Seasonal to Multi-decadal Predictability of Polar Climate

A pan-WCRP workshop initiated by SPARC and CliC

Bergen, Norway, 25-29 October 2010

Introduction to Workshop

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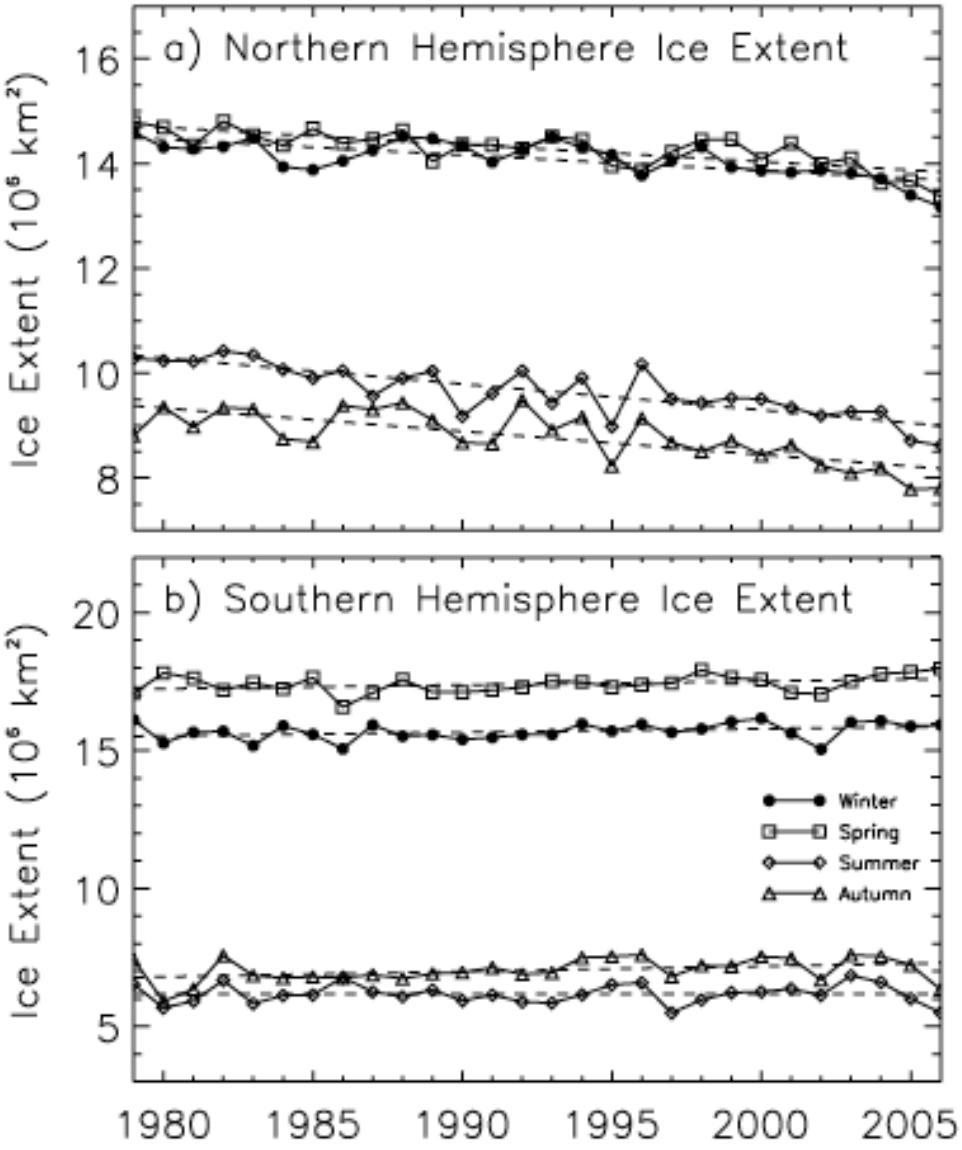
What is happening with the poles?

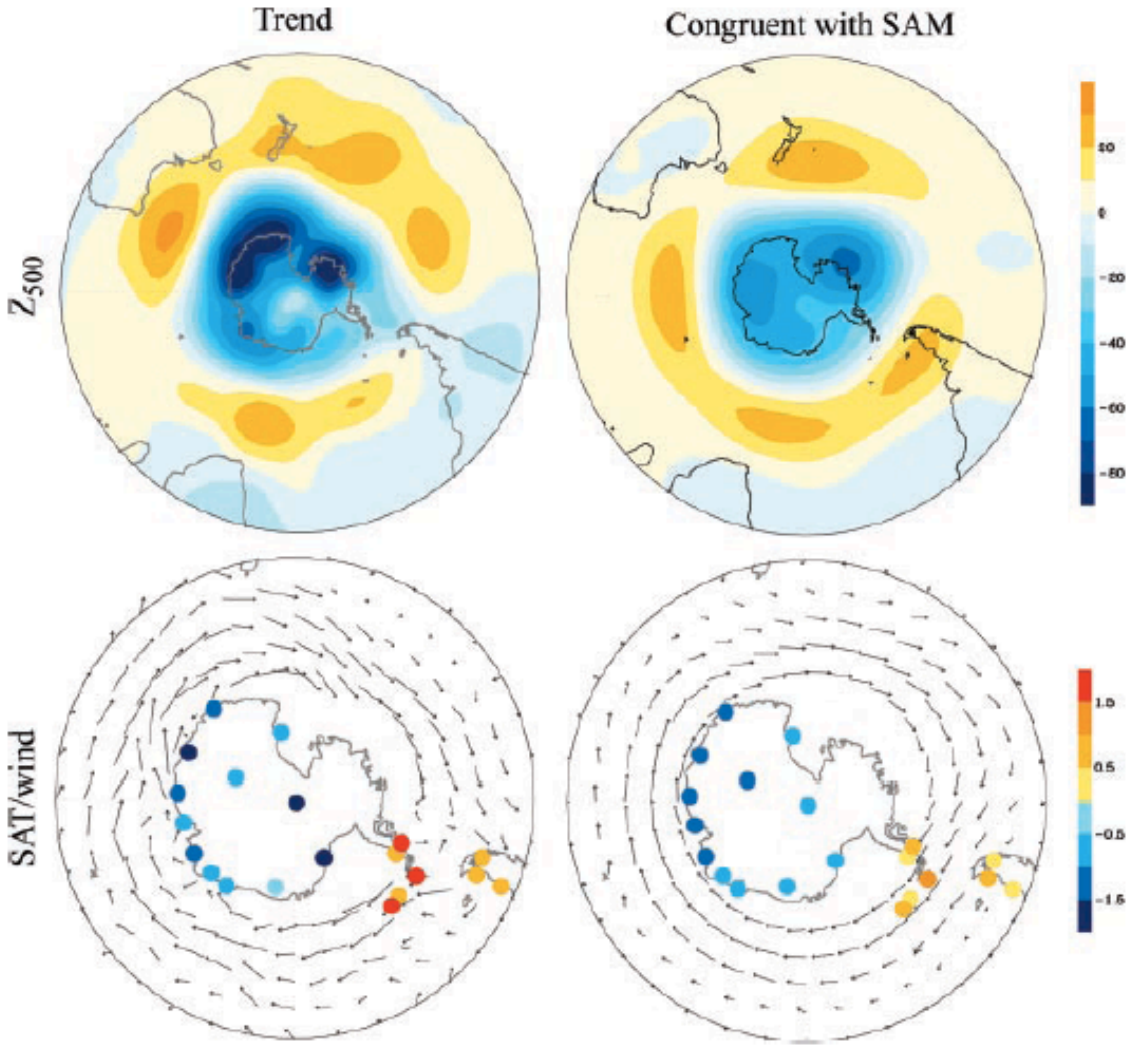


- While Arctic sea-ice extent has been declining over the last few decades, Antarctic sea-ice extent has been increasing

Analysis based on AMSR-E, SSM/I and SMMR data

Comiso & Nishio (2008 JGR)

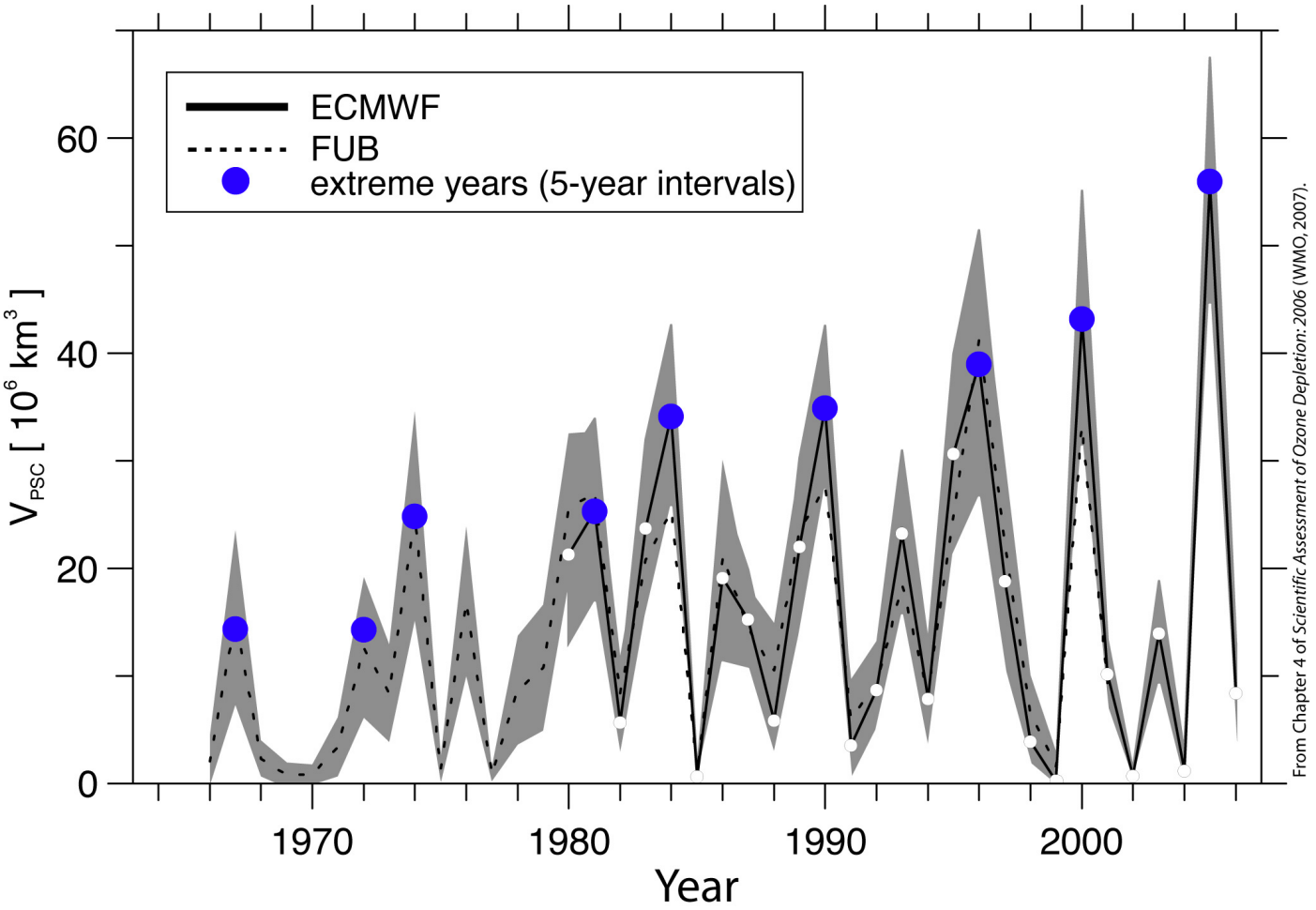
- And while the Arctic troposphere has been warming, the Antarctic has been cooling over the last few decades
  - Has been attributed to the ozone hole



December-May trends over 1979-2000 (top) and 1969-2000 (bottom)

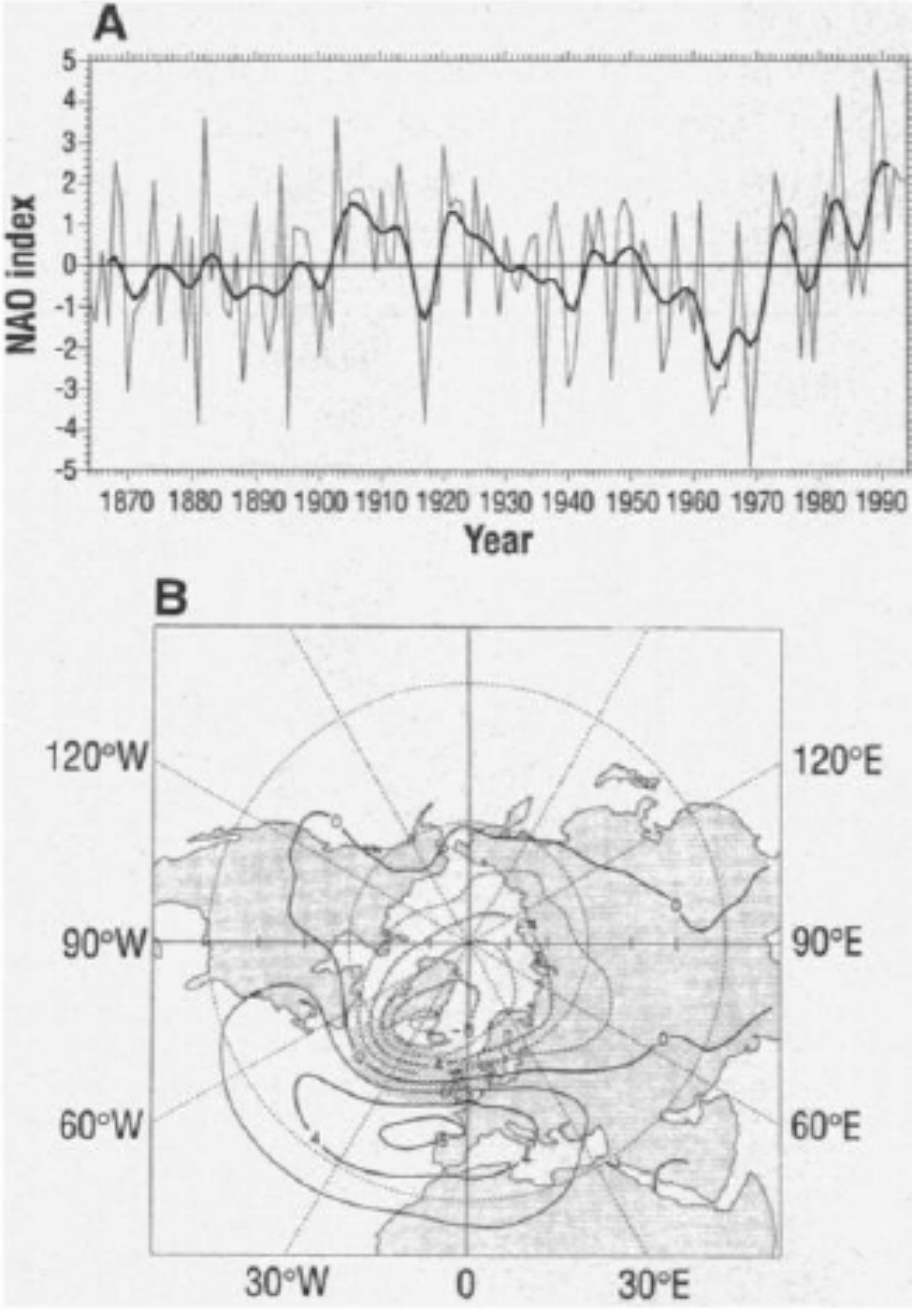
Thompson & Solomon (2002 Science)

- Yet in the Arctic *stratosphere*, the coldest winters seem to be getting colder
  - Suggestion has been this is due to climate change, but such a strong trend cannot be radiative



V_{psc} is a measure of the spatial extent of low temperatures in the lower stratosphere

WMO (2007), updated from Rex et al. (2004 GRL)

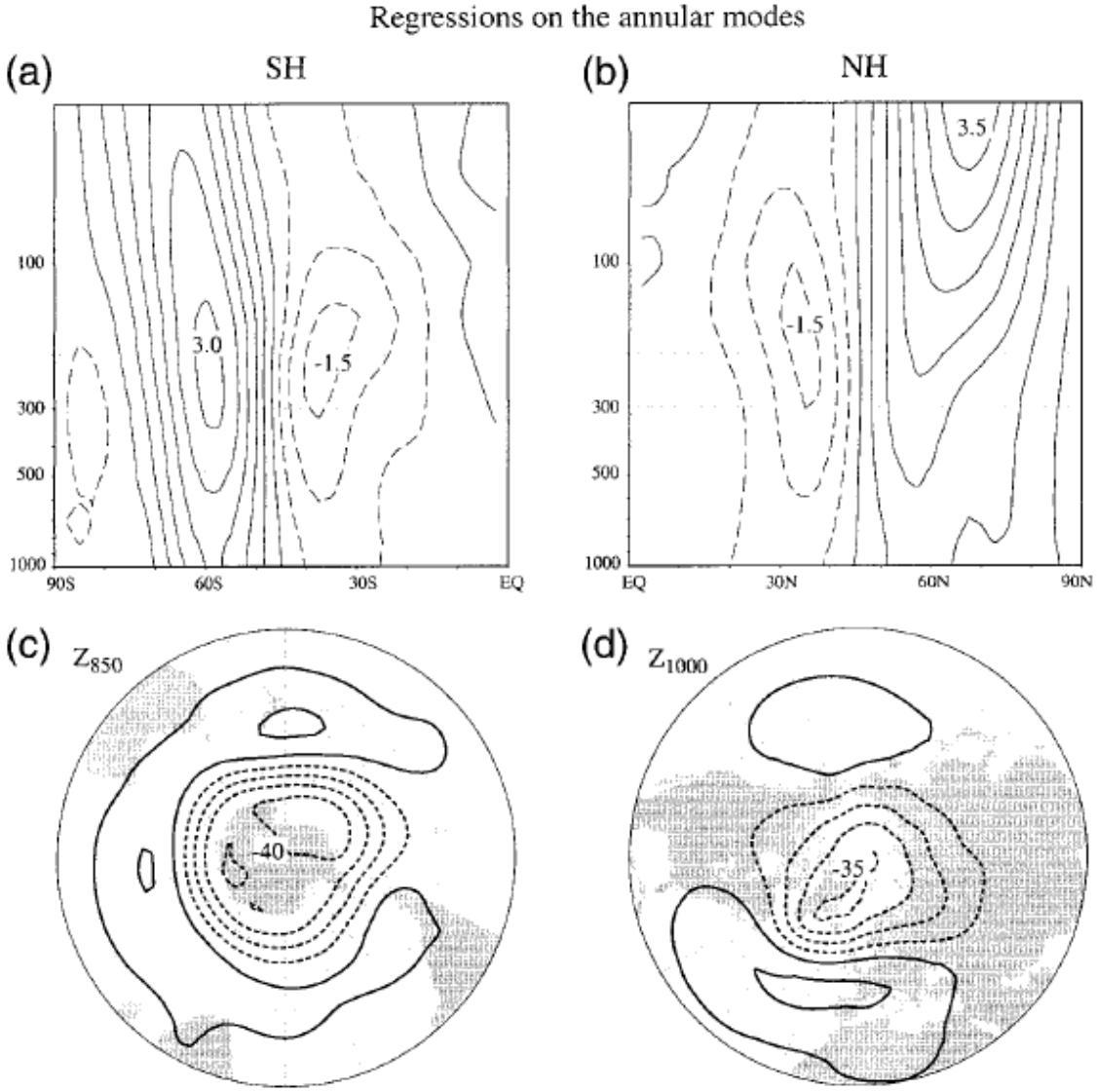


- Polar variability on both year-to-year and decadal timescales is manifested in large-scale modes, or spatial patterns
- However they are not well understood in terms of physical mechanisms, nor do they have well-defined timescales

Here the North Atlantic Oscillation (NAO), shown as SLP (bottom)

Hurrell (1995 Science)

- These polar modes of variability occur in both hemispheres, and are connected to the stratosphere

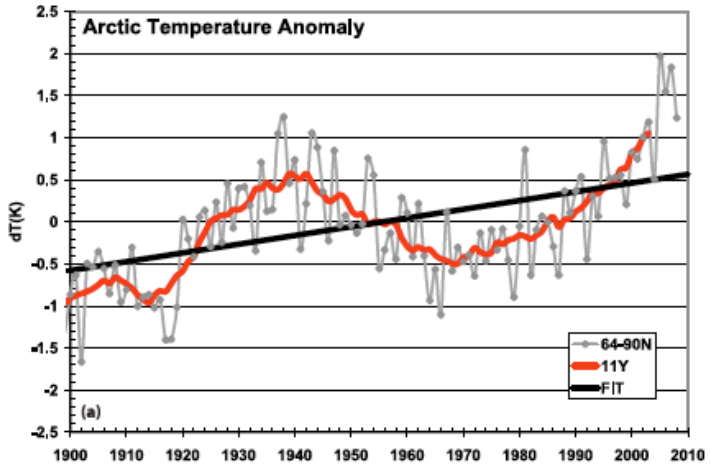


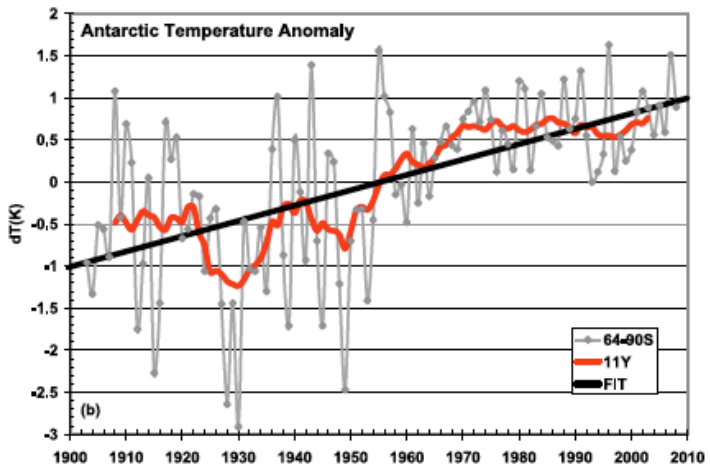
Southern and Northern Hemisphere "annular modes" (SAM and NAM), based on hemispheric EOFs

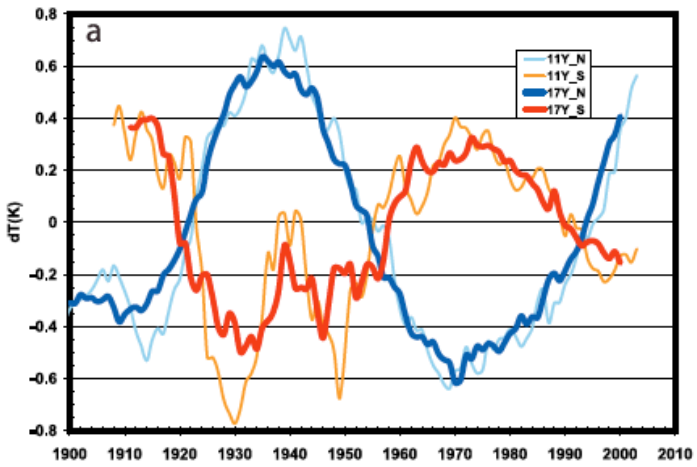
Thompson & Wallace (2000 J Clim)

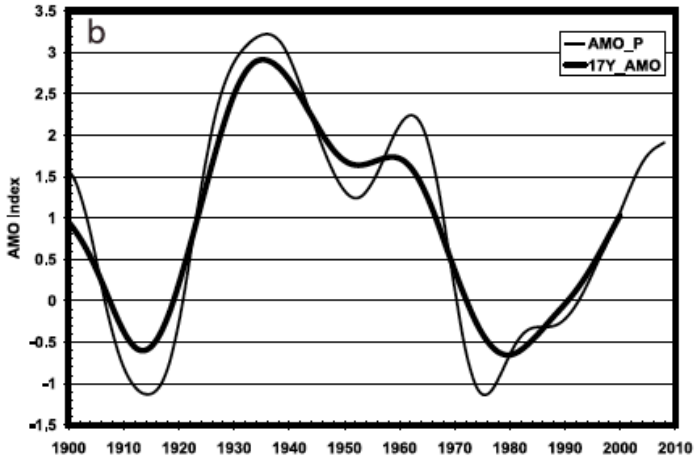
- A recent study (Chylek et al. 2010 GRL) notes the “see-saw” nature of Arctic and Antarctic variability over the last century, and its coherence with the AMO index
  - Points to internal dynamical variability; Atlantic MOC?

Surface temperature from GISS









- So we see a lot of decadal timescale trends in polar regions, with apparently high signal to noise (i.e. lots of low-frequency power)

- What is the origin of these trends? If due to natural variability, are they predictable, or at least explainable?

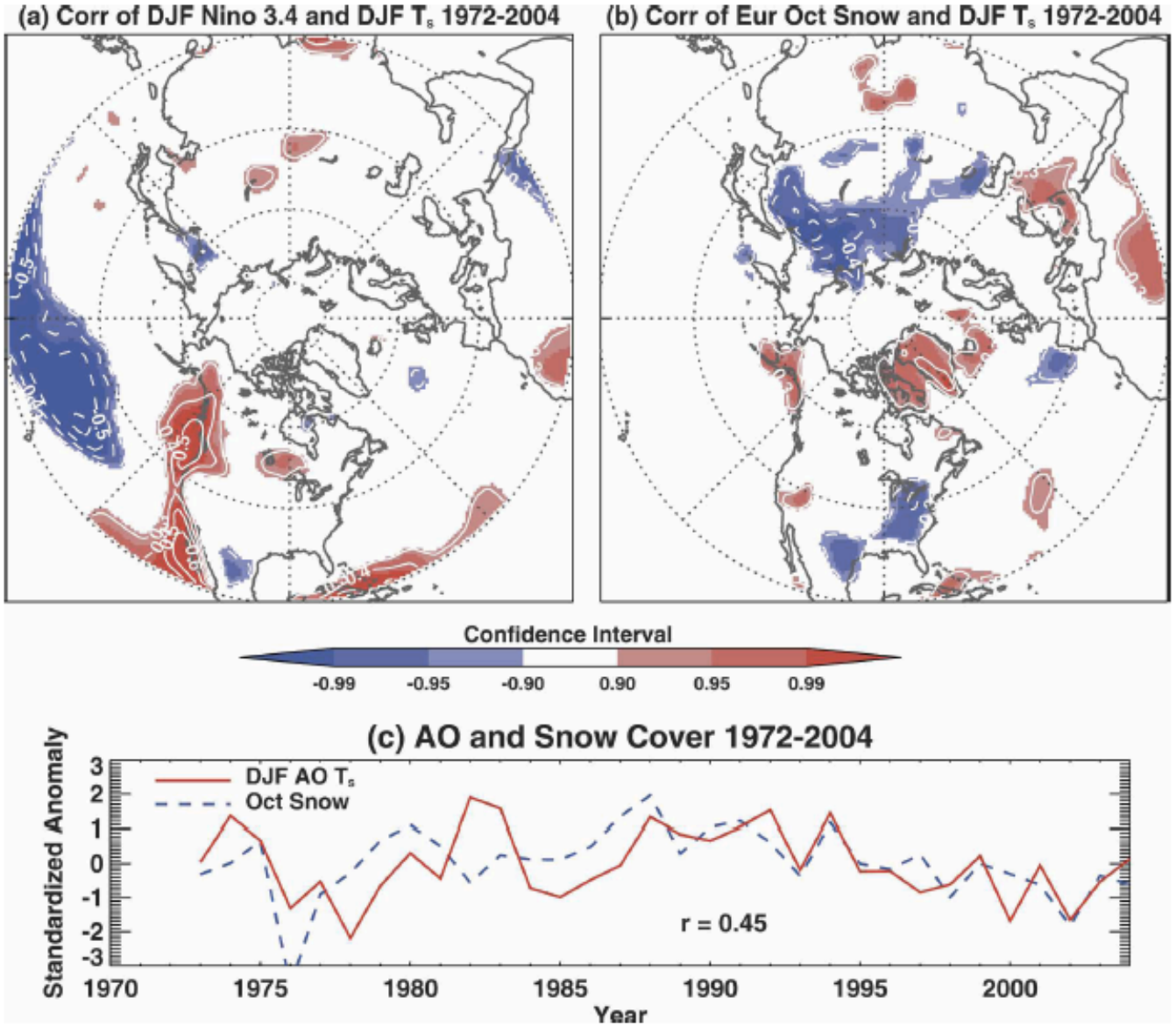
- Decadal prediction is a rapidly emerging area of climate research (Meehl et al. 2010 BAMS)
  - Seen as the natural extension of seasonal prediction
  - Would have obvious benefits for climate services
  - Also important for understanding the observed record
  - But it's not yet clear how feasible it is…

WCRP Position Paper on Seasonal Prediction
(2008, based on 2007 Barcelona Workshop)

- Enormous progress was achieved in seasonal prediction between the early 1980s and the late 1990s
  - Was mainly based on tropical ocean (i.e. ENSO)
  - Skill is mainly limited to lower latitudes
  - Since then, a plateau seems to have been reached
- There is untapped potential for seasonal predictability in the following components of the climate system:
  - Sea ice
  - Land surface, including snow
  - Stratosphere

All three — especially the 1st and 3rd — involve polar regions

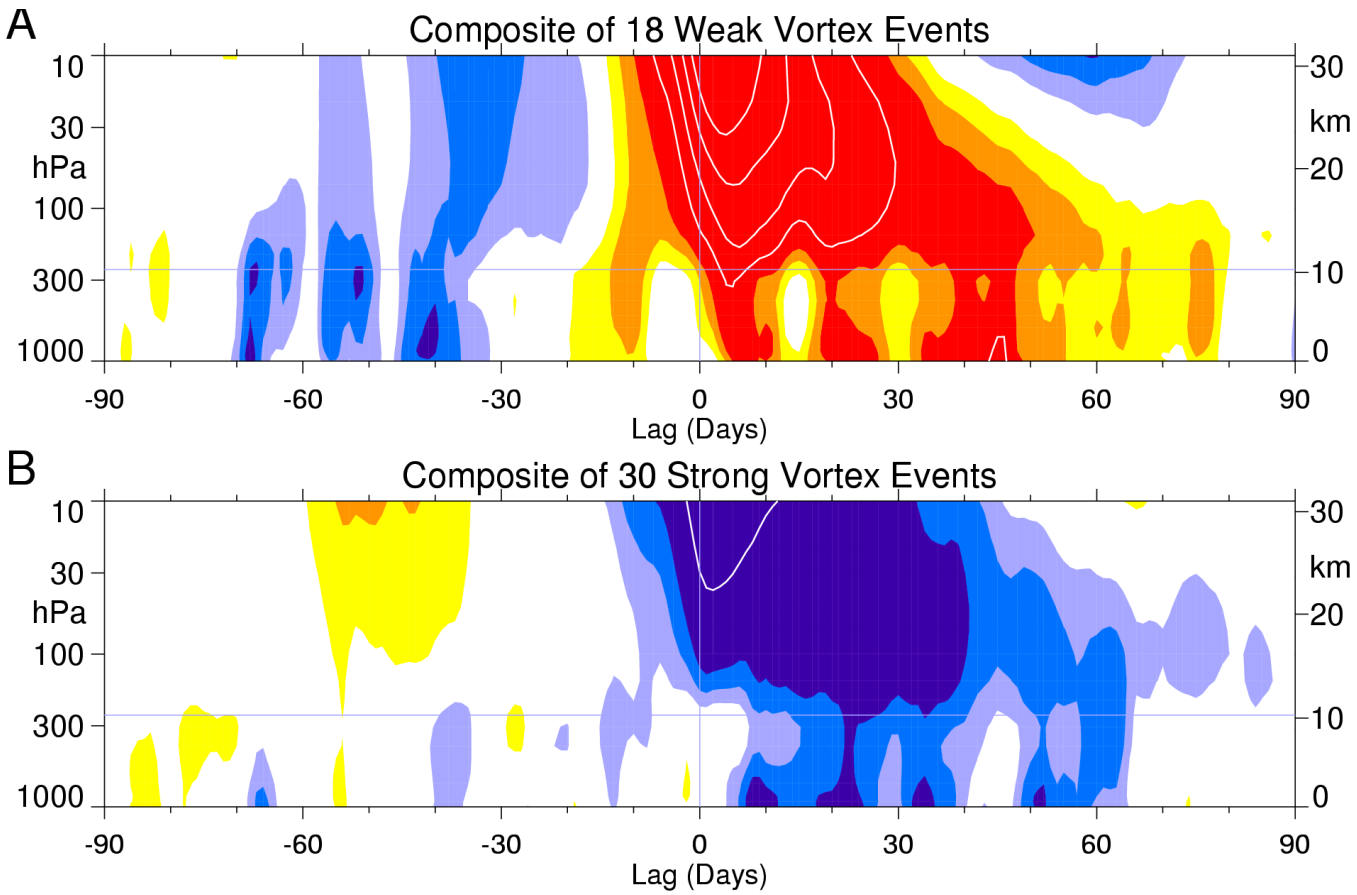
- Arctic wintertime surface temperature is far more affected by fall Eurasian snow cover than by ENSO



October Eurasian snow cover is a good predictor of the wintertime NAM/AO

Cohen & Fletcher (2007 J Clim)

- Circulation anomalies in the wintertime stratospheric polar vortex have timescales of a month or more
- They appear to influence surface weather on several-month timescales

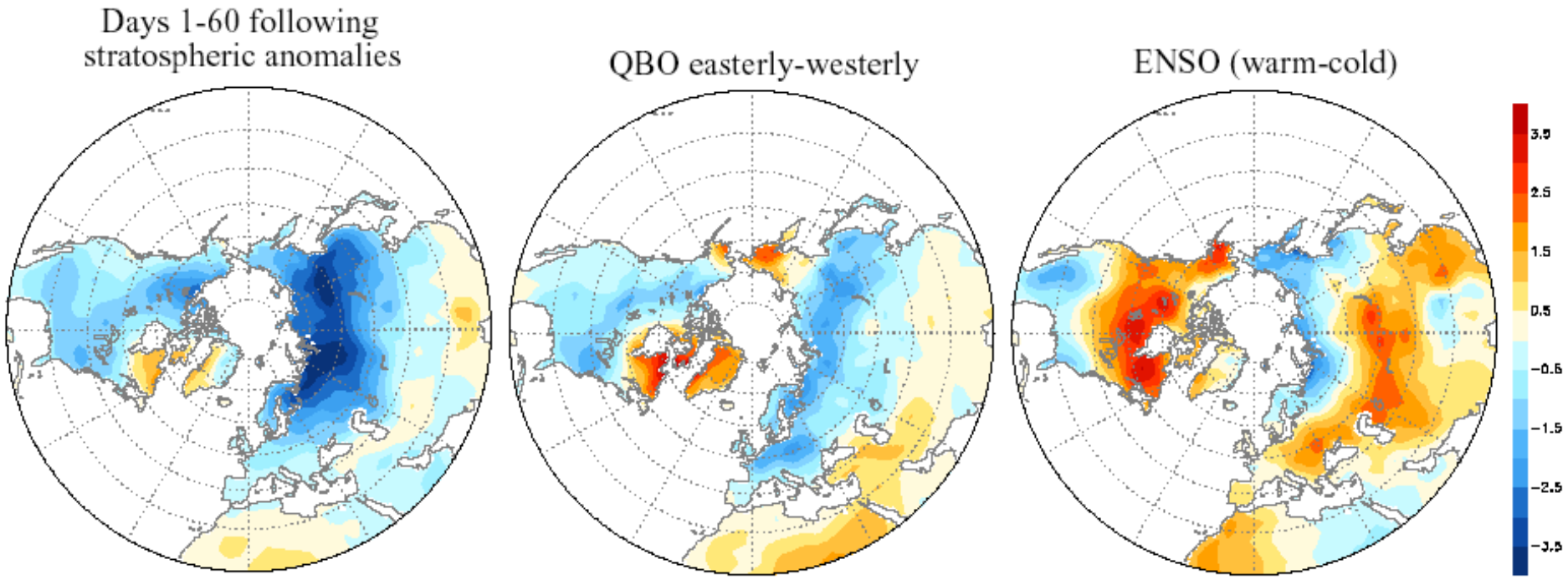


Composites of NAM indices

Baldwin & Dunkerton (2001 Science)

- At middle to high latitudes, effects of stratospheric circulation anomalies are comparable to those of ENSO
- Much of the stratospheric NAM variability appears to be attributable to the Quasi-Biennial Oscillation (QBO)
  - Holton-Tan effect; see also Boer & Hamilton (2008 CD)

Wintertime SAT differences (in K) between circulation regimes



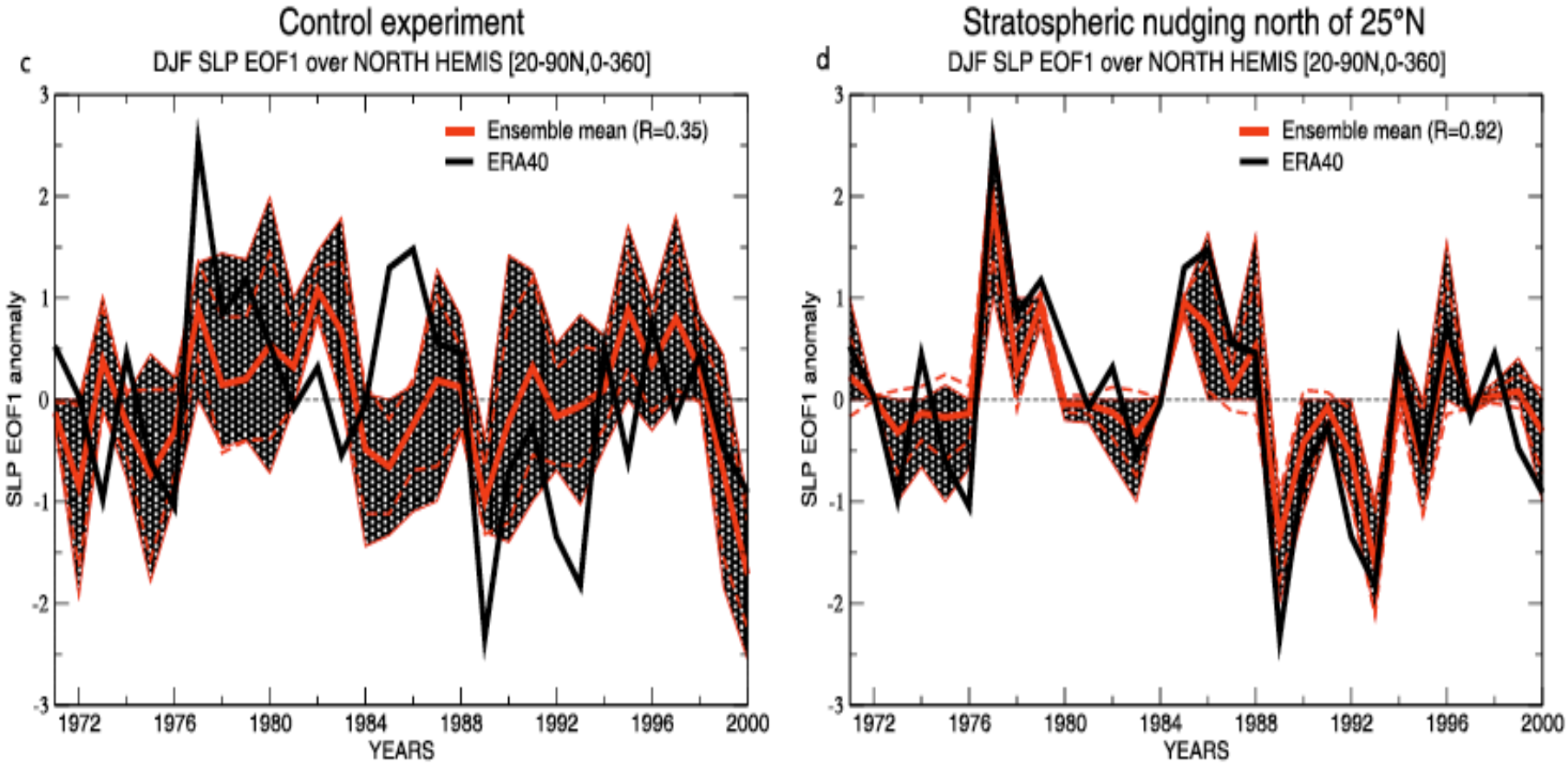
Thompson, Baldwin & Wallace (2002 J. Clim.)

US NRC Assessment of Intraseasonal to Interannual Climate Predictability and Prediction (2010)

- Sources of predictability lie in:
  - Inertia or memory
  - Modes of variability or physical feedbacks
  - External forcings (including anthropogenic)
- Research is needed on the following sources of predictability:
  - MJO
  - Stratosphere-troposphere coupling
  - Extratropical ocean-atmosphere coupling
  - Land-atmosphere coupling
  - Nonstationarity
  - Atmospheric composition, including aerosols

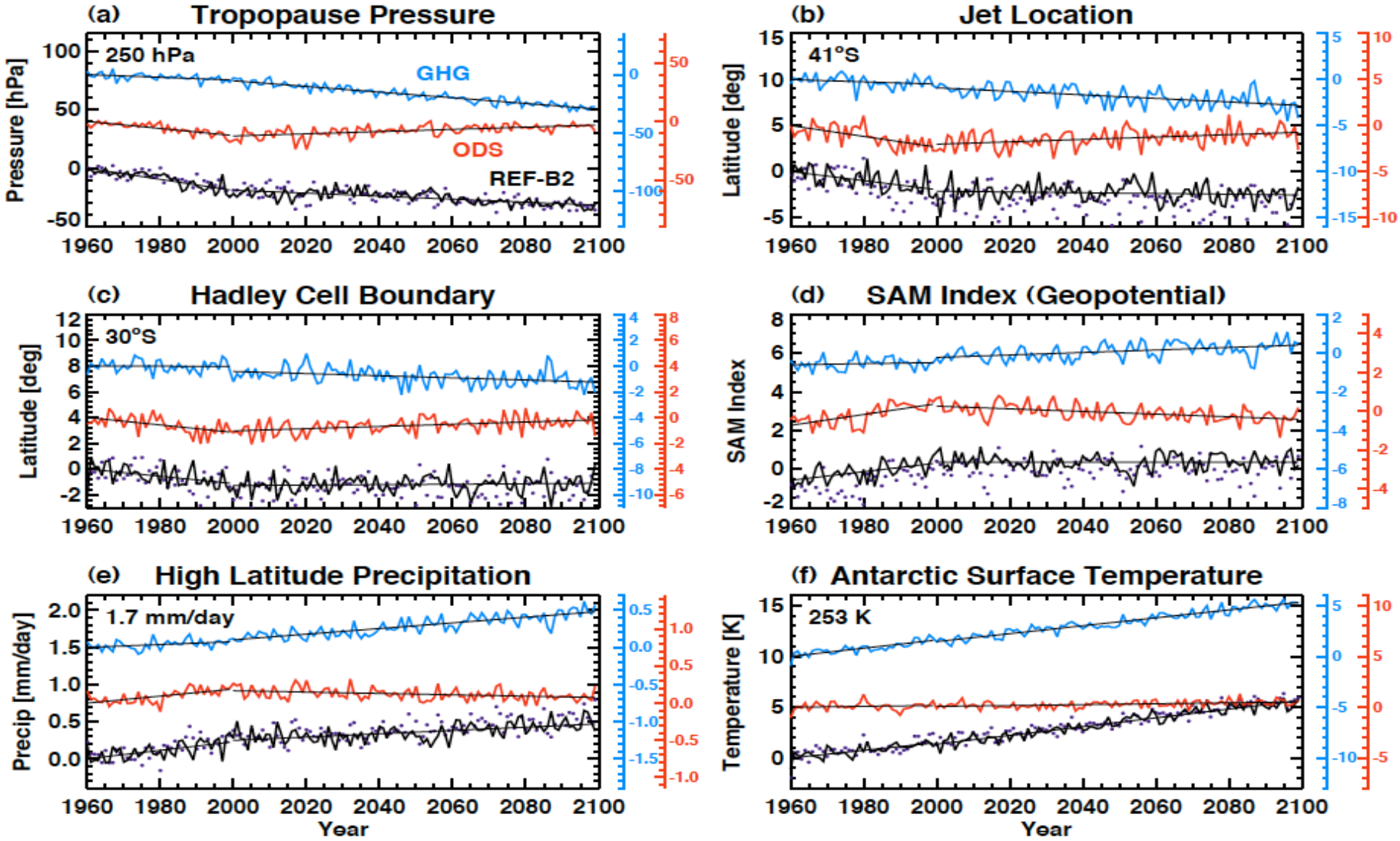
Once again, polar regions are seen to play a prominent role

- In the Météo-France model, interannual variability of the wintertime surface NAM is not related to SSTs, but well reproduces observations when the extratropical stratosphere is nudged to reanalyses



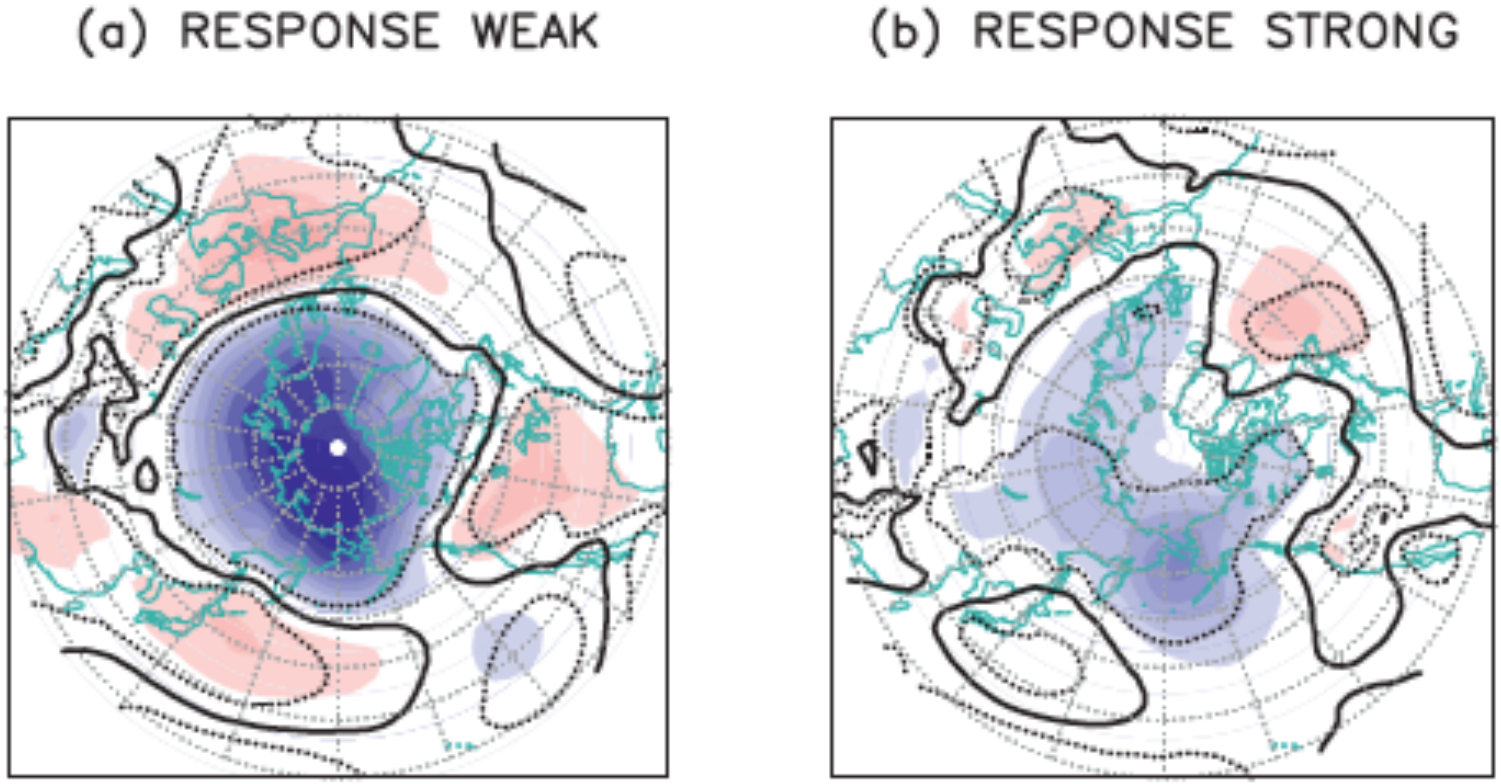
Douville (2009 GRL)

- In the Antarctic, ozone recovery is expected to have a big impact on high-latitude tropospheric climate trends



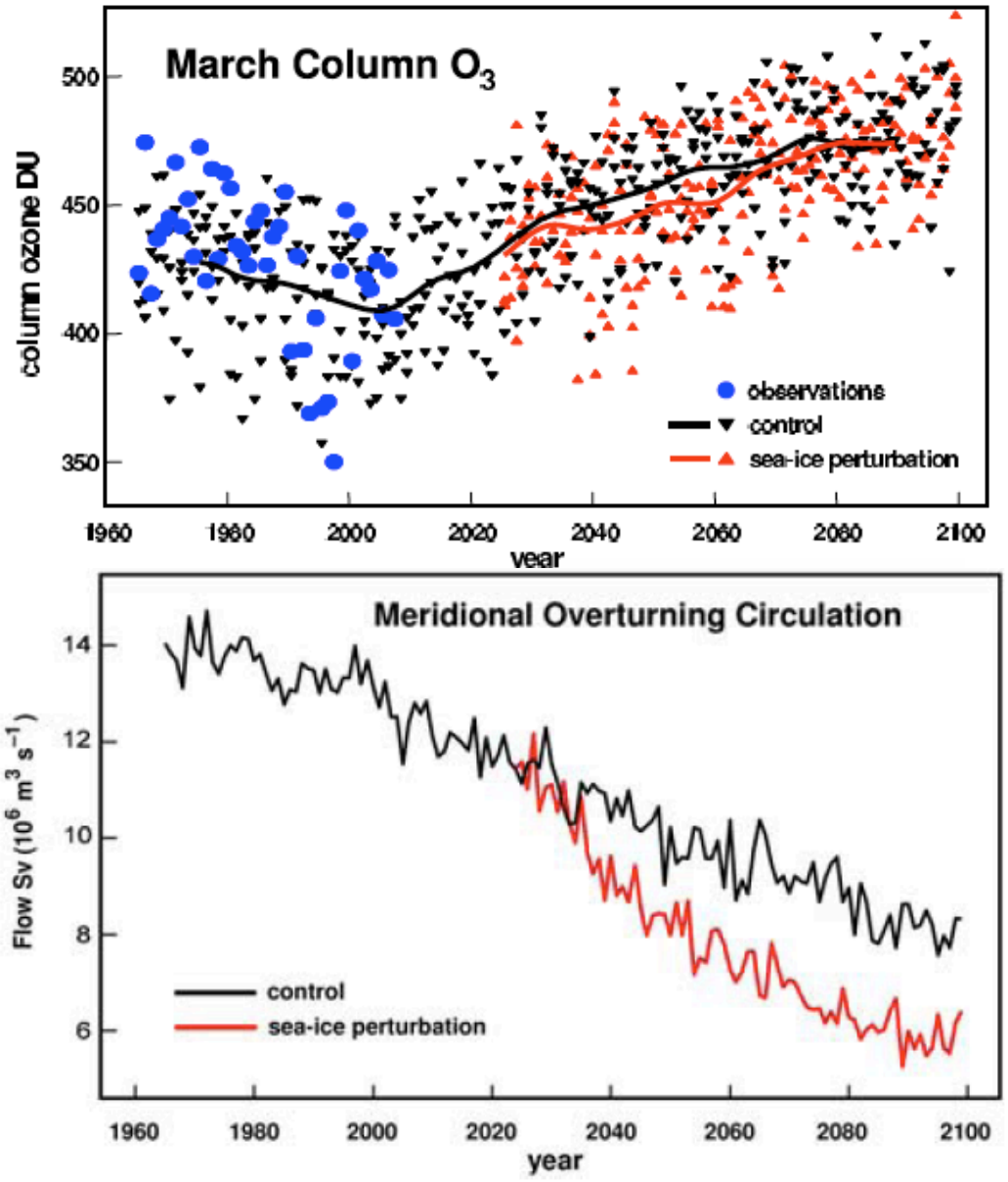
CMAM results from McLandress et al. (J Clim, under revision)

- In the Arctic, the predicted wintertime surface response (here MSLP) to doubled CO_2 depends sensitively on the settings of the orographic gravity-wave drag scheme
  - Mechanism is effect on stratospheric planetary-wave drag via effect of OGWD on climatological zonal flow



CMAM results from Sigmond & Scinocca (2010 J Clim)

- There also appears to be the potential for severe Arctic summertime sea-ice loss to affect NH springtime ozone



  - Mechanism is dynamical: reduced forcing of planetary waves into the stratosphere means less polar ozone
  - May be mediated by response of Atlantic MOC

CMAM results from Scinocca et al. (2009 GRL)

Is polar variability predictable?

- Polar variability manifests itself in large-scale “modes”, with substantial power at the decadal timescale, but whose physical nature and causality are not clear
  - Response to GHG forcing also tends to project strongly onto these modes of variability
- The stratosphere, sea-ice, land surface and ocean all represent boundary conditions for the troposphere with longer timescales (and inherent stability?), hence some memory
  - Stratosphere-troposphere coupling occurs most strongly in polar regions
- The stratosphere also represents an additional source of external forcing (solar variability, volcanic eruptions, ozone depletion, perhaps geoengineering)

- Before we even contemplate prediction, we need to better understand the physical basis for predictability in polar regions
  - Needed for designing the prediction systems (observations, assimilation systems, models)
- Key to this is understanding:
  - Sources of predictability within the different climate system components
  - The physical couplings between those components, manifested in the modes of variability
- Since the same modes of variability arise from intraseasonal to multi-decadal timescales, it makes sense to study them in an integrated way
  - Also, seasonal memory affects the seasonality of decadal variability

This workshop

- Focus on physical mechanisms for predictability in polar regions (not on their impacts; that's another story)
  - Drawing from observations, models, and theory
  - Taking a global and bi-polar perspective
  - Emphasizing couplings between system components
- The first four days are divided into thematic sessions, led by convenors
  - *The discussion periods are very important!*
  - If you wish to show a slide or two during the discussions, talk to a convenor
  - Stock-taking discussions will feed into Friday's program (so we need to be thinking ahead)

- The final day consists of
  - A synthesis based on rapporteur reports
  - A “road map” discussion on what is needed scientifically (endorsed by all of us here)
    - Needs to be focused (i.e. prioritized), identifying gaps and *bite-sized deliverables*
  - A discussion of programmatic next steps
- The goal of the workshop is to stimulate inter-disciplinary interactions, and identify a small number of top priorities which would rally the community behind them and attract support from the funding agencies
  - *Think outside your usual box!*
- Outcomes will include a SPARC Newsletter article, a review article, and a WCRP position paper/white paper

Organizing Committee

- Ted Shepherd (U. Toronto, Chair)
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- Cecilia Bitz (U. Washington)
- Thierry Fichefet/Hugues Goosse (Catholic U. Louvain)
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