Meteorological Institute, University of Bonn:
***Josephin Beer**, Silke Trömel, Clemens Simmer*
Institute for Geophysics and Meteorology, University of Cologne:
Bernhard Pospichal, Susanne Crewell, Ulrich Löhnert

Concept of the JOYCE Core Facility

1. What is JOYCE – CF?

The Juelich ObservatorY for Cloud Evolution (JOYCE) has provided scientists worldwide with ground-based remote sensing observations as an established site. Since 2017 JOYCE is transformed into a Core Facility (JOYCE-CF (Fig. 1)) of the German Research Foundation (DFG, Deutsche ForschungsGemeinschaft) as a cooperation between the Meteorological Institute of the University of Bonn, the Institute for Geoscience and Meteorology of the University of Cologne and the Research Center Juelich (FZJ, Forschungszentrum Jülich).

JOYCE - CF

Fig. 1: Logo of the Juelich Observatory for Cloud Evolution – Core Facility (JOYCE – CF).

JOYCE has operated a large set of remote sensing observations with a major focus on radar and passive microwave observations for many years, now. These instruments ensure a holistic and detailed view of developing clouds and precipitation systems. Within JOYCE–CF these observations are operated in standardized operation routines and the data is distributed via a central access and in different level products depending on the users demand. Due to the already large community from scientists in climatology, modeling and observationalists as well as water management agencies and manufacturers, JOYCE-CF delivers high quality data and supports special field campaigns as well as additional instrumentation beside the already existing instruments. For providing high quality data a special focus lies on calibration of the instruments to ensure optimal data after long-term observations and field campaigns. The well calibrated instruments enable JOYCE-CF to serve as a reference center for microwave observations.

2. Major instrumentation

JOYCE-CF is characterized by its large variety of instruments which allow a holistic view of the atmosphere. Ground based and remote sensing observations complement each other and provide detailed insights in cloud and precipitation evolution. Due to the cooperation between the University of Bonn, the University of Cologne and FZJ the instrumentation of all parties could be collected and combined for a large set of instruments combining and comparing each other for an optimal basis for research and observation.

Fig. 2: Polarimetric X-band radar in Bonn (BoXPol).

The instrumentation includes two polarimetric Doppler X-band radars 50 km apart from each other (Bonn: BoXPol (Fig.2), Juelich: JuXPol). In 3 km distance to JuXPol an observation platform provides additional ground based and remote sensing instrumentation including a Ka-band cloud radar (MIRA), an infrared spectrometer (AERI), two ceilometer, a microwave profiler (HATPRO), a Doppler wind-lidar, a microwave rain radar (MRR), a sun-tracker, a cloud camera, a pluviometer, a laser-distrometer and other temporary or additional instrumentation.

BoXPol and JuXPol operate at ~9.3 GHz in a 1° and up to 25 m resolution and observe precipitation since 2010 in ~100 km range. In 2017 the GAMIC Enigma3 signal processor was exchanged by a new GAMIC Enigma4 processor. Volume scans repeat every five minutes containing one range height indicator (RHI), one vertical pointing (0° to 360° azimuth, 90° elevation) scan and about seven different plan position indicators (PPIs) at different elevation angles >1°. As an additional special feature for research BoXPol is operated without a radome whereas its sibling JuXPol is operated with a radome. Scans are saved in hdf5 format and can be provided after request.

3. Where is JOYCE-CF located?

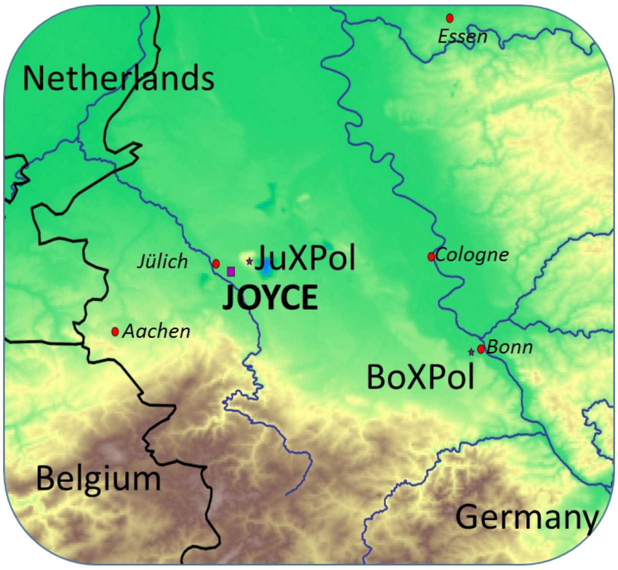

Fig. 3: Location of JOYCE-CF in western Germany.

JOYCE-CF is located in the Rhine valley in western Germany and divided in three instrument locations: the observation platform at FZJ and the locations of JuXPol and BoXPol (Fig. 3).

The observation platform at the FZJ is located 3 km south east of the city of Juelich, Germany, and includes most of the ground-based instrumentation. 5 km east of Juelich and 2 km north east to the FZJ in an artificial hill has been built from open-pit-mining, the Sophienhoehe. JuXPol is located on top of the Sophienhoehe on a 30 m platform. The area around Juelich is rather flat, beside the Sophienhoehe which has a height of 200 m above the surrounding terrain. But JuXPol is surrounded by many windmill farms, power-plants and open-pit-mining, which affect radar measurements significantly.

BoXPol is located 48 km south east of JuXPol (Fig. 3), directly at the river Rhine in the city of Bonn. The radar is installed on top of a 30 m tall building directly next to the Meteorological Institute in Bonn. This building is not the tallest in the city so the radar suffers from beam-blockage due to close chimneys, steeples and office buildings. South east of BoXPol a total beam-blockage from a close hill can be detected in the lower elevations. The topography around Bonn shows a hilly structure which causes partial beam-blockage in the west, south and east. Northwards the Rhine valley is more flat but characterized by industry and high-voltage transmission lines. The co-located Meteorological Institute operates meteorological measurements which can be related to BoXPol, including MRR, laser-distrometers, gauges, temperature-, humidity-, wind-, precipitation-sensors and other additional instruments.

The University of Cologne is located 35 km north of Bonn at the Rhine and implies research and data handling for JOYCE-CF instrumentation. At the building of the Meteorological Institute in Cologne it is not possible to install instrumentation.

Central Europe is characterized by mostly stratiform precipitation about 750 mm per year. But still convective events in German summer cause significant precipitation (about 100 mm/h) every year. Within the last years the city of Bonn and Cologne have been hit several times by strong convection leading to floodings in the city centers. Thunderstorms causing large hail (> 5 cm) caused damages with high insurance claims as well as reduced crop yields. Thunderstorm related downbursts as well as strong autumn storms also produced damages with high insurance claims and environmental damages in the surrounding woods. Beside these strong convective events winter precipitation also caused significant damages.

Within the radar covered areas height differences of 600 m appear. BoXPol and JuXPol cover flat grass and croplands as well as hilly and mountainous areas with narrow valleys. The height induced changes from rain to snow or freezing rain cause many road accidents every year. In the mountainous areas longer cold-phases and strong ice-phased precipitation lead to high snow heights and can cause floodings in strong melting periods.

4. What is the key aspect of JOYCE-CF?

The large variety of precipitation types and instruments give scientists a very well basis for large fields of research. Manufacturers are able and welcome to test their equipment in any weather condition. The influence of data assimilation for modelers can be tested in sensitivity to topography and what kind of data is assimilated. Beside the strong connection of manufacturers of meteorological instrumentation and scientists including modelers and observationalists, JOYCE-CF gives water management agencies the possibility to request data and information.

These large fields of research and wide spread use of equal data is the key point of JOYCE-CF. JOYCE-CF wants to deliver high quality data to all kind of users worldwide. As the JOYCE-CF instrumentation covers the request of a large number of customers but with different demands the data needs to be processed and made available for everybody.

Easy and free access to data and information about the instrumentation can be essential and therefore a central web-page is built up. A key aspect of this web-page is the overview about the major instrumentation and their status. Users will be able to get important information very fast and via an easy access. Major instrumentation present real-time and near-real-time quick looks of their current measurements. Scan strategies will be explained to the user in short overviews to comprehend tempo-spatial variances and gaps. Direct information about the instrument status will be transparent and inform about usual scan-modi, special scan-modi or offline instruments. Quick-looks will show the direct measurements. The instrument information includes available processed data including calibration information and values, faulty measurements and available higher level products.

Beside quick-looks the data can be requested any time either via a database or via server transmission depending of the amount of data. Special related projects may also get a possibility to get informed automatically, e. g. severe weather conditions.

To guarantee high quality data the instrumentation will scan in standard scan-modi. These scan strategies provide an optimal cover of the surrounding area, as well as an optimal basis for instrument synergies or higher level products. Long-term measurements give scientists the possibility to exploit data on a statistical and climatological basis. To attract these studies long-term observations will be performed for constant time-lines and major instruments will perform constant in these scan-modi. To guaranty users with special interest in hot spot analysis or field campaigns a detailed and holistic cover of interesting data, some instrumentation will be available for special scans. In not requested time periods the instruments return to a standard scan-strategy. This parallel administration enables JOYCE-CF to an attractive and large dataset.

The recorded data will be processed in real-time or as fast as possible and results are published directly. Precipitation rates, cloud types or hydrometeor-classifications can be obtained in near-real-time, whereas composites or calibration rely on longer time periods or multiple measurements. But still processed data is published directly.

To provide a range of higher level products beside raw data current research is integrated in data processing and cooperations with scientists deliver a basis for implementation in operational modes.

One major aspect of JOYCE-CF is data quality. Long experience with scan strategies and instrument setup gave JOYCE-CF the possibility to concentrate on further essential aspects of high quality data. Weather radar observations can suffer from many sources which reduce their quality. Some errors can be reduced by optimal locations and setups. One central idea is to cope with measurement errors that can occur by the measuring volume. Beside the location factors hard- and software can lead to errors. One large error source is miscalibration or no calibration at all. Interpretation of weather radar data suffer from miscalibration. Some hard- or software changes or changes in performance of hardware can lead to strong changes in calibration values and will be explained in the following section 5.

5. Calibration of the twinset of two polarimetric X-band radars of JOYCE-CF

BoXPol as well as JuXPol operate in a 5 minute schedule containing at least seven PPIs, one RHI and one vertical pointing scan (rotation 360° azimuth at 90° elevation, called birdbath scan).

These scans make it possible to implement different calibration routines which can be used for cross-checks of the calibration values. Three calibration routines have been studied and are used at the moment. Differential reflectivity ZDR is calibrated by the use of the birdbath scan, the self-consistency method is used for calibration of reflectivity Z and ZDR and an instrument synergy and comparison gives clues about the performance and system changes of the instrumentation.

Self-consistency method

The self-consistency method is based on studies from Diederich et al. (2015). In his work he examined different types of self-consistency relations and examined them with BoXPol and JuXPol within a special time period. Advantages and disadvantages of these relations were shown between the consistency of Z and specific attenuation A as well and relations between Z and specific differential phase-shift KDP. Both methods showed reasonable results for calibration. The relationship between Z and A is used for calibration for these studies. Based on the ZPHI-method described in Testud et. al. (2000) A is calculated with relations on Z and differential phaseshift PHIDP. This is an advantage as PHIDP is not dependent on calibration and on attenuation. From A we can correct measured Z for attenuation to ZA. But as well we are able to calculate an estimated reflectivity ZE. The difference between these two reflectivities shows the calibration value, the offset of Z. Dependencies of A on temperature or drop-size distribution can be minimized by spatio-temporal averages over the whole radar domain.

The studies of Diederich et al. (2015) were extended to bring them in an operational mode and can be applied now on the radar network for the whole time period.

ZDR calibration with vertical pointing scan

Both X-band radars have recent vertical pointing scans within their five minutes schedule. These scans are pointing at 90° elevation and turn around 360° in azimuth.

In Fig. 4 a birdbath scan with stratiform precipitation is presented. The temporal development of the brightband can clearly be seen. Beside the brightband a temporal change of the ZDR values can be observed from lower to higher values. Beside the first change of ZDR most values within this system are close to 0 dB which indicate a good ZDR calibration. Stratiform precipitation should be measured as zero for differential reflectivity ZDR in this scan. Azimuthal periodic dependencies of ZDR can indicate misalignments of the elevation angle. Simple azimuthal dependencies indicate influences from ground clutter or other artifacts seen by side lobes. An average over all 360° azimuth angles and over longer time lines should add up to zero in ZDR. If ZDR is unequal to zero this indicates the offset of ZDR, the calibration value. Convective events should also be zero but the variability here can be much higher due to strong winds which can produce size sorting or changes in the orientation of particles. Temporal averages should reduce these effects and still give a reasonable estimate about the ZDR offset.

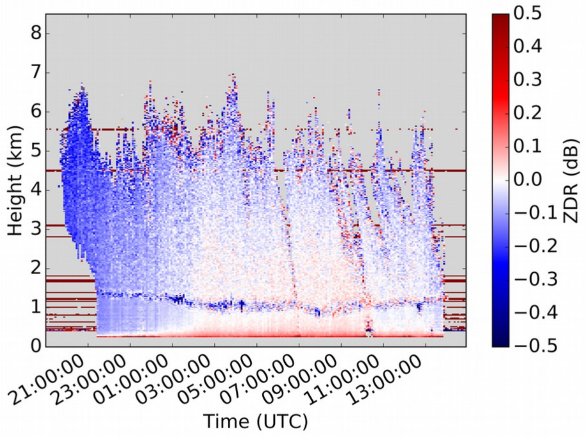

Fig. 4: Time-line of stratiform precipitation measured by BoXPol starting on 15 November 2014.

Temporal averages showed well results for estimates in ZDR calibration but also showed that for several time periods ZDR was very uncalibrated and was about 2 dB to low. Beside this large offset a chance of ZDR within a precipitation even could be seen (Fig. 4). This change shows a diurnal cycle and could be seen by BoXPol operation without a radome but also JuXPol which operated with a radome. A seasonal cycle was not observed as well as a dependency on phase or difference between stratiform or convective precipitation.

Instrument synergy

Observations from radar can be compared to observations from other instruments. As the required information should help for radar calibration we require additional information of reflectivities. In Frech et al. (2017) a calibration estimation with a co-located microwave rain radar (MRR) and laser-distrometers could be reached.

This synergy requires a special instrument setup. For an optimal intercomparison all instruments should be mounted in a close radius <800 m to the radar. The radar should have an operating birdbath scan.

The MRR is a vertical pointing frequency modulated continuous wave (FMCW) Doppler radar located 70 m next to the BoXPol radar site. It is able to distinguish between 32 gates between 25 m and 300 m bin resolution. The resolution for the comparison is not relevant for this study, only the co-location towards the radar should be given. Beside the MRR additional measurements from co-located laser-distrometers can be used for inter comparison.

The instruments either measure the reflectivity directly or they calculate an estimated reflectivity. As the radar and the MRR both suffer from a disturbance within the first near field ranges the first far field measurements are taken into account. By averaging the measurement volumes are equalized. One advantage of MRR and radar observations is that it gives information of two independent measurements of the same measurand. If these measurements differ it already gives a hint that at least one of instruments is miscalibrated. Laser-distrometers estimate the reflectivity due to their measured drop-size-distribution (DSD). If we take the falling velocity of drops into account we can estimate the temporal delay between the radar and MRR data until it would reach the distrometer. MRR and radar measure the Doppler velocity which can be estimated as the falling velocity at low horizontal winds. The height differences of the instrumentation needs to be taken into account as well.

Correlations between MRR, horizontal and vertical Z from radar and estimated Z from the distrometers showed well agreements. For the same chosen time period MRR and radar showed only a slight negative bias where as the three mounted distrometers showed higher negative bias. These results are used as quality control to the self-consistency method and monitor the calibration estimates. Changes in data can be extracted and the scale of the calibration values for Z can be calculated.

These three calibration methods are used for calibration of BoXPol and JuXPol.

6. Approaches of instrument synergies using JOYCE-CF instrumentation

In Trömel et al. (2017) the development of a mesoscale convective system (MCS) could be observed over western Germany. This MCS intensified within the observed area of JOYCE-CF and caused severe gusts, floodings and other damages in a later stadium 100 km north of Bonn. This event took place Pentecost 9 June 2014 and is known as the Pentecost event in Germany.

In the development of this MCS strong mammatus structures could be observed. The instrumentation of JOYCE-CF gave the possibility to exploit structures of these mammatus clouds by instrument synergies and gave detailed insights in microphysical processes of mammatus clouds. Decreasing Z and RHOHV together with high ZDR values can be explained by fast growing of pristine dendrites in supercooled layers. These structures were observed in this Pentecost event and the supercooled water layer was observed by the Doppler lidar and Ka-band cloud radar.

Beside this study the JOYCE-CF instrumentation has already been used for many research analysis and field campaigns.

7. Outlook

Within this project the central access to instrument information and data, high data quality and the plenary monitoring of cloud evolution will be developed. This gives science an optimal basis for further research.

One major development will be the central access to the already existing data. Data requests can be sent to Josephin Beer (jbeer@uni-bonn.de) from the University of Bonn or Bernhard Pospichal (berhard.pospichal@uni-koeln.de) from the University of Cologne. Instrument information project status and quick-looks are already available via http://joyce.cloud but will be developed further.

The web-page as well as the data access will be simplified for a better overview for users.

JOYCE-CF will also intensify and support joint projects with scientists and manufacturers and give them a basis for joint field campaigns and own installations. To simplify own installations an operators manual will be published with detailed information about possibilities, infrastructure and demands for operators and instruments.

To deliver high quality data, well known calibration methods will be tested on our data and developed to run operational. Already existing methods like ZDR calibration, self-consistency and instrument synergy will be developed further to receive calibration information that can be provided, as further research demands high quality data.

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