THE CANADIAN 3D-VAR ANALYSIS SCHEME ON MODEL VERTICAL COORDINATE: RECENT AND FUTURE WORK

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1. INTRODUCTION

The operational analysis system of the Canadian Meteorological Centre (CMC) has undergone major revisions in the last two years. The changes described here are really a follow-up to the June 1997 implementation of the first Canadian 3D variational system (3D-var) described in Gauthier et al. 1999. First, in June 2000, 3D-var was converted from a 16-pressure to a 28 terrain-following-η level system (3D-Var-η) including a complete revision of background and observational errors. In September 2000, the use of satellite data was updated to directly assimilate TOVS radiances, in replacement of SATEM thickness data. In December 2001, the 3D-var's use geopotential data from radiosondes was abandoned in favor of using temperature and surface pressure. The same was done with the synoptic surface data and both have had a very positive impact on analyses.

Some years ago, the CMC developed unified model codes for both the global and regional forecast models (Côté et al. 1998). Similarly, the 3D-var system was also coded to support both the regional and global pressure systems as described in Gauthier et al. 1999, and Laroche et al. 1999. In January 2001, the regional spin-up system was fully upgraded from the 16 pressure levels to 28 terrain-following η levels including the direct assimilation of TOVS radiances as in the global analysis system. In December 2001, its use of geopotential data from radiosonde was also abandoned in favor of using temperature and surface pressure.

2. GENERAL FORMULATION OF THE 3D-VAR, AND ESTIMATION OF NEW STATISTICS

Several operational NWP centres currently employ, or have employed a 3D-Var system. The 3D-var formulation of this study is based on the incremental approach, and the analysis variables are actually the incremental corrections. The initial misfits between the observations and the short-term forecast or innovations are computed in observation space using the full resolution background state whereas the analysis increments are calculated at lower resolution. In the global system, the trial fields are used at the full resolution (0.9 degree grid) of the GEM model and the analysis increments are calculated at the lower T108 spectral resolution.

The covariance statistics of the 3D-Var-η system were redesigned based on a 3-month ensemble of 24 and 48-h forecasts valid at the same time. The 24-48-h forecast differences are not entirely representative of 6 hour forecast error statistics, and for this reason, the estimated variance fields are assumed to be zonally invariant and were also scaled down using information from the variances of radiosonde observations minus 6h-forecast wind and temperature averaged over broad latitude bands.

The 3D-Var-η system is multivariate and like its predecessor imposes a simplified balance constraint between mass and wind analysis increments. The complete balance operator is actually the product of local horizontal and vertical balance operators as discussed in Gauthier et al. (1999). The vertical operator which transforms vertical profiles of the balanced mass variable into temperature profiles is estimated using a regression analysis over the ensemble of error samples between temperature profiles and profiles of linearly balanced stream function increments in grid-point space. This approach is used to avoid problems of increased noise in the vertical structure and the null space associated with using a theoretically based inverse hydrostatic operator. Typically, the horizontal and vertical spread of balanced is larger than those of the unbalanced component (Chouinard et al. 2001).

3. NEW SOURCES OF DATA; SATELLITE AND AIRCRAFT

In 3D-Var-η, observations are assimilated in their raw or unprocessed form with the use of so-called "observation operators" thereby avoiding interpolating data to and from a fixed pressure grid prior to their assimilation. For example, TOVS radiances are directly assimilated with the help of a radiance transfer model (RTM). The advanced microwave sounding unit (AMSU) of the recent NOAA series produces data of exceptional quality that are relatively easier to use than the IR data in most sky conditions. In the current 3D-Var-η, only the microwave data of channels 3-10 of AMSU-A from NOAA-15 and 16 platforms are used. All radiances used are quality controlled prior to the monitoring and assimilation steps as described in Chouinard et al. (1999, 2000). The impact of TOVS radiances is very large and positive everywhere, but exceptionally so in the SH, where the predictability of the system was improved by close to 24 hours (Chouinard et al. 2001).

In recent years, a very important source of wind data has become available in the form of automated aircraft wind reports (ACARS/AMDAR). The impact of these winds when added to the AIREP data was shown to be marginally negative in the previous 16-pressure level 3D-Var system and consequently was never implemented even though monitoring indicated the data was of very good quality. Because the correlation structures of the 3D-Var-η system are much improved, the impact of the additional ACARS data has now been shown to produce very positive impacts particularly when accompanied by TOVS radiances (Chouinard et al. 2001).

3.1. Direct assimilation of temperature (including significant levels) and surface pressure

Even though the analysed mass variables of the current 3D-Var-η regional and global systems are temperature and surface pressure, geopotential has remained the main source of observations from RAOBS and similarly the surface pressure was assimilated indirectly as a proximity to surface geopotential datum. Because of this, significant level temperatures from RAOBS and aircraft temperature reports were never assimilated in the current system. Recently, we have introduced the direct assimilation of temperatures and surface pressure from RAOBS instead of geopotential, and similarly, temperature and moisture observations from the surface synoptic meteorological (SM) network are now directly assimilated producing larger and more consistent corrections to the trial field thereby improving the surface and PBL structures. Parallel suites prior to the December 2001 implementation clearly indicate the positive impact of direct assimilation of surface and upper air temperature data on analyses and 10-day forecasts.

3.2. Application to the regional analysis system

Like its previous pressure system, the 3D-Var-η system was adapted to the regional model to produce analyses directly on its model levels. As in the global, the analysis increments are calculated at the low-resolution horizontal and vertical resolution of the analysis grid of the global statistics. The increments are interpolated to and from the regional model grid during the 12-h spin-up to arrive at the final analysis on the higher resolution regional model grid. As expected, the same improvements obtained with the global 3D-Var-η were obtained in the regional system, but most significantly, the moisture analyses and the precipitation forecasts were significantly improved (Chouinard et al. 2001).

4. FUTURE WORK

In preparation for the assimilation of satellite data from future platforms (NOAA-17), we have started testing with AMSU-B TOVS radiances from current NOAA polar orbiters. The model and analysis top are being raised to 0.1 hPa to accommodate the higher peaking radiances of the AIRS and IASI instruments.

5. REFERENCES

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