The Canadian Meso4dvar Continental Analysis System: Pre-Operational Evaluations

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ABSTRACT

We present an update on earlier results presented at the AMS-2006 meeting in Atlanta on the continental regional data assimilation system to be used for operational short-term weather forecasting (up to 2 days) by the Canadian Meteorological Center (CMC). Pre-operational evaluations are currently underway and early results will be presented at the conference.

1. INTRODUCTION

At Environment Canada (EC), a Limited-Area 4D-Var analysis system has been developed in order to enable the analysis of synoptic and mesoscale weather.

This system is referred to as *Meso4dvar*. The main objective of this new analysis system being the improved forecast of precipitation up to 48h, with a replacement of the Canadian Regional analysis system currently operational at CMC. Figure 1 shows two types of limited area analysis/forecast domains considered.

The large domain is for the "North American Continental" configuration. The Meso4dvar analysis is designed to suit the Limited-Area version of the GEM model (Cote et al. 1998). The latter being used operationally only in global mode with uniform and non-uniform mesh for medium-range and short-range weather forecasting respectively.

Tangent-linear (TL) and adjoint (AD) versions of GEM-LAM were developed as an extension of the work by Tanguay and Polavarapu (1999). The TL/AD GEM-LAM code was coupled last year to the limited-area version of the variational analysis code.

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Target Grid for Regional 48H Forecast at 10 km using GEM_LAM

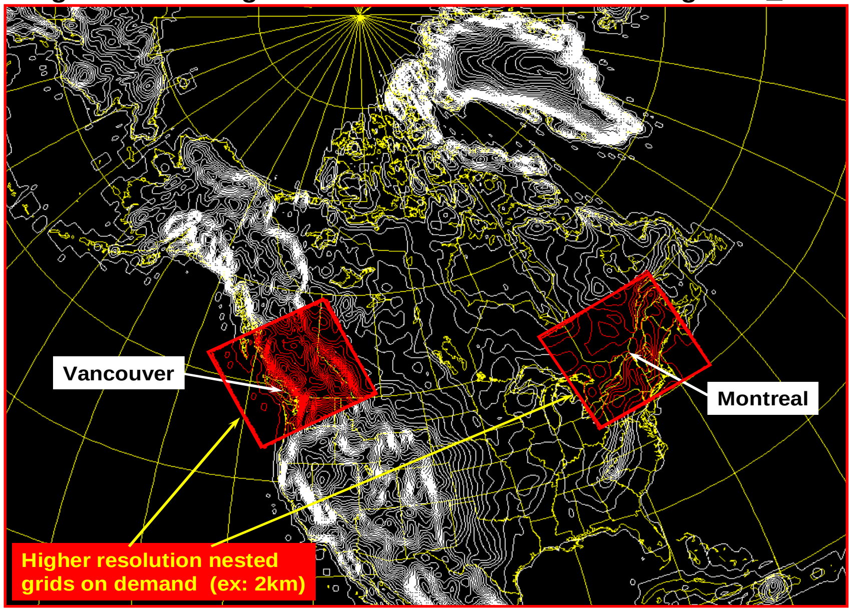
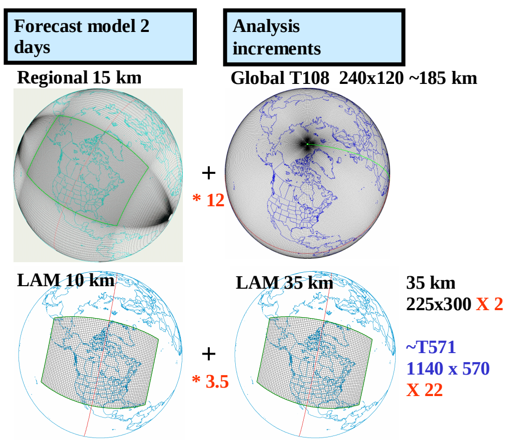


Fig.1 Meso4dvar North-American Continental Grid.

Putted simply, Meso4dvar uses bi-Fourier spectral representation on a limited area domain rather than spherical harmonics on the sphere. Otherwise, the two configurations of the code were designed to be mostly transparent to the user. Helmholtz's functions are being used in the two analysis systems with non-separable background error correlations in their respective spectral spaces.

The horizontal resolution of the Nonlinear GEM-LAM NA-Continental model is 10 km (the current operational regional model being at 15 km). However, the inner-loop resolution of the incremental Meso4dvar is currently set at 35 km (6h time assimilation window) This represents a bit more than a factor 5 increase in horizontal resolution as compared to the current inner loop of the global operational incremental 4D-Var system which is currently at T108.

The other two small analysis domains are for even higher resolutions at 2.5 km designed to improve short-range weather forecasting in the 0-12h range. The Meso4dvar code operated on this high-resolution local grid was tested under simple observation assimilation experiments but there remains more work to introduce background-error correlations representative of errors at these small scales. Recent results by Pagé et al. (2007) (Page, C., L. Fillion and P. Zwack, 2007: Diagnosing Summertime Mesoscale Vertical Motion: Implications for Atmospheric Data Assimilation. To appear in Mon. Wea. Rev.) at 2.5 km horizontal resolution with full physics clearly identify cases where a diagnostic relationship between vertical motion and diabatic forcing may still be advantageous at the convective scale. The following figure shows that (upper panels): there is a factor 12 between the current regional forecast model and the inner loop global 4dvar analysis system. This is the current operational setup; (2) (lower-panels) for a LAM context, this factor is reduce to 3.5 between the LAM nonlinear model and the inner loop of Meso4dvar. Remarkably, this can be achieved by only a factor 2 increase in the dimension of the analysis problem, whereas this type of inner loop resolution would totally be impracticable within the current operational context with the global analysis code where a factor of 22 would be required.



2. DEFINITION OF ANALYSIS CONTROL VECTOR

In the variational analysis procedure, we analyze "analysis increments"; i.e. departures from a background field (a priori estimate):

$$\delta \mathbf{x}_a = \mathbf{x} - \mathbf{x}_b \qquad (2.1) \quad .$$

In order to make the "background term" or cost-function assume the simple quadratic form

$$J_b = \frac{1}{2} \boldsymbol{\chi}^T \boldsymbol{\chi} \qquad (2.2) \quad ,$$

we make a change of analysis variables of the form:

$$\mathbf{x} - \mathbf{x}_b = \mathbf{L}\,\boldsymbol{\chi} \quad (2.3) \text{ s.t. } \mathbf{B} = \mathbf{L}\mathbf{L}^T .$$

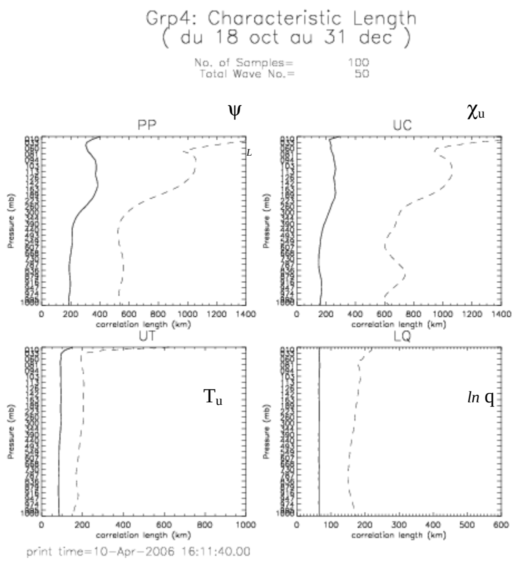
The transformation represented by the linear operator **L** is a composition of operators the reader can find in Derber and Bouttier (1999), Gauthier et al. (1999), Fisher (2003). Included in this transformation is a splitting of analysis-increments in terms of so called "balanced" and "unbalanced" components. Those are usually defined with simple linear approximation to more complex nonlinear balance equations; e.g. the local geostrophic assumption between mass and streamfunctions. This balance operator has a crucial importance (in this type of variational formulation) in order to define flow-dependent background error correlations. The reader can find in the reprint volume of the AMS-2006 meeting in Atlanta, our approach on coupling vertical motion and diabatic forcings directly within the minimization process. This methodology has been incorporated within the current version of Meso4dvar. However, a more process-type general, compact and efficient balance operator enabling flow/physical-processes-dependent background-error covariances is currently being implemented within Meso4dvar.

Details on this approach will be given at the next AMS meeting in 2008.

3. RESULTS

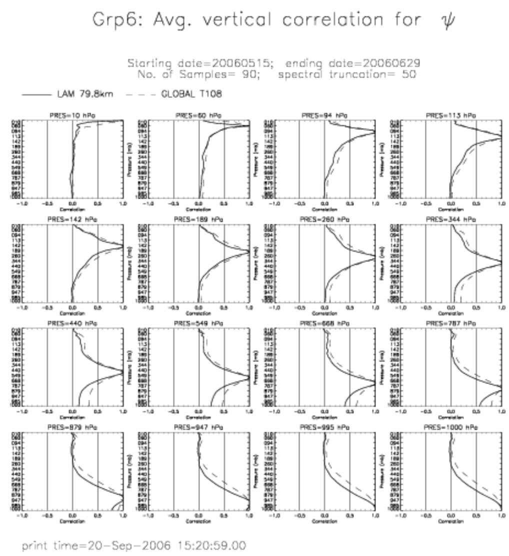
The first obvious difference between the current regional 3dvar analysis (performed with the global analysis code) is the background error correlation scales for the unbalanced analysis variables. We have used 24-12h forecast differences (forecasts valid at the same time; i.e. the NMC type of approach). The horizontal correlations scales (based on a homogeneous and isotropic representation) is reduced by more than a factor two for most analysis variables; (e.g. ψ, unbalanced divergence χ_u and temperature) (see fig. below).

Winter 2005 L



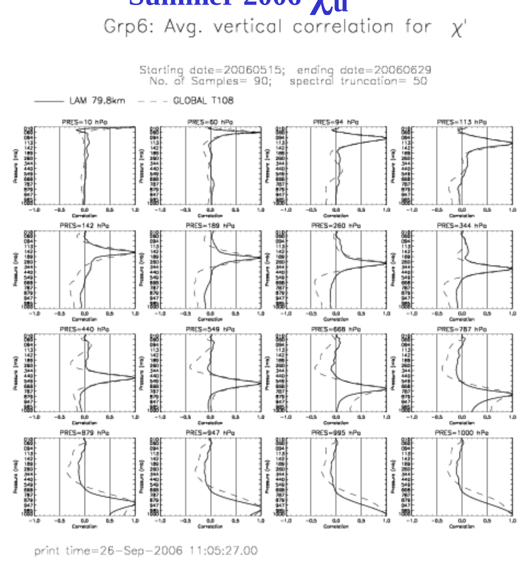
The following two figures show the mean (in terms of all horizontal wavenumbers included) vertical correlations functions for streamfunction and the unbalanced part of the "chi" field (related to divergence) for the summer 2006 season. It can be noted that the lower mid levels correlations for streamfunction is reduced as compared to the global statistics (solid versus dashed lines resp.). Another difference is the strong negative anti-correlation for the unbalanced part of chi present in the global statistics (dashed lines) and mostly absent for the LAM statistics. We reasons to believe that this difference comes mostly from the use of 24-12h differences rather than 48-24h forecast differences. The latter can't be used for LAM due to the strong dependence on lateral boundaries which then dominates the correlation structure and not representative of 6h forecast errors. The unbalanced part of temperature forecast errors is the same for both LAM and global statistics (results not shown).

Summer 2006 ψ

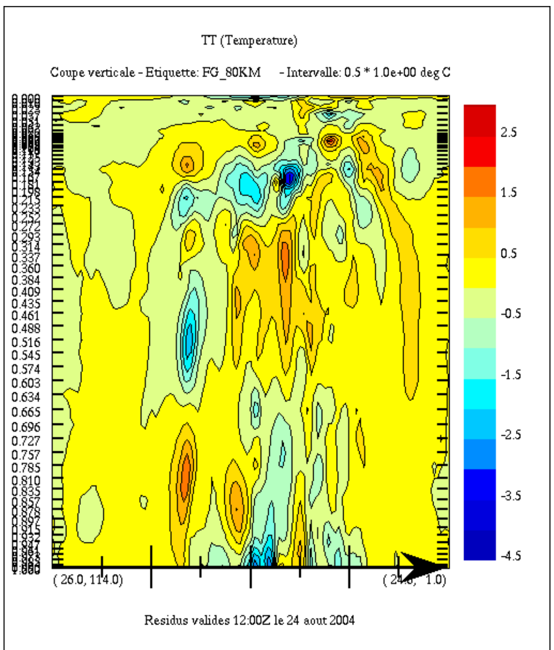


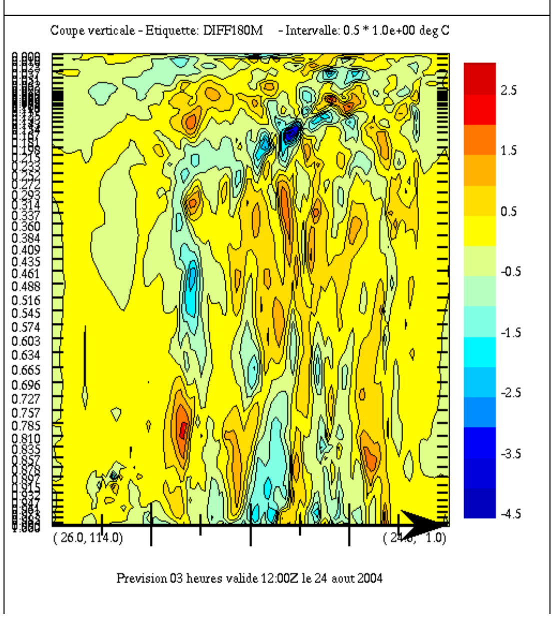
Solid line: Global; Dashed: MesoVar_C

Summer 2006 χ_u



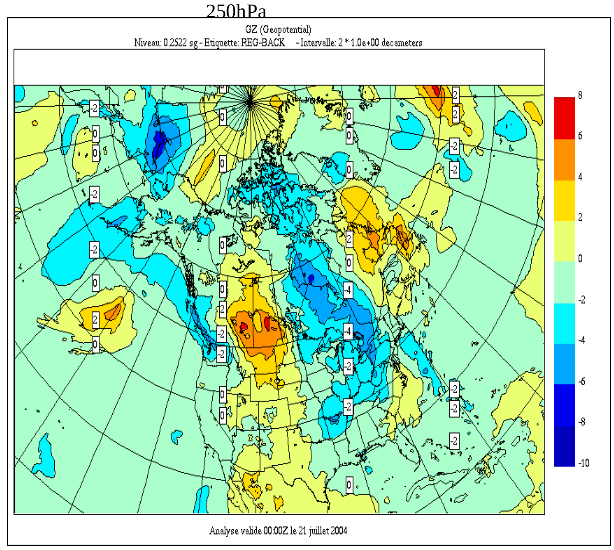
The following two figures show respectively a vertical cross-section of the temperature analysis increments for a 2004 August case using FGAT-3dvar (global analysis code) and the Meso4dvar (LAM) analysis code (here run at 80 km inner loop resolution). Due to the weakness of advective effects for this summer case at low levels, the major sloping effect expected for 4dvar and smaller scale increments (due to smaller correlation scales) appear mostly around the jet level where these effects dominate. Note that both analysis increments are valid at the same time; i.e. 3h later than the 4dvar analysis time.

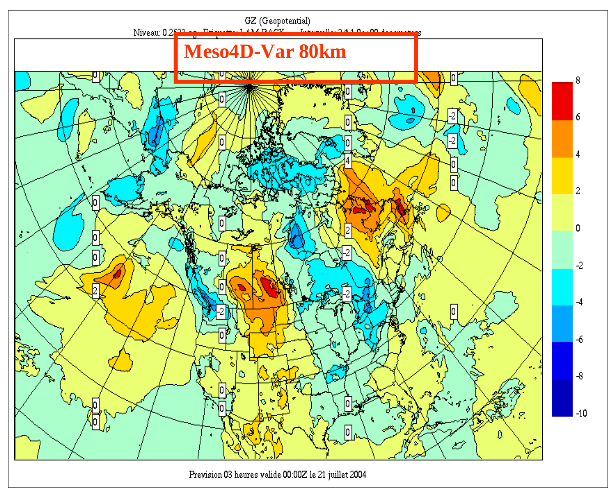




The following two figures show the geopotential analysis increments at 250 hPa for FGAT-3dvar and Meso4dvar respectively. The advantage of the 4dvar technique for influencing the flow on the pacific ocean from the assimilation of continental data (e.g. radiosondes) is present. We note that all observations currently assimilated by the operational 3dvar regional system have been assimilated here (e.g. upper-air, surface data, aircrafts, SSMI, Sat-Wind, GOES, TOVS).

GZ analysis increments
250hPa





Further results and operational implementation details will be given at the conference.____________________