Polar Climate Predictability

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Late-summer sea-ice extent: a study in contrasts

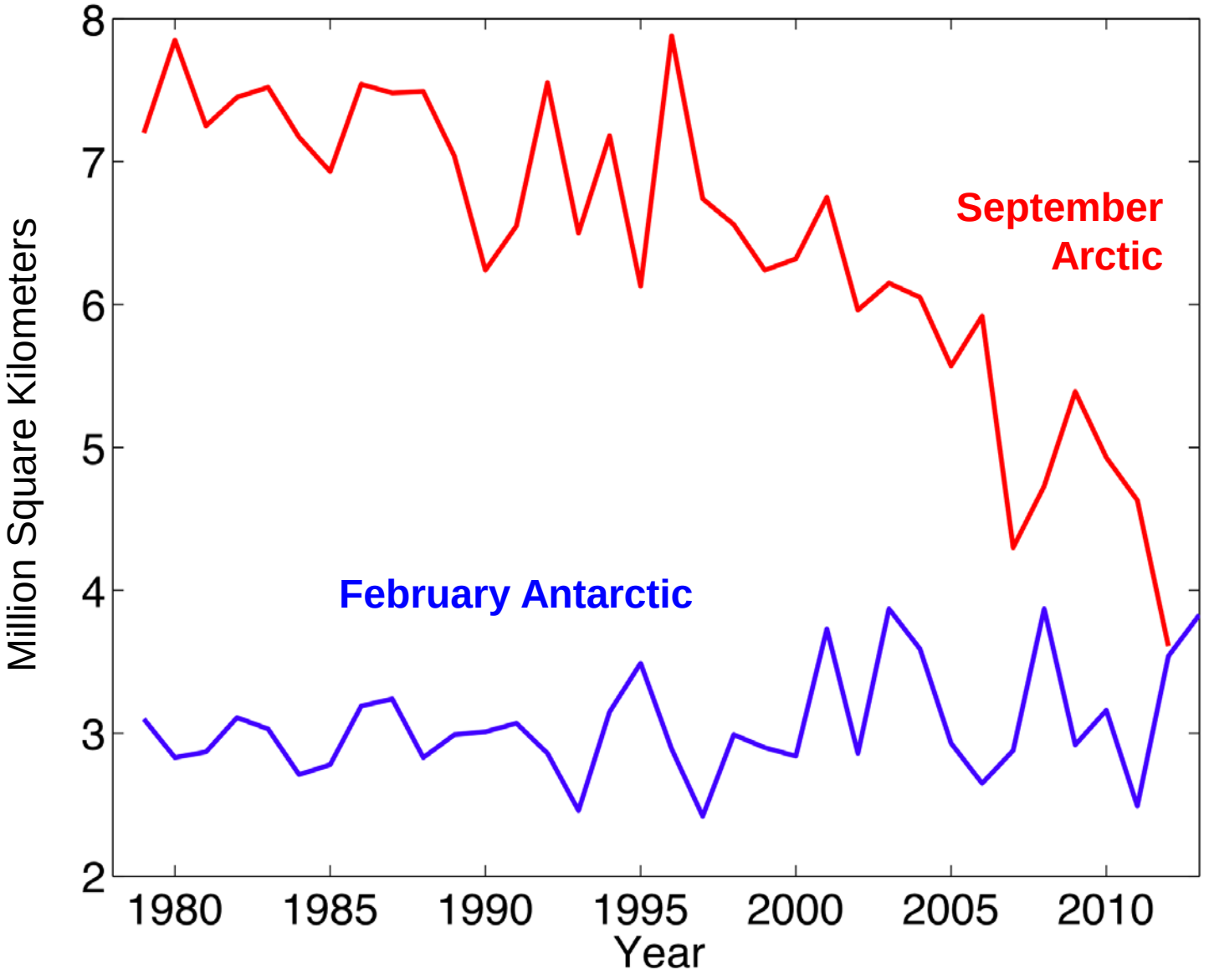


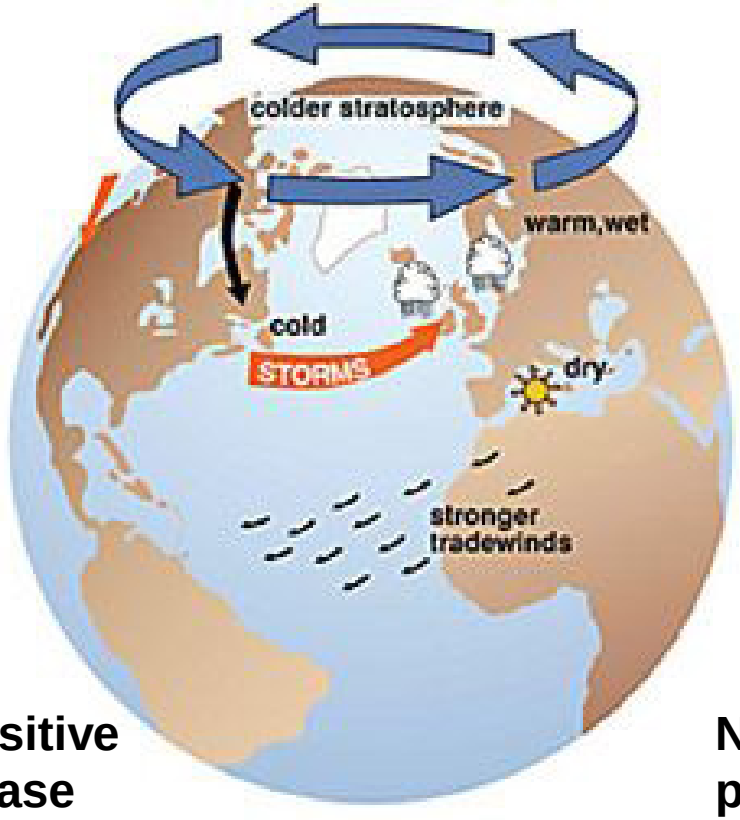
Figure courtesy of Cecilia Bitz, University of Washington

Some questions

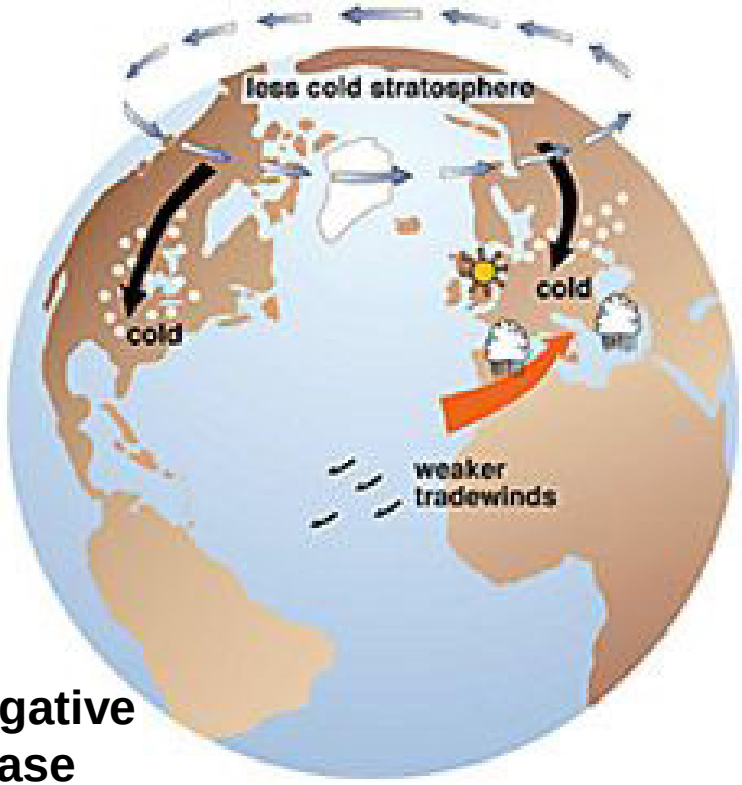
- How predictable is Arctic climate?
  - Forced component of predictability may dominate over initial condition component in as little as ~5 yr
- Why is the climate at the two poles changing so differently (with the Arctic changing rapidly, and the Antarctic unevenly), and differently to global climate?
- Why are climate models generally unable to capture the observed behaviour in polar regions?
- What does high latitude climate change mean for lower latitudes?
- Do the ongoing amplified changes in the Arctic have an influence on extremes in the Arctic?

In the Northern Hemisphere, the wintertime NAO is connected to the stratosphere through the effects of weather systems

- A weaker (stronger) stratospheric vortex is associated with an equatorward (poleward) shift of the North Atlantic storm track, **with the stratosphere leading the troposphere**

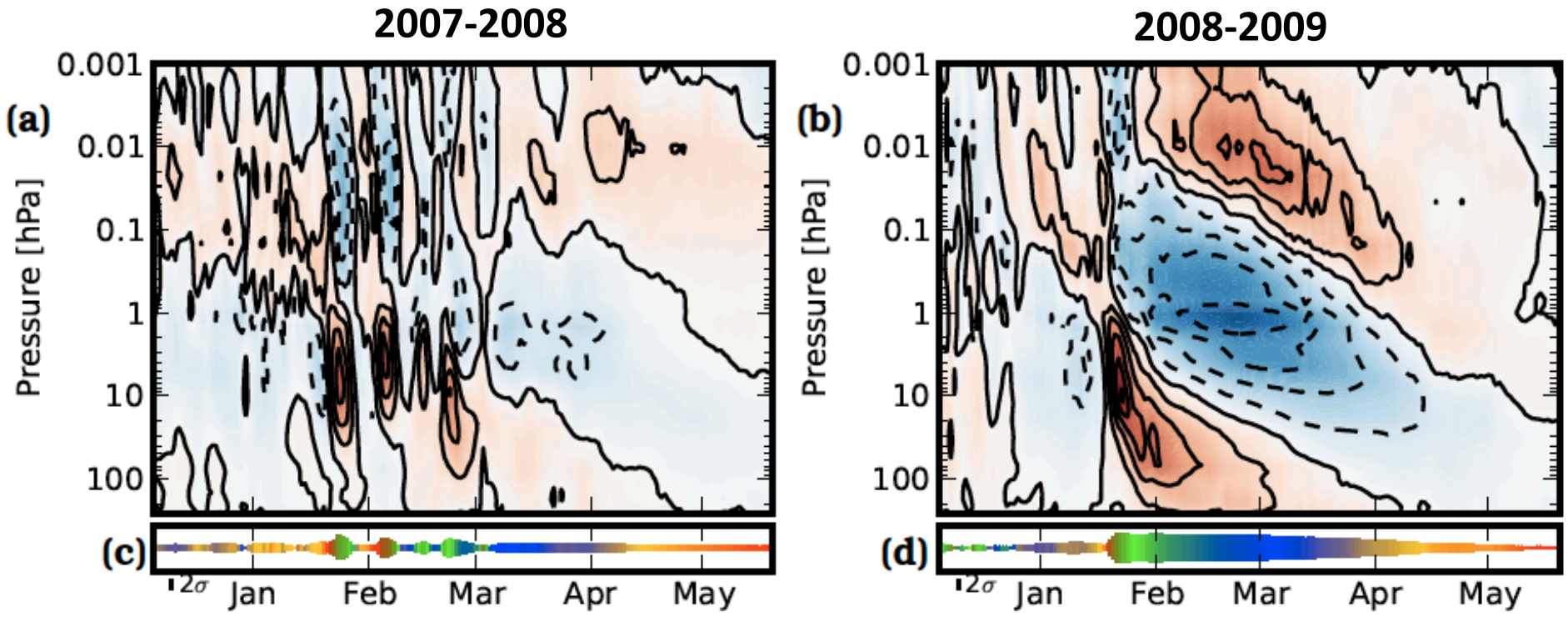


Positive phase



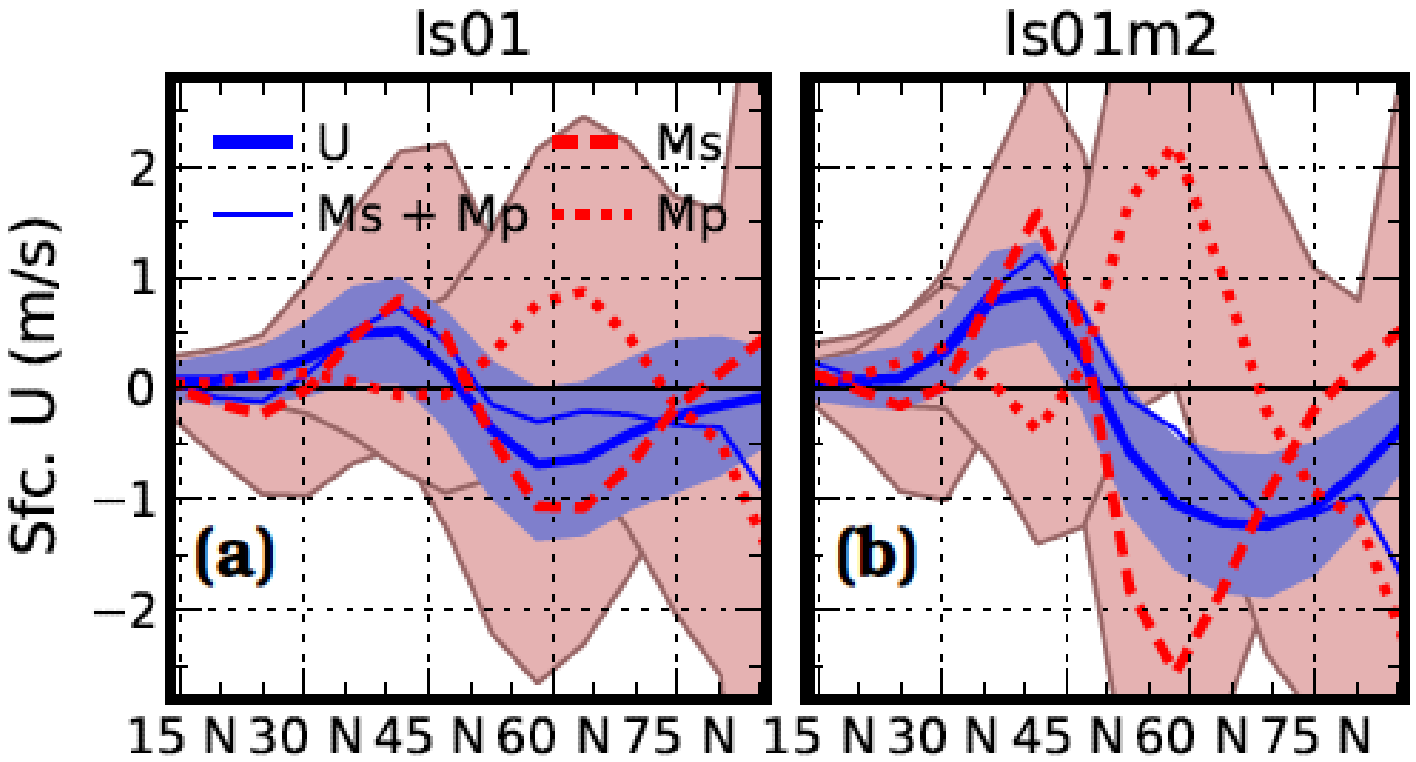
Negative phase

- About half of all **Stratospheric Sudden Warmings** (SSWs) are short-lived, as in 2007-2008 (left), while half have extended recovery periods, as in 2008-2009 (right)
  - **The extended recovery periods are highly repeatable** (i.e. predictable) — hence persistent impact on troposphere
  - Figures show MLS polar-cap average temperatures



Hitchcock, Shepherd & Manney (2013 J. Clim.)

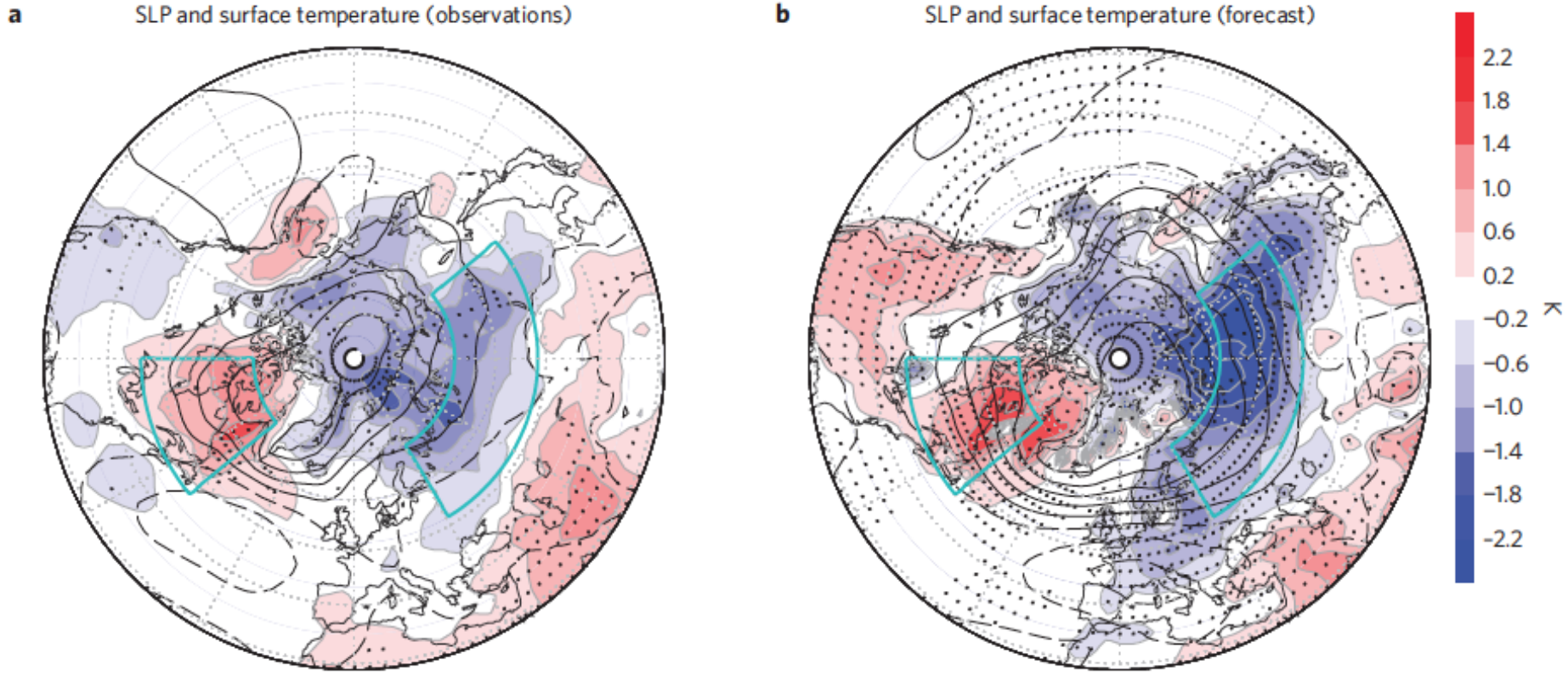
- **Mechanisms for the tropospheric response are not understood**
- Momentum budget shows equatorward shift of zonal wind is driven by synoptic-scale eddy momentum fluxes (Ms), but is strongly mitigated by planetary-scale eddy momentum fluxes and mountain torque (Mp)



Idealised experiments with wave-1 (left) and wave-2 (right) topography

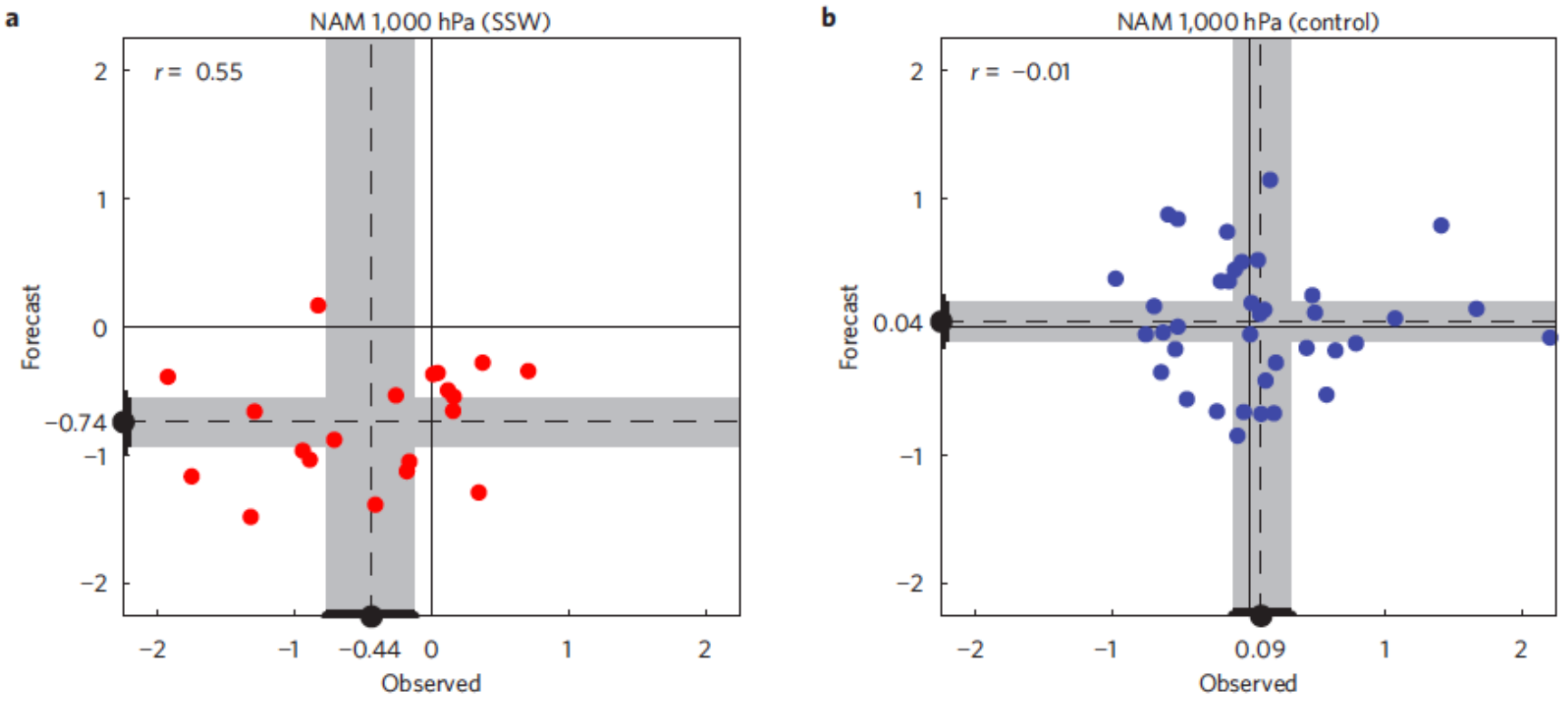
Hitchcock, Shepherd, Yoden, Noguchi & Taguchi (2013 JAS)

- Stratosphere-resolving models can correctly predict the surface response to SSWs when initialised at the time of the SSW
  - Figure shows response averaged over 16-60 days after the SSW, for 20 SSWs from 1970-2009 (model: ensemble of 10)



Sigmond, Scinocca, Kharin & Shepherd (2013 Nature Geosci.)

- However the inherent predictability of the NAM is not increased after an SSW (the scatter is not reduced)
  - The SSW just loads the dice in one direction



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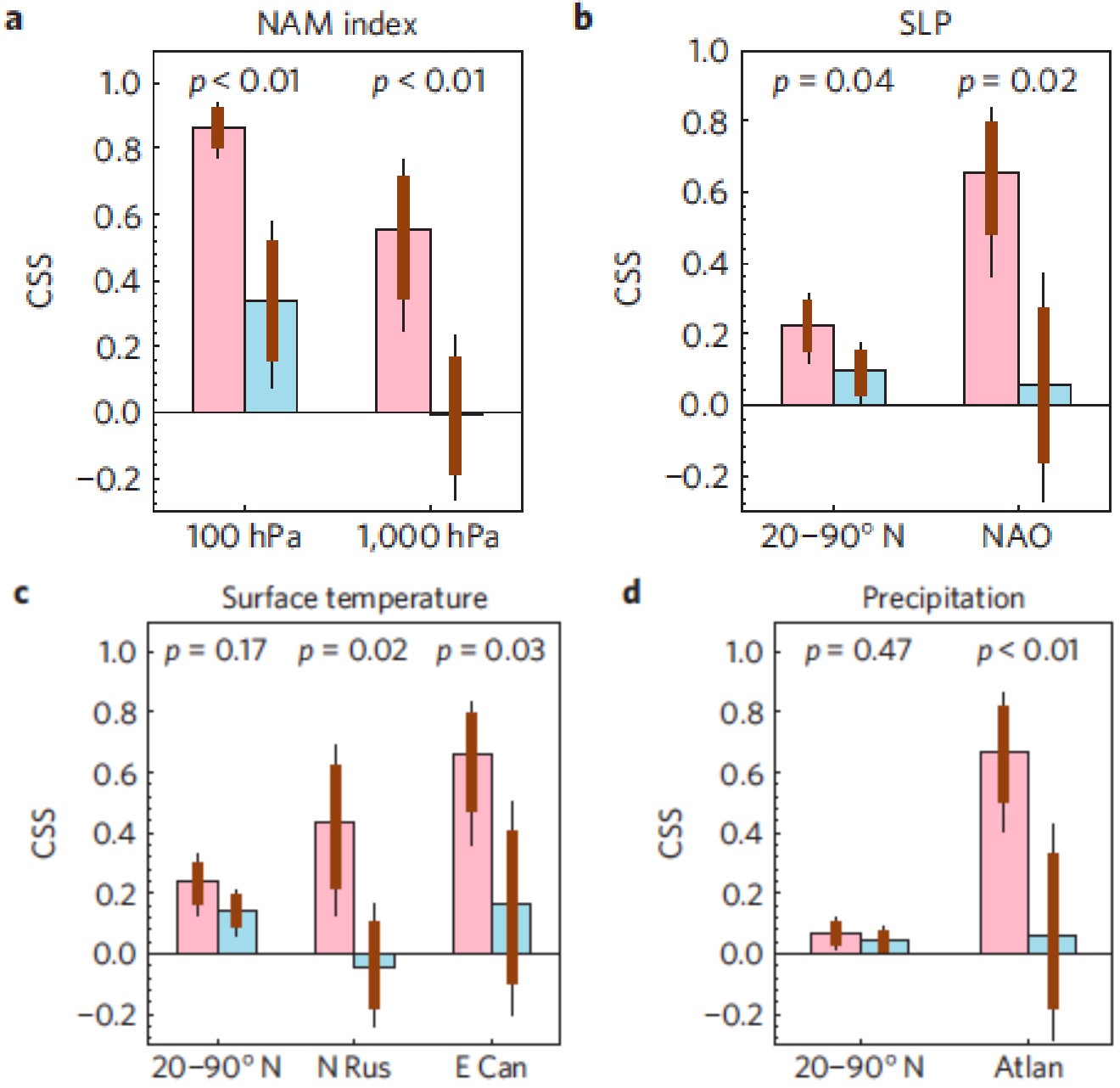
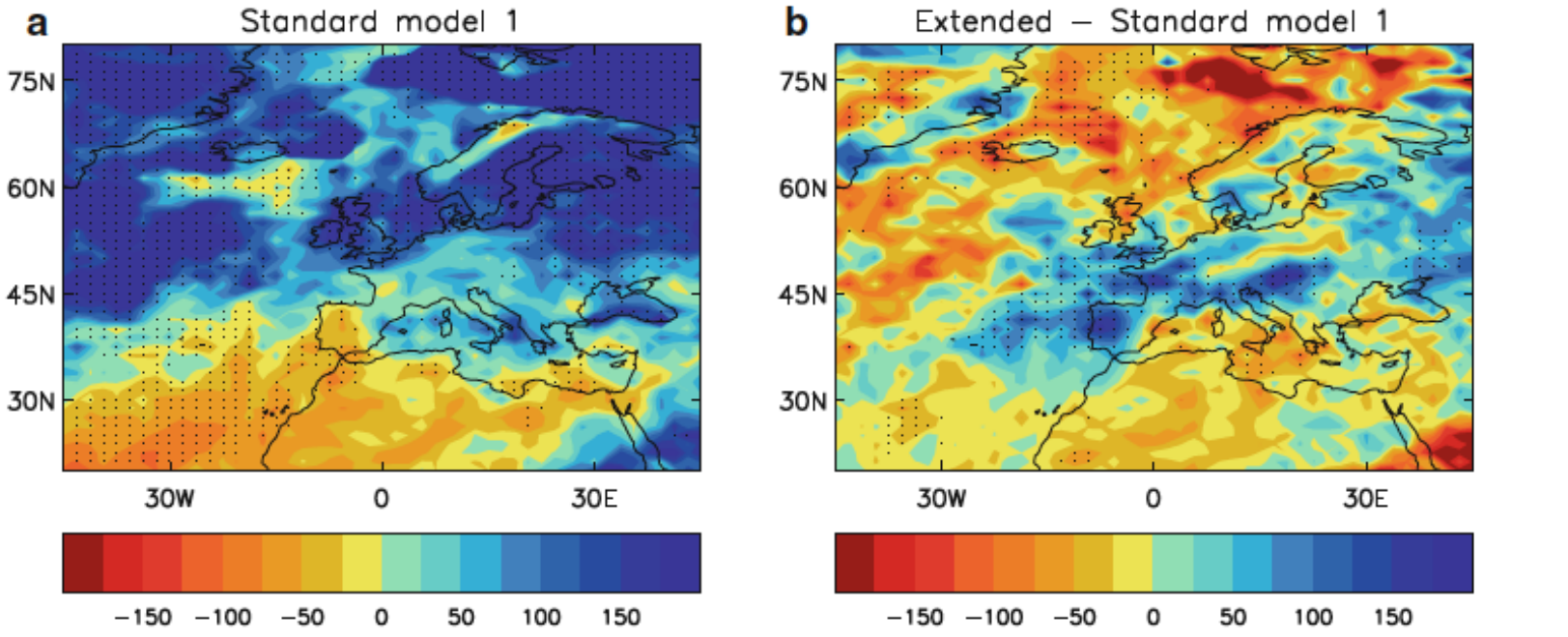


- SSWs enhance the skill of seasonal predictions of a variety of surface climate fields, especially in certain regions
  - Blue is the control, pink is after SSWs

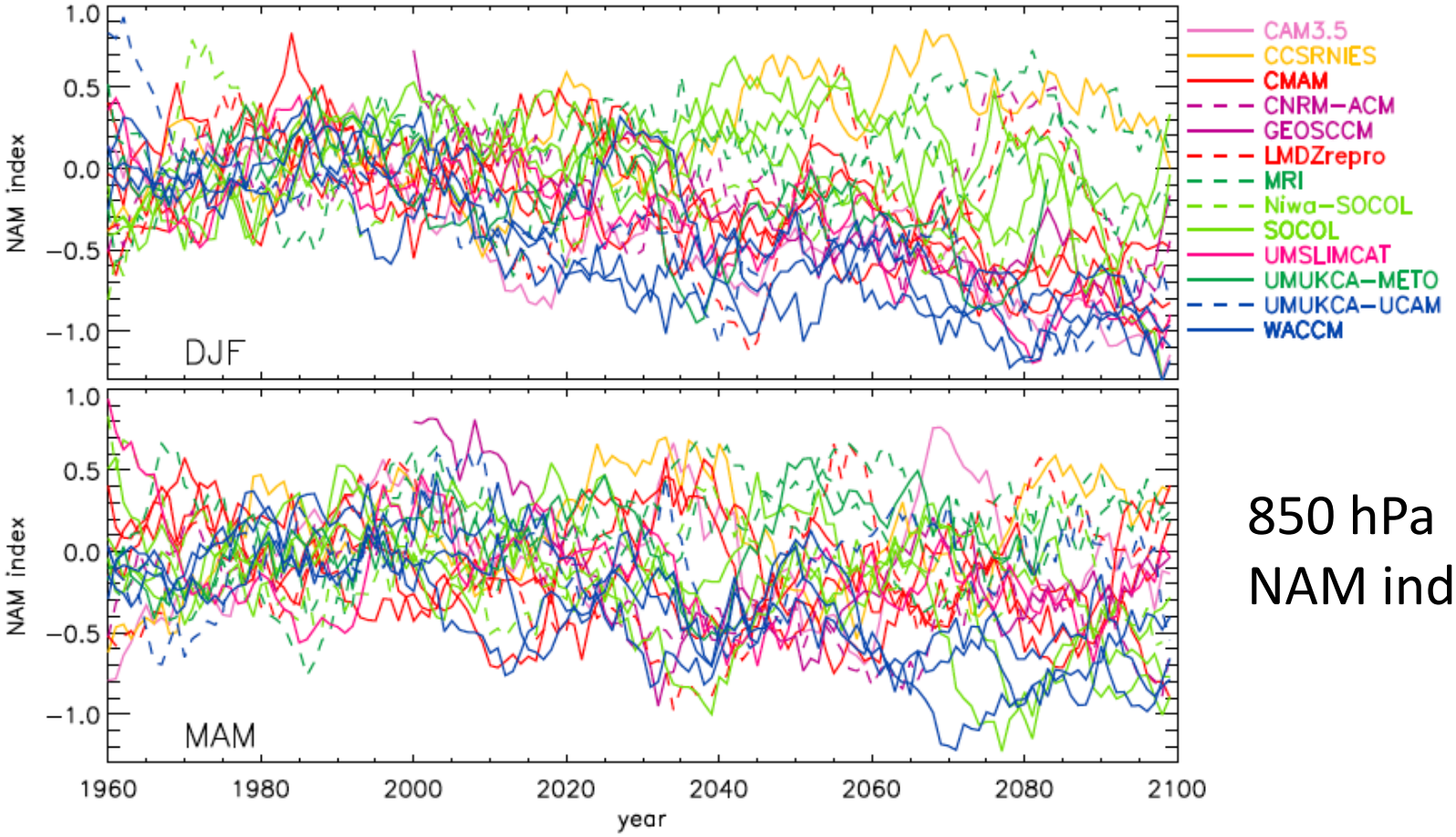
Sigmond et al. (2013 Nature Geosci.)

- Same effect is seen in the **circulation response to climate change**
  - Inclusion of the stratosphere leads to less of a poleward shift in the wintertime North Atlantic storm track from climate change, due to weakening of the stratospheric polar vortex
  - Figure shows **percentage change in frequency of extreme wintertime rainfall** from 4xCO_2: right is effect of stratosphere



Scaife et al. (2012 Clim. Dyn.)

- Yet stratosphere-resolving climate models do not provide a robust prediction of the surface circulation response to climate change
  - **How much of this spread is related to biases in climatology?**

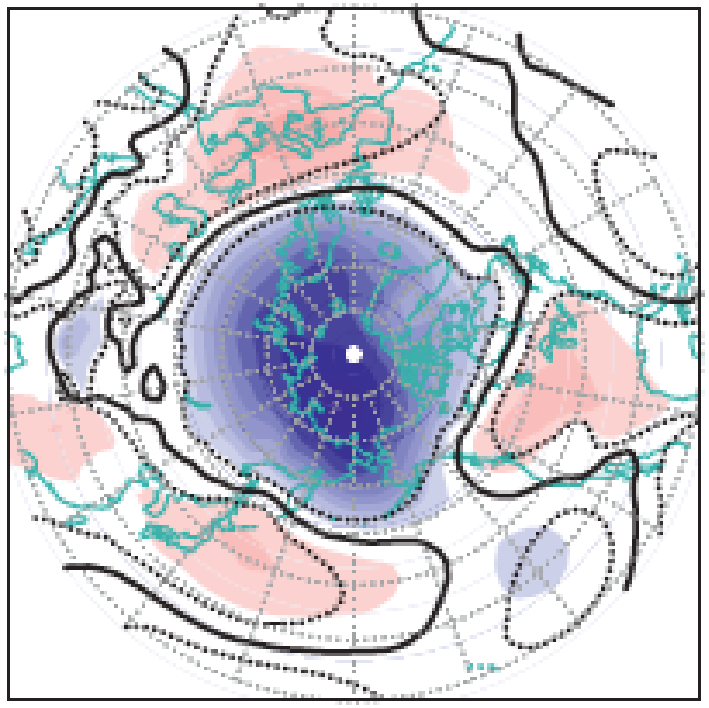


850 hPa
NAM index

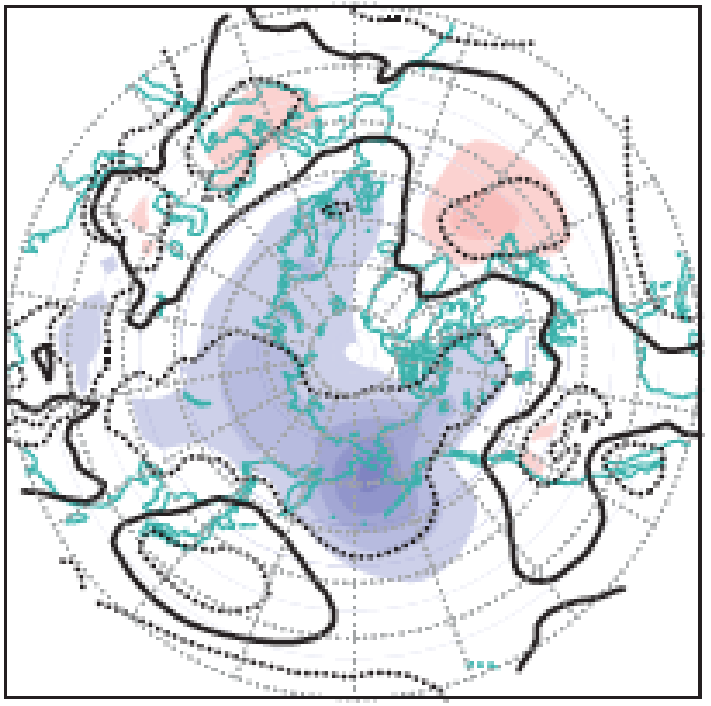
Morgenstern et al. (2010 JGR)

- In CMAM, the Arctic wintertime sea level pressure response to doubled CO_2 changed dramatically between two different (but plausible) parameter settings in the **orographic GWD scheme**
- Difference consistent with Scaife et al. (2012): weakened stratospheric vortex / weaker poleward shift in tropospheric jet

(a) RESPONSE WEAK (DRAG)

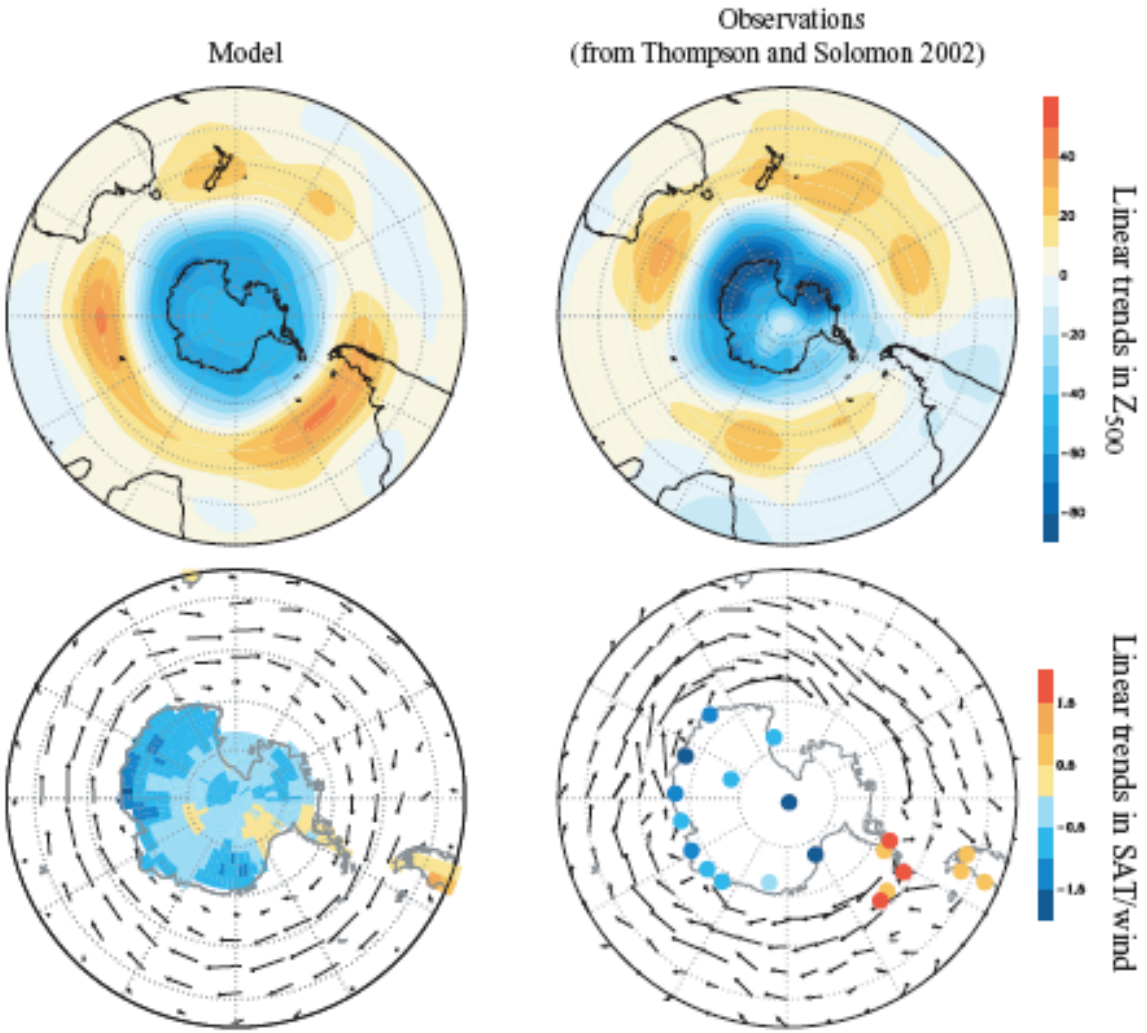


(b) RESPONSE STRONG (DRAG)



Sigmond & Scinocca (2010 J. Clim.)

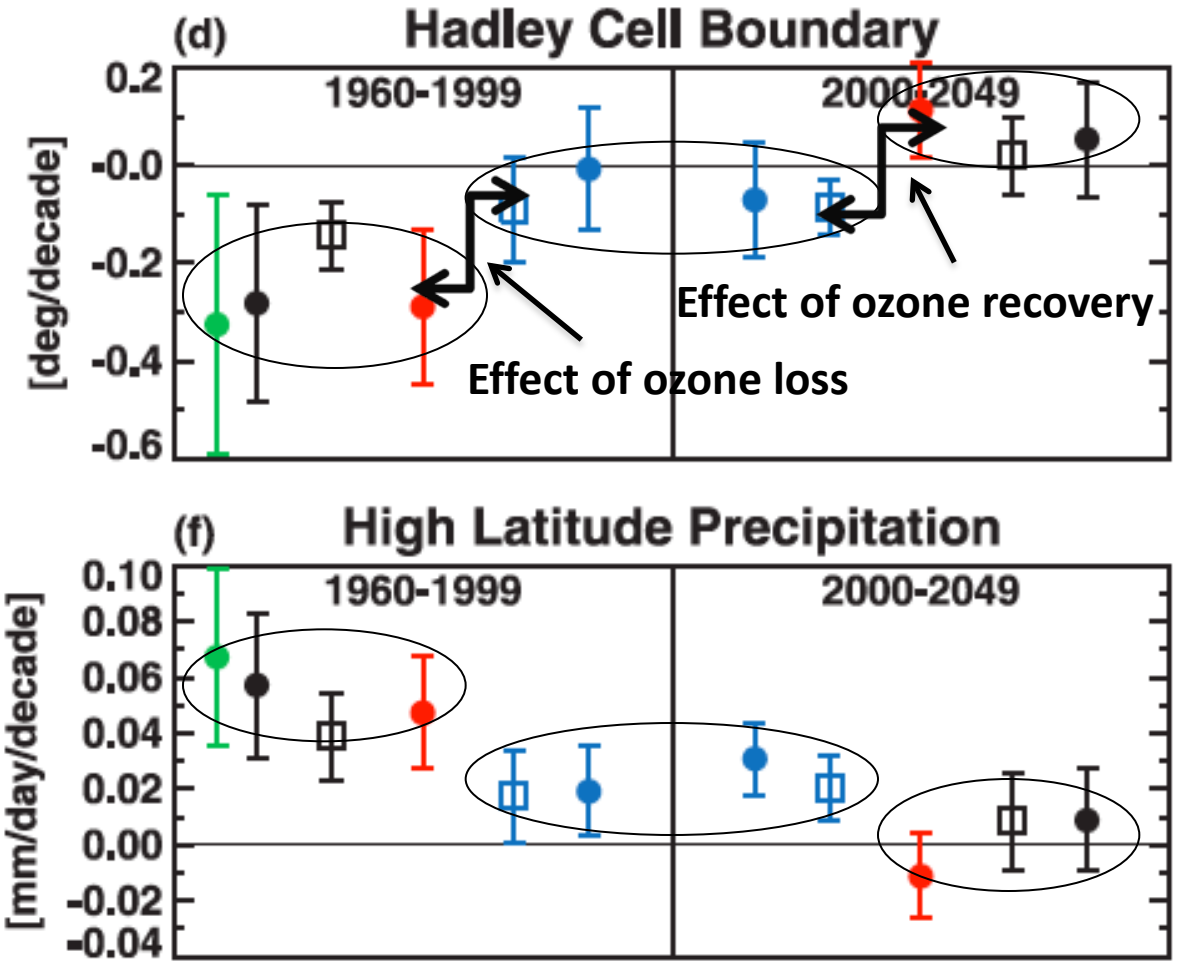
- **In the Southern Hemisphere**, the ozone hole has been the primary driver of recent summertime trends in the surface circumpolar winds (Arblaster & Meehl 2006 J. Clim.)



Linear trends up to 2000

Gillett & Thompson (2003 Science)

These ozone-induced circulation changes affect important aspects of SH regional climate (cf. Son et al. 2009 GRL)

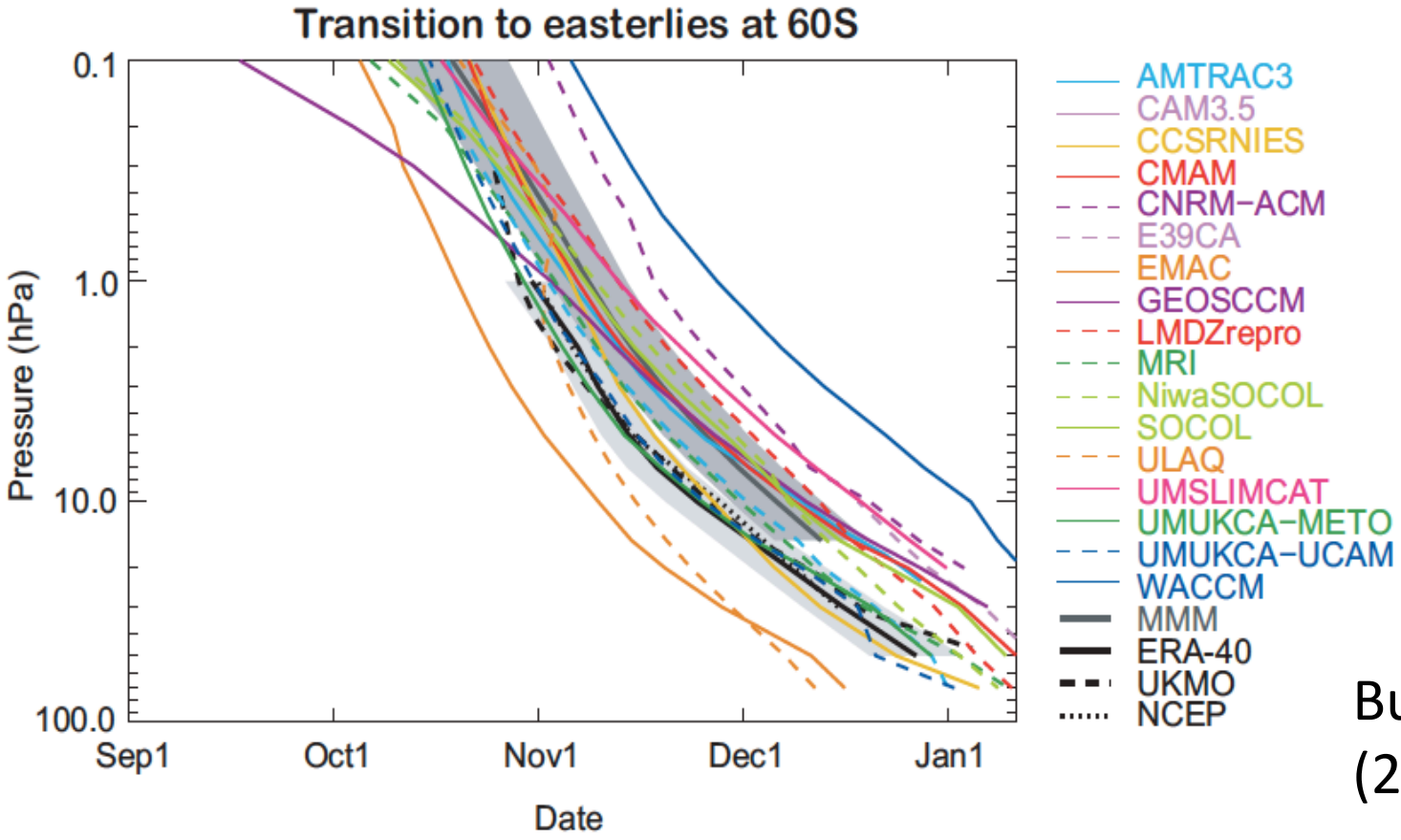


McLandress, Shepherd, et al. (2011 J. Clim.)

CMAM

- REF-B1
- REF-B2
- GHG
- ODS
- AR4 models without ozone depletion and recovery
- AR4 models with ozone depletion and recovery

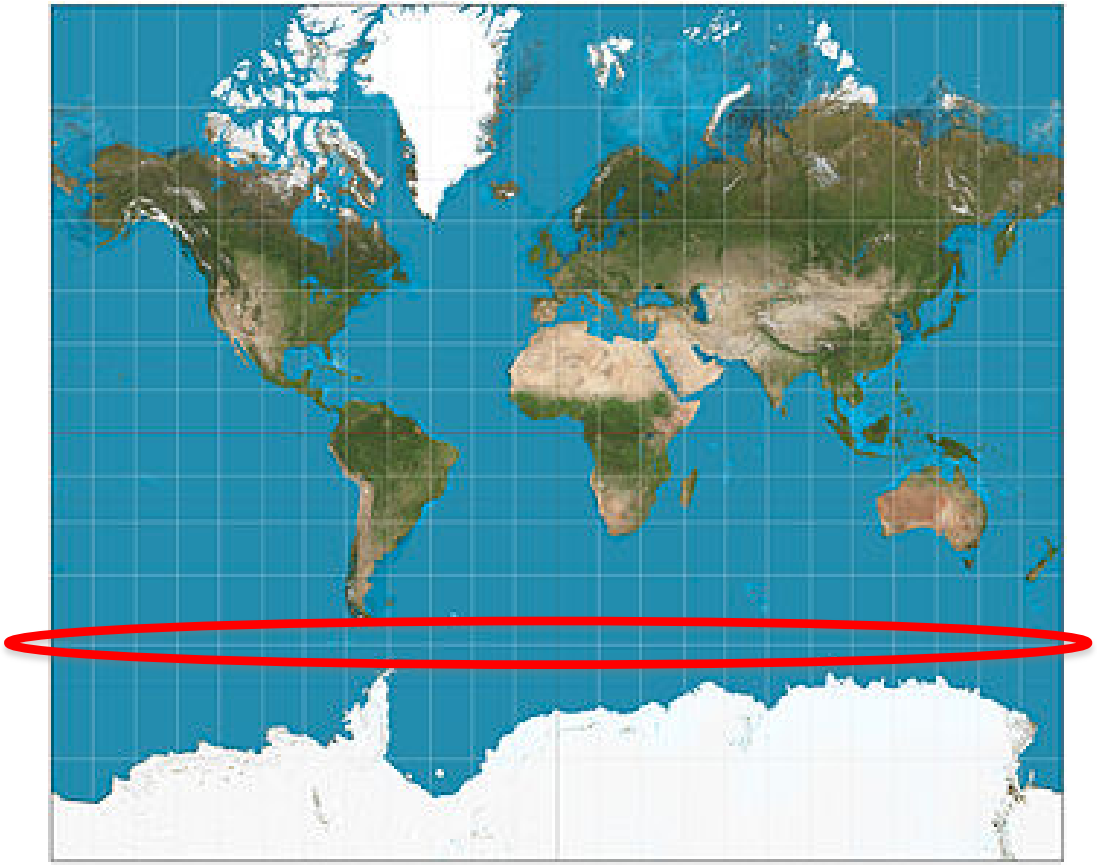
- **But do we trust the models in the Antarctic?**
  - Climate models tend to have a systematic bias towards a too-late Antarctic stratospheric vortex breakup
  - To what extent does this compromise projections of summertime SH high-latitude climate?

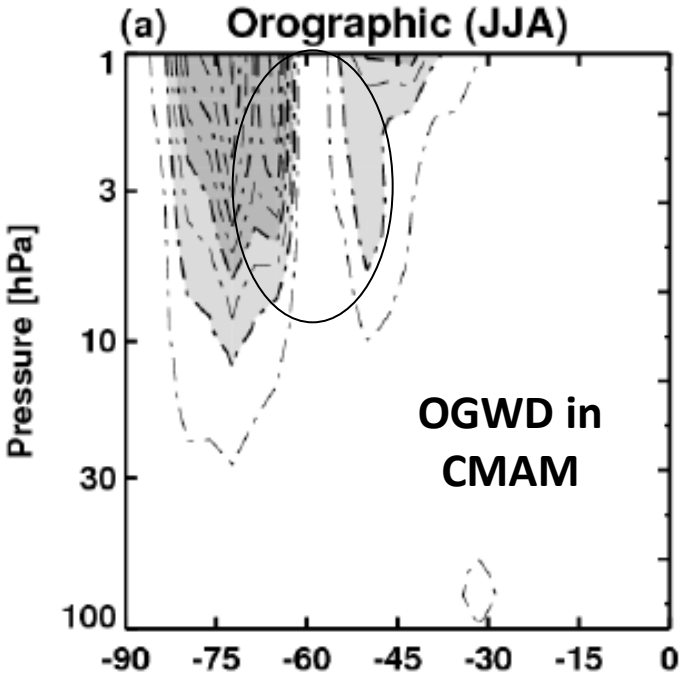


Butchart et al. (2011 JGR)

The SH jet has a maximum around 60° S

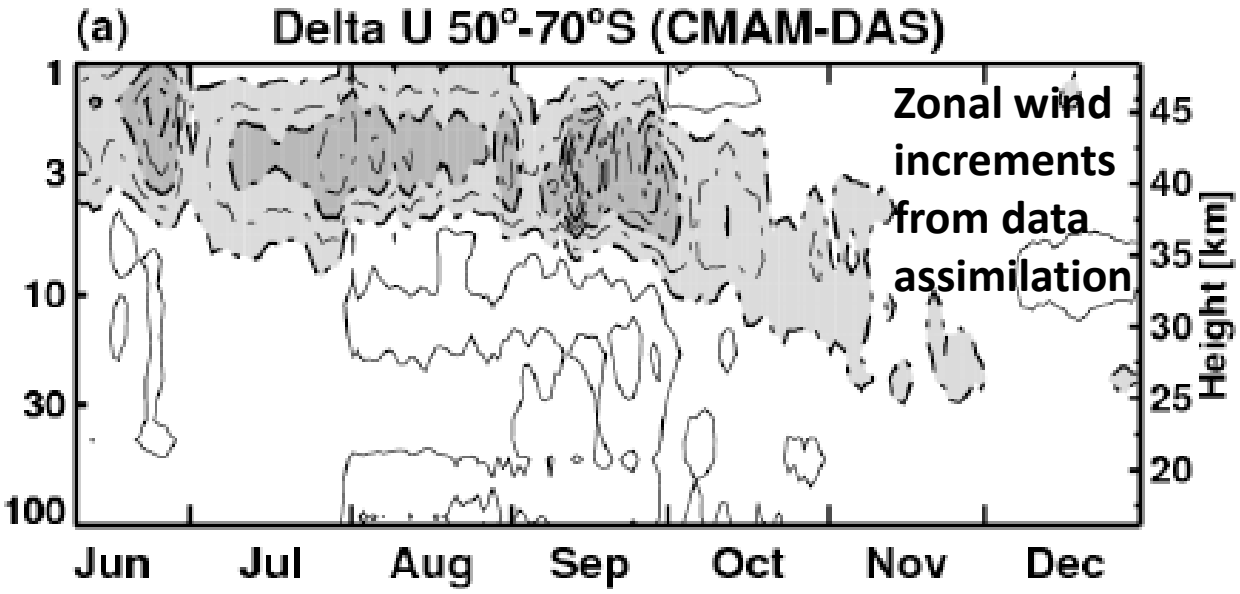
– At this latitude band, the surface is represented entirely as ocean in the models, hence no orographic gravity-wave drag!

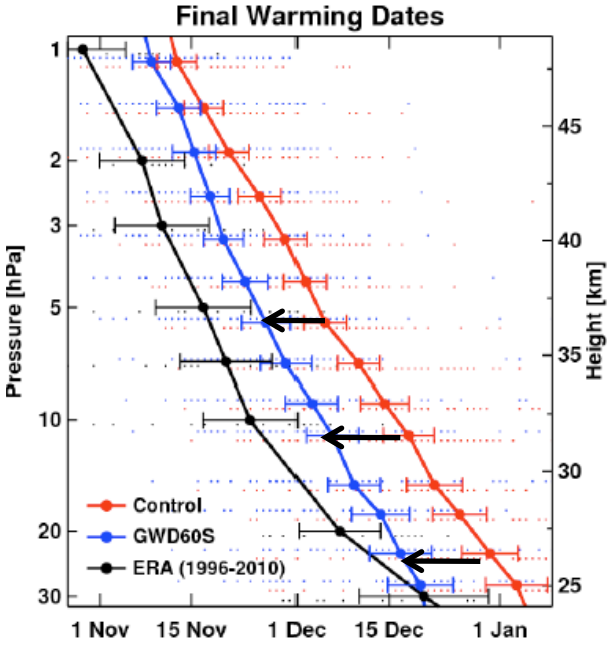




McLandress, Shepherd, Polavarapu & Beagley (2012 JAS)

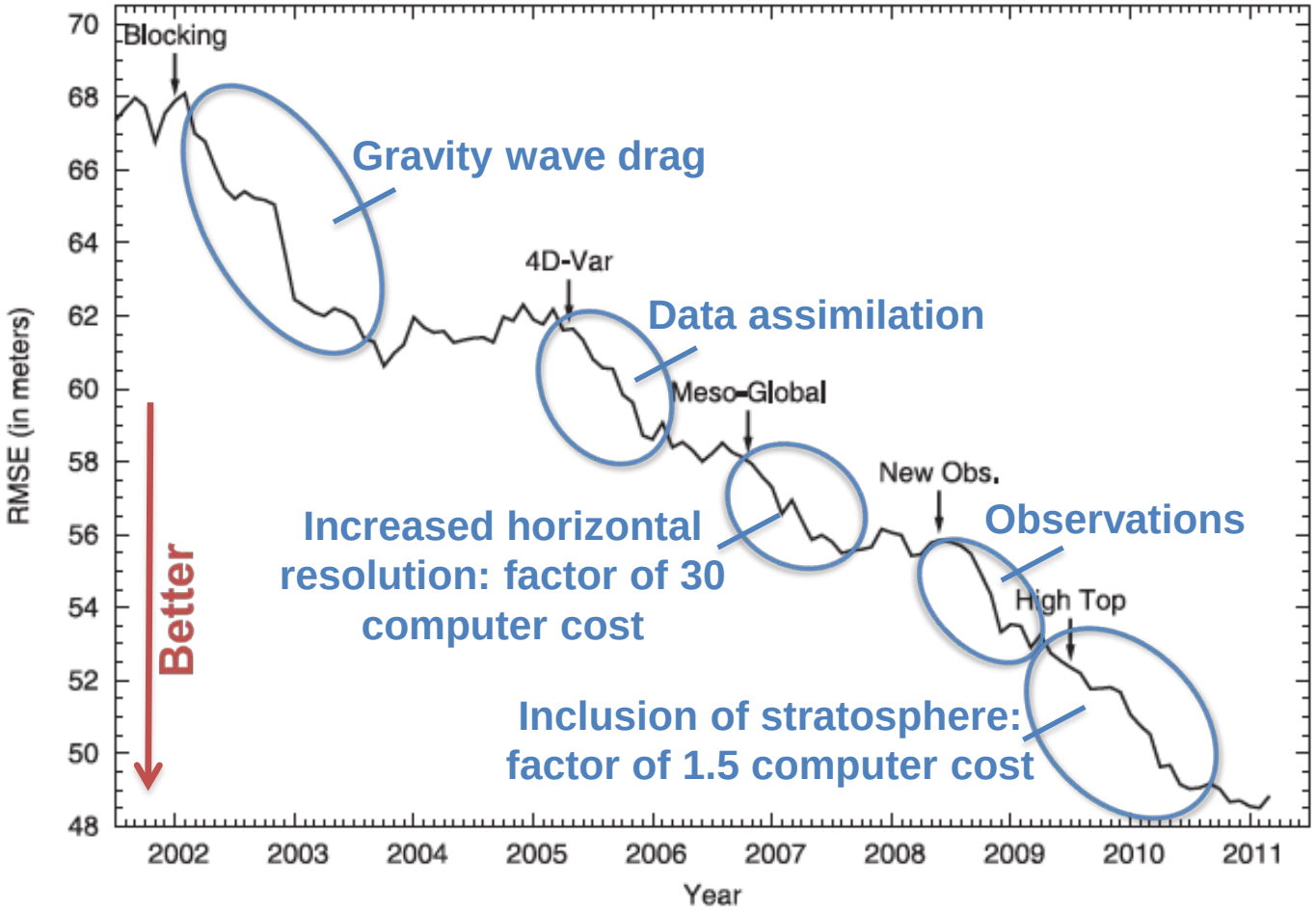
- When CMAM is run in data assimilation mode, increments imply missing drag at these latitudes, which descends from the upper stratosphere as the zero wind line descends (left)
- There is other evidence for the role of oro GWD at these latitudes
- An ad hoc inclusion of extra oro GWD in this latitude belt substantially reduces the zonal-wind bias in CMAM (right)





McLandress, Shepherd, Polavarapu & Beagley (2012 JAS)

- **Improvements in Canadian weather forecasts** over the last decade have been due as much to improving the model set-up as to other factors: *shows importance of fundamental thinking*



12 month running mean of RMS error in 500 hPa geopotential height for 5-day forecasts over northern extratropics, validated against radiosondes

Charron et al. (2012 MWR)

The WCRP Polar Climate Predictability Initiative (PCPI)

- Leads: Cecilia Bitz (U Washington, USA, representing CliC) and Ted Shepherd (U Reading, UK, representing SPARC)
- Developed from WCRP workshop in Bergen in October 2010 (see extensive workshop report published in SPARC Newsletter)
  - Further developed in Toronto meeting, April 2012
  - Draft implementation plan finalized in November 2012, approved by WCRP JSC (but needs to be developed further)
- Goal is to help advance climate prediction in polar regions
  - Climate prediction is not just about the initial-value problem
  - Most people in the community are interested in both poles
  - Need to bring together different disciplinary communities
- Will not have a formal Steering Committee; rather we are identifying champions to carry forward specific initiatives

Opportunities for Significant Progress

- Recent expansion of the ocean observing system
- New measurements of sea-ice thickness and other important surface variables
- New reanalysis products
- More comprehensive global models
- The pieces are in place
  - Much progress can be achieved just by bringing together previously disparate scientific communities to work on common problems that involve a strong coupling between the different components of the climate system
- Interest of the scientific community
- Synergy with the WWRP-PPP

Programmatic Context

- Polar climate predictability cuts across all elements of WCRP; but tends to fall between the cracks
- WCRP Working Groups need process expertise in polar regions to help improve products and strategies
  - WMO Global Producing Centres for Long-range Forecasts
  - Global Framework for Climate Services
- WMO EC-PORS is promoting a Global Integrated Polar Prediction System (GIPPS)
  - WWRP Polar Prediction Project: hours to seasonal
  - WCRP PCPI: seasonal to multi-decadal
  - Will liaise closely, have a common coordination office
    - However the role of PCPI within WCRP is rather different from that of PPP within WWRP

Programmatic context, continued

- There are existing international programs specifically focused on the polar regions: IASC for the Arctic, and SCAR for the Antarctic
  - Need to avoid duplication or competition (or confusion)
  - WCRP brings the global perspective and strength in global modelling
- Within WCRP, the PCPI will constitute a sub-initiative of the "Cryosphere in a Changing Climate" Grand Challenge
  - Specific activities will be focused, with clear timelines, in areas where WCRP can play a unique role
- The PCPI can be an 'incubator' to generate community research efforts that could be adopted, in the longer term, by more permanent components of the WCRP or of partner organizations

- **Initiative 1:** *Improve knowledge and understanding of past polar climate variations (up to 100 years)*
  - Leads: Sarah Gille (SIO, USA; WCRP JSC) and Julie Jones (U Sheffield, UK)

- **Initiative 2:** *Assess reanalyses in polar regions* (joint with PPP)
  - Leads: Dave Bromwich (OSU, USA; SCAR and WWRP-PPP SSG) and Jim Renwick (Victoria University, New Zealand; WMO EC-PORS and WCRP JSC)

- **Initiative 3:** *Improve understanding of polar climate predictability on seasonal to decadal timescales* (joint with PPP)
  - Leads: John Fyfe (CCCma, Canada) and Ed Hawkins (U Reading, UK; CLIVAR SSG)

- **Initiative 4:** *Assess performance of CMIP5 models in polar regions*
  - Leads: Hugues Goosse (UCL, Belgium) and Jennifer Kay (NCAR, USA)

- **Initiative 5:** *Model error* (joint with PPP)
  - Leads: Markus Jochum (U Copenhagen, Denmark; CLIVAR) and Gunilla Svensson (U Stockholm, Sweden; GEWEX GABLS co-Chair and WWRP-PPP SSG)

- **Initiative 6:** *Improve understanding of how jets and non-zonal circulation couple to the rest of the system in the Southern Hemisphere*
  - Leads: Gareth Marshall (BAS, UK; CLIVAR) and Marilyn Raphael (UCLA, USA; CliC)

Modalities

- Not much appetite or resources in the community for additional coordination meetings, so the PCPI will coordinate electronically and through meetings of opportunity
  - Will use initiative co-leads to represent the PCPI at other meetings, to ensure effective synergy
- Will leverage off other meetings wherever possible
  - However there needs to be a lot of cross-interaction between the different initiatives
- Thinking about possible pan-PCPI workshop in late winter 2014, perhaps in conjunction with PPP SSG meeting
- PCPI project scientist Dr. Diane Pendlebury currently funded by the Canadian Space Agency at University of Toronto (also working on SPARC projects); will liaise closely with PPP ICO