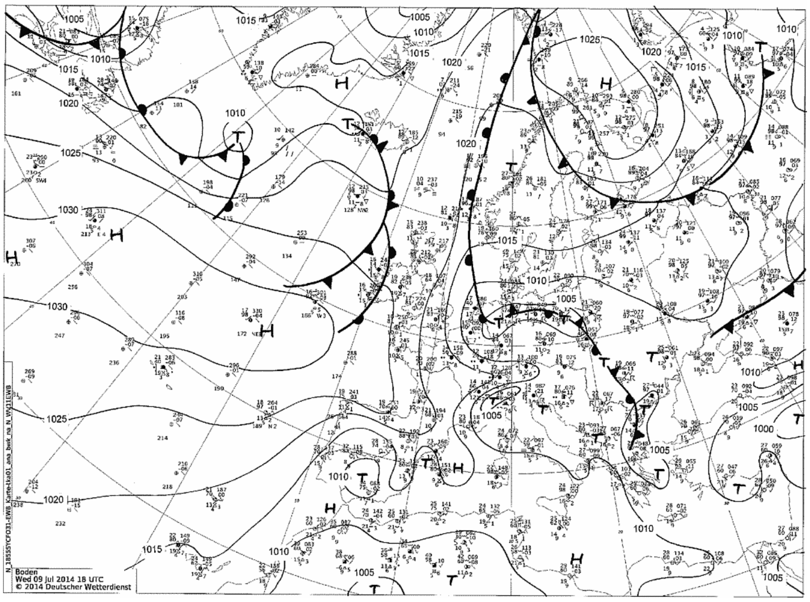

Figure 9: Synoptic analysis of the weather situation in Europe at the ground on 09 July 2014, 18.00 UTC.

Radar data are very useful for the analysis of and nowcasting in convective weather situations, e.g. when strong wind rotation phenomena like mesocyclones and heavy precipitation occur. For thunderstorm situations, there is a risk for tornadoes or hail events. Beside high-resolution radar products which show the development and displacement of these convective systems, the new dual-polarimetric radar products can help to identify (additional) hazardeous zones. Figures 8 and 9 show the weather situation on 09 July 2014, 00.00 UTC, for 500 hPa and 700 hPa levels and the synoptic analysis at the ground at 18.00 UTC. The weather situation was characterised by humid and cool air masses in the Centre and South of Germany while the situation over the North of Germany was marked by a dry and warm air mass. At the borderline between the two air masses heavy convection with embedded thunderstorms, hail and heavy rain events prevailed. This is very nicely presented in the radar product in Figure 10.

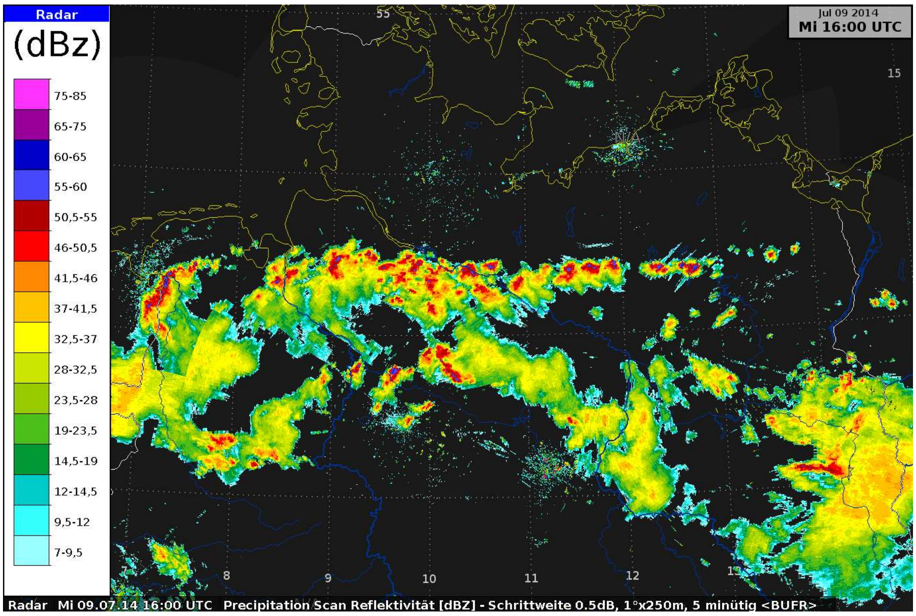

Figure 10: Spatially high-resolution radar product of 250 m of the precipitation scan over Northern Germany on 09 July 2014, 16.00 UTC.

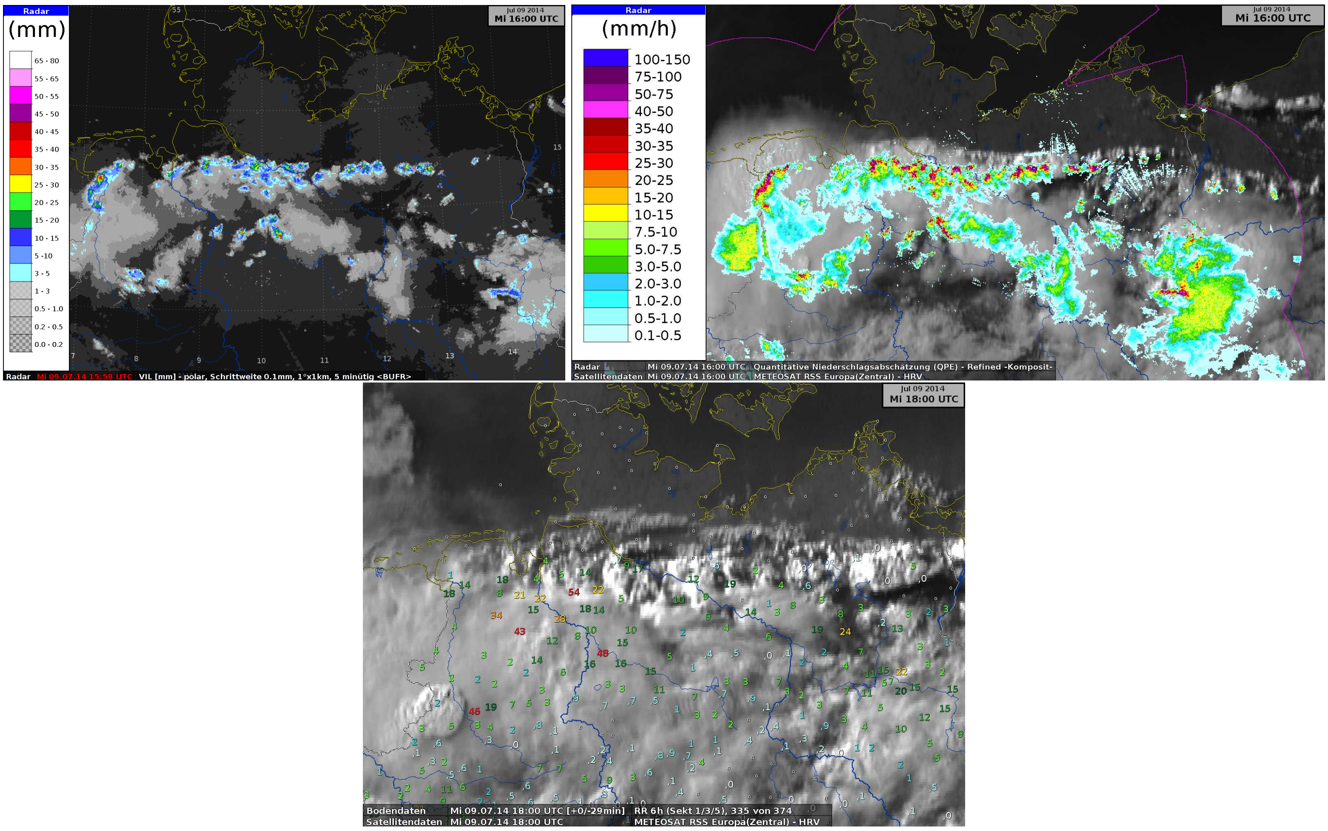

Figure 11: Products indicating the (potential) precipitation amount over Northern Germany of 16.00 UTC based on radar data: Vertical integrated liquid water and quantitative precipitation estimation product using the refined Z-R relationship. In addition, the observed 6-hours precipitation accumulation (12-18 UTC) at the ground is presented.

Radar products of 16.00 UTC show that mostly moderate to heavy rain prevailed at the borderline. This is clearly marked in VIL (vertical integrated liquid water) and QPE (quantitative precipitation estimation) products (see Fig. 11) and confirmed by 6-hours precipitation accumulation by observations at the ground. In the hydrometeor classification product it can be recognised that there were occasionally also signals of graupel and even hail inside this borderline (see Fig. 12). This is also confirmed by synoptic observations.

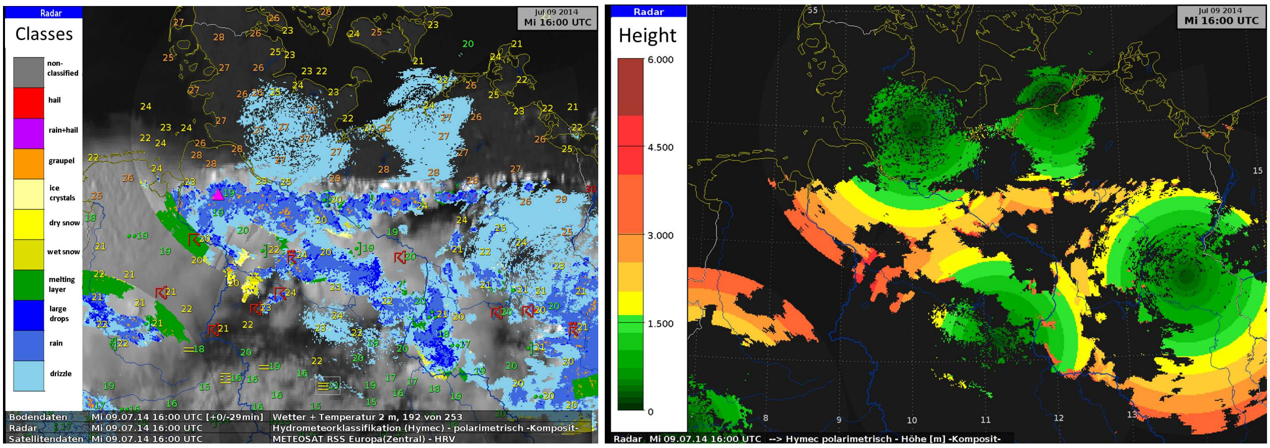

Figure 12: Hydrometeor classification product and radar beam height over Northern Germany on 09 July 2014, 16.00 UTC.

Radar data are dominating the data input for nowcasting products because of their quality, timeliness and high vertical and horizontal resolution. Some of the operational nowcasting products (see poster presentation of Ungelenk et al. (2014), NOW.P04) for the presented weather situation are visualised in Figure 13. The products show a lot of moderate and strong, sometimes even heavy warning objects especially at the borderline. The arrows show the displacement direction of the thunderstorm cells (KONRAD product). The dual-polarimetric radar data could help to set up an additional high-quality life-cycle product for nowcasting which is planned for the coming years.

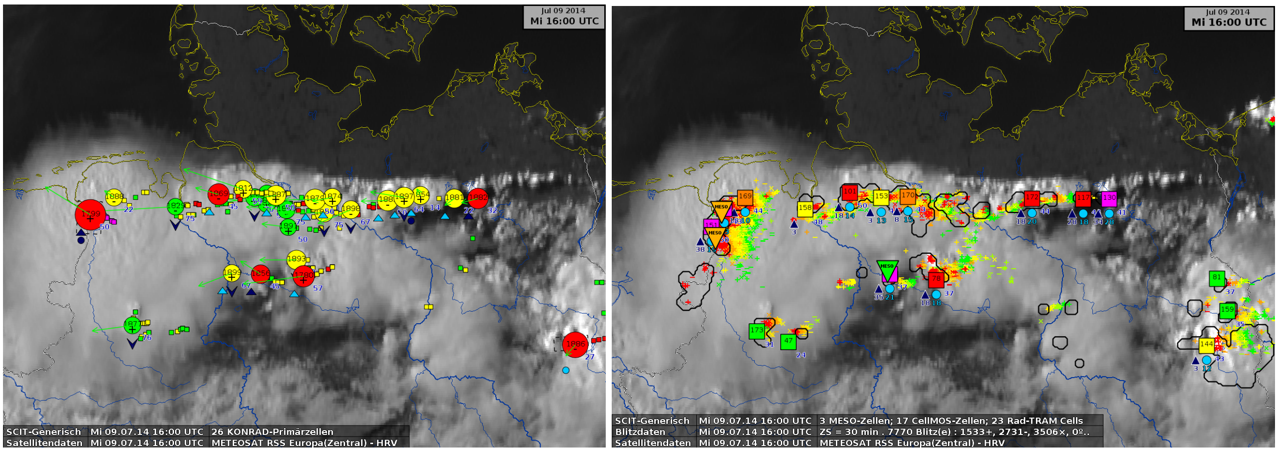

Figure 13: Nowcasting object data for Northern Germany of 16.00 UTC based on radar data (KONRAD product data on the left side) for the identification of thunderstorms and heavy precipitation events (CellMOS, RadTRAM, lightning and mesocyclone data on the right side). The green arrows represent the displacement vector of the identified convective cells of the Konrad product. The colours represent the severity of the cells or the timeliness of the lightning data.

4. Conclusion

The presented case studies show that radar data are essential for weather forecast and especially nowcasting purposes. Current operational products can help to identify hazardeous zones both in winter and summer seasons. Based on the radar and nowcasting products the warning process is controlled. Early warnings are very important for both flight and emergency management. The products lead to immediate action, e.g. by fire services, flood control services, pilots and air traffic controllers. It is therefore very important to maintain and guarantee the current product quality standard and to improve product availability, accuracy and resolution. Furthermore, the dual-polarimetric radar products show, that also new products with additional benefit can be developed.

The results show that ongoing efforts in the radar product development can lead to more safety in quite a lot of areas of life. Past experience shows that scientific and technological progress goes along with user expectations.

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