Conference on Teleconnections in the Atmosphere and Oceans

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Stratospheric influence on the extratropical circulation response to surface forcing in high-top and low-top models.

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Stratospheric Influence on the Extratropical Circulation Response to Surface Forcing

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In this talk I will:

• Describe the seasonal teleconnection between Eurasian snow cover and the Northern Annular Mode (NAM)

• Show results from a large ensemble of transient simulations using high-top and low-top AGCMs forced with anomalous Siberian snow extent

• Show how the response depends on the details of stratospheric representation

• Demonstrate the large variability in wintertime tropospheric responses to autumnal snow forcing

• Try to convince you that to better predict how the troposphere will respond to snow forcing, you should look at the initial state of the stratosphere (rather than the troposphere)

• Conclude with a brief discussion of other forcings
Graham Rawle's

LOST CONSONANTS

OK, MEN. YOU GET ON WITH IT. I'M JUST GOING TO GRAB MYSELF A NICE FROTHY COFFEE

876 It was either fight or surrender and Peter chose the latte
Teleconnection: Eurasian snow and NAM

- October snow is correlated with December upward WAF pulse
- After WAF pulse the stratospheric circulation is significantly perturbed
- Downward progression of response back into troposphere

**BUT:** $r \approx 0.5 \implies$ suggests large interannual variability in the teleconnection
- Stratospheric circulation anomalies can arise without a clear tropospheric precursor
Motivation

- Reanalysis data are suggestive but not conclusive: $r \sim 0.5$
- Previous modeling effort used a small ensemble, an older low-top AGCM and did not examine variability in the response [Gong et al. 2003 & 2004].

**Research Questions:**

1. Can land surface anomalies (e.g. snow) really act as a precursor to strat-trop interaction?

2. If so, what is the role for the stratosphere?
1. **AM2-LO**: GFDL AM2 (IPCC version of atmosphere) [Anderson et al. 2004; Delworth et al. 2006]:
   - Finite-volume dynamical core: 2° lat x 2.5° lon
   - 24 vertical levels with lid at 3hPa; 4 above 100hPa
   - Rayleigh drag in top level sponge layer

2. **AM2-HI**: Essentially the same as 1. except for:
   - 48 vertical levels and lid at 0.003hPa; 21 above 100 hPa
   - No sponge layer; replaced by non-orographic GWD scheme
Experimental Design

i. Set of 100 independent Oct 1st initial conditions from long pre-industrial control run:
   - Atmospheric composition = 1870 levels
   - Climatological SST / sea ice

ii. From each initial condition we fix snow mass at Oct 1 levels then run two new simulations Oct 1 - Dec 31:
   (1) HIGH SNOW = Fixed Oct 1 snow + 40cm snow over Siberia (January extent)
   (2) LOW SNOW = Fixed Oct 1 snow

Snow Mass for Ensemble Member $k$

- Initial Condition $k$
- HIGH SNOW $k$
- 40cm Siberia
- LOW SNOW $k$
- Time: Oct 1 . . . . . . . . . . . . . . . . . .
d1-15 Surface Response to Snow Forcing

Peak Cooling ~ 12 K in 2 weeks

SLP maximum ~ 6 hPa
Polar Cap Height Response: AM2-LO

(a) $\Delta Z_{PC}$: ENS MEAN (N=100)

(b) $\Delta Z$: d15-d92

Fletcher et al. [2008]
Response in high-top model is weaker and less persistent: related to details of model climatology.

Fletcher et al. [2008]
Polar Cap Height Response: AM2-LO

Response highly variable in the troposphere:
Can we Predict the Response From Initial State?

[Z] Initial Condition:
5 days before perturbation

Strongest and most significant 'precursor' is located in the lower stratosphere

Following Reichler et al. [2005]
Can we Predict the Response From Initial State?

[Z] Initial Condition: 5 days before perturbation

Initially STRONG Vortex

Initially WEAK Vortex

WEAK minus STRONG

Fletcher et al. [2007]
Dynamical mechanism?

Initially WEAK

\[ (Z' > 0) \]

Initially STRONG

\[ (Z' < 0) \]

\[ 0 < u < \frac{u_c}{u} \]

\[ H/L \]

\[ \text{time} \]
30-day Mean $\Delta$SLP Following WAF Pulses

Init. WEAK: 18/51

Init. STRONG: 20/49

Fletcher et al. [2007]
Same story in the high-top model?

Fletcher et al. [2008]
• Significant correlation between responses from N. Atlantic sea-ice and SST forcings
• Component of response (~25%) explained by initial conditions
• Use “Precursor method” to tease out this component

SST/Ice Data courtesy of Clara Deser
Other Forcings

SST/Ice Forcing

Snow Forcing

- Similar precursor in polar stratosphere when we consider strong responses in both SST and ICE runs
- Interesting meridional dipole in lower stratosphere

Fletcher et al. [2007]; SST/Ice Data courtesy of Clara Deser
1. **Can snow really act as a precursor to strat-trop interaction?**
   - Siberian snow forcing does induce WAF pulses, causing warming response in stratosphere and troposphere
   - **But:** response is highly variable around ensemble mean

2. **What is the role for the stratosphere?**
   - Qualitatively, mechanism is the same in high/low-top models
   - **But:** timing and amplitude of response depend on the details of stratospheric representation
   - Initial condition in polar stratosphere provides a useful predictor of tropospheric response (better than tropospheric predictor)
   - An initially weak polar vortex is more likely to produce a warming response and downward propagation back to surface (−ve NAM)
   - WAF pulse is more readily absorbed when vortex is weak

3. **Is this really about the snow?**
   - No. “Precursor Method” appears to also apply to SST/sea ice forcing

References at [http://www.atmosp.physics.utoronto.ca/people/cgf](http://www.atmosp.physics.utoronto.ca/people/cgf)  chris.fletcher@utoronto.ca
The end.
Polar Cap Height Response: AM2-LO

Low-top model response peaks ~1 month earlier than

Cohen et al. [2007]
Strat-Trop Interaction Diagnostic

Snow forcing begins Oct 1, but strat-trop interaction is associated with WAF pulses whose timing is difficult to predict:
- Find strongest WAF pulses then look at lagged SLP response
- Does strat. initial condition influence interaction?

\[ \Delta WAF \text{ at } 50 \text{ hPa} \]

Wait 10 days, then record 30-day mean \( \Delta SLP \)

(e.g. Polvani and Waugh [2004])
Northern Annular Mode in SLP

Source: NCEP/CPC
Zonal mean climatologies

ERA-40

AM2-trop.

AM2-strat.