Introduction

Surface temperatures of a doubled CO2 world can be approximated by horizontal bands of warm anomalies, the strongest of which occur in the northern mid- to high latitudes, due to the land masses there. We have used an atmospheric GCM to simulate the effects of applying idealized, zonally symmetric positive temperature forcings at the surface in distinct latitude bands. We study both the response of the stratospheric circulation, and the sensitivity of this response to magnitude and location of the applied forcing.

In the control run, monthly mean surface temperatures and surface specific humidities are prescribed. These come from a separate 100-year run in which the model interacted freely with a slab ocean and a soil scheme. In the experiments, a surface temperature forcing of 2 K is applied in the following latitude bands: 60°S – 30°S (case SM2), 30°S – 30°N (case EQ2), and 30°N – 60°N (case NM2). Prescribed surface specific humidity is consistent with the temperature forcing.

We use the RCM-FASTSEC at T31 resolution with 26 vertical levels [1], [2], [3] and run it in time-slice mode for 50 years for each experiment. Results shown are the ensemble-mean values.

All plots show differences between the three experiments and the control run. Grey shading on all plots covers areas in which results are NOT significant at the 5% level, and green lines on all plots show where surface forcing is applied.

Wave forcing (NM2, EQ2)

Fig 3: Left: Difference in EP flux divergence (10^{-5} m^2/s). Right: Difference in TEM streamfunction (µg/s).
- Top two panels, NM2: Divergence of the EP flux is seen in the vortex, implying decreased wave forcing of the mean flow, and the Brewer-Dobson circulation is correspondingly diminished. This is consistent with the stronger vortex seen on Figure 2.
- Bottom two panels, EQ2: There is significant convergence of the EP flux into the polar vortex, leading to wave-forcing of the mean flow there. The Brewer-Dobson circulation is consequently enhanced. This is consistent with the much weaker polar vortex seen on Figure 2.

Wave source regions (NM2, EQ2)

The control case isentropes overlaid on Figure 1 show that 30°N is the latitude of strongest baroclinicity in the NH, and the meridional paths of vertically propagating waves appear to be very sensitive to the surface temperature at this latitude.

EQ2 surface temperature forcing leads to increased wave forcing of the vortex. NM2 surface temperature forcing leads to decreased wave forcing, and a stronger vortex.

Wave forcing area by more than the imposed 2 degrees. A strong warm anomaly also ensues in the NH winter polar stratosphere, whose SH counterpart is much weaker.

Responses to mid-latitude forcings are qualitatively the same in both hemispheres, though weaker in the SH. The control case isentropes overlaid on Figure 1 show that 30°N is the latitude of strongest baroclinicity in the NH, and the meridional paths of vertically propagating waves appear to be very sensitive to the surface temperature at this latitude.

Fig 5: Zonal-mean eddy heat flux ($\bar{Q} \bar{T}$) (K m/s) at 100 hPa. The contours give the difference in the zonal wind speed at the jet core.
- EQ2: There is decreased eddy heat flux south of 40°N for Jan-Feb, but increased values north of 40°N, suggesting increased wave activity in the polar vortex.
- NM2: The situation is reversed, with decreased eddy heat flux north of the 40°N mark, supporting the observed strengthening of the polar vortex. There is increased eddy heat flux south of 40°N, but the wave activity associated with it is directed elsewhere than into the vortex.
- In both cases, the areas of increased eddy heat flux coincide roughly with the areas of most diminished, or least enhanced, jet core wind speed. In the NM2 case, the tropospheric jet weakens and wave flux increases in the jet latitudes. In the EQ2 case, the jet becomes stronger, and wave flux decreases in the jet latitudes.

Conclusions

- Top two panels: in accordance with thermal wind balance, the warm surface anomalies at high latitudes lead to weaker tropospheric jets. The cold NH anomaly in the polar stratosphere results in a slightly stronger polar vortex.
- Bottom two panels: the large increase in temperature throughout the tropics enhances the meridional temperature gradient and leads to stronger tropospheric jets in both hemispheres. The strong warm anomaly in the NH polar stratosphere is associated with a weaker polar vortex.

References