Anthropogenic influence on atmospheric circulation: A driver of (regional) climate change?

David W. J. Thompson
Department of Atmospheric Science
Colorado State University

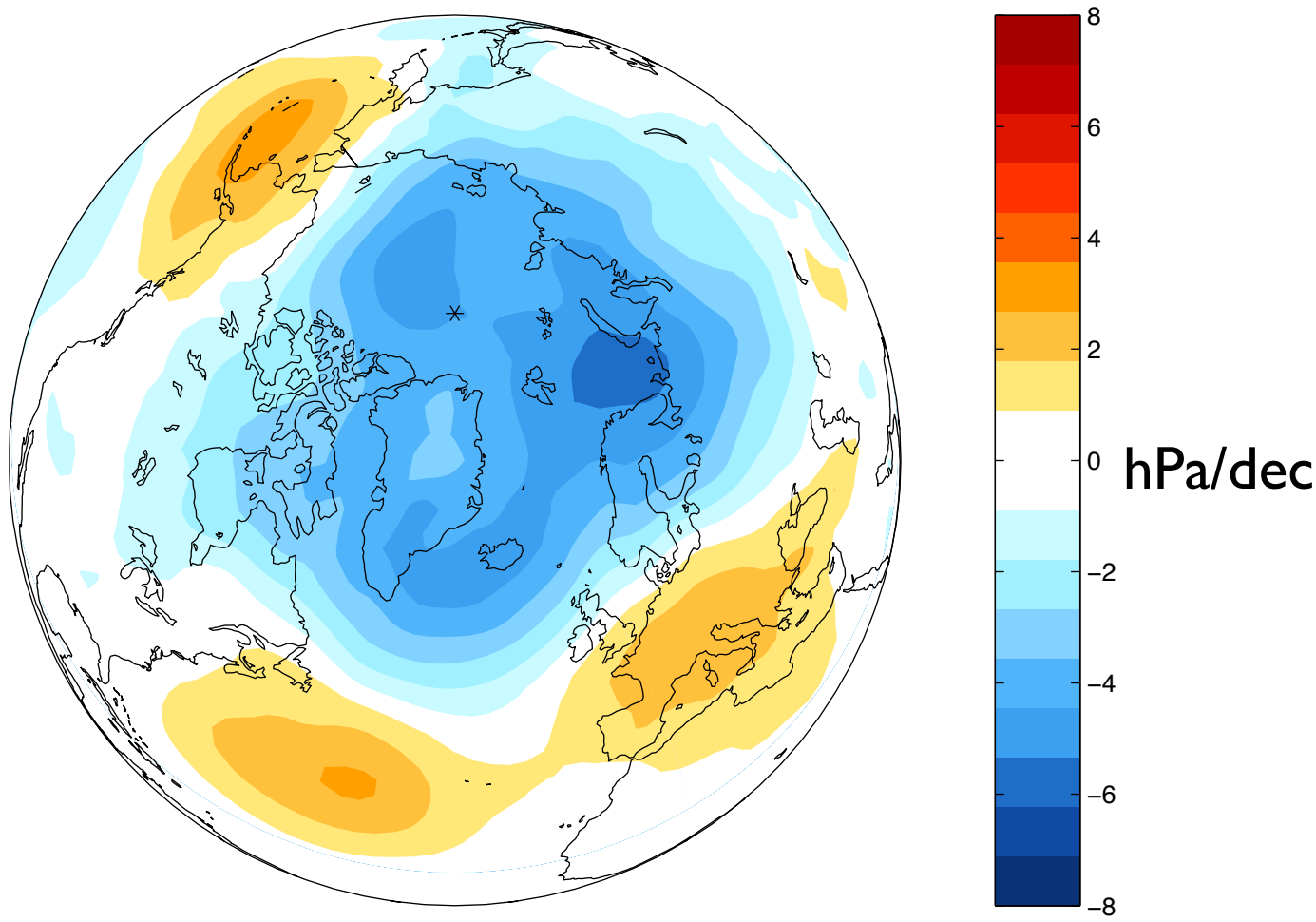
I) Observed circulation trends

II) Why the trends matter for regional climate

III) Mechanisms and outlook for the future

IV) The physics...

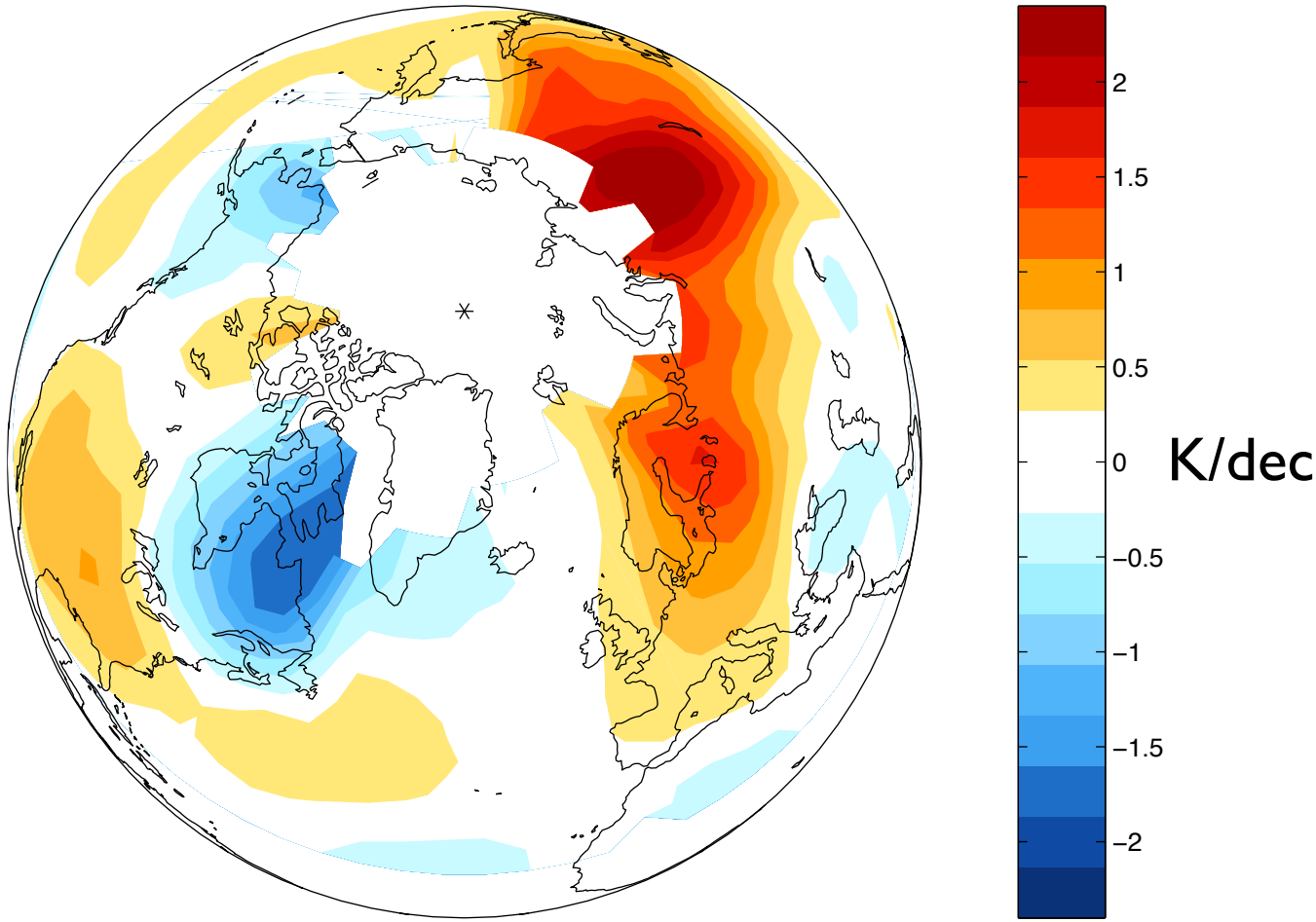
Wintertime pressure trends 1979-1997



- Trend towards stronger eastward flow ~55 north
- Trends extend from surface to stratosphere.

(Walsh; Graf; Kodera; Hurrell; Thompson/Wallace; etc)

Wintertime temperature trends 1979-1997

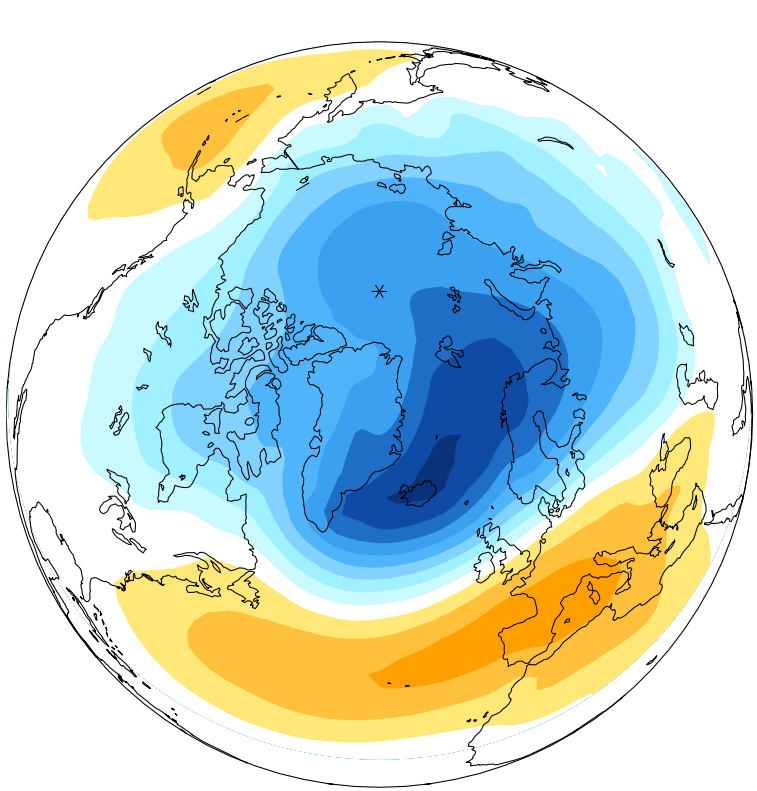


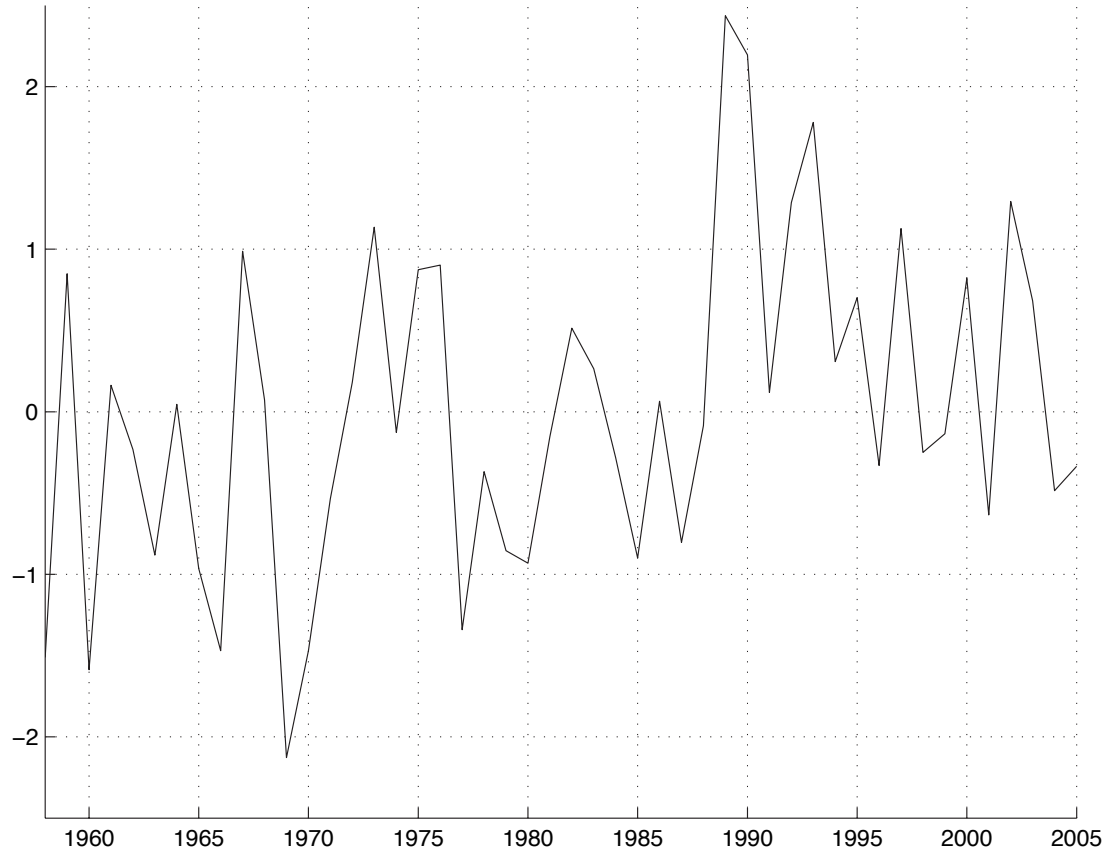
Circulation trends profoundly affect regional climate

(Hurrell; Thompson/Wallace; etc.)

Data from CRU

Time series of NAO/NAM

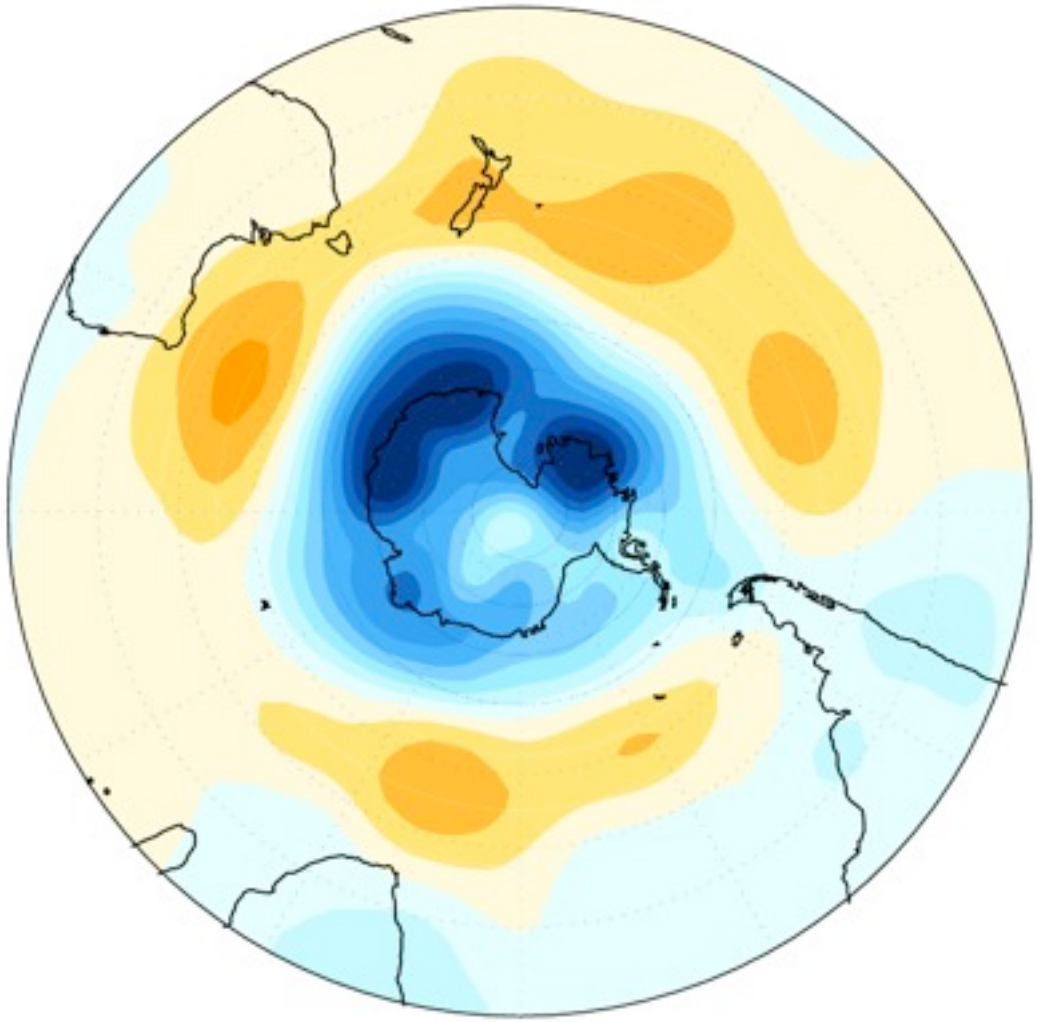




- Trends resemble the Northern annular mode/NAO
- Trends largest through late 1990s.

(Hurrell; Thompson/Wallace; etc.)

Pressure trends 1979-2000

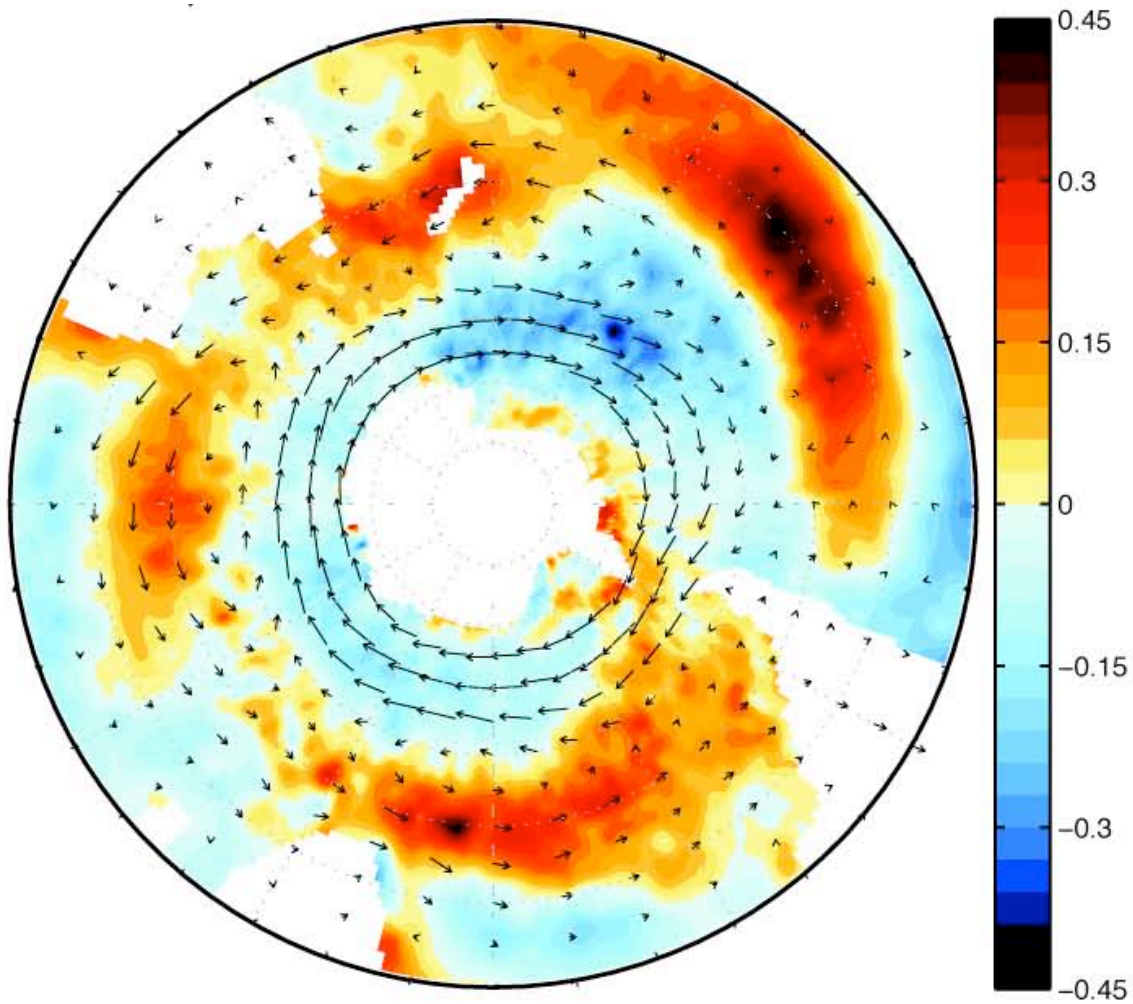


Peak ~40 m

- Southern Hemisphere summertime trends.
- Trends resemble the Southern annular mode.

(Thompson/Solomon)

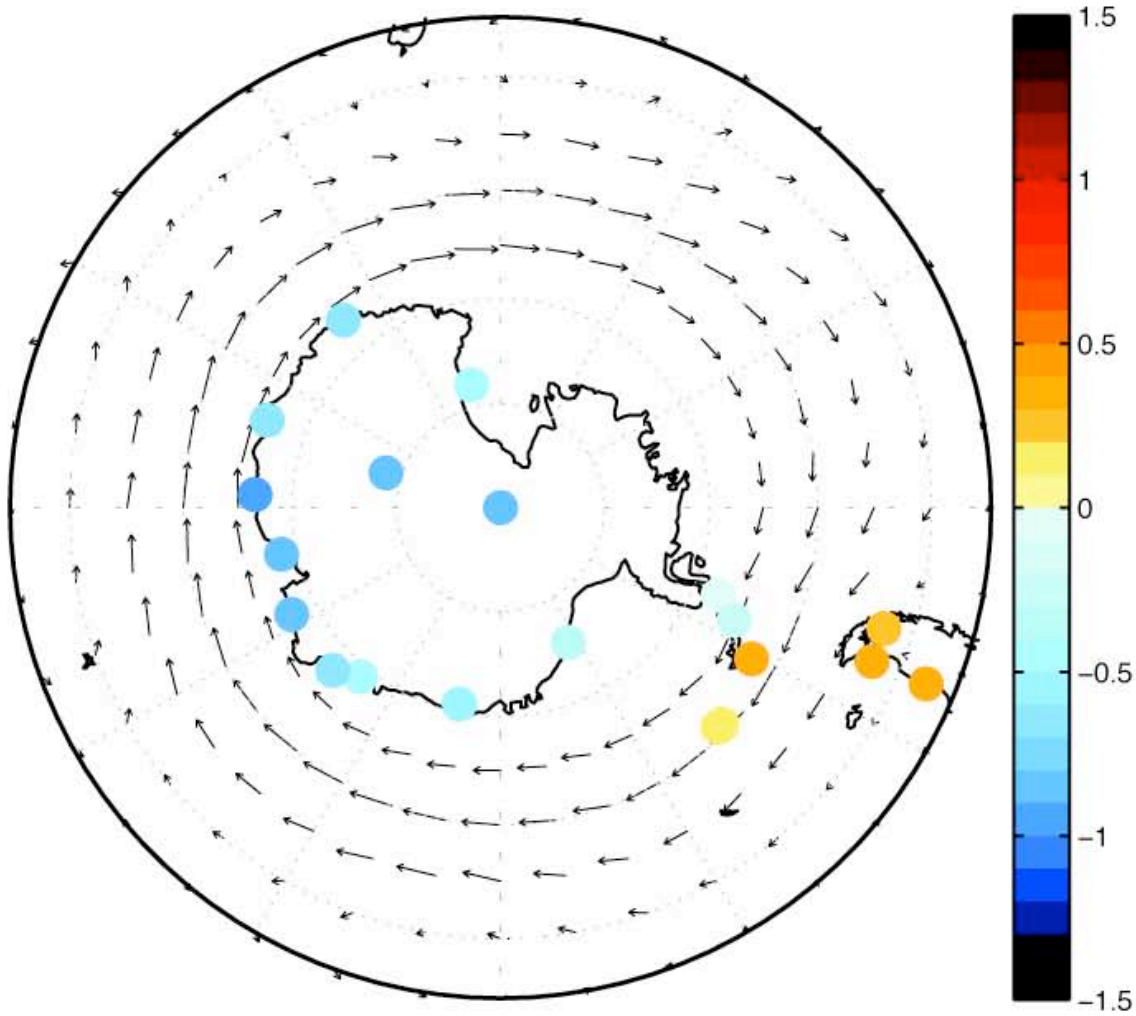
Climate changes associated with the SAM



Sea surface temperatures and winds.

(Lovenduski; Gruber; Ciasto; England; Marshall; Rintoul; Fyfe)

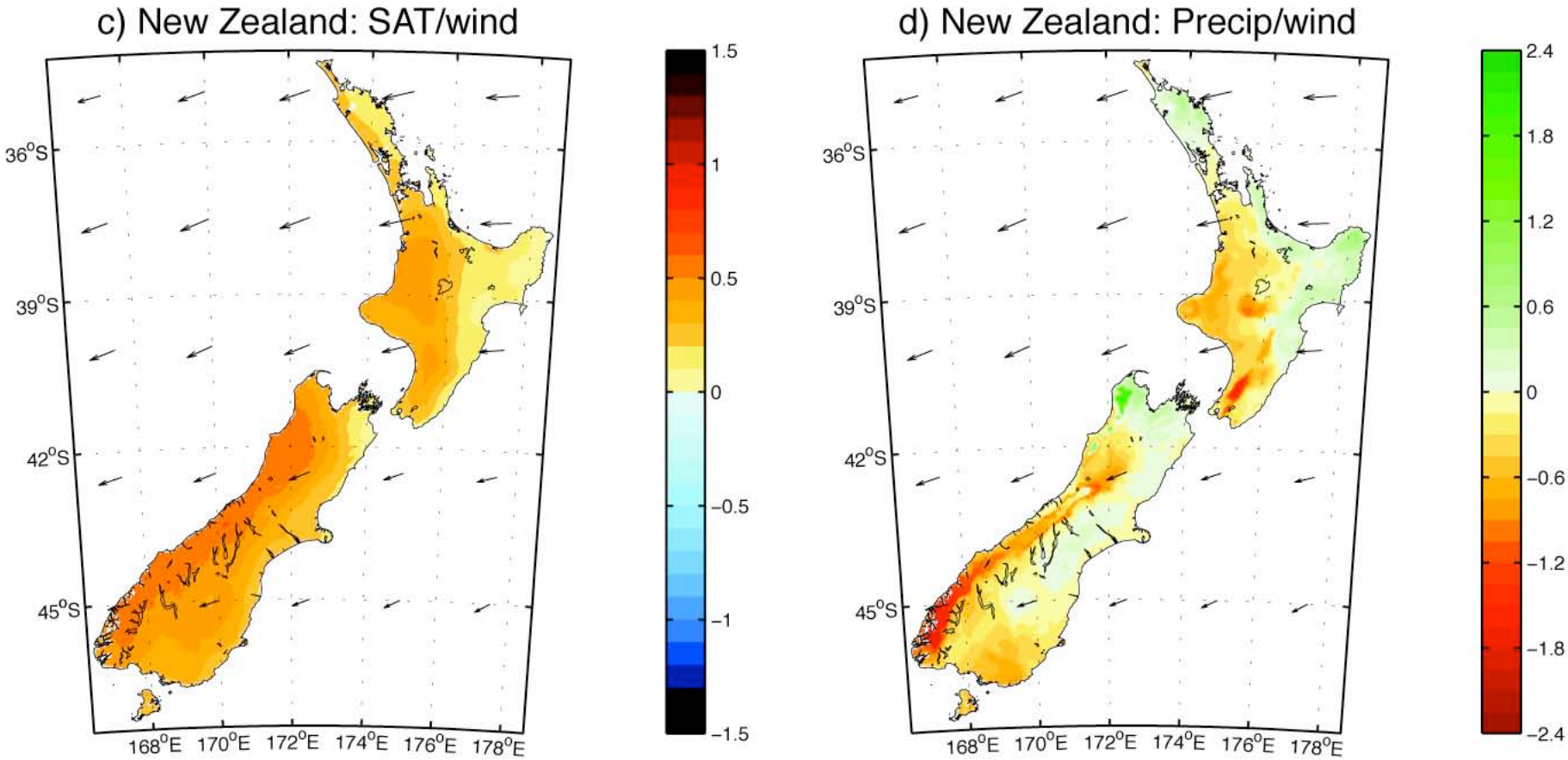
Climate changes associated with the SAM



Surface temperatures and winds.

(Thompson/Solomon; Marshall; Schneider)

Climate changes associated with the SAM

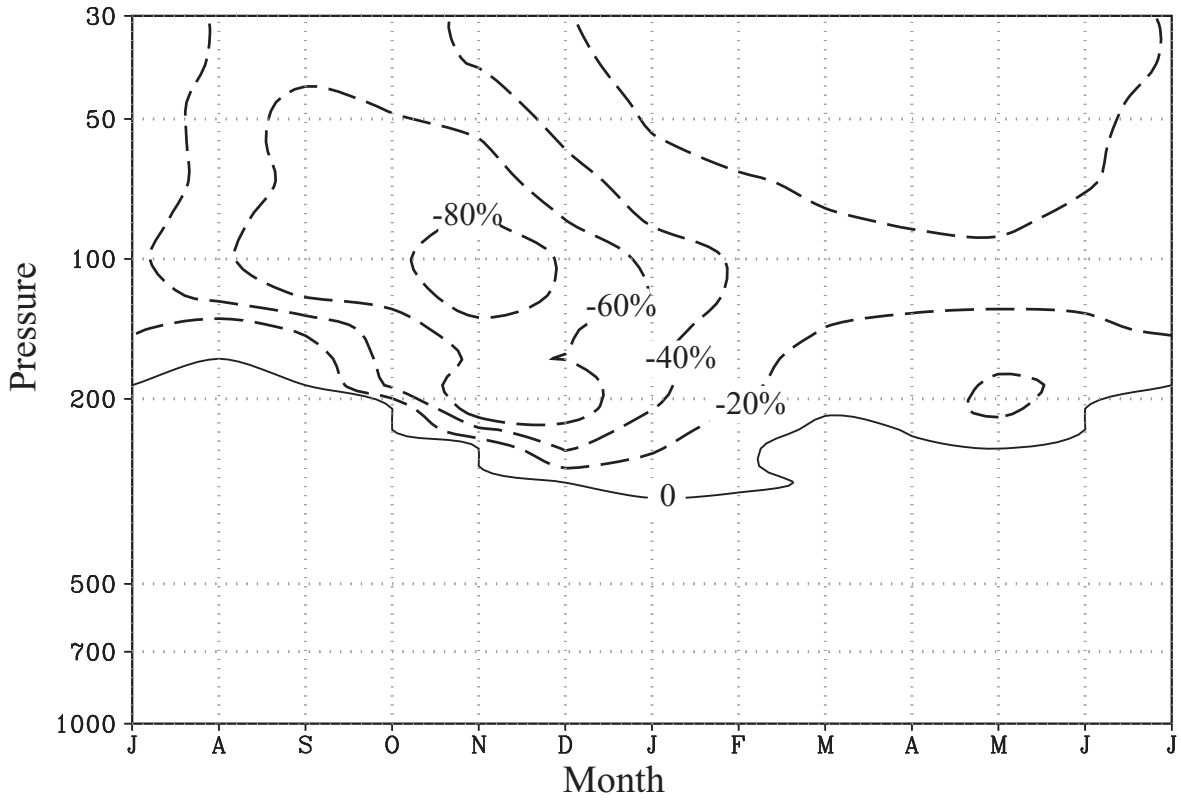


Temperatures, precipitation and winds.

what drives the trends in the atmospheric circulation?

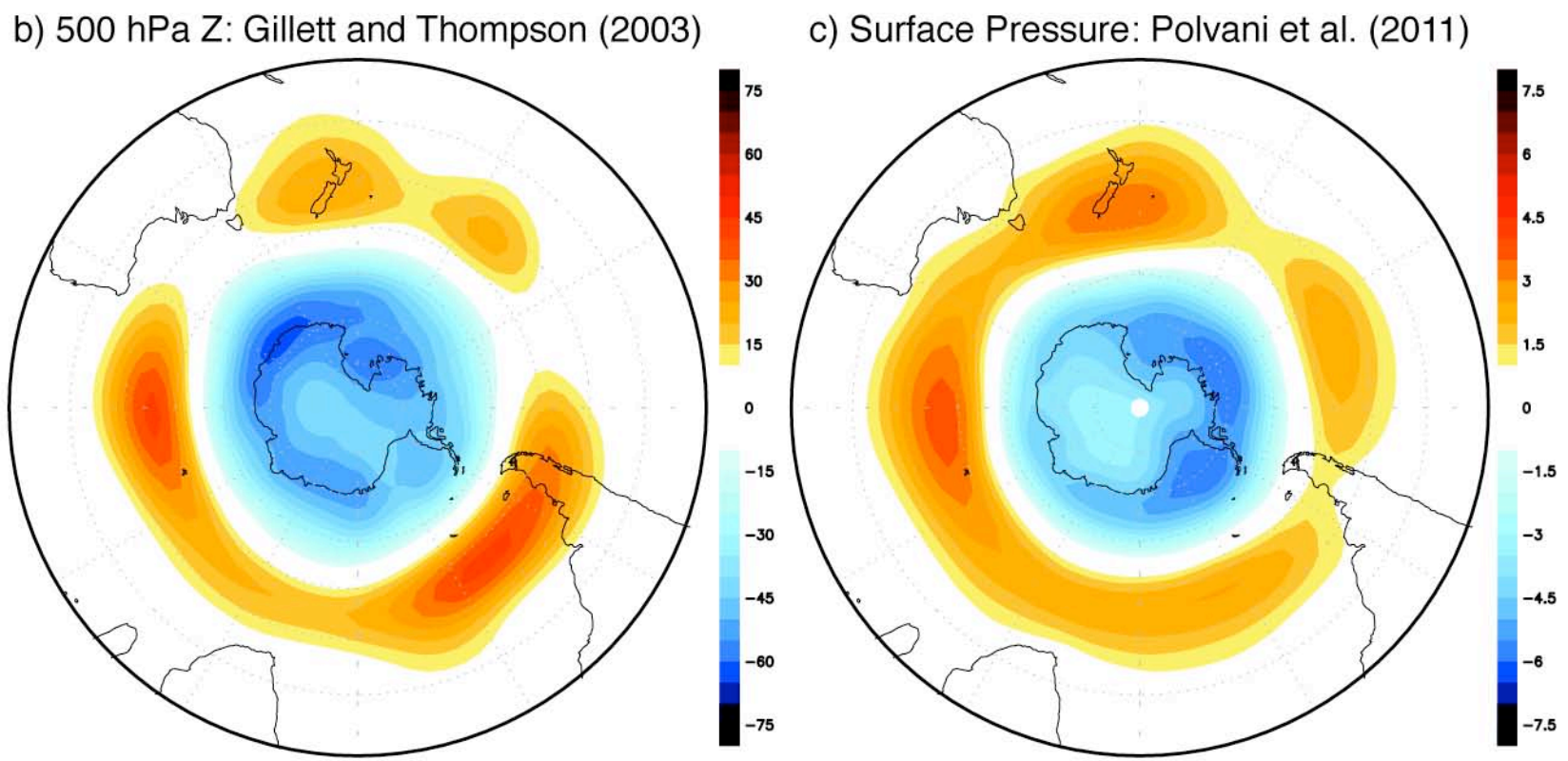
what are the underlying physical mechanisms?

Observed Antarctic ozone depletion 1979-2000.



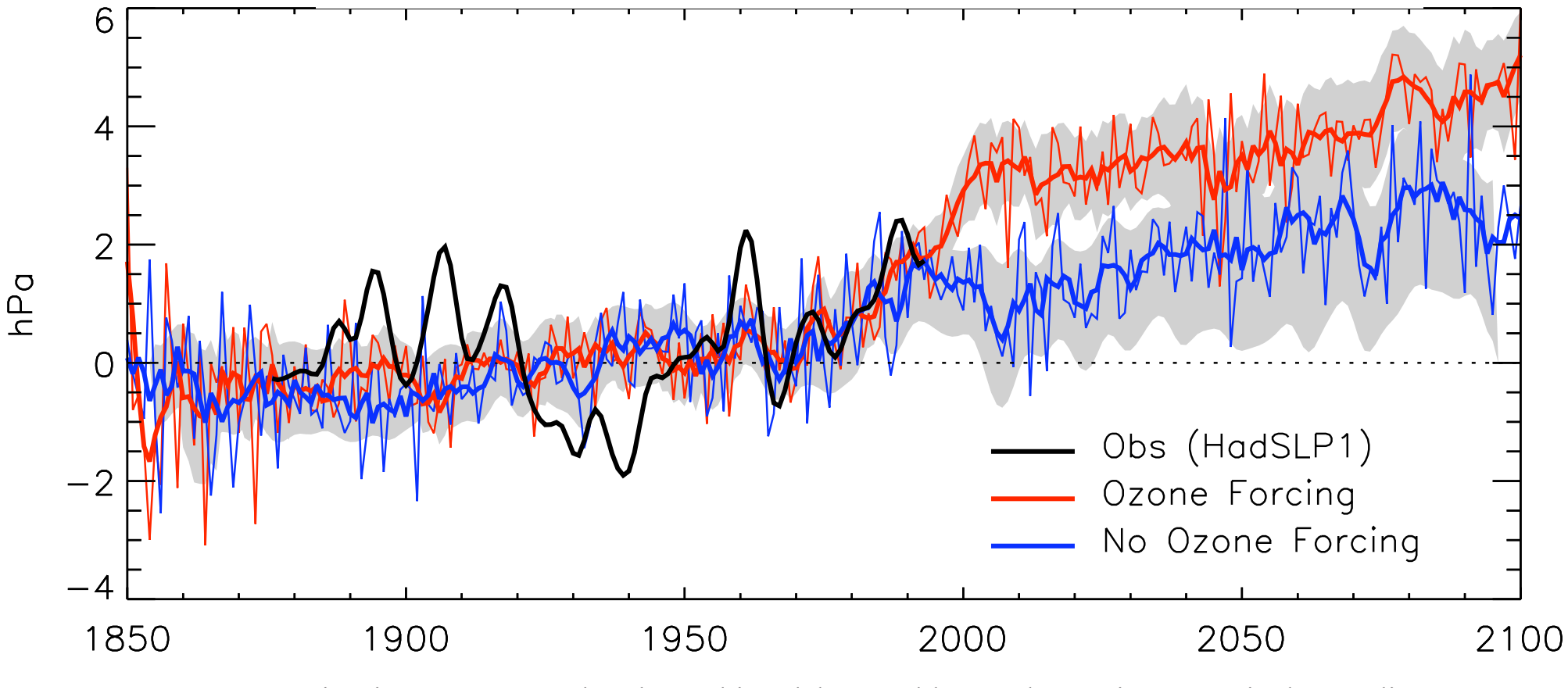
data Randel and Wu

Simulated response to ozone depletion.



(response is extremely robust in a range of experiments)

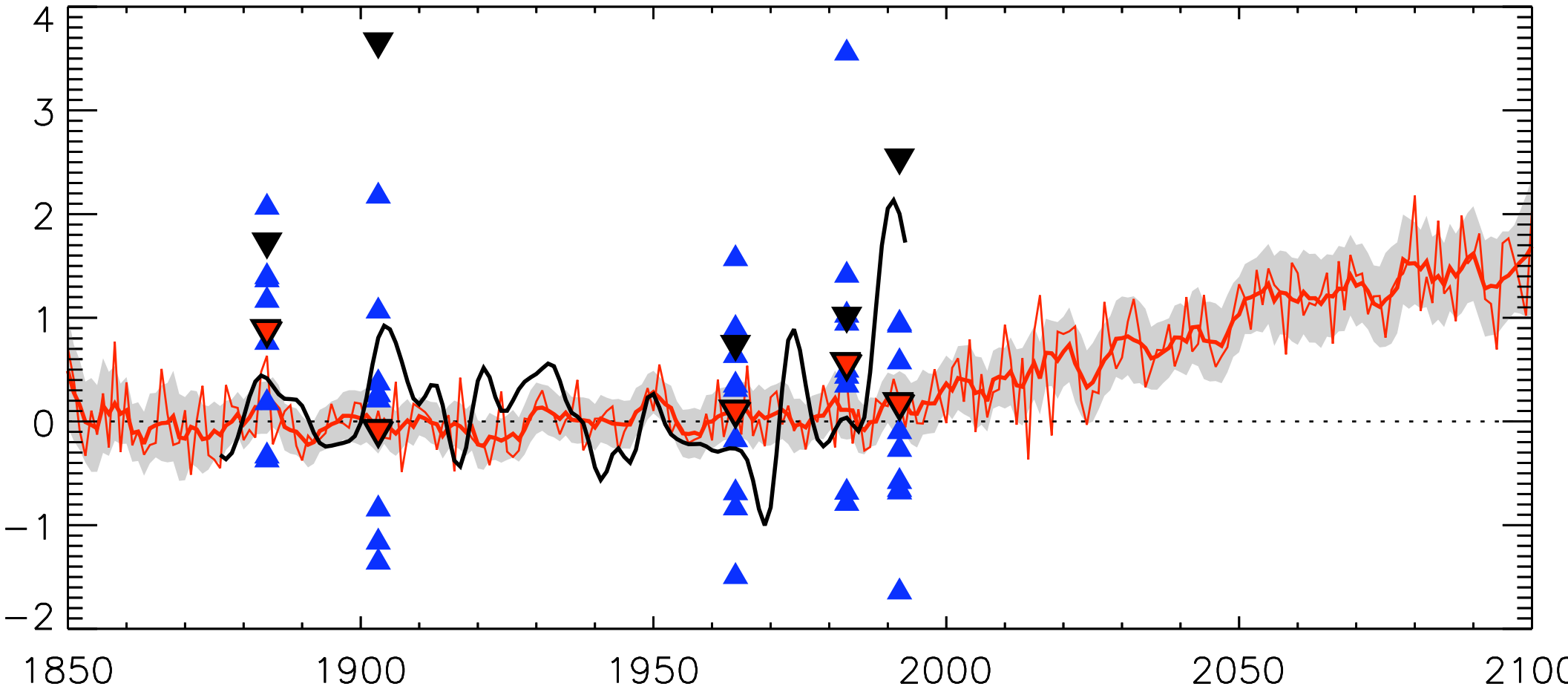
Simulated response to greenhouse gases: SAM



Miller et al. 2006

Also: Fyfe et al. 1999; Kushner et al. 2001; Cai et al. 2003; Yin 2005; Miller et al. 2006; Arblaster and Meehl 2006; Lu et al. 2008; Chen et al. 2008

Simulated response to greenhouse gases: NAM



Miller et al. 2006

Also: Shindell; Graf

what drives the trends in the atmospheric circulation?

Both ozone depletion and increasing CO2 drive robust simulated changes in the circulation similar to the observed trends.

what are the underlying physical mechanisms?

This is a wide open research question.

I will show

1) a sample hypothesis

2) a sample method for testing the hypothesis

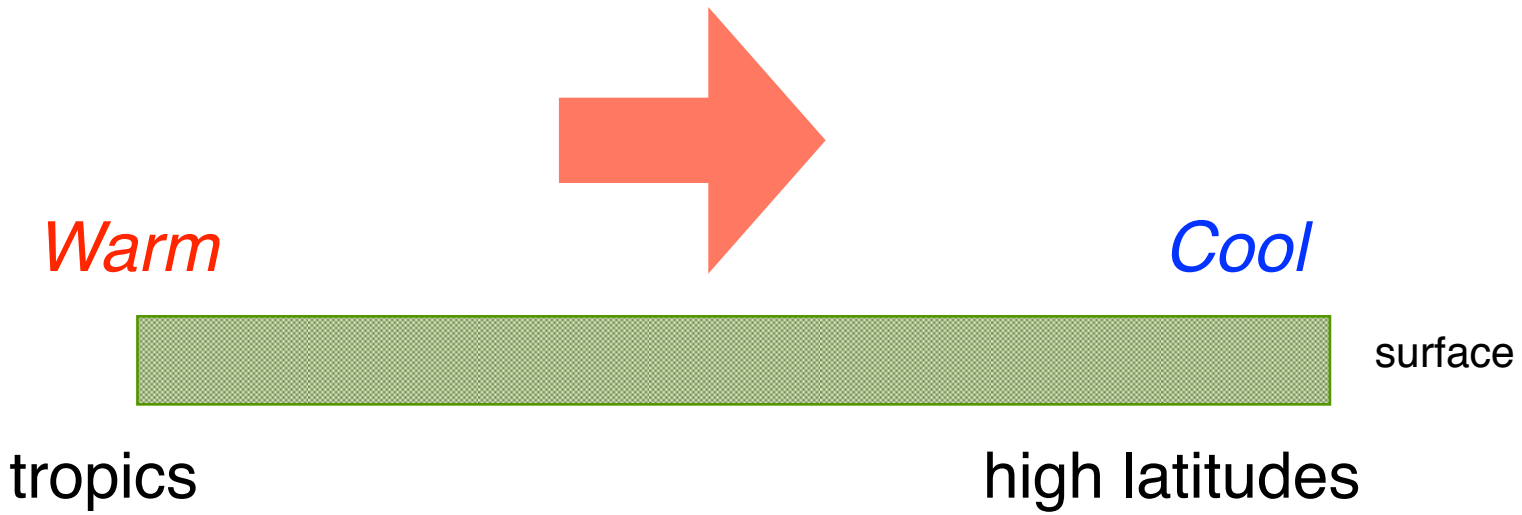
The atmospheric circulation as turbulence.

e.g., Green 1970; Held 1999

The atmospheric circulation as turbulence.

- *large heat fluxes by atmospheric waves (storms) coincide with regions of large temperature gradients.*

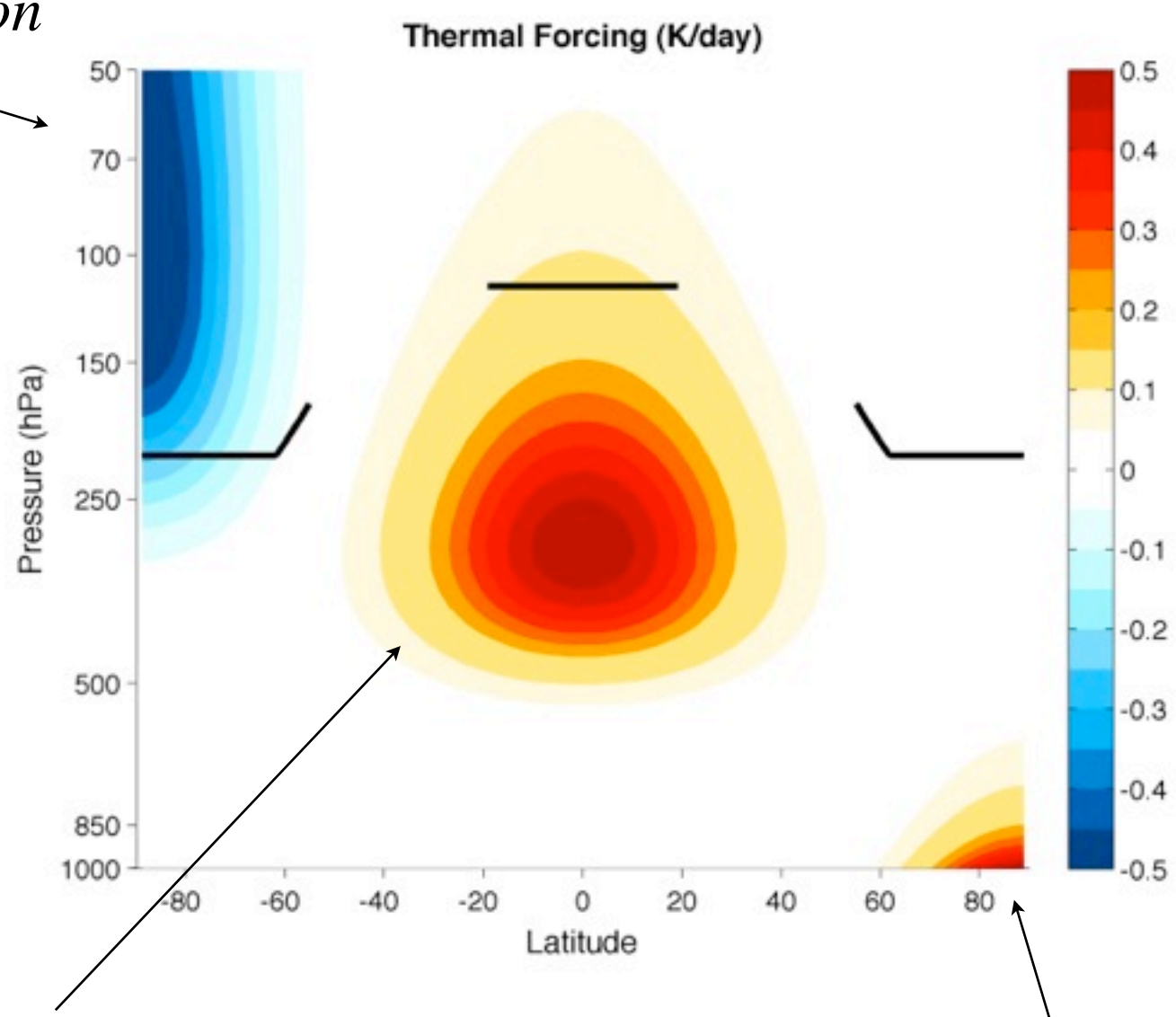
- *amplitude of heat fluxes (and thus of storms) is proportional to the amplitude of the temperature gradients*



e.g., Green 1970; Held 1999

Climate change and gradients in temperature

ozone depletion

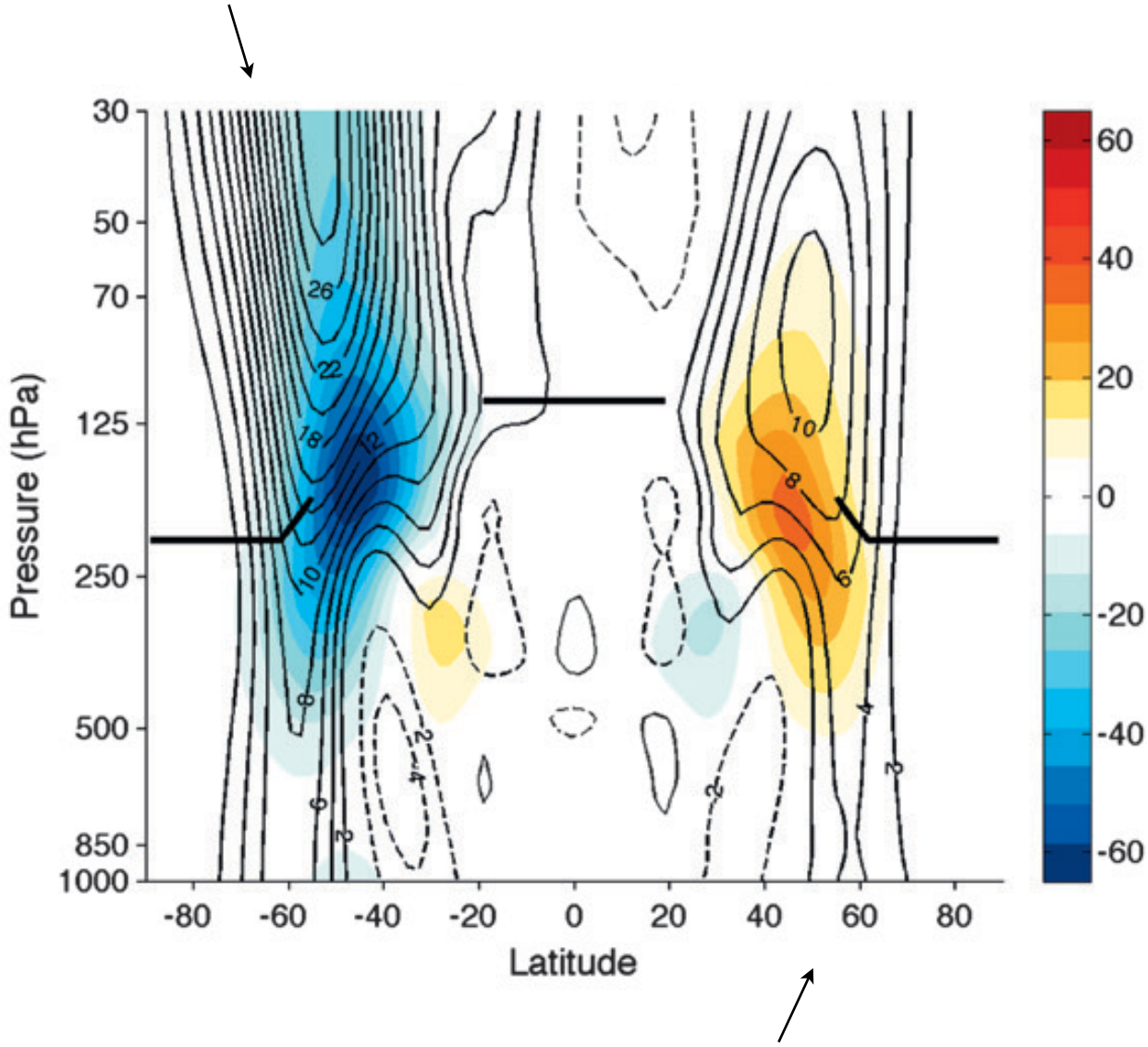


heating peaks in tropical troposphere

ice feedbacks

Idealized model response (wind in contours)

large increases in the wind near 60 south



weaker increases in the wind near 60 north

- Regional climate change is strongly influenced by changes in the atmospheric circulation (in some regions, more than it is by the global-mean warming)

- Numerical models suggest ozone depletion and CO2 have and will play a key role in extratropical circulation trends.

- The circulation response to ozone depletion and increasing CO2 is among the most robust responses found in climate change experiments.

- The mechanisms whereby anthropogenic forcing drives changes in the circulation remain unclear. UNDERSTANDING THE MECHANISMS IS KEY.