Usefulness of Bright Band Climatology in South Central Canada

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1 Introduction

Numerous studies have shown that one of the major factors producing errors in radar rainfall estimates at the surface is the effect of the vertical profile of reflectivity (VPR) (Joss and Lee, 1995). Of particular interest is the effect of the radar bright band that is due to the melting level in climatic regions where the precipitation has a significant stratiform contribution (Mittermaier and Illingworth, 2003). Several methods for determining a VPR correction scheme are presented in the literature, but in general they can be classed into direct and indirect methods. Direct methods involve the use of volumetric radar data in some way to determine a VPR and then apply a correction factor to the radar data. Vignal et al. (2000) describe three methods to determine a VPR from volume radar data and detailed formulations are given by Andrieu and Creutin (1995a,b). Indirect methods are mainly based on deriving a family of simulated VPRs by varying the height of the melting layer and the magnitude of the peak of the bright band. Indirect methods can be either static, based on climatology, or dynamic, based on some assessment of current atmospheric conditions (Kitchen and Jackson 1993). It should be noted that static range dependent corrections of radar rain estimates are implicitly based on a static VPR.

The main focus of this paper is on the latter method of VPR determination, but more specifically the importance of the melting layer heights in applying a VPR correction scheme in the absence of sufficient radar data to determine reflectivity profiles. Since the VPR is dependent on the meteorological conditions, knowledge of the climatic conditions of the region of interest would be useful. The climate of Southern Ontario is semi-continental, with a mixture of flows from continental air masses from the north and central United States and modified maritime masses from the Gulf of Mexico and the Atlantic Coast.

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The regional climate is also complicated by the surrounding Great Lakes to the south and northwest. Lake breezes can severely affect the climate in the region during winter with heavy snow squalls and moderate convection in the summer months.

Two results of this complicated meteorology should be noted. First, the bright band height can vary quickly as regimes change. Second, multiple occurrences of 0^oC can occur in temperature profiles when different air masses are overlaid. Given this climate we wish to assess how well static profiles might be expected to perform. In other words, we wish to determine how variable the bright band height is with time.

2 Data.

The Canadian Meteorological Centre (CMC) regional model was selected as a source of melting level data from 1999 to 2005. The data is in Model Output Location Time Series (MOLTS) format which provides data on all model levels at 1-hour resolution. Model runs from 00 UTC provide a 36 hour forecast of surface pressure, rainfall rate, and dry bulb temperature at 58 ETA levels. In developing our climatology only the first 24 hours are used. The grid point selected for the model runs was chosen to coincide with the location of a 915 Mhz wind profiling radar at Egbert Ontario (43.96N 79.57W) about 70 km to the northwest of Toronto.

The height of the 0^oC degree isotherm is interpolated from the MOLTS temperature profile. In the case of 0^oC at multiple levels, the upper level was chosen. In situations where the entire profile is below freezing, isentropic extrapolation using a lapse rate of $-6.5^oC/km$ was applied to get the 0^oC level below ground. This extrapolation was necessary to avoid biased statistics.

The wind profiler can be used to estimate the melting layer by examining the vertical structure of reflectivity and vertical velocity. When the wind profiler is running, an estimate is produced approximately every 4-6 minutes with a vertical resolution of 105 metres. False estimates can occur when non-precipitation artefacts produce the same patterns as precipitation. These data can be used to assess whether NWP performs reasonably well at forecasting melting levels in our region.

3 Results

The wind profiler estimates of the melting layer were created for all available vertical profiles. The heights were averaged for each hour to compare with the heights given by the MOLTS data. Figure 1 shows the scatter plot of the heights of peak reflectivity from the profiler (2800ns pulse) against MOLTS melting levels. There is a relatively high correlation of 0.9 for the data pairs. Outliers are a combination of model errors and misdiagnosis of the wind profiler data. A Least Absolute Deviation (LAD) regression gives a slope of 0.95, and the mean absolute deviation is approximately 200 metres, with an intercept of 100 meters. In general the bright band peak is expected to be a hundred metres or more below the melting level (Fabry and Zawadzki 1995). In addition the smoothed model topography differs from the true elevation at the profiler site.

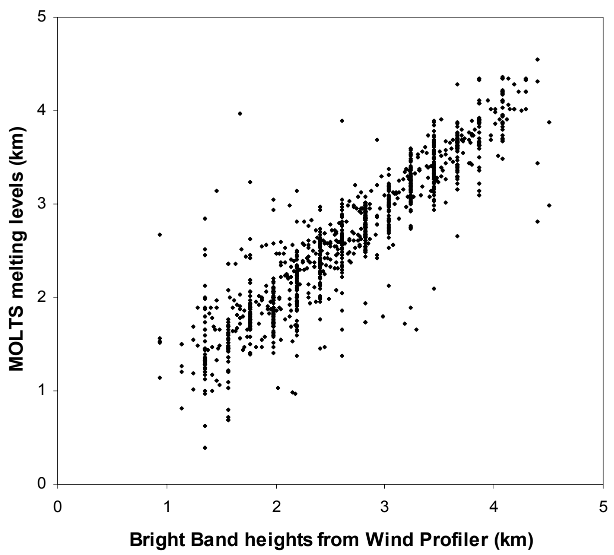

Fig. 1. Scatter plot of hourly averaged wind profiler bright band heights against melting levels from MOLTS.

MOLTS melting level data were selected in two groups, one when the model estimated rain rates at the surface were at least 0.1 mm/h and the other for rate greater than 1.0 mm/h. This resulted in a total of 6956 hours of melting level heights for R>0.1 mm/h and 1310 hours for R>1.0 mm/h for statistical analysis. Figures 2 and 3 show the monthly distributions of 0^{o}C heights for the period 1999 to 2005 for the respective rain rates.

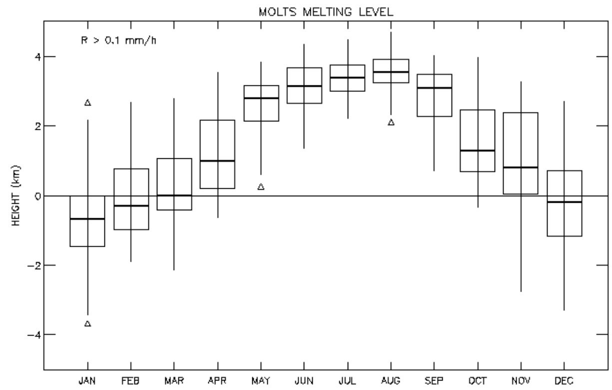

Fig. 2. Box and whisker plot of monthly melting height distributions from 1995-2005 when surface model rain rates were at least 0.1 mm/h.

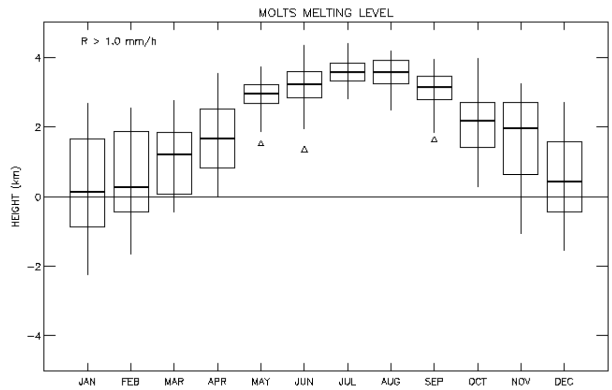

Fig. 3. Box and whisker plots of monthly melting height distributions from 1995-2005 when surface model rain rates were at least 1.0 mm/h.

In these plots the horizontal thick lines show the median monthly melting level heights. The boxes represent data between the first and third quartiles and the whiskers show data from the 12.5 to 87.5 percentiles. Although Figures 2 and 3 show that the distributions are clearly skewed, Table 1 summarizes the conventional statistics of the monthly distributions of the melting level heights for R > 0.1 mm/h. The extremes have been highlighted.

During the winter months the median height of the melting levels is slightly above ground when R>1.0 mm/h and below when R>0.1 mm/h. The difference between these thresholds is largely due to the proportionally lighter precipitation in Arctic masses. Median melting levels rise to above 3.5km in mid-summer. It is apparent that bright band problems can occur in all seasons, although the high levels in summer mean that overshooting at very long ranges is a larger problem than direct bright band contamination. Seasonal changes in variability can be seen by comparing August and November for the lower rain rate threshold. In August the central 50% of the melting level heights fall in a range of about 750m, whereas in November there is a much larger variation of around 2500m. For the larger rain rates cases a similar trend is observed. Overall the distributions of the melting layer heights show large spreads in all months, with the least spread in summer.

Month	Mean (km)	Median (km)	st.dev. (km)	m.a.d. (km)
JAN	***-0.61***	***-0.67***	1.22	0.94
FEB	-0.03	-0.28	1.13	0.93
MAR	0.27	0.00	1.05	0.85
APR	1.20	1.00	1.05	0.92
MAY	2.54	2.81	0.89	0.70
JUN	3.10	3.15	0.70	0.57
JUL	3.41	3.40	***0.50***	0.41
AUG	***3.51***	***3.56***	***0.50***	***0.39***
SEP	2.80	3.08	0.89	0.73
OCT	1.54	1.29	0.98	0.86
NOV	1.09	0.81	***1.25***	***1.11***
DEC	-0.10	-0.18	1.24	1.02

Table 1. Summary statistics of monthly distributions of 0^oC isotherm heights from 1999-2005 (R > 0.1 mm/h).

4 Conclusions

We conclude that there is little benefit to using static, climatological VPR's in our region. With the high variation of bright band height within individual months, any gain due to bias reduction would be offset by large increases in the variances of the estimates. On the other hand good comparison of the NWP to the wind profiler suggest reasonable corrections can be obtained using VPR derived from hourly melting levels from the model.

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References

Andrieu, H. and J. –D. Creutin, 1995a: Identification of vertical profile of reflectivity for hydrological applications using an inverse method. Part I: Formulation. *J. Appl. Meteorol.,* 34, 225-239.

1995b: Identification of vertical profile of reflectivity for hydrological applications using an inverse method. Part II: Sensitivity and case study. *J. Appl. Meteorol.,* 34, 240-259.

Fabry, F and I. Zawadzki. 1995: Long-Term Radar Observations of the Melting Layer of Precipitation and Their Interpretation. *J. Atmos. Sci.,* Vol. 52, No. 7, 838–851.

Joss, J. and R. Lee, 1995: The application of radar-gauge comparisons to operational precipitation profile corrections. *J. Appl. Meteorol.,* 34, 2612-2630.

Kitchen, M. and P. M. Jackson, 1993: Weather radar performance at long range – Simulated and observed. *J. Appl. Meteorol.,* 32, 975-985.

Mittermaier, M. P. and A. J. Illingworth, 2003: Comparison of model-derived and radar-observed freezing-level heights: Implications for vertical reflectivity profile-correction schemes. *Q. J. R. Meteorol. Soc.,* 129, 83-95.

Vignal, B., G. Galli, J. Joss and U. Germann 2000: Three methods to determine profiles of reflectivity from volumetric radar data to correct precipitation estimates. *J. Appl. Meteorol.,* 39, 1715-1726.