

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

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- Over the past five years, Environment Canada has developed a **limited area variational data assimilation system (3D and 4D)**
- Two ongoing R&D project are using this new system to improve short range forecasts:
  - North America (15 km)
  - Targeted areas over Canada (2.5 km)

• Improve the balance imposed on mass and wind analysis increments over precipitation areas

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

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

The overall paper is related to the second phase of the LAVAS development work, i.e. a high-resolution local limited area 3D-Var analysis system. The latter producing reanalysis forecasts at 1.2 km to 20h. Besides of the spatial resolution 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:**

- 3D-Var system
- 4-Physics spectral increments
- Analytical functions used to define control variables
- Non-separable background error covariances

**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 Deiter and Fischer (2009):

$$\begin{bmatrix} \delta \mathbf{v} \\ \delta \mathbf{v} \end{bmatrix} = \mathbf{V} \delta \mathbf{v}$$

Where  $\mathbf{V}$  represents a balance operator, and is obtained by a linear regression between orographic height and mass (both through level balance equations) and both temperature and surface pressure in a large ensemble of forecast error samples.

Traditionally, when conducting  $\mathbf{V}$  at 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 MFC method (Farrish and Deber, 1992), an ensemble of lagged forecast differences is used to build the different background operators and the background error statistics for our 3D-Var system.

Region	Forecast difference	Background operator	Period	Resolution
Canada	0h - 12h	0h - 12h	1998 - 2008	15 km
North America	0h - 12h	0h - 12h	1998 - 2008	15 km

Precipitation areas and classes are based on the mean instantaneous precipitation rate (PR) from lagged forecasts valid at the same time. (threshold: PR > 0.5 mm/h)

**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 one and precipitation areas using the linear balance equation (i.e. geostrophic balance approximation):

$$\nabla \times \mathbf{v} = -f \mathbf{v}$$

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 area of the ensemble of lagged forecast differences.

b) Simple observation experiments

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

Diabatic operators produce significant differences in the analysis increments. Differences are proportional to observation height decrease. 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 surmounting precipitation regimes
- Compare with other improved balance approaches in VAR systems
- Diabatic normal mode (Fillion et al., 2007) 3D-Var balance operator (Farrish et al., 2007)
- Does ENLIF perturbations exhibit similar balance differences over precipitation areas?

**References**

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## In this poster we paid attention to mass – rotational wind balance

- Do this balance differs between dry and precipitation areas ?

Balance characteristics were investigated in a large ensemble of forecast error sample (lagged forecast differences: NMC method to estimate background error statistics)

- Current balance operator:

In our system, coupling is currently done by an operator obtained through a linear regression between streamfunction and mass ( $T$  and  $p_s$ ) in the forecast error samples

All points (dry and precipitation) are mixed together, preventing the operator to represent the particular balance within precipitation areas.

- **Tested approach: Use only precipitation points to build a ‘diabatic’ balance operator by linear regression**
  1. Do the diabatic operator reproduced better the forecast error temperature than the standard operator in precipitation areas ?
  2. Impact of this new operator is tested in a series of single observation experiments