P4A.9 Summer Severe Weather Occurrence in Southern Ontario – A Climatological Perspective.

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1. INTRODUCTION

The objective of this study is to develop a severe weather climatology for southern Ontario using the King City radar archive. The information from this study will be beneficial in radar-based severe weather algorithm development, nowcasting applications, and climate studies (Bellon and Zawadzki, 2003).

The King City C-Band Doppler radar data archive extends back to 1985. The recent implementation of the universal radar processing (URP) software within the Meteorological Service of Canada (Joe and Lapczak, 2002) has provided the necessary tools for developing the methodology. The modular nature of URP and its ability for thunderstorm cell detection and cell tracking is the basis for the study. Additionally, the study provides a means of assessing the algorithms within URP.

2. METHODOLOGY

The radar scanning strategy in place at King City since 1985 consists of the following cycle. Firstly, the radar performs a 24 angle volume scan from top to bottom collecting reflectivity (Z) only data. The highest elevation angle is 24.7^o and the lowest is 0.3^o. The maximum unambiguous range is 256 km. The reported data resolution is 1.0^o in azimuth by 1.0km in range. Next, three PPIs collecting Doppler velocity as well as Z are carried out at 3 elevations, 0.5^o, 1.5^o, and 3.5^o. The range of these scans is 112 km. The Doppler scan data is reported at a higher resolution of 0.5^o in azimuth and 0.5 km in range. The scan cycle is repeated every 10 min.

The database for the first phase of the analysis consisted of the years 1995 to 2001 and concentrated on the summer months, May to August. The images from the data archive were examined for significant precipitation. As a result 403 days from the seven years of data were selected for further analysis.

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The archived data is then processed sequentially by the URP modules. The products of interest from the conventional volume scan were the Maximum Columnar Reflectivity (MAXR) above a height threshold of 2.0 km, Vertically Integrated Liquid (VIL) above 1.5 km (Vil15), 3.0 km (Vil30), 5.0 km (Vil50) and Echotop (ET). Also, a Severe Weather (SVRWX) product was derived. The definition of the severe weather levels are given in Table 1.

SVRWX Level	Height Threshold (km)	Reflectivity Threshold (dBZ)
1	5.5-8.5	40
2	8.5-10.5	40
3	10.5-12.0	40
4	>12.0	40

Table 1. Definition of SVRWX levels.

The Doppler scan data is ingested by the URP Mesocyclone detection algorithm (Zrnic et. al., 1985). The URP predefined alert codes for this product are defined in Table 2.

Alert Code	Condition
1	Azimuthal shear at either of the top 2 elevations.
2	Azimuthal shear is found at top 2 elevations.
3	Azimuthal shear found at all 3 elevations.
4	Code 3 plus gate to gate shear greater than 12 $ms^{-1}km^{-1}$ and momentum greater than 100 $ms^{-1}km$.
5	Code 4 plus shear across multiple azimuths.

Table 2. Definition of mesocyclone alert codes.

Some advanced features of URP are its Cell Identification (CellID), Cell Property (CellProp), and Cell Tracking (CellTrack) algorithms. Additionally a complex Storm Assessment and Classification (SAC) routine is implemented. These routines are based on the methodology

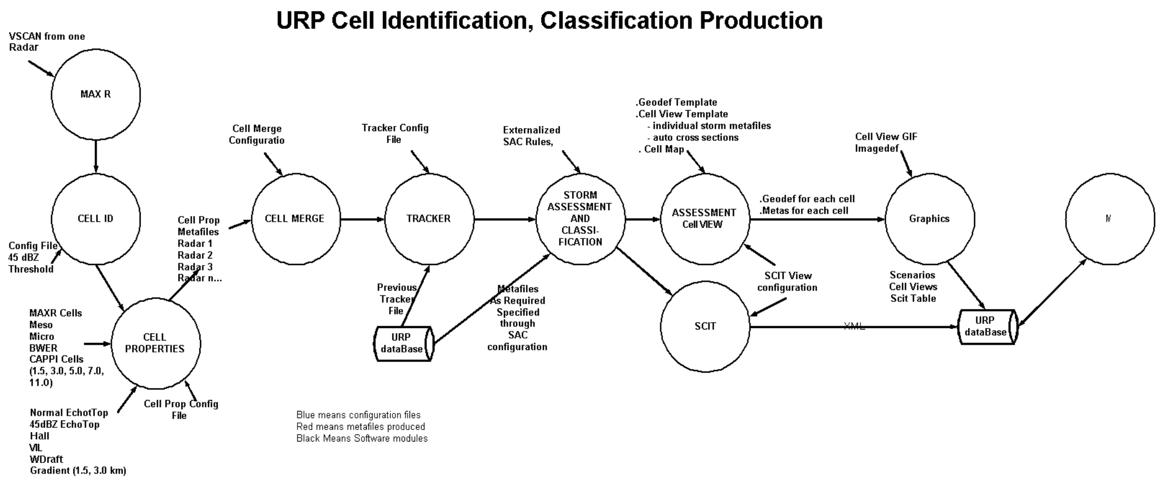

Figure 1. Flow chart of URP radar processing software
and storm cell processing and tracking. From Joe and Lapczak, 2002.

of Dixon and Wiener (1993). Storm cells were identified by CellID using the MaxR product. A threshold of 45 dBZ and a minimum of 2 pattern vectors were used. Storm cells are then passed to the CellProp module, which extracts a pre-defined set of properties of the identified cell such as the VILs, Echotops, SVRWX, and Meso. The storm cells are then tracked by CellTrack and their properties carried along until the cell ceases to fit the criteria for a storm cell. Figure 1 summarizes the cell processing functions of URP (Joe and Lapczak, 2002).

3. RESULTS

3.1 Convective Cell Identification

The initial analysis of cell counts from the seven years of data produced on the order of 160,000 individual cell detections. These were then filtered to better identify severe weather cells using the criteria for SVRWX of level 2 or greater and echotops higher than 8 km. The resulting total cell counts was 19,350 or approximately 12% of the original counts. Svrwx level 2 and higher indicates the 40 dBZ threshold above 8.5 km. The following are characteristics of this reduced set of storm cells. The maximum Vil15 values ranged from 5 kgm^{-2} to over 100 kgm^{-2} with a median of 32 kgm^{-2}. The median echotop height was 13.3 km and the median reflectivity was 60 dBZ.

Figure 2 shows the frequency distribution of storm cell detection as a function of time of day (UTC=Local Time + 4 Hours). The trend clearly indicates the diurnal variation due to daytime dynamic forcing. The maximum thunderstorm activity occurs at 2200 UTC (1800 local time) and a broad minimum from 0800 UTC to 1600 UTC (0400 to 1200 local time)

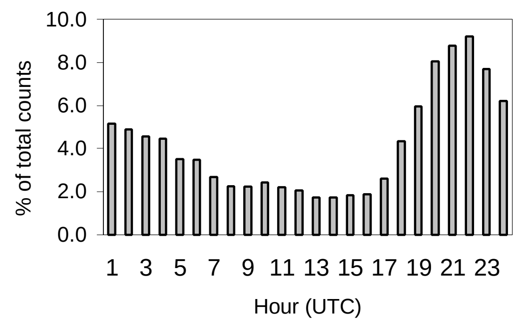

Figure 2. Diurnal variation of cell counts.

Figure 3 shows the monthly variation of cell counts. A peak of activity occurs for July, which is typically the warmest month of the season. Cell counts in July are more than double those in May.

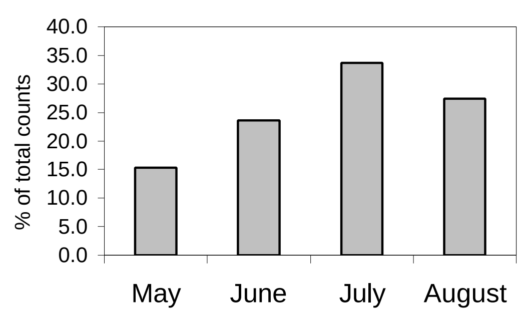

Figure 3. Monthly variation of cell counts.

Figure 4 shows the yearly variation of storm cells. The year-to-year variation is considerable with more than a factor 4 difference in cell counts from the lowest to highest year. Most noteworthy is the minimum in cell activity in 1997 corresponding to the strong El Nino episode.

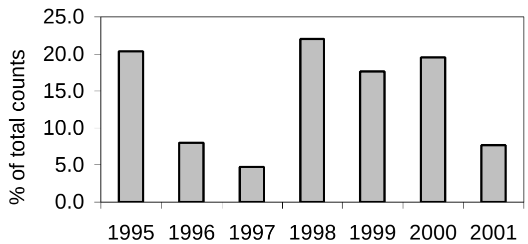

Figure 4. Yearly variation of cell counts.

3.2 Diurnal variation of cell properties

The diurnal variation of the characteristics of the storm cells was examined next. It was decided to focus on the maximum cell properties rather than average properties, as this would be a better indicator of the severity of a particular storm cell.

Figure 5 shows the hourly averages of the maximum echotops. The echo tops have a maximum at 1100 UTC (0700 local time) with a secondary maximum at 2200 UTC (1800 local time). The latter peak corresponds well with the cell count hourly peak. The former one, when cell counts are a minimum probably is representative of extensive warm frontal cloud systems where the number of individual cells is less.

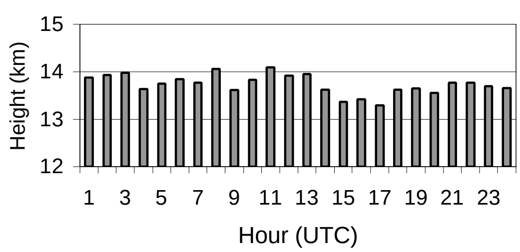

Figure 5. Diurnal variation of echotop height (km).

Figure 6 shows the diurnal variation of the averaged maximum reflectivity of the storm cells. This pattern is similar to Figure 5. The VIL properties of the identified cells (not shown) display similar maximum and minimum with hour of the day.

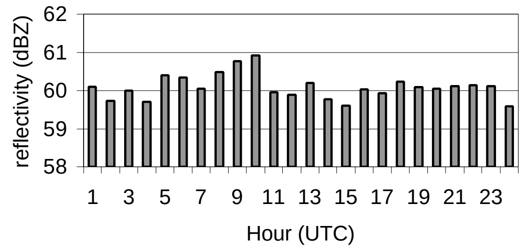

Figure 6. Diurnal variation of reflectivity (dBZ).

3.3 Geographic distribution

The distribution of storm cell location was gridded to 20 km and superimposed on a topographic map of southern Ontario (Figure 7). Besides the three Great Lakes, the main topographic feature is higher terrain (darker shading) running in a north-south line west of the radar (WKR), known as the Niagara Escarpment. In Fig. 7, H indicates maxima in cell counts and L minima. The minimum near the radar is due to the cone of silence of the volume scan. The maxima and minima in cell count locations can be seen to be tied to the shores of the Great lakes and over the Niagara escarpment. There have been other studies of the spatial distribution of convective activity over southern Ontario. Burrows et. al. (2002) examined lightning flash density for the period 1998 to 2000 and King et al. (2003) examined tornado occurrence. The geographical distribution of cell location in this study will provide a valuable data sources with which to examine the relationship among thunderstorm location and lightning and tornado occurrence.

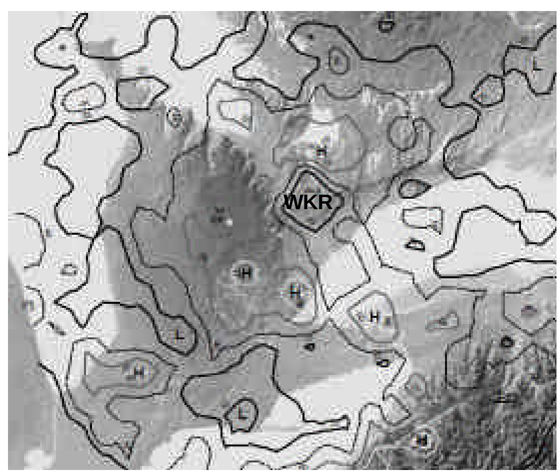

Figure 7. Geographical distribution of storm cells.

3.4 Mesocyclone detections

The mesocyclone detection algorithm was used to process data for 1996-1998. Detections of alert code 1 and above was included in the preliminary analysis.

The occurrence of mesocylone centres as a function of radar range is given in Figure 8. It is evident that there is a clear range bias in the data. Mesocyclone detections are highly concentrated at and around the radar within the first 10 km. The detections then level off to 60 km, then drop off sharply beyond 60 km. This is an effect of the angular resolution and beam broadening on the meso algorithm.

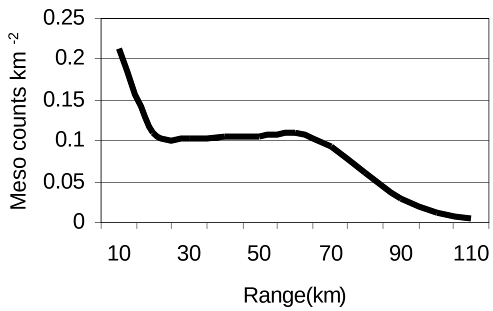

Figure 8. Counts of mesocyclone detections for range bins of 10 km and normalized by area.

4. SUMMARY

A methodology for creating a radar-based climatology of severe weather has been developed with the use of URP. Based on cell identification, tracking, and analysis of cell properties the diurnal, monthly and year to year variation of severe thunderstorms in southern Ontario have been presented. The preliminary climatology have shown temporal and geographical features consistent with independent climatologies of lightning and tornadoes. Additionally the processing of an extensive data set has provided some insights into the radar algorithms and have lead to improved guidance into their interpretation.

Analysis of cell tracks and their related properties is currently underway. Also, additional years are being added to the analysis. In the longer term, the information from this study can be used to relate severe weather events to larger scale climatology of weather patterns and to also provide a validation database for climate models.

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