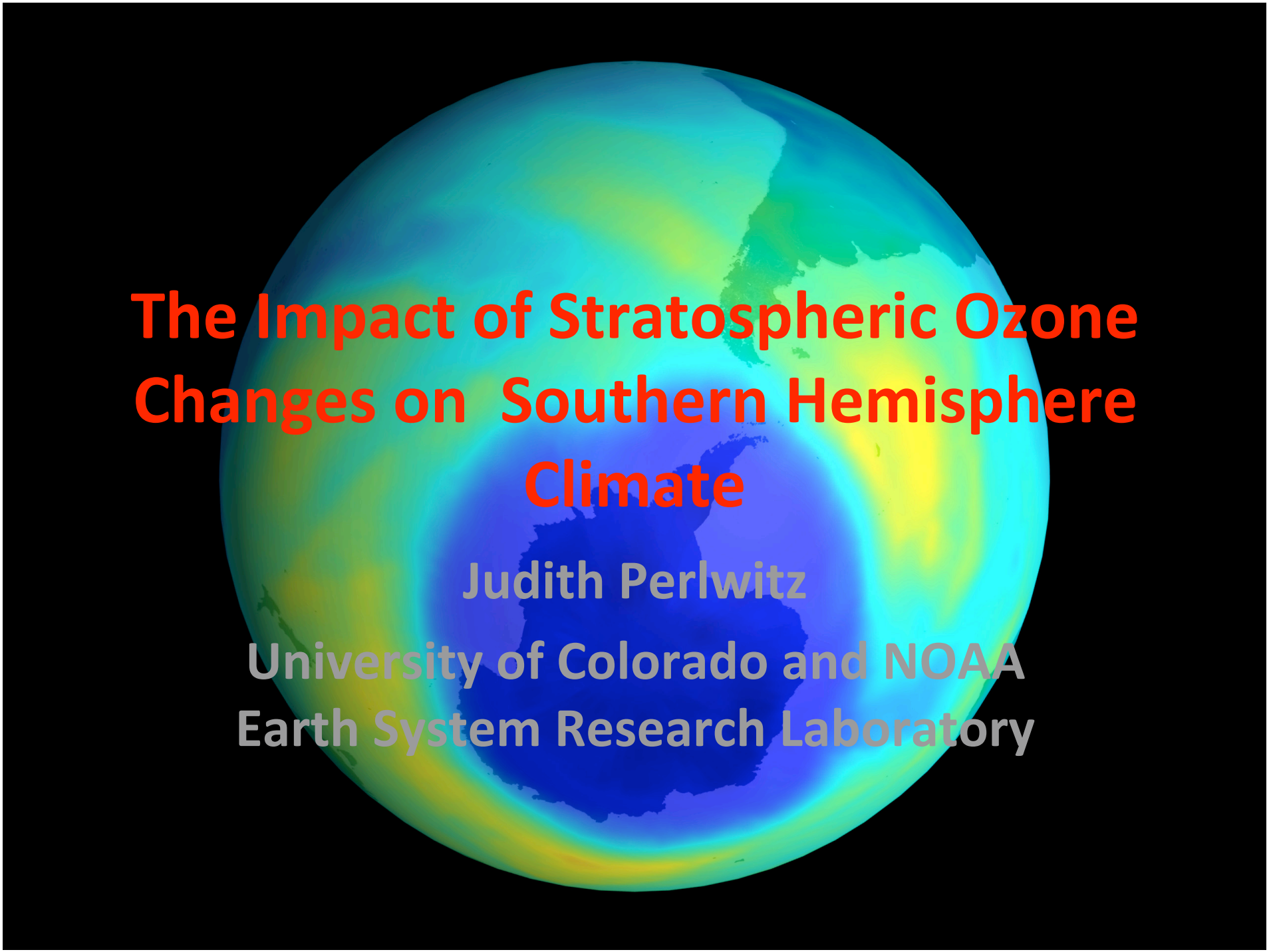

The Impact of Stratospheric Ozone Changes on Southern Hemisphere Climate

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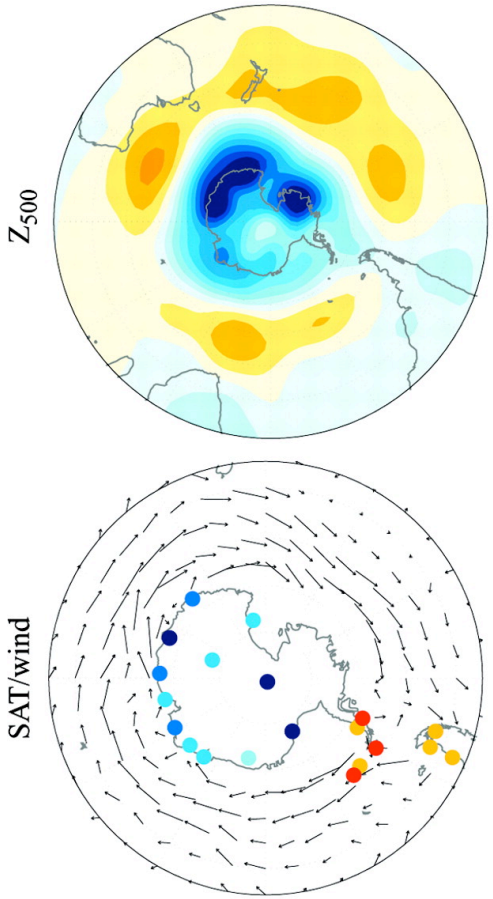
Earth System Research Laboratory

Outline

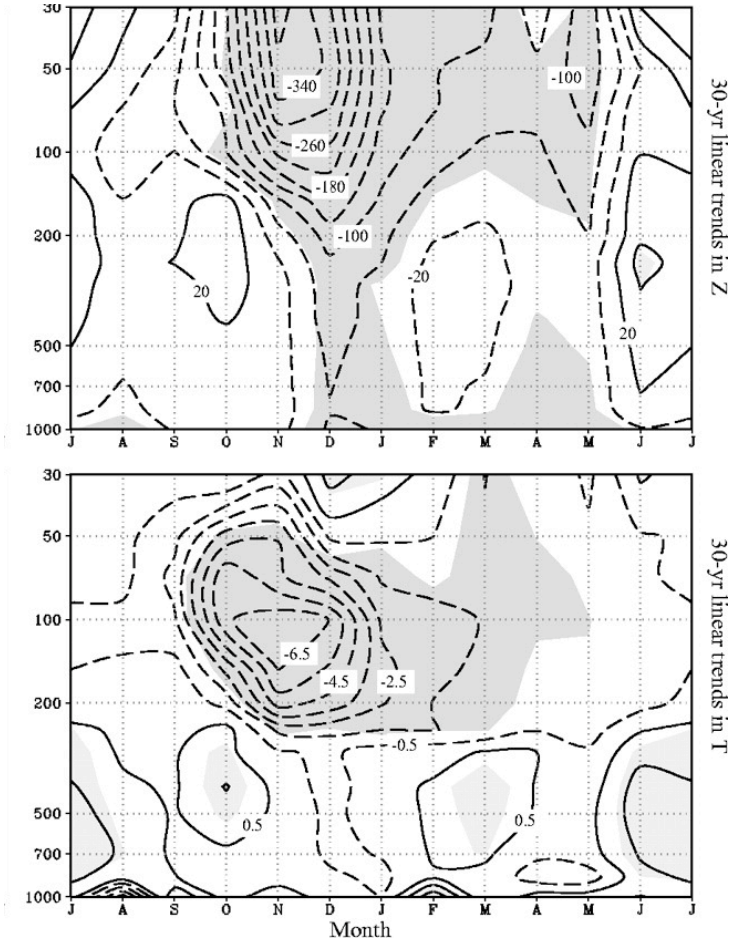
- Introduction
- Impact of ozone depletion on Southern Hemisphere tropospheric climate
- What is going to happen during the 21st century?
- Summary

Linking Surface Climate Changes to Stratospheric Polar Ozone Depletion (Thompson and Solomon, 2002)

Dec-Mar Changes in Z500 and SAT/Wind 1979-1998



Changes in polar cap temperature and geopotential heights, 1969-1998



Sources For Our Understanding of Possible Climate Impacts of Antarctic Ozone Changes

- AGCMs forced with stratospheric ozone changes
- Chemistry climate models (CCMs) forced with changes in ozone depleting substances
- Coupled atmosphere-ocean-sea ice models (source: CMIP3) forced with and without changes in stratospheric ozone
- Coupled CCM/Ocean/Sea ice models

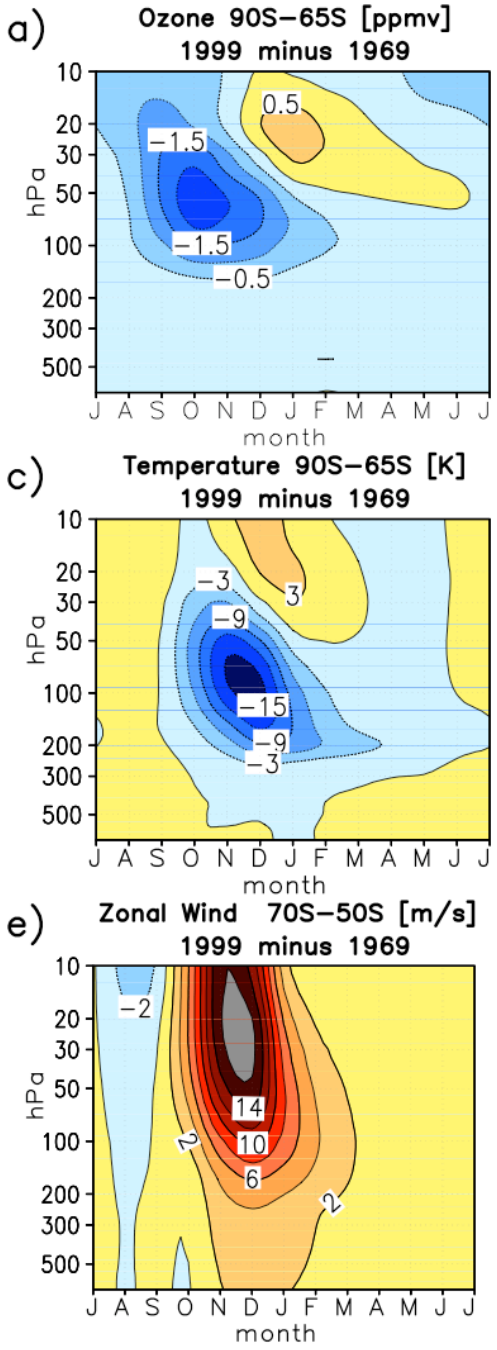
Limitations

- AGCMs
  - lack air-sea interaction and chemistry-climate interactions
- CCMs
  - lack air-sea interaction
  - Chemistry-climate interactions can amplify biases in stratospheric climatology
    - Simulating a realistic Antarctic ozone hole, realistic stratospheric variability and realistic vortex breakup is a challenge
- AO-GCMs simulations used for IPCC AR4 (CMIP3)
  - Lack chemistry- climate interactions
  - Stratospheric ozone forcing varies between models (from no-ozone changes to exaggerated ozone changes)

References

- Perlwitz et al 2008: Impact of stratospheric ozone hole recovery on Antarctic climate, *Geophys. Res. Lett.,*
  - GEOS CCM and AR4 model analysis
- Son et al. 2009: Ozone hole and Southern Hemisphere climate change, *Geophys. Res. Lett., 36*
  - AR4 model analysis
- Polvani et al. 2010: Stratospheric ozone depletion: the main driver of 20th Century atmospheric circulation changes in the Southern Hemisphere, J. Climate, in press
  - Attribution study based on time slice experiments with NCAR CAM3 model
- Also important:
  - Son et al 2008, 2010 (CCM and AR4 model comparisons)
  - McLandress et al. 2010 for coupled CCM/Ocean results

Ozone-Antarctic Climate: Past Changes, 1969-1999

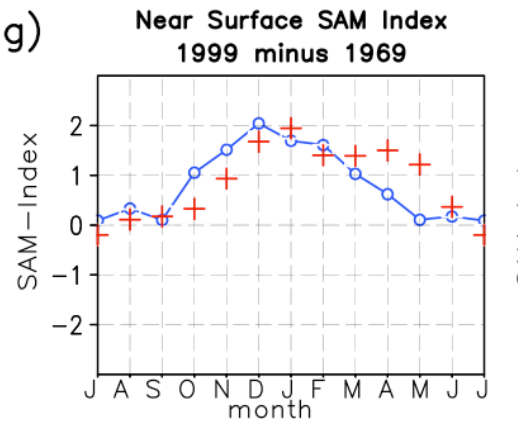


Increased troposphere westerlies about one season after stratospheric ozone loss

Perlwitz et al. 2008

Ozone hole causes substantial seasonal circulation changes at the surface

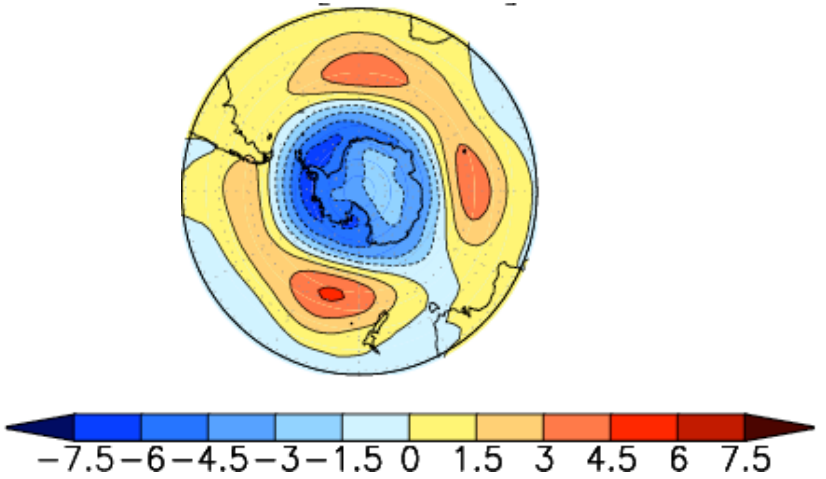
SAM index



+ Observations

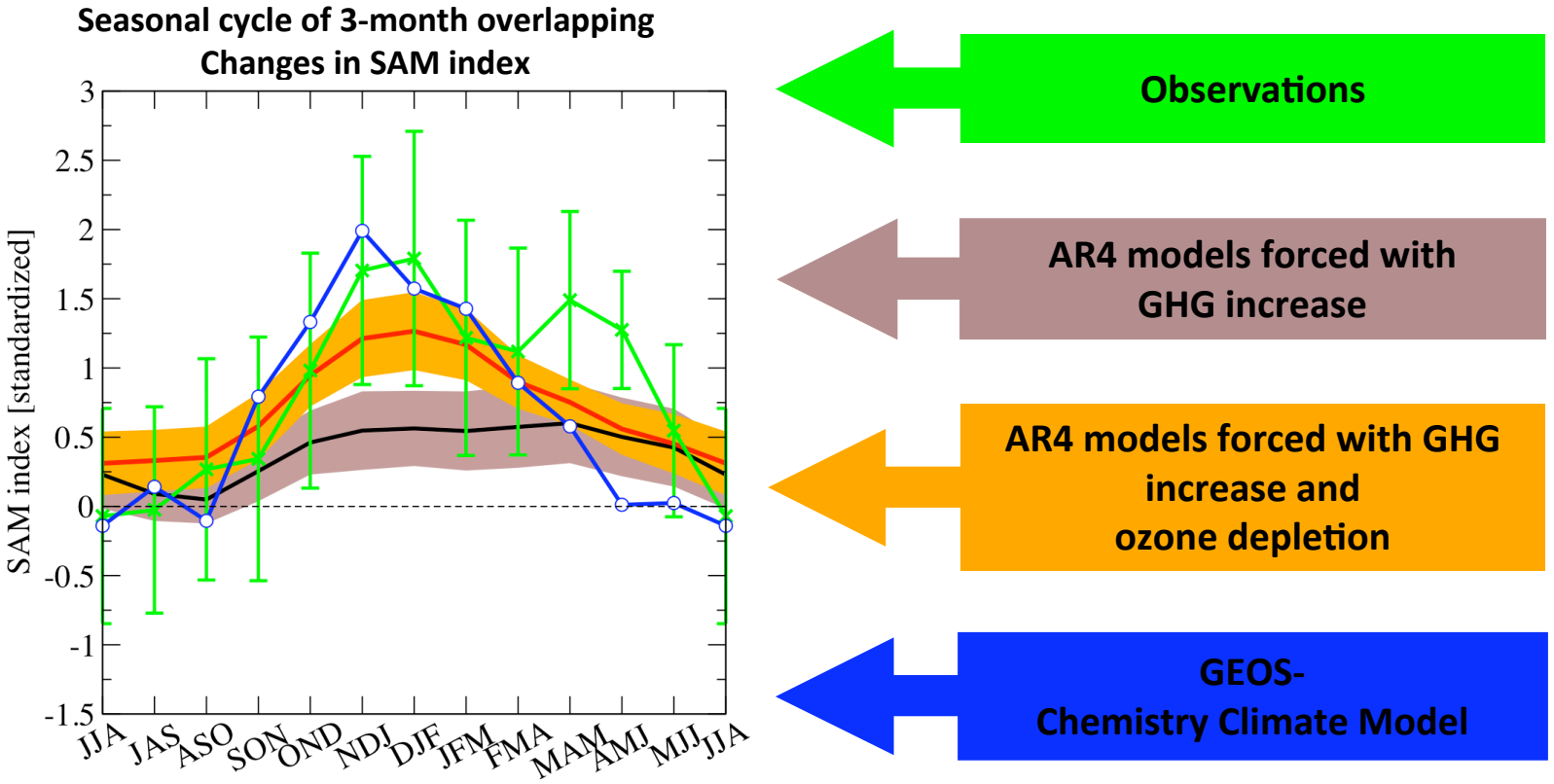
-- Mean [P-1;P-2]

Change in surface pressure in DJF



(Perlwitz et al. 2008)

Attribution of Past Changes in SAM index (1969-1999)

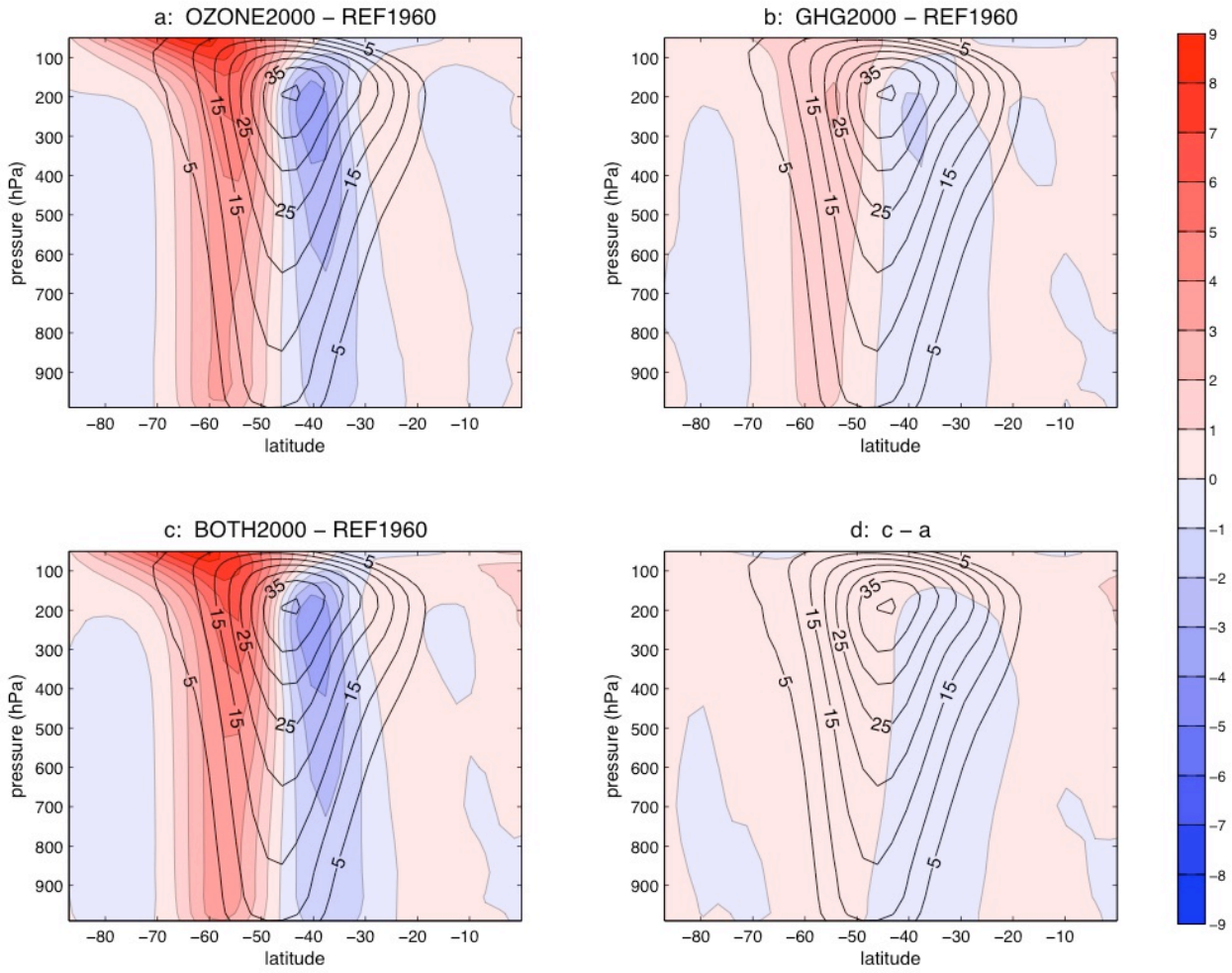


Both GHG increases and ozone depletion contributed to observed shift of summertime SAM index towards positive phase with ozone forcing dominating.

Impact of ozone depletion is seasonal.

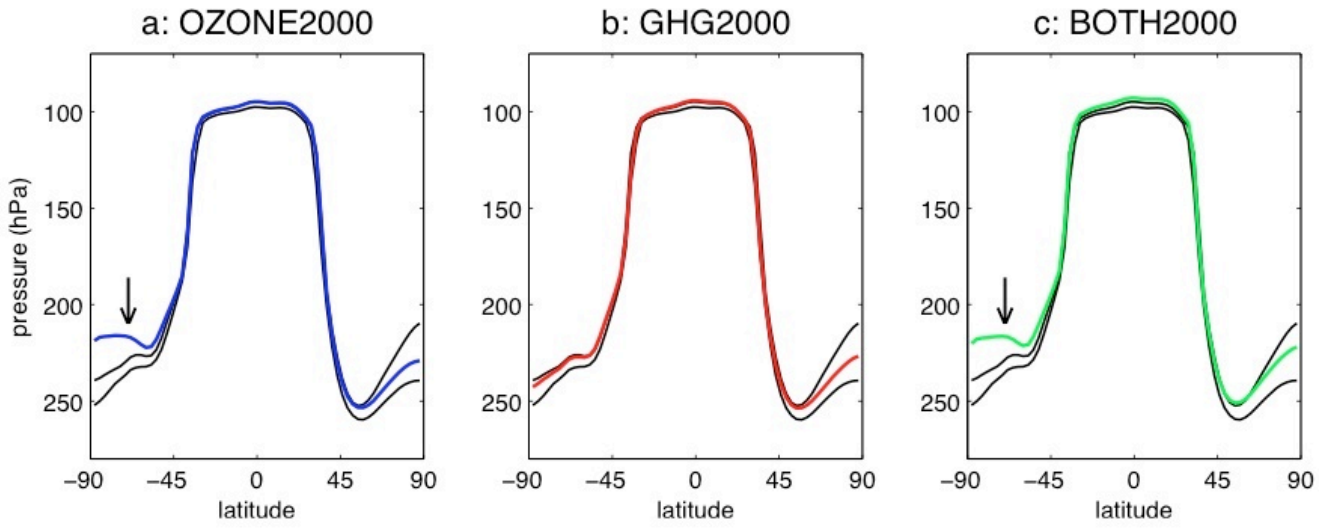
Ozone depletion causes poleward shift of subtropical jet

Simulations:
REF1960
OZONE2000
GHG2000
BOTH2000



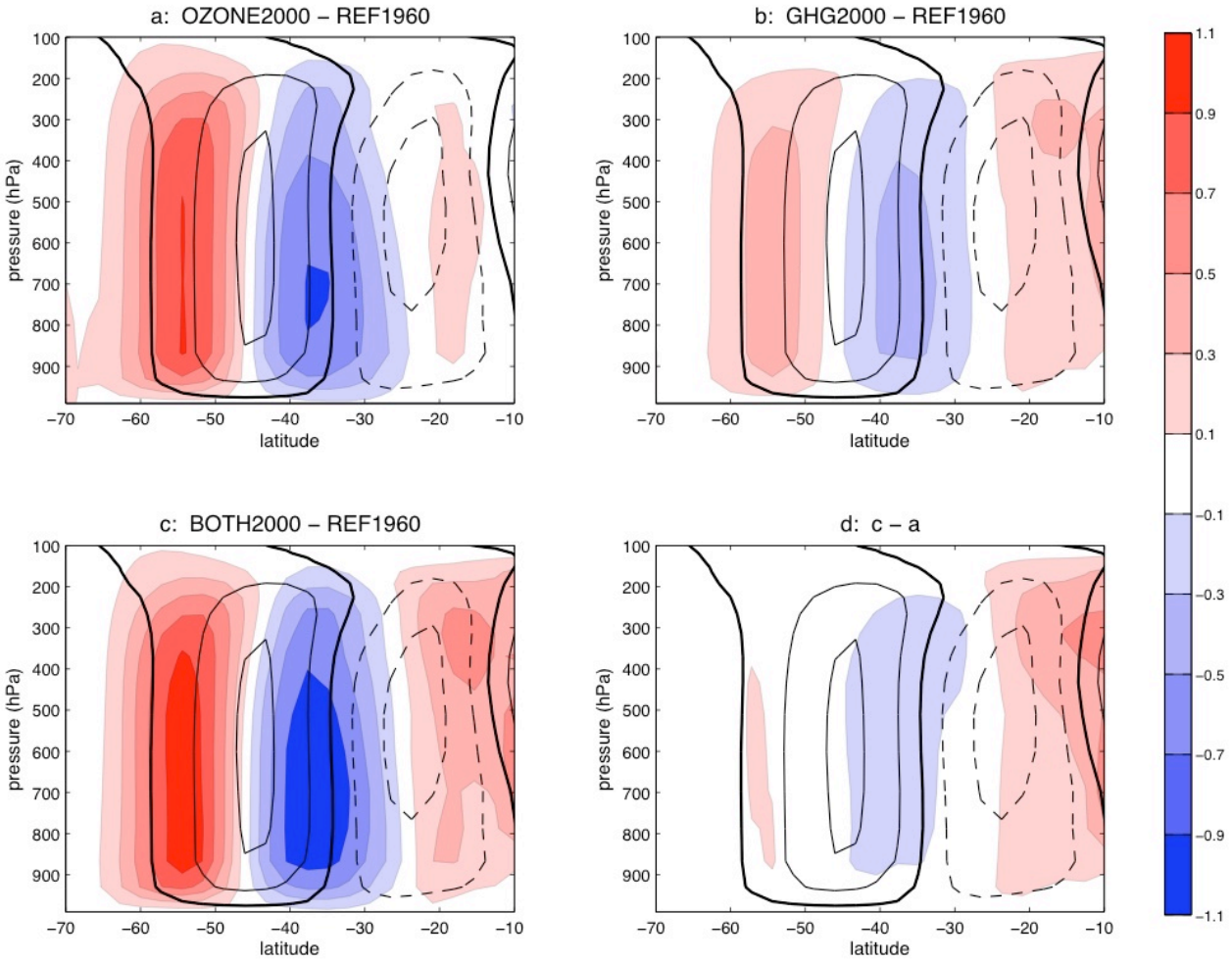
Polvani et al. 2010

Ozone depletion causes raise of tropopause over polar latitudes



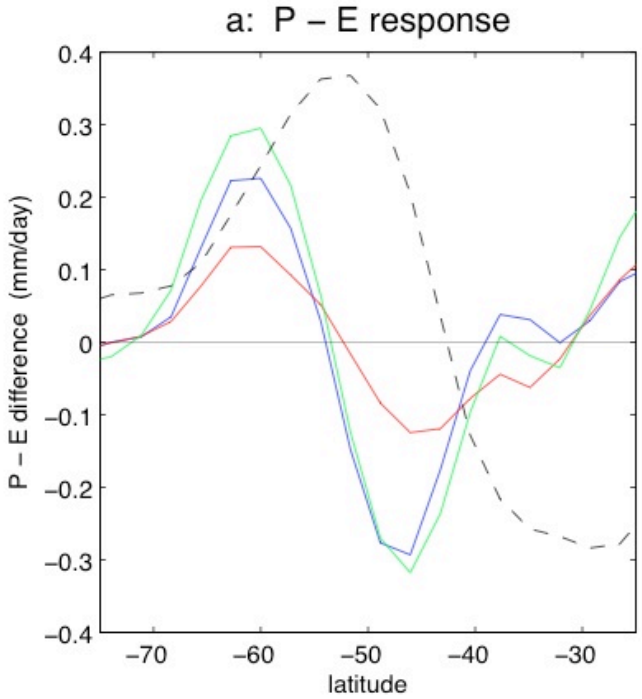
Polvani et al. 2010

Ozone depletion causes poleward shift of Hadley Cell boundary



Polvani et al. 2010

Polar ozone depletion causes a poleward expansion of subtropical dry zone

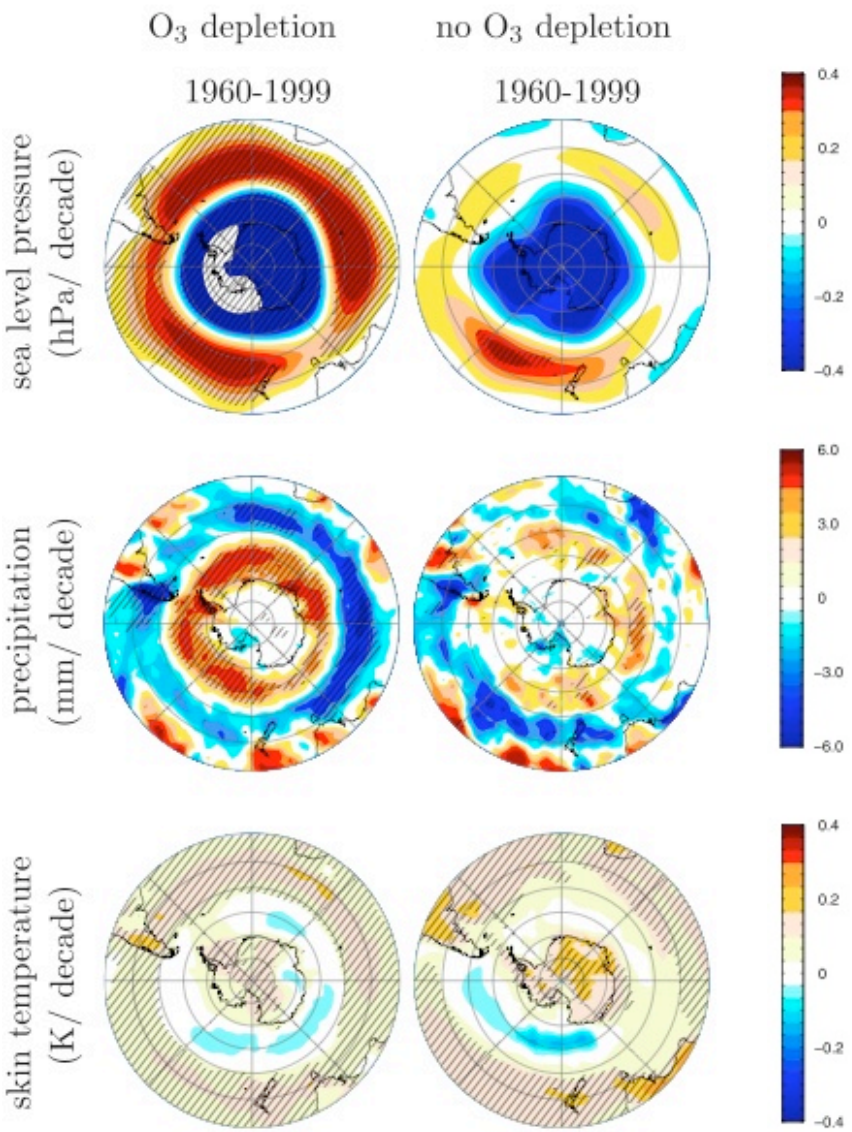


OZONE2000
GHG2000
BOTH2000

Polvani et al. 2010

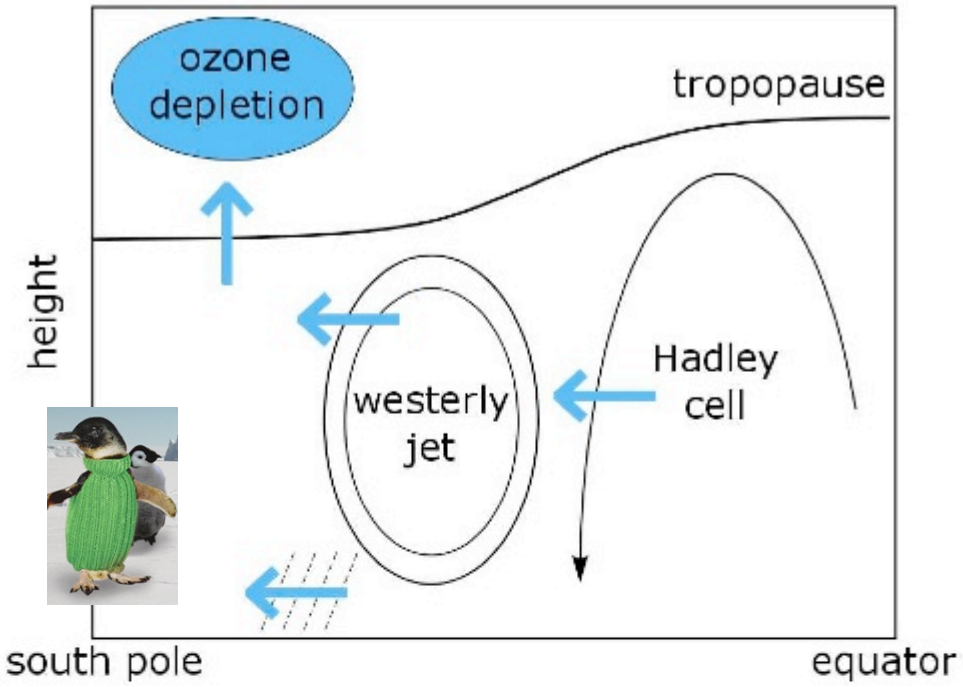
Polar ozone depletion has limited warming of Antarctic continent

Issue here: differences result not only from ozone forcing but also from different model sensitivity



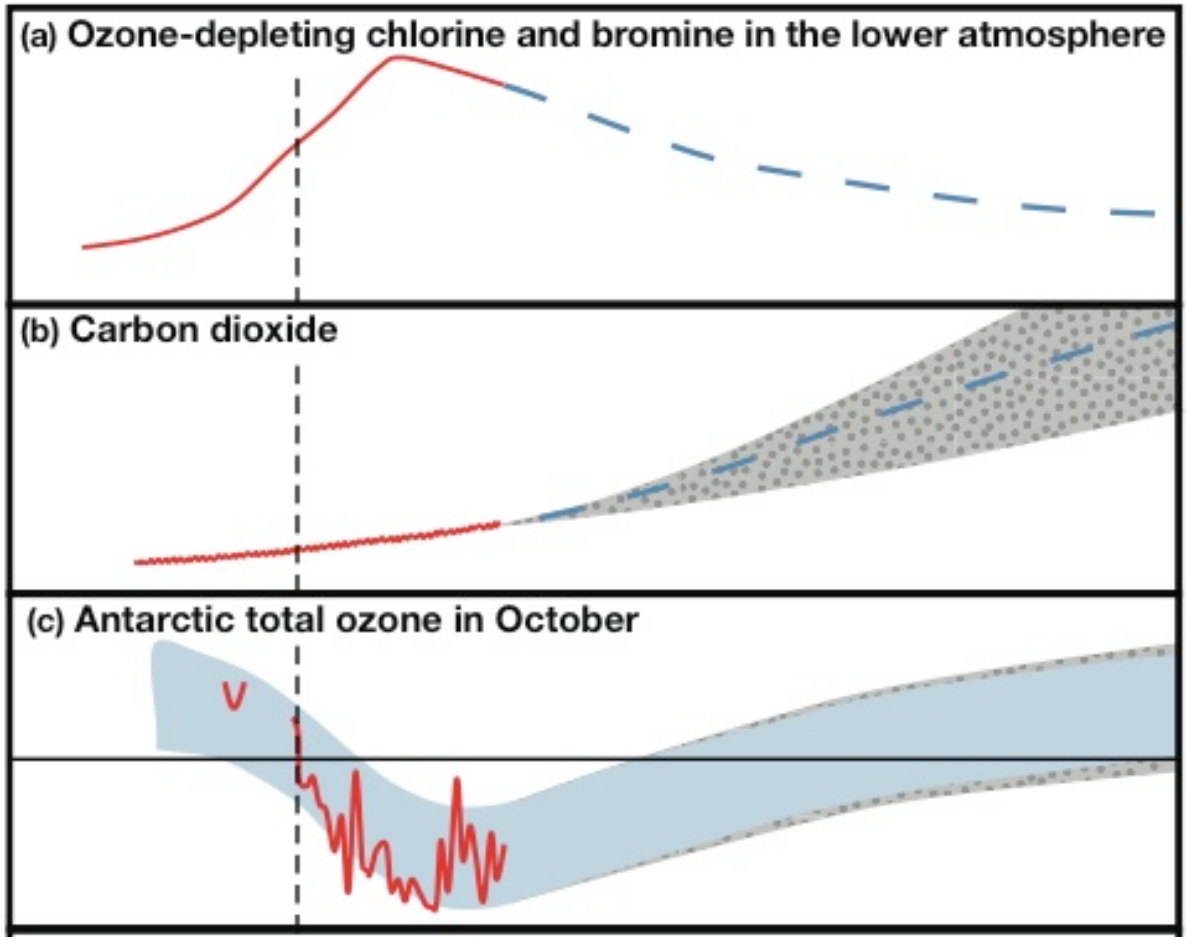
Son et al. 2009

Polar ozone depletion affects summertime Southern Hemisphere climate on a hemispheric scale



Son et al. 2010

What is going to happen during the 21st century?

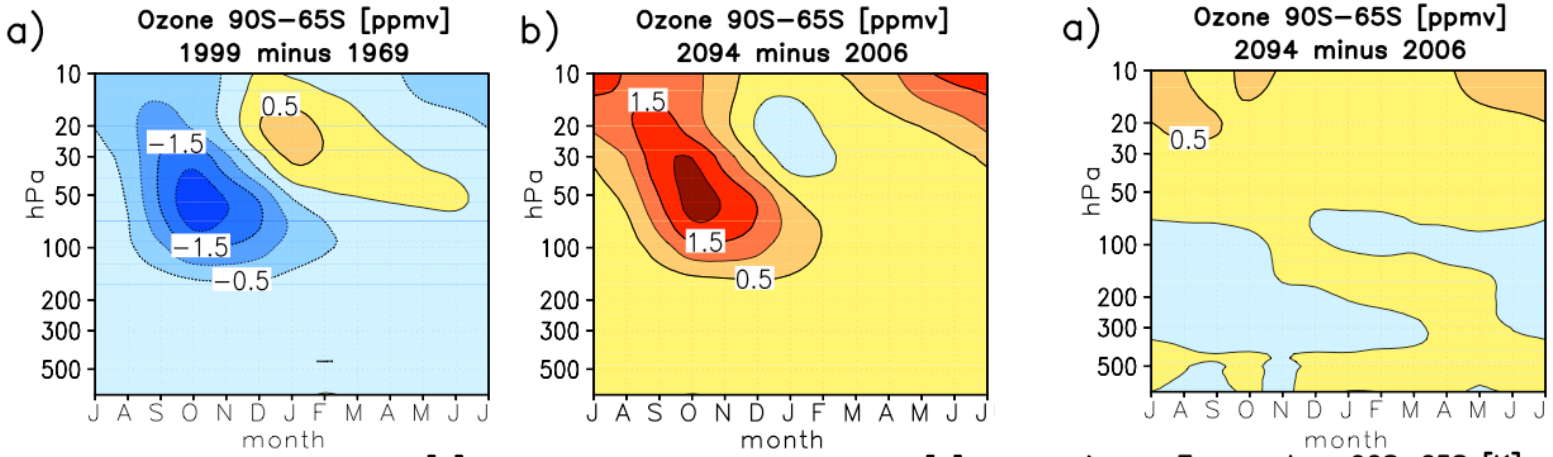


WMO/UNEP, 2010:

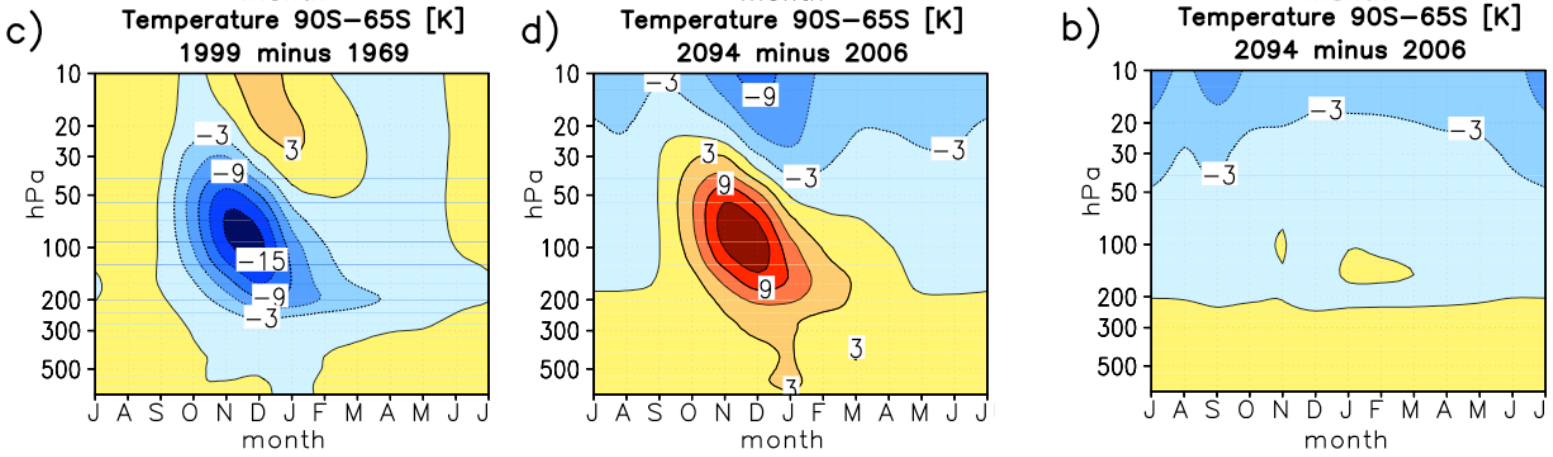
Antarctic O_3 & T

1999 - 1969 | **2094 - 2006** | **2094 - 2006 No Cl change**

ΔO_3

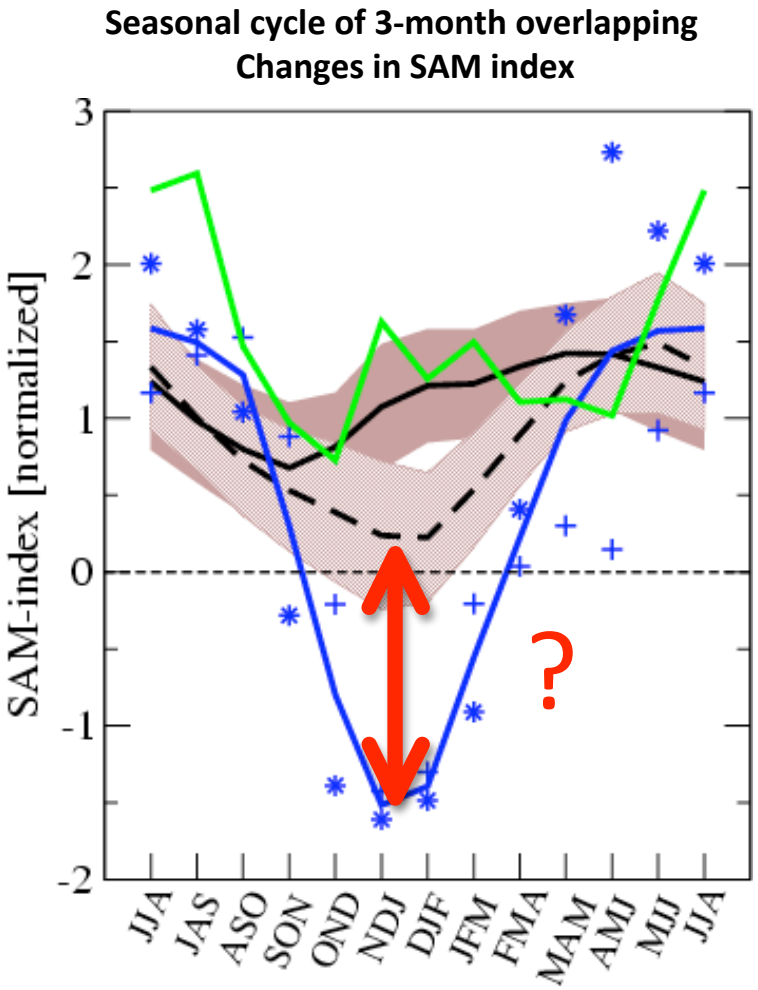


ΔT



Perlwitz et al 2008

SAM change during 21st Century



GEOS CCM, fixed Cl

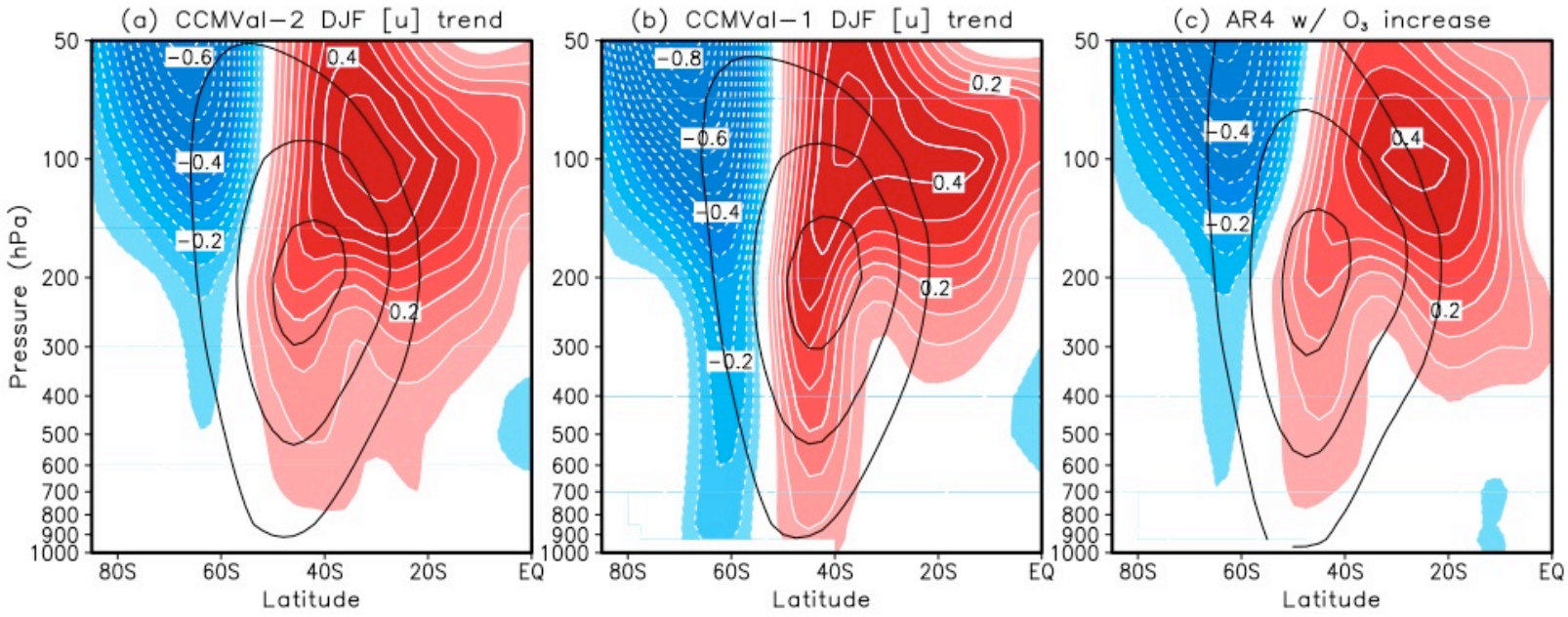
AR4 models, with no ozone recovery

AR4 models, with ozone recovery

GEOS CCM

2001-2050 Change in DJF Zonal Mean Zonal Wind

CCMVal-2 | CCMVal-1 | AR4 with Ozone

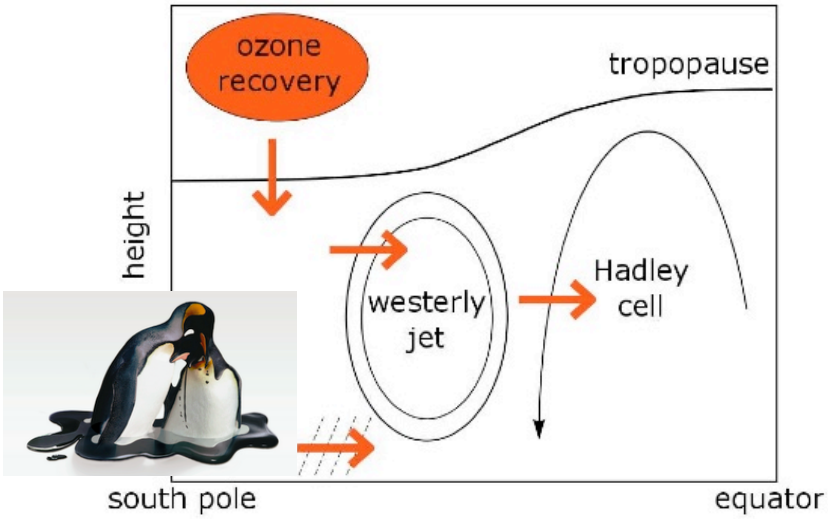


No change | Equatorward shift | no change

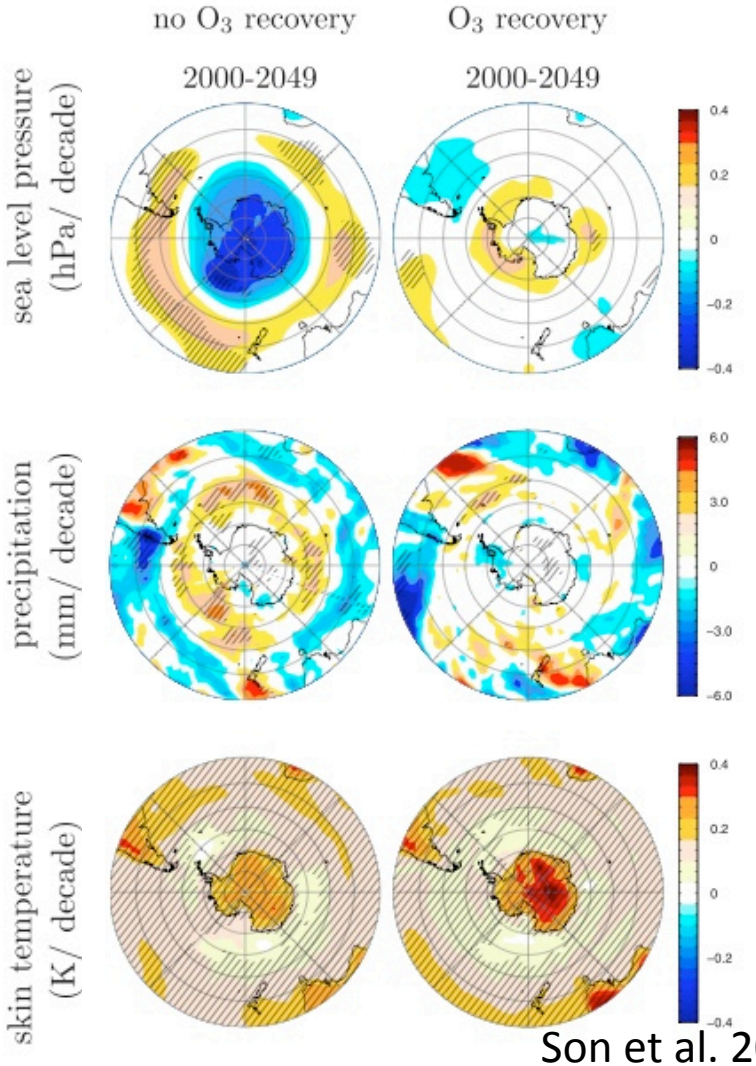
At this point, magnitude and sign of future summertime SAM changes during the 21st century is still uncertain. It is clear, however, that past trends will not continue.

Son et al.2010

Antarctic ozone hole recovery will modify the Southern Hemisphere climate response caused by GHG increase



Son et al. 2010



Son et al. 2009

Road Ahead

- CMIP5
  - More realistic ozone forcing is provided
  - Will include models with better resolved stratosphere
- Further development of Chemistry Climate models (increased number of CCMs coupled to an ocean/sea ice model)
- Non-zonal climate impacts of stratospheric ozone changes
  - For new results on this topic: http://www.esrl.noaa.gov/psd/people/judith.perlwitz/pubs.html
- SPARC Workshop on Dynamics and Variability (DynVar) of the Stratosphere-Troposphere System (November 3-5, 2010 at NOAA ESRL in Boulder)

Summary

- Antarctic ozone changes are an important driver of **summertime** Southern Hemisphere climate
- Impact of ozone changes involves both zonal and non-zonal tropospheric circulation changes.
- During the 21st century, the atmosphere will most likely not go back to a state of pre-ozone depletion because of climate change
- Our understanding about the relative contribution of ozone hole recovery and anthropogenic increase of well mixed greenhouse gases on future southern hemisphere climate is evolving.
- **Linear trend diagnostics with start point in the past and end point somewhere in the 21st are not appropriate!!!**