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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:

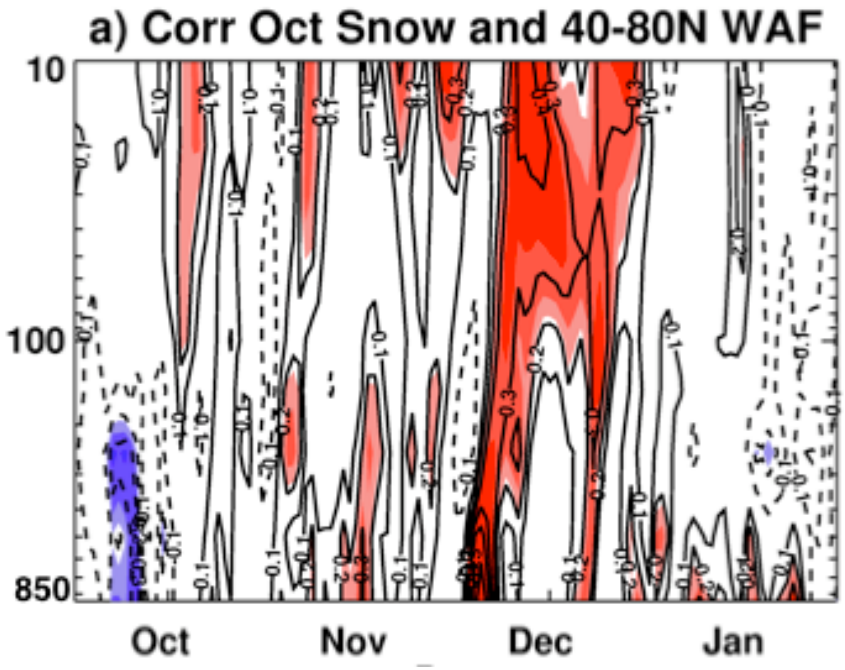
- Describe the seasonal teleconnection between Eurasian snow cover and the Northern Annular Mode (NAM)
- Show results from a large ensemble of transient simulations using high-top and low-top AGCMs forced with anomalous Siberian snow extent
- Show how the response depends on the details of stratospheric 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

876 It was either fight or surrender and Peter chose the latte

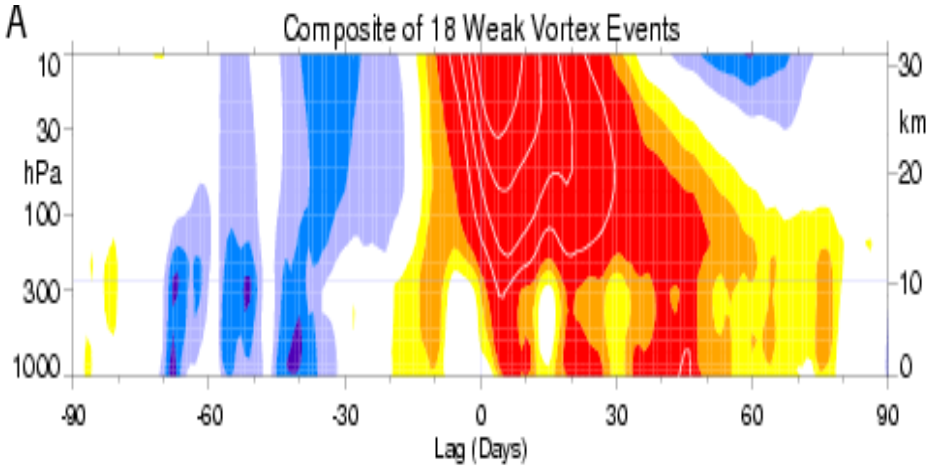
Teleconnection: Eurasian snow and NAM

- 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



Cohen et al. [2007]

- **BUT:** r~0.5 ⇒ suggests large interannual variability in the teleconnection
- Stratospheric circulation anomalies can arise without a clear tropospheric precursor



Baldwin & Dunkerton [2001]

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]*.

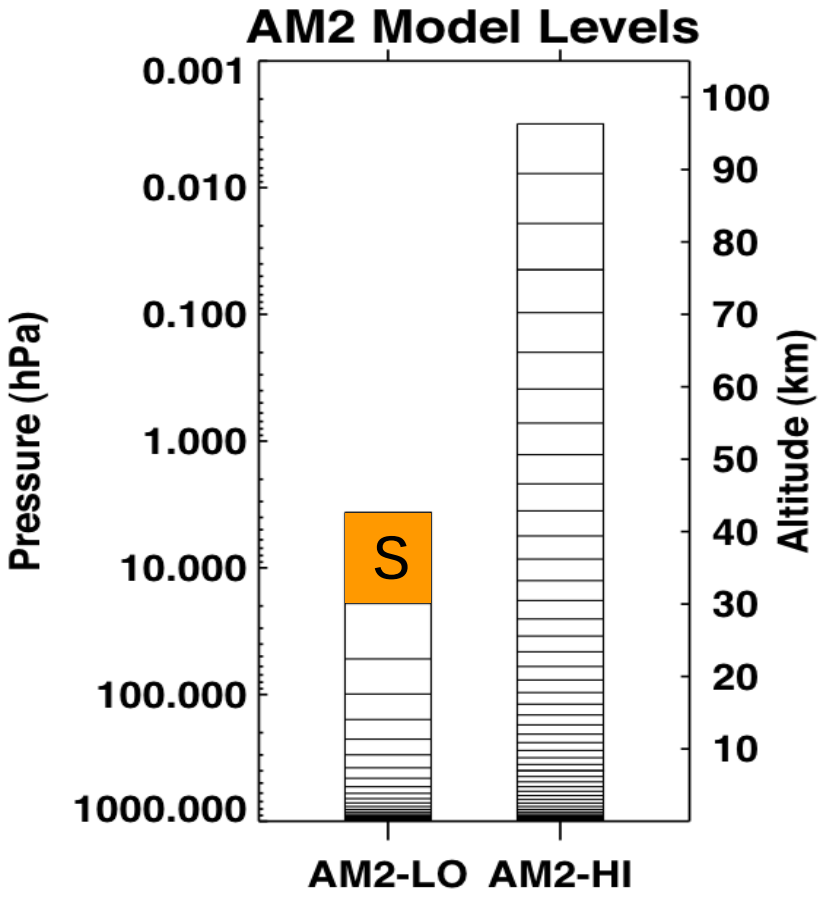
Research Questions:

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?

Low/high-top AGCMs

1. **AM2-LO**: GFDL AM2 (IPCC version of atmosphere) *[Anderson et al. 2004; Delworth et al. 2006]:*
   - Finite-volume dynamical core: 2º lat x 2.5º 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



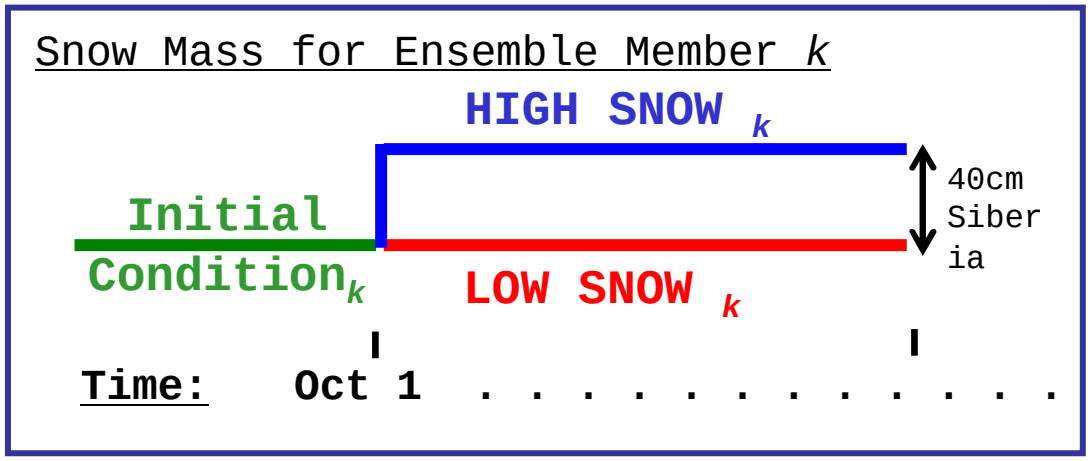
Experimental Design

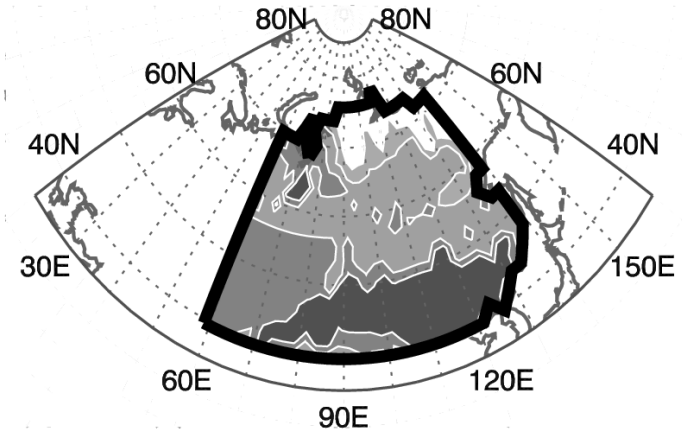
i. Set of 100 independent Oct 1st initial conditions from long pre-industrial control run:
   - Atmospheric composition = 1870 levels
   - Climatological SST / sea ice

ii. From each initial condition we fix snow mass at Oct 1 levels then run two new simulations Oct 1 - Dec 31:

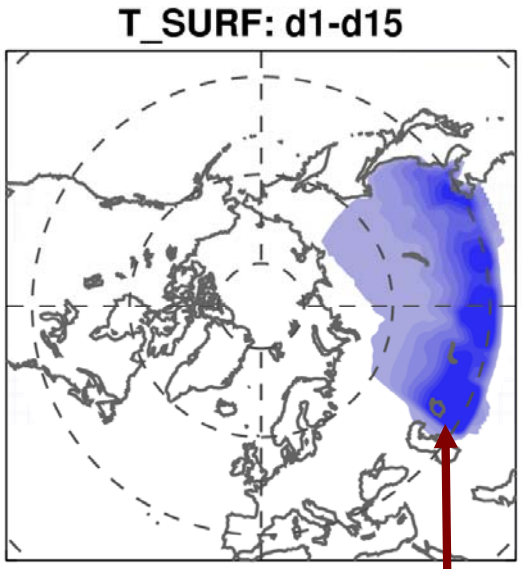
(1) HIGH SNOW = Fixed Oct 1 snow + 40cm snow over Siberia (January extent)

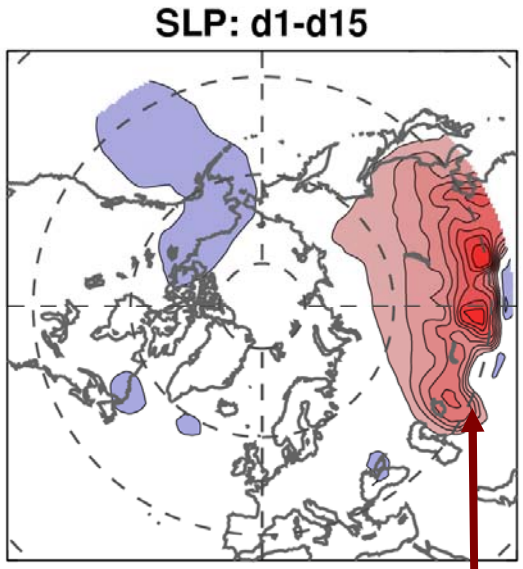
(2) LOW SNOW = Fixed Oct 1 snow





d1-15 Surface Response to Snow Forcing

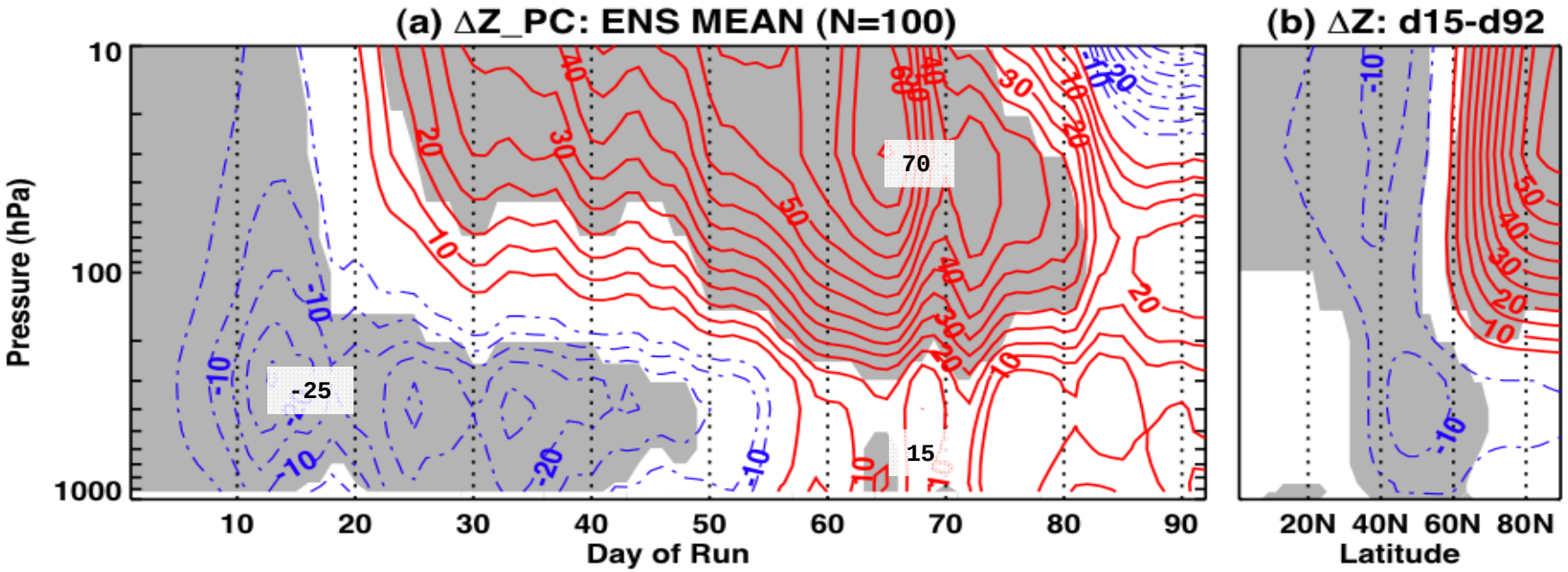




Peak Cooling ~ 12 K in 2 weeks

SLP maximum ~ 6 hPa

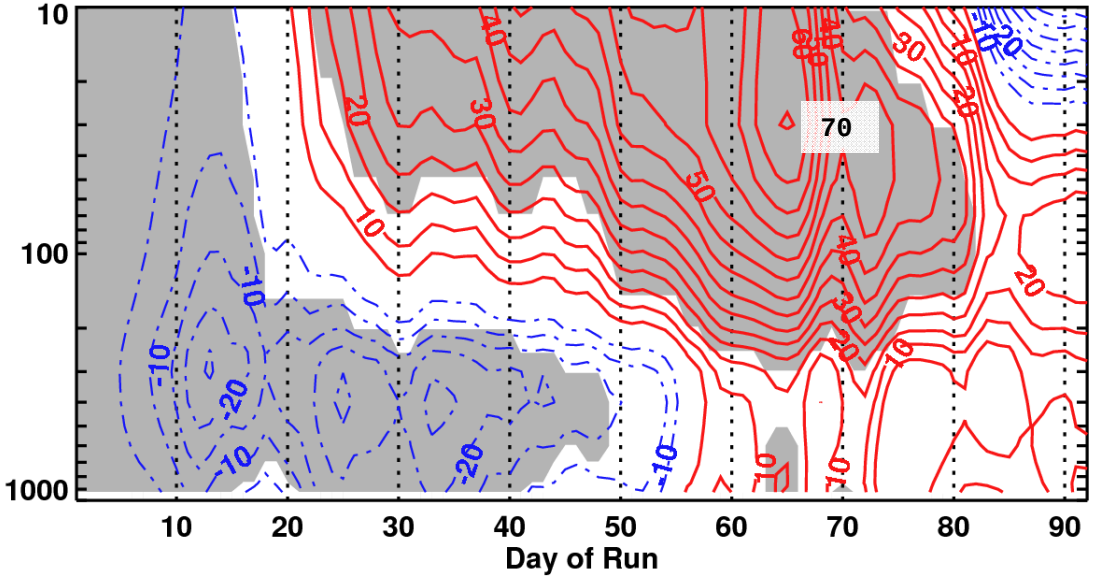
Polar Cap Height Response: AM2-LO



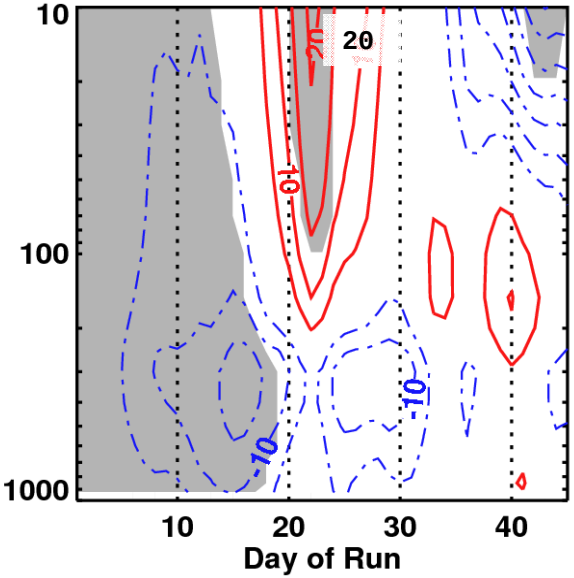
Fletcher et al. [2008]

High/Low-top Ensemble Mean Response

AM2-LO



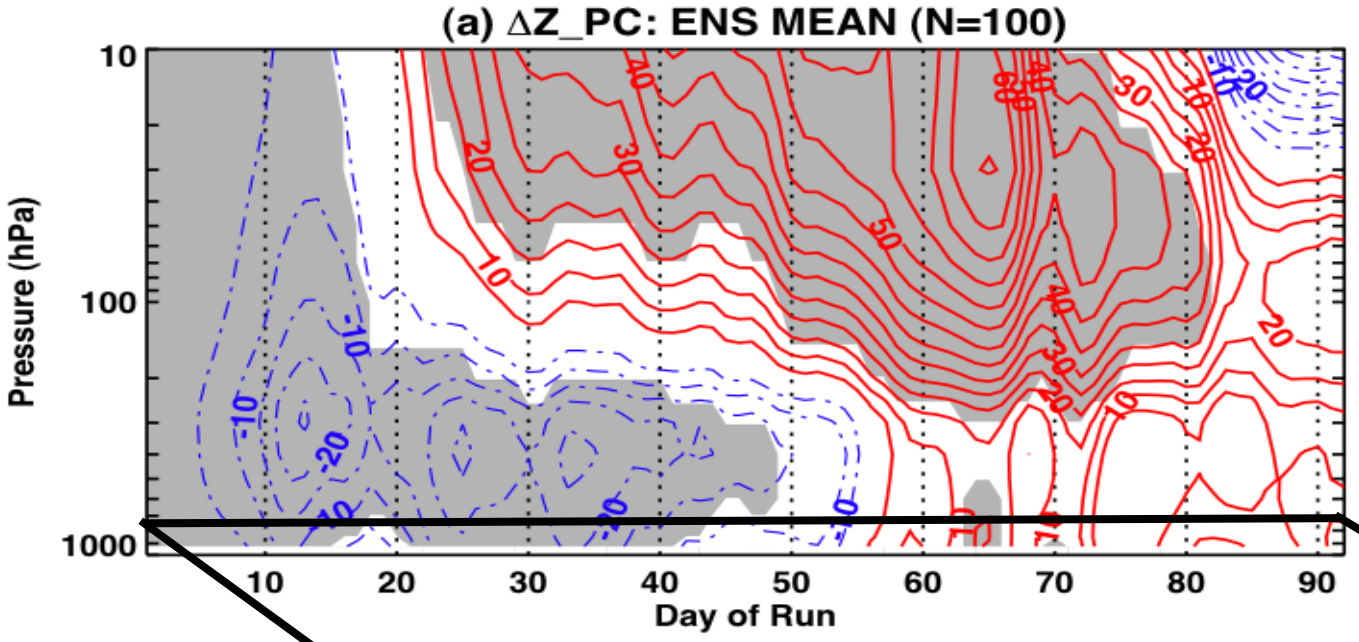
AM2-HI

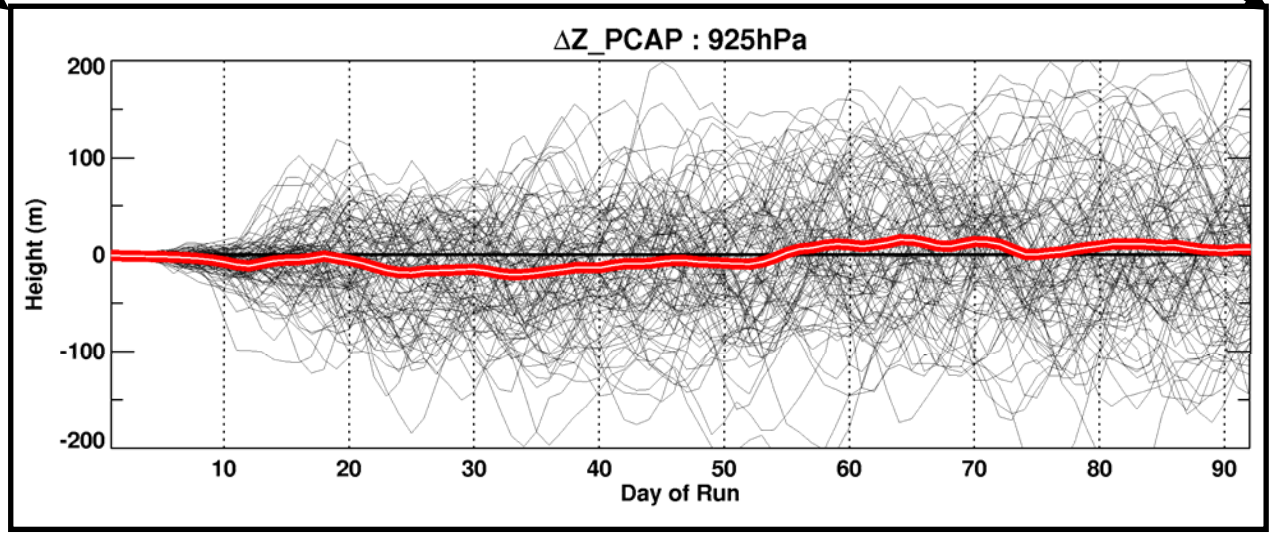


Response in high-top model is weaker and less persistent: related to details

Fletcher et al. [2008]

Polar Cap Height Response: AM2-LO

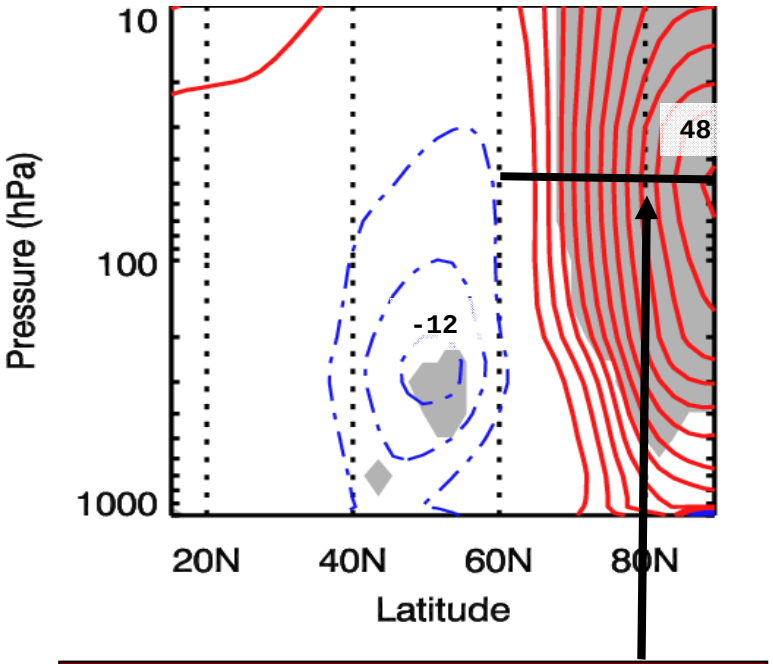




Response highly variable in the troposphere:

Can we Predict the Response From Initial State?

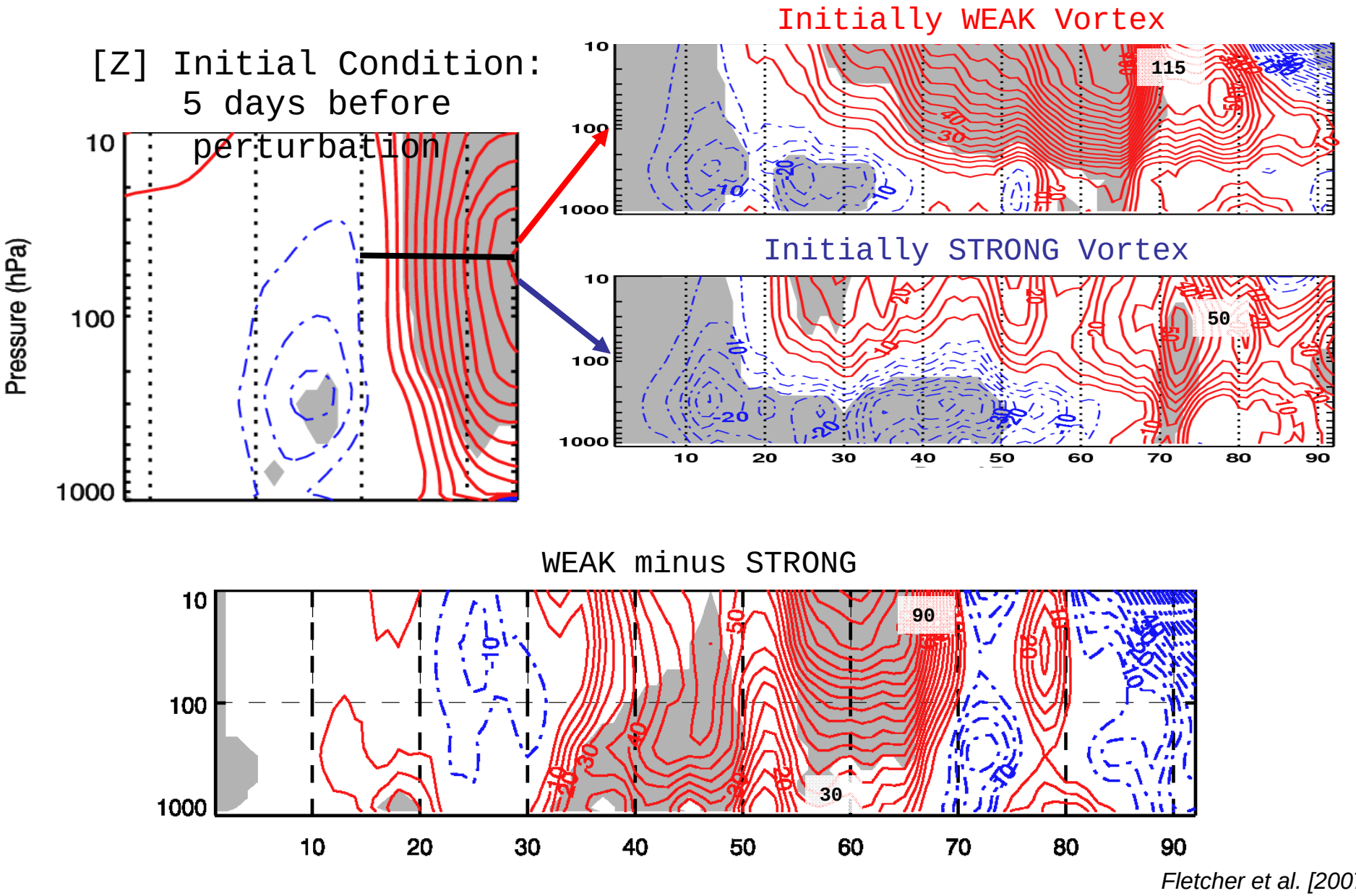
[Z] Initial Condition:
5 days before perturbation



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

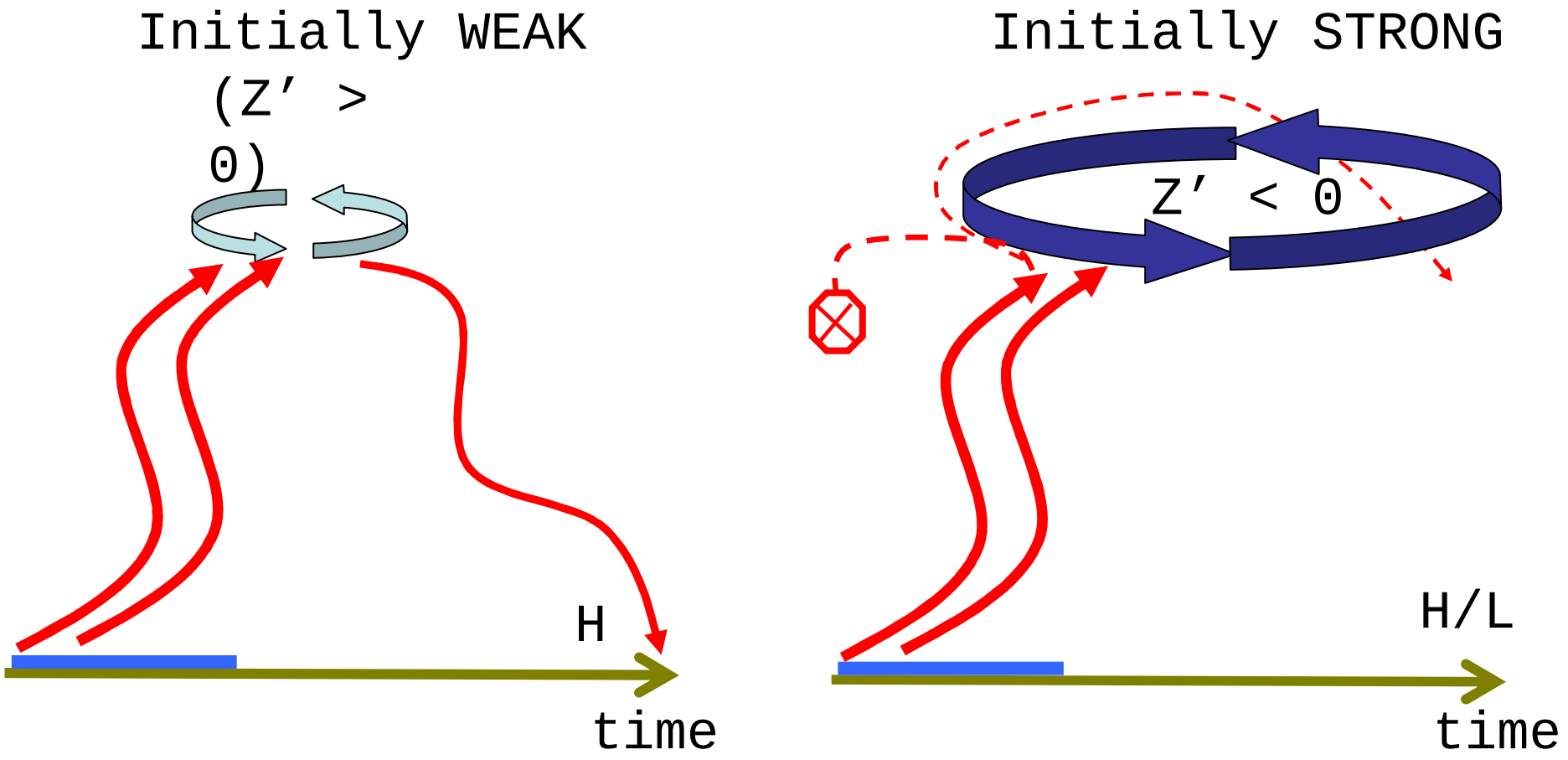
Following *Reichler et al. [2005]*

Can we Predict the Response From Initial State?



Fletcher et al. [2007]

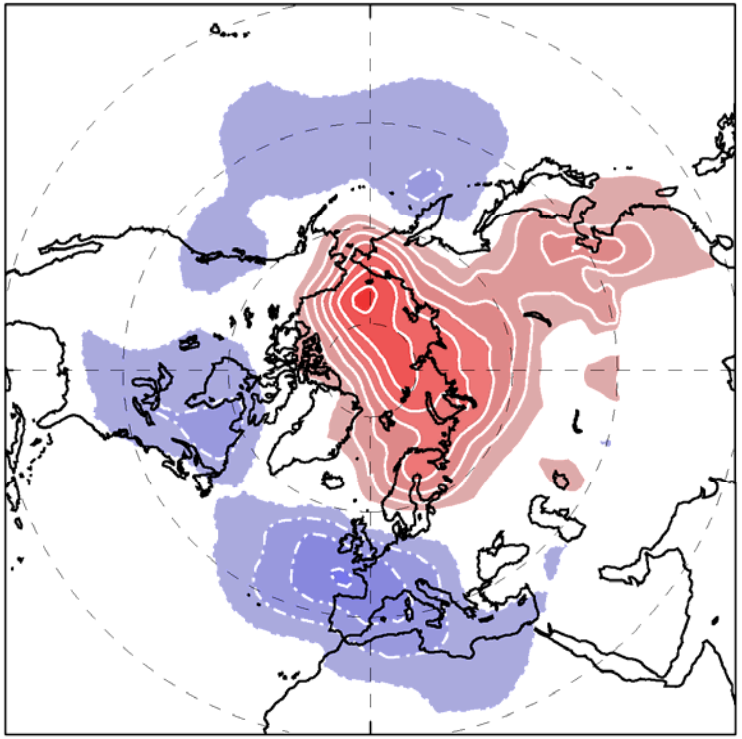
Dynamical mechanism?



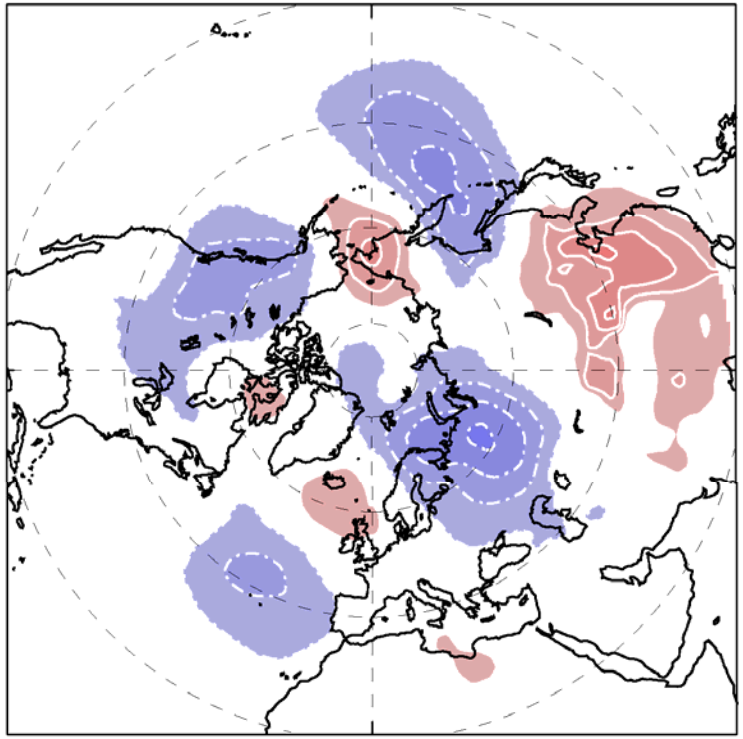
$0 < u < u_c$

30-day Mean ΔSLP Following WAF Pulses

Init. WEAK 18/51

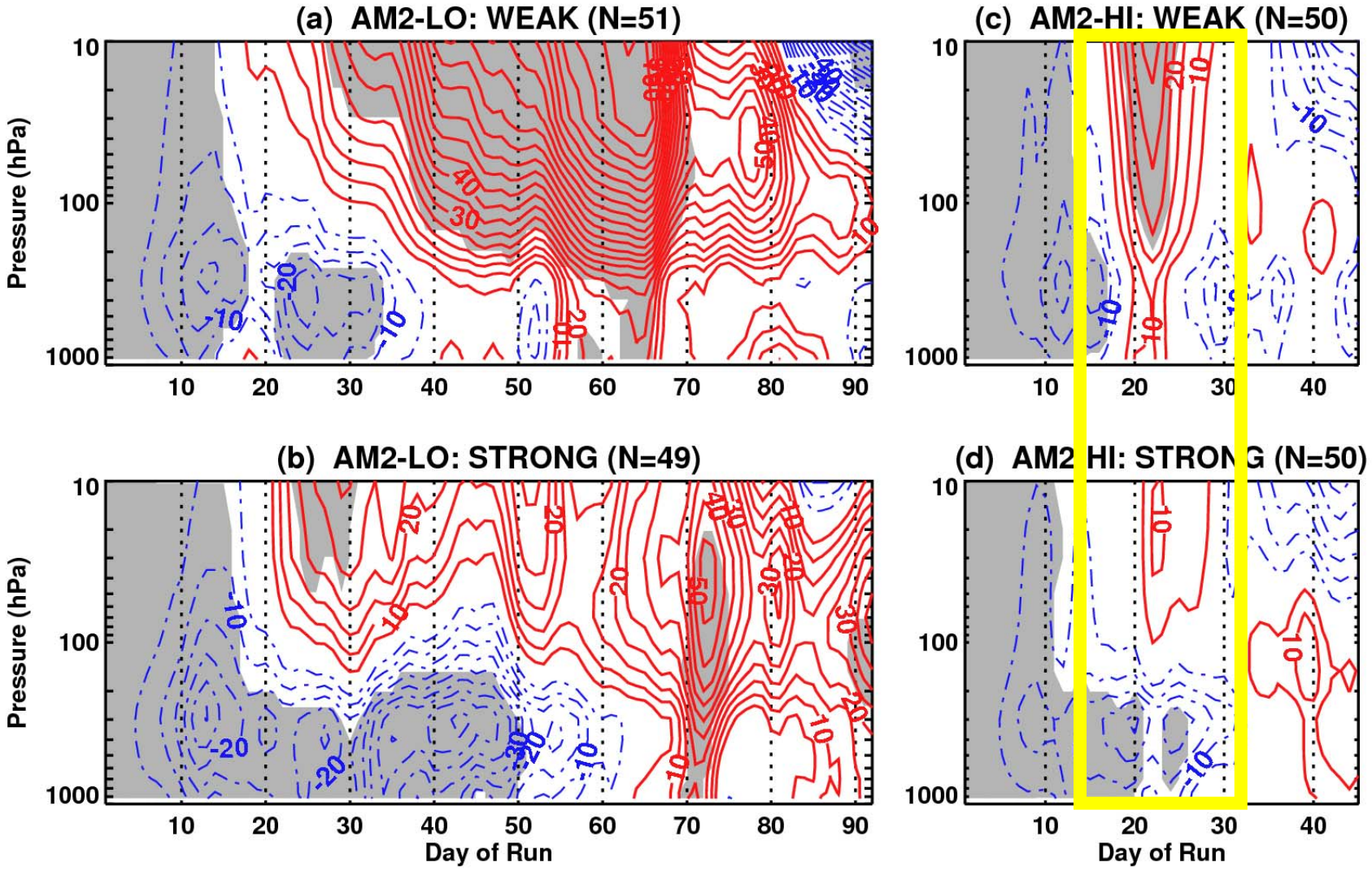


Init. STRONG: 20/49



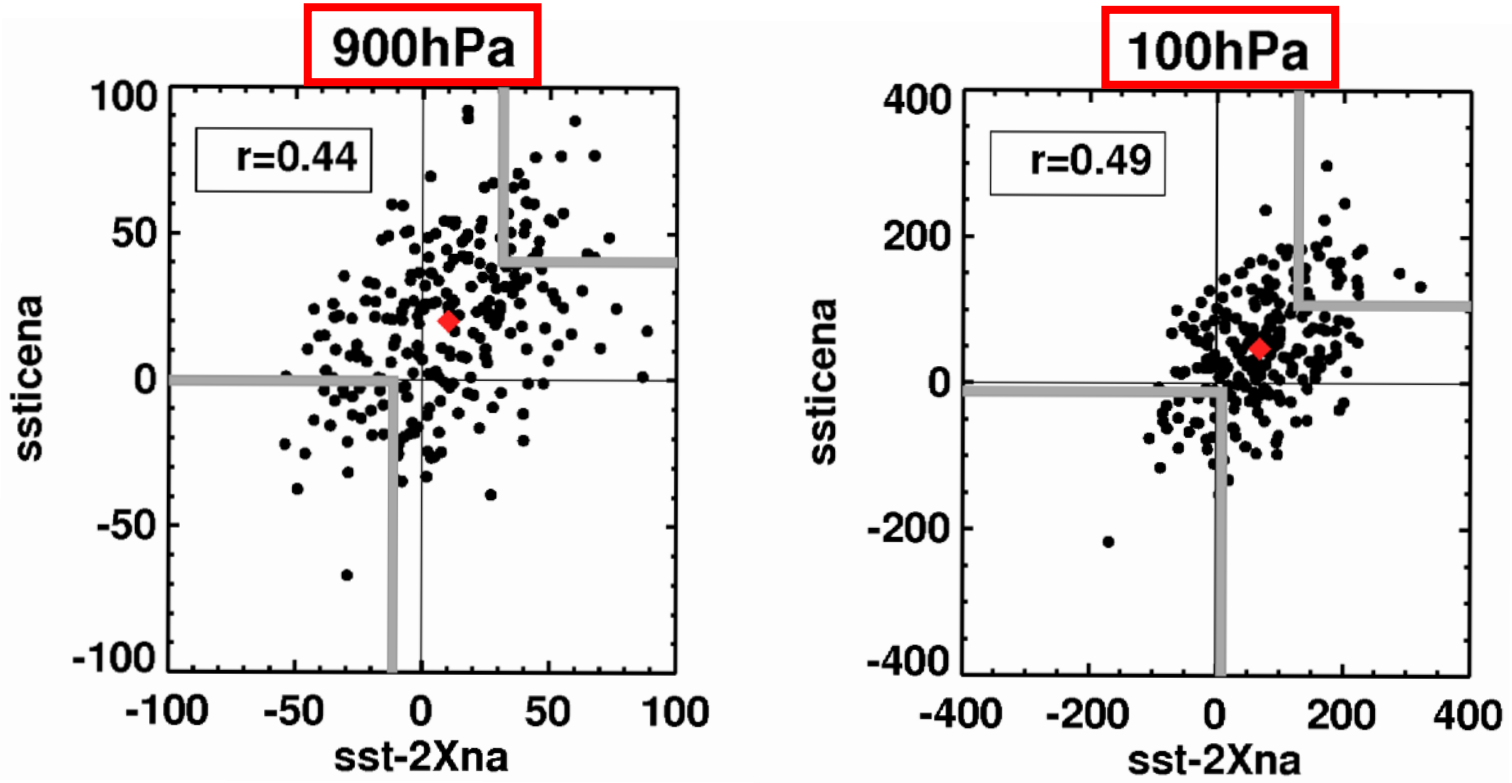
Fletcher et al. [2007]

Same story in the high-top model?



Fletcher et al. [2008]

Other Forcings

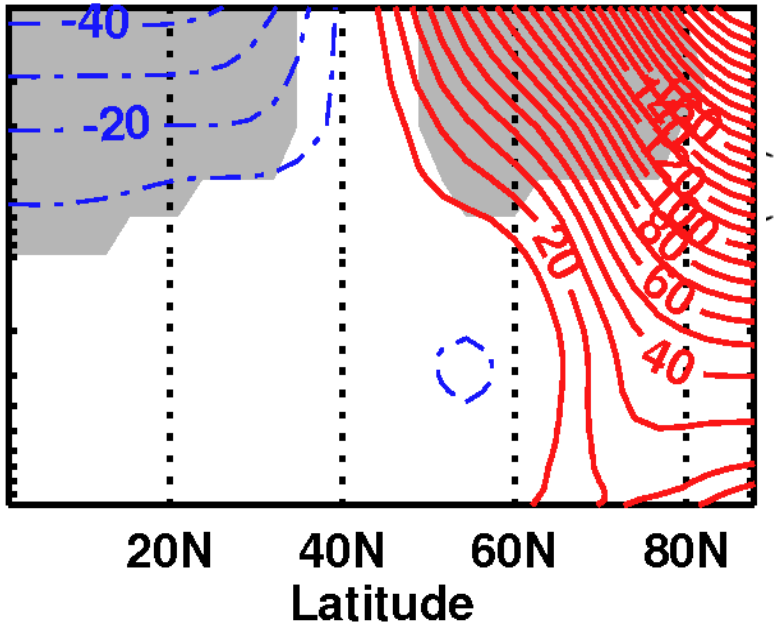


- Significant correlation between responses from N. Atlantic sea-ice and SST forcings
- Component of response (~25%) explained by initial conditions
- Use “Precursor method” to tease out this component

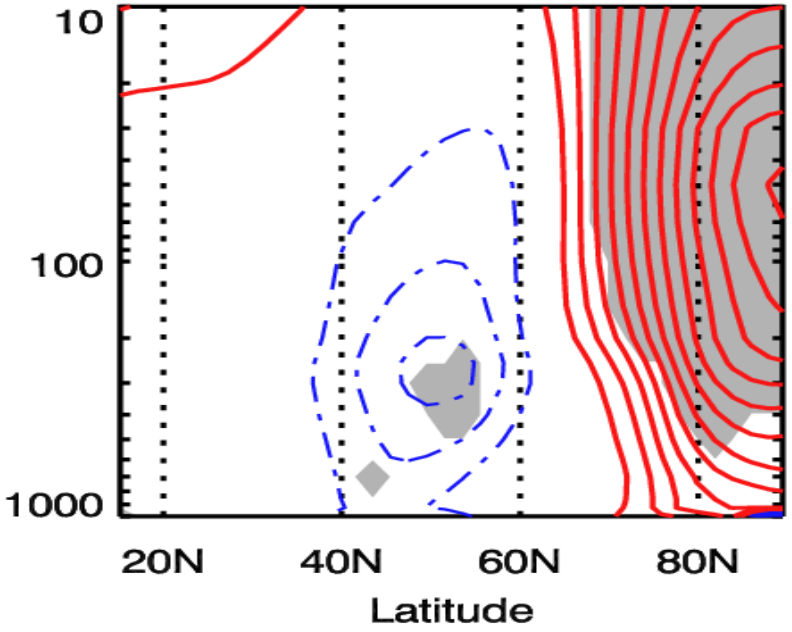
SST/Ice Data courtesy of Clara Deser

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

Conclusions

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

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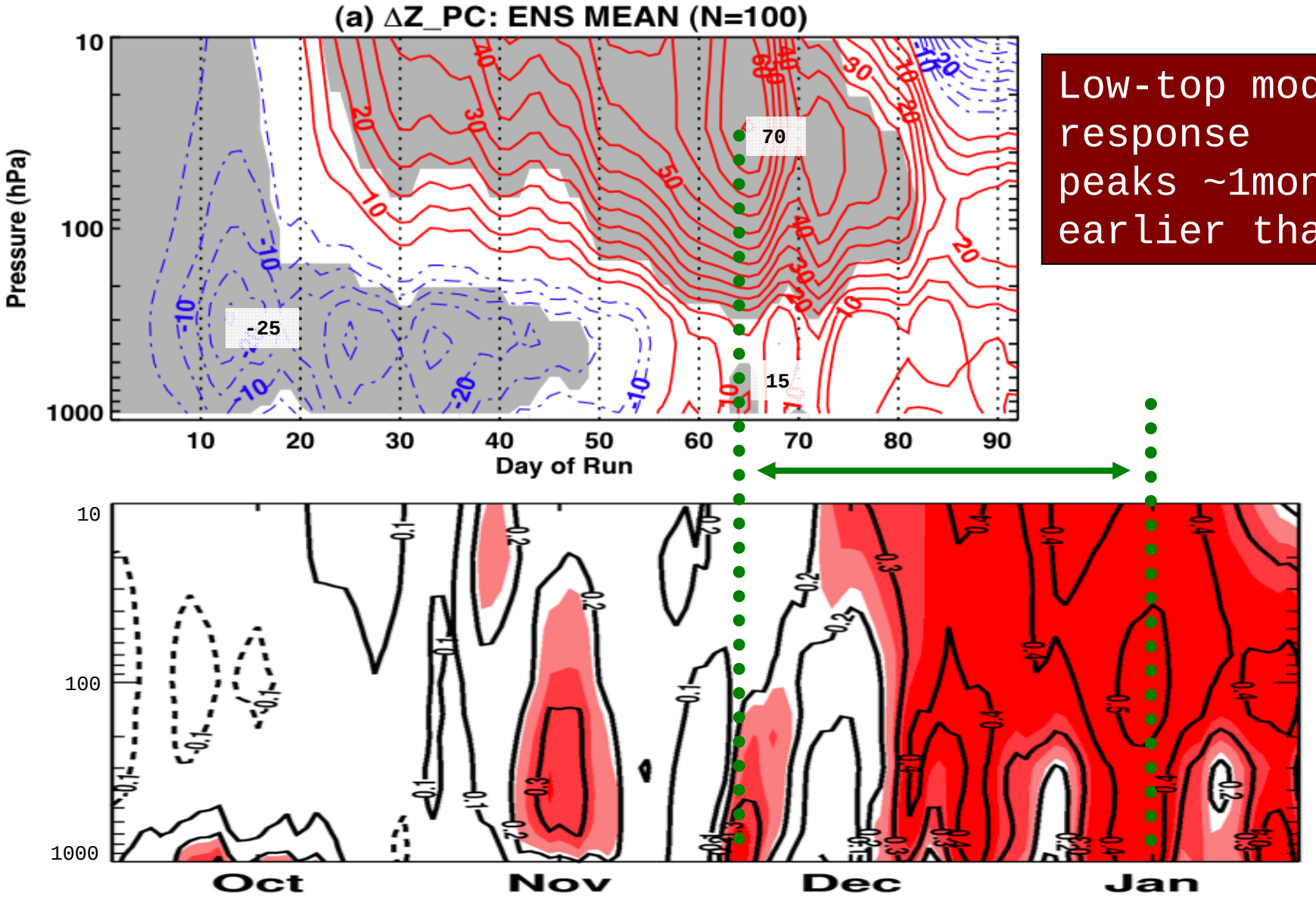
The end.

Polar Cap Height Response: AM2-LO



Low-top model response peaks ~1month earlier than

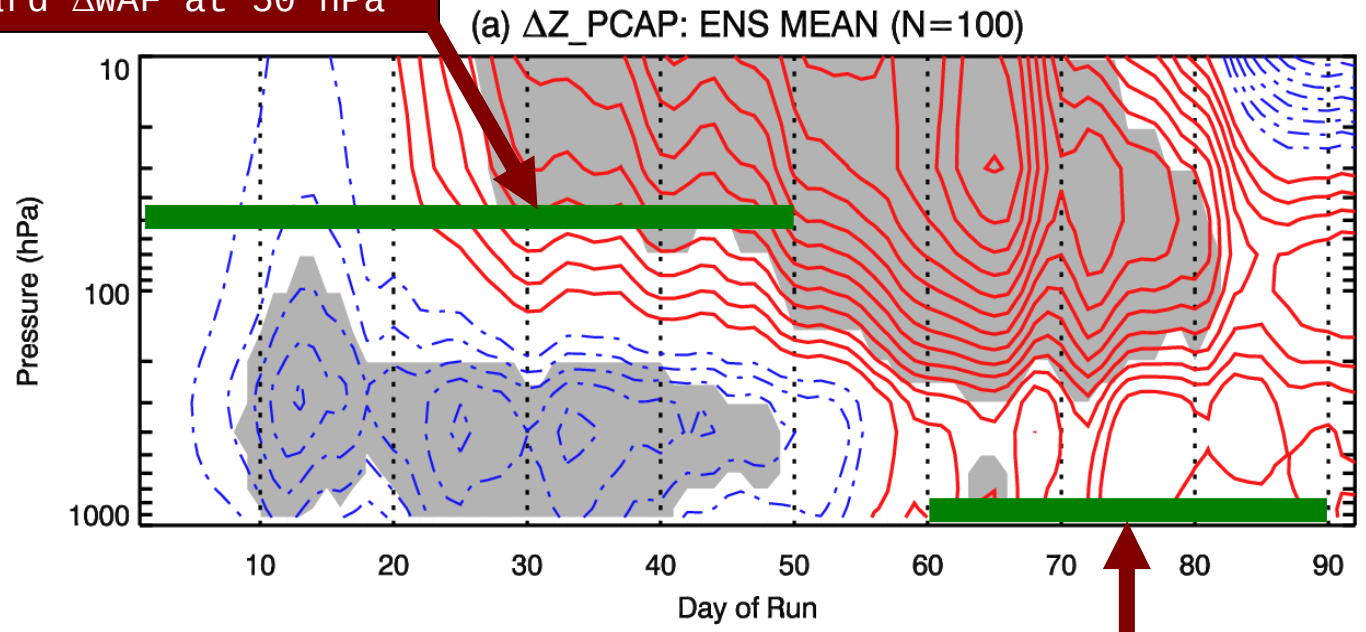
Cohen et al. [2007]

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?

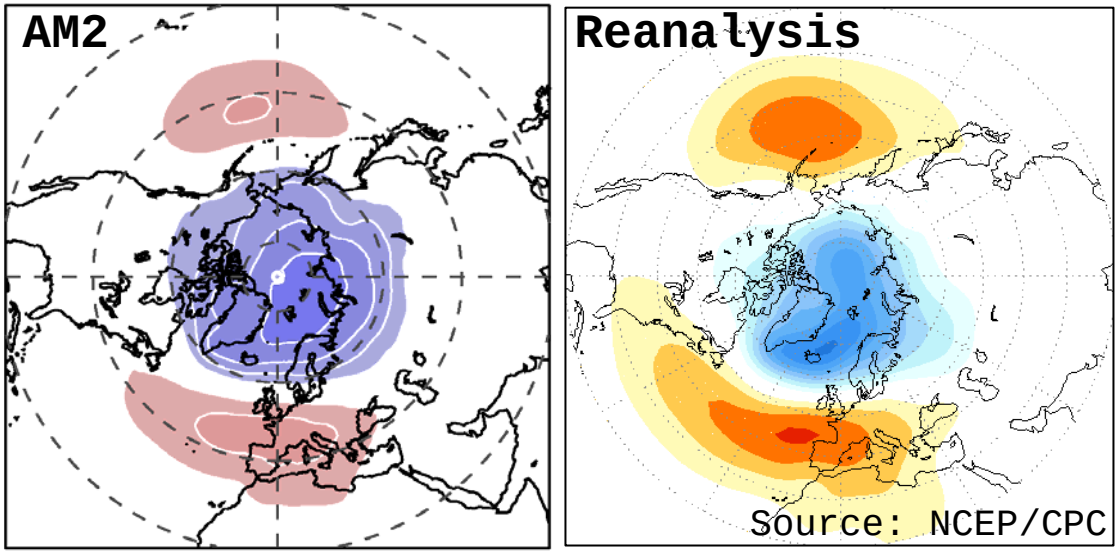
d1-50: Find day of max upward ΔWAF at 50 hPa



Wait 10 days, then record 30-day mean ΔSLP

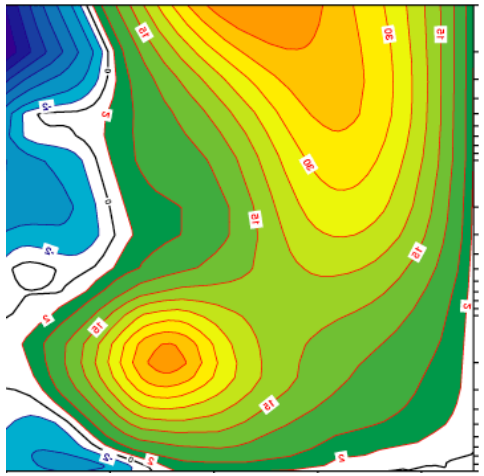
(e.g. *Polvani and Waugh [2004]*)

Northern Annular Mode in SLP

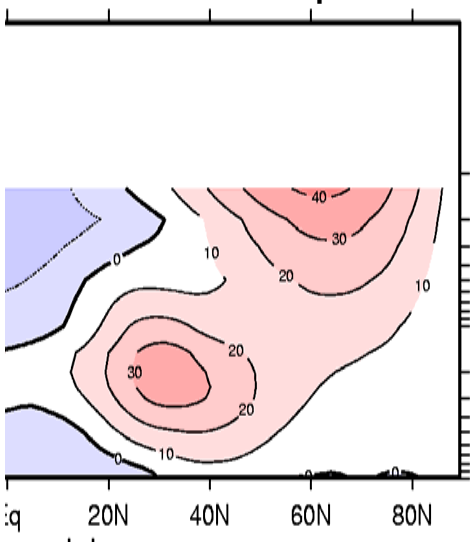


Zonal mean climatologies

ERA-40



AM2-trop.



AM2-strat.