Hadley Centre Technical Note 88

Modifying the stratospheric zonal wind and temperature in HadGEM3

March 2011

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The climatology and variability of the simulated dynamical fields in a model stratosphere need to be realistic if the interactive chemistry is to generate realistic results. For example, polar stratospheric clouds (PSCs) form in the winter mid-stratosphere at temperatures below 195K (nitric acid trihydrate clouds) or 188K (ice clouds) (Pawson et al., 1999) so a model temperature bias here of just a few degrees will drastically alter the simulated area of PSCs and the subsequent amount of ozone depletion which occurs. The quasi-biennial oscillation (QBO) of the tropical zonal mean zonal wind is also important, not only as a significant component of dynamical tropical variability but also through the induced QBO in ozone (Butchart et al., 2003).

The parametrised non-orographic gravity wave drag scheme in the HadGEM models (Warner and McIntyre, 1999; Scaife et al., 2002) can be used to modify the extratropical stratospheric temperature and the period of the tropical QBO by changing the coefficient of the non-orographic gravity wave flux amplitude at the launch level, denoted FA_0 here. The standard model configuration sets $FA_0 = FA_{0c}$, a constant, independent of latitude. In general, increasing FA_{0c} will increase the winter extratropical stratospheric temperatures and decrease the period of the QBO. Thus there is a trade off between realistic extratropical temperatures and realistic QBO period, with the value of FA_{0c} chosen to give the best possible solution. However, it is likely that in reality there is a greater source of gravity waves in the tropics than in the extratropics, so it is reasonable to set

$$FA_0 = \begin{cases} FA_{0c} + FA_{0T}\ \cos^2(3\phi) & -30^\circ < \phi < 30^\circ, \\ FA_{0c} & \text{otherwise.} \end{cases} \quad (1)$$

Now the extratropical temperatures and the QBO period can be modified independently by changing the values of FA_{0c} and FA_{0T} respectively. To demonstrate this, two 10 year HadGEM3 simulations, one with constant launch level flux amplitude coefficient (CFA) and one with latitudinally varying launch level flux amplitude coefficient (LVFA) are compared. The CFA simulation uses $FA_{0c} = 1.5$ and the LVFA simulation uses $FA_{0c} = 1.0$ and $FA_{0T} = 0.7$, see Figure 1.

Figure 2 shows model temperature biases in northern hemisphere winter (December–January–February, hereafter DJF) and southern hemisphere winter (June–July–August, hereafter JJA) in both CFA and LVFA simulations. The model biases are relative to the temperatures in the UKMO stratospheric analysis (Swinbank and O'Neill, 1994). Relevant to PSC formation is the temperature at around 50hPa, averaged from 60° to 90°, in the winter hemisphere. These temperature biases in DJF and JJA in the CFA simulation are 2.73K and 3.79K respectively. By decreasing FA_0 in the extratropics from 1.5 to 1.0 in the LVFA simulation the biases are improved to 1.03K and 2.29K respectively (Figure 2). Modifying the polar night jet strength and extratropical temperatures remains a

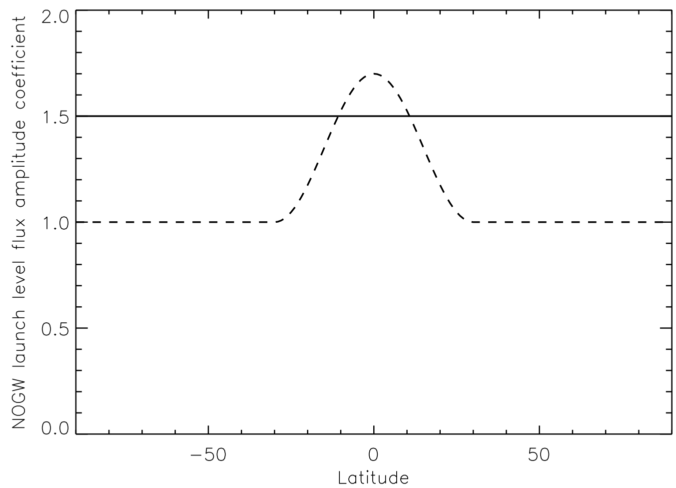

Figure 1:
Non-orographic gravity wave (NOGW) launch level flux amplitude coefficient used in constant flux amplitude (CFA; solid line) and latitudinally varying flux amplitude (LVFA; dashed line) simulations.

trade off and the greater temperature biases in the winter upper stratosphere in Figure 2 (d) than those seen in Figure 2 (b) is an indication of a less realistic polar night jet strength in JJA in the LVFA simulation. Furthermore the tropical tropopause temperature bias of 2–4K, although much improved in HadGEM3 over earlier model versions, cannot be modified using the non-orographic gravity wave drag scheme.

Figure 3 shows the QBO of the tropical zonal wind in both CFA and LVFA simulations. The period of the QBO in the CFA simulation is 33.5 months. By increasing FA_0 in the tropics from 1.5 to around 1.7 in the LVFA simulation this period is decreased to 25.5 months, much closer to the observed value of 27 months.

This change is implemented in subroutine src/atmosphere/gravity_wave_drag/gw_ussp.F90, altering variable CCL0 to be a function of latitude.

References

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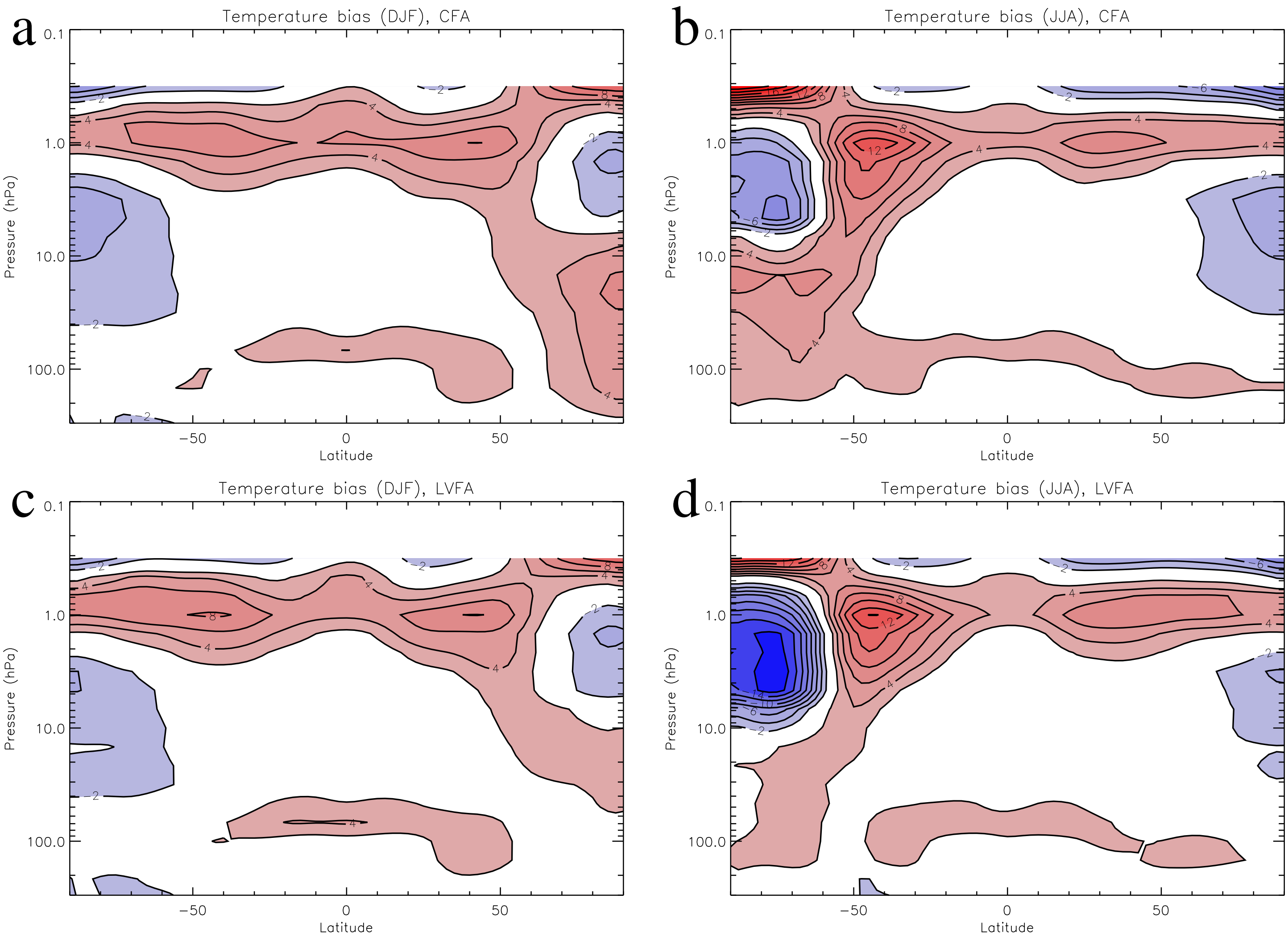

Figure 2:
Climatological temperature biases (HadGEM3 - UKMO stratospheric analysis) for (a) DJF, CFA simulation, (b) JJA, CFA simulation, (c) DJF, LVFA simulation, (d) JJA, LVFA simulation. Red/Blue shading shows a positive/negative bias. Contour interval is 2K.

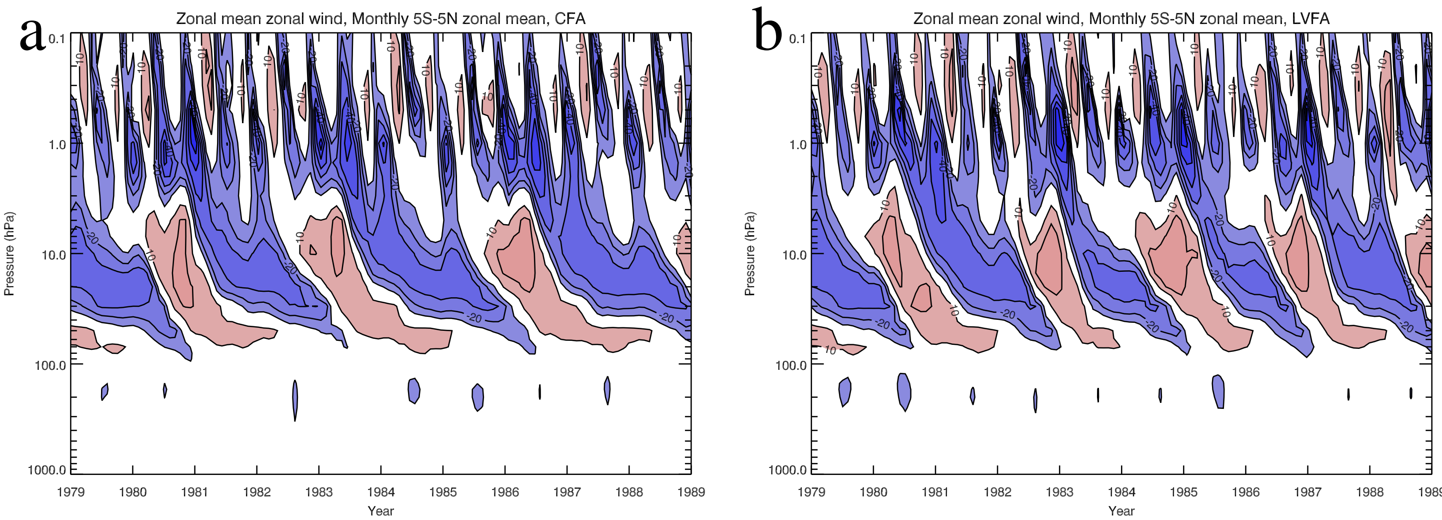

Figure 3:
QBO of the tropical zonal mean zonal wind in (a) CFA simulation, (b) LVFA simulation. Red/Blue shading shows eastward/westward wind. Contour interval is 10m s^{-1}.

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