The WMO Radar Quality Control Quantitative Precipitation Estimation Inter-comparison Project

Paul Joe
Environment Canada
4905 Dufferin St, Toronto, Ontario, M3H 5T4 Canada
Email: paul.joe@ec.gc.ca

Introduction

The Radar Quality Control and Quantitative Precipitation Estimation Inter-comparison (RQQI, pronounced Rickey) is envisioned to be a series of workshops to identify, document and exchange the best signal and data processing techniques for quality control of ground based Doppler weather radar data primarily for quantitative precipitation estimation applications in a variety of radar scanning scenarios and in different weather and environment regimes. In order to assess the impact of various algorithms, data quality metrics will be developed. In addition, regional and global requirements, driven primarily by nowcasting, data assimilation, numerical weather prediction models, climate diagnostic extend the use of radar data beyond quantitative precipitation estimation. In addition, dual-polarization radars are now being deployed operationally and need to be taken into consideration.

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. Non-precipitating radar echoes (due to insects and Bragg scattering) can reveal valuable Doppler wind fields for NWP and for the identification of low level convergence boundaries for nowcasting convective initiation. In the latter situation, reflectivity fields are also useful. Dual-polarization radar is an emerging operational technology that provides considerable data quality information. It is able to identify ground clutter, distinguish biological targets, rain-snow boundaries and the presence of hail. Therefore, a data quality framework that can distinguish or classifies the radar targets is needed.

Radar QC processing is a common problem for all NMHS' and a collaborative and sharing approach of the techniques and results will have mutual benefits. Processing differences include techniques or algorithms to mitigate ground clutter at the signal and data processing stages, to determine the appropriate vertical profile of reflectivity, to identify attenuation and partial blockage effects and to make bias corrections. Product differences include temporal and spatial scales of the data, accuracy and precise, data format exchange standards.

The Problem

The following figure (Fig. 1) illustrates the artifacts that arise due to the physics of beam propagation, Earth curvature, non-weather targets, and variations in the three-dimensional distribution of precipitation. The RQQI project starts by assuming that the radars are electronically well calibrated and the performance of the system is known. This is not always true and many workshops and studies are already addressing those issues. The RQQI project addresses how well the algorithms perform that correct for the artifacts in this figure.

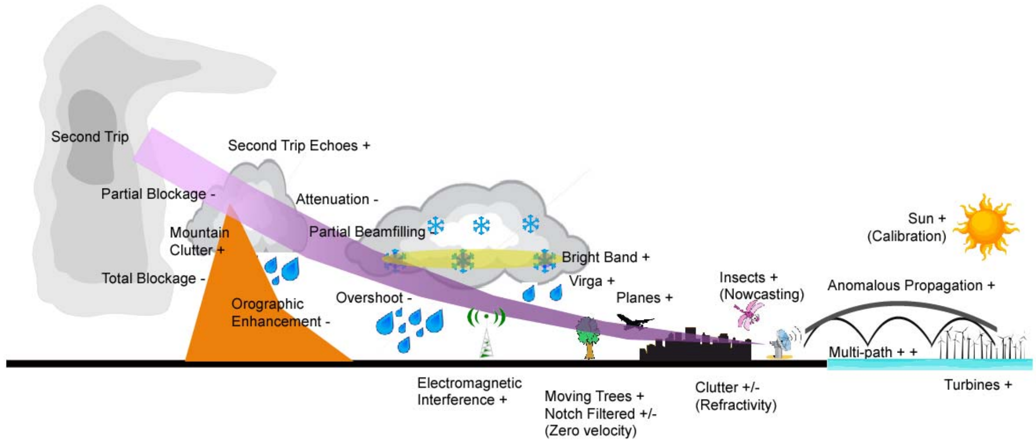

Figure 1: A cartoon depicting some of the physical effects that impact on radar QPE. Even if a radar is perfectly calibrated, these physical effects dominate the use of radar data for QPE. Substantial progress has been made in this area in the past few years and operational systems correcting and adjusting the radar data for these factors are now just emerging. The +/- signs indicate the impact on QPE.

Goals

The goals of the project are:

- Undertake systematic inter-comparison and validation of radar QC algorithms evaluated under a variety of environmental conditions for QPE, nowcasting, NWP and climate applications.
- Provide guidance to WMO members on quality control processes employed in radar quality control algorithms.
- Characterize and assess errors involved in radar quality control algorithms.
- Report on algorithms employed in radar QC.

And will be accomplished by meeting the following objectives:

- To develop a framework for QC algorithms inter-comparison.
- To collect, collate and create inter-comparison and validation test data sets that would consider a variety of radar types, scanning modes and environmental conditions
- To develop quantitative radar data quality metrics.
- To compare and evaluate radar QC algorithms in a series of focused inter-comparison workshops.
- To develop a data quality framework (metadata)
- To develop or promote existing data and product exchange formats that includes data quality.
- To conduct and report on inter-comparison workshops with recommendations approved by a International Organizing Committee (IOC) of experts

Inter-comparison Metric

The critical concept of the inter-comparison project is to develop or specify a metric that does not use precipitation gauges. This is to initially avoid and to separate regional rainfall characteristic issues (Z-R relationship differences) issues, to avoid the point to area spatial variance issues and the QPE application requirements. In advanced radar QPE data systems, radar-gauge biases are commonly “calibrated” or "adjusted" to meet the requirements of the applications. A nowcast QPE system is quite different from a climate QPE system with respect to the frequency of the adjustment procedure.

The key concept is that artifact adjusted radar reflectivity data in "uniform" situations should have a smooth bias with range due to vertical profile of reflectivity effects and should have low azimuthal variance (see Fig. 2).

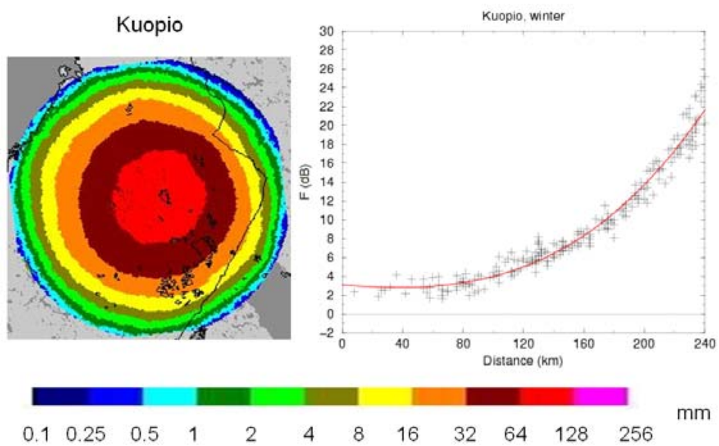

Figure 2: An accumulation of radar derived precipitation for Kuopio radar Finland. On the right, is the comparison of precipitation accumulation as a function of range. Figure courtesy of Daniel Michelson of SMHI and of the FMI.

It follows that the inter-comparison metric is:

$$\sigma^2(R) = \Sigma_\theta(Z(R)-<Z(R)>)^2/N_\theta(R) \quad (1)$$

where R is range from radar
Z is linear reflectivity
Σ_θ is the summation in azimuth
$N_\theta(R)$ is the number of points in azimuth at the specific range
$\sigma^2(R)$ is the variance of reflectivity as a function or range

and

$$\sigma_{Ave}^2 = <\sigma^2> = \Sigma_R\, \sigma^2(R) / N_r \quad (2)$$

$$\sigma_{Max}^2 = \max(\sigma^2(R)) \quad (3)$$

where σ_A^2 is the overall average variance
σ_{Max}^2 is the overall maximum variance

Characteristics of a Inter-comparison Dataset

Uniform radar fields are needed in order to compute the variance metric in order to remove the impact of the variability of the weather. These can be a single snapshot, or it could be generated from an accumulation of a whole (or more) season of data to generate a uniform data set for the radar.

Pilot Mini-Project

A pilot inter-comparison project was conducted to test the feasibility of the inter-comparison modalities. Various weather and artifact scenarios were selected and include:

- Uniform Weather (null case) with local clutter (well sited radar) or partial blocking
- Urban clutter
- Zero Notch Filtered
- Strong and multi-reflection Anomalous Propagation
- Sea Clutter of various intensity and characteristics

A sample of algorithms were selected and included.

Algorithm	Brief Description
CAPPI	Constant altitude slice through the volume scan data were made at 1.0, 1.5 and 3.0 km AGL. EC uses a 24 elevation scan with Zt data.
Doppler Notch Filtering	Signal processing technique. EC collects PPI data with both Zt and Zc data as part of the archive. Can also compare with the CAPPI techniques.
Fuzzy Logic – AP	The author coded up a version of the NCAR Fuzzy Logic technique that removes Anomalous Propagation echoes. This was applied to the sea clutter case as well.
Fuzzy Logic - SC	The author coded up a version of the NCAR Fuzzy Logic technique that removes Sea Clutter echoes. This was applied to all the other cases as well. This algorithm differs from the previous one in that radial velocity is not available and the membership functions are tuned differently.
Fuzzy Logic – CMA	The author had both QC and NONQC data from CMA that was part of the Beijing 2008 FDP project.
PRECIP-ET	Norman Donaldson of Environment Canada processed the data using a prototype EC algorithm that uses echo top, vertical reflectivity gradient to identify clutter. It was only run on a limited number of cases.

The following table shows preliminary results.

Case	Technique							
	RAW	CAPPI15	CAPPI30	Precip-ET	DOPPLER	REC_AP	REC_SC	CMA_AP
BOM_seaClutter		7.3	8.1		8.5	8.7	8.5	
Saudi_20020517		23.6	20.3		26	7.3	26.4	
Saudi_20020527		18.8	15.3		21.2	10	20	
TJ_bigAP_20060815_nonQC		8.2	7.2		8.7	7	9.4	
TJ_mix_20070825_nonQC		8.4	8.8		8.2	8.5	8.8	7.2
TJ_mix_20070825_QC		7.5	7.9		7.2	7.9	8.1	
VVO_zeroNotch_snow	7.3	7.1	5.6		6.7	6.7	6.7	
WKR_cnTower_Snow_20110324_dop*	11.5	10.3	8.4	7.4	9	10.3	10.6	
WYR_uniform_blockage_20101117_dop	9.3	9.4	8.1	6	8.8	8.6	8.8	
XLA_uniform_20100101_dop	5.9	4.4	3.1	3.2	4.6	4.4	4.5	

Summary

A concept for the RQQI project has been proposed, piloted and seems feasible. The concept of generating uniform reflectivity accumulation fields using short data sets seems feasible but will require some subjective interpretation.

One challenge will be to get before and after data sets where signal processing has been used to remove some of the artifacts. In these situations, special data sets may be required to be collected. Testing of signal or signal-data processing algorithms will be limited to research and some operational radars. The use of synthetic and/or simulated data sets are considered.

There are many other metrics that could be conceived and welcomed. Some thought is given to restricting the analysis to only artifact prone areas to increase the power (dynamic range) of the metric.

Not all techniques can be fairly applied to all data sets. This is fairly obvious but this should be kept in mind when processing case data in batch mode. For example, many techniques require a substantial number of elevation angles (greater than four; that is, a volume scan) to properly apply. Some techniques require radial velocity and some require spectral width. So these techniques can not be applied to those data sets.

At this stage in the project, the inter-comparison is restricted to reflectivity. Dual-polarization moments are considered in future projects.

Acknowledgements

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