RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

METEO FRANCE

3rd Weather Radar Calibration Workshop

17-19 November 2021
Météopole, Toulouse, France

Book of Abstracts

Contents

Hardware monitoring and maintenance

Mitigation of the ZDR Bias Temperature Dependence

Frank Gekat, Markus Hille, Markus Krings
LEONARDO Germany GmbH

It is known that the ZDR bias of a polarimetric weather radar varies with temperature. It will be shown that at least part of this variation is caused by thermal variation of the propagation parameters of the waveguide circuit, and that conventional matching may even increase the ZDR bias variation. A mitigation method will be presented which reduces the ZDR bias variation to an acceptable figure.

Application of OPENCV in radar system monitoring

Sun-JIN Mo, Ji-Young Gu, Geun-Hyeok Ryu
WRC, KMA

For the stable operation of weather radar, it is very important to operate within the available physical range of radar hardware. However, it is not easy to check the physical state of the radar in real time. In order to more easily monitor the physical state of the radar, computer image processing(OPENCV) is applied. When using OPENCV, real-time streaming protocol access, continuous monitoring of CCTV images, and real-time monitoring of rapid changes are possible. In particular, CCTV images can be used to check the rotational state of the radar by checking the uniformity of movement of pixels in the image, and to check whether there is a risk of water liakage inside the radome by using the difference in brightness and color tone. In addition, it is possible to check the danger warning in real time by distinguishing the pixels of the alarm lamp inside the radome. It is also possible to check the radiation status and azimuth error in real time by recognizing the real-time display monitor of the radar as an image. Using computer image processing, it is possible to monitor the physical operation status of the radar and expect easier and more stable radar operation through real-time monitoring.

Informing calibration with drones and UAVs

Thomas Chen
Academy for Mathematics, Science, and Engineering

This abstract was withdrawn

Weather radar calibration enables the achievement of accurate, high-quality observations. Harnessing UAVs (unmanned aerial vehicles), and drones, particularly, can serve as a stable aerial

platform that can carry a metal sphere. The UAV flies over the radar illumination areas to complete the calibration. This novel proposed UAV-enhanced calibration methodology is backed by recent experiments, which demonstrate that antenna pointing calibration can be completed and antenna pattern can be retrieved and weather radar constant can be accurately calculated.

Update on Monitoring and Calibration of Slovak Weather Radar Network

Luboslav Okon
Slovak Hydrometeorological Institute

SHMU operates four identical C-band dual-pol radars METEOR 735 CDP10 by Leonardo that were installed in 2015-2016. Monitoring and calibration of the measured data as well as pointing accuracy is important for proper usage of the radar data. Regular preventive maintenance and monitoring of the radars status allow to reveal in time potential failures of the radar components and thus prevent from (or shorten) the radar outages.

SHMU remote sensing specialists took the opportunity to participate on both the 1st and 2nd WXRCalMon workshops held in Offenbach, where they exchanged experience in operation, maintenance, monitoring and calibration of the weather radars with participants from many countries all over the world.

This poster gives an overview of the current monitoring and calibration procedures performed at SHMU and highlights the improvements made since the last WXRCalMon workshop in 2019. The main changes include start of the manual correction of the ZDR offset, addition of history browsing in the monitoring web pages or the latest update on the detection of interfering RLANs at SHMU. The most severe and/or repeating failures of the radars components that have emerged over the 6 years of their operation are described as well.

Weather Radar Calibration, Recent progress and sharing experiences calibrating, shipborne, spaceborne and ground based systems

Chandra V Chandrasekar
Colorado State University

The accuracy of weather radar measured products such as reflectivity and differential reflectivity plays a crucial factor in obtaining good quality derived remote sensing products such as hydrometeor classification. A slight mismatch of few decibels in reflectivity may cause quantitative inference such as rainfall estimates and qualitative experience such as hydrometeor classification to deviate from the actual truth. In order to get accurate remote sensing measurements, calibration of weather radars should be carried out at regular intervals of time. CSU radar Laboratories have been operating a number of radars including the CSU-CHILL, which is a dual-frequency dual polarization radar at S and X band, the CHIVO and SEAPOL at C band and several X band radars and the NASA D3R radar, which is a dual-frequency, dual-polarization, Doppler radar (D3R), which operates at Ku and Ka band frequencies. While calibrating single radars is a fairly well established filed, we have been focusing recently on consensus between multiple platforms, as well as calibration in challenging environment such as shipborne operation. All these radars have operated in several field campaigns in the past providing accurate remote sensing observations, this could not be achieved without calibrating the radars regularly. There are various methods which are used for calibration of weather radars such as suspending a metallic sphere from a weather balloon or using corner reflectors on top of a tower or structure. With the ease of drone availability, we have been regularly conducting drone-based calibrations also. With several exercises, using UAV for calibration has several advantages over the previous methods. This paper will discuss a summary of the various procedures we have used for routine calibration of radars mainly from a practical and systems perspective.

Trying to understand the antenna pointing variability at X-band

Béatrice Fradon
METEO-FRANCE

At METEO-FRANCE, the accuracy of antenna pointing is checked by performing sun tracking twice a month. Sun tracking consists in performing one scan in each direction at the theoretical sun elevation, and a vertical scan in each direction at the theoretical azimuth of the sun. The sun appears as an increase in the measured power and the real sun position is computed as a barycentre. No treatment is made on the power signal before computing the barycentre.

This method performs well for C- and S- band radars. For the X-band radars in the Alps, the bias of the antenna for elevation shows quite large variations over time, that could not be explained. For one radar, the sun tracking fails almost every time.

A careful check of the power measurements made during sun tracking for X-band radars showed that interferences are frequently observed and that our method is quite sensitive to them, because of a miscomputation of the barycentre.

Some tests were made to make our method more robust, by cleaning the data before computing the barycentre, and by adjusting a Gaussian curve rather than using a barycentre. These improvements are still under progress.

We could re-compute the pointing errors for ten radars for a 5-years period, using the archived sun tracking data and the improved method. For some radars, the variations observed could be explained by a tilt of the pedestal – but not for the X-band radars in the Alps. We also explored a possible effect of the radome but there was no evident correlation between the positioning errors and the position of the seals.

As there is no valid explanation for the positioning errors for elevation for X-band radars, we decided to check the antenna pointing with an inclinometer. The sensor has been tested on a C-band radar and will be soon installed on the X-band Vars radar.

Z and ZDR calibration and monitoring procedures

ZDR Calibrations and Monitoring – ECCC's new S-Band Radars

Stephen Holden, Daniel Michelson, Sudesh Boodoo, Norman Donaldson, Peter Rodriguez, Qian Li, Peter Leibiuk
Environment & Climate Change Canada

Environment and Climate Change Canada (ECCC) has recently undertaken a major project to replace 31 late 1990's C-Band radars (Magnetron – 200kW, Vaisala/SIGMET) with new S-Band radars from Leonardo (Klystron, 1MW). As of the summer of 2021, approximately 60% of the radars have been replaced. ECCC determined that receiver ZDR bias could not be determined from the available system outputs, but have leveraged the BALTRAD radar processing software to process the operational radar data. In this manner, we are able to detect solar hits and use them to remove the ZDR system offsets from the transmitter chain. The Observation Based Research Section of Atmospheric Science and Technology Directorate also applies a procedure to estimate total system ZDR bias from operational data for light rain. Both methods are run daily for the radar network and when combined, produce estimates of the receiver ZDR bias. With these bias estimates, we are able to adjust the systems'ZDR offsets to minimize the ZDR bias and monitor it for drift or changes due to system adjustments or hardware replacements.

Z and ZDR calibration using natural target and self-consistency methods

Jacques Testud, Erwan le Bouar
NOVIMET

This paper is about calibration technique for Z and ZDR.

The usual approach to calibrate ZDR is to practice vertical pointing of the radar where ZH and ZV should be equal, thus vertical pointing provides the reference of ZDR= 0dB. This paper proposes an alternate technique consisting to exploit radar signal from light rain at low elevation and in direct sight of the radar (to avoid any significant differential attenuation along path). The interest of this technique is that it can discriminate ZDR calibration according to azimuth and thus it may take account of the imperfection of the radome.

Once ZDR is calibrated, Z may be calibrated using the functional relationship (independent of the DSD) relating Z, ZDR and KDP.

Evaluation of DWD radar calibration based on collocated spectral polarimetric observations from W-band cloud radar

Alexander Myagkov*, Michael Frech+, Mathias Gergely+, Thomas Rose*
**Radiometer Physics GmbH, +DWD*

Cloud radar spectral polarimetry is a promising technique for meteorological applications. In stratiform rain, spectral polarimetric observations at low elevation angles can be potentially used for profiling of drop-size-distribution (DSD) with high temporal and spatial resolution. The obtained DSD profiles can be converted to profiles of variables expected to be observed at centimeter wavelengths. The expected profiles can be used as a reference to evaluate the calibration of weather radars. In a joint project, Radiometer Physics GmbH (RPG) and Deutscher Wetterdienst (DWD) are currently testing the concept of this calibration approach. During the summer season 2021 a scanning polarimetric W-band cloud radar was set up near the C-Band research radar of the German weather radar network at the DWD observatory Hohenpeißenberg in order to acquire a collocated dataset. In this talk first preliminary results will be shown.

Offset correction on radar differential reflectivity using quasi-vertical profiles

Daniel Sanchez-Rivas, Miguel Rico-Ramirez
Department of Civil Engineering, University of Bristol

The differential reflectivity Z_{DR} is a crucial input to generate accurate quantitative precipitation estimates using polarimetric weather radars. However, a system bias between the horizontal and the vertical channels generated by the radar yields into an offset in Z_{DR}. In this work, we present and analyse a method for correcting and monitoring the Z_{DR} offset using quasi-vertical profiles of polarimetric variables. The method is applied to data collected through one year of precipitation events by two operational C-band weather radars. The proposed method proves effective in achieving the required accuracy of 0.1 dB for the calibration of Z_{DR} compared to the traditional method based on vertical profiles. Additionally, the method is evaluated using disdrometers located nearby the radar sites. The results showed a good agreement between disdrometer-derived and radar-calibrated Z_{DR} measurements.

Monitoring of radar reflectivity for operational S-band weather radar network

Jeong-Eun Lee*, Soohyun Kwon*, Geun-Hyeok Ryu*, and Sung-Hwa Jung*
WRC, KMA

The radar calibration is prerequisite to support severe weather monitoring and very short-term rainfall forecasting based on radar network. The mis-calibration of radar measurements causes considerable discrepancies in rainfall estimation over a national radar network. The main issue of radar calibration is the unexpected malfunction and miscalibration of radar system components after

the routine inspection. In addition, challengeable issue is to estimate calibration bias in real-time.

In this study, three methods are combined to complement the limitation of each methods which are the ground clutter, self-consistency and intercomparison. To estimate the absolute calibration bias, the self-consistency method between dual-polarimetric observations was used. Since the self-consistency is valid for rain echoes, it is impossible to monitor reflectivity during non-precipitation period and winter season. The ground clutter, which is an ever-present echo, can be used to monitor reflectivity regardless of weather conditions. The change in the calibration bias caused the change in ground clutter reflectivity. The status of radar such as antenna pointing also can be checked from ground clutter reflectivity. In terms of radar network, comparison of reflectivity between adjacent radars can be used to examine the consistency of reflectivity. If two radars are well calibrated, then the mean bias should be 0.0 dB. The calibration bias estimated from self-consistency is evaluated by calculating the mean bias between adjacent radars. After correcting calibration bias, the spatial discontinuity of radar rainfall significantly improved and the structure of radar rainfall is similar with that of AWS rainfall. In conclusion, monitoring of radar reflectivity in real-time make it possible to diagnose the status of radar system as soon as possible.

Monitoring Z calibration to 0.5dB using a co-located disdrometer and very high resolution gauges

Anthony Illingworth, Robert Thompson
University of Reading, UK

We report on the comparison of the reflectivity values from the UK Dean Hill operational radar with reflectivity values computed from a disdrometer on the ground at Chilbolton 20km distant from the radar. Analysis suggests the radar can be calibrated to within 0.5dB. The disdrometer is absolutely calibrated to better than 0.5dB using three co-located rain gauges that each have a precision of 0.2mm/hr for a one-minute sample. Comparisons of the Z values for a single radar scan have errors of about 2.5dB, which we ascribe to different sample volumes of the radar and the disdrometer. This error can be reduced to 0.5dB, if we consider 200 radar scans obtained only when 12 consecutive radar scans all exceed 20dBZ, and the copolar correlation exceeds 0.99. The time to obtain the 0.5dB accuracy varies between a few weeks and several months, but we find the calibration was constant over a two year period. In contrast we are unable to confirm that the ZDR calibration is sufficiently constant to improve estimates of rain rate from the radar.

The interaction of data quality monitoring and operational surveillance of weather radar networks

Hassan Al Sakka, André Weipert
Leonardo Germany GmbH

Data quality monitoring and operational weather radar surveillance become more and more essential for every meteorological service or airport. On one hand, there is a continuous need to improve predicting the availability of physical assets and on the other hand, there is an increasing demand for more accurate, stable, and well-calibrated data for quantitative measurement, severe weather monitoring, rainfall estimation, and numerical weather prediction models.

Modern technologies provide a lot of potential to derive performance and quality measures without interfering the radar operation partially even independent from different weather radar system hardware or system manufacturer. Many of these inherently given capabilities do not only base on hardware monitoring, but also on data capture, integration, visualization and analytics of atmospheric measurements. Therefore, for improved data quality performance management capabilities, LEONARDO has decided to enable the commercial software for easy integration of available open source radar data processing and analytics packages such as BALTRAD, wradlib, Py-ART or pyrad. Using the new feature “COSMOS” = Commercial Software Meets Open Source, existing algorithms can be extended by customized analytics in order to improve the overall asset performance management and to implement new skills based on data mining and machine learning methods.

In connection to the general strategy improving the monitoring and surveillance of weather radar networks, the anticipated solution concept is currently refined. Conducted surveys result in a flexible, coherent three-tier concept approach incorporating inter alia real time capabilities as well:

- Tier 1: General, operational monitoring and surveillance level, web page and dashboard driven (based on a synergy of commercial and non-commercial software).

- Tier 2: For specific meteorological or hardware related issues, beyond the web application, a dedicated set of different applications will be used.

- Tier 3: For a comprehensive study, other software are dedicated for deep case studies, historical analysis and trend search. A user group of experts may be consulted if needed.

The Argentinian meteorological radar: solar calibration and monitoring

Federico Renolfi, Roberto Costantini, Daniel Vela Diaz
INVAP S.E.

This work presents the method used for solar calibration and monitoring of the Argentinian Meteorological Radar (RMA). It covers the rationale behind the design of the method, some details of its implementation and real data examples from the research and training facility site RMA0.

The Argentinian network of weather radars: Sistema Nacional de Radares Meteorológicos (SINARAME) is composed by 15 C-band weather radars running 24/7, 12 of these are RMA units. The network also connects to 4 old S-band units that only operate in summer, for the hail season.

The history of RMA started roughly 10 years ago, when Argentina launched project SINARAME with the purpose of building a nationwide network of dual polarization weather radars. To materialize that long term plan, the Secretaría de Infraestructura y Política Hídrica commissioned INVAP, to design and manufacture the first Argentinian weather radar.

RMA is a novel C-band, Doppler, dual polarization, simultaneous transmit and receive, magnetron based weather radar.

Since its first conception it was meant to serve both as an operational radar and a research tool; for that reason it includes a development framework consisting of an embedded python interpreter with access to key internal radar state data, and a mechanism for the user to add new commands to the radar control unit in the form of python scripts.

Above this framework, a solar calibration semi-automated procedure was implemented as a minimal set of python commands, with the goals of making the code readily available to extend and also being easily user auditable.

As a result of this implementation, the radar delivers not only pointing calibration parameters: azimuth and elevation offsets but also a set of plots that aids in the assessment of the quality of the data used for calibration and some extra useful parameters for monitoring the health of the radar receiving chain.

Benefits of automated receiver reflectivity calibration monitoring

Timothy Darlington
Met Office

In the previous workshop we reported on our efforts to bring together many possible sources of reflectivity calibration information and to synthesise them into the best possible overall estimate of radar calibration. This work brings together: routine engineer led power injection calibrations, per-pulse noise source injection data, opportunistic sun hit power estimates, and atmospheric noise profile (tipping curve) based power estimates. These sources of information are brought together using a particle filter to account for their varying characteristics and an overall correction to the current calibration is estimated. Here we update on the performance of this monitoring tool and present an example of its use.

Feasibility analysis of monitoring a C-band weather radar reflectivity calibration using a K-band Doppler radar profiler

A Garcia-Benadi*, J. Bech*, M Udina*, P Altube+, F Fabro+
University of Barcelona, Meteorological Service of Catalonia+*

This presentation examines the feasibility of monitoring the radar reflectivity calibration of a conventional scanning C-band weather radar using a nearby K-band Doppler radar profiler. Vertically pointing Doppler weather radars may provide direct estimates of precipitation particle fall speeds assuming vertical air motion is negligible. This allows to obtain, for liquid precipitation, a raindrop size distribution at each height bin and the corresponding radar reflectivity profile. Derived rainfall amounts at the lowest bin profile are compared with co-located rain gauge measurements to check absolute calibration of the vertically pointing radar. Then, radar reflectivity observations from the vertically pointing intersecting the scanning radar beams can be compared considering differences in the observed radar volumes. This procedure may contribute to monitor the transmitter and receiver chain of the weather radar, complementing other existing methodologies. Specific details are given of a comparison carried out between operational C-band radar observations from the Meteorological Service of Catalonia and Micro Rain Radar observations of the University of Barcelona. Data were recorded during the Land Surface Interactions with the Atmosphere over the Iberian Semi-Arid Environment (LIAISE) field campaign (WISE-PreP project, RTI2018-098693-B-C32, Spanish AEI/MINECO)

Comparison of three methods used for radar reflectivity calibration

Tom Nicolau, Nan Yu, Jean Millet
Météo-France

Accurate measurements of radar reflectivity (Zh) are essential for reliable quantitative precipitation estimations (QPE). To achieve rainfall estimates with an accuracy of 15%, the uncertainty of the Zh calibration must be reduced to 1dB. In this study, three daily calibration methods based on ground clutter monitoring, self-consistency of dual-pol variables and comparison with rain-gauge measurements, are compared using data from four Météo-France's operational C-band polarimetric radar. The Zh bias determined by the ground clutter monitoring is the most robust method with a variability of less than 1 dB. However, this method cannot provide an absolute calibration figure and is prone to large systematic errors when clutter echoes are confused with precipitation. The self-consistency method is able to provide an absolute Zh calibration, but uncertainties induced by the attenuation correction and the Zdr calibration make that the residual variability at C-band is larger than 1 dB.   The indirect Zh calibration obtained from the radar rain comparisons is the method historically used at Meteo-France. However this method is also largely biased by residual errors of the VPR correction. The study of the 2 by 2 correlations between the three methods suggests that in the future, a combination of first two methods should be used instead of the third one.

Long-term evaluation of the Météo-France QPE product

Nicolas Gaussiat
Météo-France

15 years of close monitoring of the quantitative precipitation estimation (QPE) obtained from the French radar network against gauges show the global benefit of the successive changes made to the radar network and to the products over the years. Scores have been calculated using all the gauges available on the entire metropolitan domain, Corsica included and are presented in the form of time series of bias difference (BIAS), root mean square error (RMSE), probability of detection (POD), False Alarm Rate (FAR) and Correlation Coefficient (CC) for different thresholds. While the trends of these scores tell us of the global positive outcome, a closer look at them suggests that some particular changes have been more effective than others. A detailed analysis of the seasonal variability of each score, for instance, indicates that the improvement brought by the dual polarisation in summer can have an adverse effect on QPE in winter. A 30x30km moving window was also used to produce a spatialized version of the scores. The derived maps can be used to both illustrate the improvement brought by new radars in the mountainous regions as well as the difficulties of managing a much larger network.

Using Data-based Calibration to Harmonize Swedish Weather Radar Network

Qing Cao*, Michael Knight*, Richard Stedronsky*, Daniel Johnson[+], Ingemar Carlsson[x]
*Enterprise Electronics Corporation (EEC), [+]Swedish Meteorological and Hydrological Institute (SMHI), [X]SAAB

Weather radar has become a critical tool for weather surveillance, and the weather radar network plays a key role for a national weather service. Any inconsistent radar data among a network would negatively affect the accuracy of weather observation and forecast. Consequently, the calibration process becomes essential to obtaining consistently accurate radar data. There are some considerations for calibrating and harmonizing the network. Ideally, the calibration would be performed online, could be easily repeated, and/or could be done in real-time. As a result, the databased calibration becomes a practical option for this purpose. The Swedish national weather radar network (SWERAD) consists of 12 C-band weather radars. In order to calibrate and harmonize the network, the Swedish Meteorological and Hydrological Institute (SMHI) and Enterprise Electronics Corporation (EEC) have agreed to a radar calibration campaign since the middle of 2019. The major purpose is to calibrate the reflectivity (ZH) and differential reflectivity (ZDR) among the network so that the accuracy of precipitation estimation and forecast can be improved for the entire country. The physical consistency-based reflectivity calibration method and the automated differential reflectivity calibration method are used for the data processing and analysis. These two methods rely on the polarimetric data of weather echoes and will have little effect on the major operational tasks. Since late summer, the corresponding radar scan strategy has been added into the radars to collect the useful datasets for the calibration.

Commercial and non-commercial monitoring software

Development of integrated and easy-to-understand radar monitoring system

Jinwoo Park, Sun-Jin Mo, Ji-Young Gu, Geun-Hyeok Ryu
Weather Radar Center of the Korea Meteorological Administration

To enhance the surveillance of low altitude hazardous weathers through the high temporal and spatial resolution. the Weather Radar Center (WRC) of the Korea Meteorological Administration has established the SSPA X-band dual-polarization radar network over the Seoul metropolitan area. three SSPA X-band dual-polarization radars are installed in the military zone and operated unmanned remotely. Even though we have the simple radar monitoring system provided by the manufacturer an improved system to monitor the whole radar network is needed. The main purpose of this monitoring system is not to miss the inspection point of the radar network and to manage it more effectively.

This system consists of for parts. The 1st part is monitoring the radar data acquisition including data transmission, access permission, and quality control precess. The 2nd and 3nd parts are checking server availability including network infrastructure and environmental sensors (temperature, humidity, UPS power level, and etc.), respectively, The last part is monitoring of radar H/W state using IRIS BITE variables and radar parameters's (differential reflectivity and reflectivity) system offset level using WRC in-house developed program.

We will plan to improve this system continuously through testing and adding other parameters to the monitored parameters and plugging the better graphical output information.

Monitoring with Grafana

Jan Petersen
DWD

In addition to optimizing data quality, a major goal of radar systems is to minimize the downtime. Therefore monitoring has become an essential part of the radar network at DWD (Deutscher Wetterdienst) to ensure high availability of meteorological data. To process and visualize the large amount of data an open source visualization and analytics software is used - Grafana.

The display of the BITE data as time series is a helpful tool to detect critical events early and to prevent long-term failures by analyzing trends. Furthermore, the setup of notifications and annotations helps to identify the relevant events in the large amount of data. In addition to monitoring the hardware, Grafana is also suitable for verifying the data quality by displaying e.g. the ZDR offset or comparing with additional sensors.

Monitoring the Quality of Quality-controlled Radar Moments

Annette BOEHM
DWD

Radar data are input to many subsequent procedures, such as hydrometeor classification, quantitative precipitation estimation and data assimilation for numerical weather prediction. To ensure the optimal performance of these downstream applications, the radar moments first have to be quality controlled (Werner et al. WXRCalMon 2017). Continuous longterm monitoring of these quality control procedures for the entire radar network provides valuable insight into the performance of the quality control system, and thus uncovers weak spots and fosters improvements. The performance of individual quality control algorithms can be surveilled, long-term trends in the data can be detected, and changes caused by updates to the data processing system can be quantified based on realtime information.

In this workshop contribution, a system monitoring the German radar network will be presented. The quality of the quality-controlled radar moments is assessed individually for each radar, compared for areas with overlapping radar coverage and analyzed over different periods of time.

The presented Grafana dashboards provide easy ways to compute custom metrics, choose from a wide variety of visualizations, and enable to interactively and flexibly analyze the data.

PIEUVRE

Isabelle Sanchez, Tom Nicolau
Météo-France

The main purpose of the PIEUVRE project is to gather together all the tools needed to monitor the french radar network and the quality of the final products. Still under development, the future monitoring system is built around a database containing a long term history of monitoring parameters (radar operating conditions, quality indicators, statistical scores...) supplied by automatic processes and generated through a modernized toolbox. The system is also designed to be capable of producing semi-automatically all the metadata needed for real-time data processing, such as adjustment factors, clutter identification and beam blockage maps. A final aim of the project is to provide an HMI for plotting interactively charts and maps or for updating the database. Several tools are already available, mainly developed using Python and C++ libraries. Current plans are to develop the HMI using java-script and python-django features.

The use of Pyrad for data quality monitoring

Daniel Wolfensberger*, Jordi Figueras i Ventura+
**MeteoSwiss, +Météo-France*

Pyrad is an open-source Python-based real-time data processing framework initially developed by MeteoSwiss and currently developed jointly between MeteoSwiss and Météo-France. The framework is aimed at processing and visualizing data (from IQ signals to composite Cartesian products) from weather radars (and up to some extent other active remote sensing sensors such as lidars) both off-line and in real time. The software was first presented in the WXRCalMon2017 workshop.

Within Pyrad, all the standard data quality monitoring functionalities have been implemented and statistics are provided on a daily basis. The data can provide detailed information on the temporal and spatial variability of the polarimetric data. The quality of the antenna system is monitored using daily observations of the co-polar correlation coefficient in rain (with the 80% quantile expected to be above 0.99). The stability of the transmit-receive path is monitored by gathering statistics of the system differential phase offset in precipitation. The channel imbalances are controlled by observing the differential reflectivity in moderate rain (0.2 dB at 20-22 dBZ of reflectivity). The self-consistency of the polarimetric variables in rain is used to monitor the absolute calibration of the system and its stability is tracked by observing the variability of ground clutter echoes. In the frameworkan algorithm to inter-compare the reflectivity of two radars in precipitation, is also implemented, which is very useful to homogenize a network. Furthermore, the methods first developed by Holleman and Huuskonen to monitor the radar performance using the sun are also implemented. For each monitored parameter, a set of user-configurable alarms are available so that when the parameters exceed a particular threshold the user is notified via email.

In our contribution we will discuss the current status of the software and give details on the efforts we are undertaking to facilitate its installation and use.

Accuracy of phase measurements and dual polarisation variables

On the use of unique targets for assessing and monitoring the accuracy and stability of phase measurement and dual-polarization measurables: the example of two Bright Scatterers complemented by a Mountainous Scatterer

Marco Gabella, Marco Boscacci
MeteoSwiss

Previous studies have shown that the stable and peculiar echoes backscaterred by single Bright Scatterers (BS) can be used to monitor the accuracy of dual-polarization measurables. In order to be “bright”, a point target with deterministic backscattering properties should be present at a near range and be hit by the antenna beam axis. For the Monte Lema radar (1625 m altitude) in Southern

Switzerland, the first identified BS is the 90 m tall metallic tower on Cimetta (1633 m altitude, 18 km range). During two sets of 5 clear sky days (1440 echoes) in winter 2015 and 2017, the copolar correlation coefficient was on average 0.9962±0.024 and 0.9961±0.023, respectively. The daily standard deviation of the differential phase shift was between 4 and 8 deg and between 3.6 and 5.3 deg, respectively. The daily average of the differential reflectivity was between 0.8 and 1.8 dB and between 3.6 and between 1.0 and 1.7 dB, respectively. Coming to more recent times (January 2019), the polarimetric signatures of Cimetta were still reproducible: the 5-day average of the copolar corr. coef. was (as high as) 0.9983; the daily standard deviation of the differential phase shift was between 2.5 and 4.4 deg. The daily average of the differential reflectivity was between 0.7 and 1.3 dB. This fact has triggered the search of an additional BS for a second radar: we found, at 33.5 km range from Albis, the Hammetschwand touristic elevator, whose polarimetric signatures are peculiar, too! In summer 1999, the Lema Calibration Unit (including LNAs and stable reference signal delivered by a Noise Source) has been replaced: disappointedly, five clear sky days show poorer characteristics of the polarimetric signatures and a few outliers affecting the spectral signatures: for instance, the 5-day average of the copolar corr. coef. was (as low as) 0.9770. Also the daily dispersion was much worse than in previous years. The daily standard deviation of the differential phase shift was between 28.4 and 76.1 deg. The average differential reflectivity has remarkably increased. We had the possibility to discuss with the manufacturer, such anomaly: mutual investigations and interactions are still going on. One suggestion that has emerged was that of looking for other peculiar scatterers. We found Monte Vada, a Mountainous Scatterer (MS) at 20.9 km range. This MS confirms the poorer characteristics of the polarimetric signatures after hardware replacement. Using the same 5-day data sets in January 2019 vs 2020 and considering, for instance, daily averages, we find that the “best” day in 2020 has figures worse than the “poorest” day in 2019. On the one hand, we wil go on analyzing BS and MS polarimetric signatures as well as look for additional reference targets for other radars. On the other hand, it is confirmed that “historical” polarimetric and spectral signatures of a bright scatterer can represent a benchmark for an in-depth comparison after hardware replacements.

Perspicacious radar polarimetric spectral filtering: Adaptive thresholding using the copolar correlation

Albert Oude Nijhuis
SkyEcho

A new filtering algorithm has been developed that separates pixels from a radar Doppler spectrogram with superior contrast into two classes: hydrometeor and non-hydrometeor. This algorithm consists of the following steps: 1. Sorting copolar correlation (cc) values; 2. Estimation of noise distribution parameters for cc values, using the lowest 20% of cc-values and the assumption of a truncated normal distribution; 3. Jensen-Shannon divergence (JSD) testing for different threshold values by comparing the actual histogram of cc-values with a theoretical noise distribution; and 4. Estimation of the cc-threshold based on the minimum in JSD. When the

minimum is reached, the cc-threshold separates non-hydrometeor and hydrometeors in the most optimal way. It will be demonstrated that the distributions for noise and hydrometeor cc-values is properly taken into account by this algorithm. It is concluded that by using an adaptive cc-threshold better results are obtained than by using a fixed cc-threshold. Further potential of this technique will be discussed. The algorithm is used in the SkyTorque software from SkyEcho that is currently being used by the IDRA, Rijnmond and MESEWI radars in the Netherlands.

Characterization of background noise during dry and wet radome conditions

Philipp SCHMID
MeteoSwiss

Being able to operate a radar in a stable, perturbation-free electromagnetic environment is anything but obvious. Using a set of noise measurement performed for calibration and monitoring purposes, we analyzed the noise power as a function of time and azimuth for the two highest elevations, 35° and 40°, of the Swiss scan strategy. The question we wanted to answer is if for these two elevations a characteristic, perturbation-free, noise pattern can be established. Determining such a structure for each elevation, could allow to quantify, possibly in real time, the contribution of wet radome to the measured noise power.

During the Swiss scan strategy, which consists of 20 interleaved elevations repeated every five minutes, dedicated noise power measurements are performed at elevation 35° and 40°. These measurements are done over the entire sweep at a range interval between 60 km and 70 km. One average noise value is computed every 10°, resulting in 36 average noise values. Both sweeps are ten seconds long and separated by 2.5 minutes from each other.

We observed that for the analyzed elevations, the measured noise power depends on azimuth and changes over time. For each of the five Swiss weather radars, the signal of the sun was observed. Perturbation caused by obstacles intercepting the antenna beam, or by signals of unknown origin, are instead site dependent. During wet radome conditions, the measured noise power was up to 1.5 dB higher than during dry radome conditions. The noise power increase is not necessarily uniformly distributed, but can show a strong azimuthal dependence within one sweep.

Installation and adjustment of a phase shifter at the DWD Hohenpeißenberg research radar

Michael Frech, Bertram Lange Mathias Gergely Maximilian Schaper
DWD

The dualpol systems operated by DWD are specified to transmit in linear polarization with 0° phase difference upon transmission. There is no means to adjust for the transmit phase in the original design. Dualpol data quality are affected depending on the actual transmit phase. In order to investigate aspects to this, we purchased a phase shifter from EEC which was installed at the research radar Hohenpeißenberg in November 2020. In this contribution we will report on the on-site installation of the phase shifter and describe its adjustment. This includes a transmit phase measurement at the antenna feed horn using a gain horn and a transmit phase measurement in the far-field of the antenna. The far-field measurement was taken at a site 8.4 km away from the radar. Some examples with meteorological measurements will be shown as well.

Measurements of the radar differential phases upon transmission and reception on WSR-88Ds

Valery Melnikov
National Severe Storms Laboratory

Radar polarization variables in icy media depend on the phase difference between incident orthogonally polarized waves. This differential phase contains a contribution from the differential phase upon transmission (Φt) for radars employing simultaneous transmission of the orthogonal waves. The phase Φt is needed to un-bias the polarization radar variables. A method for obtaining Φt is discussed. This phase is obtained from measurements of the differential phase from clouds and the phase of signal from an external transmitting horn. Data obtained for a static and a hybrid power dividers used to forms radar channels are presented. The Φt was -30° for the static divider and 112.5° for the hybrid device. The Φt exhibits uniformity across the beamwidth of the WSR-88D radar.

Electrical and Sun calibration: what to trust when they disagree?

Marco Gabella, Maurizio Sartori, Marco Boscacci, Urs Germann
MeteoSwiss

The radio noise that comes from the Sun is an effective reference not only for monitoring dual-polarization weather radar receivers but also for quantitatively assessing their calibration accuracy. Two complementary methodologies are now used in Europe for operational C-band weather radars:

1) operational monitoring based on the analysis of a large number of “not-maximized” solar signals (“hits”) in the polar volume reflectivity data produced during the operational weather scan program (Holleman et al. 2010a, Holleman et al. 2010b, Gabella et al. 2015, Huuskonen et al. 2016).

2) Special-purpose, accurate, “long-lasting” (some tens of seconds) observations with MAXimized Sun-to-Noise ratio, where the dedicated observations are obtained by pointing (and tracking) the antenna beam axis at the center of the solar disk, i.e. on-demand Sun-track (Gabella et al. 2016).

To maximize the Sun-to-Noise ratio is crucial because even when the beam axis is hitting the center of the solar disk, this ratio can be as small at 7 dB (quiet Sun) for state-of-the-art operational weather radar operating at C-band. Unfortunately, the Sun-track procedure is often run manually and the operational weather scan program is interrupted for a few minutes. There are cases of fully automatic Sun-track, although applied to a single radar: Frech and Hubbert (2020) have implemented during several weeks a special purpose, 10-min, Sun-track scan program entirely devoted to monitor the Rx differential solar power using the DWD research radar in off-line mode. Gabella and Leuenberger (2017) have implemented a weather scan program that includes 30-min Sun-track observations using a non-operational X-band radar on wheel.

In Switzerland, the Sun-track procedure, which is typically run twice per year, is used for absolute Rx calibration. Method 1) is successfully used for daily monitoring and relative calibration. Thanks to OPERA, method 1) is now run for monthly monitoring the received solar signal by a very large number of radar in the whole Europe. Furthermore, it has been proven to be successful even for absolute Rx calibration in Finland: for instance, an exceptional "increase" of the received signal has been introduced at the end of January 2018 for the ANJ radar signal processor. Such change was the consequence of a robust statistical analysis based on method 1). At the workshop we will focus on two important and similar exceptional outcomes of Sun observations on operational dual-polarization radars in Switzerland, although based on method 2): A) an "increase" of +0.5 dB of the received signal for both polarizations of the ALB radar in zxc. B) an "increase" of +1.0 (+0.3) dB of the received signal at horizontal (vertical) polarization, after having changed the Calibration Unit of the WEI radar in summer 2021. It is worth noting that according to available clues, we think that change A) could be attributed to an "optimistic" antenna Gain (hence, it will last for the whole antenna life), while change B) could be attributed to a "pessimistic" value of the reference Noise Source (hence, it is a temporary change, associated just to the current Calibration Unit). We will be glad to discuss clues and implications with the audience at the workshop.

Costs & benefits of SSPA

Comparison between SSPA and Magnetron X-band radars in maintenance field

Sun-Jin Mo, Ji-Young Gu, Geun-Hyeok Ryu
WRC, KMA

The Korea Meteorological Administration has been operating an X-band radar to study the usability of severe weather monitoring at a local scale. The difference between the X-band dual polarization radar operated from 2009 to 2017(currently discontinued) and the X-band radar equipped with the SSPA transmitter that was introduced in 2017 were compared and analyzed in terms of operation and maintenance. Both radars have the same frequency (9360Mhz) as the X-band. The biggest difference between the two radars is the operational stability of the hardware. In the case of radar with a magnetron transmitter, the use of high pressure increase internal temperature then durability deterioration of equipment is the biggest issues. In addition, the management of the dehydrator which is used to maintain the humidity and pressure inside the waveguide is also difficult, and if the dehydrator does not operate properly, the feed horn might be damaged by high pressure. In contrast, in the case of a radar with an SSPA transmitter, there is little change in the generation frequency and the internal temperature rising is not high because it uses a low voltage, so it is stable in operation. In the case of SSPA radar, there is no dehydrator and the waveguide is also flexible type, so that damaging to the feed horn does not occur. In this study, the differences in maintenance and operation experienced while directly operating two types of radars are explained, and an appropriate maintenance plan for each type of radar is presented.

The characteristics of observation using solid-state dual-polarization radar

Sumida Yasuhiko
JMA

The Japan Meteorological Agency (JMA) had updated 14 of its 29 C-band weather radars to solid-state dual-polarization versions as of July 2021.

This presentation will cover the characteristics of observation using these solid-state radars for various phenomena, including precipitation and non-precipitation events, detection of low-level wind shear, and contamination of interference waves. Focus will also be placed on JMA countermeasures for typical issues relating to solid-state transmitters. These include the adoption of relatively short long pulses and various widths for long pulses to mitigate low sensitivity within the short-pulse range, the introduction of non-linear frequency modulation (NLFM) to suppress the range sidelobe, and calibration between short and long pulses based on the range in which both overlap, thereby helping to eliminate discontinuity in the range direction. The presentation will also cover efforts relating to spectrum sharing between C-band solid-state radar and RLAN in Japan.

Overview of solid-state weather radar and related operational experience

Soshi Okamoto
JMA

The Japan Meteorological Agency (JMA) operated 14 C-band solid-state dual-polarization radars as of summer 2021, along with 44 C-band and X-band solid-state dual-polarization radars operated by the country’s Ministry of Land, Infrastructure, Transport and Tourism (MLIT). With data from these radars used on a cross-agency basis, along with related operational experience, JMA believes in the potential for solid-state dual-polarization radars to overcome conventional issues in the field and replace vacuum-tube radars. This presentation will leverage JMA’s operational experience to highlight the various unprecedented advantages offered by solid-state dual-polarization radars, including compactness, reduced running costs (low power consumption and elimination of the need for periodic vacuum tube replacement), safety (elimination of high-voltage parts), highly reliable transmission, low potential for inter-radar interference, and rapid observation thanks to high phase stability and range resolution. Focus will also be placed on points for consideration, including loss of sensitivity in the short-pulse range, complex calibration and monitoring, range sidelobe issues and interference from RLAN.

Calibration Of Reflectivity And Differential Reflectivity From Sspa X-Band Weather Radar

Jeong-Eun Lee*, Soohyun Kwon*, Geun-Hyeok Ryu*, and Sung-Hwa Jung*
WRC, KMA

Korea Meteorological Administration installed three X-band dual-polarization radars equipped with solid-state power amplifiers (SSPAs) to monitor the severe weather phenomena over metropolitan area in 2018. SSPA has many advantages which are small size of antenna system, long life time and easy maintenance, compared to magnetron and klystron with the high power consumption. In terms of performance of a radar system, the low peak power of SSPA weakens the ability to detect weak echoes. The pulse compression technique, transmitting the long pulse and compressing the returned signal, is used to improve the sensitivity and produce the fine resolution data. In addition, the hybrid pulse transmission technique is utilized to fill the blind zone of the long pulse by transmitting the unmodulated short pulse at the end of the long pulse. Unfortunately, the use of hybrid pulse technique causes the discontinuity in radar sensitivity and polarimetric observations.

In this study, we analysed the discontinuity in polarimetric observations of SSPA X-band radar and developed the method to calibrate the reflectivity (ZH) and differential reflectivity (ZDR). The sensitivity of hybrid pulse was examined by extracting the minimum detectable reflectivity from the long-term ZH data. The discontinuity in differential phase (PH) was shown at transition zone. To resolve this, the difference in PH at the transition zone was calculated, and then the PH in the long pulse region was shifted. The rain attenuation was corrected by using the linear equations between specific attenuation (AH) and specific differential phase (KDP)/differential specific attenuation (ADP). The theoretical ZH-ZDR relationship was used to calibrate the ZDR. The median value of measured ZDR was compared with the ZDR calculated from theoretical relationship. The calibration bias in ZH was calculated from self-consistency between ZH, ZDR and KDP. The PH change in rain region was compared with the calculated PH. The corrected ZH from X-band radar (rain attenuation and calibration bias) were compared with ZH from well-calibrated S-band radar to evaluate the consistency.

Reflectivity calibration of complex waveforms with Vaisala WRS400 X-band weather radar

Pekka Puhakka
Vaisala Oyj

Solid state power amplifier (SSPA) technology is becoming an increasingly common solution also for weather radars. Compared to conventional transmitter types, peak power output of an SSPA is

relatively low but it is capable of producing very long pulses with high duty cycle. With such circumstances, complex waveforms with pulse compression in signal processing must be used to achieve adequate sensitivity and spatial resolution for the radar measurement.

Vaisala WRS400 compact X-band weather radar with SSPA transmitter utilizes pulse compression based on non-linear frequency modulation. Compared to conventional signal processing with fixed frequency transmission, special attention must be paid in order to take into account the effects of the complex waveform in the reflectivity calibration.

Earlier procedures have been based on performing the calibration in conventional way for a normal fixed frequency short pulse, or so called reference pulse, and then converting that for the complex waveform pulses by using factors such as ratios of pulse lengths to estimate the increase of pulse energy. However, this method has its limitations degrading the calibration accuracy.

New procedure for complex waveforms follows the same principle and measurement steps as what has been used conventionally. This procedure with preliminary results obtained with a C-band research weather radar were presented two years ago in WXRCalMon2019 in Offenbach. The new procedure is now officially used with the Vaisala WRS400 weather radar. Radar uses hybrid pulsing and thus, the calibration performance has been verified by analyzing the cumulative reflectivity data from rain events over the transition from the short conventional pulse region to the long complex pulse region. Results indicate that the procedure is functioning as expected and calibration between different pulse types matches well with each other.

Comparisons of Solid-State C-Band vs. Klystron S-Band Weather Radar Observations over the Southeastern United States

Richard Stedronsky, Qing Cao
Enterprise Electronics Corporation (EEC)

Enterprise Electronics Corporation (EEC) recently launched a new, fully-solid-state C-band Doppler weather radar system. Branded Endurance C, this next generation of weather radar systems is driven by lower powered solid-state C-Band amplifiers versus legacy magnetron or klystron tubes. Endurance C systems provide for ultra-wideband performance and low life-cycle costs thanks to advanced solid-state power amplifiers operating in the widest C-band frequency range available. EEC recently tested the performance of their in-house Endurance C system, utilizing pulse compression technologies, against a nearby S-band NEXRAD system and found many positive results, further justifying solid-state transmitter and pulse-compression technologies as a viable, operational solution for weather radar users around the globe.

Monitoring of threats to radar networks

High temporal resolution polarimetric signatures of a peculiar Bright Scatterer: an (almost) steady Wind Turbine observed with a fixed-pointing antenna

Marco Gabella, Martin Lainer, Jacopo Grazioli
MeteoSwiss

Wind turbines can heavily affect the observations of various radar systems: from weather radars to surveillance and air traffic control radars. To better understand the effects of such large scatterers on radar returns, MeteoSwiss performed two dedicated measurement campaigns in March 2019 and 2020. A X-band dual-pol radar was deployed at a range distance of approximately 8 km from three wind turbines. In 2020 the radar data were collected with a fixed-pointing (stare-mode) antenna towards the nacelle of the closest wind turbine (WT). The stare-mode scan program lasts ~100 min and is followed by a volumetric PPI providing an overview for the whole wind park area (21 elevations in less than 15 min). The pulse width was 500 ns (~75 m range resolution); the angular resolution at the range of the wind turbine was ~180 m and the PRF was 2000 HZ. Since 128 pulses are used to derive polarimetric measurables, the temporal resolution was as high as 64 ms. To complement the data set, environmental and instrumental operational data of the WT (at 10 minutes resolution) were available including ancillary parameters such as 10-min average rotor speed (RS), nacelle orientation and blade angle. Despite being unusual, a “calm” situation (10-min average RS exactly equal to zero) with peculiar polarimetric observations occurred for example on the first day of the campaign, precisely between 17:00 and 17:10 UTC. ZH was perfectly constant and equal to 56.5 dBz, ZV was ranging from 38.5 to 43.5 dBZ (mode at 40.5 dBz) and rhoHV was always equal to 1. The occasional fluctuations of ZV were the smallest possible (+-0.5 dBz, which is the quantization step). It is quite impressive how far Zdr (obviously ranging from 13 to 18 dB) was from a “neutral” interval around 0 dB. The very small dispersion (2.9 deg) of the differential backscattering shift was also remarkable. During the successive 10 minutes, metadata report a slightly different blade angle and an average RS of 0.02 rpm. Radar data show that nothing has changed dring the first 3.5 minutes. Then, Zdr has slowly started (in ~64 s, 1000 echoes) moving toward 0 dB, where it has remained until 17:17:50. Finally, the stare-mode radar data seem to show that the 72-deg rotation (0.2 revolution) started after 17:17:50. In the last 130 s, in fact, polarimetric signatures returned to the typical fluctuations: ZH from 39 to 66 dBZ, ZV from 42 to 65 dBZ, Zdr +- 14 dB, with median at 0.5 dB. Thanks to the very high temporal resolution, we could observe in detail the transition from ZERO rotor speed to the ordinary moving conditions (from 17:20 to 17:30 UTC average RS was as large as 2.25 rpm). On the one hand, a steady WT in the center of the beam width showed indeed polarimetric signatures similar to a Bright Scatter (e.g., the 90 m tall tower at 18 km range from the C-band Lema radar). On the other hand, thanks to the unique and precious stare mode observations, we start understanding also what the BS dual-pol signatures would be, if the C-band radar antenna were fixed-pointing.

Insights into wind turbine reflectivity and radar cross-section (RCS) and their variability using X-band weather radar observations

Martin Lainer*, Jordi Figueras i Ventura*, Zaira Schauwecker*, Marco Gabella*, Montserrat F.-Bolaños+, Reto Pauli[x], Jacopo Grazioli*
**MeteoSwiss, +armasuisse, [x]Swiss Military Aviation Authority*

In this work effort was put into the analysis of the data of two dedicated field campaigns which took place in March 2019 and March 2020, aiming at gathering weather radar measurements in the X-band frequency of three large wind turbines. Dedicated scan strategies, consisting of PPI (plan position indicator), RHI (range–height indicator) and fixed-pointing modes, were defined and used for observing the small wind park in 24/7 operation. The primary focus of this study is to present a statistical analysis of radar reflectivity (ZH) and retrieved RCS values and to find correlations between those variables and the operational data of the wind turbines (orientation, blade pitch angle, revolution speed).

The highest measured maxima of horizontal reflectivity (ZH) and RCS reached 78.5 dBZ and 44.1 dBsm, respectively. Although the temporal analyses of the radar signals was contraint to a time scale of 10 minutes (to be compliant to the sampling granularity of the WT operational data), we find clear indications that the blade pitch angle of the rotor blades plays a major role in the observed variability of the radar returns.

RF - interference mitigation process

Maximilian Schaper
DWD

The data obtained by weather radars is a crucial component in today's forecast and nowcasting tools. Nowcasting applications and the analysis of local phenomena depend upon the high temporal and spatial resolution provided by weather radars. As such the 17 operational weather radars are a crucial part of the observation network run by the German Weather Service (Deutscher Wetterdienst, DWD).The data gathered by weather radars has to be available at all times and has to satisfy specific quality criteria.

Weather radars are progressively compromised by RF interference. There is no filter available to restore the compromised weather signal in the presence of an interference. This highlights the importance of efficient and objective detection and removal of external RF interference sources by radio frequency authorities (RFA) which is an ongoing challenge. This poster will append upon the poster from the 2nd Calibration Workshop where we have presented an automated detection algorithm applied on a sweep by sweep basis. Since then the interference mitigation process has been optimized to provide all necessary information to the radar service and RFA for an optimized mitigation process. We present the overall statistics on interferences in Germany since 2017 and report about the experience from the mitigation process. As the improved interference mitigation process was implemented in May 2019, there exist multiple examples of successful RF interference removals, which will be included.

By using a wifi device, which is connected to the radar receiver (RHUNT), a systematic verification of our interference detection algorithm is carried out. For this systematic verification, the data acquisition software of the RHUNT has been improved significantly.

Testing the influcence of wind turbines on weather radars by generating virtual Doppler-RCS signatures

Marc Schneebeli, Andreas Leuenberger
Palindrome Remote Sensing

Radar reflectivities induced by wind turbines are a long standing problem in many radar applications. Weather radars are specifically affected since they are supposed to cover large areas and specific spots with wind-turbine contaminated pixels cannot be easily removed without removing weather information that is also contained in these areas. In addition, wind turbines are often located on mountain crests and therefore within the direct view of weather radars.

A wealth of mitigation procedures were developed in recent years but it is still close to impossible to obtain meaningful weather radar data in the surroundings of wind turbines, with the consequence that authorities inhibit the construction of new wind turbines if there is a slight potential that the foreseen turbine might hamper the quality of the radar data.

However, the assessment of the influence of the yet to be built wind turbines on the radar data quality is a difficult task.

Palindrome Remote Sensing has developed a tool to generate realistic radar signatures of wind turbines at arbitrary locations within the field-of-view of a radar. The tool is based on Palindrome's dual-polarization target simulator technology that can be used to calibrate weather radars by comparing virtually generated radar targets against the radar measured reflectivities.

Within a research project funded by the Swiss Federal Office of Civil Aviation, the capability of Palindrome's target simulator was enhanced such that not only point targets but also complex time-varying Doppler-RCS patterns can be generated. Radar signatures from a wind turbine were recorded with an experimental radar system. The recorded data was used to develop a simplified parameterized model that can be implemented in the target simulator, from where the wind turbine signatures can be replayed. The artificially generated radar signature from the wind turbine is then again observed with the radar system in order to compare the real with the virtually generated Doppler-RCS pattern.

With this new technology, artificial wind turbines with arbitrary parameters can be set-up within the field-of-view of a weather radar. It can hence be tested, if a wind turbine is disturbing the radar under test and if signal-processing based mitigation techniques are capable to clean contaminated radar pixels.

Wind Turbine Clutter detection in real-time Weather Radar Signals, developments for the DWD C-Band Weather Radar Network

Simon Gerhards*, Patrick Tracksdorf+
GAMIC GmbH, DWD+*

The Wind Turbine Clutter (WTC) detection algorithm, developed by GAMIC in cooperation with the Deutscher Wetterdienst (DWD), enables to flag at signal processing level unwanted high reflectivity range bins generated by wind turbines in the near surroundings of Radar locations. This algorithm works on the raw radar measurements in real-time during signal processing allowing to include the detection information in the post-processing algorithm chain, particularly for quality assurance purposes. Currently, a first analysis and evaluation is carried out within the DWD C-Band Weather Radar Network to measure the probability of detection and the false alarm rate of the WTC-detection that quantifies the quality of the algorithm. In order to have a broad and meaningful evaluation for different wind turbine constellations and wind turbine operating states as well as weather scenarios, the algorithm is running in the operational environment on every radar system of the DWD C-Band Weather Radar Network.