3.5 MIDDLE ATMOSPHERE DATA ASSIMILATION WITH A CLIMATE MODEL

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1. INTRODUCTION

A new data assimilation scheme has been developed for the Canadian Middle Atmosphere Model (CMAM) for two reasons: (1) confronting the climate model with data will lead to improvements in the model and its errors, which will in turn lead to a better understanding of atmospheric dynamics and chemistry, and (2) to create a platform to aid in the testing and assimilation of data from new satellite instruments targeting the middle atmosphere (10-90 km).

2. THE MODEL

CMAM is a spectral T47 climate model with interactive chemistry, dynamics and radiation. There are 65 vertical levels from the ground to 0.001 hPa (90 km). This model was designed to study middle atmospheric dynamics and chemistry so it produces a realistic ozone climatology and is capable of producing QBO-like oscillations. Beagley et al. (1997) provides a general description of the model.

3. THE DATA ASSIMILATION SCHEME

The 3DVAR scheme which is used for operational weather forecasts at the Canadian Meteorological Centre (Gauthier et al. 1997) has been adapted and coupled to CMAM. The operational weather forecast model is GEM and is described in Côté et al. (1998). Recently the operational 3DVAR scheme has been modified to produce analyses directly on model levels (rather than on pressure levels). The analysis variables are temperature, streamfunction, velocity potential, log of specific humidity and log of surface pressure. The background error statistics were recomputed on model levels using the NMC method based on 48-24 h forecast differences. Also, TOVS radiances are now being directly assimilated.

It is this most recent operational version that has been coupled to CMAM. Some additional changes were necessary to accomodate the new model (CMAM). In particular, 3DVAR was modified to allow a generalized vertical coordinate (which includes CMAM and GEM coordinates) and the lid was raised from 10 hPa to 0.001 hPa. We also computed background error statistics appropriate for CMAM. Since CMAM has never before been used for data assimilation, it was not possible to use the NMC method to compute the background error covariance matrix since no forecasts (or analyses) are available. Thus, statistics based on CMAM's climatology are used as a first guess of the background error covariance. Interestingly, however, there are some similarities between CMAM's climatology-based statistics and those of GEM which are derived based on the NMC method. Specifically, the power spectra of autocorrelation functions are similar. Standard deviations were scaled to be similar in the troposphere. Once a data assimilation system is in place, these statistics can be updated using an innovations-based or NMC-type method.

4. VALIDATION OF THE SYSTEM

The new assimilation scheme is being tested using past data from Jan 1994, during the UARS period, because of the availability of middle atmosphere data (e.g. from MLS and HRDI) and because the climate of this period has been well documented. However, as a first step, we are validating the system with conventional meteorological observations from the troposphere and lower stratosphere only. The testing period starts in Jan. 1994 and the first background state is taken from a model climatological state for January.

Fig. 1 shows a time series of comparison of 6-h forecasts (or trial fields) against radiosonde observations, averaged over the world. The dashed line shows the present assimilation scheme with 65 CMAM levels and a lid of 0.001 hPa. The background error statistics are from CMAM climatology and the initial trial field is rather poor – a mean Jan. climatological state. For comparison, an older cycle is shown (solid line), where the initial background was obtained by nudging to archived CMC analyses. The older cycle also used

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GEM's 28 model levels (up to 10 hPa) for the analysis, and GEM's background error statistics although the forecasts were done by CMAM. Comparing the dashed line to the solid one shows how quickly the poor trial field (from climatology) is improved. A rapid reduction in error is evident within the first few cycles. Only the temperature field is shown here, but other variables also rapidly adjust to the data within a few days. However, the humidity field takes much longer to adjust (and forget the initial condition) because of the dearth of humidity observations and because its assimilation is decoupled from that of other variables. The rapid improvement of the trial fields suggests that a poor background can be used in a "spin-up" cycle. The actual cycle would begin after the trial field errors had become reasonable. Because of the slower adjustment of the humidity field, a "spin-up" period of about 1 month is expected.

Results thus far are very preliminary, being from the spin-up period. Results from after this period will be produced shortly, and presented.

5. FUTURE PLANS

In the coming year we plan to: implement an initialization scheme based on incremental analysis updates; validate the system for tropospheric data; obtain improved statistics based on assimilated fields; implement a bias correction algorithm and assimilate new data sources from the stratosphere and mesosphere including some of MLS, CLAES, ISAMS, HRDI, WINDII, SBUV, TOMS and Brewers. As a first step toward species assimilation, only retrieved ozone profiles and column amounts will be used and ozone will not be correlated with other variables. Eventually, additional species will be assimilated and the system will be validated for stratospheric and mesospheric data.

6. SWIFT

The Stratospheric Wind Interferometer For Transport Studies (SWIFT) instrument is a Canadian instrument scheduled to fly on the Japanese GCOM-A1 satellite in 2007. SWIFT will provide high-resolution global measurements of winds and ozone in the stratosphere (20-45 km) with an expected accuracy of 5 m/s for the winds. The assimilation of SWIFT winds using CMAM (and GEM) is planned. The goal is to obtain improved stratospheric analyses for climate studies, but also to investigate the value of these wind observations for improving NWP forecasts.

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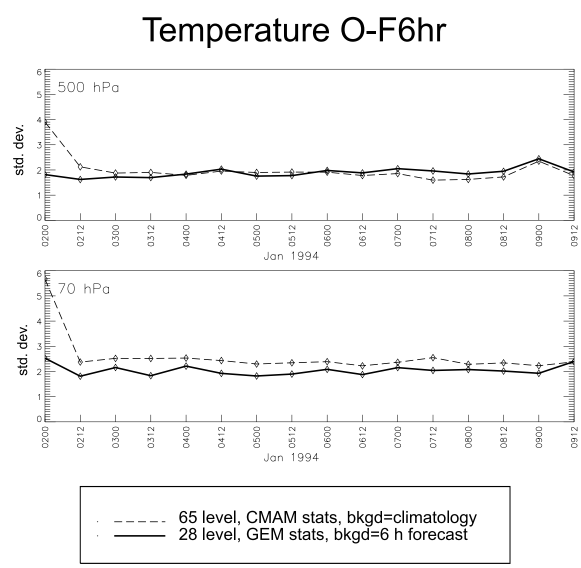

Figure 1: Time series of temperature observation minus forecast differences during the first 9 days of spin-up, at 500 hPa (top panel) and 70 hPa (bottom panel). The dashed line is the present scheme with 65 CMAM levels and climatological statistics and where the initial background is a model January climatology. The solid line shows an older scheme where the initial background was from a trial field nudged with archived CMAM analyses. Also the older scheme used 28 GEM levels, a lid of 10 mb, and GEM's NMC-derived statistics.