WGNE NWP stratospheric prediction comparison

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In this study we examine how well NWP models simulate the stratosphere when the polar vortex undergoes large changes. To do this we compare analyses for the period from 15 Sep.-15 Oct. 2002 (Days 0-30 in this study) and forecasts from 20 Sep.- 3 Oct. 2002 (Days 5-18) during the southern hemisphere major sudden warming of 2002 from five current NWP models: the Australian BMRC Atmospheric Model (BAM); the ECMWF IFS; the NCEP MRF; the NRL NOGAPS and the UKMO model. These models provided forecasts out to 8, 10, 10, 5 and 10 days, respectively. TOMS plots (not shown) indicate that the vortex started to deform on 20 Sep. (Day 5), split in two by 24 Sep. (Day 9) and had a single vortex centre again by 30 Sep. (Day 15)

Figure 1 shows the 30 hPa temperature RMSE between the model 5-day forecasts and their respective analyses starting at 00UTC on 20 September (Day 5) for 14 days to 12UTC 3 October 2002 (Day 18.5) averaged over latitudes 60^oS to 90^oS for the four models BAM, ECMWF, NCEP and NOGAPS. For forecasts initiated on Days 5-10 (20-25 September), when the vortex was splitting, all the models have almost continuously increasing RMSE for any given forecast. This implies that over this period there is a steady reduction of forecast skill and that this is an increasingly difficult period for all the models. From initialization Days 10-12 (25-27 September) the skill in all the models is seen to improve.

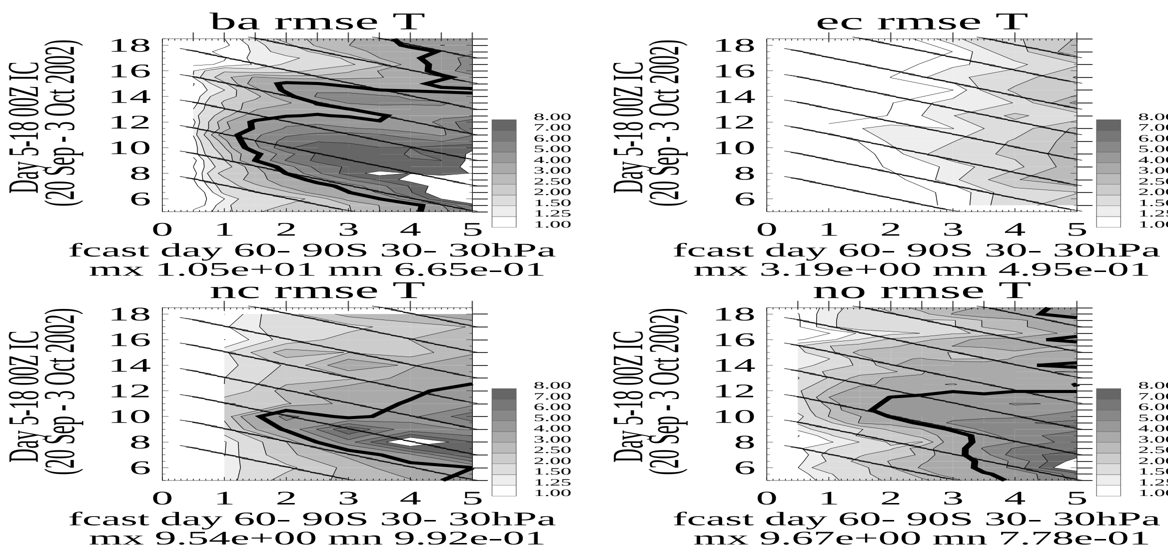

Figure 1: *Plots of forecast day (0-5) against initialization analysis day from 00UTC 20 September to 12UTC 3 October 2002 (Days 5-18.5) of the 30 hPa temperature field (K) RMSE between the* <u>*BA*</u>*M,* <u>*EC*</u>*MWF,* <u>*NC*</u>*EP and* <u>*NO*</u>*GAPS forecasts and their respective analyses averaged over latitudes 60^oS to 90^oS. The maximum and minimum are below each plot, the diagonals are lines of constant verification day and contour intervals are the same and are indicated. The thick contour is the $4K$ contour line.*

The average of these RMSE values over the initialization and forecast days are seen in Figure 2. All models have errors increasing with forecast time and show that initialization Days 10-12 (25-27 Sep. 2002) separate an early period with large RMSE from a later period with smaller errors.

Can these RMSE difficulties be related to particular days? If this is true then there should be a strong dependence of the RMSE on the verification day, where lines of constant verification day are indicated by the diagonals in Figure 1. In this figure there are contoured regions which extend along the verification diagonals encompassing one or several verification days eg all the models show that the periods 27-28 September (Days 12-13) and around 2 October (Day 17) are dynamical situations which they have difficulty with forecasting. These periods are when the split vortex is decaying and when the reformed vortex is moving westward, respectively.

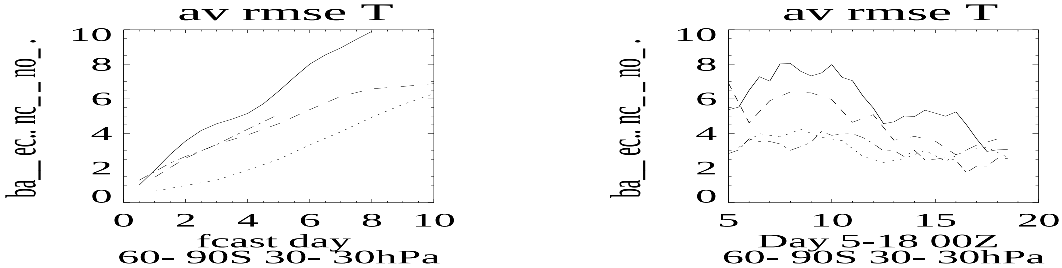

Figure 2: *Plots of the mean 30 hPa BAM, ECMWF, NCEP and NOGAPS temperature fields (K) RMSE and (left) averaged over initiation day for forecast days (0-10) and (right) averaged over forecast day for initiation Days 5-18.5. The line style for each model is indicated.*

What do these forecast errors look like? We plot in Figure 3 the 50 hPa polar stereo plot of the geopotential height field for the first and last forecast from the BAM , ECMWF and NCEP models initiated on 23 September. We can see the large changes that the vortex undergoes over this period, going from a two cell vortex to a single cell, but all the models show a final forecast vortex which is smaller, more circular, more poleward and more westerly displaced and with a more easterly orientation, though the latter is not as obvious in the ECMWF case. The creation of a smaller, more circular and more polewardly displaced vortex indicates that all the models are trying to create weaker and less disturbed vortices.

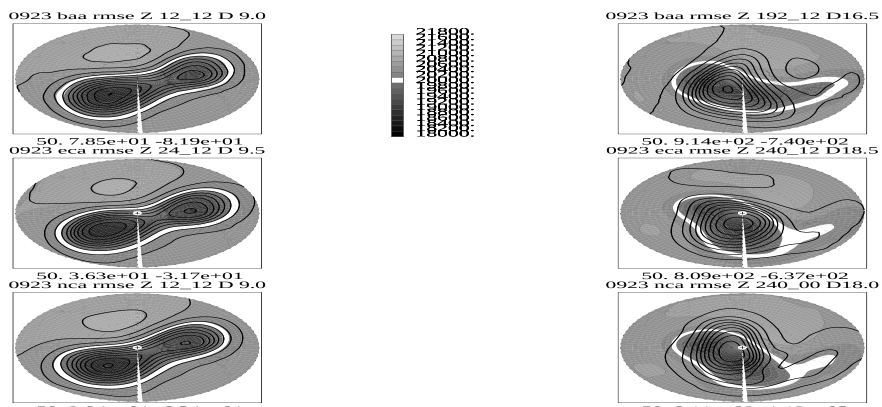

Figure 3: *50 hPa polar stereo plot of the geopotential height (m) field for the (left) first and (right) last forecast from each of the models (top) BAM, (middle) ECMWF and (bottom) NCEP initiated on 23 September.The forecasts are the line contours while the corresponding analyses are the filled contours. The forecast time (in hours) and corresponding verification Day (eg D 9.0 in the first plot) are at the top of each diagram.*

The forecasting ability of the BAM, ECMWF, NCEP and NOGAPS NWP models has been studied during this sudden warming and we find that if the vortex undergoes rapid changes after forecast initialization all the models have some degree of difficulty in capturing this event. There are certain verification days, common to all the forecast models, which the model forecasts have difficulty, and these errors are largest in the stratosphere. These characteristic errors were that the forecast vortex was seen to be: smaller; displaced westward; displaced poleward; have a faster easterly rotation of its orientation and to be more circular.

We also found that the BAM, ECMWF, NCEP, NOGAPS and UKMO NWP models analyses are well correlated over the period of our study when the vortex is quasi-stationary but that when the polar vortex is undergoing rapid changes these analyses are seen to have larger RMSE differences and to become less correlated. Also during these active periods the model analyses correlations with TOMS total column ozone decreases dramatically from the very high values found when the vortex is quiescent.