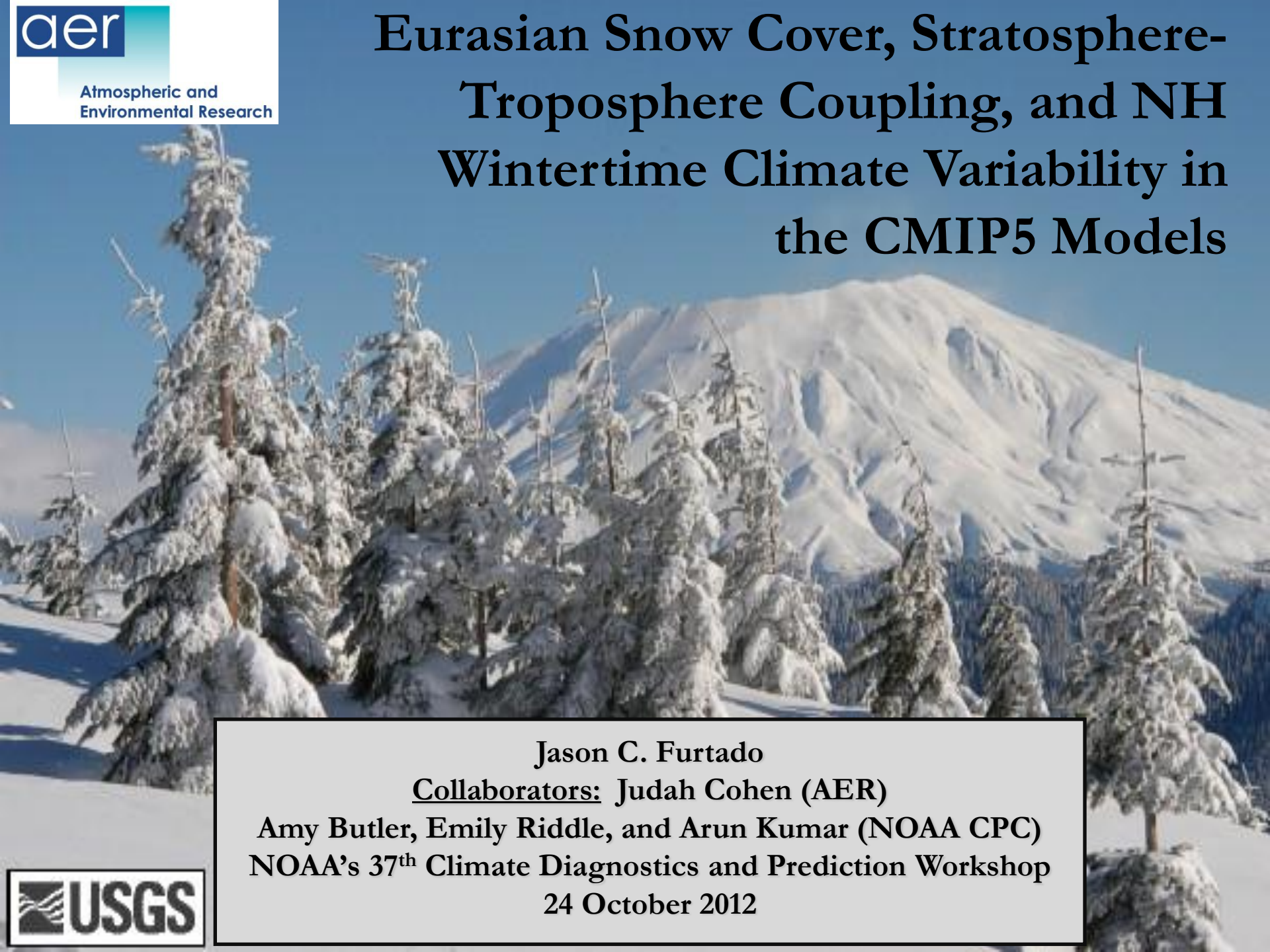


Eurasian Snow Cover, Stratosphere-Troposphere Coupling, and NH Wintertime Climate Variability in the CMIP5 Models

Jason C. Furtado

Collaborators: Judah Cohen (AER)

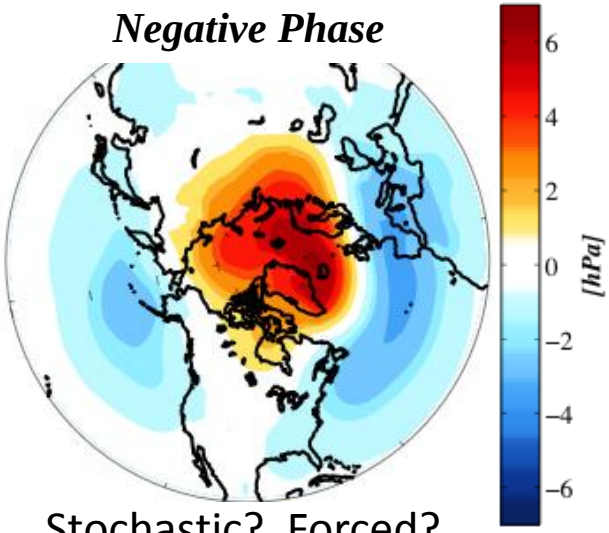
Amy Butler, Emily Riddle, and Arun Kumar (NOAA CPC)

NOAA's 37th Climate Diagnostics and Prediction Workshop

24 October 2012

NH Winter Climate and the AO

Forecasting the phase of the Arctic Oscillation is a factor for seasonal and longer-range forecasts.



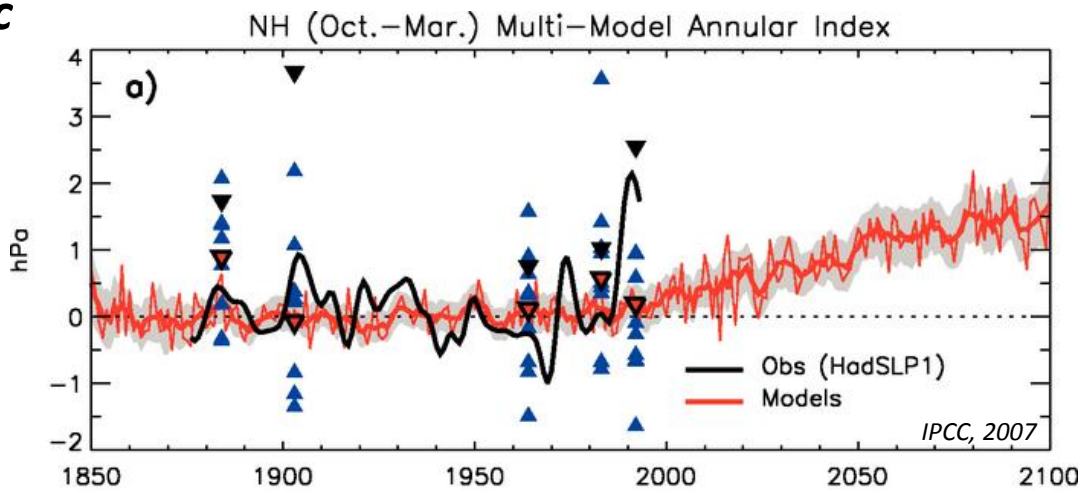
Stochastic? Forced?

Solar Forcing

ENSO

Eurasian Snow Cover

Arctic Sea Ice

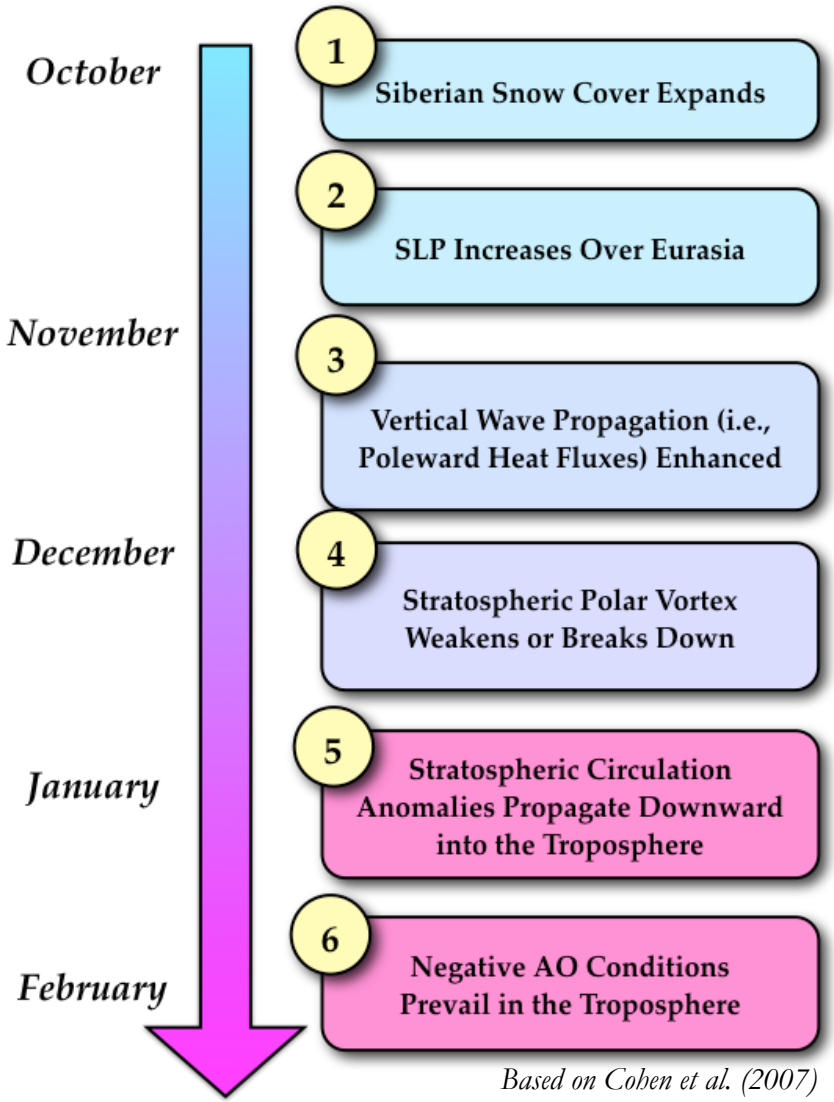


Future climate change

(1) Greenhouse gas forcing predicts more +AO conditions (e.g., Shindell et al. 1999, Hurrell et al. 2004; Miller et al. 2006, Scaife et al. 2012).

(2) Will winters grow increasingly warmer? Or are there important feedbacks that could mitigate the positive trend, even intermittently?

Fall Eurasian Snow-Winter AO Hypothesis



Based on Cohen et al. (2007)

Evidenced in observations (e.g., *Foster et al.* 1983; *Cohen and Entekhabu* 1998; *Saito et al.* 2001; *Cohen et al.* 2007).

Model-produced snow cover does *not* demonstrate the response (e.g., *Hardiman et al.* 2008; *Allen and Zender* 2011), but a model with prescribed snow can (e.g., *Fletcher et al.* 2009; *Allen and Zender* 2010, 2011).

Objectives

1) Examine salient features for the mechanism in the models (e.g., snow cover, AO).
2) Evaluate the 'six-step process' in CMIP5 models and compare with observations.
3) Offer suggestions for why CMIP5 models do not agree with observations.

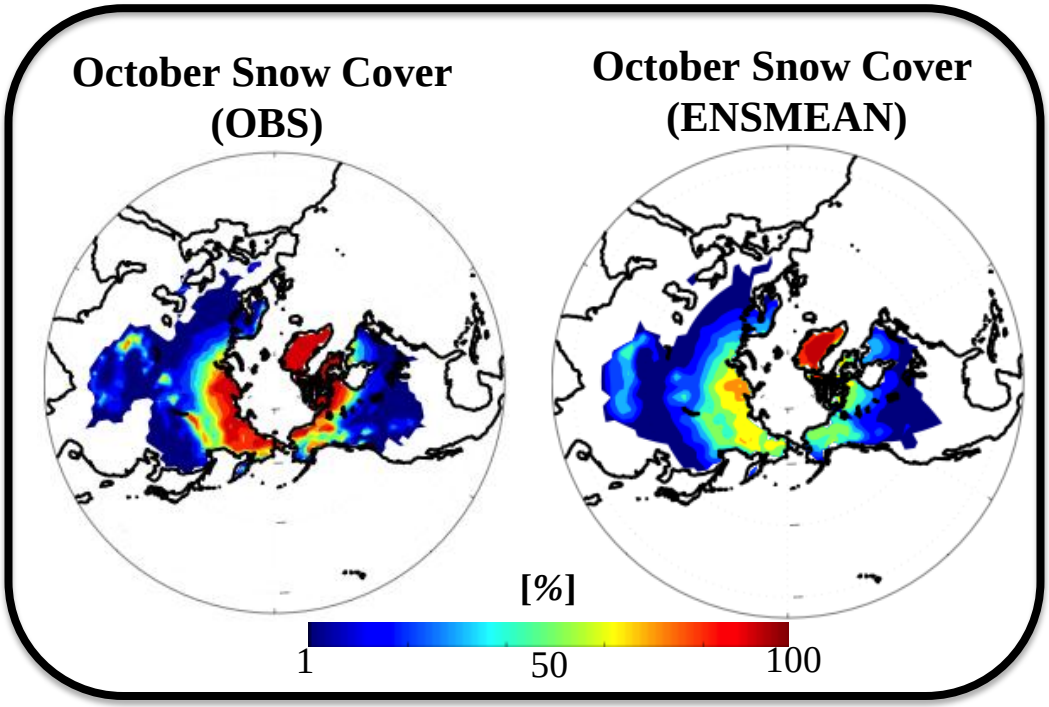
Data and Methodology

Observational Data

- Monthly-mean ERA-Interim (1979-2011)
- October Monthly-Mean Rutgers Eurasian Snow Cover Index (20-75°N, 0-170°E) (1979-2010)

CMIP5 Models

- Monthly-mean piControl runs (15 models).
- Selected based on availability of snow cover extent (snc) as downloadable variable.
- Regridded to a 2.5° by 2.5° grid for inter-model comparisons.



Methodology

- Subdivide the piControl runs into 40-yr segments.
- Compute statistics on each segment separately.
- Present results by model (aggregate segment statistics) and as 'multi-model ensemble-mean.'
- Focus on NH extended cold season (ONDJFM).

ECMWF

WCRP World Climate Research Programme

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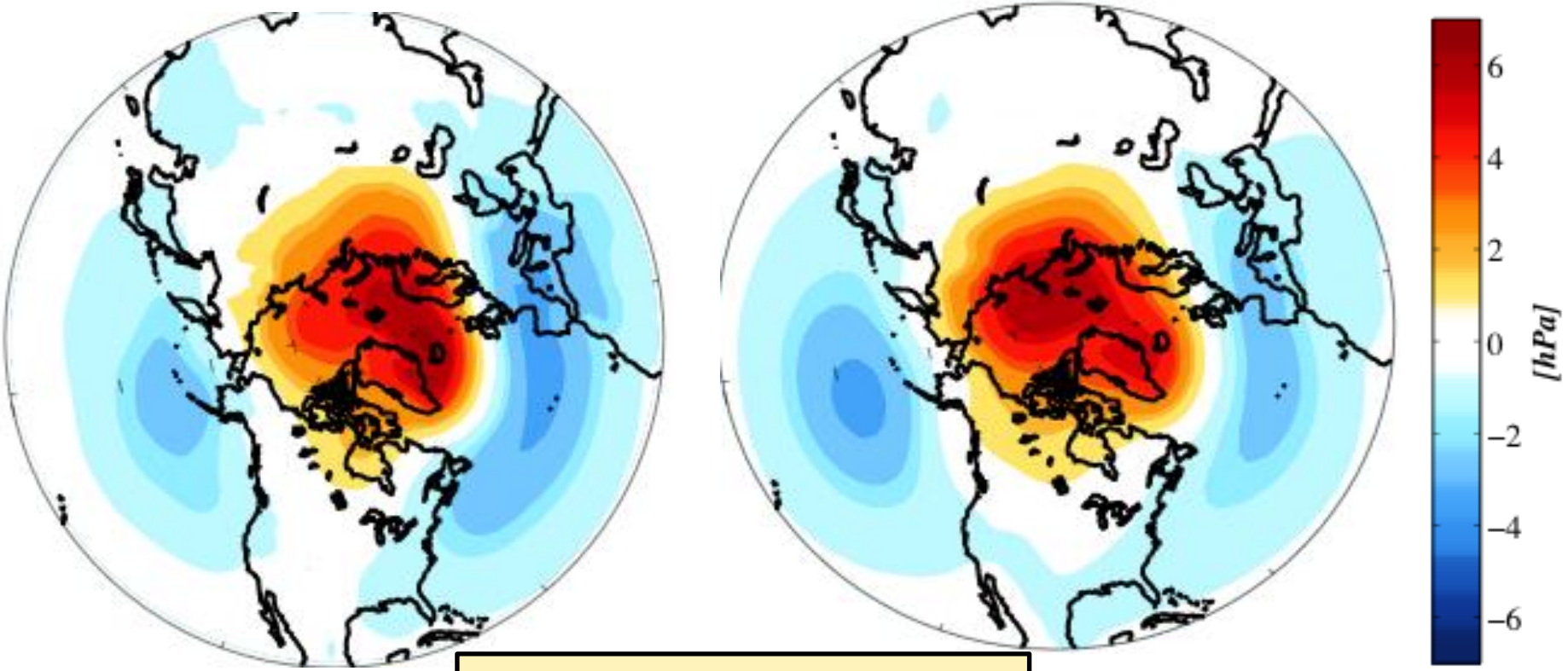
The AO Pattern – Obs. vs. CMIP5

SLPa Regressed on -PC1
Of NDJFM SLPa

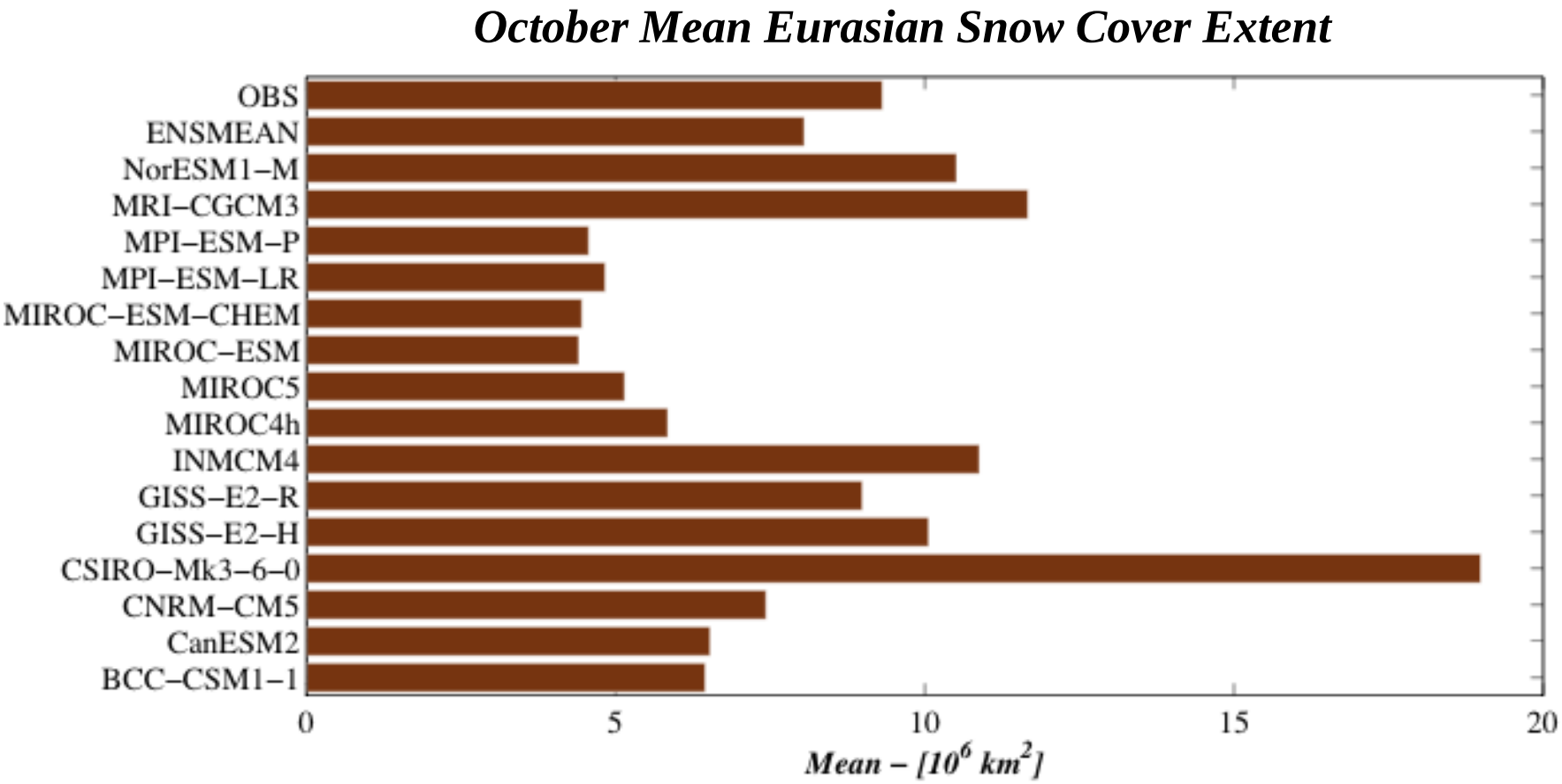
Observations

Multi-Model Mean

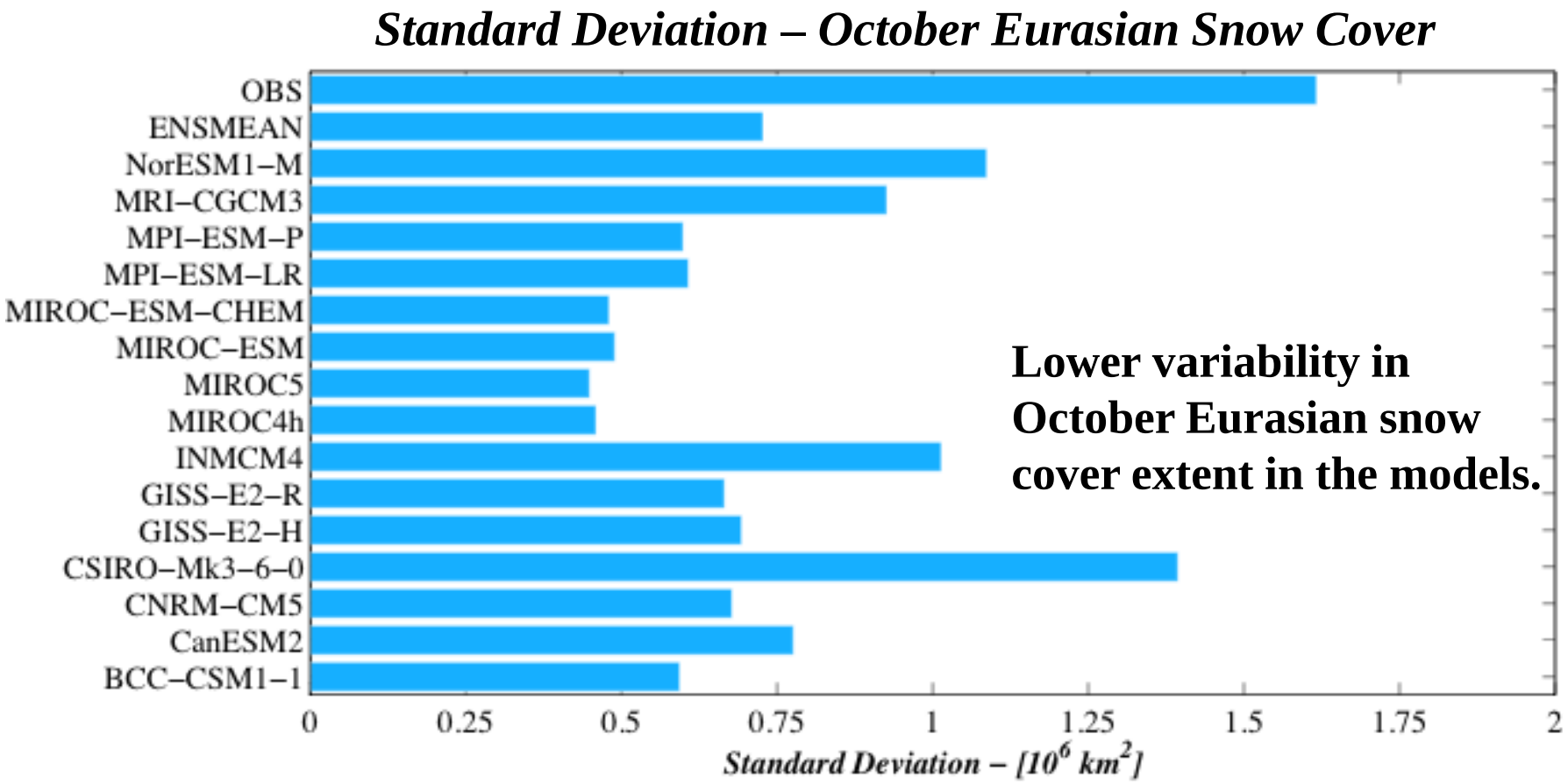


Pattern correlation strong for ensemble-mean (r = 0.84)

October Eurasian Snow Cover Statistics



October Eurasian Snow Cover Statistics

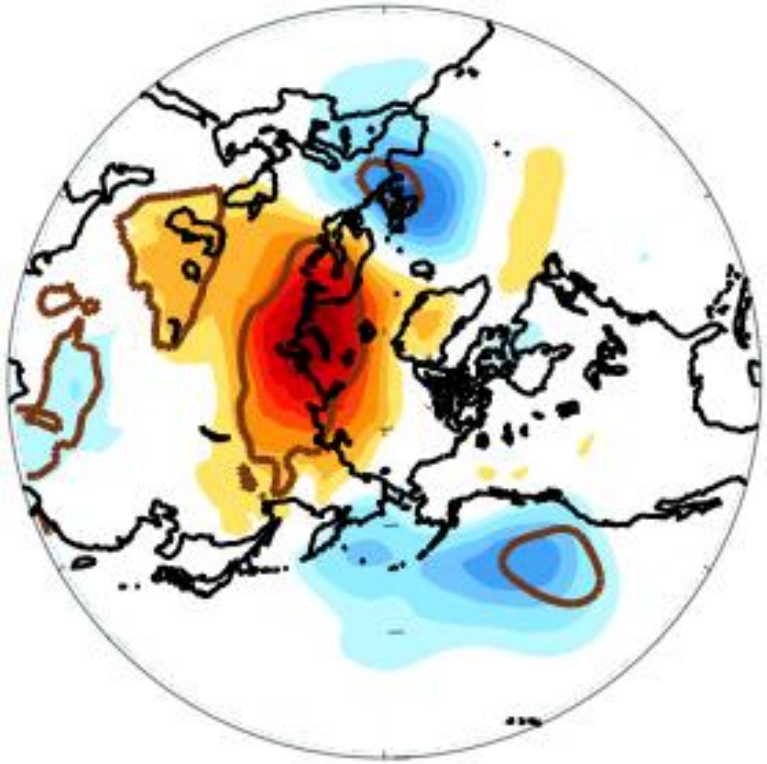


Eurasian Snow/SLP Relations

1. Siberian Snow Cover Expands
2. SLP Increases Over Eurasia

ND SLPa Regressed Onto Oct. Eurasian Snow Cover

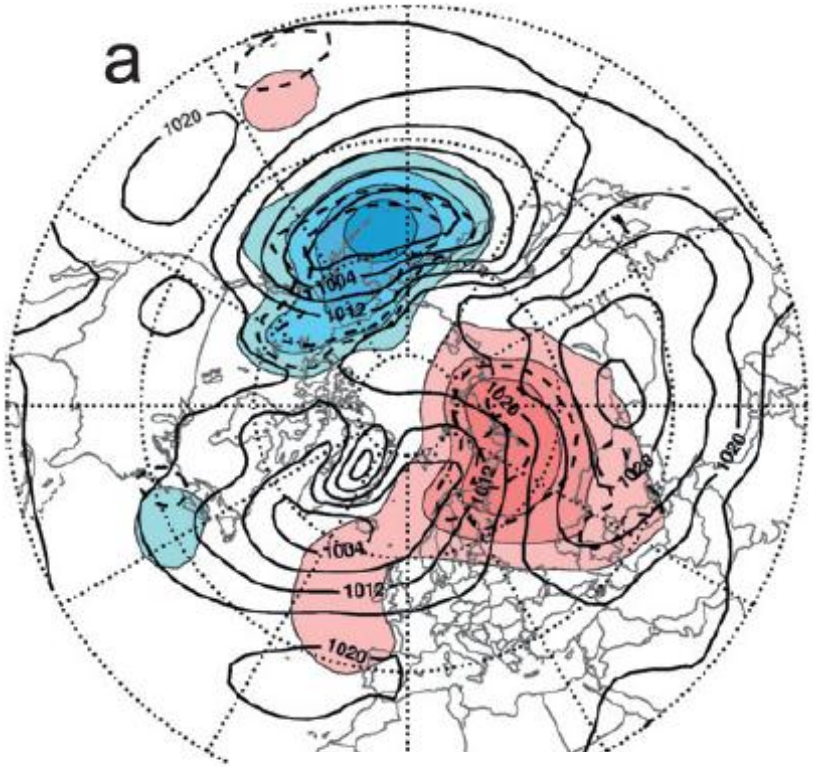
Observations



[*hPa*]

-3 0 3

Multi-Model Mean



-0.3

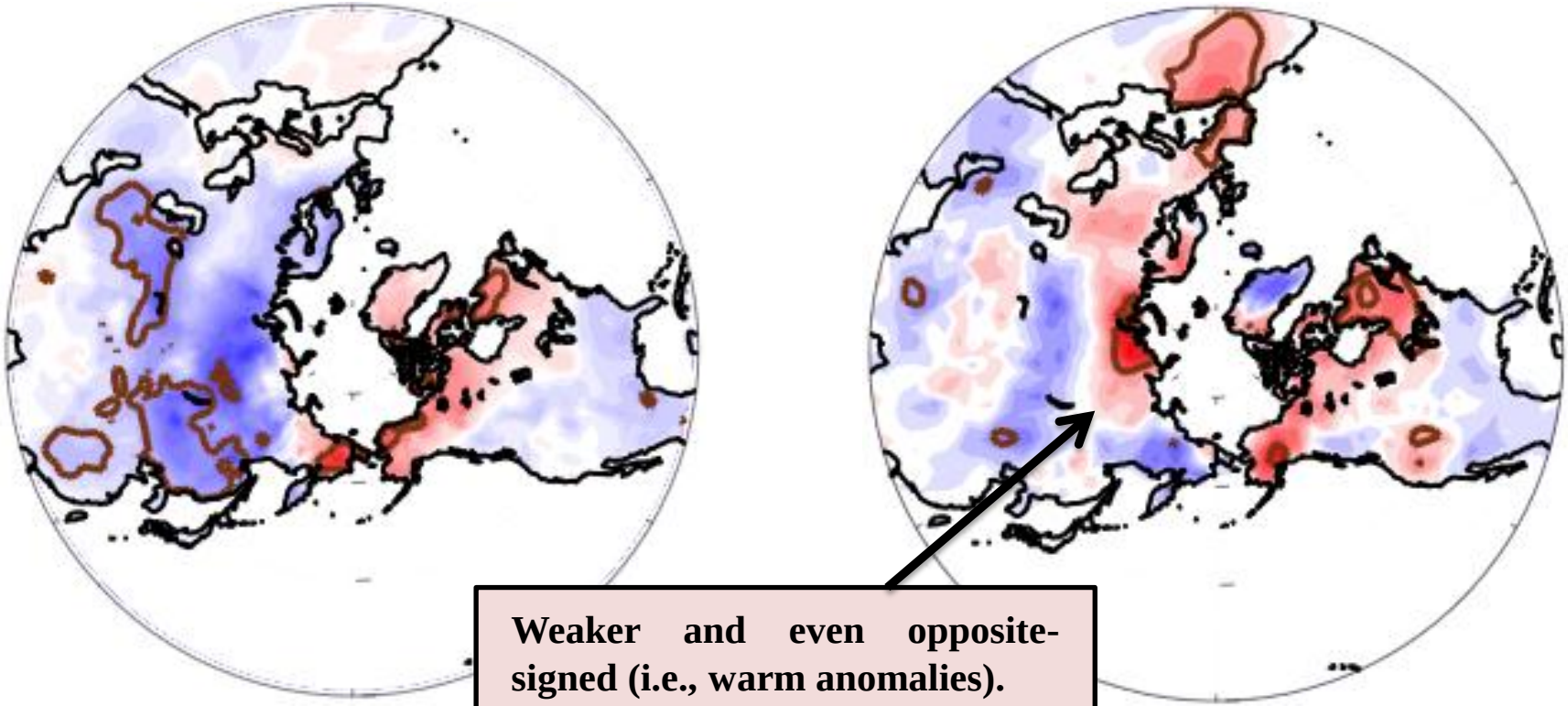
SLP Precursor to SSWs (e.g., Cohen and Jones 2011)

Eurasian Snow/Surf. T Relations

ND Surface Ta Regressed Onto Oct. Eurasian Snow Cover

Observations

Multi-Model Mean



Weaker and even opposite-signed (i.e., warm anomalies).

[°C]

-2 0 2

[°C]

-0.1 0 0.1

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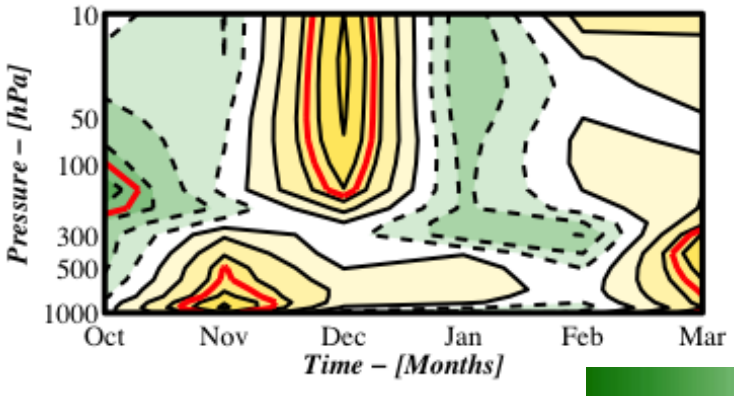
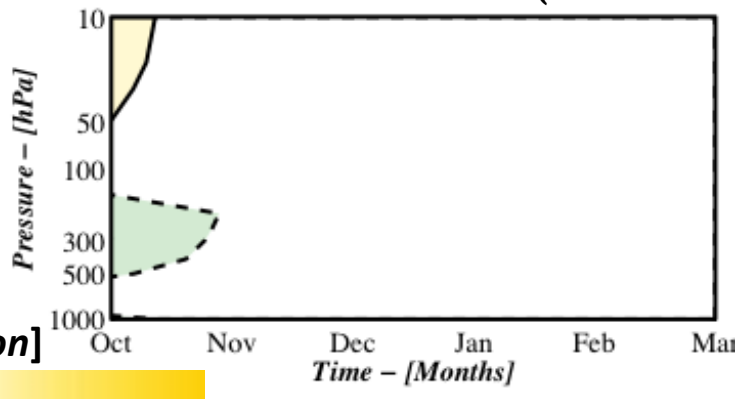
Steps 3 – 5 of the Hypothesis

3. Vertical Wave Propagation (i.e., Poleward Heat Fluxes) Enhanced
4. Stratospheric Polar Vortex Weakens or Breaks Down
5. Stratospheric Circulation Anomalies Propagate Downward into the Troposphere

40-80°N WAFz / Oct Snow (Obs)



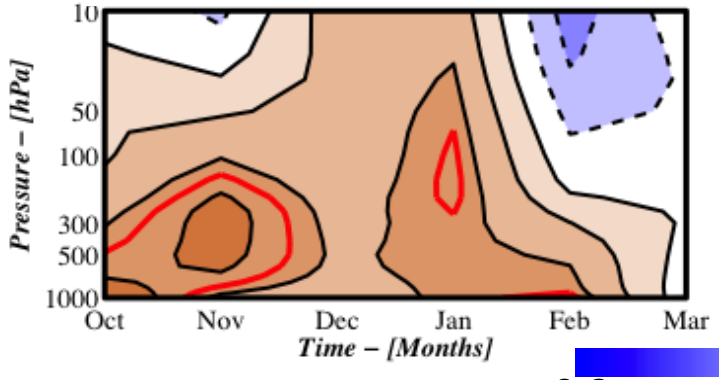
40-80°N WAFz / Oct Snow (ENSMEAN)



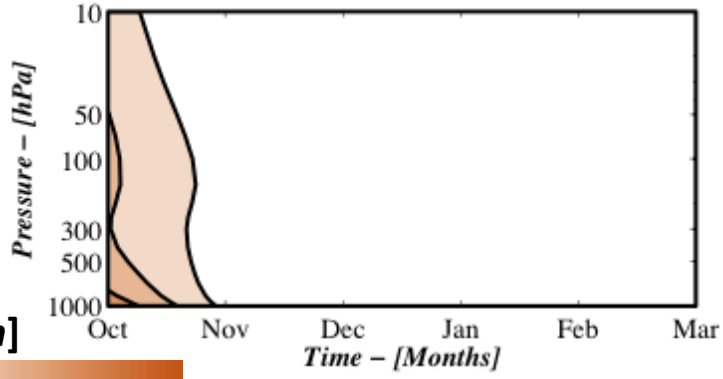
[Correlation]

-0.7 0 0.7

60-90°N GPH / Oct Snow (Obs)



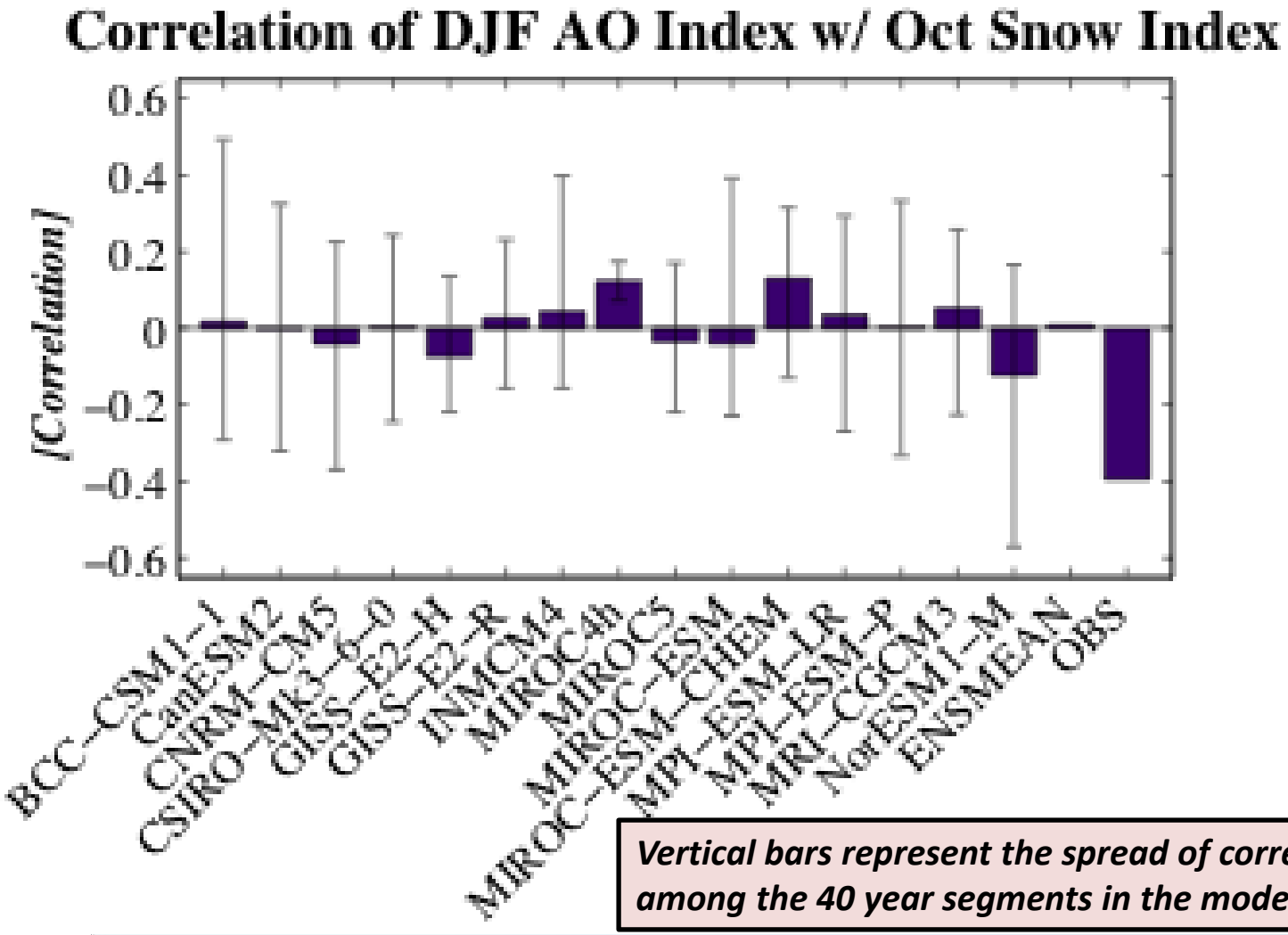
60-90°N GPH / Oct Snow (ENSMEAN)



[Correlation]

-0.6 0 0.6

Step 6 - Link to the DJF AO

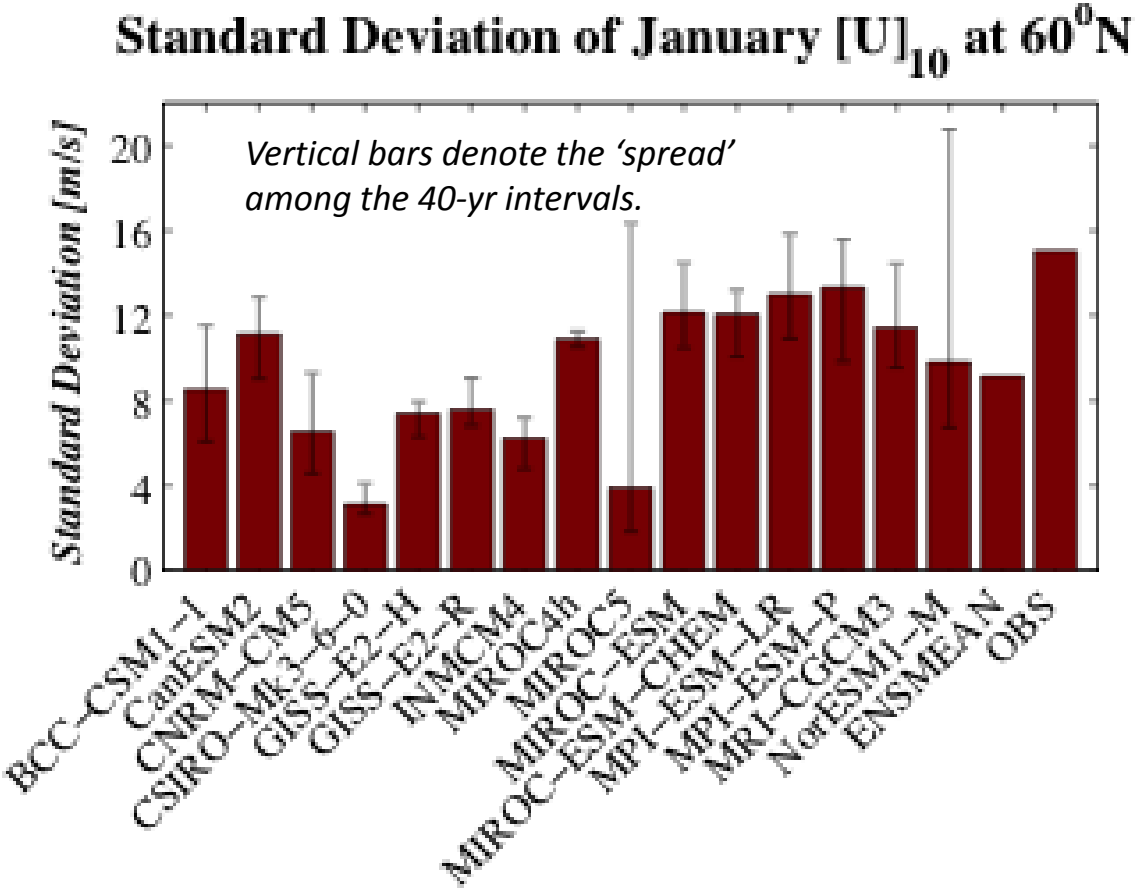


Vertical bars represent the spread of correlations among the 40 year segments in the model.

Possible Explanations for Poor Model Agreement

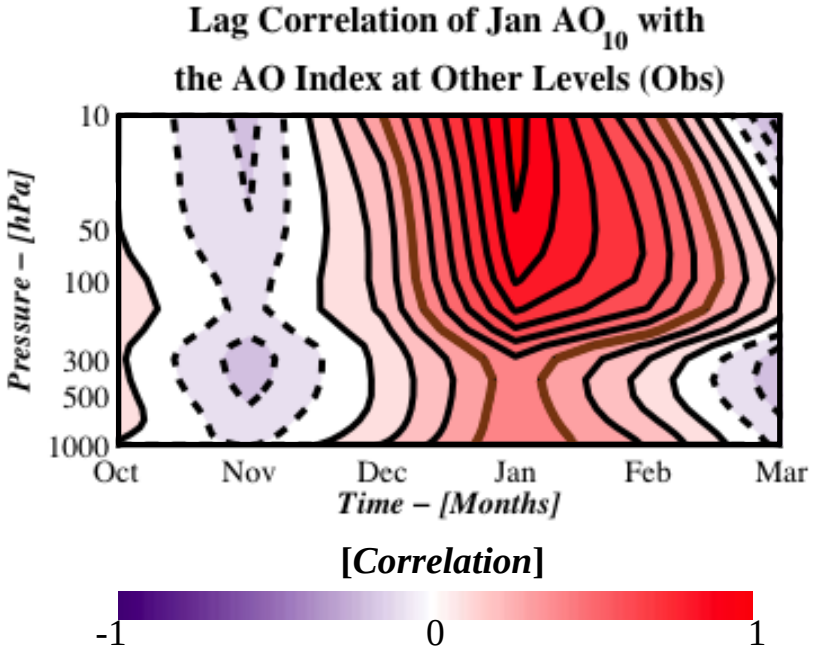
(1) Variability in the Stratospheric Polar Vortex

- All models show lower variability than observed, some significantly lower (e.g., CSIRO).
- Ensemble-mean σ_{U60} = 9.1 m/s vs. Observed σ_{U60} = 15 m/s.



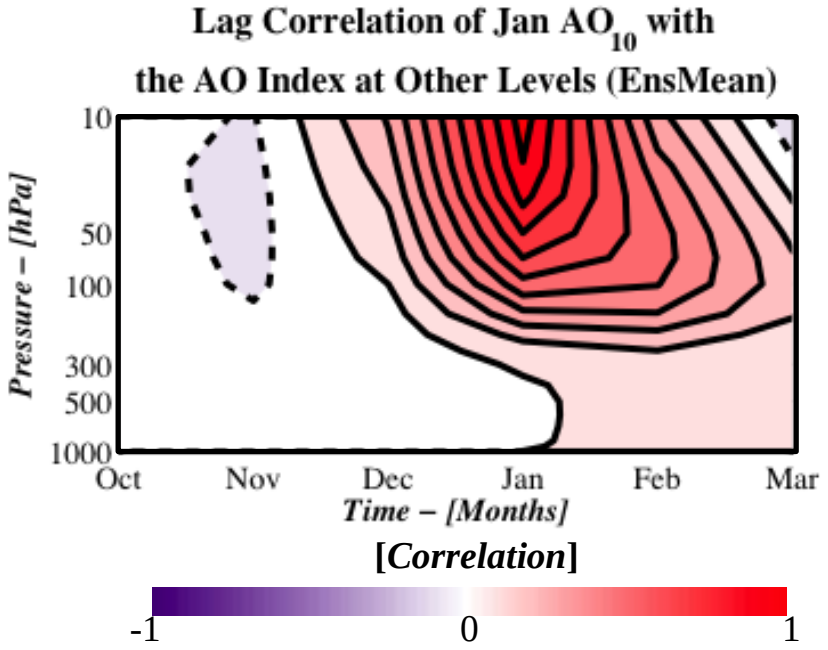
Possible Explanations for Poor Model Agreement

(2) Downward Propagation of Stratospheric Anomalies



Ensemble-mean correlations show downward propagation to ~150 hPa but not to the surface.

***r*(Jan AO_{10}, Jan AO_{1000}) ranges from -0.54 (INMCM4) to 0.20 in MIROC5.**



Summary and Conclusions

- The six-step snow-AO hypothesis does not verify in the CMIP5 models, similar to the results from the CMIP3 models (*Hardiman et al.* 2008).
- Models continue to underperform on simulating fall snow cover extent, its variability, and the lagged atmospheric response to the snow.
- Analysis with the historical runs yields very similar conclusions.
- Irrespective of the snow relationship, the coupled climate models have issues with stratospheric vortex variability and 'downward propagation'.
  - This fact may give pause for wintertime climate model projections.
- **Remaining Challenges/Future Work**
  - Snowfall/snow cover in the models. Precipitation-related? Land surface?
  - Investigation of daily-mean output for downward propagation and wave dynamics propagation. This is relevant for both S/T studies as well as the snow-AO hypothesis.

Thank you!

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Atmospheric and Environmental Research

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EXTRA SLIDES

October 24, 2012
Jason C. Furtado,
Atmospheric and Environmental Research, Inc. (AER)
NOAA 37TH Annual Climate Diagnostics Workshop

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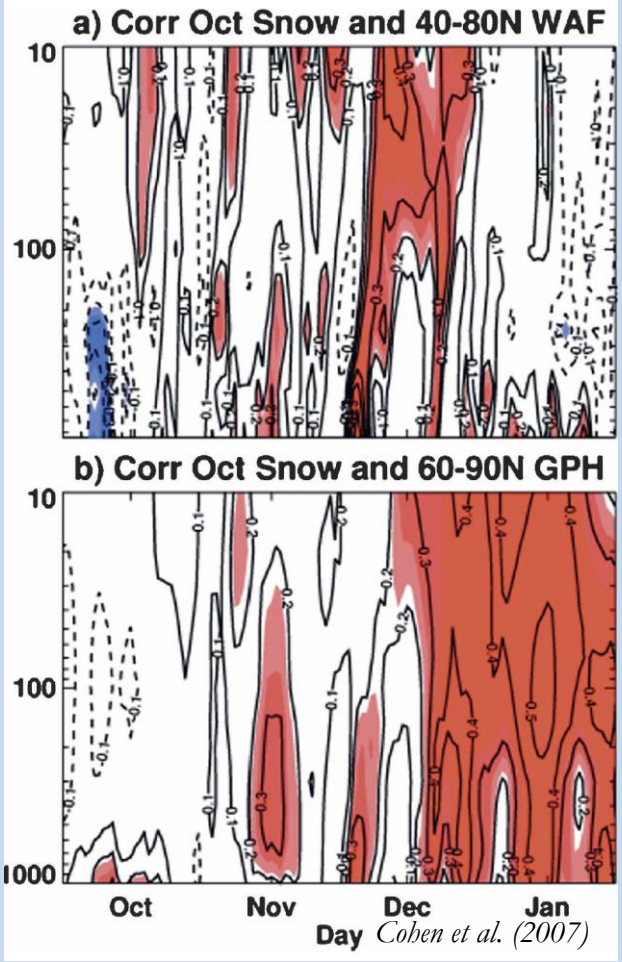
Prior Work

Observations

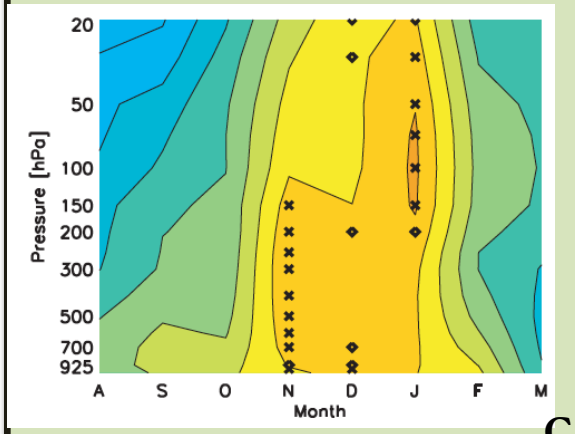


Cohen et al. (2007)

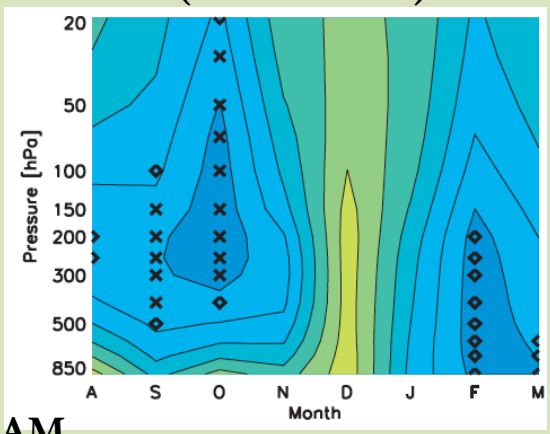
Climate Models

Polar Cap Height / SON EA Snow Correlations

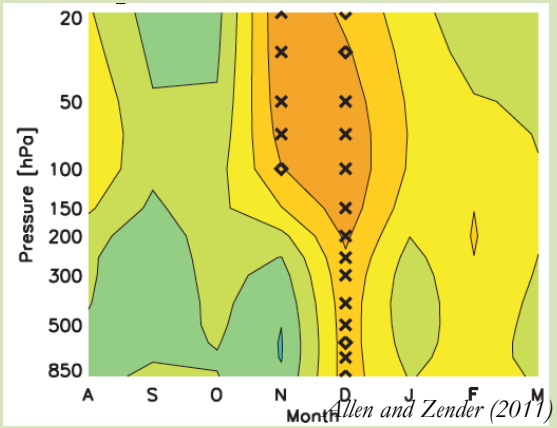
Reanalysis



CAM (Model Snow)



CAM (Prescribed Snow)

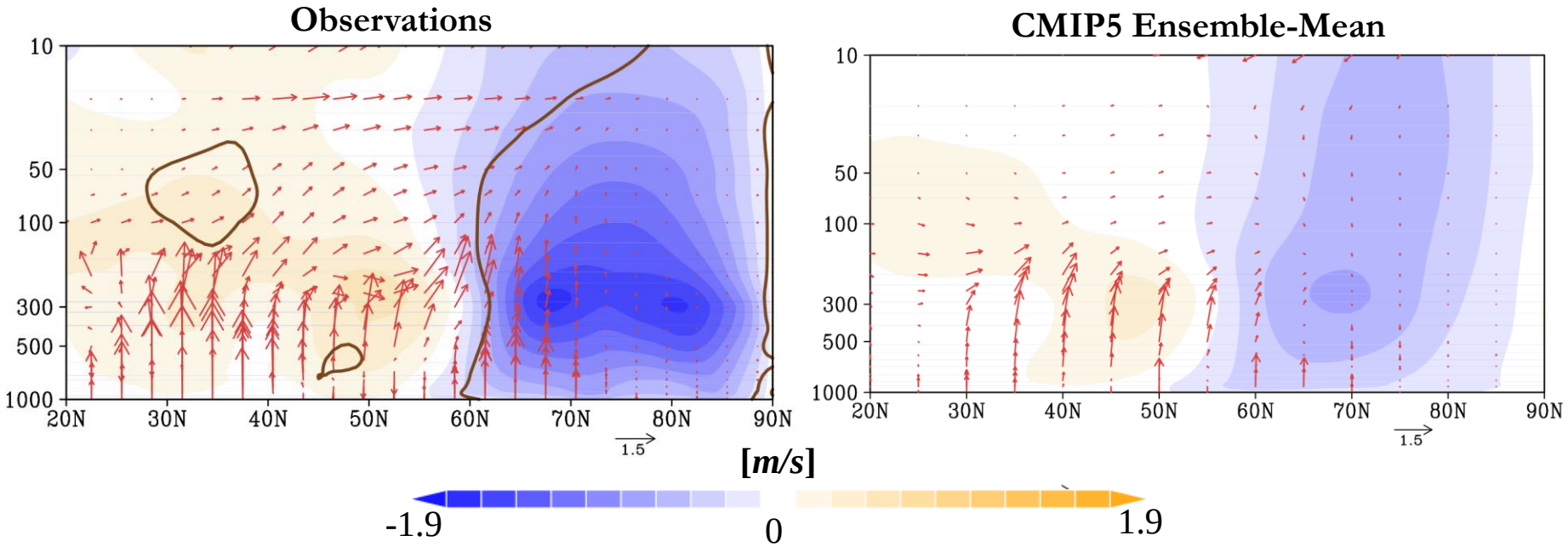


Allen and Zender (2011)

Possible Explanations for Poor Model Agreement

(1) Wave Forcing and Wave Propagation

Oct Zonal-Mean U (shading) and EP-Fluxes (arrows)
Regressed onto the Oct Snow Index



Strong vertical and poleward wave propagation in obs.

Weaker wave forcing in models.

Possible Explanations for Poor Model Agreement

(2) ND WAFz / JF SLPa Covariability