Validation of Met. Office Mesospheric Analyses

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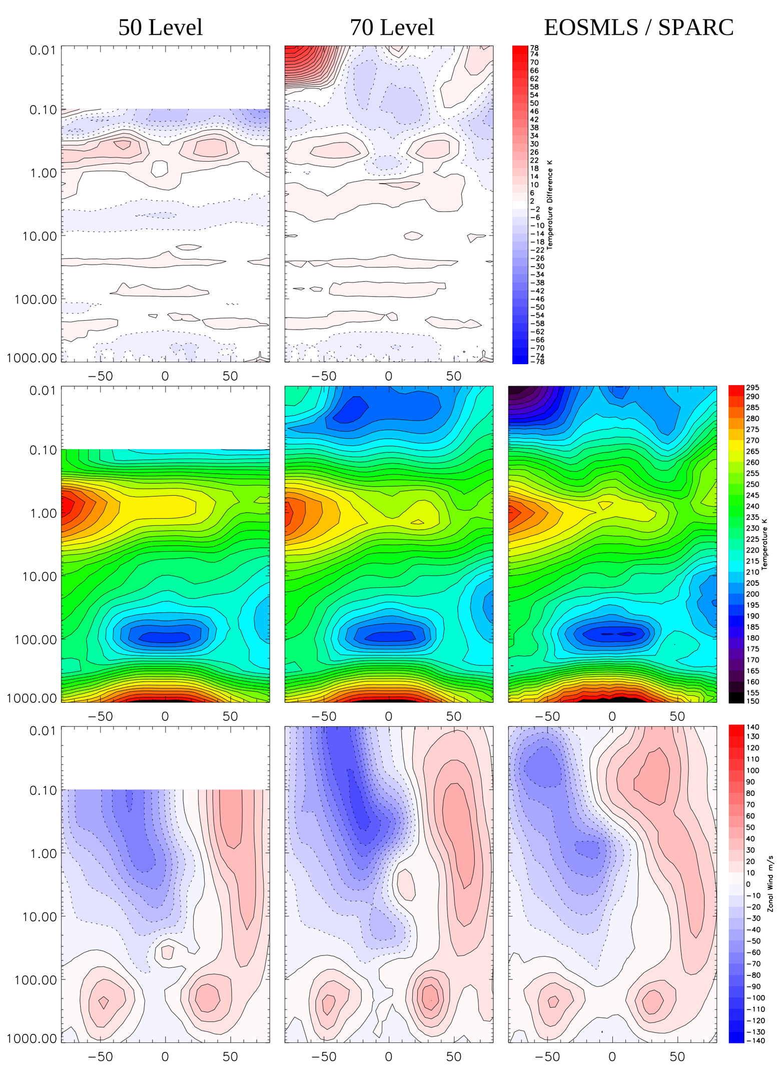
1 Introduction

The project has focused on the validation of the Met Office stratospheric assimilated dataset, which has recently upgraded to a 70 level model with a vertical domain extending to ∼80 km . We consider the influence of this extended domain by comparing validation results, using EOS MLS data, for selected months of January pre and post the aforementioned upgrade. Furthermore the impact on mesospheric temperatures and zonal winds are discussed when experimential forecasts are performed using transparent or opaque model lid conditions, tuning of the gravity wave paramterisation and the inclusion of turbulent heating rates due to gravity wave dissipation.

2 L50 versus L70



The adjacent figure details the monthly zonal mean error between Met Office analyses and temperature profiles from the EOS MLS experiment. The 50 level results are for January 2009, while the 70 level results are for January 2010. Also detailed are the associated monthly zonal mean temperature and zonal wind fields, with EOS MLS monthly zonal mean temperatures for Januray 2010 and SPARC climatological zonal wind values shown for comparison.

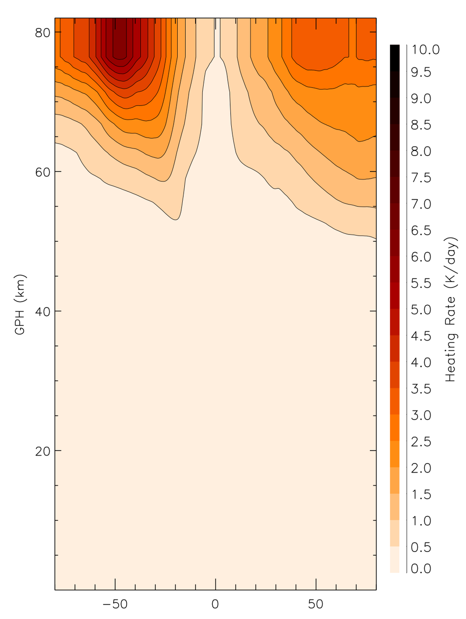
The latitudinal independent cold bias signal of ∼6→10 K from ∼0.3→0.1 hPa in the L50 analyses is probably caused by deficiences in the Li and Shine ozone climatology (Li and Shine 1995), resulting in insufficient radiative heating at these altitudes (Mathison et al 2007). The warm biases between ∼1.0→0.3 hPa in the L50 analyses are assumed to be a consequence of inadequate long wavelength cooling by the Edwards-Slingo radiation scheme (Jackson et al 2001).

The ∼26→30 K cold bias confined to the winter polar region, would also strongly suggest that the L50 analyses have an underestimated mean meridional circulation and hence gravity wave forcing in this region is too weak. This is consistent with the eastward winter zonal mean winds of the L50 analyses typically having ∼10 ms^{-1} stronger magnitudes than SPARC values in the lower mesosphere. The aforementioned bias signals are present in all L50 analyses from 2005 to 2009, where cold polar biases of similar magnitudes and locations are seen for southern hemisphere winter months.

For the L70 analyses cold biases in the winter polar region of the lower mesosphere have been reduced to ∼14→18 K. Here vertical temperature gradients are noticeably smaller than those seen for the L50 model and the eastward zonal winds of the winter hemisphere show increased tilt towards the equator with height, as shown by the SPARC climatology. There is a strong warm bias of ∼54→58 K in the southern summer polar regions of the upper mesosphere, where meridional temperature gradients poleward of ∼35^o have the incorrect sign compared to SPARC values. The location and sign of this bias would strongly suggest that adiabatic cooling due the ascending branch of the single cell summer to winter pole mesospheric circulation is underestimated in the L70 model as a result of inadequate gravity wave drag in this region. Again this is consistent with the summer westward zonal mean winds in the upper mesosphere of the L70 analyses having magnitudes ∼20 ms^{-1} larger than SPARC values.

3 Turbulent Heating Rates

Currently most modern middle atmospheric general circulation models do not include turbulent heating rates due to the dissipation of gravity waves. Previous results have shown that significant impact of such heating are limited to the upper mesosphere. With the extension of the L70 model to include the upper mesosphere, the currently operational Ultra Simple Spectral Parameterisation (USSP) (Warner and McIntyre 2001) gravity wave scheme was adapted to calculate turbulent heating due to saturation of the initial momentum flux launch spectrum as it propagates vertically through the atmosphere. Following the theory of (Warner and McIntyre 2001) the wave energy flux, $\mathbf{F_E}$, can be obtained from knowledge of the wave momentum flux $\mathbf{F_p}$ via,



$$\rho\mathbf{F_E}(z,m,\phi) = \rho\,|\mathbf{F_p}(z,m,\phi)|\,\frac{N}{m}\frac{\Delta\phi}{2\sin(\Delta\phi/2)}. \qquad (1)$$

Where z is the geopotential height of the vertically propagating spectrum, m in the vertical wavenumber, ρ is atmospheric density and ϕ is the azimuthal direction of propagation. Assuming that the wave energy flux convergence favors viscous dissipation (i.e. the potential energy increase due to dissipation can be ignored) from equation (1) it is possible to determine the following term for turbulent heating due to gravity wave dissipation. .

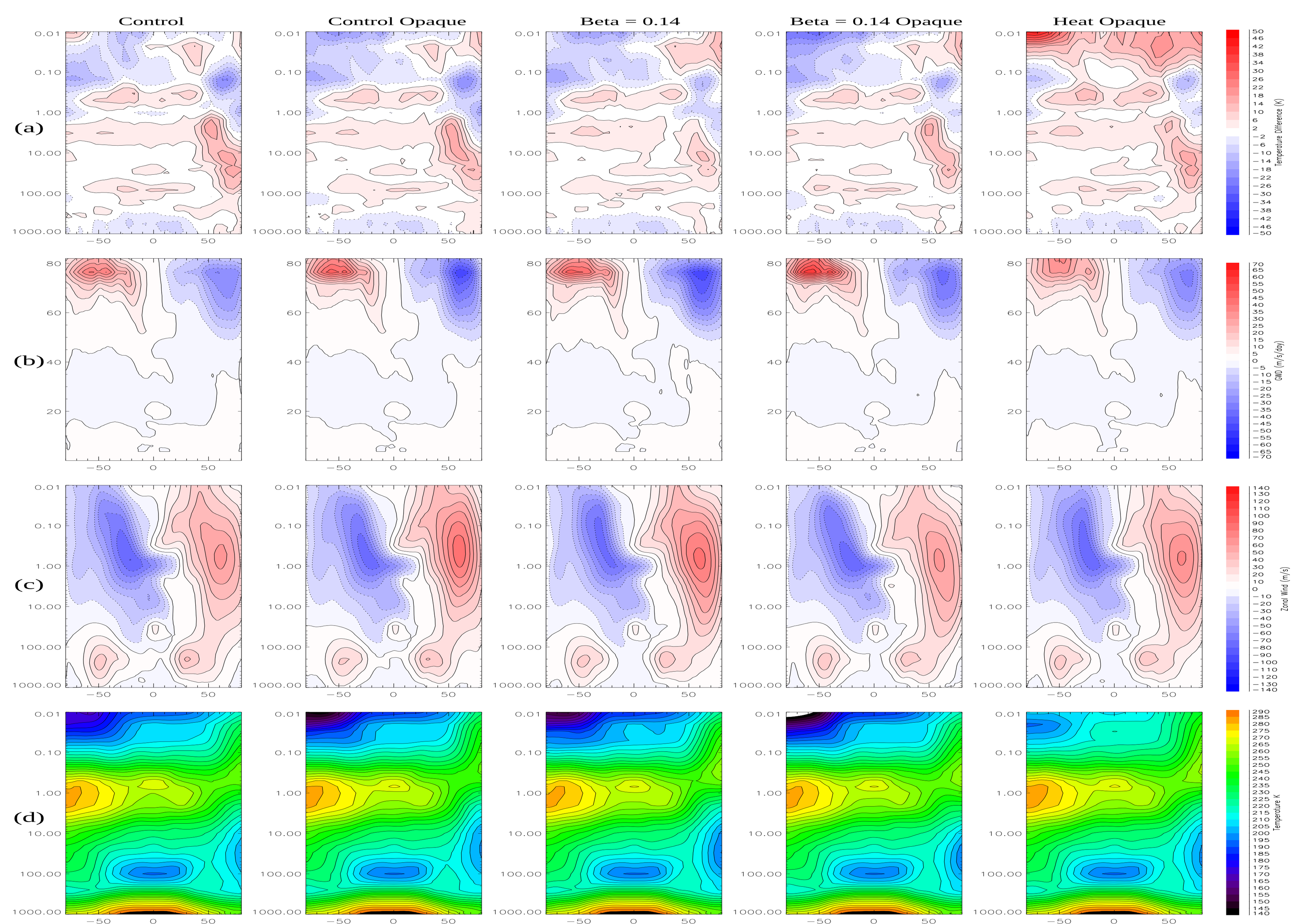
$$\varepsilon = -\frac{1}{\rho}\frac{\partial}{\partial z}\rho\mathbf{F_E} - \frac{\partial \mathbf{U}}{\partial z}\cdot\mathbf{F_p} \qquad (2)$$

Here the first term on the right of equation (2) is the vertical divergence of the wave energy flux, and the second term involving the vertical shear of the horizontal component of velocity $\mathbf{U}$ accounts for wave mean flow interaction. Monthly zonal mean heating rates calculated during forecast runs for January 2010 are shown above. Heating of ∼6 K day^{-1} is seen in the summer upper mesosphere, where radiative time scales of ∼5 days could result in a ∼30 K increase for temperatures of the upper mesosphere.

4 Forecast Experiments

In order to study the impact of tuning the USSP scheme and the inclusion of turbulent heating rates have on biases in the L70 analyses presented in Section 2, numerous experiments were conducted using an 85 level configuration of the global UM with model lid at ∼85 km. Initial fields were supplied by reconfigured ECMWF analyses for the 1st of December 2008. Model forecasts were run for 2 months, allowing a 'spin up' time for biases present in the initial ECMWF fields to be replaced by biases more characteristic of the UM. The Figure below shows January 2009 monthly zonal mean plots of (a) temperature bias with respect to EOS MLS; (b) gravity wave drag produced by the USSP scheme; (c) zonal winds; (d) temperatures for the following experiments.

- **Control:** Using standard parameter values of the USSP scheme with a transparent lid condition, allowing any remaining momentum flux at the model lid to leave the domain.
- **Control Opaque:** Using standard parameter values of the USSP scheme with an opaque lid condition, forcing any remaining momentum flux to be deposited at the model lid.
- **Beta=0.14:** The energy scale factor β in the USSP scheme is changed to 0.14 compared to it's orginal value of ∼0.1. This altered value is within observational constraints. Here a transparent lid condition is used.
- **Beta=0.14 Opaque:** As for **Beta=0.14** with an opaque lid condition
- **Heat Opaque:** Using standard parameter values of the USSP scheme with an opaque lid condition, and the inclusion of turbulent heating rates.



Control vs Control Opaque: An opaque lid increases drag in the summer mesosphere by ∼8 ms^{-1}day^{-1} and in the winter hemisphere by ∼18 ms^{-1}day^{-1}. Temperature biases of the polar summer region are ∼6→10 K colder, while biases in the winter polar region have are ∼2→6 warmer.

Control vs Beta=0.14: Using a larger energy scale factor has similar effects to applying an opaque lid condition for the summer hemisphere. In the winter hemisphere the drag has increased again by ∼18 ms^{-1}day^{-1}, however over a larger latitude interval. The resulting impact is that biases from ∼0.1→0.01 hPa from ∼30^o north to polar regions are ∼2→6 warmer.

Control vs Beta=0.14 Opaque: Differences in drag values and temperature biases in the winter hemisphere are similar to those seen when applying an opaque lid to the control experiment. In the summer hemisphere the introduction of a larger energy scale factor with an opaque lid results in an increase of ∼18 ms^{-1}day^{-1} in mesospheric gravity wave drag. This results in biases of the summer polar upper mesosphere being ∼26→30 K colder.

Control Opaque vs Heat Opaque: The inclusion of turbulent heating rates in the USSP gravity wave scheme has an significant impact in the upper mesosphere. Temperature biases in the winter mesosphere are ∼10→14 K warmer, while for the summer hemisphere biases are ∼30→34 K warmer in the polar regions approaching the model lid.

References

Jackson, D.R. and Austin, J. and Butchart, N.,2001:An updated climatology of the troposphere–stratosphere configuration of the Met Office's Unified Model.*Journal of the Atmospheric Sciences*.**58**.2000-2008

Li, D. and Shine, K.P.,1995:A 4-dimensional ozone climatology for UGAMP models.*UGAMP Internal Rep*.**35**.

Mathison, C. and Jackson, D.R. and Keil M.,2007:Methods of improving the representation of ozone in the Met Office model.*NWP Technical Report No. 502*.

Warner, C.D. and McIntyre, M.E.,2001:An ultrasimple spectral parameterization for nonorographic gravity waves.*Journal of the Atmospheric Sciences*.**58**.1837-1857

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