Improvements to the Canadian Regional Ensemble Prediction System (2.0.1)

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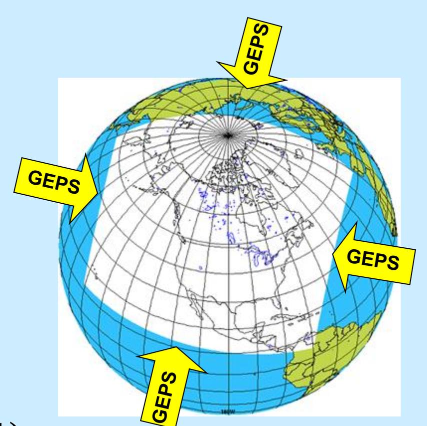
Introduction

- The operational Regional Ensemble Prediction System at the Canadian Meteorological Centre (CMC), originally implemented on September 22 2011 (v1.0.0) was updated to version 2.0.1 on December 4th 2013.
- REPS (v2.0.1) continues to use the limited area (LAM) version of the Canadian Global Environmental Multi-scale model, GEM-LAM (See Cote et al. 1998a,b for the global version).
- REPS produces 72 hour forecasts daily at 00 and 12 UTC for its 20 members. Its initial conditions are provided by the Global Ensembles Prediction System (GEPS). REPS members are generated using stochastic physics perturbations. A control member is also included but it not perturbed.
- Main changes with REPS 2.0.1 are; an increase in the horizontal grid spacing, an increase in the vertical resolution and a new design in the application of the physics tendency perturbations (PTP) in areas of convectively unstable air mass and topographically enhanced vertical velocities. The physics remains very similar to version 1.0.0.

Model configuration



• The domain of the system covers North America.

The main changes in the dynamics for REPS (2.0.1)

• Reducing the horizontal grid spacing from 33 km (REPS 1.0.0) to 15 km (REPS 2.0.1).

• Reducing the time step from 900s (REPS 1.0.0) to 450s (REPS 2.0.1).

• Increasing the number of vertical levels from 28 levels (REPS 1.0.0) to 48 levels (REPS 2.0.1).

Some of the physics common in both versions of REPS

• Sundqvist (1978) condensation scheme
• The Kain and Fritsch (1993) deep convective scheme
• The ISBA surface scheme (Noilhen et Planton, 1989)
• The radiation scheme of Li and Barker (2005) called « CCCmarad » in house. This scheme reduces temperature forecast errors and biases in the stratosphere, and to a lesser extent, in the troposphere (Charron et al. 2011).
• The stratospheric ozone climatology is from Fortuin and Kelder (1998).
• Surface fluxes are computed implicitly.

Physics Tendency Perturbation (PTP) with Markov Chain

$$f(\lambda,\phi,t) = \mu + \sum_{l=L_{min}}^{L_{max}} \sum_{m=-l}^{l} a_{lm}(t) Y_{lm}(\lambda,\phi)$$

$$a_{lm}(t+\Delta t) = e^{-\Delta t/\tau} a_{lm}(t) + R(t)$$

L_{min} = 1
L_{max} = 14
τ = 6 h
m = 1

• They are the spectral coefficients of an expansion of spherical harmonics.
• An autocorrelated random field is obtained.
• The independent variables λ, Φ, t are lon., lat. and time.
• Y_{lm} are spherical harmonics, l the total horizontal wave number, m the zonal wave number
• L_{min} and L_{max} are specifying the spectral range of the random function.
• τ is the decorrelation time scale of the spectral coefficients. It is chosen to be constant and independent of wave number.
• The resulting values of PTP have a range of values between 0.7 and 1.3.
• PTP is applied to the subgrid-scale physical tendencies on winds and temperature.

New design for the application of PTP

• Localised excessive precipitation amounts were detected with the REPS 1.0.0.
• Investigation showed a problem in the design of the PTP application.
• When values of PTP were applied to temperature, in areas of convective instability, the environmental CAPE was increased non-linearly resulting to excessive amounts of precipitation (> 1000 mm in 72 hrs).
• The already large temperature tendencies caused by the condensation (Sundqvist) scheme was further exaggerated by the high PTP multiplicative factors.
• Similar phenomenon was detected with topographically enhanced vertical velocities and some areas of surface convergence.
• The added convective available potential energy or CAPE was not controlled by varying the range of values of PTP or any other parameters such as the alteration of the Kain and Fritsch Convective scheme. These changes caused other concerns and problems to the system.
• One way to avoid this issue is to restrict the application of PTP on areas where any CAPE exists.
• For the vertical velocities enhanced by topography and areas of surface convergence, no PTP is applied when a vertical speed of ~ 0.5 m/s or higher is detected.
• More realistic precipitation amounts are produced with this new design.

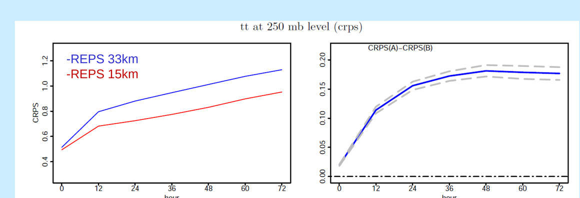
Objective validation

- Winter and summer periods of 2011 (total of 4 months)
- Verifications were done at 12, 24, 36, 48, 60 and 72h lead times.
- The upper air fields verified are temperature, dew point depression, zonal and meridional wind components and geopotential height at 925, 850, 500 and 250hPa. The REPS was compared to the radiosonde network of approximately 110 stations.
- The surface fields used are the 2m temperature and dew point depression and the 10m zonal and meridional wind components. The system was compared to the surface network of approximately 4600 observations.
- 24h precipitation forecast amounts were compared to the surface and SHEF (Standard Hydrometeorological Exchange Format) network of approximately 8000 observations
- The **Continuous Rank Probability Score (CRPS)** was used for upper air & surface fields.
    - CRPS is an integral measure of all the probabilities for the square of the difference between the forecasts and the observations. In other words, it is a measure of the squared distance between the predicted and the observed cumulative density functions (CDF). CRPS can be decomposed into resolution and reliability terms (Candille et al).
- The bias and dispersion were also used in the validation.
- A bootstrapping method was used to build 5% and 95% confidence intervals
- For precipitations amounts, the Brier score was used. The score was also decomposed into resolution and reliability terms. Area under the ROC and economic values were also calculated.

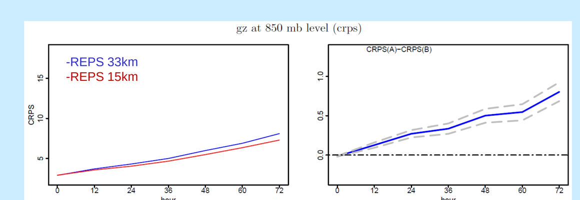
Objective validation results

- Scores for the upper air fields showed a significant improvement at all levels during summer and winter.

A)



B)

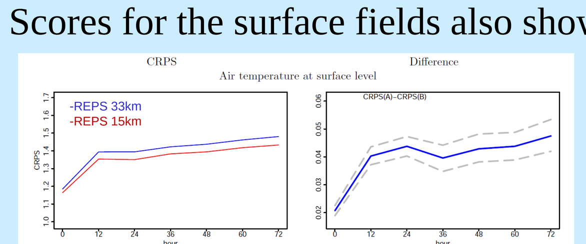


CRPS (left) and CRPS difference (with 90% confidence intervals, right) between the REPS 1.0.0 (blue) and the REPS 2.0.1 (red). Lower CRPS values on the left graphs indicate better skill. Positive differences on the right indicate that the REPS 2.0.1 is better then the REPS 1.0.0.

A) Temperature at 250 hPa and B) 850 geopotential for the summer period

- Scores for the surface fields also showed a significant improvement during summer and winter

A)



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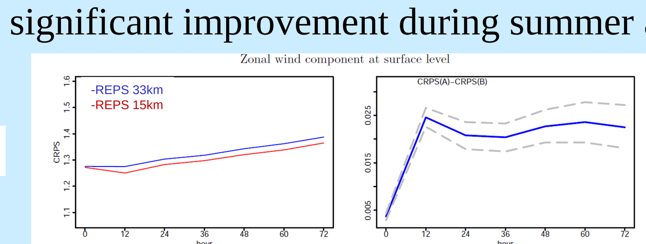
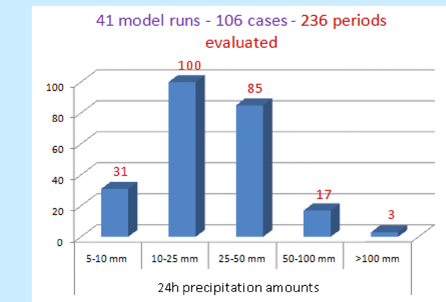


CRPS (left) and CRPS difference (with 90% confidence intervals, right) between the REPS 1.0.0 (blue) and the current REPS 2.0.1 (red). Lower CRPS values on the left graphs indicate better skill. A) 2m temperature B) 10m zonal winds for the summer period.

Subjective verification

- Conclusions from the objective evaluation of precipitation amounts were difficult to draw. For this reason, seven meteorologists from the Analysis and Prognostic (A&P) group at CMC were asked to perform a subjective event-based validation during the parallel run of summer 2013
- 106 cases from 41 REPS runs were studied.
- Meteorologists compared the two REPS (2.0.1 vs. 1.0.0) and classified each event into five categories: slight or significant improvement, slight or significant deterioration and equivalent.



Number of events studied categorized into precipitation amounts

Subjective verification results

• For half of the events the two systems performed equally
• For the second half, REPS 2.0.1 performed better than REPS 1.0.0 by a ratio of 5:1.

	Which model performed better?					
	15km -	15km +	33km -	33km +	Equal	Total
5-10 mm	11		5		15	31
10-25 mm	34		7	1	58	100
25-50 mm	43	3	4	2	33	85
50-100 mm	8		1		8	17
>100 mm		1			2	3
Total	96	4	17	3	116	236
	41%	2%	7%	1%	49%	

Verification results: 15km- (15km+) indicates a slight (significant) improvement of the REPS 2.0.1 system . 33km- (33km+) indicates a slight (significant) deterioration of the REPS 2.0.1 system.

REPS Products

REPS products link and technical documents can be found at the following address:
http://collaboration.cmc.ec.gc.ca/cmc/cmoi/product_guide/submenus/reps_e.html

Future plans

- Assimilation component
    - Regional ensemble Kalman filter and variational method.
        - A major milestone for the regional EPS
        - Background at 15 km grid spacing
- Forecast component
    - Possible lead time up to 4 or 5 days.
    - 4 runs per day. 00Z, 06Z, 12Z and 18Z
    - Possible stochastic convection.
    - Increasing the horizontal resolution to 10 km.
    - Better surface and near-surface model error representation by perturbing uncertain parameters and fields related to the surface scheme.
- North American regional ensemble system (NAEFS-LAM from NCEP and CMC)

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