#### Does the stratosphere control the upward flux of wave activity from the troposphere?

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#### Context

Intraseasonal variability of the stratosphere and troposphere

- Stratosphere: sudden warmings
- Troposphere: Arctic Oscillation
- Connection between the two on intraseasonal timescales

Can knowledge of the stratosphere be used to improve tropospheric forecasts?

### **Annular modes**

Singular value decomposition of geopotential at each height  $\rightarrow$  Spatial pattern and index

- Stratosphere: index  $\sim$  strength of winter polar vortex (correlates with jet maximum)
- Troposphere/surface: index  $\sim$  phase of the Arctic Oscillation
- Anomalous values of the index appear to propagate downward from the stratosphere to the ground

### **Composite annular modes**



Baldwin & Dunkerton (2001)

### **Stratospheric vortex events**

- Strong "events" not dynamical (radiative cooling always present)
- Weak events sudden warmings, strong dynamical events

What forces the stratospheric variability?

• All planetary wave forcing is from the troposphere

 $\rightarrow$  stratospheric variability should be linked to the tropospheric variability

# **Tropospheric forcing**

Heat flux  $\overline{v'T'}$  into the stratosphere  $\approx$  total force exterted by wave forcing on the mean flow

Polvani & Waugh (2003, ... and this afternoon):

• Strong (anti-) correlation between accumulated  $\overline{v'T'}$  at 100 mb and index of the annular mode at 10 mb (-0.8)

i.e. Variability in tropospheric forcing linked to stratospheric variability

# $\overline{v'T'}$ and NAM Index

Annular Mode Annular Mode nnular Mode -8 të -12 H -16 Annular Mode -12 -16 

NAM at 10 mb  $\overline{v'T'}$  at 100 mb

Polvani & Waugh (2003, submitted)

 $\overline{v'T'}$  at 100 mb correlates strongly with NAM at 10 mb QUESTION:

What controls the variability of  $\overline{v'T'}$ ?

- 1) tropospheric variability
- 2) state of the stratosphere

In this talk we consider (2)

# **Model study**

Want to consider the effect of the stratosphere in isolation:

... remove tropospheric variability

Two ways:

- (1) fix troposphere (troposphere/stratosphere model)
- (2) remove troposphere (stratosphere only model)

Use a "dynamical core":

- Spherical PE model
- stationary wave-1 forcing in troposphere
- perpetual January (Newtonian cooling); 4000 days



NAM index at 10 mb

#### NO TROPOSPHERIC VARIABILITY

1) Stratosphere/troposphere: Fixed tropospheric heating (wave-1). Stable troposphere

2) Stratosphere only Lower boundary (200mb) geopotential perturbation

Stratosphere is capable of generating own internal variability

- Seen previously in lower order models (Holton & Mass; Yoden; Christiansen; Scott & Haynes)
- Variability arises because state of stratosphere affects strength of wave propagation

# Nature of (model) variability

Intermittent:

regular strong/weak vortex events irregular weak vortex

Unusual dependence on forcing amplitude steady state  $\rightarrow$  weak vortex with increasing amp.

Problem with perpetual January?

What sets the timescale?

- forcing amplitude,  $\theta_e$ , sponge, etc. (on going work)
- <u>resolution</u> ... (PV gradients)

Variability exists and is robust

#### $\bar{u}$ at 60°N, 40 km



### **Dynamics**

Focus on strong/weak vortex events

Is there downward propagation of deceleration?

Controlling dynamics: wave-mean flow interaction

Cause of the variability in upward wave flux?

### **Diagnostics**

**1)**  $\bar{u}$  at 60°N (z,t)

- 2) Annular mode index (z,t)
- 3) latitudinally averaged  $\nabla \cdot \mathbf{F} \quad (z,t)$
- 4)  $F^{(z)}$  though the tropopause/lower boundary (t)

#### $ar{u}$ at 60°N



#### NAM index



latitudinally averaged  $\nabla\cdot\mathbf{F}$ 



#### $F^{(z)}$ though the tropopause



Previous question:

What controls the variability of wave flux into the stratosphere?

- 1) tropospheric variability
- 2) state of the stratosphere

Have shown that stratosphere alone is enough

Which is dominant (assuming (1) also true)?

What is the mechanism for the stratospheric control?

Scott et al. (2003, submitted)

Enhancement of upward wave propagation and breaking on steep vortex edge

E.g. CASL model: barotropic (cylindrical) vortex



1) Wave propagation/breaking enhanced on steep edge

2) Wave propagation/breaking reduced in low resolution models

Implications

1) vortex edge as a valve:

weak WB  $\rightarrow$  edge erosion/steepening strong gradients  $\rightarrow$  strong upward wave flux weak gradients  $\rightarrow$  reduced upward wave flux

2) low resolution models may not be able to capture stratospheric variability arising from such a mechanism

# **Resolution dependence of variability**

 $ar{u}$ , at 60°N



# **Summary/Conclusions**

- Variability of stratosphere/troposphere here we have removed troposphere
- Variability persists purely stratospheric
- Variability agrees with observations:
  - downward propagating deceleration (wave-mean flow interaction)
  - cumulative upward wave flux correlates strongly with NAM index (but controlled by the stratosphere)
- Possibly bad to regard the stratosphere as slaved to the troposphere

#### **Vortex deceleration**

 $\bar{u}(t) - \bar{u}(0)$ , t = 26 days



# **Upper vortex**



# **Resolution dependence (PE model)**



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