P7.1 COMBINING C-BAND RADARS IN CANADA'S UPGRADED WEATHER RADAR NETWORK

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1. INTRODUCTION

Environment Canada has been engaged in a major upgrade of its weather radar network. (Lapczak, et al., 1999) This modernization will result in more radars, with Dopplerization across the network. An addition, communications to the radar sites haved been greatly improved, and now allow "raw" volume scan data to be available at weather centres and ultimately across the entire Environment Canada network. This allows more sophisticated processing to be done, particularly for techniques that combine data from multiple radars.

With more data flowing, a single forecaster may easily have six or more radars to consider, each of which may be producing more than 10 products. Needless to say, this disjointed situation is not conducive to either happy or efficient forecasting. One solution to this is to move from a single radar approach to one in which products are displayed on a single composite, with the ability to focus down onto individual storms when necessary. In principle, the only products that truly need to be seen on a single radar basis are radial velocity products, on which the viewing direction is critical.

Another issue that has become increasingly clear is that radars may not always agree in their calibrations. Techniques using multiple radars make it possible to routinely monitor relative calibration.

2. COMPOSITES

At the present time Environment Canada uses of radar composites ("mosaics") qualitatively as a supplement to other data, so their quality has not be of prime importance. On the other hand, when composites become the primary radar interface to forecasters then it becomes critical that the data in the composites be of the best possible quality and relevance.

There are a great many existing techniques for combining radar data in areas of overlap. Some choices are

a) Choose data from the closest radar
b) Choose the maximum value reported
c) Choose the data that is closest to the surface
d) Average together all nearby data regardless of source.
e) Choose radar with the smallest beam size
f) Choose radar data with time closest to analysis time

Behind these methods there is usually some implicit attempt to select data of the best quality (or relevance). For example, radar quality usually drops off at long range due to broadening beam size and increasing height, so choosing the nearest radar should help minimize those problems. The Canadian national composite is constructed from "maximum values", using the logic that the worst case data will be displayed and if the view from one radar is blocked then other radars may pick it up. On the other hand, this scheme has also excelled at finding ground clutter on clear days.

Quality issues which should be addressed in making a composite can be characterised as either permanent and transient. Permanent issues include ground clutter, blockage or partial blockage by terrain, and beam size. Transient problems are ones like attenuation and anomalous propagation. Solution of the transient problems requires dynamic quality assessment, which in practice usually means access to complete data sets (as opposed to building composites from a mosaic of images). Some issues are less clearly categorised. Beam height can be regarded as more or less fixed by the requested elevation angle, but the actual angle may differ or atmospheric conditions may bend the beam.

It is probably best to move from these implicit quality measures, to schemes that explicitly attempt to choose data of the best quality. This document will present some preliminary steps in that direction.

The immediate motivation for developing an

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improved composite generation was radar analysis of days with significant amounts of heavy rain. Since the Canadian network is C-Band the heavy rain can produce areas where the radar signals are highly attenuated. These areas are blind spots that are not always immediately recognised by forecasters, so it is desirable to flag them and pick up data from other sites instead.

Figure 1 shows an example from May 10, 2000. A line of strong cells is approaching King Radar from the south west. Badly attenuated areas are flagged as dark grey and it can be seen that the radar is blind over a large area to the south west. Conversely, the Exeter Radar, which lies to the south west in the blind area of King Radar, is blinded on the King City side of the storms.

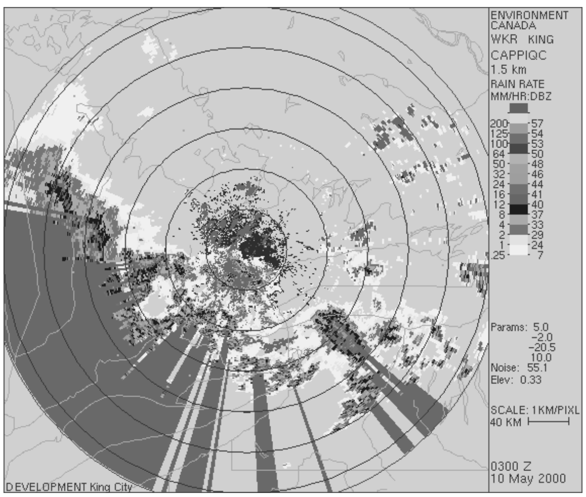

Figure 1- CAPPI image from King Radar on May 10, 2000. Dark grey indicates attenuated areas.

The development composite product discussed here is a CAPPI product made from the output of these same two radars in southern Ontario, but it is designed to ingest any combination of radars.

In the modular design of the radar processing system, CAPPI's from each radar are produced, in polar coordinates. For each datum in the CAPPI a dynamic assessment is made of its quality. Two factors are considered at the moment: similarity of the radar echo profile to the typical profile of ground echoes and an attenuation estimate due to echoes along each radial. If either of these is assessed as sufficiently negative then the cell is flagged. The polar coordinate data from each radar is then passed to the composite module. The composite module ingests each CAPPI in sequence and produces a gridded product. At each grid cell the appropriate datum from each CAPPI is assigned a quality value, based on a monotonic function of range from the reporting radar and on the quality flag from the CAPPI generator. If the quality factor of the current CAPPI is higher than the existing previous quality for the cell (initialized as -99) then the new datum and quality factor are assigned to the cell. After all radars are considered, the datum in the cell is accepted if its quality factor is high enough. If the composite module receives data that doesn't contain quality flags then the algorithm uses only range and degenerates to a "nearest radar" algorithm.

Figure 2 shows a composite from the same time as Figure 1. In this case, white areas are the ones in which nothing is considered to be known. The two radars are complementary, with one covering blind spots of the other. Some attenuated areas remain in the single-radar area to the south east of the King Radar.

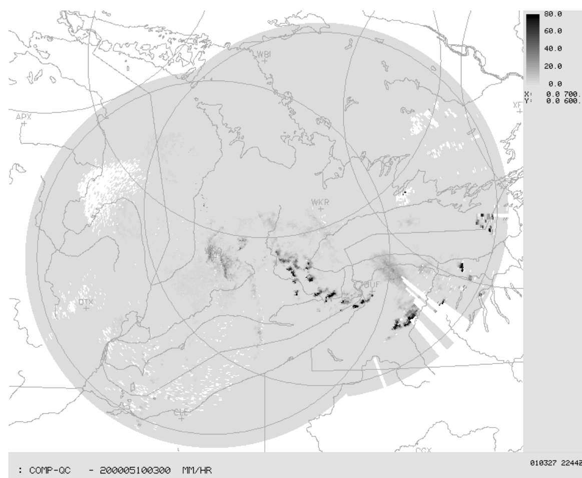

Figure 2 - quality controlled composite using two radars (King City and Exeter) on May 10, 2000.

The procedure is promising, but still very preliminary. Several improvements can be foreseen. First would be the inclusion of masks for blockage (distinguishing between total and partial). More fundamentally, the quality assessment procedure should be made more flexible by adopting either Bayesian or fuzzy logic techniques.

3. RADAR INTERCOMPARISON

Since complete radar volumes are now available on the Environment Canada network, procedures can be developed to collect collocated data from multiple radars and look for evidence of differences in calibration. This is not quite as simple as it initially seems. The sample scan times are only approximately aligned so the radars do not look at exactly the same volumes at the same time. On the other hand most radars run on a similar schedule so a given area at a specific elevation angle is scanned within a minute by nearby radars. Also significantly, there are typically height differences to be considered and good height matches need to be found. In the presence of strong vertical gradients some sort of vertical interpolation may be needed, but has not be done to date.

To cross-compare two radars, a module was written to extract columns of radar data centred over 5-10 locations along the centre line between the radars. For each radar the column consists of 24 elevations in the typical scan strategy. On each elevation an average reflectivity (ie average of Z not dBZ) was calculated for an area of about 3km along the beam and 13km across it (for results discussed below). Areal averages are adopted to give a better chance of corresponding volumes. Simultaneously, rays are checked for evidence of attenuation. After columns are available at each time from each radar another program collects all pairs of data for which both radars seem to have valid data. Differences are calculated for each point. Finally the results from some period of time are gathered and mean differences calculated.

Figure 3 shows a two dimensional histogram of reflectivity pairs from the King City and Exeter radars in southern Ontario. The data was collected from a variety of days through the year 2000. Ideally data would all fall along the diagonal line, but there is a clear offset of about 4 dBZ, accompanied by considerable scatter in individual measurement pairs. Breaking the data into individual sub-periods gives estimates that vary by about 1 dBZ, but there is no sign of a time trend. (Time trends in mean radar-radar differences give a clear indication of serious hardware problems, and have been seen on occasion at other sites.) The difference between the two radars here occurs because comparisons to surface data have historically indicated a 5 dBZ offset at King City, which is applied to the data after engineering calibration procedures. No such empirical offset is applied to the similar system at Exeter. At the moment data from the two radars can be offset to become consistent, but more work is required to decide on corrective action.

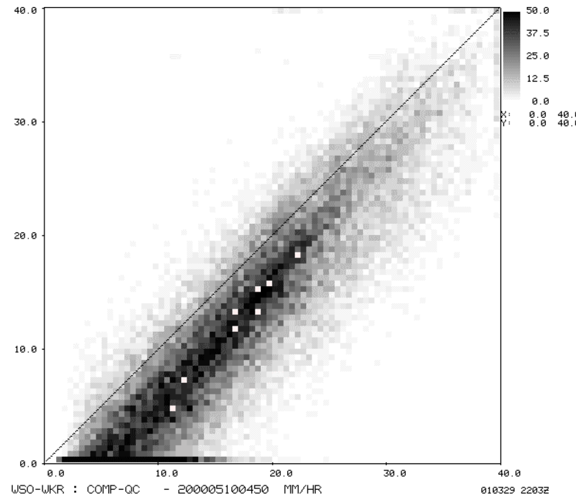

Figure 3 Two dimensional histogram of reflectivity pairs from King City (horizontal) and Exeter (vertical). Dark colours indicate pairs with highest occurrence.

6. CONCLUSIONS

With higher quality networked radars, there is a need to move to improved products that combine the results of multiple radars. Two areas of immediate application are the creation of composites with explicit consideration of radar quality and algorithms that cross-compare calibrations between radars.

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