Post-Processing of Canadian Regional-Scale NWP Data to Develop First-Guess Forecasts of Thunderstorm and Severe Weather Threat Areas

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1. Introduction

- In a Next-Generation forecast system, EC forecasters will modify area-based "First-Guess" (FG) MetObjects to generate forecast products and alerts
- Short-range NWP guidance in Environment Canada (EC) is mainly from the Regional Deterministic Prediction System (RDPS; 10-km horizontal grid spacing [upgraded from 15 km in Oct 2012])
- Scale of the RDPS is suitable for identifying "pre-storm" environmental conditions for thunderstorms and severe thunderstorms (local storm intensity, mode, etc. are available via the 2.5-km HRDPS or other higher-res. NWP)
- Post-processing of the RDPS is fast, efficient, and computationally inexpensive…but…

Can a single regional-scale NWP model be used to provide thunderstorm and severe weather forecasts that are ***a useful starting point (first-guess) for the human forecaster***?

2. Data and Methods

- RDPS data and observed CLDN lightning data are used to calibrate post-processed NWP output over a selected domain via the following process:

Start with grid-point values of selected parameters (we used hourly T+1 - T+24 h output) → For each grid point use locations of the 24 surrounding points (2●Δx) to define a 5x5 grid point "search" box (see Fig. 1) → From hourly lightning observations determine if flashes occurred within the box ("yes") or not ("no")

Compare "yes" and "no" datasets via boxplots and the Wilcoxon-Mann-Whitney test → Evaluate results and associated z-scores to select parameters to discriminate between "yes" and "no" events → From "yes" distributions define unique probability thresholds from decile values for each forecast hour

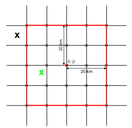

Fig. 1: Schematic representation of the 5x5 grid point search area (red box). Current RDPS horizontal grid-spacing is 10 km. The forecast value is that of the central grid point (red circle). The green "X" represents a flash that would constitute a "yes" event. The black "X" is a flash outside the search box and would not be counted.

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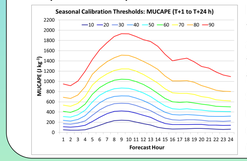
3. Forecast Parameters

Analysis from Section 2 resulted in the selection of four predictors:

MUCAPE	MULPL-3 km CAPE
MUCIN	Integrated VV (below MUEL)

- Predictors are consistent with a simple conceptual model for thunderstorm initiation with three characterizations of stability and one of vertical motion
- Selection was based on the discrimination analysis and relates to the analysis-diagnosis-prognosis process used by forecasters (i.e., assessment of stability and vertical motion)
- QPF output was intentionally not considered – focus on larger environment without inconsistent location, timing, intensity, and coverage of QPF forecasts
- Thresholds for all four parameters at a given probability must be met to produce a positive forecast



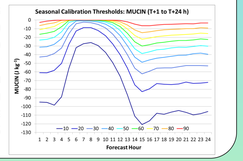


Fig. 2: Thresholds for MUCAPE (left) and MUCIN (right) for T+1 - T+24 hour forecasts based on seasonal calibration using 12 UTC runs of the 10-km RDPS (see below).

4. Calibrated Forecasts

i) Seasonal Calibration (1 May to 30 Sep 2013)

- Hourly probability thresholds determined from decile values averaged over the entire 153-day period from the previous thunderstorm season

ii) Running Calibration (based on previous 5, 10, 20, or 30 days in 2014)

- Hourly probability thresholds recalculated daily based on the selected calibration period between 1 May and 30 Sep 2014

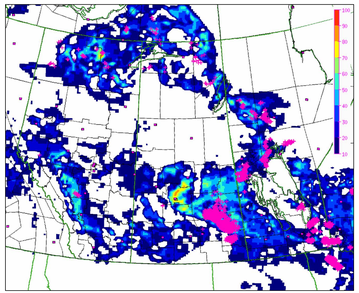
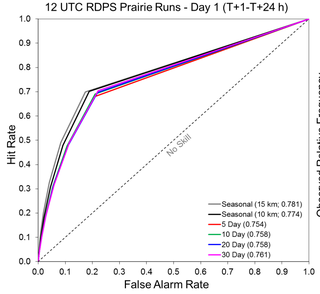


Fig. 3: Example seasonal calibration forecast based on the 10-km RDPS for T+12 h valid at 00 UTC 6 July 2014. Forecast probabilities range from 0-100 %. Lightning observed from 00:00:00 to 00:59:59 UTC is plotted as magenta crosses.

5. Forecast Verification

- A search area of 60 x 60 km^2 was used to determine if lightning (T+0 - T+59:59 min) was associated with the forecast at each grid point
- 2 x 2 contingency tables were generated for each forecast probability and forecast hour (results from calibration/verification using the 15-km RDPS are shown for comparison)



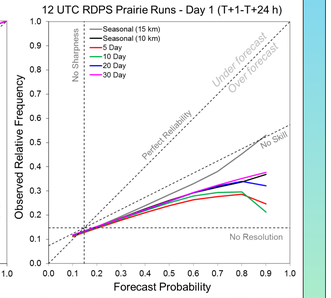


Fig. 4: ROC curves (left; ROC area in parentheses) and attributes diagram (right) for the seasonal (10 km with 15 km for reference) and running-calibration (10 km only) thunderstorm forecasts. 30-day calibration period results are similar to those of the seasonal calibration and slightly better than those for other calibration periods. Results from the calibration/verification via the 15-km RDPS appear better than those at 10 km.

6. Severe Weather Areas

As a proof-of-concept experiment, ≥ 30 % probability forecast thresholds from previous seasonal calibration using the 15-km RDPS were coupled with several well-known severe weather parameters (thresholds shown below) to highlight FG severe weather threat areas based on the NWP-based "storm environment".

Environment Category	Parameter	Threshold
Severe Pulse / Multicell	MLCAPE (MUCAPE - only if MULPL ≥ 500 m)	≥ 1000 (1250) J kg^{-1}
	Effective Bulk Wind Difference	< 30 kt
	Precipitable Water	≥ 20 mm
Convective Wind Gusts	DCAPE	≥ 500 J kg^{-1}
	Wind Index (WINDEX)	≥ 40 kt
Non-Supercell Tornadoes / Funnel Clouds	0-3 km MLCAPE	≥ 100 J kg^{-1}
	MLLCL	< 1500 m
	Effective Bulk Wind Difference	< 30 kt
	Surface Relative Vorticity	≥ 8x10^{-5} s^{-1}
Supercell / Bow Echo	MLCAPE (MUCAPE - only if MULPL ≥ 500 m)	≥ 500 (750) J kg^{-1}
	0-6 km Bulk Wind Difference (Effective Bulk Wind Difference)	≥ 30 (30) kt
Supercell Tornadoes	MLCAPE	≥ 1250 J kg^{-1}
	MLLCL	< 1500 m
	Effective Bulk Wind Difference	≥ 40 kt
	Effective Storm-Relative Helicity	≥ 150 m^2 s^{-2}
	0-1 km Bulk Wind Difference	≥ 15 kt

7. Forecast Verification

An example of the FG severe weather area forecast is shown below for 00 UTC 29 May 2014 (T+12 h forecast from 12 UTC RDPS run).

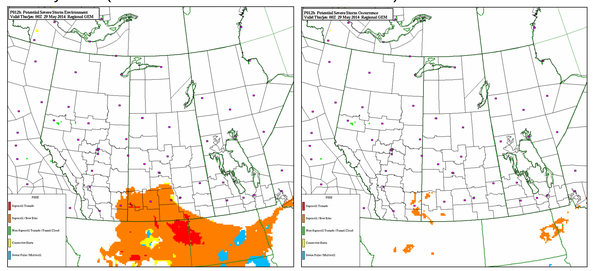


Fig. 5: Conditional (left; parameters in section 5) and occurrence (right; with ≥ 30% probability calibrated thunderstorm forecast mask) forecasts of severe weather threat areas. The calibrated forecast mask significantly reduces the size of the severe weather threat area by highlighting areas where the NWP environment is favourable for thunderstorms.

FG occurrence forecasts (having ≥ 8 contiguous grid cells for ≥ 2 consecutive hours in a public forecast region) were verified from 15 Jun - 31 Jul 2014 against

- Canadian Prairie severe weather reports (159 reports [92 regions] ± 1 h of forecast valid time)
- Canadian SPC severe weather watches (anytime from 12-06 UTC)

Verification	POD	FAR	HK	HSS	ETS	BIAS	ORSS	SEDI
FG vs Reports	0.58	0.95	0.34	0.05	0.03	12.7	0.62	0.47
Watches vs Reports	0.67	0.82	0.61	0.26	0.15	3.7	0.94	0.79
FG vs Watches	0.83	0.75	0.63	0.30	0.18	3.3	0.90	0.78

8. Summary

- Subjective (not shown) and objective verification of calibrated forecasts suggest some utility as a starting point for the human forecaster
  - Limited overall skill may preclude use as automated forecasts at this time
- Degradation of performance for the 10-km calibration (c.f., at 15 km) suggests a review of the calibration and/or verification procedure at 10 km grid spacing is required
- When combined with conventional severe weather parameters, the calibrated forecasts can be used to identify FG severe weather threat areas that compare well with actual watches issued by forecasters

Data from a regional-scale, deterministic, NWP model can provide a useful starting point for forecaster-modified thunderstorm and severe weather forecasts