Accounting for Particular Balance Properties Over Precipitation Areas within Variational Data Assimilation Systems

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2008 EWGLAM/SRNWP meetings, 6-9 October, Madrid, Spain.

Workshop on 4D-VAR and Ensemble Kalman Filter Inter-Comparisons, 10-13 November 2008, Buenos Aires, Argentina.

Over the past five years, Environment Canada has developed a limited area 4D-Var data assimilation system (LAM4D). The primary goal of this work being the improvement of North American data assimilation and mesoscale weather forecasts up to two days. This continental version is currently under intensive evaluations and is being compared with the current operational regional data assimilation system.

The present poster is related to the second phase of this LAM development work; i.e. a high resolution local limited area 3D-Var analysis system. The latter producing mesoscale forecasts at 2.5 km up to 24h. Because of the spatial scales considered and the importance of moist physical processes, it is necessary to improve the balance imposed on mass and wind analysis increments over precipitation areas.

Characteristics of EC's limited area 3D-Var data assimilation system:

- Bi-Fourier spectral representation
- Helmholtz's functions used to define control variables
- Non-separable background error correlations

v. Continental

Model:
GEM-LAM 15 km
Analysis Increments:
55 km

Plan to be operational in 2009

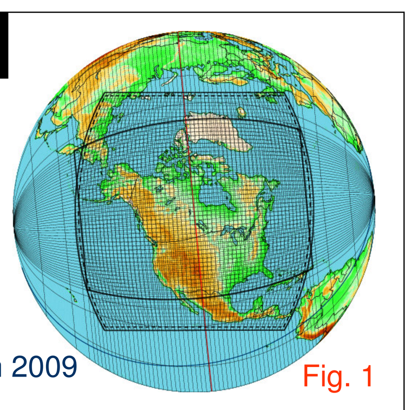


Fig. 1

v. Local

Model:
GEM-LAM 2.5 km
Analysis Increments:
10 km

Operational in 20??

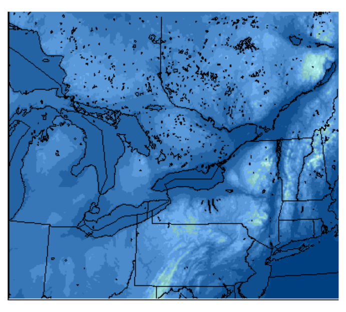


Fig. 2

1. Treatment of balance in VAR systems

a) Standard mass - rotational wind coupling

Coupling between mass and rotational wind analysis increments in the current version of EC's limited area VAR system follows Derber and Bouttier (1999):

$$[T'_b , p'_{s_b}] = \mathbf{V} f \psi'$$

Where **V** represents a balance operator and is obtained by a linear regression between streamfunction (transform into mass field through linear balance assumption) and both temperature and surface pressure in a large ensemble of forecast error samples.

Constructing V : Step 1 $\Phi'_b = f\psi'$ Step 2 $\Phi'_b \overset{\mathbf{V}}{\longleftrightarrow} [T', p_s']$

Traditionally, when constructing **V**, all points (dry and precipitation) are mixed together, preventing the operator to represent the particular balance within precipitation areas.

b) Diabatic balance operator by linear regression

We examine balance operators adapted to precipitation areas built by applying the linear regression technique only where precipitation occurs in forecast error samples.

We tested here three 'diabatic' balance operators built for light, moderate and heavy precipitation regimes respectively ($\mathbf{V}_l$, $\mathbf{V}_m$, $\mathbf{V}_h$).

2. Data and precipitation classes

For this investigation, we used the continental configuration (Figure 1) of EC's limited area 3D-Var. This choice is motivated by the large size of the domain (which offers a rich diversity in precipitation regimes) and the familiarity of the behavior of our limited area VAR system in this configuration.

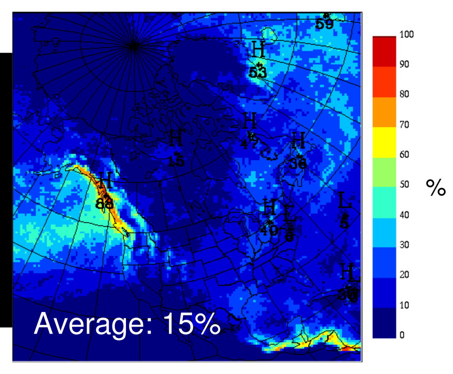
Following the NMC method (Parrish and Derber, 1992), an ensemble of lagged forecast differences is used to build the different balanced operators and the background error statistics for our 3D-VAR system.

Source	Forecast difference	Resolution (domain)	Period	Members
Global-GEM 33 km	48h – 24h	55 km (158x158)	Winter (Dec-Jan)	100

Precipitation areas and classes are based on the mean instantaneous precipitation rate (PR) from lagged forecasts valid at the same time. (threshold: PR ≥ 0.1 mm/h)

Frequency of "precipitation point"

Fig 3: Percentage of member grid point considered to be precipitation point within the 100 ensemble members



Precipitation Classes	Precipitation Rate (mm/h)	Fraction of total precipitation points
Light	0.1 ≤ PR < 0.5	64%
Moderate	0.5 ≤ PR < 1.5	27%
Heavy	PR ≥ 1.5	9%

3. Degree of balance in precipitation areas

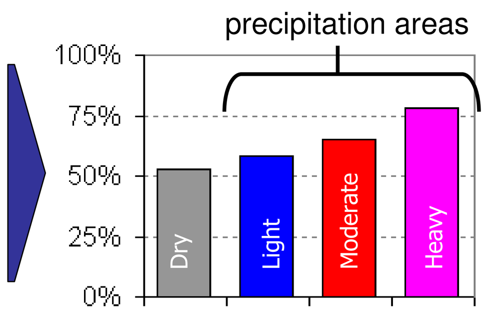
The degree of balance between mass and rotational wind component within the ensemble of forecast differences were investigated in dry and precipitation areas using the linear balance equation (i.e. geostrophic balance approximation).

$$\nabla^2\Phi' = f\zeta'$$

Mass component — Wind component

Normalized Deviation From Linear Balance

Fig 4: RMS linear balance residual (mass minus wind) normalized by the average RMS of mass and wind, and average over the 100 members between 250 and 950 hPa

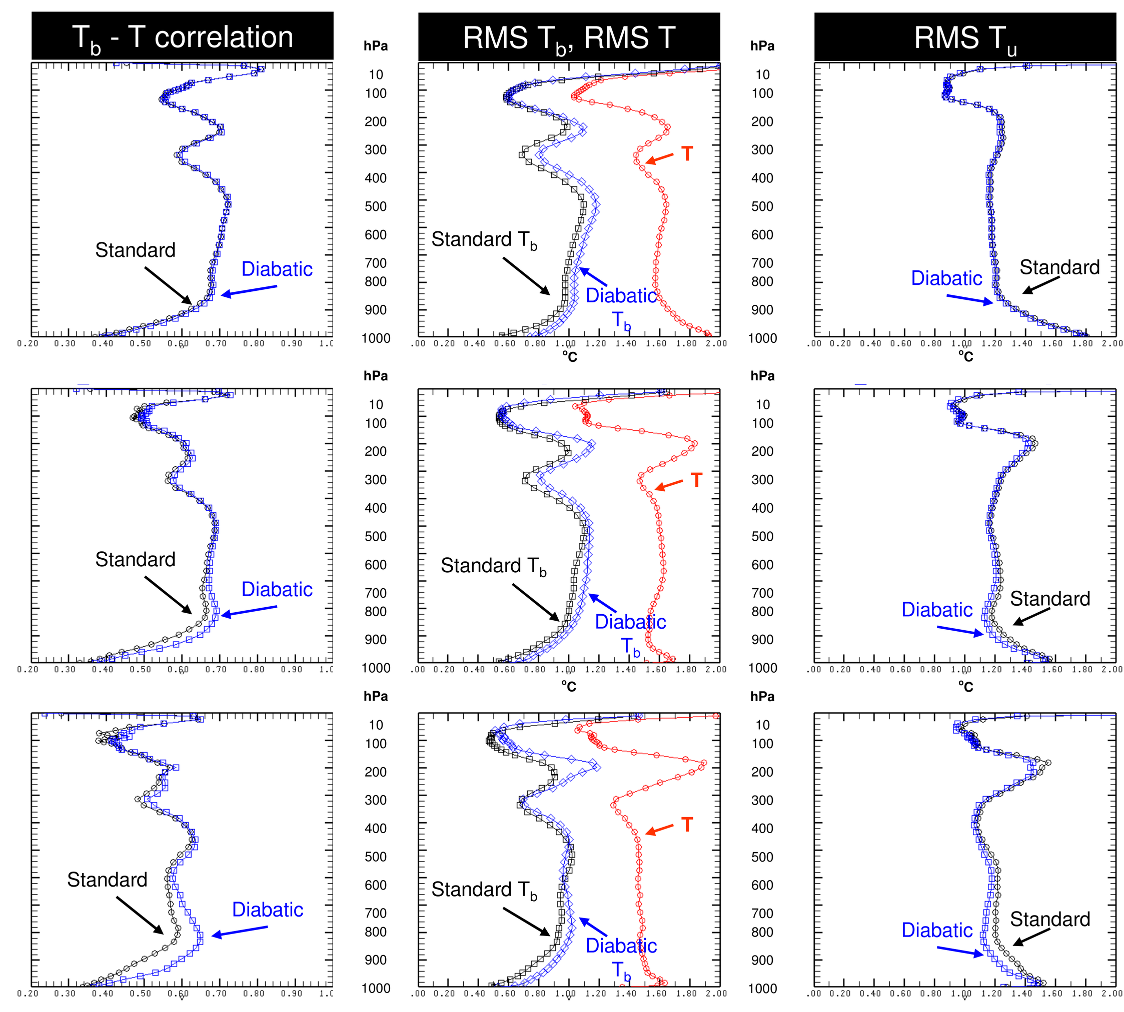


- The perturbation flow is further away from geostrophic balance in precipitation areas
- The deviation from geostrophic balance is proportional to the precipitation intensity

4. Standard VS Diabatic balance operator

a) Explained temperature

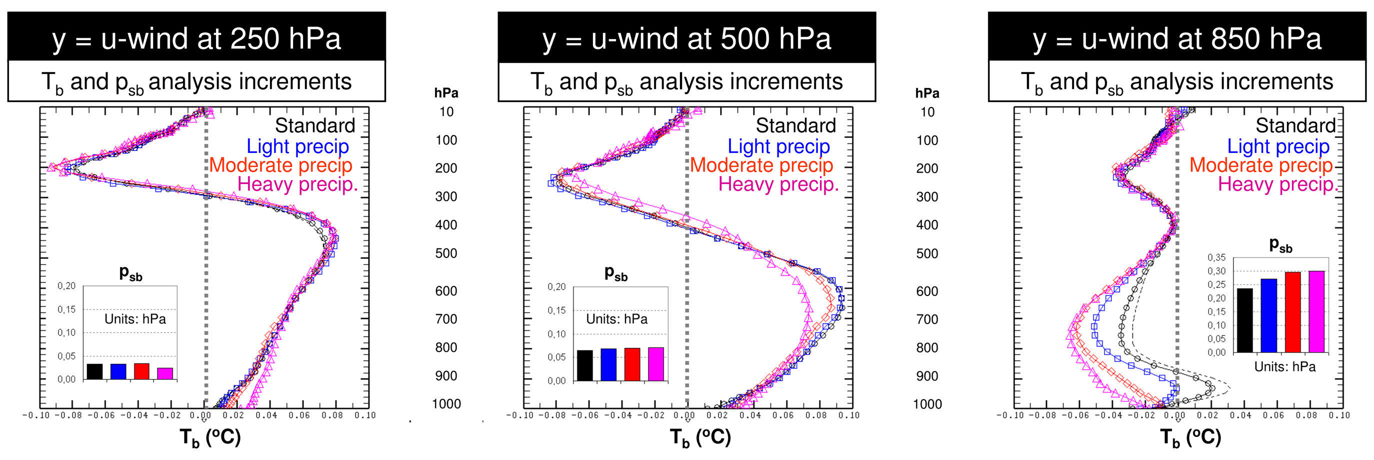
We compare here the correspondence between balance temperature (T_b), as obtained by standard and diabatic balance operators, and temperature (T) within the precipitation areas of the ensemble of lagged forecast differences.



- Largest improvements are located in the lower troposphere

b) Single observation experiments

The impact of the diabatic operators are tested in a series of assimilation of a single simulated observation located at the center of the domain, but at different heights.



- In all experiments: innovation (d) = 1 m/s , observational error (ε) = 1 m/s

- Diabatic operators produce significant differences in the analysis increments
- Differences are proportional to precipitation intensity
- Differences increase as the observation height decrease

5. Future work

- Examine the implementation and the impact in a full fledged analysis system
- Do linear regression diabatic operators improve the precipitation forecasts ?
- Investigate balance and diabatic operators behavior for summertime precipitation regime
- Compare with other improved balance approaches in VAR systems
  a) Implicit normal mode (Fillion et. al., 2007) b) Mesoscale balance equations (Pagé et. al. 2007)
- Does EN_KF perturbations exhibit similar balance differences over precipitation areas ?

References

Derber, J., and F. Bouttier, 1999: A reformulation of the background error covariance in the ECMWF global data assimilation system, *Tellus*, **51A**, 195-221.

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Parrish, D. F., and J. C. Derber, 1992: The national meteorological center's statistical-interpolation analysis system, *Mon. Wea. Rev.*, **120**, 1747-1763.