11B-8 Considerations for the Detection of Low Lying Winter Weather in the Canadian Weather Radar Network

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1. Introduction

Low lying, low reflectivity snow is a prevalent feature of winter weather in Canada and often escapes detection by radar due to overshooting. Snow can be topped as low as one kilometer above the ground, with observations from field campaigns indicating that about one tenth of 10 dBZ echotops and one quarter of 0 dBZ echotops lie below 1km. While low top snow does not usually have large precipitation rates, it can cause serious visibilty problems on highways, and in some locations it can persist for many hours or even days, which leads to significant accumulations. Forecasters have been very keen to have this snow detected, and past trials of FFT Doppler ground clutter filtering at the King City radar indicated the potential usefulness of zero degree elevation scan. Therefore an analysis was done of all radars in the Canadian weather radar network (Joe and Lapczak, 2002) to improve detection of low lying winter weather. The analysis indicated that it was practical to lower scan elevations at most radars and this was done for the winter 2002-03. Forecasters accessed the new scan strategy using a new product suite called the Winter Drill-Down Scenario (WIDDS). The results of lowering the elevation angles were monitored and have been considered a success.

2. Visibility Analysis

In order to establish the lowest angles feasible, the GTOPO30 digital elevation map (DEM) was used to calculate the range from the radar antenna to the nearest topography for each radar antenna, as a function of antenna azimuth and elevation. GTOPO30 was created though a collaboration led by the US Geological Service and has a 30arc second resolution. Figures 1 and 2 show two sample outputs from the analysis. The analysis is imperfect because the GTOPO30 resolution of 1km can be inadequate where there is significant topographic variation near the radar site and because it does not account for trees and buildings. Nonetheless, previous comparison of DEM based clutter maps with observed clutter gave confidence that using DEM was basically sound. The shortcomings were recognized and some knowledge of particular radars used to subjectively adjust the application of the results.

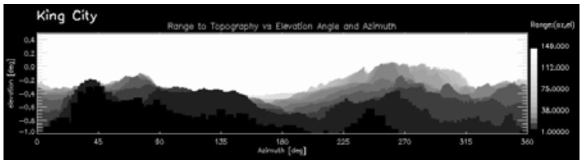

Figure 1: Calculated radar horizon from the King City radar. Grey scale indicates the range to nearest topography as a function of azimuth and elevation.

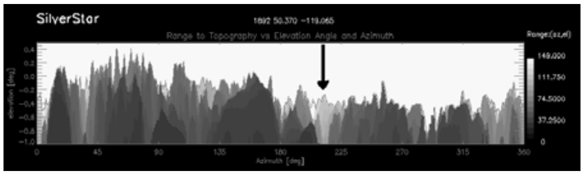

Figure 2: Calculated radar horizon from the mountain top SilverStar radar. Grey scale intensity indicates the range to nearest topography as a function of azimuth and elevation. An arrow indicates the valley of prime interest.

Several parameters were used to determine the very low elevation scans to be used. Maximal precipitation detection over local population centres and highways needed to be balanced against issues of ground clutter, partial and full beam blockage and the loss of long range coverage. Two concepts developed: the LOwest Local Application Angle (LOLAA) and the Best Angle for Long Distance - (BALD). LOLAA was undertaken with a slow Dopplerized scan with FFT clutter suppression, BALD was undertaken with a faster scan at a higher elevation to give coverage in range for monitoring synop-

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tic scale precipition.

Determining BALD was usually straightforward, while the LOLAA was determined from a more subjective balancing of many factors. At most radars the starting point for LOLAA was the lowest angle at which the radar beam centre passes closely along the median angle of the horizon. This starting point was adjusted to balance the priorities for the radar. It was recognized that quantitative reflectivity estimates and precipitation estimates using the LOLAA scans would be compromised due to violation of the beam filling assumption and/or overcorrection by the ground clutter filters. Table 1 shows distribution of LOLAA and BALD elevation angles across the Canadian network for winter 2002-03.

The King City radar presents a typical case. The 30m tower is atop a small ridge, giving reasonable visibility in all directions. At this radar zero degree elevation scans have been done previously but examination of the DEM data indicated a slightly lower LOLAA scan (-0.1) could improve coverage of several lake-effect snow areas, while introducing some blockage to the east and west. The BALD angle was slightly higher, at 0 degrees to provide good long range coverage.

An extreme case of the LOLAA occurred at the mountain top (1880 m ASL) radar at Silver Star in British Columbia. The Silver Star peak is surrounded by other peaks, so extremely low level scans are blocked for most azimuths, but the overwhelming majority of the regional population lives below in a single valley (indicated with an arrow on Figure 2). In this case LOLAA was an extremely low (-0.5 degree) elevation, whereas the BALD angle intended to monitor synoptic precipitation patterns remained at the more moderate elevation of 0.0 degrees.

Finally it should be mentioned that Canadian forecasters use multi-radar regional composites as their interface to radar data. The Canadian Radar Decision Support system (CARDS) allows the compositing by means of either "nearest radar" or "maximum reflectivity" algorithms. "Maximum reflectivity" has the distinct advantage of implicitly compensating for blockage issues in low level precipitation but has the disadvantage of selecting virga seen aloft at long ranges by a distant radar, rather than "no echo" as actually measured at low elevations by a nearby radar. A decision was made to move to nearest neighbour for the WIDDS interface.

Summary of LOLAA and BALD angles
Winter 2002-03

Radar ID	Radar Name	BW	LOLA	BALD
	PrevStandard		0.5	0.3
WTP	Holyrood	1.10	-0.2	-0.22
XME	Marble Mtn	0.65	-0.4	0.0
XMB	Marion Bridge	1.10	0.0	0.1
XGO	Gore	0.65	0.0	-0.1
XAM	Val d'Irene	1.10	-0.6	-0.5
WMB	Lac Castor	1.10	-0.5	-0.3
WVY	Villeroy	1.10	0.1	0.3
XLA	Landrienne	1.10	0.0	0.0
XFT	Franktown	0.65	0.0	0.3
WKR	King	0.65	-0.1	0.0
WBI	Britt	0.65	0.0	0.3
WSO	Exeter	0.65	-0.1	0.0
WGJ	Mtl River	1.10	-0.4	0.1
XNI	Lasseter	1.10	0.0	0.2
XWL	Woodlands	0.65	0.0	0.1
XFW	Foxwarren	1.10	0.1	0.3
XBE	Bethune	0.65	0.0	0.3
XRA	Radisson	1.10	0.1	0.3
WHN	Jimmy Lake	1.10	0.1	0.3
XBU	Schuler	1.10	-0.1	0.1
XSM	Strathmore	0.65	0.0	0.2
WHK	Carvel	0.65	0.1	0.3
WWW	Spirit River	1.50	-0.2	0.2
XSS	Silver Star	1.10	-0.5	0.0
WUJ	Aldergrove	1.10	0.5	0.3
XSI	Mt Sicker	0.65	-0.4	0.1

The table shows the LOLAA and BALD elevations for the radars in the Canadian network. BW is the beamwidth of the antenna.

3. Operational Results

3.1 General Reaction

After the new winter configurations were implemented the radar team monitored radar data and waited for forecaster feed-back. Given the imperfections in using the coarse DEM, there was some risk of the unexpected, but reaction was very positive. Forecasters from both Ontario and British Columbia made the point that they had issued warnings that would not have been possible before.

3.2 Sea Clutter

Forecasters from Atlantic Canada sent a request for interpretation of a phenomeneon they did not recognize. It was quickly diagnosed as sea clutter since the radar elevation side lobes were now seeing the ocean surface down two valleys. (The sea clutter appeared and disappeared in strange ways, which may have been due to sea ice being pushed by the wind.) On examination other radars were also seeing water surfaces, but sea clutter was not considered a significant problem at any radar.

3.3 Clutter Filtering

At King City radar weak snow cells were seen to disappear and reappear as they moved. It was quickly realized that this behaviour was due to radar pixels which contained weak ground clutter in addition to even weaker snow echoes. Our system uses the clutter-to-signal ratio (CSR) to decide whether or not to reject radar echoes. The CSR threshold is initially applied weakly in the signal processor and then again in product generation software. The signal processor CSR threshold is 40 db (i.e. reject data if weather signal is decided to be less than 1 part in 10,000). In winter 2002-03 the product CSR threshold was set at 18 dBZ. Since the software threshold was historical and based primarily on summer weather, a re-examination was undertaken of this value. Products were generated with various levels of the software CSR threshold. Raising the threshold would be expected to allow more ground clutter into the products while increasing the amount of weak precipitation. It was found that completely removing the software threshold gave the best results. Very few new ground echoes appeared, while a significant number of weather pixels appeared. (Figure 3). It has been recommended that this filter be turned off in the next network-wide winter configuration change. It is not clear that these conclusions apply equally to summer weather, where anomolous propagation (AP) is more common and detection of weak precipitation less important.

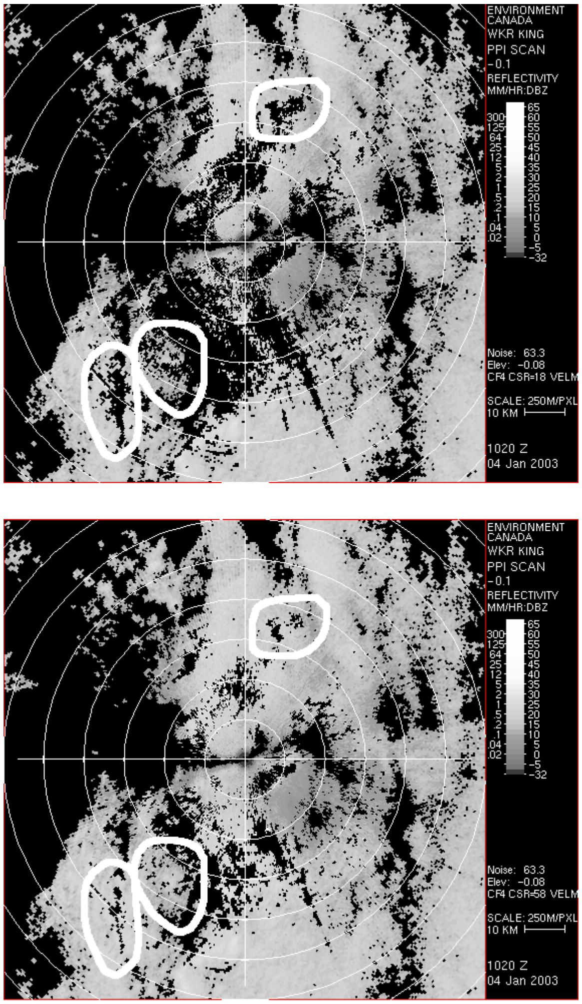

Figure 3: Radar PPI of corrrected reflectivity from King City with 2 levels of clutter processing: CSR=58 and CSR=18. Some areas where the 18dBZ threshold is removing precipitation are indicated.

3.4 Blockage

At the King City radar site, tree and nearby topographical variations made some calculations from the DEM seem a bit uncertain. To assess this, accumulations were examined during periods of widespread precipitation. Blockage and partial blockage appeared in the expected area but some areas were more serious than hoped.

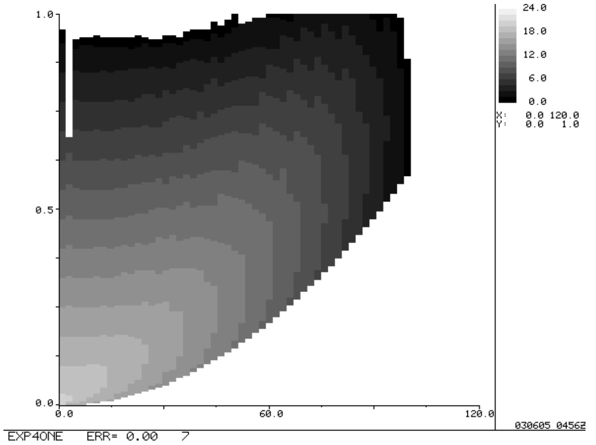

Figure 4: Simulated RHI of exponentially decreasing snow profile seen with a 0.67 degree beam. Ranges in kilometres and heights in kilometres. The horizon is assumed to be at 0 degree elevation.

3.5 Antenna settling

In the process of verifying blockage from the King City site it became evident that the antenna was occasionally not settling properly and the the antenna elevation wandered around the requested elevation. The King Radar antenna pedestal dates from 1984 and it was hoped that newer antennas settled more predictably. Checking with data from the nearby Exeter radar, with a newer antenna, showed the antenna settling quickly at all times. Nonetheless, all antennas seemed to settle to angles slightly lower than the requested elevation.

4. Sampling Simulations

The results of the accumulation assessments suggested that the strategy of choosing a LOLAA elevation such that the beam centre was near the median horizon might not be optimal. This was explored further by writing a program to calculate an idealized RHI for an exponential profile typical of snow, based on ones seen in southern Ontario. The calculation assumed a Gaussian beamwidth of 0.67 degrees and smoothed the profile to reflect this. (Within the Canadian radar network 10 radars have 0.67 degree beamwidths, and the rest have 1.1 degree beamwidths.) Contributions from the portion of the beam pointing below the horizon were removed. Figure 4 shows a typical result, with the horizon set at 0 degrees elevation. The important thing to note here is that the maximal signal is not achieved by pointing the beam at the horizon. The beam pattern is essentially "flat" near the antenna axis so raising the elevation slightly only negligibly decreases the power skimming the horizon while increasing the power illuminating higher elevations. Thus the antenna axis should be pointed slightly above the horizon for maximal chance of detection of low level precipitation. The exact angle above the horizon will depend on the precise details of the antenna pattern and the exact, unknown, profile of the reflectivity of the precipitation. In general the angular height above the horizon that provides maximum returned power is also a function of range to the precipitation. In the example shown the maximal returned power at 60km is obtained 0.15 degrees above the horizon. From these simulations it is concluded that for maximum detection capability our antennas should point at an elevation of 0.1 to 0.2 degrees above the horizon.

5. Conclusions

The low level scanning (LOLAA and BALD) introduced for the winter of 2002-3 proved highly successful and was well received by the forecast community. Weather was detected by radar in locales that were “blind” in the past and weather warnings were issued that previously would not have been previously made.

Evaluation and assessment of observations and simulations indicate that some of the LOLAA angles may have set been slightly low. The initial concept of pointing the antenna at the horizon to maximize detection of shallow precipitation gives an elevation that not optimal, and this was compounded by antennas that settle slightly below the requested angles. Some sea clutter appeared at sites where it had not been noted previously but this was not a significant problem. It was also noted that clutter filtering was too aggressive for winter situations.

It is intended that this strategy will be repeated in subsequent winters, with minor revisions based on the follow-up assessment.

6. References

Joe, P. and S. Lapczak, 2002: The Canadian Radar Network Performance and Network Processing Concepts. *Procedings 2nd European Conference on Radar Meteorology*, 370 - 382, Delft.

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