Response to Sudden Sea Ice Loss in CCSM4

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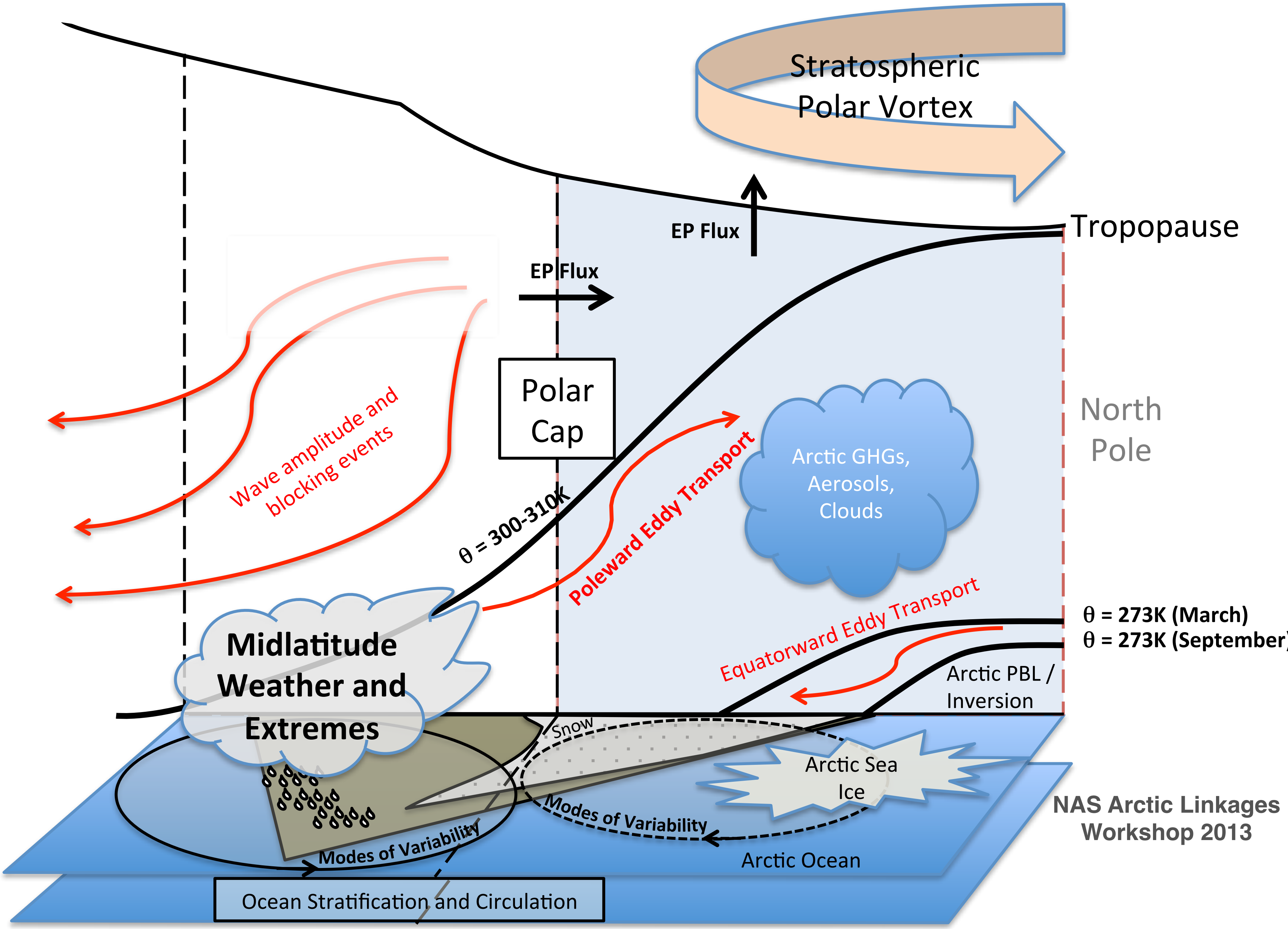
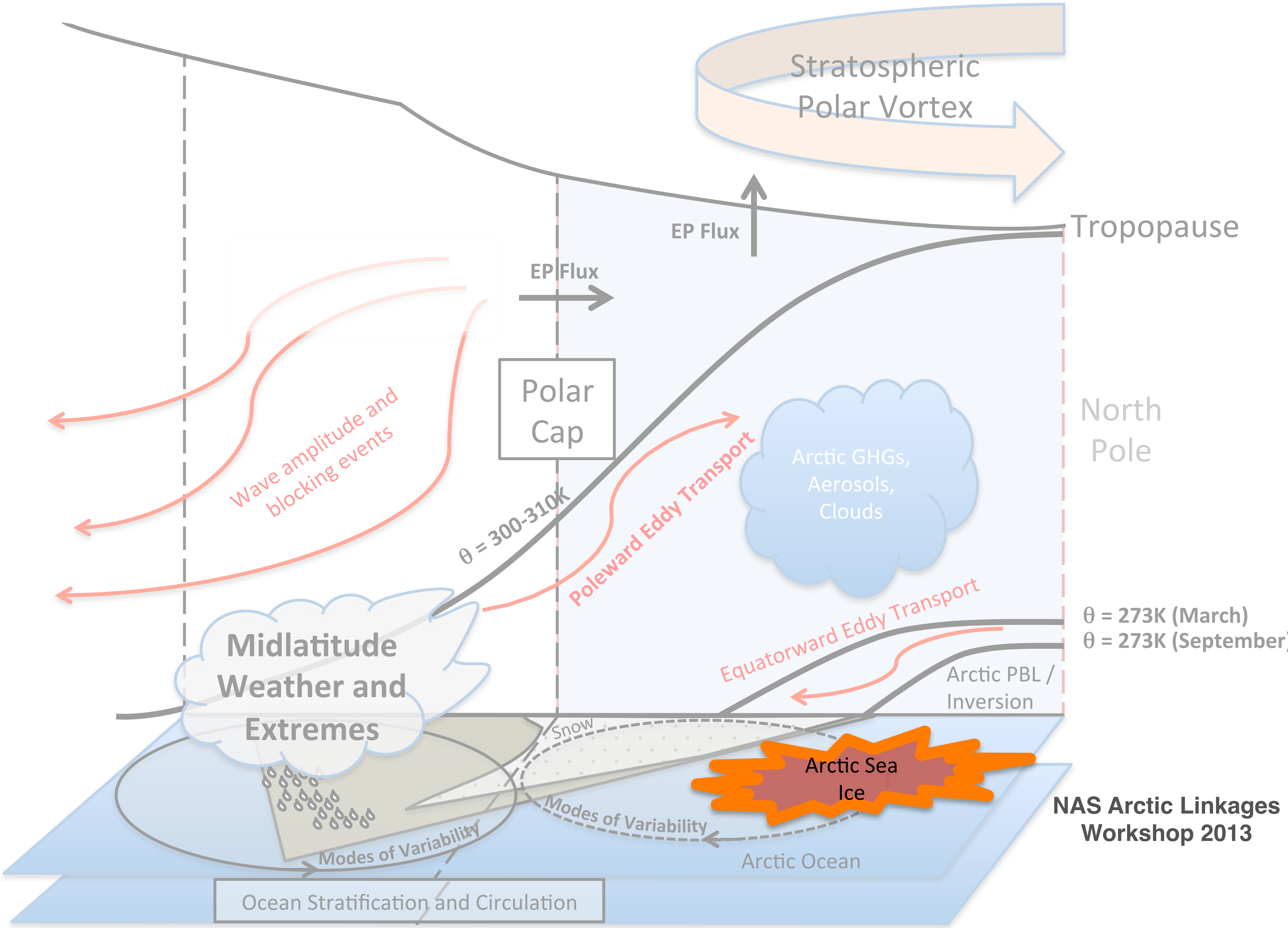
- Motivation & methods
- Equilibrated response in circulation, variability
- Transient response

Arctic-Midlatitude System: Big Picture View

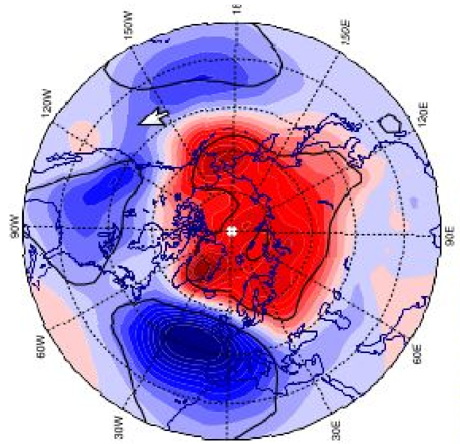


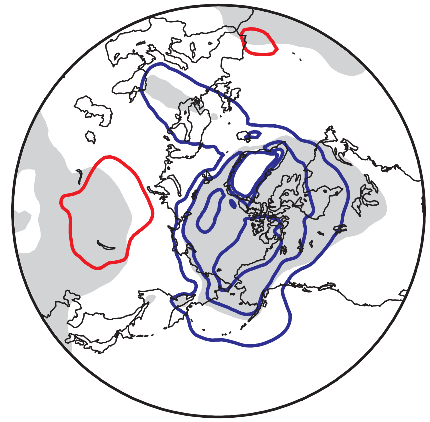
Arctic-Midlatitude System: Sea Ice Focus

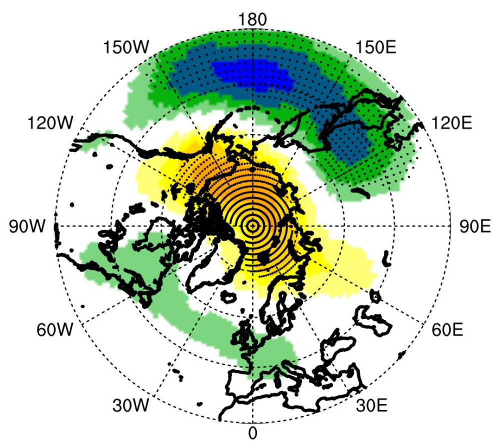


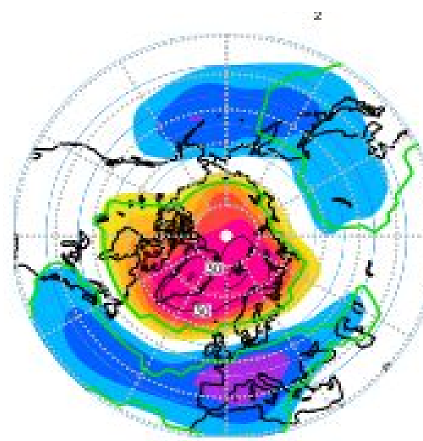
NAS Arctic Linkages
Workshop 2013

Sea Ice Loss: A Range of Teleconnections









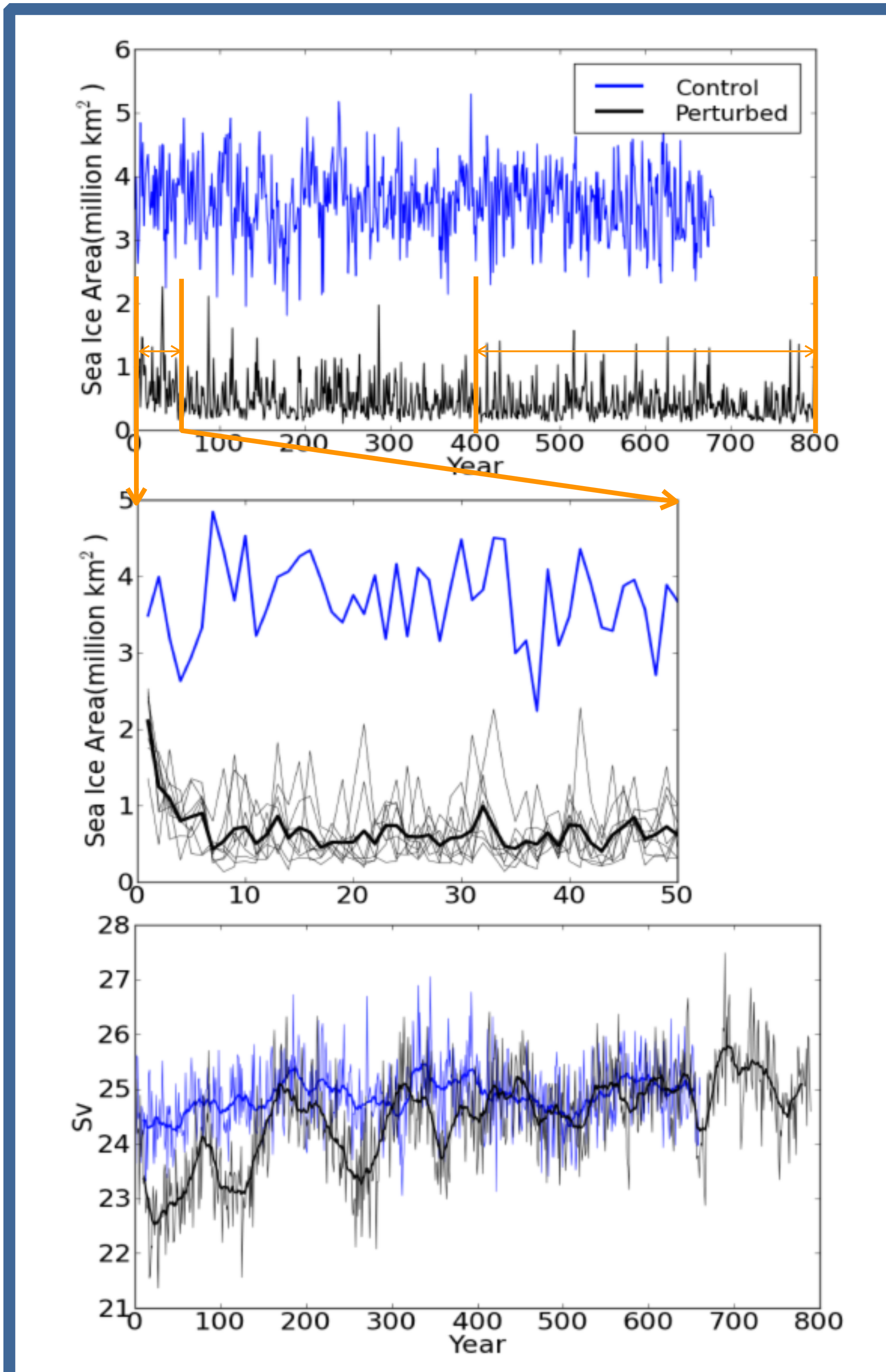
Screen et al. 2013, Liu et al. 2012, Deser et al. 2010
Peings & Magnusdottir 2013, Petoukhov & Semenov 2010 …

Motivation & Approach

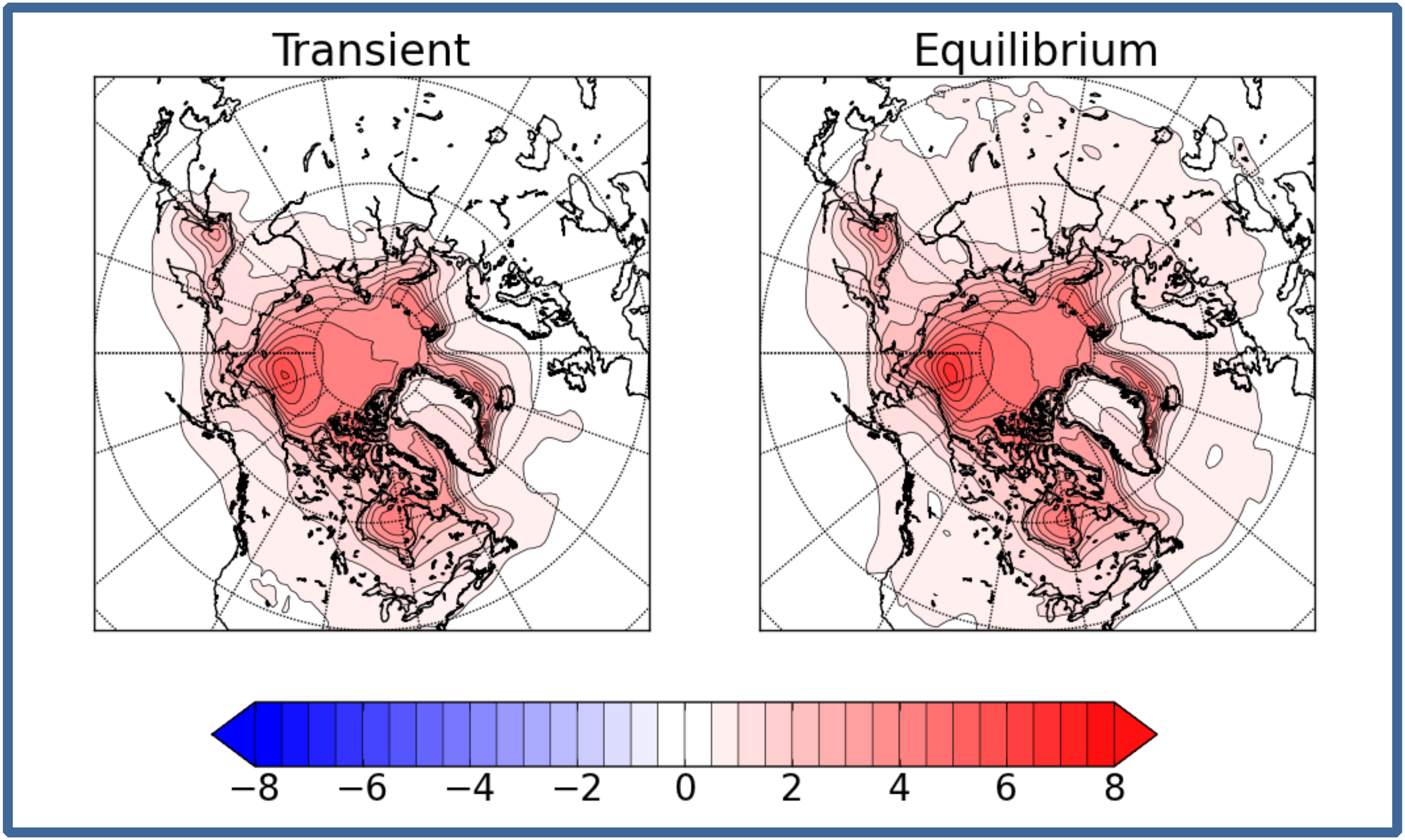
- Our view on Arctic/midlatitude linkage discussion:
  - Important to separate sea ice loss from broader Arctic Amplification (see Deser et al. 2010, 2014).
  - There is an ongoing need for idealized perturbation experiments.
- Response to sea ice loss remains uncertain.
- We perturb sea ice albedo in a coupled model (see Scinocca et al. 2002, Deser et al. 2014)
  - Easily reproduced, energetically self-consistent, robustly sampled.
  - Interested in adjustment to equilibrium and robustness of transient response.

Simulation Design

- NCAR CCSM4, 1°
  (U of Toronto SciNet).
- Multicentury control.
- Adjust `r_snw,r_ice,r_pnd`
  to reduce sea ice albedo.
- Perturbation runs:
  - 1 x 800 y
  - 2 x 350 y
  - 5 x 50 y
- “Equilibrated” phase:
  Years 400-800
- “Transient” phase:
  Years 1-50

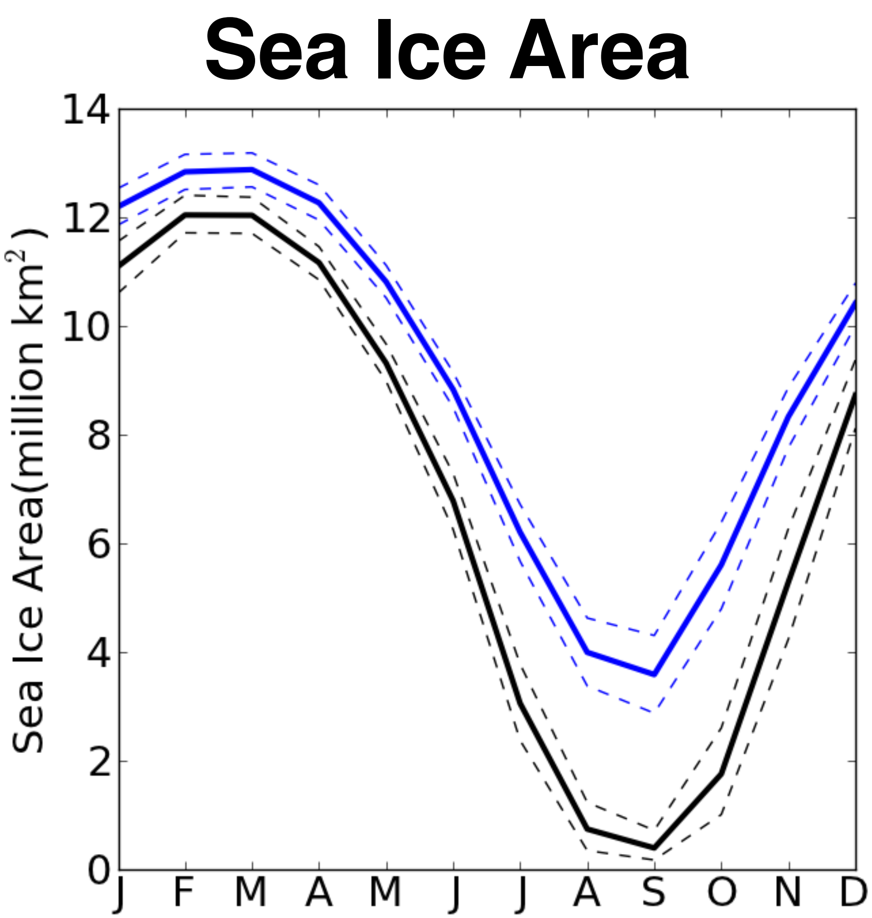


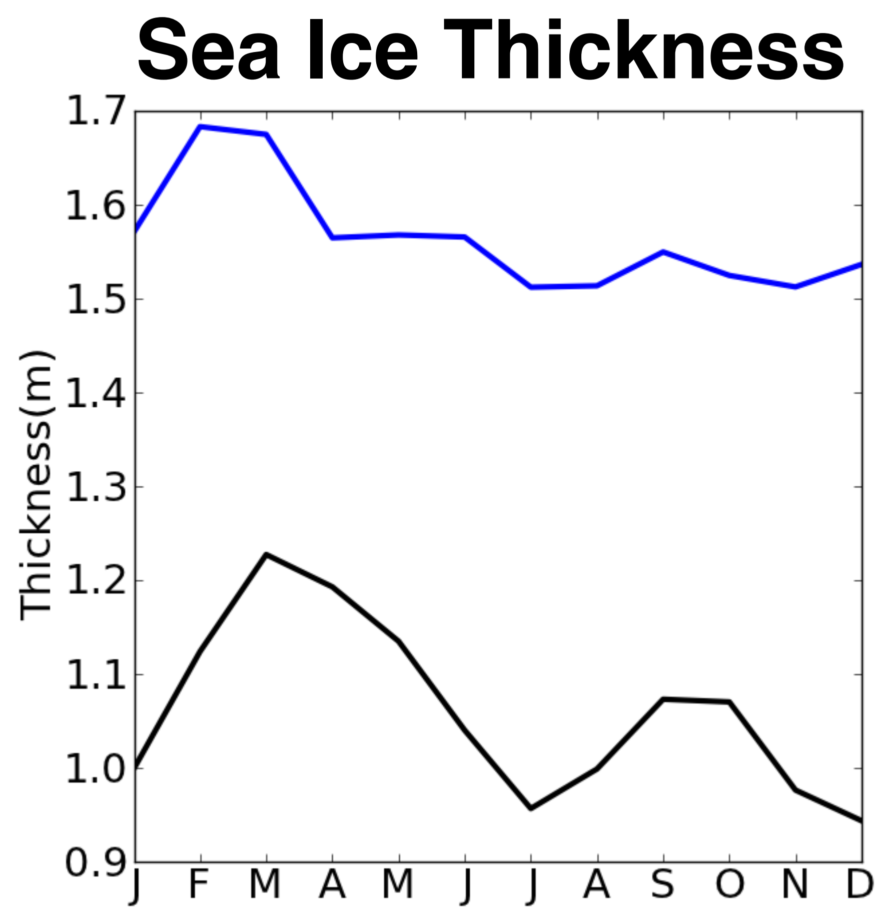
Wintertime Warming



- Global warming response associated with imposed sea ice loss (Deser et al. 2014).

Control and Equilibrium States



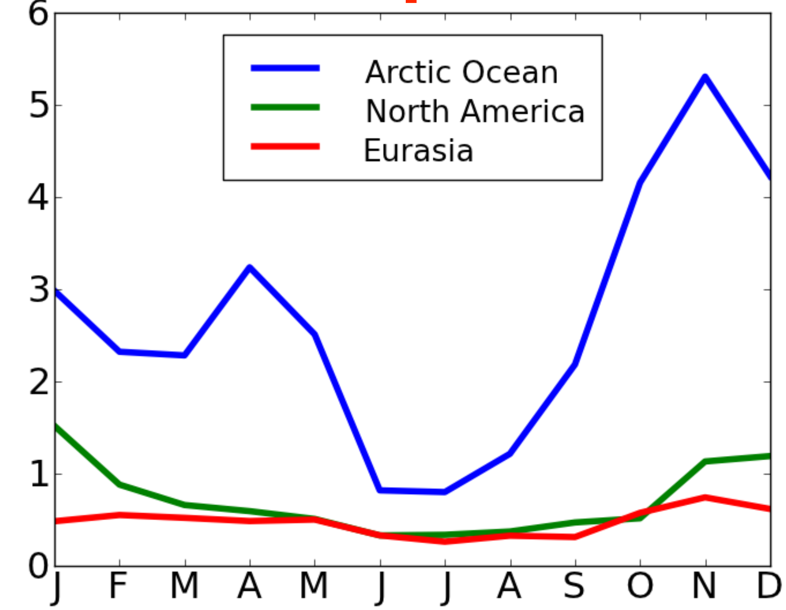


- Sea ice area loss is focussed in summer, as expected.
- Considerable reduction in average thickness and volume (not shown) all year.

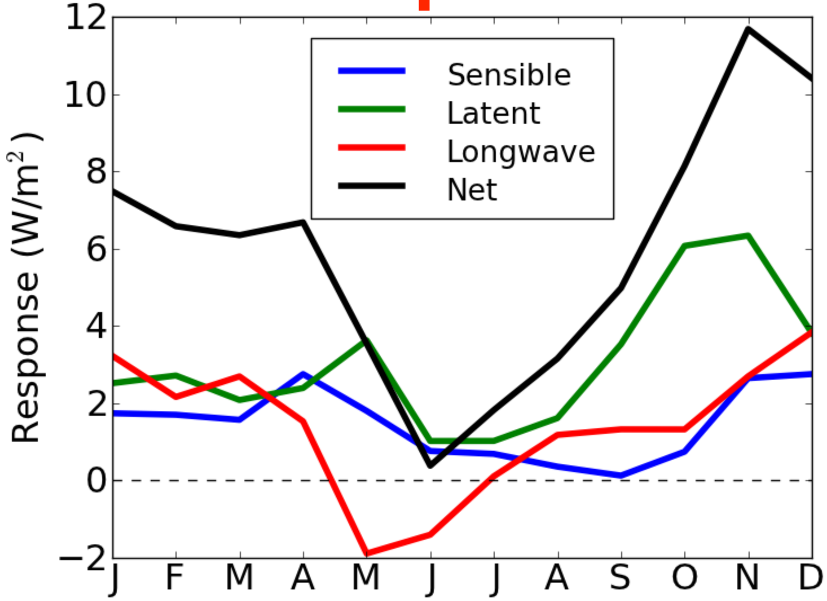
Surface Energy Budget

- Turbulent and longwave fall/winter fluxes increase into atmosphere.
- Similar to but larger response than prescribed sea ice experiments.
- Energy budget response coherent with Arctic Ocean region surface temperature response.
- Continental temperatures reflect Arctic and global warming.

T Response

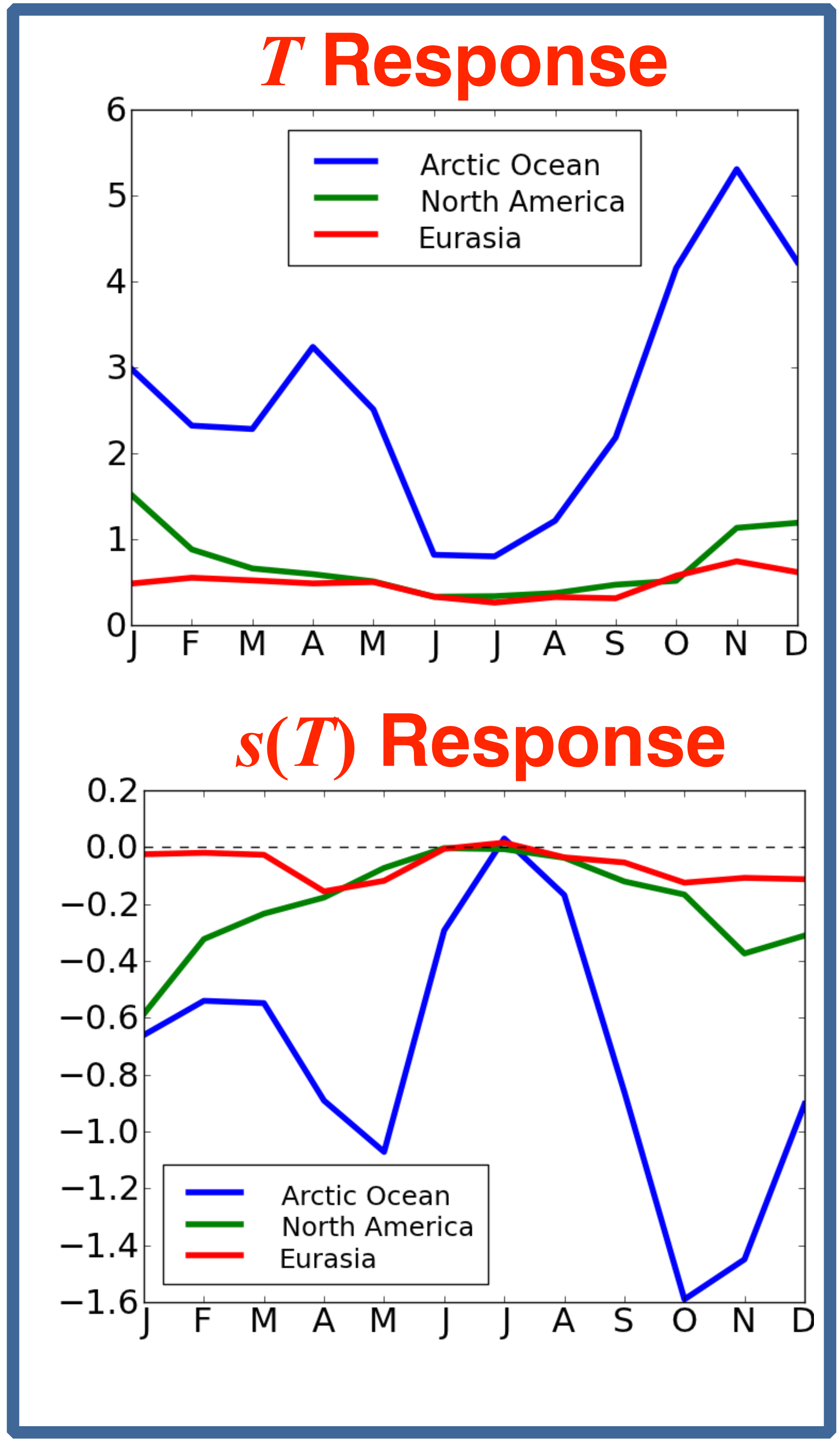


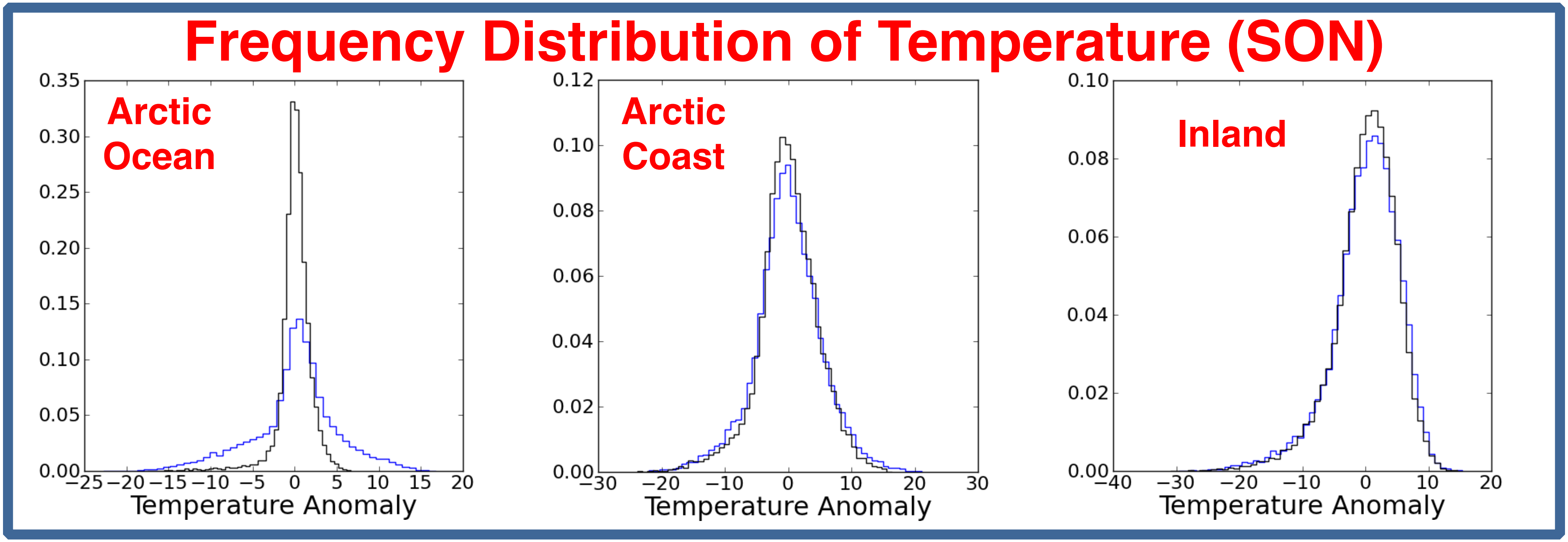
Energy Budget Response



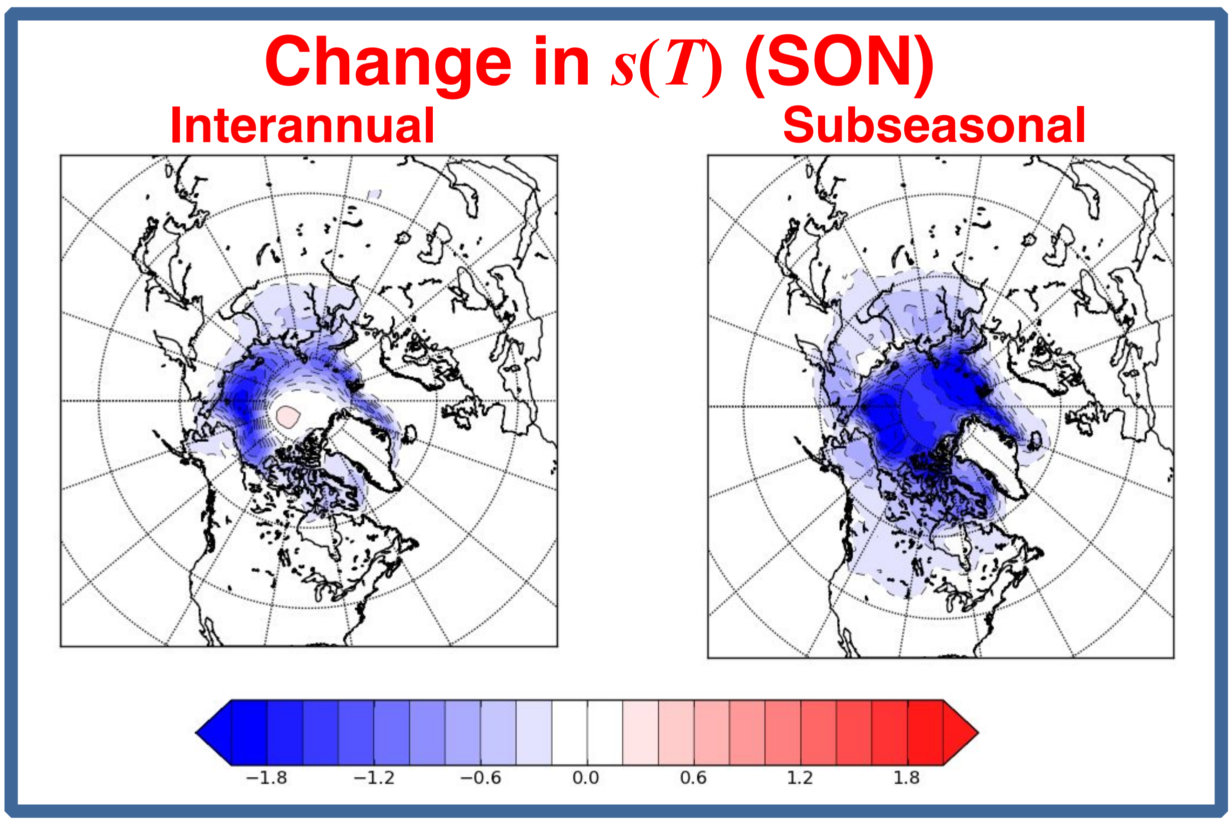
Reduced Temperature Variability

- Striking reduction in variability in surface temperature (s(T), RMS of daily T anomalies) over Arctic Ocean and to a lesser extent continents.
- Strongest loss of variance in seasons of strongest warming.
- Reflects transition to maritime climate, stronger coupling to ocean, even in spring.

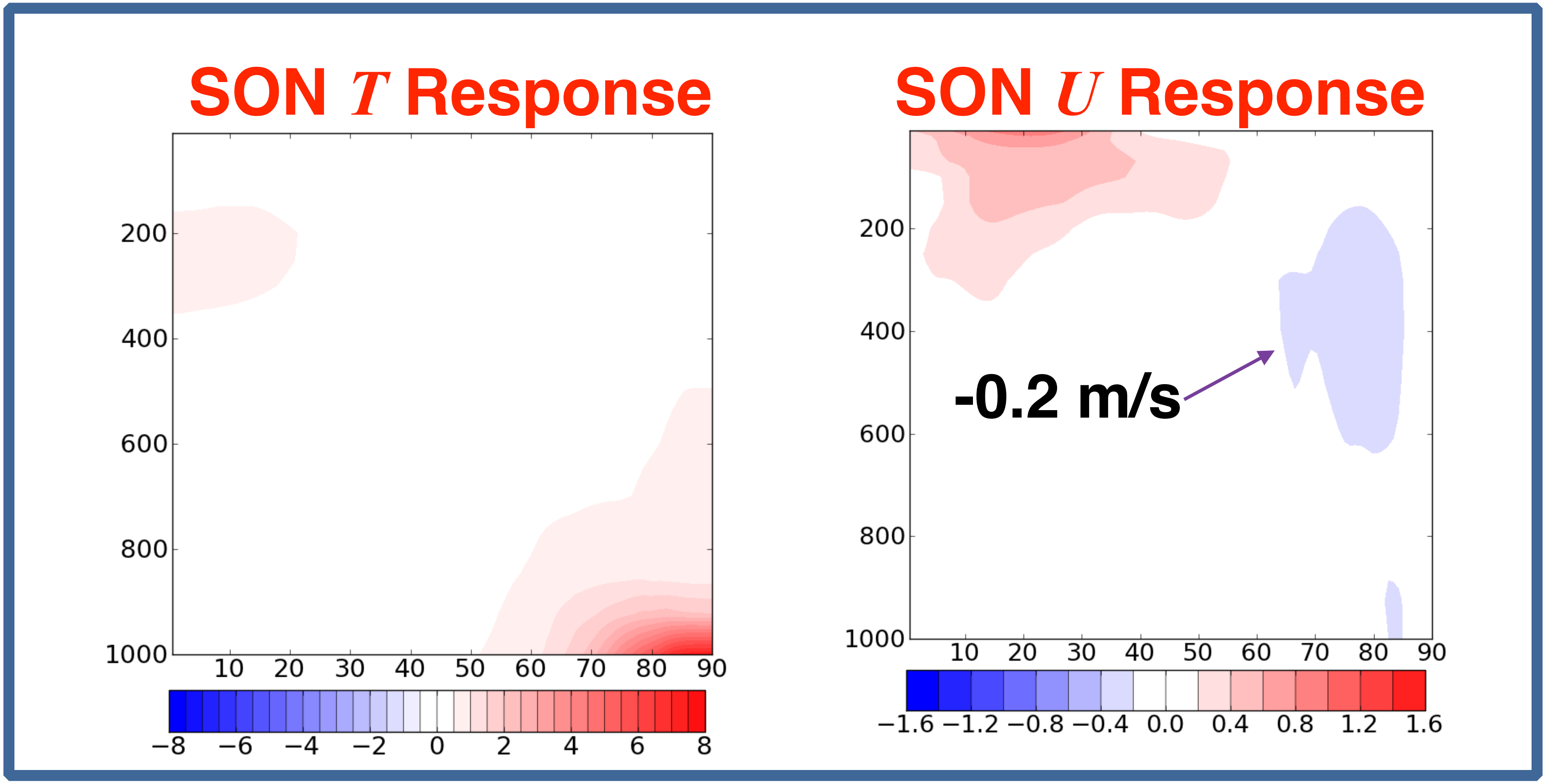




Reduced variability on sub-seasonal and interannual timescales.



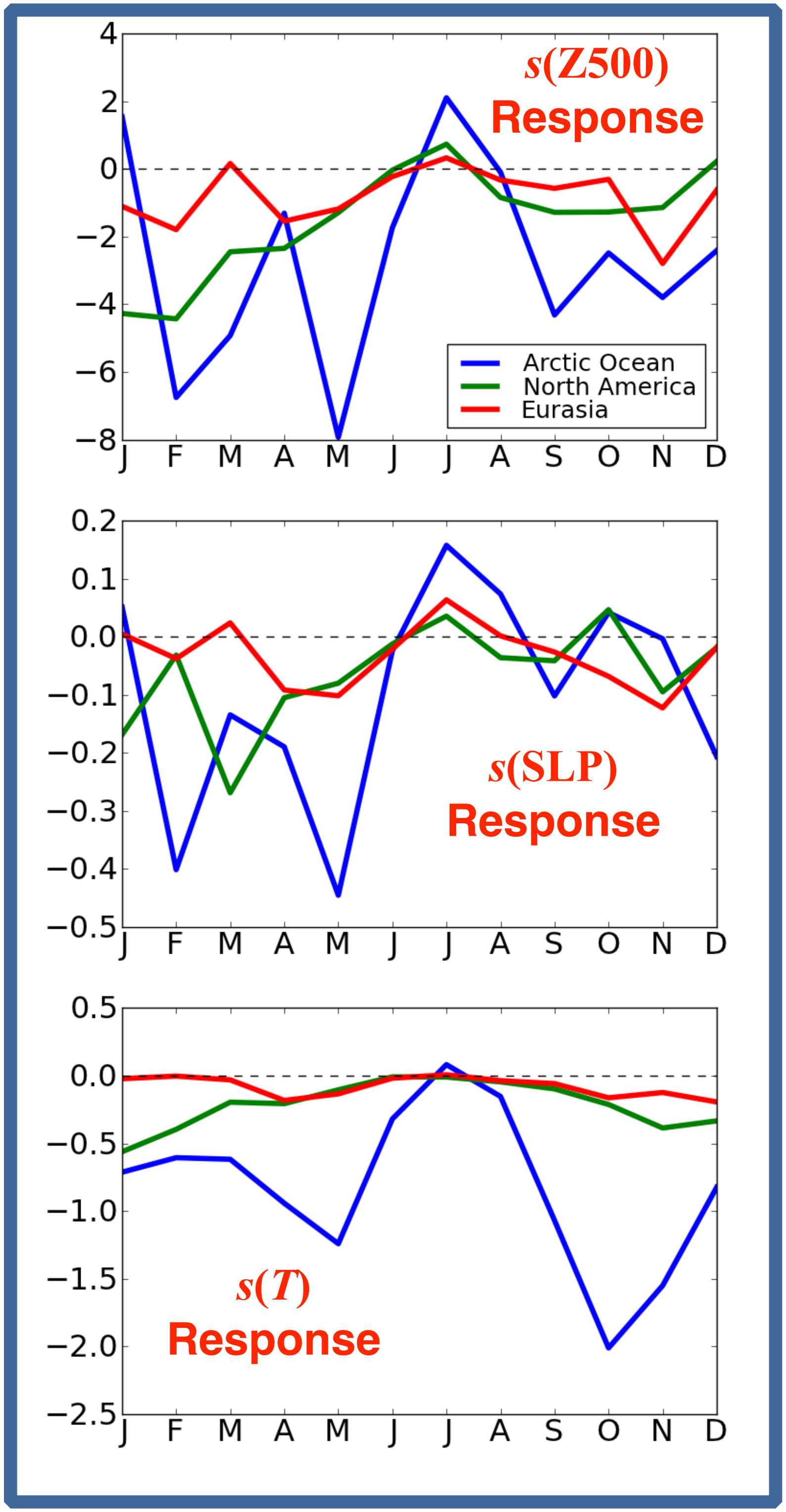
A Weak Circulation Response



- Warming confined to Arctic lower troposphere.
- Polar winds slightly weakened.
- Tropical response influenced by global warming.
- No polar stratospheric response once sufficient averaging is done.

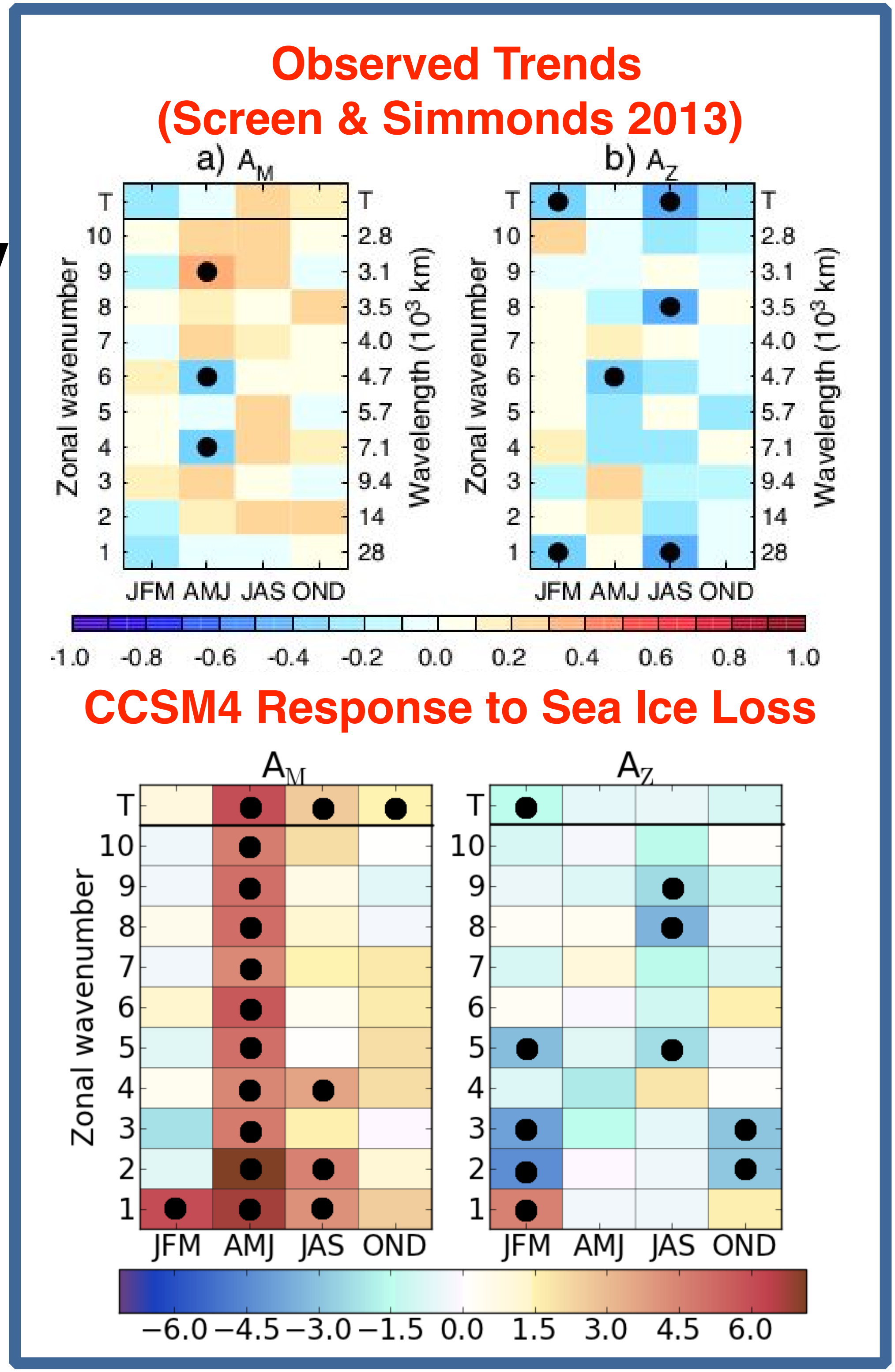
Mixed Response in Atmospheric Variability

- Reduced surface temperature variability accompanied by mixed response in SLP variability
- These both contribute to changes in mid tropospheric variability.
- Variability over continents is reduced.
- Maps (not shown) show a highly structured pattern of change.

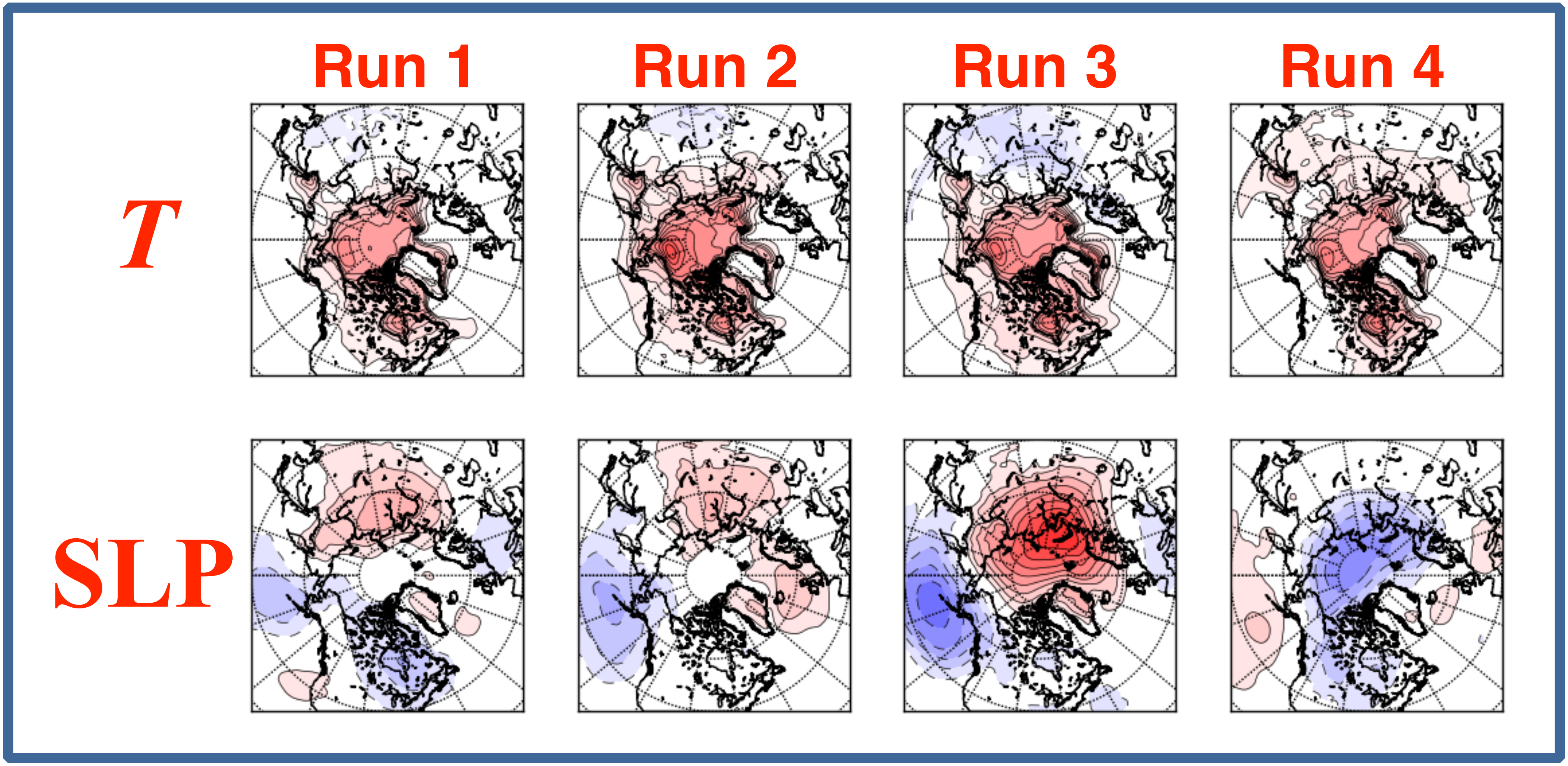


Mixed Response in Atmospheric Variability

- Meridional meander amplitude A_M (Francis & Vavrus 2012, Screen & Simmonds 2013) increases.
  - Reflects polar amplification of global warming?
- Eddy amplitude(Fourier amplitude) A_Z generally decreases. Partially agrees with observed trends.
- But wintertime Wave-1 A_M and A_Z both increase.



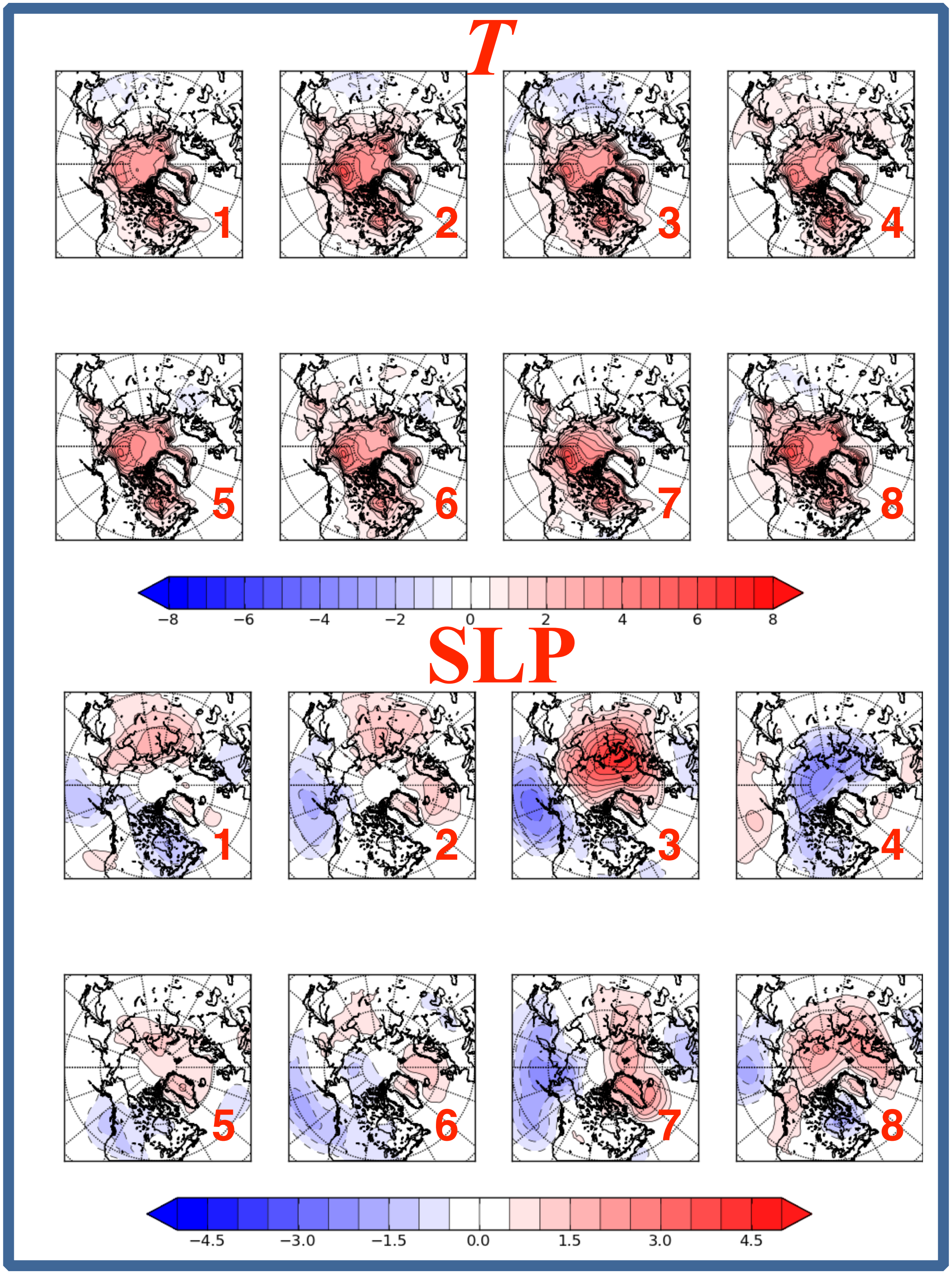
Variability of Transient Response (Years 1-50)



Run #4 shows Warm Arctic & Warm Siberia (no coastal high)!

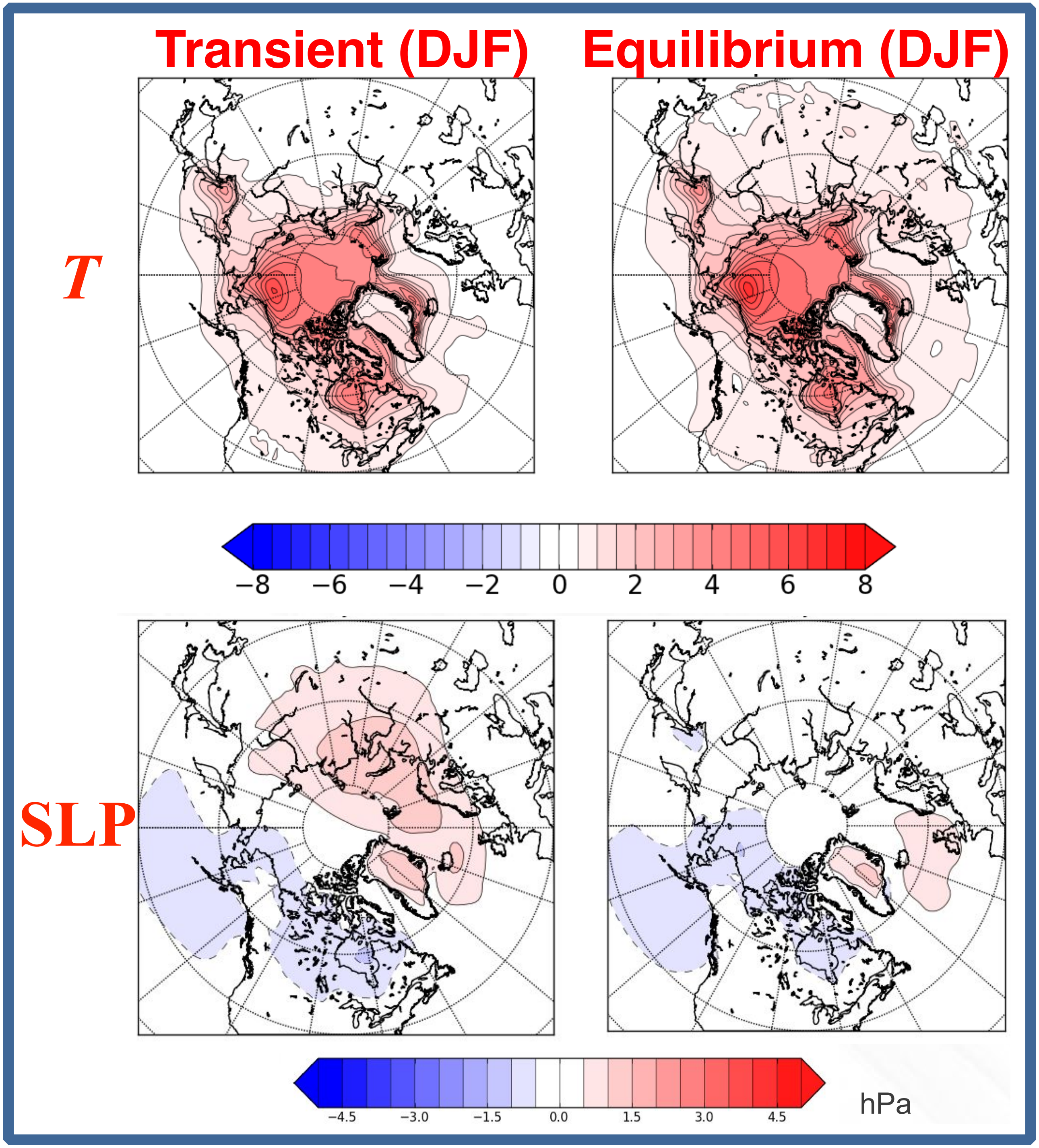
Variability of Transient Response

- WACS Pattern Response not consistent
- Aleutian low/Eurasian coastal high SLP is fairly robust.
- In runs with a high Eurasian SLP response, often obtain Siberian cooling. But this is not guaranteed.



Adjustment to Equilibrium

- Coastal high is a feature of transient adjustment, but WACS pattern in transient response is subtle.



Conclusion

- Motivated by contradictory results of recent studies, we analyzed the response to idealized sea ice loss in a relatively simple coupled model framework.

    - Tropospherically trapped Arctic response with weak global warming (Deser et al. 2014).

    - Very weak circulation response.

    - Mixed changes in variability: suppressed surface temperature variability and wave amplitudes except planetary Wave 1, increased meandering consistent with Arctic Amplification.

    - Highly variable multidecadal adjustment.

- Would idealized perturbations in coupled models be worth investigating more broadly?