WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR INSTRUMENTS AND
METHODS OF OBSERVATION

INTERNATIONAL ORGANIZING COMMITTEE (IOC)
FOR RADAR QUALITY CONTROL AND
QUANTITATIVE PRECIPITATION ESTIMATION (RQQI)
First Session

Exeter, United Kingdom
14 – 15 April 2011

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PROJECT CONCEPT PRESENTATION, CLARIFICATION AND DISCUSSION

The WMO Radar QC QPE Inter-comparison Project RQQI

(Submitted by P. Joe)

Summary and purpose of document

This document provides an overview of the project and the manner in which the intercomparison is planned to be carried out.

ACTION PROPOSED

The Meeting is invited to note this information and to identify any point needing clarification.

The WMO Radar QC QPE Inter-comparison Project

RQQI[1]

20110222
V3.1
Paul Joe

Project Statement

Inter-comparison workshops will be conducted to identify, document and exchange the best techniques for quality control and quantitative precipitation estimation from weather radar in a variety of radar scenarios and in different weather and environment regimes and to develop data quality metrics for global and regional applications.

Goals

1. Undertake systematic inter-comparison and validation of radar QC/QPE algorithms evaluated under a variety of environmental conditions
2. Assess the impact and provide guidance on quality control processes employed in radar-based QPE
3. Characterize errors involved in radar-based QPE
4. Report and provide a source of applications employed in QC/QPE

Objectives

1. Development of a framework for radar QC/QPE algorithms inter-comparison.
2. Development of inter-comparison and validation data sets. Collect data sets in a variety of radar types, collection modes, weather and site conditions
3. Development of radar data quality metrics.
4. Inter-comparison and evaluation of algorithms at focused workshops and develop a data quality framework
5. Development of data and product exchange formats that include data quality.
6. Report on results with recommendations approved by a International Committee of Experts

The Need

Advances in severe weather nowcasting, data assimilation, weather and climate model validation, satellite rainfall verification, and hydrological applications have led to new and enhanced requirements for high quality regional and global radar data and radar precipitation products. Also, recent advances in radar technology, signal and data processing have brought the field to the brink of operational readiness for these products for its quantitative use. In the past, radars were perceived to address only local and

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[1] Pronounce Rickey

qualitative applications, such as severe weather diagnosis and warning, but this view is rapidly changing as telecommunication networks and storage capacity allow vast amounts of data to be transferred and archived, as National Meteorological and Hydrological Services consolidate weather offices and automated data processing into fewer locations.

While the progress in the radar QPE has been impressive, it is also recent and there are many differing approaches and solutions. It is therefore necessary to harmonize, consolidate, validate, verify, identify the best algorithms and under what conditions to specify the quality of the products.

Radar QC-QPE processing is a common problem for all NMHS' and a collaborative and sharing approach of the techniques and results will have mutual benefits. Otherwise, diverse and difficult to reverse programs will emerge that will confound the integrated use of radar QPE products in the future. Many global issues arise that need consensus, resolution and quality assessment.

Processing differences include techniques or algorithms to mitigate ground clutter,, vertical profile of reflectivity, attenuation effects, bias correction and consistency , etc. Product differences include temporal and spatial scales of the data, accuracy and precise, data format exchange standards.

Radar Technology

The Radar Technology: Radars are complex instruments and there can be many technical differences related to the radar hardware technology (reflectivity-only, Doppler, dual-polarization, data resolution), equipment location (ground echoes) and purpose (scan strategy).

The radar technology and signal processing options have significant impact on the range of approaches available for one of the primary issues for rainfall measurement – ground clutter and anomalous propagation removal and the potential errors. Conventional radars still form the bulk of the operational radar technology globally though this is rapidly changing. Reflectivity statistical techniques, ground clutter maps, texture of the data and high altitude CAPPI maps to mitigate ground clutter are still used to mitigate ground clutter. Doppler radars afford the possibility of using velocity signal processing to remove stationary targets. This has been a significant improvement but there are some drawbacks (see Fig. 2). Polarimetric radars are now being deployed operationally and offer significant potential through differential phase measurements to identify and separate clutter targets, mitigate the impact of drop size distribution effects, attenuation in precipitation, and a number of non-meteorological error sources.

Performance, Calibration and Maintenance: A number of engineering, system design and related sources impact the accuracy of measurement and may dominate without careful treatment. These are loosely lumped into "radar calibration" but can be separated to performance, electronic calibration and system maintenance. Performance refers to the sources of uncertainty related to the radar specifications such as the antenna pattern, gain and sidelobe structure, receiver and filter losses, pulse shape, frequency drifts, noise and even antenna tilt. For the radar engineer, calibration refers to the accuracy and precision of the received power only. In the past, this was a major source of uncertainty and some research radar receivers were calibrated on a daily basis. The receivers are much more stable now. Maintenance refers to monitoring for component failures and drift. Changes in these factors over time is requires a systematic approach to metadata definition and reporting. Considerable experience has been gained over a number of years with a range of radars and the application of various techniques for analysis and treatment of this problem.[2] While it is initially assumed that the radar is calibrated and maintained, this will be addressed in specialty workshops such as RADCAL[3] and RADMON.[4]

Figure 1: Radar calibration course conducted by the Turkish Meteorological Service on behalf of WMO. Figure courtesy from Oguzhen Sireci.

Processing Radar for Precipitation Estimation

The following figure describes the steps required to process radar data for quantitative precipitation estimation. The purpose of this figure is to illustrate the complexity of the data processing steps that are required to convert radar measurements to precipitation estimates. While the details and sequence may be debated, it serves to illustrate the problems that need to be solved. The steps are briefly described. Radar QPE application is the focus of this inter-comparison. Nowcasting and NWP applications, where clear air echo and convergence lines are important are not covered here.

Radar hardware changes over time (component failure, mis-adjustments, etc) and in order to make use of radar data archives, calibration-related meta data on each radar is needed in order to perform re-analysis of the data.

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[2] The issue of network calibration, important to many agencies employing different radar hardware has been investigated extensively within the Nordic Weather Radar Network and within the U.S. Nexrad radar network. Polarimetric techniques also offer ways forward for self-consistent reflectivity bias calibration.

[3] RADCAL was a workshop sponsored by the AMS in 2001.

[4] RADMON was a workshop sponsored by WMO in conjunction with ERAD2010.

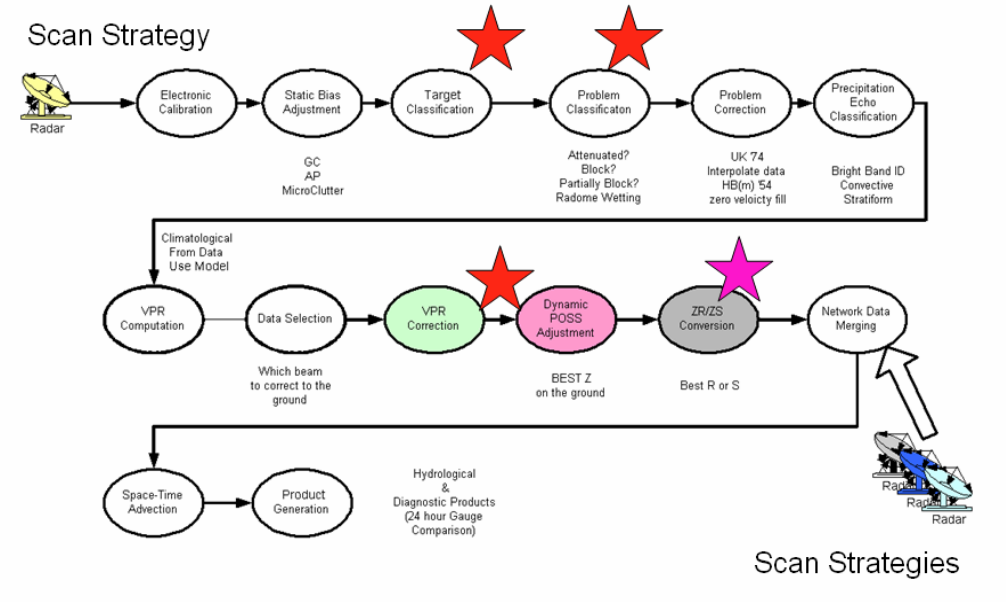

Figure 2: A representation of the processing chain for radar QPE. Currently, only electronic calibration and Z to R conversion is universally done. Impact of other adjustments (red stars) can be substantially larger depending on the environment and application.

1. The processing chain begins with radar data (moment data). It is assumed that calibration (as described in the text) has been done.
2. The static bias adjustment step (second bubble) refers to ground clutter and anomalous propagation removal step. With Doppler technology, the zero notch filter and second trip echo removal techniques can be applied in signal processing. Recently, a combination of signal and data processing techniques have been developed to address these issues.
3. The next step is to classify the echo and determine if it is due to precipitation or due to non-meteorological targets. For the QPE application, that data must be flagged or eliminated.
4. Areas of partial or complete blockage, attenuation or wet radome need to be identified.
5. Then corrected using various techniques (for example, using vertical profile of reflectivity or dual polarization).
6. Then, the weather echo needs to be classified as stratiform, convective, bright band, rain or snow or hail.
7. Then an appropriate VPR needs to be computed (in real-time, statistically or climatologically).
8. Then appropriate base data value is needed to be determined. (The lowest beam may be corrupted and a higher elevation scan may need to be identified and used.)
9. The VPR and/or horizontal spatial data can then be used to compute the best reflectivity at the surface.
10. Then if there is a DSD device, the Z value may be adjusted.
11. Once the best Z is determined, a conversion from Z to precipitation is done using a ZS, ZR, ZA relationship.
12. If there are sufficient rain gauges available, the precipitation values may be adjusted.

13. Then the radar data may be merged on a network basis. The merging of rainfall estimates from overlapping and non-overlapping radars into one product can overcome the sudden attenuation due to a wet radome or heavy rainfall.
14. Ideally, another adjustment at the radar boundaries (i.e., inter-radar power calibration) should not be necessary but could be included at this point.
15. Hourly (or other) accumulated products from each radar cycle, with an advection accumulation technique applied, is required.

Currently, only electronic calibration and Z-R are widely implemented[5]. The effect of the other adjustment factors can be substantially greater particularly at long ranges from the radar.

Major QPE Issues

Weather and Radar Environment Variation: Identification of applicability and quantitative assessment of these techniques in a wide variety of conditions is needed to under their impact on quantitative precipitation estimations. Fig. 3 shows some of the environmental impacts on the weather radar and includes biological and clear air targets useful for other purposes than QPE.

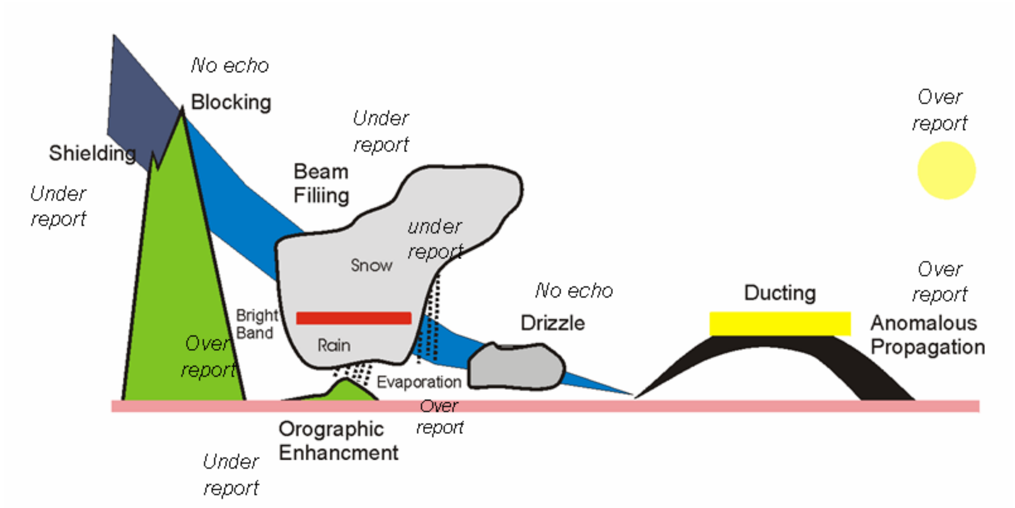

Figure 3: A cartoon depicting some of the physical effects that impact on radar QPE. Even if a radar is perfectly calibrated, these physical effects due to the environment dominate the use of radar data for QPE. Substantial progress has been made in this area in the past few years and operational systems correcting and adjusting the radar data for these factors are now just emerging. Bold text indicates the physical effect and the italics indicate the impact on QPE.

Ground Clutter Mitigation: All radars have ground clutter, particularly around the radar due to the side of the main lobe and side lobes. A major improvement has been the deployment of Doppler technology where the narrow power spectra due to ground clutter can be separated from the broader weather spectra. See Fig. 4. However, when the

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[5] A recent WMO survey of weather radar practices indicated that some countries do not do electronic calibration.

weather spectra is narrow (as in the case of light snowfall) and the radial velocity is near zero, the technique can fail. Newer techniques involve a fuzzy logic decision system to identify whether a ground echo is predominant and whether to apply a Doppler filter in order to minimize the damage to the data. Without Doppler radar, a common technique was to use a CAPPI product so the data used for display is above the height where the ground echoes are observed.

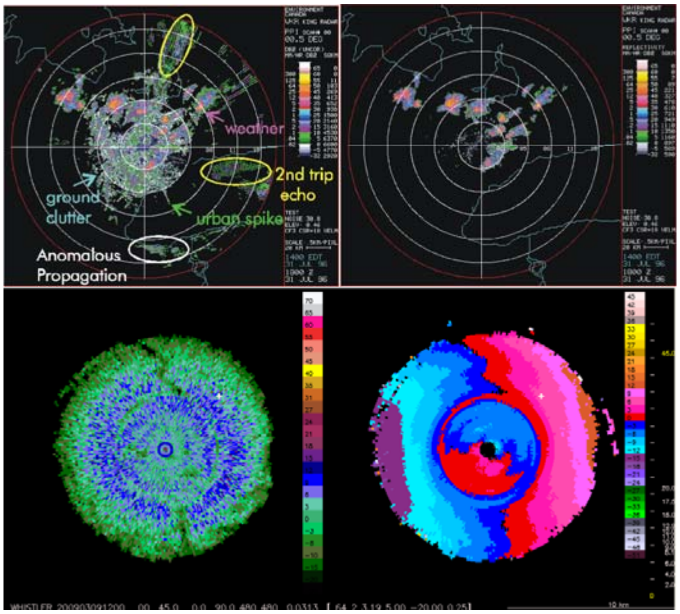

Figure 4: An example of the ability of Doppler signal processing to adaptively remove ground clutter and anomalous propagation echoes. Image on left is a reflectivity image without filtering and image on the right is with filtering. The technique can at times remove too much weather echo and not enough in other situations on a data point basis for local QPE applications but may be perfectly fine for larger scale applications.

Vertical Profile Effects: Other physical processes can also dominate the estimation process in a practical sense including the contamination of rain by melting hydrometeors e.g., hail and the bright band effect. These effects are particularly important in stratiform rain for non-tropical winter time situations and have regional, seasonal and local variations that impact the estimation process. See Fig. 3 for a cartoon of the source of the various factors.

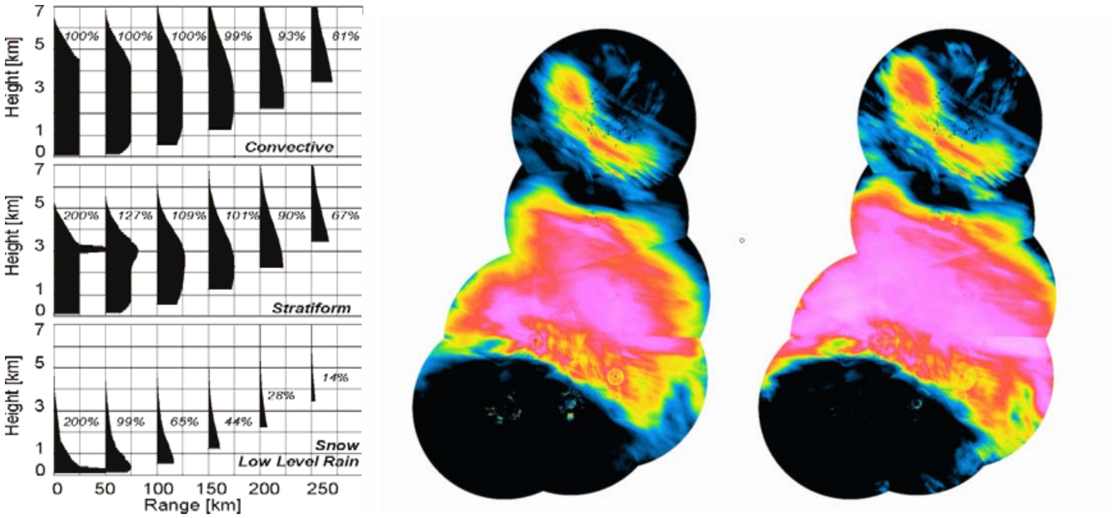

Figure 5: An example of a precipitation accumulation product from the Finnish radar network where the vertical profile of reflectivity corrections have been applied to a case of a quasi-stationary front where precipitation accumulations are expected to be uniform. On the left is an uncorrected image and it show a drop off of accumulation with range from the radar. This is due to beam filling (beam not filled and hence precipitation is under-reported) and vertical profile decrease of reflectivity (VPR) with height leading to underestimate of surface precipitation. The figure on the right shows an accumulation after VPR correction (Left figure after Joss and Waldvogel, 1990; right figure courtesy of Jarmo Koistinen).

In the following example, the precipitation is accumulated over a winter season from Finland. The fall off with range in the accumulation on the left most figure is due to the VPR effect. The near circular and uniform fall off is indicative of a very high quality radar site free of artifacts. On the right of the figure, is a comparison with the range gauge data. The falloff is evident and the scatter is relatively small. This is a key image upon which the proposed metrics are based on. The uniformity in azimuth and drop off with range is considered ideal. Ideally, ground clutter and anomalous propagation correction should attempt to achieve this performance.

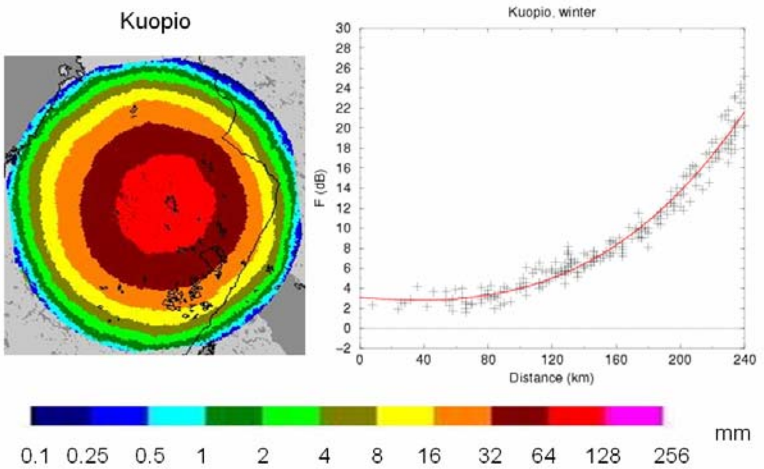

Figure 6: Precipitation accumulation over a winter season from the Kuopio radar in Finland. The right figure shows the gauge-radar ratio. At 200km, a bias of 20dB (factor of 100) is applied to the radar data. Figure courtesy of Daniel Michelson.

The following figure shows a similar plot but this site has terrain blockage and it is for summer. The increased scatter is due to the greater variability of the Z-R relationship in convective situations but also due to the data in the partially blocked area. Corrections for partial blockage and precipitation type should result in reduction in the scatter. This forms the concept for another quality metric.

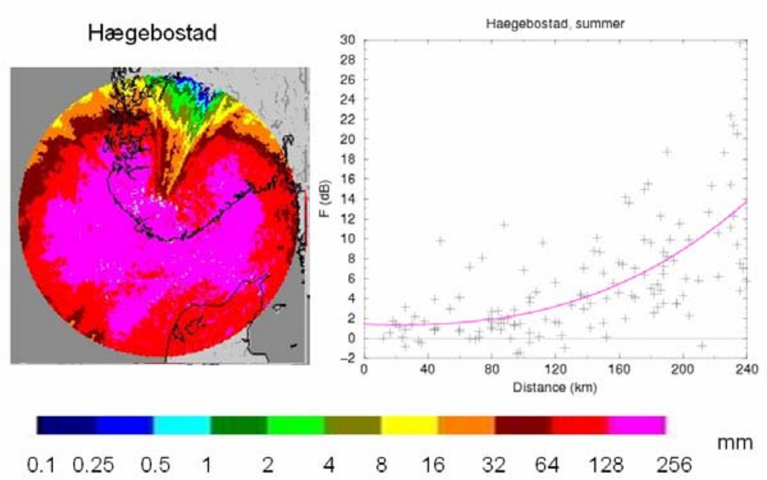

Figure 7: Similar to the previous figure, except an area of partial blockage is included and for summer where there is greater variation in the Z-R relationship (stratiform-convection). Figure courtesy of Daniel Michelson.

Radar Scanning Geometry: The limitations imposed by the above physical process are further confounded by issues related to the scan strategy, geometry and data/signal of the radar viewing of precipitation. Potential non-uniform filling of the radar beam with increased range, the height of the radar beam above the ground, blockage of the beam by obstacles especially in mountainous terrain, ground clutter are examples of non-meteorological factors that can further limit the accuracy and bias precipitation measurements. Fig. 5 shows an example of a corrected precipitation map. These factors vary significantly from site to site and under various conditions.

Drop Size Distribution Factor: Precipitation is inferred most frequently through the reflectivity factor Z, which is well known to suffer significant limitations imposed by the microphysical changes impacting drop size distribution. With a climatological Z-R the limit of measurement accuracy is approximately 30-40%. With adaptive methods based on precipitation type this can be improved as it can be through the adoption of polarimetric approaches (combinations of Z_{DR} and K_{DP}). The physical limits to accuracy are then somewhere near 10-15% with systematic variations in dropsize characteristics. Such systematic variations occur in orographic situations with low concentrations of large drops, convective maritime with high concentrations of smaller size drops, convective subtropical/continental modes with lower concentrations of large drops and of course within different stratiform precipitation processes e.g., melting of large dry snow and cases with small rimed ice. The accuracy of QPE is strongly situation dependent and therefore it is necessary to sample a wide range of weather, locations, and radar configurations when characterizing QPE errors.

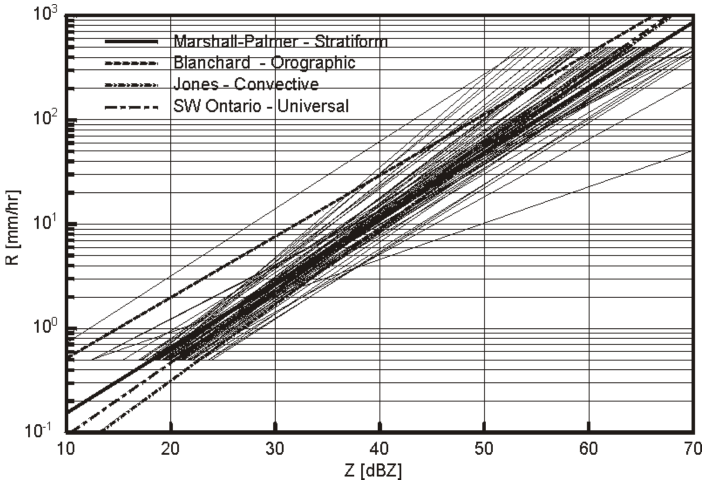

Figure 8: A plot of various Z-R relationships found in the literature. Note that the original and classic Z=200R^1.6 relationship is drawn in a thick line.

Advanced Techniques: Polarimetric radars using differential phase shift can be helpful in overcoming a number of limitations including beam blocking situations. The practical treatment of these issues certainly impacts the overall accuracy of the rainfall measurement and varied approaches to mitigation have been adopted. A particular contribution that polarization can make is in the classification of the radar echo. The following figure shows the results of a particular scheme on a C-band radar.

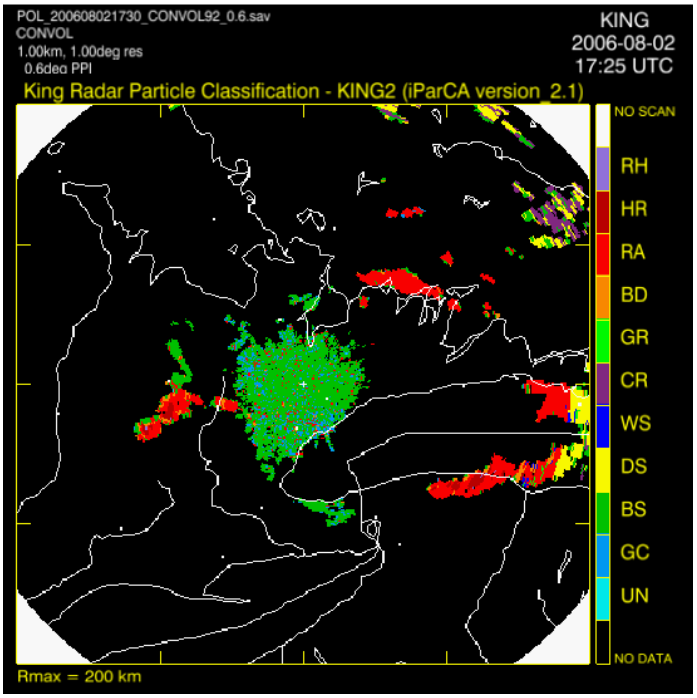

Figure 9: Particle classifiction from the King City Radar in Canada. The symbols are as follows: RH = rain/hail; HR = heavy rain; RA = rain; BD = big drops; GR = graupel; CR = crystals; WS = wet snow; DS = dry snow; BS = biological scatterers (includes birds, bugs, chaff); GC = ground clutter; UN = unclassified. Figure courtesy from Dave Hudak.

Prioritized List of QPE Issues

The following is a prioritized list of QPE:

- Ground Clutter and Anomalous Propagation
- Vertical Profile of Reflectivity
- Partial Occultation
- Reflectivity Bias Calibration (Monitoring)
- Attenuation Correction/Handling
- Minimize Impact of DSD Variability
- Gauge Adjustment (function of density)
- Consistent verification and Data Quality Metrics
- Uncertainty/Scale/Probability Concepts

QPE Validation Issues

The validation of the radar estimates of rainfall, typically undertaken by inter-comparison with gauges raises a number of serious issues. Radars and gauges measure rainfall on different scales and both are affected by individual sampling and instrument errors. Dense gauge networks are crucially important with attention to calibration just as required with the radar measurements. Quality control of gauge data is also an important consideration. Utilization of independent, systematic and consistent validation processes and techniques are certainly desirable. This is also true for NWP and satellite validation and climate change applications. As this is application dependent, it will be addressed at later stages of the project.

Data Quality Metrics

Driven by a variety of applications, including data assimilation, NWP and satellite validation, hydrological applications, uncertainty in radar precipitation estimates have been a hot topic of discussion and research. Given the differences in radars, radar networks, a consistent framework for describing the quality of the final QPE products is needed. An outcome of this project will be recommendations on the metadata and procedures required to describe the quality of the radar data and of the products.

Fig. 6 shows what a near-perfect radar under the correct uniformly distributed precipitation conditions would look like. It is smooth indicating that it is free from ground clutter. It is symmetric indicating that there are no spatial biases in the area. There is tight scatter between the radar and the precipitation estimates. The difference in range is due to the physical vertical profile effect of the weather for that area.

There appears to be a bias of 2 dB at zero range. One would expect the curve to be very flat within the effective range of the radar for QPE. The effective range is defined by the flat part of the curve which is about 80 km.

While the figure shows that the shape of the curve is computed from a radar – gauge comparison, the curve should be computable from the data within the effective range of the radar.

This premise for data quality metric is therefore that perfectly corrected reflectivity accumulations should be smooth and are available spatial correlations or variograms could be used to quantify the smoothness of the resulting ground clutter and AP corrected fields. That is, there are no lumps or holes. Given the weather, the shape of the curve may be steeper or shallower. Once the curve is computed, the scatter of the data around the curve should be small.

Metrics could be developed at the pixel level or summarized for the entire radar space. We leave radar network issues till later.

Inter-comparison Modality

Two modalities are identified for the inter-comparisons. Comparing algorithms against a common dataset and comparing an algorithm on diverse radar datasets both in terms of hardware and technology configuration but also in different weather and beam propagation regimes (mountains, coastal, flat).

The target QPE product needs agreement. It is proposed that totals at 4 km^2 spatial resolution with an hourly time granule within approximately 150 km of the radar be the base product for consideration. This would fulfill many requirements including significant hydrological applications. This is not meant to preclude other products and with other user requirements but sets a base product for evaluation.

The proposed inter-comparison process is summarized as follows:

- Existing quality control and rainfall estimation applications developed by various groups are applied to a set of radar datasets.
- These datasets are collected from a set of representative locations.
- In this model the individual groups with existing quality controal and rainfall estimation algorithms will agree to run their estimation applications on these new independent datasets. This will mean an agreed radar data format and radar operating process for the collection of the respective radar datasets.
- In the fullness of the project, availability of ancillary information will also be required e.g., numerical weather prediction fields, soundings, clutter maps, dependent radar data for algorithm optimization and learning, spatial, uncorrected reflectivity and geographical datasets etc.
- The estimation algorithms will have to provide output in agreed product form e.g., an hourly granule of rainfall accumulation for verification.
- Initially the focus of the QC/QPE goals will be single radar approaches are envisaged but will not preclude network approaches.

Verification and inter-comparison of the results would then be undertaken using agreed metrics with techniques and applications available to all contributors

Based on the initial verification and inter-comparison, an iterative process to optimize and improve the estimates is likely to be required. This is could potentially involve collective use of “best” algorithms that are shown to improve the estimation process.

Potential issues relate to radar calibration and sub-optimal performance of the estimation algorithms\quality control processes for both the radar and gauge data. The incorporation of improved QC applications may require hardware intervention on the radars. This possibility should be considered.

Linkages and Stake Holders

This project addresses a core issue that contributes to other WMO mandates and initiatives. Core links are evident with the CIMO ET on Upper and Remote Sensing , WWRP nowcasting group, the THORPEX DAOS group and WMO WCRP GEWEX RGP (WGPRN), amongst others.

The best approaches need to be identified, documented and shared with all member countries. Commonality of approach, when possible, is needed to promote collaboration and efficiencies. Data quality metrics and standards need to be identified and developed so that these data and products can be integrated as part of the Global Observing System and as part of Global Earth Observation System of Systems(GEOSS)[6]. Processes for maintaining, monitoring and meta-data reporting radars need to be established to support a long term archive.

Many new radars are being established in developing nations where societal impact is high. An example is Africa and this proposed project will help them attain the Millennium Development Goals through improvements in the use of their radars for climate purposes. Other related WMO programs will also benefit from this project and include: WMO Information Systems, Quality Management Framework, Natural Disaster Prevention and Mitigation, Flash Flood Initiative, contribute to foster closer collaborations between NHS and NMS’s and International Exchange of Data and Products and enhance the social and economic benefits of NHMS’.

A Climate Perspective

The extremes in the hydrological cycle manifest in changing extremes of precipitation. Precipitation rate is so highly variable in time and space that it is one of the most difficult of the essential climate variables to measure and monitor precisely, particularly the more extreme (rarer) events. Current surface precipitation gauge arrays are much too sparse in spatial coverage and (usually) report too infrequently to resolve precipitation variations and can easily miss extreme events. Although indirect satellite precipitation products do exists at relatively high space and time resolution, the indirect nature of these methods may not be able to properly capture the extreme events that represent non-average conditions by their very nature. Spaceborne radars have good spatial resolution but have very low time sampling frequencies compared with the variations of precipitation.

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[6] The GEOSS goal is to establish a global, coordinated and sustained observing system to meet societal needs particularly in respect of severe weather warning and disaster management.

Weather radars, specifically designed to observe precipitation at high temporal and spatial resolutions, are becoming ubiquitous in many nations around the world and are currently the only precipitation-measuring system with the requisite space-time sampling. However, until now these systems have also been generally sparsely distributed and operated and analyzed separately in a case-study approach. The recent significant growth in the number of radars being operated, now makes possible high-resolution determinations of precipitation over extensive land areas and over long time periods. Such datasets, when merged with very stable spaceborne radar reflectivities would provide the observational basis for learning how the small-scale extreme events are connected with the large-scale atmospheric circulation and how this may be changing in time. To provide this type of data requires systematic collection and analysis of data from these radar networks in as many different climate regimes as possible on a retrospective basis to produce appropriate "climate-scale" statistics. The potential of these radar networks for climate studies is high but has not been realized.

The detailed corrections and adjustments are a pre-requisite for the generation of appropriate products to study climate variations and extremes. A consistent global measure of radar data quality applicable for a variety of radar networks in different climate regimes and recording of quality meta-data are needed to make use of the radar data for these types of studies.

Inter-comparison Datasets/Testbeds

The above process implies that data will be required from representative locations. Some sample regimes and potential locations/groups that could be considered include:

- i. High Latitude Regime Including Mixed Phase Precipitation (Winter rain)–
    1. Nordic weather radar network (FMI)
    2. UK MetOffice
    3. Polarimetric Radar Montreal (McGill University)
- ii. Tropical Maritime (Tropical convection)
    1. Darwin, (CPOL, Polarimetric), Australia (BMRC)
    2. Melbourne, Florida or Kwajalein (NASA TRMM)
- iii. Sub Tropical Regime (Moist severe weather regime)
    1. Brisbane (Polarimetric -CP2), Australia (BMRC)
    2. Beijing, PRC (CMA/BMB, B08 FDP)
    3. Japan (JMA)
    4. Korea (KMA)
    5. Hong Kong (HKO)
- iv. Continental Regime (Arid regimes with severe weather)
    1. KOUN Oklahoma, USA (NNSL)
    2. CHILL, Colorado, USA (CSU)
- v. Mountainous (Orographic enhancement process and blocking)
    1. Meteoswiss, Switzerland
    2. Catalunya, GRAHI-UPC, Spain
    3. Germany (DWD)
    4. France (Meteofrance)

        5. Canada (Vancouver 2010 project)
    vi. Signal processing QC
        1. NCAR
        2. Environment Canada
        3. NSSL

Project Deliverables

- Intercomparison data sets
- Standard data quality metrics.
- Intercomparison Workshops
- Workshop summary reports.
- Reports/publications on best techniques and best practices for radar QC and QPE.
- Recommendations for global implementations
- Training workshops

International Organizing Committee

WMO has guidelines for organizing inter-comparison projects and has a requirement for a Science Committee to review plans, results and sign off on the recommendations resulting from the workshops. See Annex 2 for the list of IOC members.

Kick-off/Pilot Workshop

A pilot workshop is proposed to be held in 14-15 April 2011. There are many variables with perhaps some controversial elements. In preparation for a full inter-comparison, a kick-off meeting of the IOC and invited experts is planned. The following are the objectives of this kick-off meeting.

- Discuss and refine the project concept - inter-comparison modality, data set selection, ancillary data, inter-comparison processes, metrics and metric interpretation) leading to an implementation plan for the full inter-comparison.
- As part of the kick-off meeting, a limited number of data sets will be chosen and only a few algorithms highlighted.
- The focus will be the removal of ground clutter and anomalous propagation echo to generate the best low level (i.e. surface) reflectivity and radial velocity field from a single radar.
- The data sets will be chosen from a few locations (to test the scan strategy and format issues) from selected situations (to test different ground clutter and anomalous propagation) and will focus on one or two steps of the adjustment chain (removal of ground clutter and anomalous propagation, infilling perhaps by vertical profile extrapolation). It is envisioned that 4 cases, each of 24 hours or so duration will be prepared (see table below).
- A limited number of groups will be asked to process the data to generate “best” surface reflectivity product. At this stage, bias correction is not considered.
- There results of each data cycle will be accumulated and the spatial variogram metrics will be computed.

- The results will form a core element of the kick-off meeting. The key questions will be whether carefully "short" data sets are adequate, whether the metrics are adequate and can be interpreted qualitatively or quantitatively leading to viable recommendations to WMO members.

Table 1: Four Initial Test Data Sets

It is envisioned to prepare volume scan data sets with total reflectivity, zero notch corrected reflectivity (option) and Doppler velocity. These parameters are commonly available in Doppler systems. While reflectivity metrics are the primary focus, radial velocity metrics are relatively novel and adjusted Doppler velocity fields will be evaluated, if available.

	Case	Notes
1	Ground Clutter with uniform precipitation	A "common" standard test case with moderate ground clutter with no weather and uniform weather. Ground clutter and Anomalous Propagation echo has zero Doppler velocity.
2	Sea Clutter with uniform precipitation	Similar to previous, sea clutter is very low level, uniform in reflectivity but has non-zero Doppler velocity.
3	Strong Anomalous Propagation with convective weather	AP echoes have a vertical structure that can be used to detect and remove. The issue is whether two dimensional detection and correction algorithms will also remove convective weather.
4	Partial Blockage and uniform precipitation	There are detection and correction algorithms that work on a two or three dimensions and this examines issues

Annex 1: Glossary

Signal Processing – processing of the time series, or IQ data

Data Processing – processing of the moment data.

Raw Data – generally refers to the moment data

Time Series Data – this is the voltages or the in-phase or quadrature data

Products – refers to highly processed raw data into relevant end-user units such as mm/h

Annex 2: International Organizing Committee

Paul Joe (chair)	EC, Canada	Yoshihisa Kimata	JMA, Japan
LIU Liping	CAMS, China	Alan Seed	BOM, Australia
Vicenzo Levizzani	WCRP, Italy	Daniel Michelson	SMHI/BALTRAD, Sweden
Daniel Sempere-Torres	GRAHI, Spain	Nicolas Gaussiat	UKMO/OPERA, United Kingdom
John Hubbert	NCAR, U.S.A.	Tim Crum	NEXRAD ROC, U.S.A.
Deon Terblanche	SAWS, South Africa	Roberto Calheiros	IPMET, Brazil