9A.1 THE RESEARCH SUPPORT DESK (RSD) INITIATIVE AT ENVIRONMENT CANADA: LINKING SEVERE WEATHER RESEARCHERS AND FORECASTERS IN A REAL-TIME OPERATIONAL SETTING

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1. INTRODUCTION

Sustained collaboration between forecasters and researchers, particularly when they are co-located, has been shown to be a very fruitful endeavor. In the United States, advances in severe weather understanding and forecasting occurred much faster during times when storm forecasters and researchers were located together and worked collaboratively than when they were separated (Robert Johns, personal communication, 2004). This 'sharing the water cooler' approach allowed daily interaction between people with different perspectives on a shared problem. In 2000, such interaction was formalized in an initiative called the Spring Program – an annual multi-week period over which a number of forecasters and researchers were brought together in the National Severe Storms Laboratory at Norman, Oklahoma, to use, discuss, and evaluate cutting-edge forecasting systems and techniques (Kain et al. 2003).

During the Sydney 2000 Forecast Demonstration Project (Keenan et al. 2003), researchers from Australia, Canada, the United Kingdom, and the United States shared a research support area adjacent to the Australian Bureau of Meteorology operations area. Various nowcasting systems assembled for the project were monitored and researchers took turns being the 'champion' that collected pertinent information from each forecaster. A web-based display was also provided so that operational forecasters could access output from the nowcasting systems in real-time. On 3 November 2000, the day during the project with the most severe weather (see Sills et al. 2004), the nowcasting systems and the presence of the researchers enhanced the quality and timeliness of storm warnings (Fox et al. 2004).

In Canada, Environment Canada (EC) operational forecasters and researchers have collaborated in a limited number of ways. Forecasters are sometimes asked to act as project meteorologists for field studies that require weather prognoses. Researchers have also worked with operational forecasters on a small number of recently published studies (e.g., Joe et al. 1995, Benoit et al. 1997, Desjardins et al. 1998, Joe and Dudley 2000, Burrows et al. 2002, Murphy et al. 2002, King et al. 2003). Probably the best example of collaboration to date is the Atlantic Environmental Prediction Research Initiative (AEPRI) in Halifax, Nova Scotia. AEPRI adopted a multidisciplinary approach to maritime meteorological problems that has involved government researchers and forecasters, universities, and industrial interests since the late 1990s. To the author's knowledge, however, there has never in the past been sustained collaboration between forecasters and researchers in a truly co-located setting in Canada (being on different floors of the same large government building doesn't count).

The Research Support Desk (RSD) initiative at the Ontario Storm Prediction Centre (OSPC) in Toronto began to take shape in 1999 when the lead author started interacting directly and in real-time with operational forecasters during summer severe weather events. Of particular interest were days when Great Lakes lake breezes were expected to have a significant influence on the location, timing, and intensity of severe storms since this was, and still is, a very active area of research in the region (see Sills et al. 2002 and King et al. 1999).

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Storm Prediction Centre	National Laboratory
Atlantic	Marine and Coastal Meteorology
Québec	Severe Weather
Ontario	Nowcasting and Remote Sensing
Prairie and Arctic	Hydrometeorology and Arctic Weather
Pacific and Yukon	Mountain and Coastal Meteorology

Table 1. Storm Prediction Centres and associated National Laboratories.

In 2003, EC announced plans to concentrate forecasting operations into five regional centres across Canada. A national research laboratory, modeled after AEPRI, would be co-located with each centre and have a unique focus, taking advantage of the particular resources available in the associated region (see Table 1). Fig. 1 shows the locations of forecast offices and national laboratories across Canada.

The implementation of the National Laboratory for Nowcasting and Remote Sensing at the OSPC provided an opportunity to formalize the existing real-time interaction between forecasters and researchers. This would be accomplished via a support desk in the operations area regularly operated by researchers.

Through the RSD initiative, forecasters would be exposed to new techniques, tools and data, while researchers would get the chance to apply their severe weather-related work in real time and gain first-hand knowledge of the science gaps facing operational meteorologists.

In this paper, we describe the RSD initiative at EC and results from the past five years. Section 2 discusses the implementation at the OSPC in Toronto. The more recent implementation at the Prairie and Arctic SPC (PASPC) in Edmonton is discussed in Section 3. A discussion and future goals are presented in Section 4, and Section 5 summarizes the paper.

2. THE RSD AT THE OSPC

The first RSD was implemented at the OSPC in May of 2004 with a desk within the OSPC operations area set aside for its use. This desk is located adjacent to the lead severe weather forecaster desk and the summer student desk, and is also within sight of all other operational desks in the office. This location maximizes the ability to coordinate with both the convective lead and the student who was constantly working the phones during significant weather events. Fig. 2 shows the OSPC operational area adjacent to the RSD while Fig. 3 shows the RSD.

A prototype nowcasting platform called Aurora (Greaves et al. 2001) is the centrepiece of the research tools brought to the RSD. Aurora is a research version of a commercially available, object-oriented, meteorological database and forecasting system developed at EC called the Forecast Production Assistant (see http://www.msc.ec.gc.ca/fpa). Aurora can be used to graphically combine surface observations, satellite imagery, radar data, and NWP output as required. The user is then able to introduce modifiable objects to represent boundaries, areas, or other features, and even modify gridded field objects in the database such as surface pressure and temperature.

The RSD is also equipped with a fully-functional operational workstation including software for radar and satellite analysis, upper-air analysis, and surface observation and lightning plotting.

The following are the goals of the RSD initiative at the OSPC:

- to support nowcasting in real-time by providing the OSPC severe weather desk with mesoscale analyses and prognoses,
- to transfer knowledge through interactive training with real-time data and ongoing training via seminars, etc.,
- to identify science needs / gaps (i.e., areas where science is not used, is used incorrectly, and/or needs updating),

Fig. 1. Map of Canada showing the areas of responsibility for the five Storm Prediction Centres (SPCs). The Prairie and Atlantic SPCs have two forecast offices.

- to introduce techniques and technologies that are new or have never been transferred to operations,
- to evaluate experimental products such as output from high resolution numerical weather prediction (NWP) models,
- to enable interactions between forecasters and researchers with similar interests, and
- to generally enhance the relationship between operations and research.

Real-time mesoscale analysis and nowcasting was chosen to be the main focus for RSD activities at this location based on the needs of the OSPC and the focus of the national lab. Real-time mesoscale analysis of the pre-storm environment and the locations and movement of low-level boundaries (such as lake breeze fronts and gust fronts) are critical for nowcasting convective initiation (CI) in the Great Lakes region and determining subsequent storm evolution. The RSD initiative provides a great opportunity to test boundary-related mesoscale analysis and nowcasting techniques in real-time.

Though there have been numerous improvements to the RSD at the OSPC since its inception in 2004, the essential elements have remained the same.

The RSD is typically operated during the summer months by up to three research meteorologists (ResMets) in order to cover as many significant weather events as possible. The ResMet participates in the morning operational briefing, and then begins to work on mesoscale prognoses. Pop-up windows are used to notify forecasters that RSD products are ready and be viewed via an internal web site accessible by all forecasters. Later in the afternoon, a mesoscale analysis is produced. If the RSD is active and severe weather is a possibility, mesoscale analyses are generated on up to an hourly basis. Once storms have formed, the focus often shifts to storm-scale analysis and nowcasting. It should be noted that the RSD initiates a discussion of any new products with the forecasters as necessary, gauging the appropriate time to communicate so as not to disrupt the forecaster’s concentration.

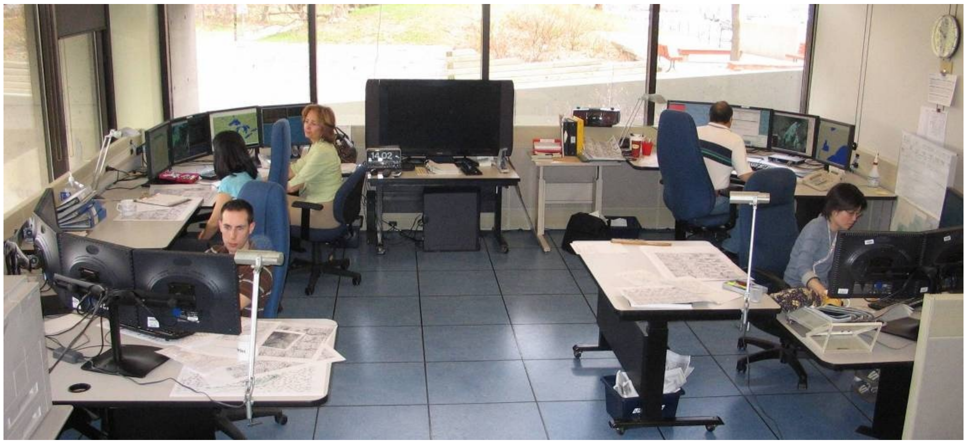

Fig. 2. A view of the OSPC operational area adjacent to the RSD.

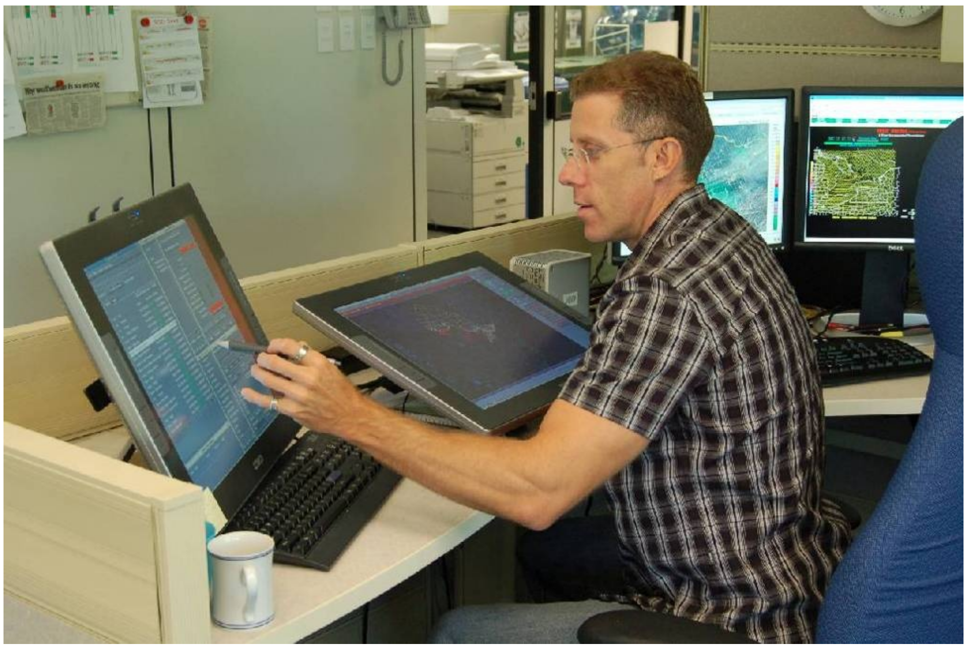

Fig. 3. This photo shows the RSD being operated by Bryan Tugwood. Two touch screens (at left) are used for work with Aurora. The operational workstations is shown at right.

The following section describes the experimental products generated by the RSD at the OSPC in detail.

2.1 *Experimental Products*

Aurora is used at the RSD at the OSPC to generate two different kinds of experimental products: mesoscale prognoses and mesoscale analyses.

Mesoscale prognosis

The mesoscale prognosis is produced in the morning and is valid for 18 UTC (2 p.m. local time). This time was chosen in order to characterize the pre-storm environment, including the positions of lake breeze fronts. The data used to generate the prognosis are morning observations, short range ensembles (e.g., Short-Range Ensemble Forecast (SREF) severe weather fields from the US SPC – see http://www.spc.noaa.gov/exper/sref), and particularly the operational regional NWP model known as the Global Environmental Multiscale (GEM) model (see Coté et al. 1998) and the high-resolution, limited-area version of the GEM model know as the GEM-LAM (see Erfani et al 2005). The regional GEM has a horizontal grid spacing of

15 km while the GEM-LAM has a horizontal grid spacing of 2.5 km.

Based on interpretation of the model fields, the ResMet creates line and area objects representing mesoscale features important for convective nowcasting. These include upper jets, low-level jets, synoptic-scale fronts, lake breeze fronts, and outflow boundaries. The ResMet can insert several lines of text at the bottom of the product to highlight certain aspects of the mesoscale prognosis, including the anticipated convective mode.

Also appearing on the mesoscale prognosis product are areas where thunderstorms are expected between 18 UTC and 21 UTC. The data used to predict these areas include 12 UTC radiosonde data, NWP-based convective instability / inhibition fields, and statistical lightning forecasts (e.g., Burrows et al. 2005).

The ResMet works on the prognosis for all of Ontario and surrounding regions, and from this Aurora automatically generates products over Ontario, northern Ontario and southern Ontario. An example of a mesoscale prognosis for southern Ontario from 27 June 2008 is shown in Fig. 4.

At the request of forecasters, a Day 2 mesoscale prognosis with the same features is also produced. Though this not a product related to nowcasting, it helps severe weather forecasters, as well as public and marine forecasters, fine tune their Day 2 forecasts.

Mesoscale analysis

The mesoscale analysis is typically produced for 18 UTC to allow verification of the mesoscale prognosis. Mesoscale analyses are also generated on an up to hourly basis when the RSD is active and severe weather is a possibility.

The data used to generate the mesoscale analyses are Canadian and US surface observations, GOES visible satellite imagery, radar data from all Ontario radars as well as neighbouring US radars, and lightning from the North American Lightning Detection Network (NALDN, Orville et al. 2002). Surface observations, satellite imagery, and blended radar imagery are displayed on the product. As with the prognosis, the ResMet creates a variety of mesoscale features (such as lake breeze fronts and outflow boundaries). The ResMet can insert several lines of text at the bottom of the product to highlight certain aspects of the mesoscale analysis.

Also appearing on the mesoscale analysis product are areas representing the convective trend over the next hour. The convective trend categories are: initiation, intensification, dissipation, and no change. The data used to nowcast convective trend are radar cell trends and fine lines, cumulus fields and development at boundaries as observed via visible satellite imagery, lightning trends, and convective instability / inhibition fields from the one-hour forecast of the US Rapid Update Cycle (RUC) model (Benjamin et al. 2004). Also used are conceptual models related to convective nowcasting development via EC research (effects of lake breeze circulations and fronts) and research by US scientists such as those at NCAR (e.g., Wilson et al. 1998).

The ResMet works on the analysis for all of Ontario and surrounding regions and from this Aurora automatically generates products over Ontario, northern Ontario and southern Ontario. An example of a mesoscale prognosis for southern Ontario on 27 June 2008 at 18 UTC is shown in Fig. 5.

Occasionally, it is possible to create special mesoscale analysis products that focus on convective activity in one particular area, as shown in Fig. 6. This often involves relatively isolated convection with pronounced boundaries. Finer detail may be captured upon zooming into an area and products can be generated at 10 min time intervals if necessary. It is also possible to add lightning data from the NALDN to such products.

Future techniques and products

Via Aurora, we have worked to optimize human strengths in the forecast process, allowing the ResMet to focus on meteorology while Aurora automatically generated products. Thus, nowcasting is done mostly manually at this point. However, we have started to experiment with ways in which to maximize ‘machine’ strengths in order to achieve an optimal human-machine mix (as discussed in Sills et al. 2005). Beginning in 2009, some ‘first guess’ nowcasting guidance will be implemented. Canadian radar data coming into Aurora include cell tracking and extrapolation nowcasts based on the TITAN algorithm (Dixon

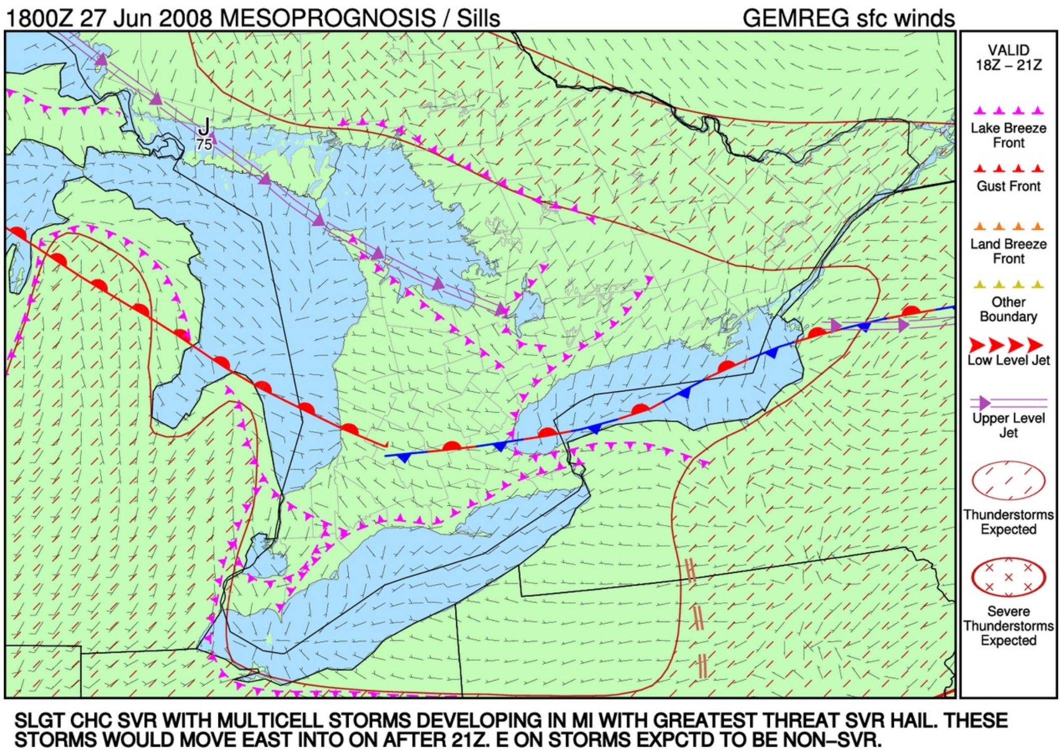

Fig. 4. Day 1 mesoscale prognosis product for southern Ontario valid at 18 UTC on 27 June 2008. Surface winds are from the GEM Regional model. All other features manually added by the ResMet.

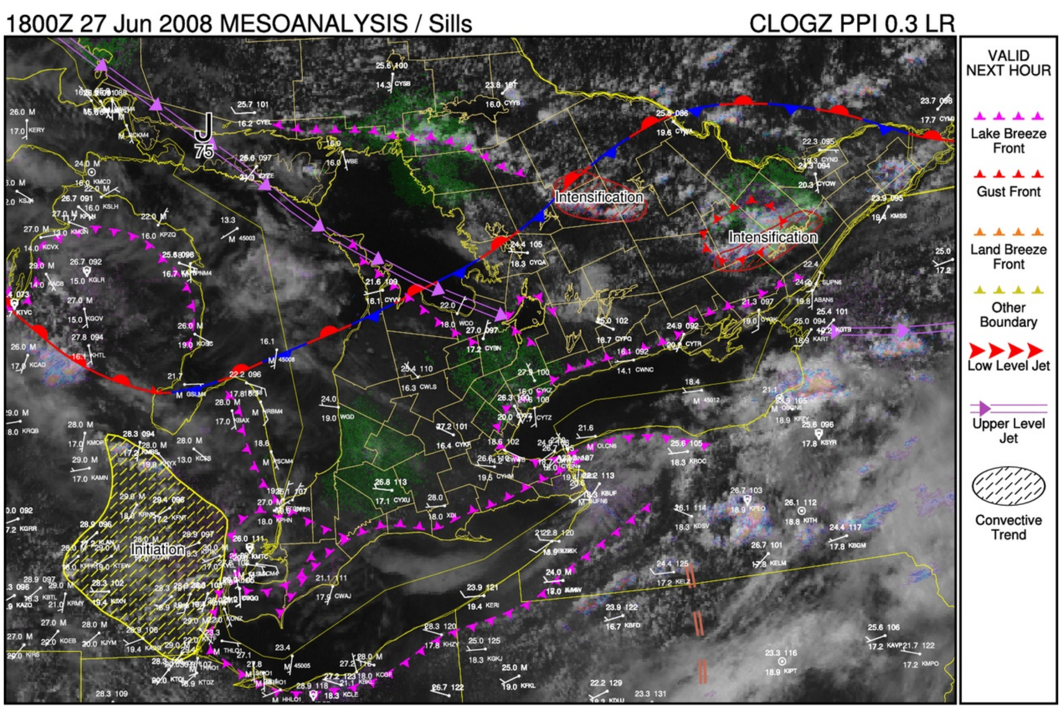

Fig. 5. Mesoscale analysis product for southern Ontario valid at 18 UTC on 27 June 2008. Shown are surface observations, visible satellite imagery and blended radar imagery. All other features, such as lake breeze fronts and convective trend areas, manually added by the ResMet.

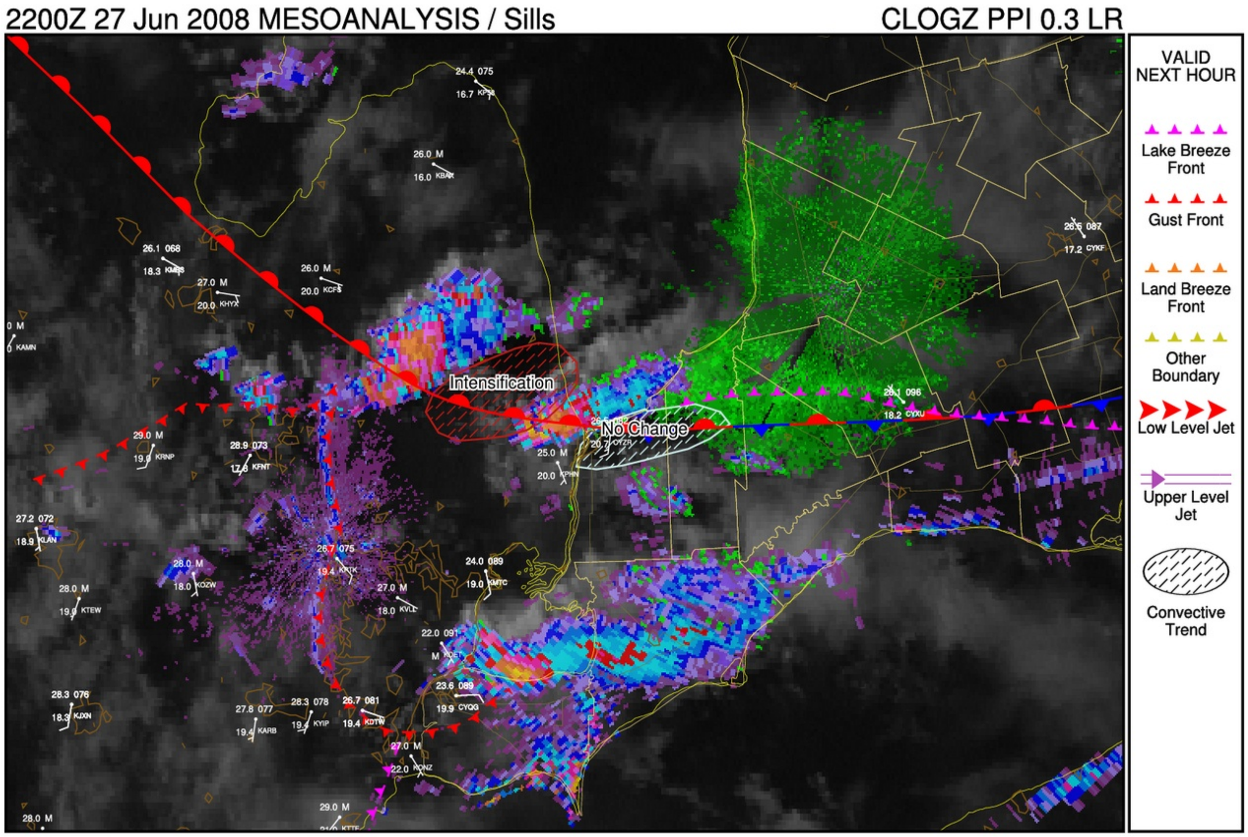

Fig. 6. Mesoscale analysis product focused on southwester Ontario valid at 22 UTC on 27 June 2008. Shown are surface observations, visible satellite imagery and radar data. All other features, such as lake breeze fronts and convective trend areas, manually added by the ResMet.

and Wiener 1993). Cell tracks and cell ellipses (past, present, and future) are ingested as objects and displayed (see Fig. 7). The ResMet will be able to modify these objects, and derived first-guess fields for convective trend, or add new fields such as storm initiation areas.

We will also be experimenting with artificial intelligence methods of generating first-guess convective trend fields, similar to what has been developed as part of the Autonowcaster system (see Wilson and Mueller 1993).

2.2 *Post-Season Surveys and Verification*

Post-season surveys

To gauge the success of the RSD initiative at the OSPC, forecasters were asked to respond (anonymously) to post-season surveys in 2004 and 2005. Around 20 forecasters responded in each case giving a survey return rate close to 80%. Results from the inaugural 2004 season (see Sills 2005) served as a benchmark from which further progress could be gauged.

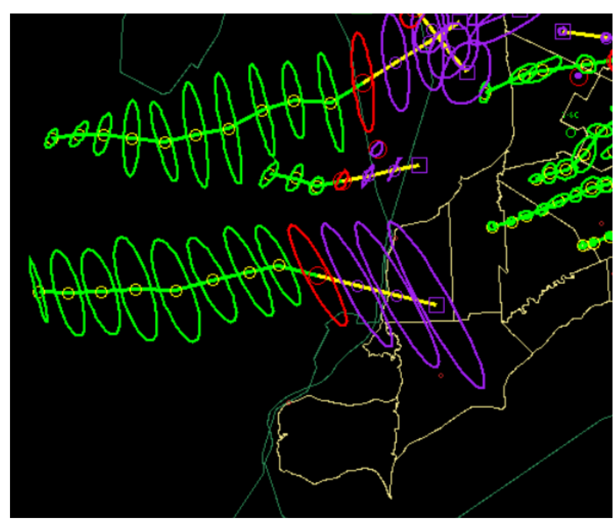

Fig. 7. Radar-derived cell tracks and ellipses over southwestern Ontario and southeast Michigan. Green ellipses are past, red ellipses are present, and purple ellipses give a 30 min extrapolation nowcast.

From the 2004 survey:

- those comfortable with a researcher in the operational area grew from 63% to 91% over the season
- 78% interacted with the RSD occasionally to very often
- 64% thought the RSD resulted in better watches / warnings
- 59% thought the RSD provided an enhanced learning environment
- 81% had a positive overall impression of the RSD
- 81% wanted to see the RSD continue into the future

Results from the 2005 survey showed improvement in each of the above categories:

- 100% were comfortable with a researcher in the operational area
- 83% interacted with the RSD occasionally to very often
- 88% thought that the RSD improved the quality of OSPC forecasts / watches / warnings
- 72% thought the RSD provided an enhanced learning environment
- 83% had a positive overall impression of the RSD
- 94% wanted to see the RSD continue into the future

The 2005 season was the first to have experimental mesoscale analysis and prognosis products generated on a regular basis. Of the forecasters surveyed, 83% used the mesoscale analysis and prognosis products at least occasionally, and about 90% thought they were somewhat to very useful.

An interesting result from the 2005 survey was that the forecasters rated “mentoring during real-time events” as their top learning method, with simulations and COMET-type training modules tied for second. Reading scientific papers and attending seminars rated third and fourth, respectively. It is the experience of the authors, and several experienced operational colleagues, that real-time, interactive training is better retained by forecasters than probably any other training method. This method is quite labour intensive for the researcher. However, researchers providing this type of training over a period of years may be able to transfer knowledge more efficiently than through the traditional ‘broadcast’ process (i.e. through presentations and paper-writing).

Verification

Post-season surveys offer a subjective method of determining the success of the RSD. However, some quantitative measures are also required. Work has commenced on developing ways to verify both the impact of the RSD on operations and RSD nowcasts.

For the 2008 season, we have started verifying the thunderstorm areas from the mesoscale prognoses (both Day 1 and Day 2) against lightning data from the NALDN. An example of a Day 1 verification product is shown in Fig. 8. This has offered a subjective verification of our thunderstorm forecasts, but a method for quantitative verification needs to be developed.

3. THE RSD AT THE PASPC

Following on the success of the RSD at the OSPC, a second RSD was implemented at the Edmonton office of the PASPC in 2006 via the Hydrometeorology and Arctic Lab (HAL). The objectives are similar to those at the OSPC RSD. However, the focus here is on forecasting and nowcasting the initiation of severe convective storms, with an emphasis on mesoscale processes important on the Prairies including characterization of boundary-layer moisture and the development of low-level boundaries such as the dryline.

Like the RSD at OSPC, the desk is located adjacent to the severe weather desk and the summer student desk, and is within sight of all other operational desks in the office. The RSD is equipped with a fully-functional operational workstation and uses Aurora for data analysis and product generation. Much work has gone into developing and evaluating a suite of experimental model fields targeting the problem of forecasting CI. These model fields are derived using full-resolution output from the GEM Regional model at 1 h intervals.

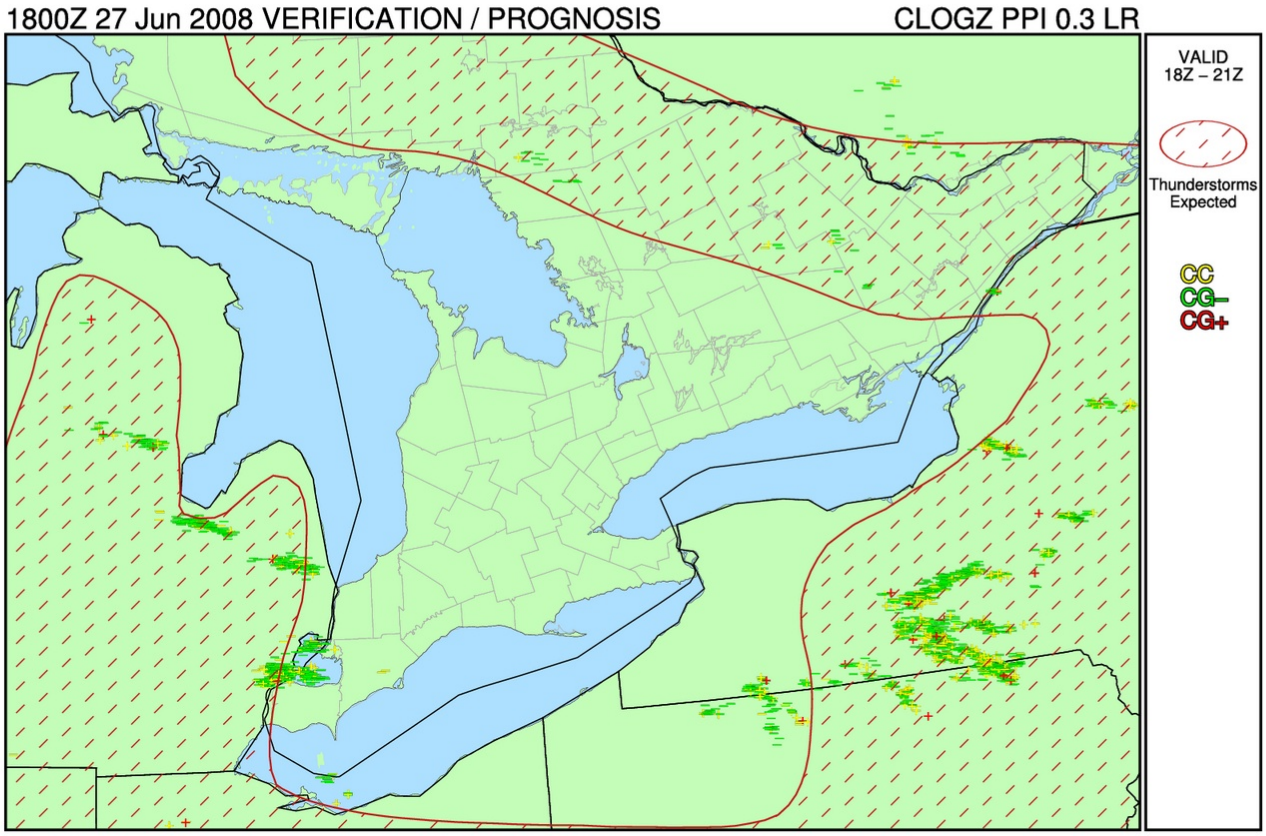

Fig. 8. Thunderstorm prognosis verification product for 27 June 2008 showing the area over which thunderstorms were expected between 18 UTC and 21 UTC from the Day 1 mesoscale prognosis (hatched red area) and lightning flashes recorded between 18 UTC and 21 UTC. Lightning types included cloud to cloud (CC), negative cloud to ground (CG-) and positive cloud to ground (CG+).

Such fields include:

- 50 hPa mean dewpoint
- Mixed moist layer depth in the atmospheric boundary layer (ABL)
- Height difference between level of free convection (LFC) and the lifting condensation level (LCL)
- Bowen Ratio
- Low-level convergence depth
- Ratio of convergence depth to mixed layer (ML) LFC height
- Ratio of lifting height (below 500 hPa) and LCL / LFC heights
- Surface-based convective inhibition (CIN) / ML CIN
- Surface divergence and winds
- 0-LFC bulk shear
- 0-3 km ML instability and LFC-2km above LFC bulk shear

An example of the low-level convergence depth model field is shown in Fig. 9.

Using these experimental fields, plus operational models and observational data (including radiosonde and aircraft soundings, radar and satellite data, and surface observations), target areas for CI of severe storms are identified. The CI prognosis product is generated for 18 UTC (12 p.m. local time) in order to best characterize the pre-storm environment. Due to the size of the PASPC domain, and because numerous CI areas may be present in all three provinces on a given day, the areas in the graphic focus on regions with potential for the initiation of severe storms and/or areas where the forecast of CI may be most uncertain. Textual information is included as a more CI-specific discussion utilizing experimental information. An example of a CI prognosis product valid at 18Z on 24 July 2007 is shown in Fig. 10.

Accompanying the CI prognosis product is a CI discussion. An attempt is made to determine what

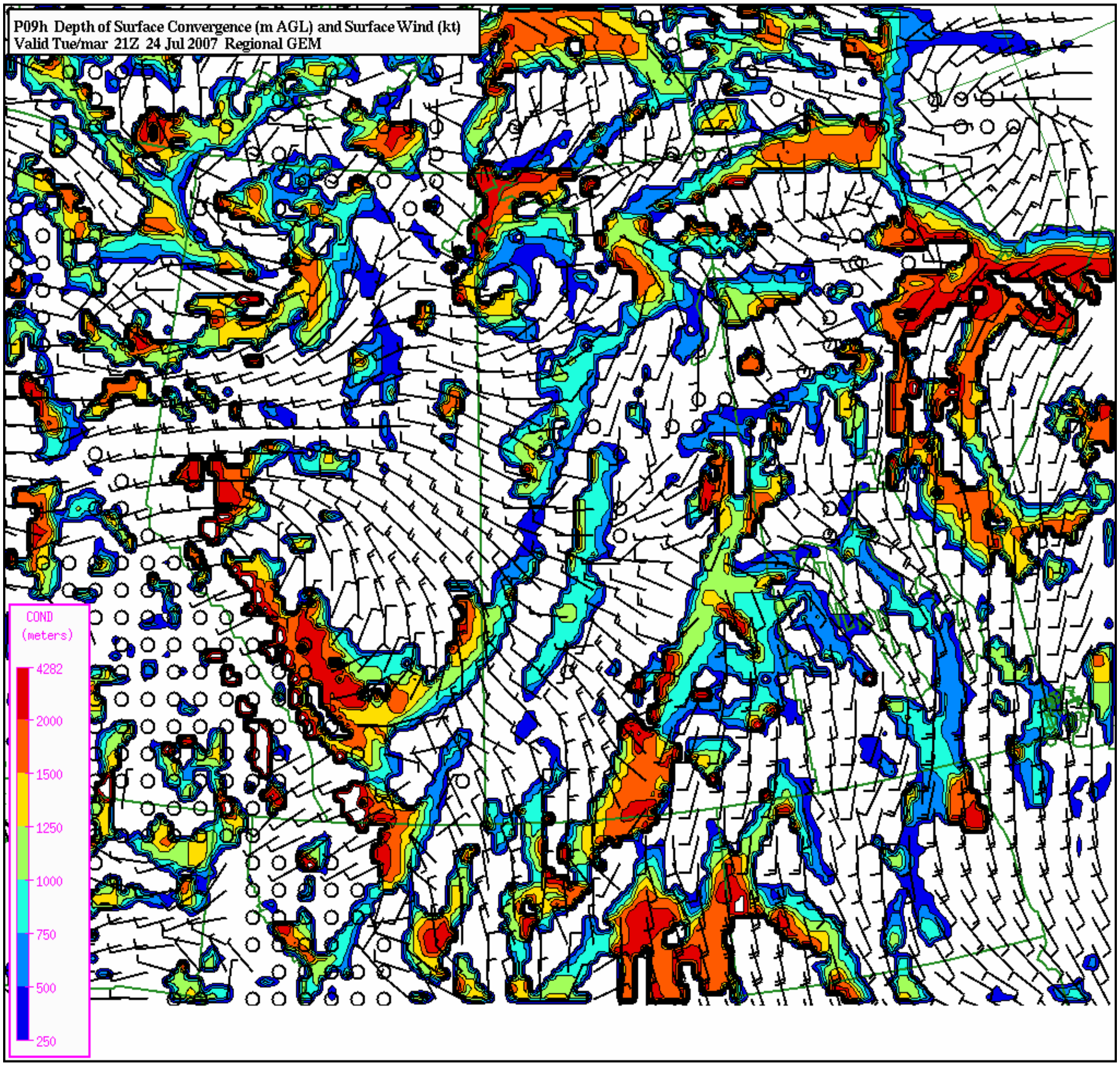

Fig. 9. Experimental model field depicting surface winds and low-level convergence depth. The outlines of Canadian provinces and US states are shown in green with Alberta being at centre left.

aspects of the experimental model fields are valid given current observed conditions, and how they may relate to the CI problem of the day. The discussion includes a description of the synoptic / mesoscale setting and severe weather threat, expected ABL water vapour distribution, depth, and evolution, convergence / lift mechanisms, convective inhibition and mechanisms, shear and circulations near and below the LFC, the expected convective mode, and caveats that may complicate the situation.

Following the posting of the CI graphic and discussion on the internal RSD web page, a briefing is typically held with PASPC operational staff in either Edmonton, Winnipeg, or both, as required.

3.1 *Post-Season Survey*

To gauge the success of the RSD initiative at the PASPC, forecasters were asked to respond (anonymously if preferred) to a post-season survey in 2006.

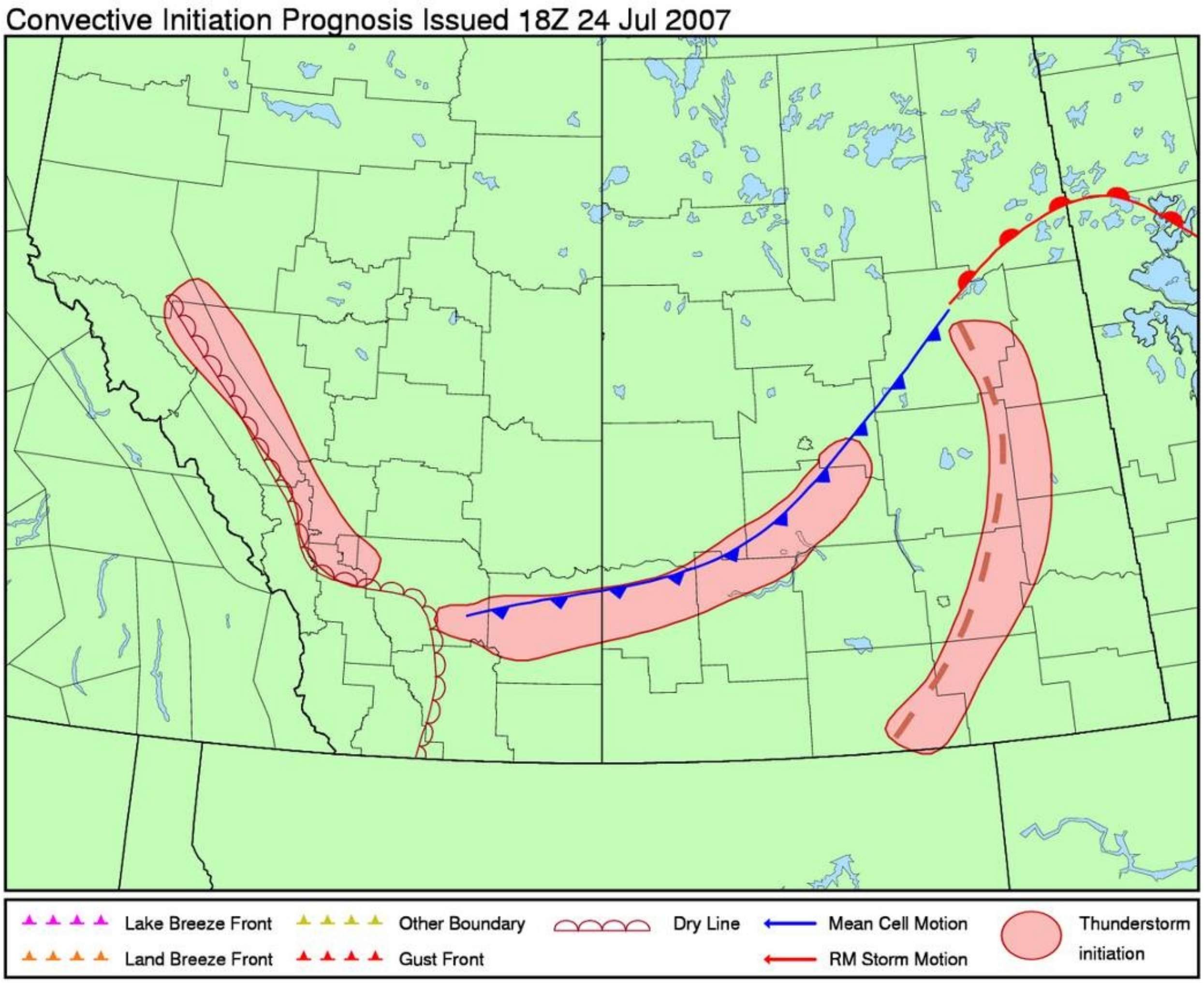

Fig. 10. Convective initiation prognosis product for the Prairies valid at 18 UTC on 24 July 2007. Features such as the synoptic-scale fronts, the dryline, and convective initiation areas are manually added by the ResMet.

Around 20 forecasters responded from both the Winnipeg and Edmonton offices, giving a survey return rate just under 50%. Results from the inaugural 2006 season (see Taylor 2006) served as a benchmark from which further progress could be gauged.

From the 2006 survey:

- those comfortable with a researcher in the operational area grew from 79% to 89% over the season
- 63% interacted with the RSD occasionally to very often
- 64% thought the RSD resulted in better watches / warnings
- 53% thought the RSD provided an enhanced learning environment
- 84% had a positive overall impression of the RSD
- 100% would like to see the RSD continue into the future

Note that these results are similar to those from OSPC forecaster surveys discussed in Section 2.2.

4. DISCUSSION AND FUTURE GOALS

What types of people make good ResMets, able to effectively operate an RSD? Ideally, ResMets should come from the research side of the organization in order to fully meet the goals of the RSD initiative. However, there are not a lot of researchers available to do such work within EC, and some researchers have little interest in spending time working shifts in an operational setting.

What has seemed to work best so far is recruiting people that have experience and interest in both research and operational aspects of meteorology, and are considered to be subject matter experts. Such people can come from either a research or a forecasting background. ResMets to date have had expertise in boundary-layer meteorology, radar meteorology, and severe weather forecasting.

An important quality that appears to be a mandatory requirement for the job is the ability to communicate well. There is little point in working with experimental techniques and products in a real-time, operational setting if knowledge is not effectively communicated to the forecasters, and forecaster knowledge is not readily absorbed.

A further application of the RSD that has not yet been described is its use during field research programs. The BAQS-Met 2007 air quality field study in Ontario (see Flagg et al. 2007) and UNSTABLE 2008 convective initiation study in Alberta (see Taylor et al. 2008, this volume) were both supported by RSDs.

For BAQS-Met, the field project forecasters and coordinators made full use of mesoscale Day 1 and Day 2 prognoses, and mesoscale analyses, generated for a special BAQS-Met study domain. For UNSTABLE, the RSD at the PASPC in Edmonton provided Day 2 and Day 3 forecasts in the form of a CI depiction similar to the RSD CI prognosis, but targeting the much smaller UNSTABLE study domain. The RSD also provided a CI discussion and a daily 'blog' discussing features and events of interest. This helped complete the documentation of daily events during the campaign.

Future goals for the RSD initiative include implementing RSDs at each of the SPCs across Canada. SPC offices in Vancouver and Halifax are planning to implement a RSD, focusing on nowcasting in mountainous and coastal environments, respectively. The Vancouver RSD will likely figure prominently in the EC meteorological support planned for the coming 2010 Winter Olympics there.

A winter version of the RSD, focused on mesoscale phenomena such as lake-effect snowsqualls and rain-snow boundaries, is also a possibility in the future. A partial winter RSD was attempted at the OSPC over the winter of 2004-2005 with some success, especially with detecting rain-snow boundaries using newly developed polarimetric radar fields. However, it was found that the time scales for winter watches and warnings are much longer than that for summer severe weather, and therefore the ResMet has reduced opportunities to interact in real-time with the operational forecasters.

5. SUMMARY

The Research Support Desk initiative at Environment Canada seeks to increase collaboration between EC researchers and forecasters by having researchers work directly and interactively with forecasters in a real-time, operational environment during severe weather events. An RSD at the OSPC has been active during the summer seasons of 2004-2008 while an RSD at the PAPSC has operated during the summer seasons of 2006-2008. Surveys of forecasters at both locations have shown strong support for the initiative, and it is anticipated that the concept will be expanded to the remaining SPCs across Canada.

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