Radar Data Processing for Severe Weather in the National Radar Project of Canada

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1. INTRODUCTION

The Meteorological Service of Canada is implementing a network of thirty C Band Doppler radars (Lapczak et al, 1998). The project began in 1997 and will end in 2003. It updates an existing network of twenty conventional radars. There were four existing Doppler radars. Ten new radars were added and the rest were upgraded. As the radars were installed, they were commissioned for operations resulting in a mixed network of Doppler and conventional volume scanning radars during the life of the project. In addition, the radar locations were selected with the expectation of taking advantage of bordering Nexrad radars.

Radar processing software was developed in a phased approach. The first version of the software was based on the research-operational processing system at the King City radar. It was modified to meet operational maintenance requirements and was implemented to process the first two project radar installations. The second version of the software addressed Y2K issues and was implemented right across the country. The most recent version of the software, called the Canadian Radar Decision Support (CARDS) system, focuses on the needs of the summer severe weather forecaster. Highlights of the system will be described here.

2. THE SOFTWARE REQUIREMENTS

The requirements of the software are demanding. A single forecaster is responsible for providing severe weather warnings typically encompassing an area of up to eight radars - a region of 3 x 10^6 km^2 - an area comparable to the size of Europe. The forecaster must be able to maintain a broad view of the weather while at the same time be able to focus on individual thunderstorms. In addition, the type of severe weather across the country is quite varied.

3. THE DATA

At the current time, the scan strategy of the Doppler radars consists of a 5 minute 24 elevation conventional scan and a 5 minute 4 elevation Doppler scan. For the existing conventional radars, the 24 elevation volume scans are performed every 5 minutes.

4. THE SOFTWARE DESIGN

In order to maintain surveillance over the entire forecast domain and to make warning decisions at the thunderstorm scale, a multi-radar composite was developed in which the forecaster could "drill down" to products either at a radar scale or at a thunderstorm scale. Philosophically, there has been a major paradigm shift in the radar processing from single radar to a network concept.

In addition, the plethora of radar products must be presented in a succinct fashion to allow rapid and decisive assessment of individual radar views of thunderstorms. Algorithmic products are used to identify severe thunderstorm features in the radar data. Thunderstorm scale "cell views" were developed to merge the various products. Another important aspect was to rank and classify all the storms across all the radars and present the information in a SCIT table (Johnson et al, 1998).

In any product-display system, it is always a balance between effective products versus viewing functionality and display performance. A platform independent Java based viewer was developed to access and to interact with the radar products. To effectively use the limited screen space, the radar processing-viewer software was designed to use two high-resolution monitors. To effectively access a thunderstorm cell view product, "point and click/drill down" functionality was developed to link the composite, SCIT and cell view products.

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To create the maximum flexibility in a wide variety of weather regimes, virtually all aspects of the system are user configurable including the severe weather classification rules. To maintain a watch on upstream and cross-border weather, the system ingests, processes and integrates the Level 3 data from the NWS WSR88D radars acquired via NOAAPORT.

5. PROCESSING OVERVIEW

Fig. 1 shows an overview of the flow of the radar data volume scans from radar to processing centre. There a five major radar processing centres for severe weather; these include Vancouver, Winnipeg, Toronto, Montreal and Dartmouth. The warning offices are not necessarily co-located with the processing centres. However, they are connected via T1 network links and the viewing software can access the radar server over the wide area network.

Figure 1: Data topology of the Canadian National Radar Network. The radar icons indicate the location of the radars. Solid lines indicate existing pathways for the volume scans and the dashed lines indicate future radar installations. Dash-dot lines indicate inter-Regional data flow paths. Note the ingest of NEXRAD data at the Canadian Meteorological Centre and the subsequent re-transmission to the Regions via SATNET.

Fig. 2 shows the processing at a Regional radar processing office. Multiple radar volume scans (including NEXRAD Level 3 data) are ingested by a single invocation of the CARDS software. Two key elements of the software are that it is file based and that the science and graphics processing modules are split up. This allows the science processing and the image product processing to be distributed across Regions. Each science module creates a "metafile" product. For example, these may include fields of CAPPI's or EchoTops formatted in radar coordinate space and maintained at the volume scan data quantization resolution. These may also include outputs of the cell identification and mesocyclone algorithms, among others.

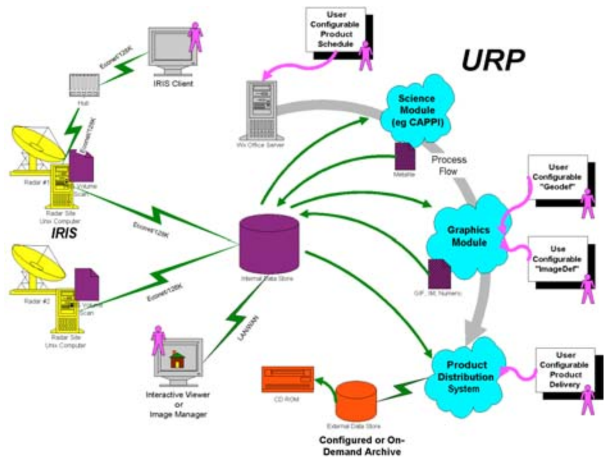

Figure 2: Schematic of the radar processing. See text for details.

Fig. 3 shows the "cell processing" processing specific to the severe weather aspects of the system. A MAXR metafile product from a single radar is created. This is thresholded, nominally at 45 dBZ, and a pattern vector feature identification technique (Zrnic et al, 1985) is used to identify thunderstorm cells. The average and maximum MAXR reflectivities and their locations (in latitude-longitude co-ordinates) are computed and stored in the CELLID metafile as well as the pattern vectors. These pattern vectors are used as a template or footprint and applied to other radar fields such as the echotop, VIL, etc and the properties of the cell are computed and built up. At the end of the CELL PROPERTIES module, the storm cell will be described by a plethora of radar derived storm properties.

The next step is to merge the cells in the overlapping radar regions. If the same cell is identified on two radars, we select the cell that has the largest reflectivity value. Other criteria could have been chosen but at this first implementation and considering that attenuation at C Band can be significant, this selection criteria seem most reasonable. At the end of the CELL MERGE step, we have a data set of all the cells from a single time step for all the radars in the Regional composite.

At this point we pass the data on to the TRACKER module which is based on the work of Dixon and Weiner (1993) to track the storms within and across radars.

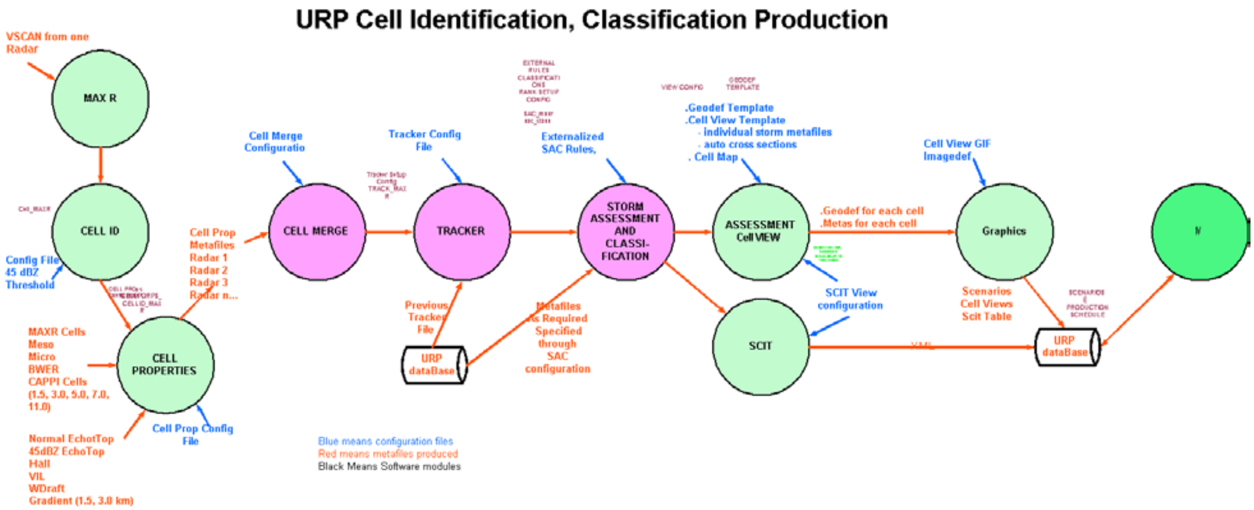

Figure 3: Thunderstorm cell to SCIT and Cell View processing. See text for details.

Following the TRACKER, we assess the storm for severity. This is done in two ways - by rank and by classification. To compute the rank, we categorize the following parameters - the maximum reflectivity, the VIL density, max Hail size, max 45 dBZ echo top, the downdraft potential, mesocyclonic shear and BWER confidence - as detected, weak, moderate or severe by thresholds. Then these categories are assigned a numeric value from 1 to 4 and then summed to get an overall rank for the storm. To compute the classification (such as supercell), user configurable rules are implemented to combine radar detected features (such as existence of BWER, mesocyclone and alignment of the echo top over the low-level gradient). Note that in practice, the rank is more useful since it sorts all the storms in the entire Regional domain and across all the radars.

The ASSESSMENT CELL VIEW module then takes the output from the TRACKER and STORM ASSESSMENT and CLASSIFICATION (SAC) module and creates the metafile for the SCIT table and the metafiles of individual thunderstorm cells.

6. THE INTERACTIVE VIEWER

The user interface to the products is absolutely critical. The functionality and performance of the user interface must match the products and interaction concept. To reduce the use of screen real estate and to increase the usability, all products can be created as multi-radar composites and these products are layered in the viewer so that the user can toggle instantly from one product to another. A platform independent JAVA application called the Interactive Viewer (IV) was created. This uses interactive web technology to serve and interact with the image products in the CARDS database.

The usual animation, pan and zoom features are available. Other functionality of the IV include the ability to draw lines (grease pencil), do manual extrapolations, do cross-sections, add text, drill down to access single radar products, drill down to access cell views and toggle between products and backgrounds.

7. HARDWARE

The server processing system is a collection of LINUX Intel computers configured as a cluster. The front end of the cluster is a dual CPU 1.26GHz with 1Gbyte of RAM. This does most of the scientific processing. The back end of the cluster is a collection of similar machines. The primary purpose of the back ends is to generate the graphical images that are the bottleneck in the processing chain.

The IV is an application that uses the existing LINUX based display workstation in the forecast office. It could also be used on a Windows machine. The main requirement is that the machine has 512Mbyte or more of memory but this is dependent on the product sizes. Typically, in the MSC Regional operational environment, the Regional composites are 2000x1600 pixel images and so they drive the memory requirements. A dual monitor with single logical screen configuration is recommended.

8. DEMONSTRATION OF CAPABILITY

Fig 4 shows a typical Regional composite. The size of the composite is 2000x1600 pixels with ~1km per pixel resolution. The forecaster will typically leave this product up on a single monitor to maintain situational awareness. The forecaster can then zoom and pan on this image to focus on the area of interest. Circles and lines indicate cells and tracks. The cells are colour coded based on the rank weight. The figure shows a grey scale topography background. Lightning and the NEXRAD radars are included.

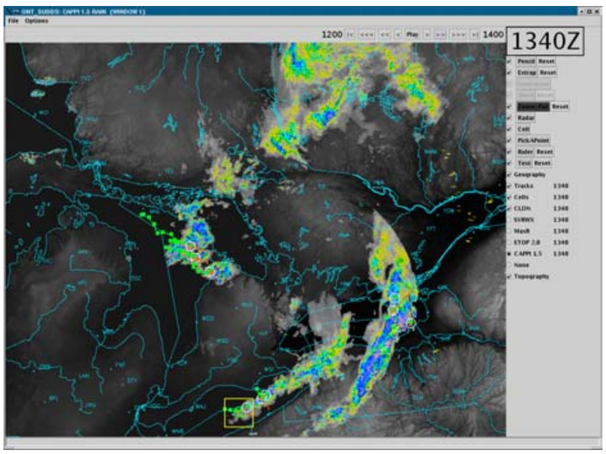

Figure 4: An example of a Regional composite. This is the size of the domain used at the Ontario Forecast Centr (~2000kmx1600km). The image shows a zoomed image of the cells, tracks and lightning strikes. Eight Canadian radars and 12 US radars contribute to the image.

Fig. 5 shows a SCIT table. The composite and the SCIT table products are invoked and displayed at the same time. The forecaster can either drill down to a CELL VIEW (Fig. 6) into a storm via the composite or via the SCIT table. She/he can also rapidly do survey the cells from the SCIT table without invoking the CELL VIEW products.

XWL_SUDDS: SCIT (WINDOW 2)

Table Time: 2300

sNumber	RANK	Rank_Wei...	Category	WDRAFT	BWER	Meso	Hail	VIL	MAXZ	ETOP45	Speed
32	1	6.6	not_a...	44.1	26.0	8.1	10.0	113.6	65.50	138.0	6.7
43	2	5.4	SST	39.9	24.0	0.0	8.3	88.1	66.00	126.0	5.7
21	3	5.2	SST	42.6	22.0	0.0	7.5	104.8	67.00	130.0	12.0
37	4	5.0	SST	36.1	22.0	0.0	8.3	76.9	64.50	124.0	4.5
41	5	3.4	SST	21.5	0.0	0.0	5.7	41.0	63.00	103.0	14.5
27	6	3.1	WST	18.4	22.0	0.0	2.3	27.2	59.00	76.0	1.7
11	7	3.1	WST	28.8	0.0	0.0	7.5	57.5	60.00	115.0	6.1
34	8	3.0	SST	25.3	0.0	0.0	4.8	45.0	61.50	100.0	9.4
44	9	2.7	MST	16.0	0.0	0.0	4.1	23.9	55.00	93.0	N/A

sNumber	RANK	Rank_Wei...	Category	WDRAFT	BWER	Meso	Hail	VIL	MAXZ	ETOP45	Speed
32	1	6.6	not_availa...	44.1	26.0	8.1	10.0	113.6	65.50	138.0	6.7

Figure 5: An example of a SCIT. The colour coding indicates the categorical ranking. The extra line at the bottom hightlight the data for the selected cell.

Fig. 6 shows a CELL VIEW product. This shows a variety of images that allows the forecaster to quickly make a decision as to the severity of the storm. There are two CELL VIEW images created for each storm - one based on reflectivity and one based on Doppler data (not shown). The product shows an ensemble product of the algorithms (upper left hand corner, not described), automatically determined cross-sections, four CAPPIs (1.5, 3.0, 7.0, 9.0 km), reflectivity gradient, MAXR, echo top, VIL density, Hail, BWER and 45 dBZ echo top and time graphs.

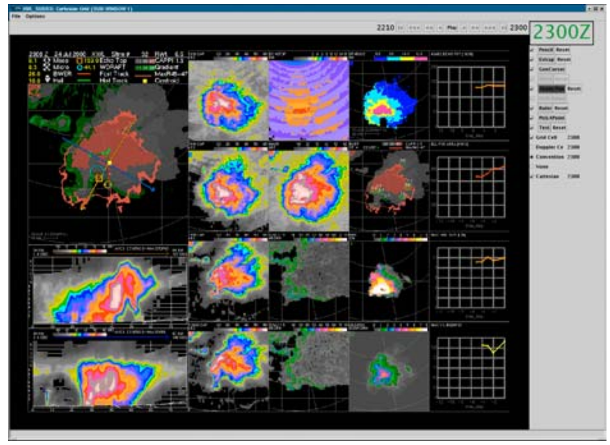

Figure 6: An example of a CELL VIEW.

9. CONCLUSION

This version of the software addresses many of the needs of the Canadian severe weather forecaster. There are several innovations - network radar processing, multi-cell merging, ranking, and classification - that require extensive tuning across the diverse weather regimes across the country. In the operational implementation, upstream CAPPI and Echotop product metafiles are transferred from one region to another for inclusion in the downstream composite to create, in concept, a distributed but integrated national radar processing system.

10. REFERENCES

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