Operational Implementation of 4D-Var at the Meteorological Service of Canada

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The three-dimensional variational data assimilation (3D-Var) for the operational medium-range forecasting system (Gauthier et al., 1999a; Chouinard et al., 2001) has been extended to 4D-Var. Presently, the Global Environmental Multi-scales (GEM) model is used in this forecasting mode with a uniform horizontal resolution of 0.9^{o} and 28 vertical levels with a top at 10 hPa (Côté et al., 1998). The 4D-Var upgrade has been achieved by including the model integration as part of the observation operator, along with additional and improved features. First guess at the appropriate time (FGAT) from the full-resolution model trajectory is used to calculate the misfit to the observations. The tangent-linear of the GEM model and its adjoint (Tanguay and Polavarapu, 1999) are employed to propagate the analysis increment and the gradient of the cost function over the 6-h assimilation window. The analysis is obtained after two outer loops: 40 iterations with only the vertical diffusion as simplified linearized physics (Laroche et al., 2002) are first performed, then after updating the full-resolution trajectory, 30 more iterations are done with a set of simplified physical parameterizations which includes vertical diffusion, subgrid-scale orographic effects, large-scale precipitation and deep moist convection (Zadra et al., 2004; Mahfouf 2005). The data selection process has been modified for all observation types except the surface reports. The 6-h assimilation window is divided into 9 time intervals (rather than one in 3D-Var). For each interval, the data are spatially thinned to retain the observation closest to the middle of the time interval. This has considerably increased the number of frequently reported data such as aircraft, satwind and profiler data. Finally, the resolution of the analysis increment (T108), background error statistics (Gauthier et al., 1999b) and the data quality control remain the same as in 3D-Var (Gauthier et al., 2003).

An extensive pre-implementation evaluation of 4D-Var against the operational 3D-Var was conducted. Anomaly correlation scores for two-month assimilation periods in winter 2003-2004 and summer 2004 are presented in Fig. 1. A consistent improvement in the northern hemisphere and nearly 9-h gain in predictability in the southern hemisphere have been obtained with 4D-Var. The impact of 4D-Var is however rather neutral in the tropics (not shown). We found that about half of the improvement is explained by the used of the tangent-linear and its adjoint to properly propagate the information over the assimilation window. The other features of 4D-Var, that are the increased number of observations assimilated at the appropriate time, the use of a set of simplified physical parameterizations in the second outer loop and the trajectory update then explain (ranked in order of importance) the remainder of the overall improvement over 3D-Var. The 4D-Var will be implemented in the operational suite of the Canadian Meteorological Center by mid March 2005.

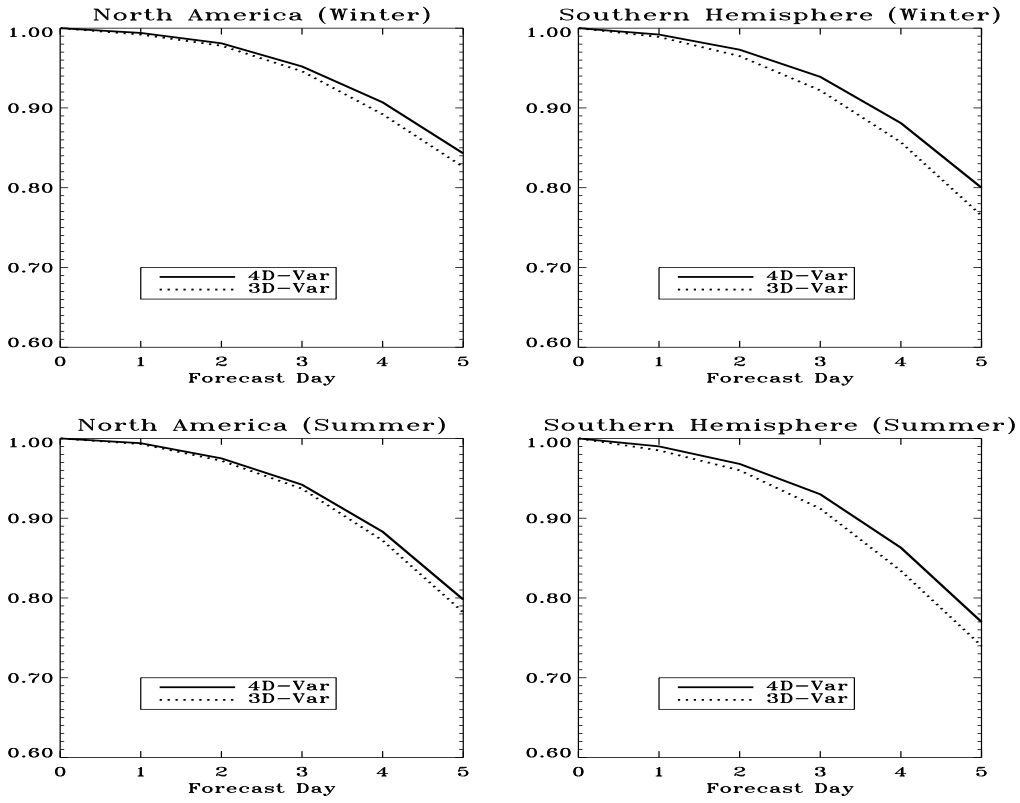

Figure 1. Anomaly correlation scores for 4D-Var and 3D-Var for the summer (15 Jul.-15 Sep. 2004) and winter (11 Dec. 2003-11 Fev. 2004) periods over North America and the Southern Hemisphere.

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