THE ROLE OF EDDIES IN DRIVING THE TROPOSPHERIC RESPONSE TO STRATOSPHERIC HEATING PERTURBATIONS

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INTRODUCTION

- Previous experiments using a simplified general circulation model (sIGCM) have demonstrated that stratospheric heating perturbations can result in altered tropospheric circulation (Haigh et al. 2005).
- Equatorial heating results in a poleward shift of the jet whereas polar or uniform heating results in an equatorward shift of the jet.
- We now present spin-up ensemble experiments to investigate the chain of causality whereby changes in tropospheric circulation and temperature are produced in response to stratospheric heating perturbations. This is presented in the context of an equatorial heating case, as it is relevant for understanding the observed tropospheric response to changing solar activity (Haigh et al. 2005).

THE MODEL AND EXPERIMENTS

- Reading ICM02.2
- Dry, spectral-dynamical core
- Newtonian relaxation of the temperature field towards a zonally symmetric reference state (Held and Suarez 1994)
- Equinox mode.
- No orography.
- 200 × 50 day runs.
- Each run starting from a different day of a control run simulation.
- Heating perturbation applied to the stratosphere by changing $T_0$ as in Fig. 1.

WHAT DRIVES THE TROPOSPHERIC ZONAL WIND CHANGES?

Solving momentum balance for (See Simpson et al. for details):

\[ \frac{\partial \mathbf{v}}{\partial t} = -\nabla \cdot (\mathbf{v} \cdot \nabla \mathbf{v}) - \nabla \cdot \mathbf{F} + \mathbf{f} \]

TERM 1

- 0–500 hPa vertically averaged: Dominant balance between term 1 and 2 with 2 being larger to give a net acceleration (See Fig. 3a).

TERM 2

- 700 hPa–900 hPa: Term 1 dominates and gives the increased zonal wind (See Fig. 3b).

AGEOSTROPHIC TERMS

- a) E-P Flux and
- b) Poleward eddy momentum flux
- c) Horizontal eddy eddy momentum flux

WHAT CAUSES THE CHANGE IN POLEWARD EDDY MOMENTUM FLUX?

A refractive index can be defined for eddies in the atmosphere (Matsumo 1970). It is given by:

\[ \text{Refractive index} = \frac{\nabla \cdot (\mathbf{v} \cdot \nabla \mathbf{v}) + \nabla \cdot \mathbf{F}}{\nabla \cdot \mathbf{F}} \]

The meridional gradient of potential vorticity (\( \psi \)), the zonal wind (\( u \)) and the eddy phase speed (c) are the dominant terms. The E-P flux gives an indication of the direction of eddy propagation. Eddies are refracted up the gradient of:

- Altered eddy propagation changes eddy momentum flux through the dependence of the horizontal component of E-P flux on
- Figs. 4 and 5 a and c show the importance of the change in wind on the meridional gradient and its localisation in latitude
- Days 0 to 9: dominant term
- Days 40 to 49: the change in wind is responsible for the increased equatorward gradient of the zonal wind.

SPIN-UP EVOLUTION

The spin-up evolution for 4 fields is shown in Fig. 2. This shows:
- A weakening and poleward shift of the mid-latitude jets.
- A weakening and expansion of the Hadley cell and a poleward shift of the Ferrel cell.
- A dipole change in poleward eddy momentum flux (\( \psi \)) with a reduction around the tropopause on the equatorward side of the jet and an increase on the poleward side stretching down into the troposphere.
- A change in Eliassen-Palm flux. The horizontal component (\( \psi \)) can be seen to be consistent with the change in

WHAT CAUSES THE CHANGE IN PV GRADIENT?

- PV gradient can be thought of as consisting of 3 terms:

- Both the vertical shear and curvature of and vertical wind contribute to change the PV gradient with the contribution being slightly larger.
- Analysis of the uniform and polar heating cases (not shown) demonstrates that it is the change in vertical temperature gradient and how it is localised in latitude that determines the initial eddy changes and consequent direction of jet shift.

CONCLUSION

- A summary of the proposed mechanism whereby the stratospheric heating perturbation alters tropospheric circulation is given in Fig. 7.
- Altered vertical temperature gradients and vertical wind shear around the tropopause affects eddy propagation initially.
- There is a feedback with the zonal wind changes in the troposphere affecting eddy propagation there.
- The change in vertical temperature gradient and its localisation in latitude is important in determining the direction of jet shift.

REFERENCES

Simpson, I. R., Mike Blackburn and J. D. Haigh. The role of eddies in driving the tropospheric response to stratospheric heating perturbations. Journal of the Atmospheric Sciences, Submitted.