Ozone/Climate Coupling: New Challenges

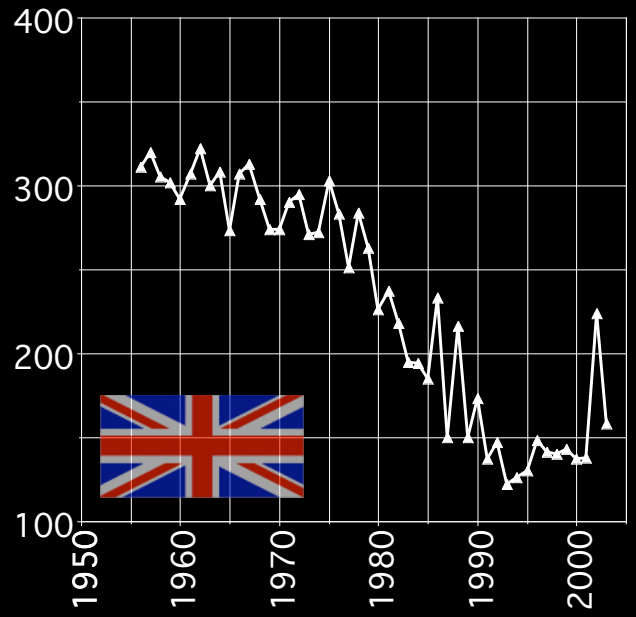
Susan Solomon Senior Scientist, NOAA Boulder, CO

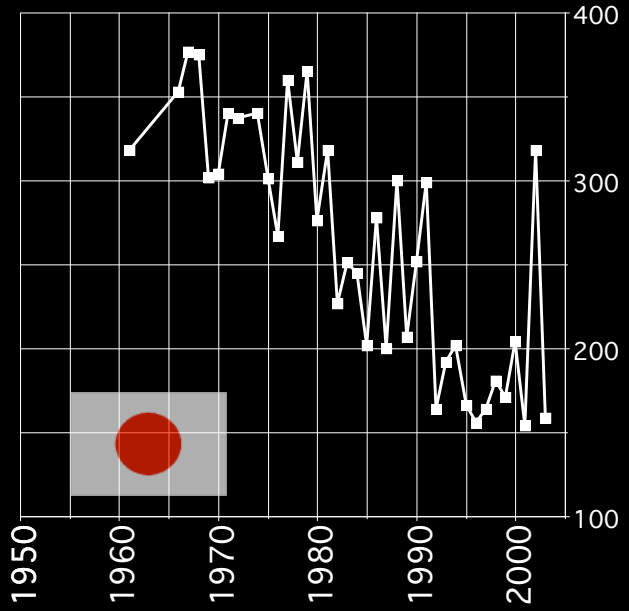
1. Polar stratospheric change and surface climate: SAM and NAM
2. How Montreal helped Kyoto, and can help more
3. Brewer-Dobson circulation changes: Mechanism(s)? Implications? Expansion of tropics/link to drought? H2O? Ozone?

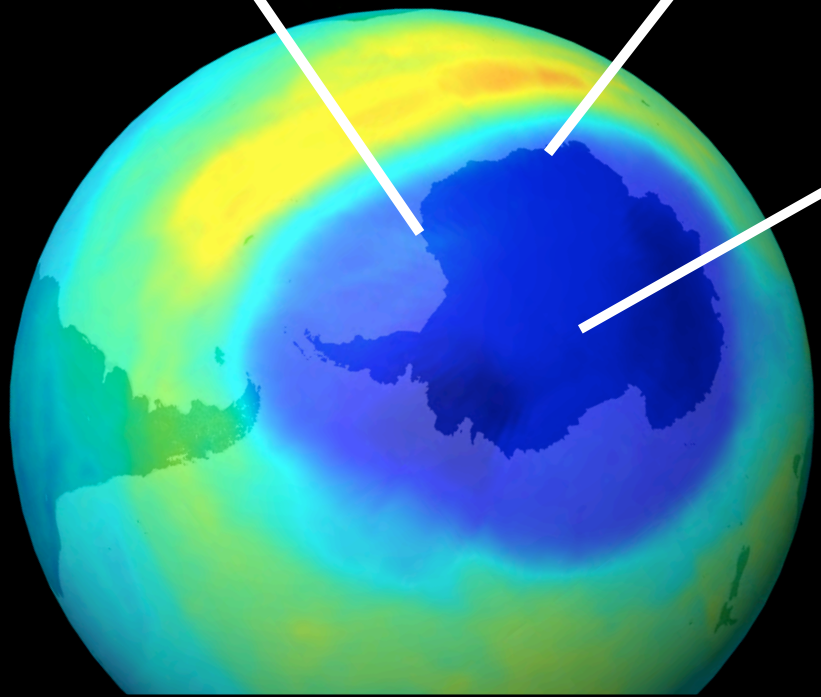
My Key Conclusion:

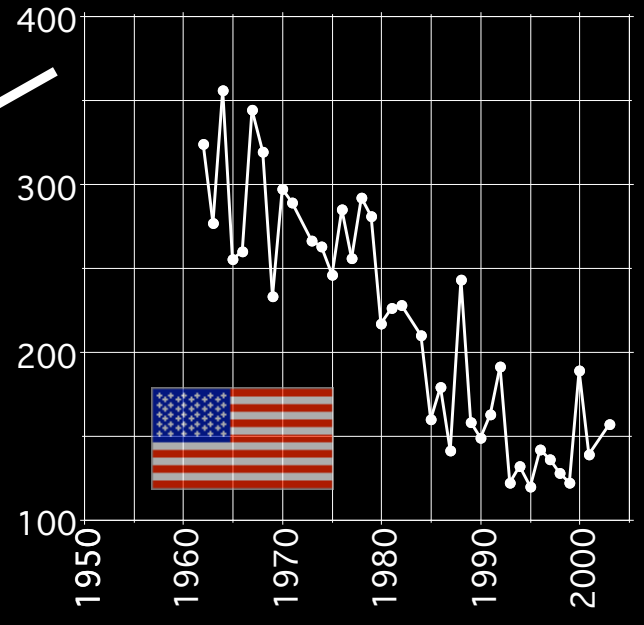
There has never been a better time to invest yourself In stratospheric processes and their role in climate.

The Antarctic ozone hole



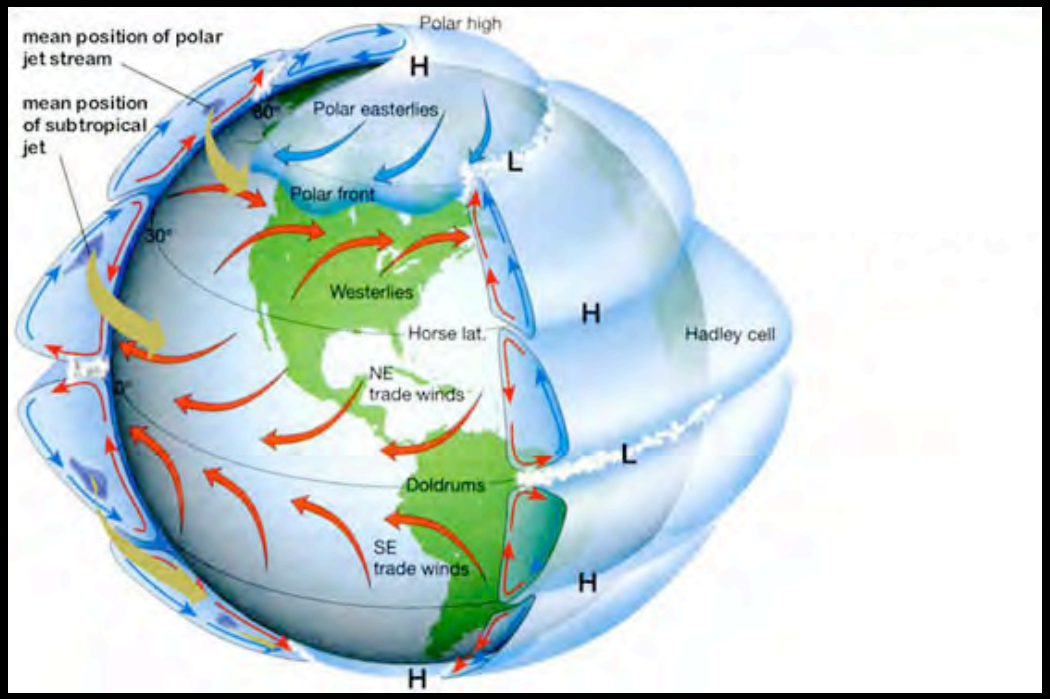


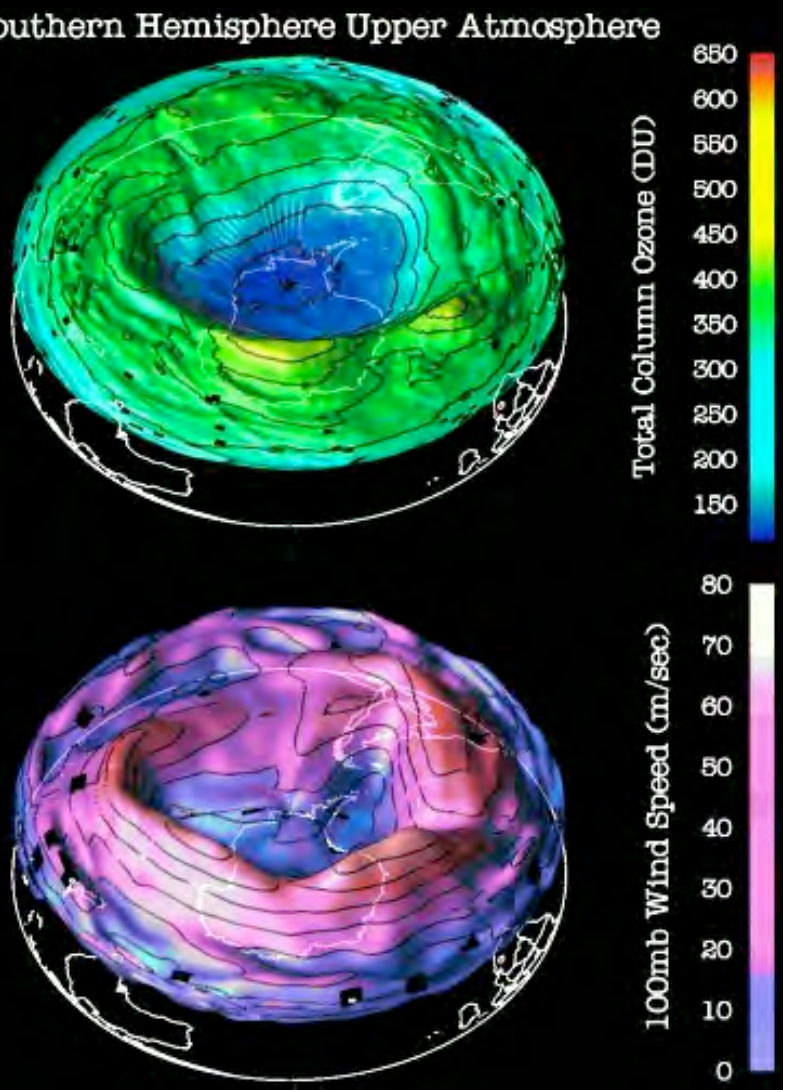




Ozone and Climate in the Vortex

A fundamental aspect of temperature, wind, and climate variability in the polar regions

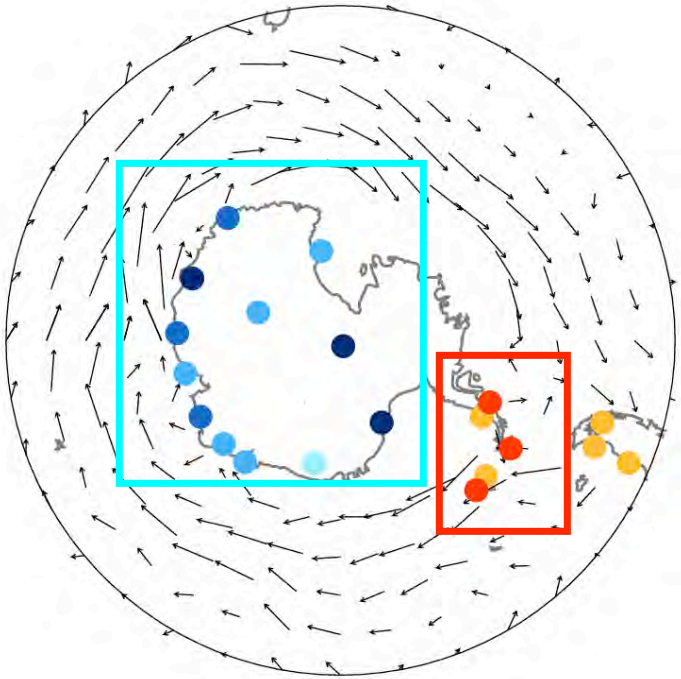




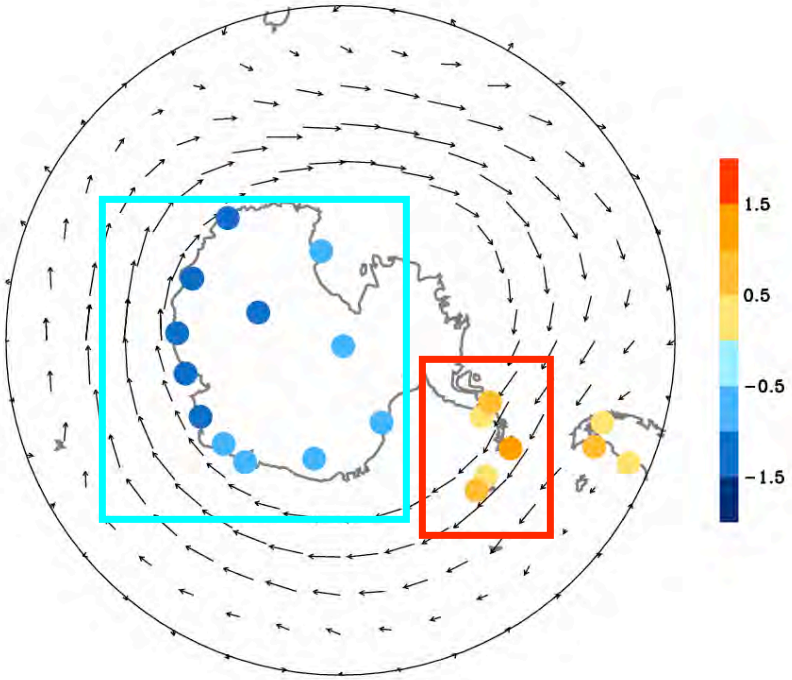
Less ozone-> colder, tighter vortex in stratosphere.
Effects on troposphere?

Recent surface climate trends and the vortex

Total trends



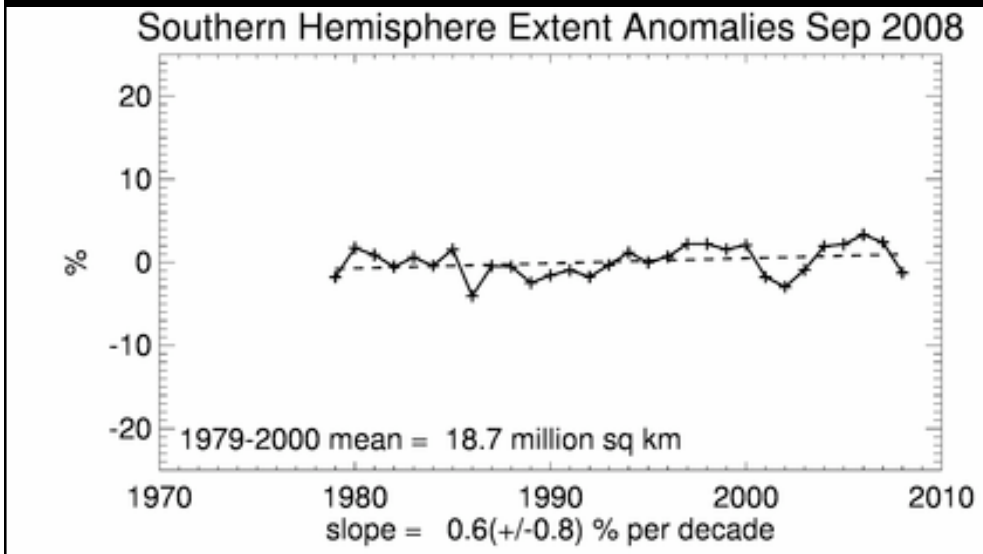
Congruent with SAM

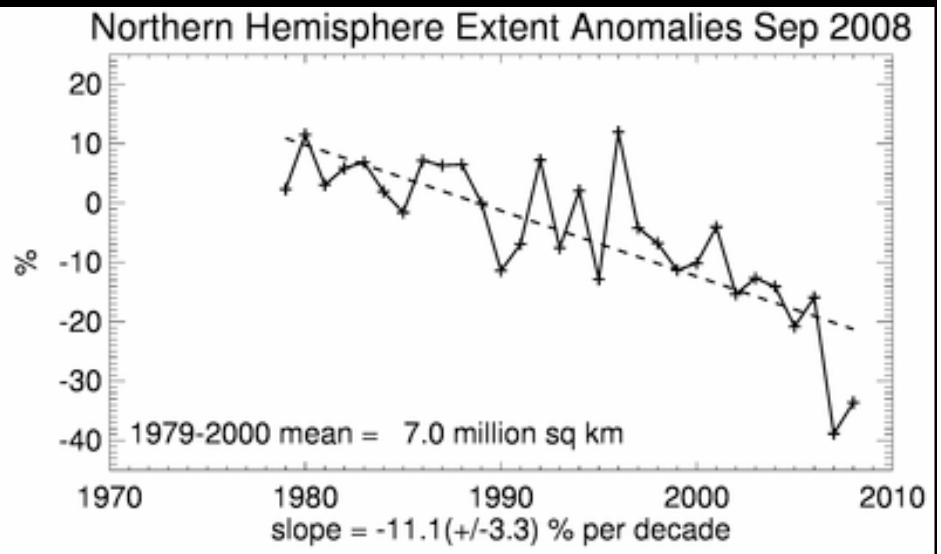


Recent trends in surface temperature and wind (Dec-May 1969-2000).
Stronger vortex: cold air stays bottled up in the vortex, so the plateau gets colder while the peninsula gets warmer

Thompson and Solomon Science 2002

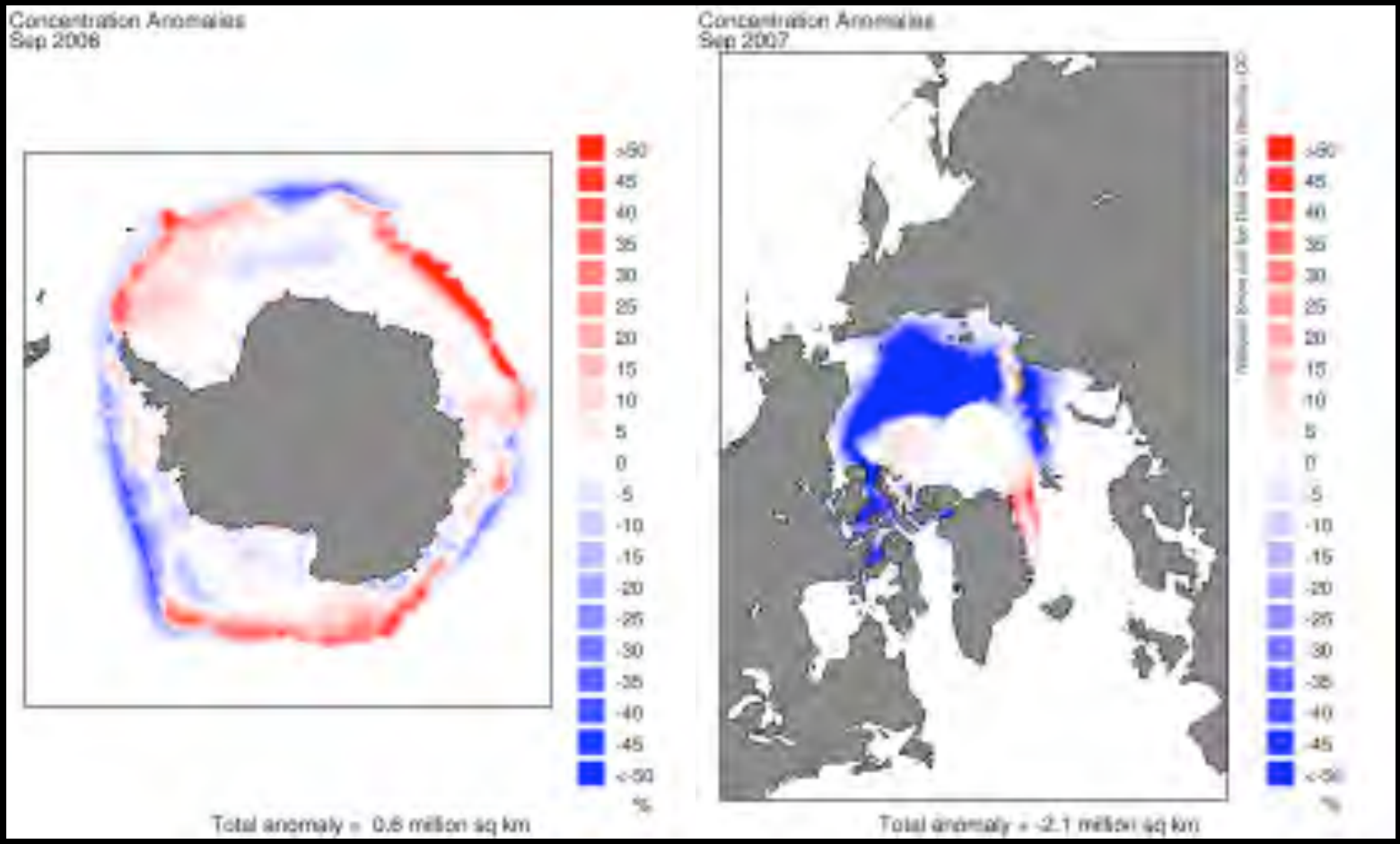
Arctic and Antarctic sea ice trends





Overall trends very different. Ozone and SAM has affected the air temperatures and circulation patterns in SH summer (and probably fall as well). Is this affecting sea ice? What about ice shelves and SLR?

Arctic and Antarctic sea ice trends



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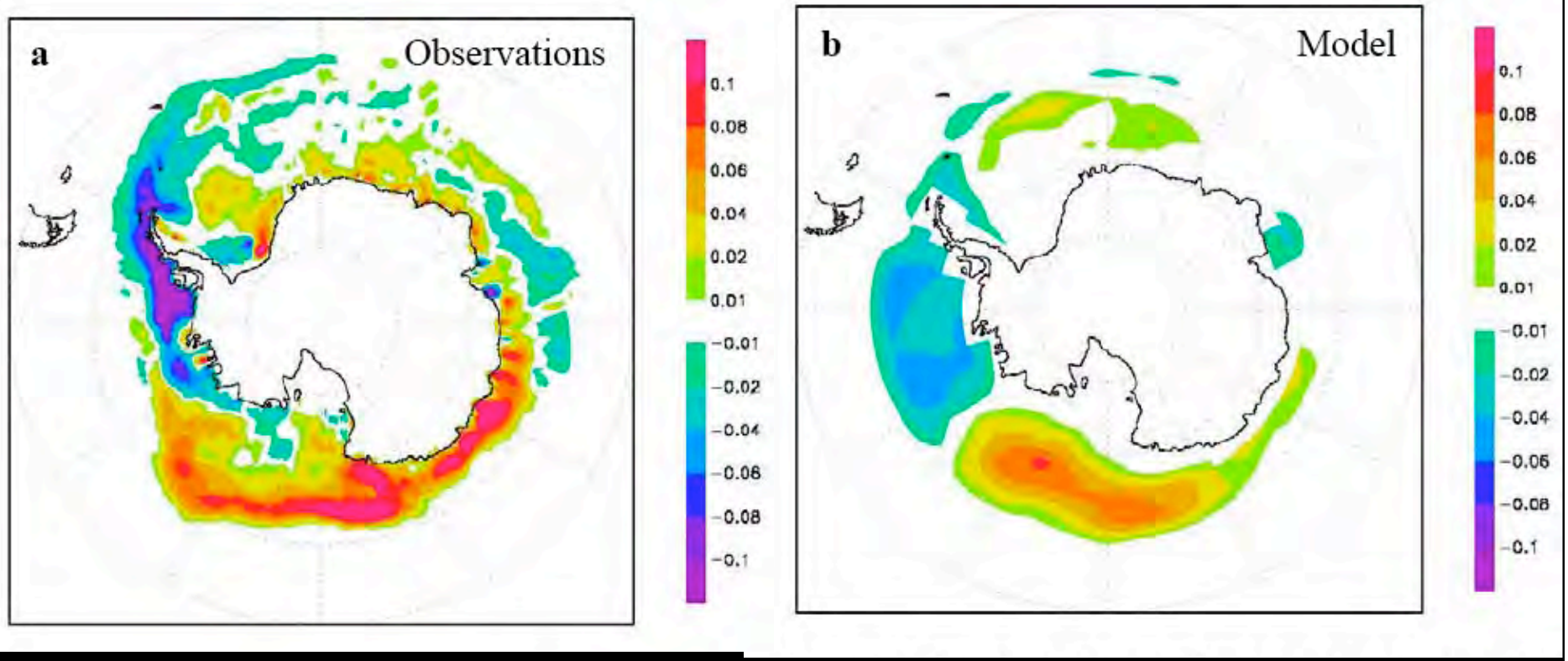
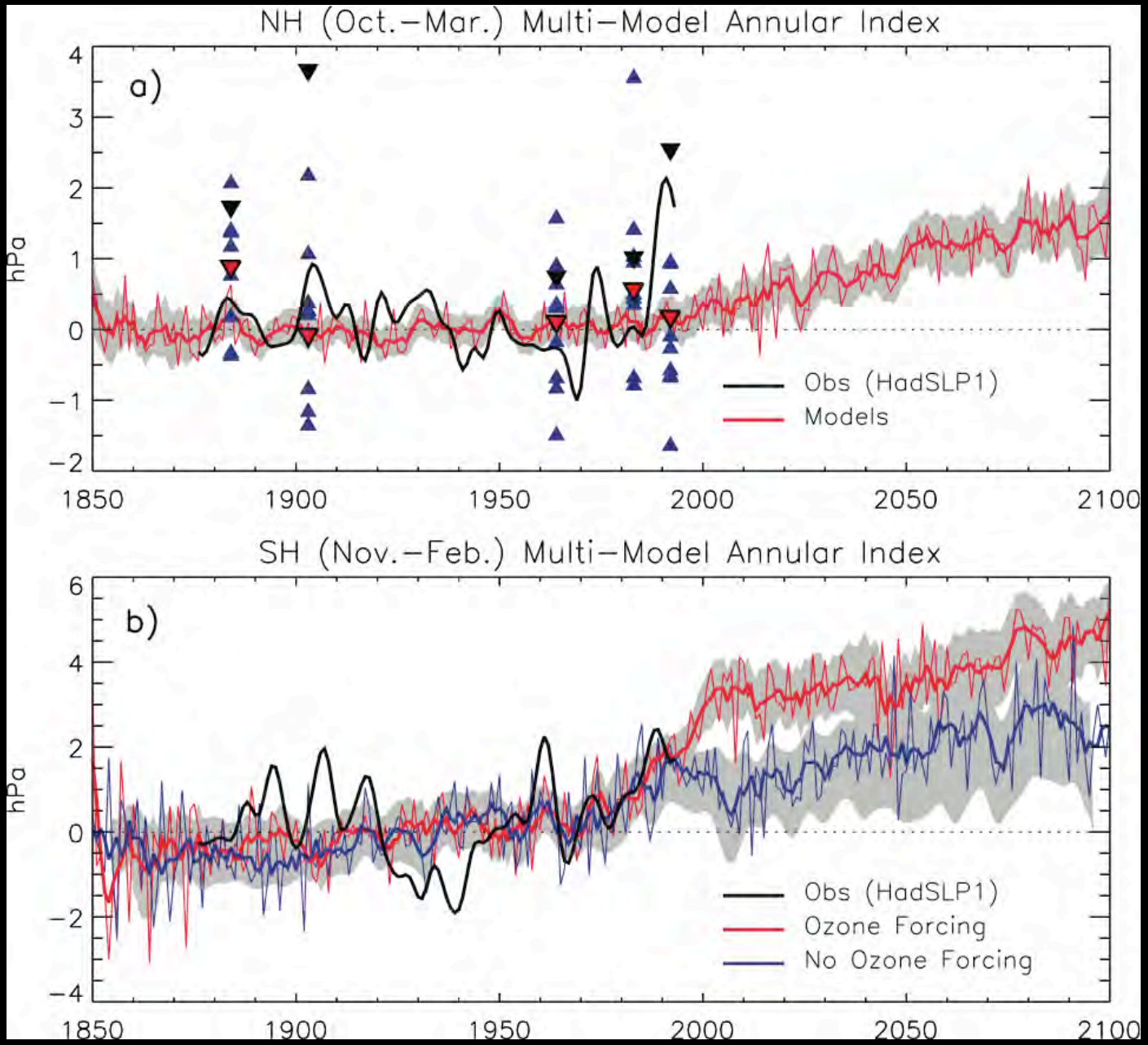
Arctic and Antarctic sea ice trends for 1980-2000 vs model with data assimilation to capture SAM trends:



Goosse et al, in press, Clim. Dyn., 2008

Increases in sea ice extent driven by SAM changes 1980-2000 (circulation, ozone?). Model also shows decreases for 1950-1980 (warming, GHG?).



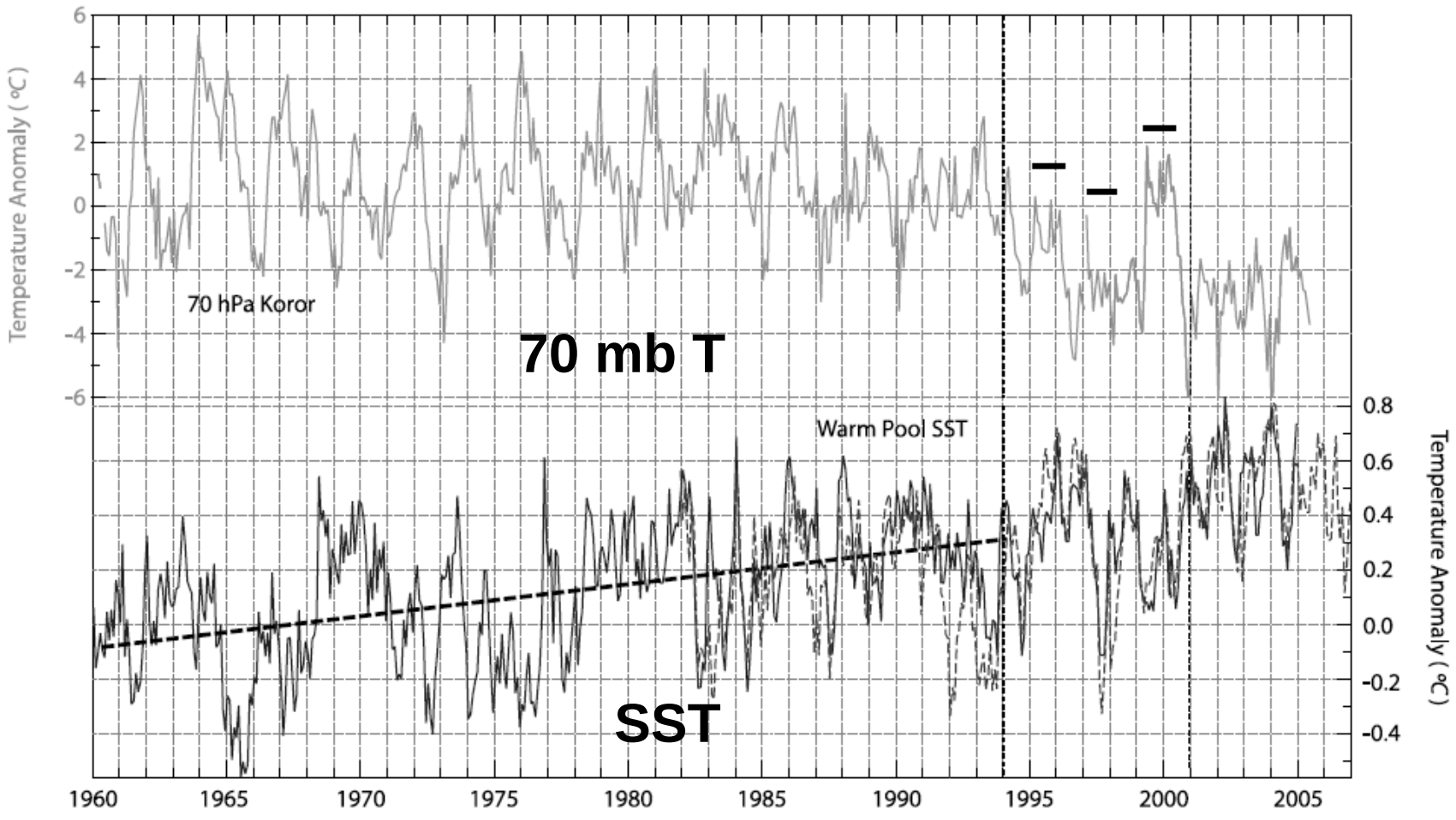
NAM in NH?

Needs a better assessment

SAM in SH√

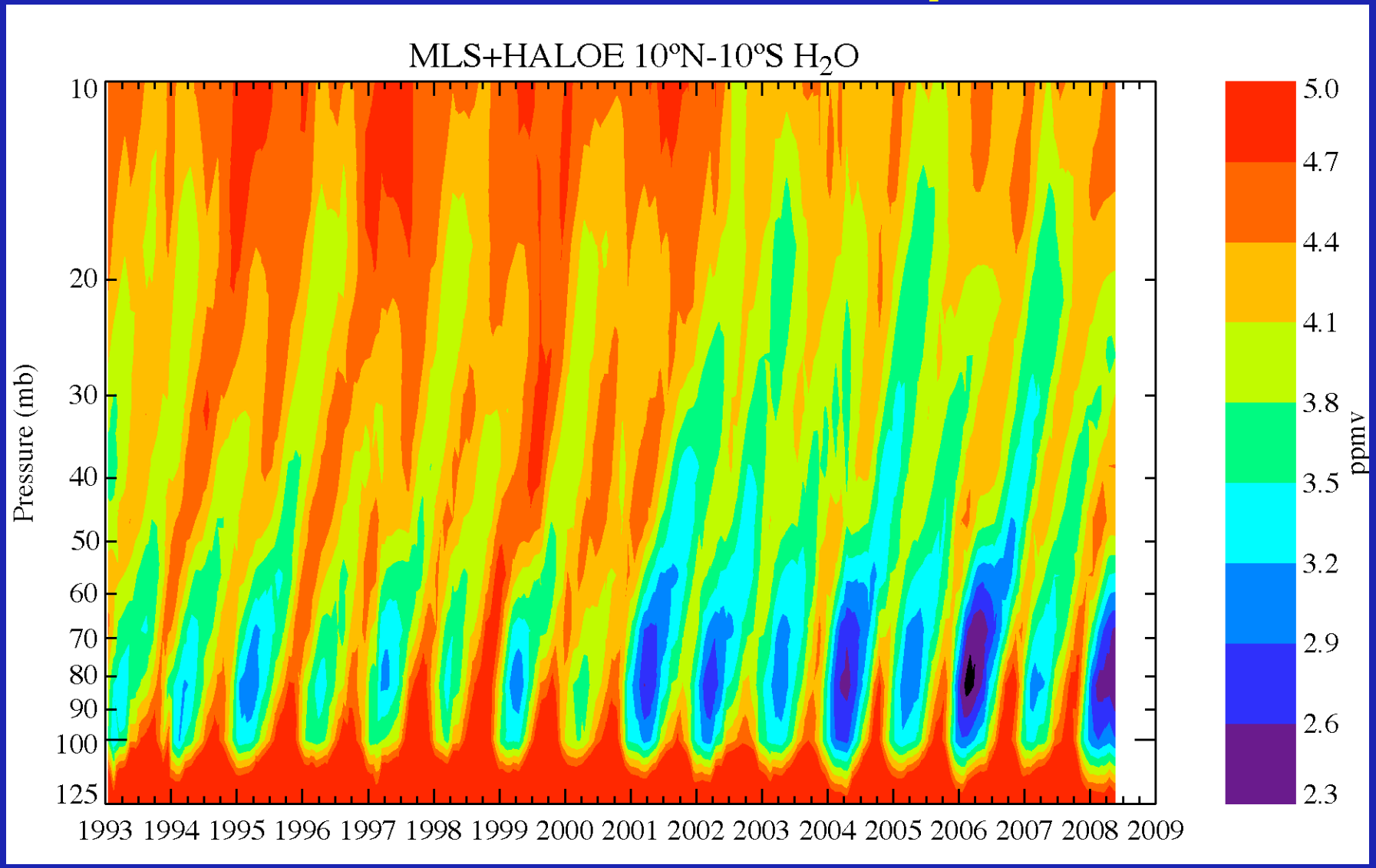
Miller et al. JGR 2005; IPCC (2007) Ch 10; Perlwitz et al. (2009)

Changes in the Tropics



- **Stratospheric cooling and SST linkage; effect on water vapor, coupling to troposphere?**

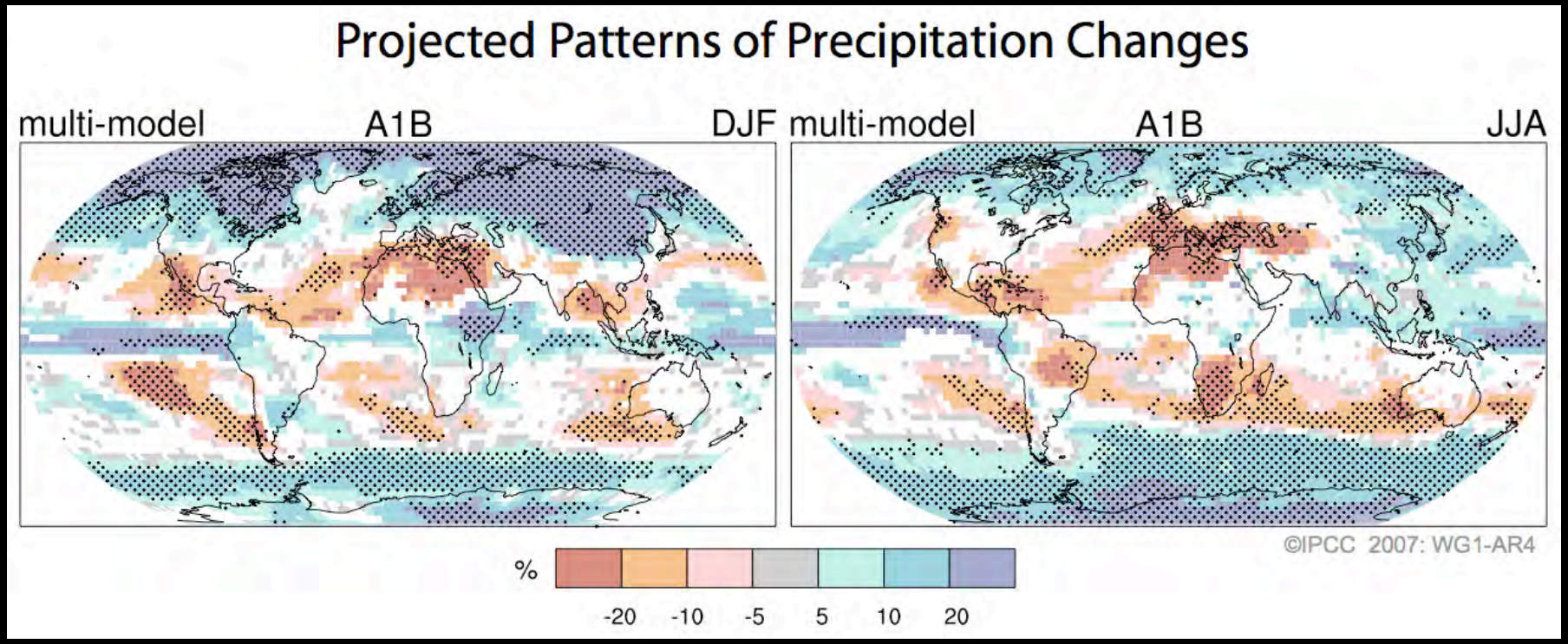
Link To Water Vapor



Rosenlof, Reid, Dameris, others: SST/convection…

Radiative forcing?

A World of Change:
More Rain for Some, Less for Others

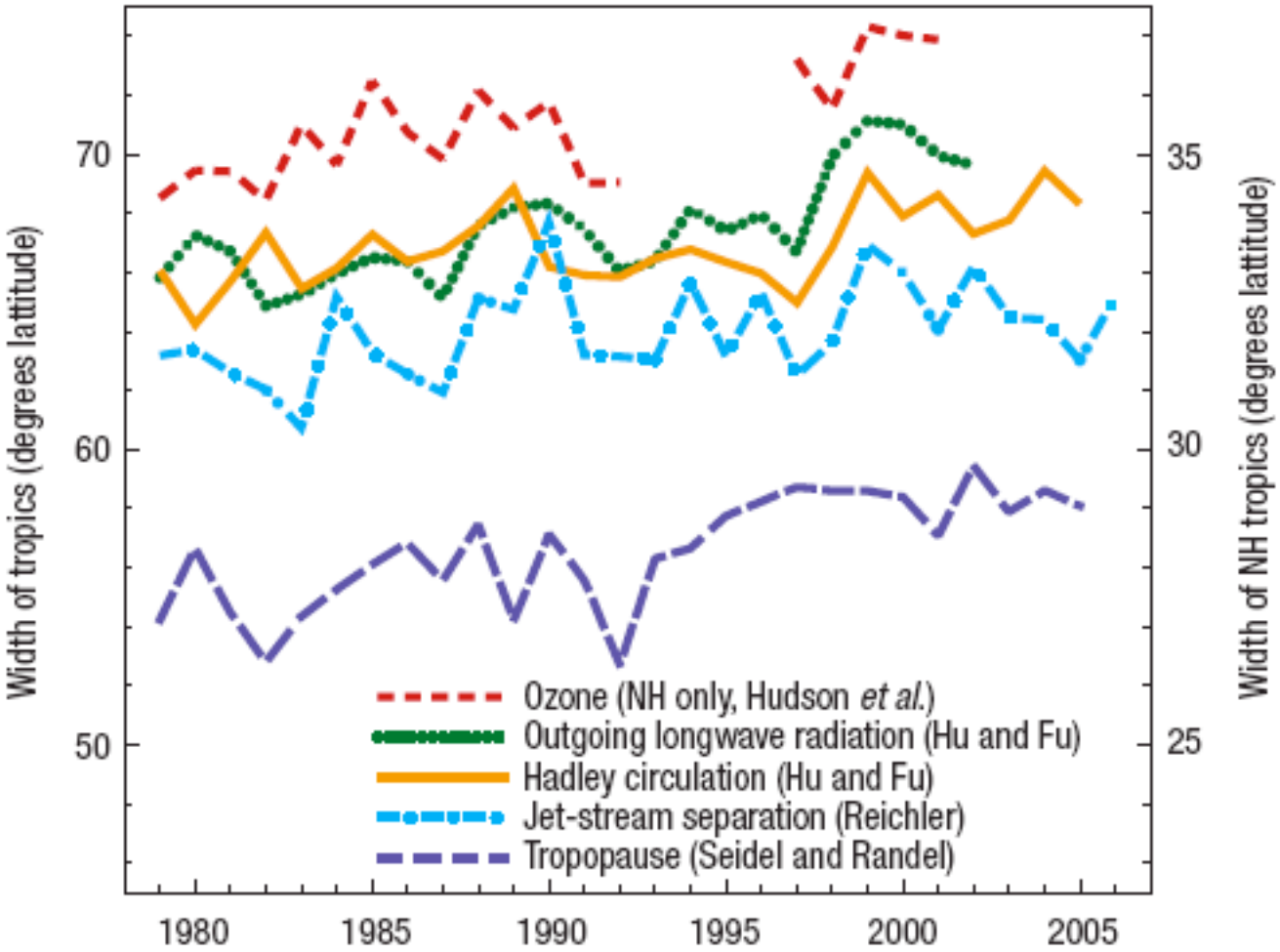


- Regional changes (+/-) of up to 20% in average rainfall
- Drying in the subtropics in both hemispheres
- More precip in high latitudes

(2090s: medium emissions scenario; high confidence in stippled areas)

IPCC (2007) Summary for Policymakers

The Meaning In The Stratosphere



Widening of the tropics seen robustly in various datasets [Seidel et al. Nature, 2007]. Strat/trop linkages?

The Meaning In The Stratosphere

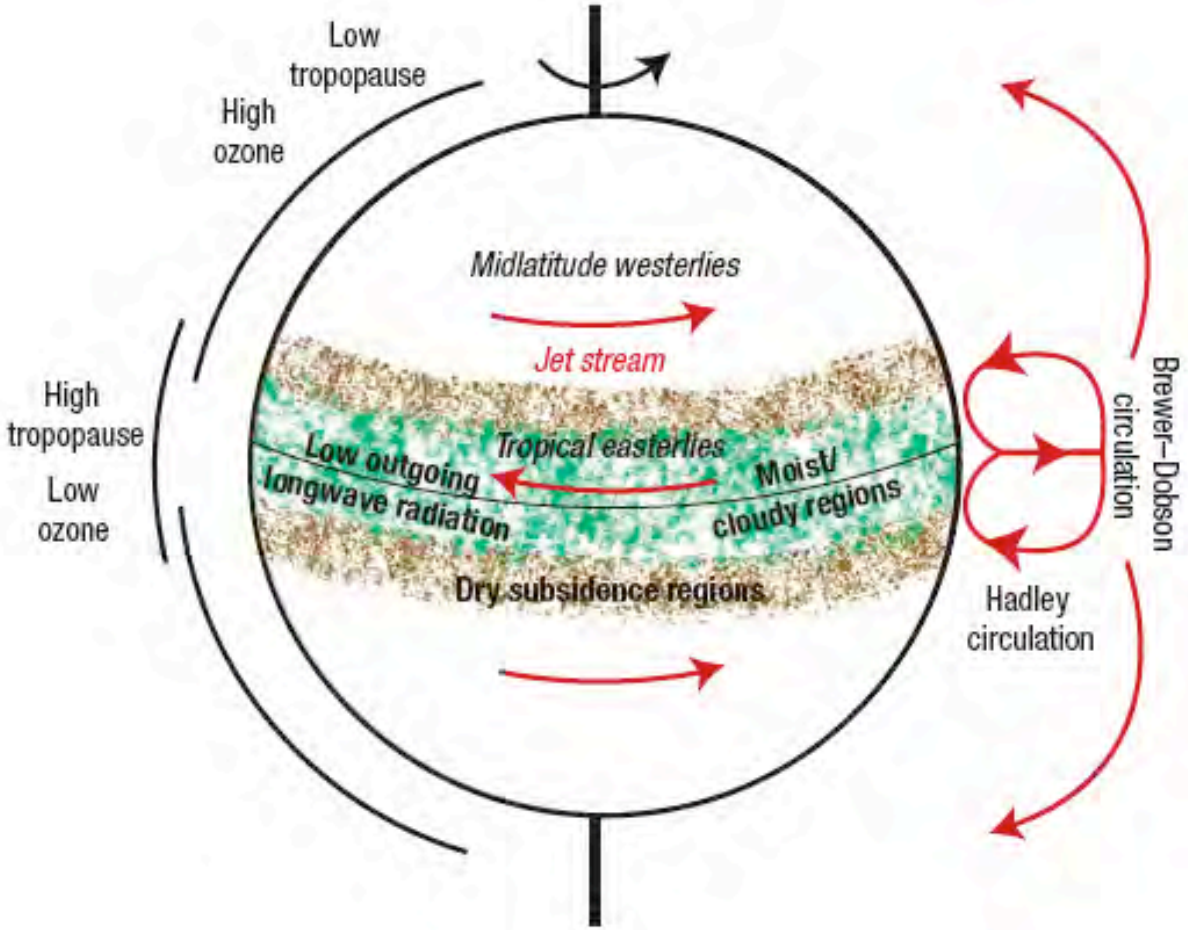
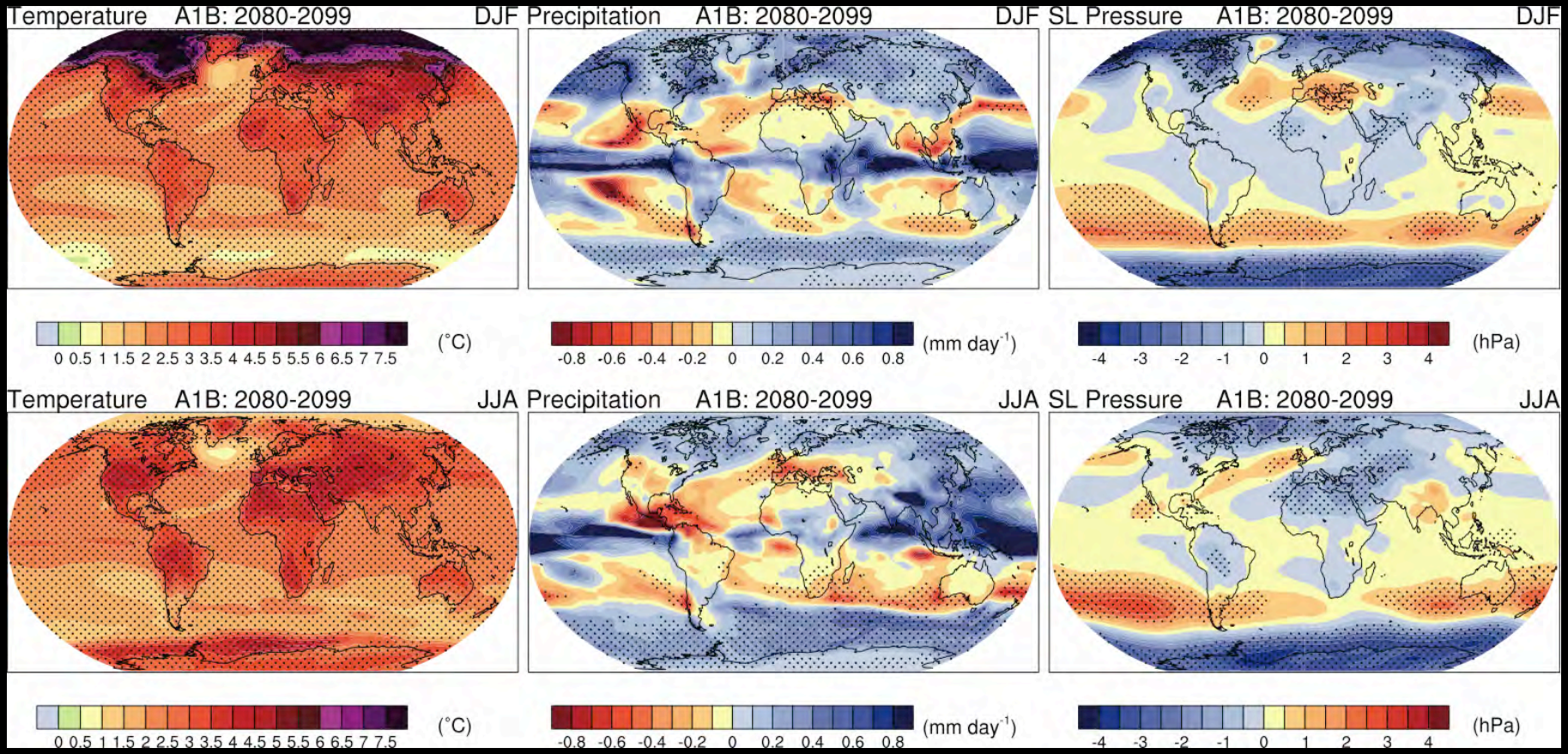


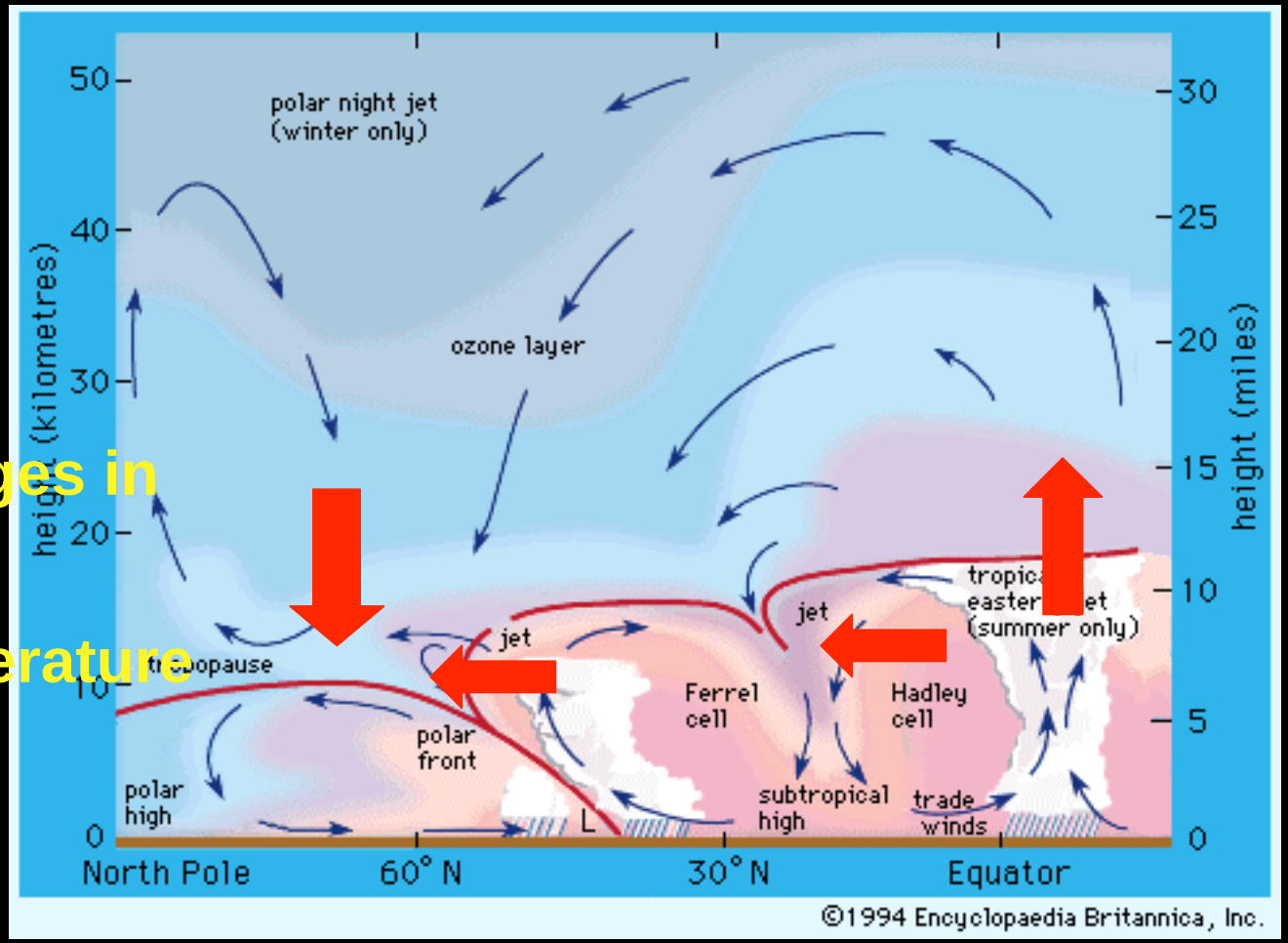
Figure 1 What climatological features distinguish the tropics? Some of the atmospheric structure, circulation, and hydrological features shown in this schematic diagram of the Earth have moved poleward in recent decades, indicating a widening of the tropical belt and the Hadley circulation.

Climate Changes of IPCC (2007)



IPCC (2013): To do better on many aspects of structure/regional behavior, will benefit from a better understanding of the stratosphere

Cartoon Of Some Key Stratospheric And Climate Changes

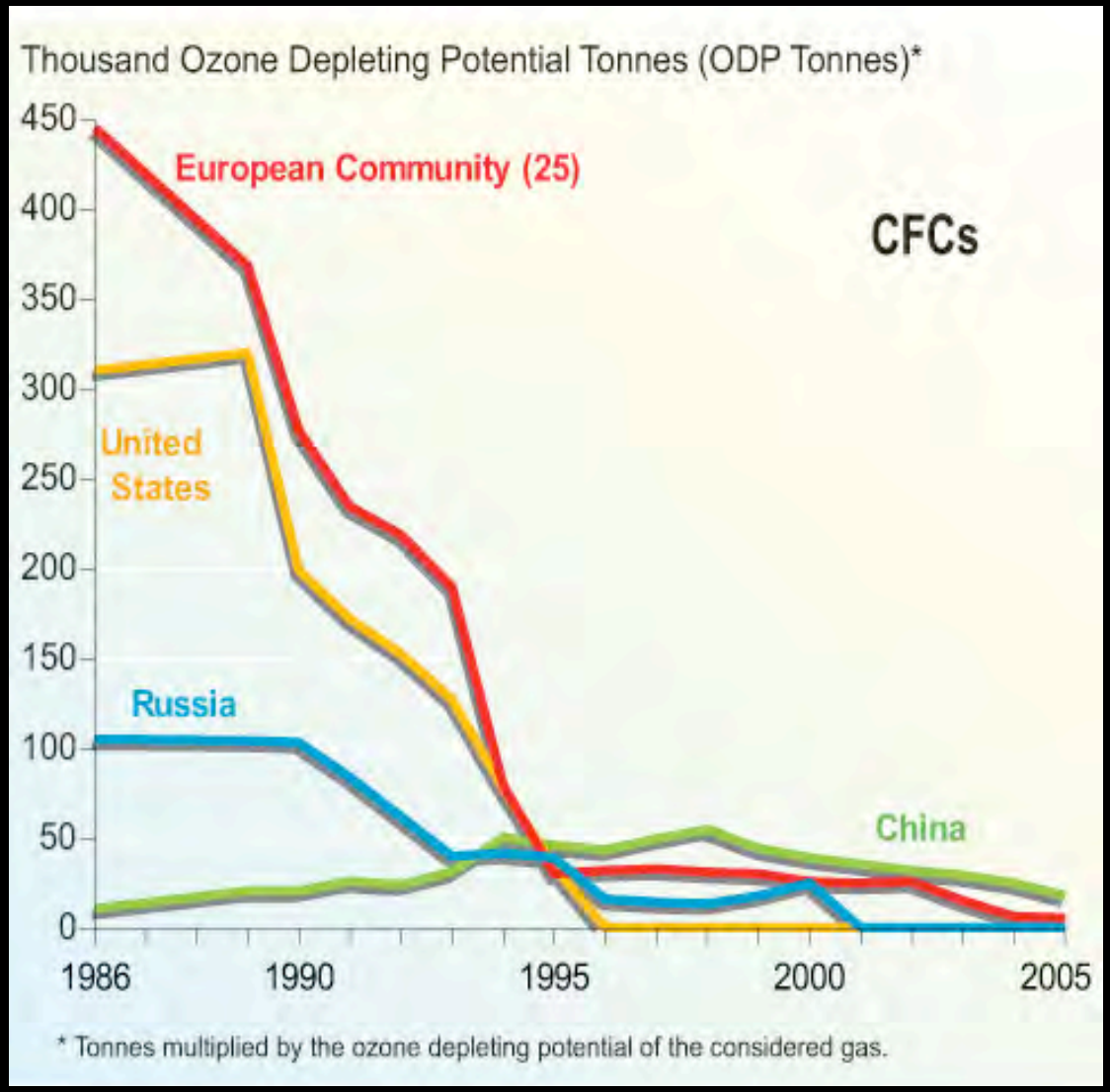


- changes in ozone
- temperature trends
- Cooling
- less strat H2O
- Shift of storm tracks, regional climates, SAM, NAM
- Drought in subtropics?

How Are We Doing? The Montreal Protocol is On Track In Terms of Phasing Out Global *Production* of CFCs.

The US was a leader in the CFC production phaseout, beginning with a domestic spray-can CFC ban in 1978.

All countries have now phased out CFC production.



GWP-Weighted Emissions

Combined CO_2-eq from halocarbons:

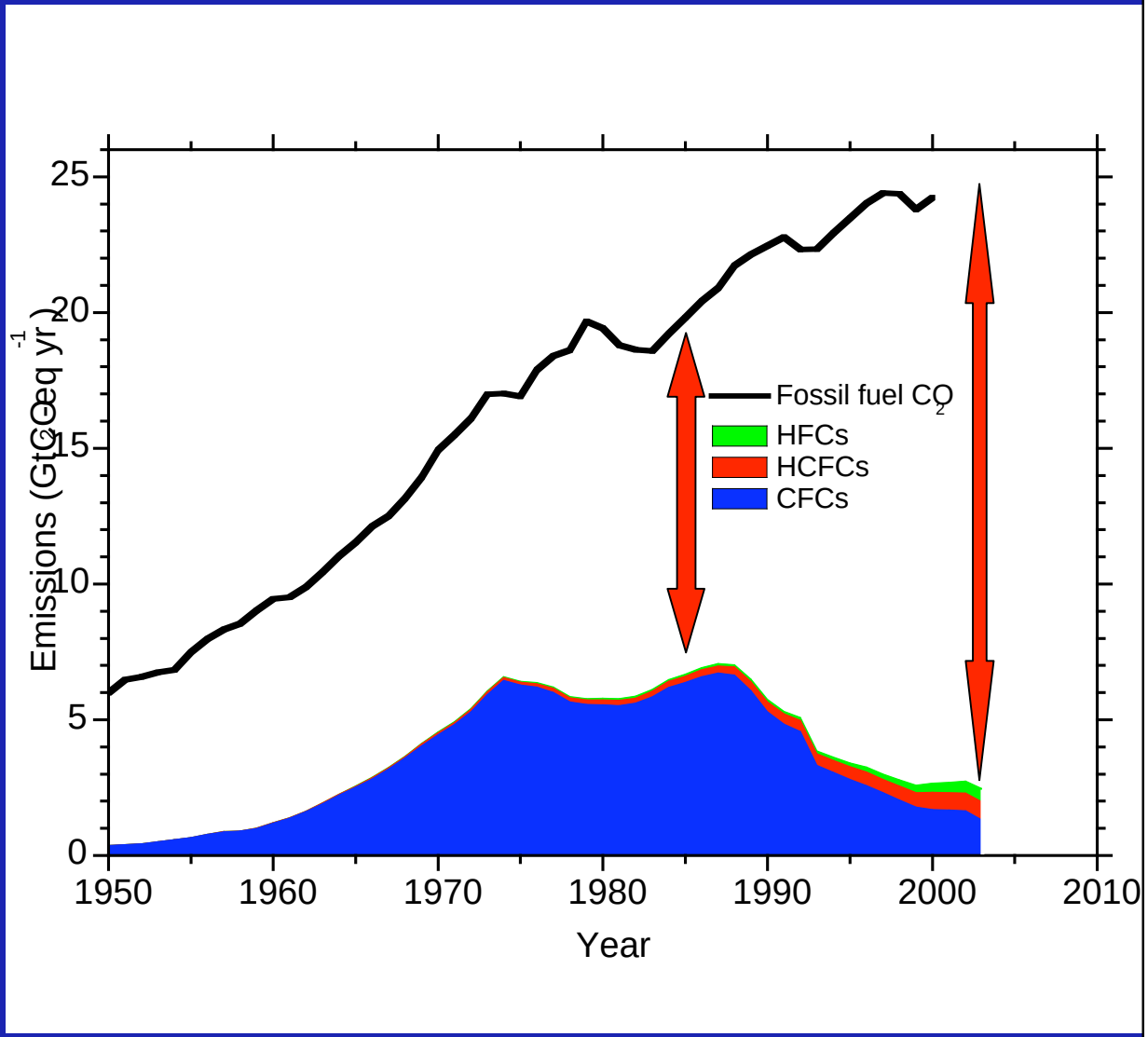
~7.5 Gt near 1990, about 33% of that year's CO_2 emissions from global fossil fuel burning.

2002 breakdown:

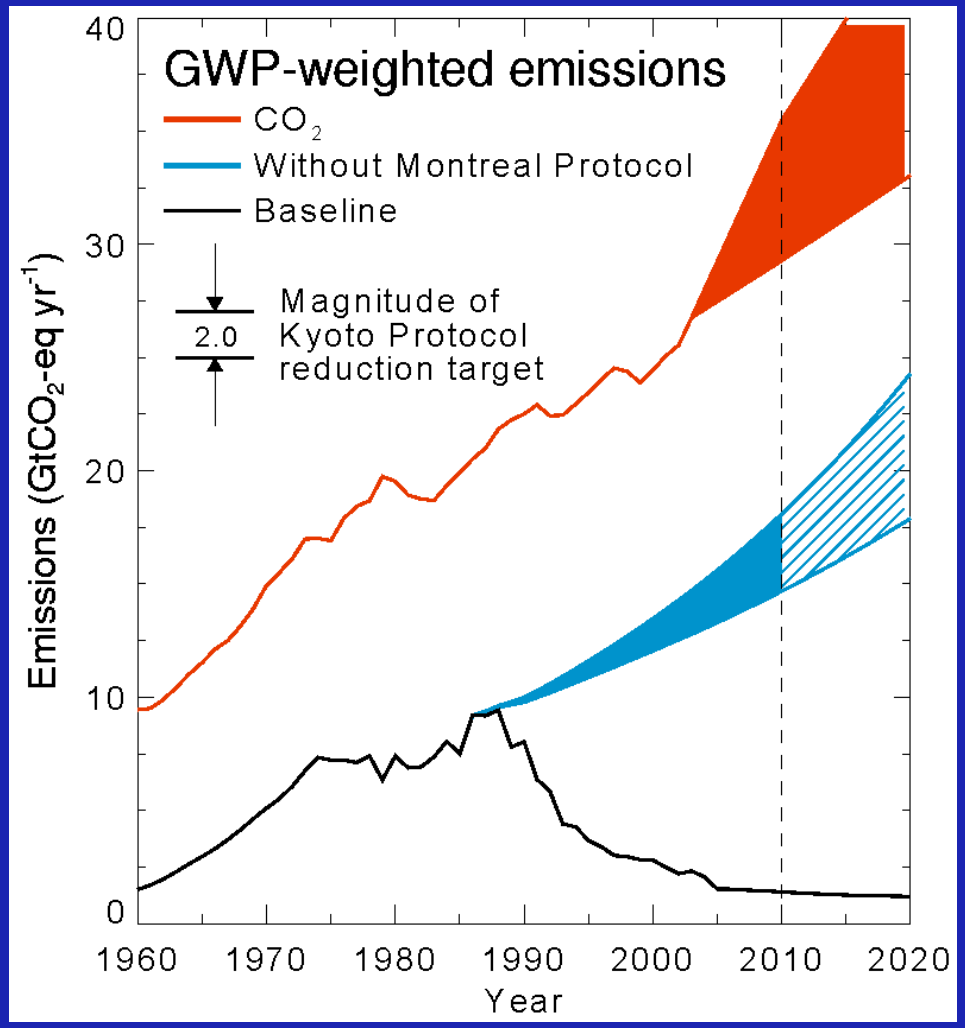
1.5-1.9 Gt for CFCs;

0.53-0.56 Gt for HCFCs;

0.36 Gt for HFCs



Benefits of Montreal Protocol for Climate



Velders et al., PNAS, 2007

CO_2 emissions

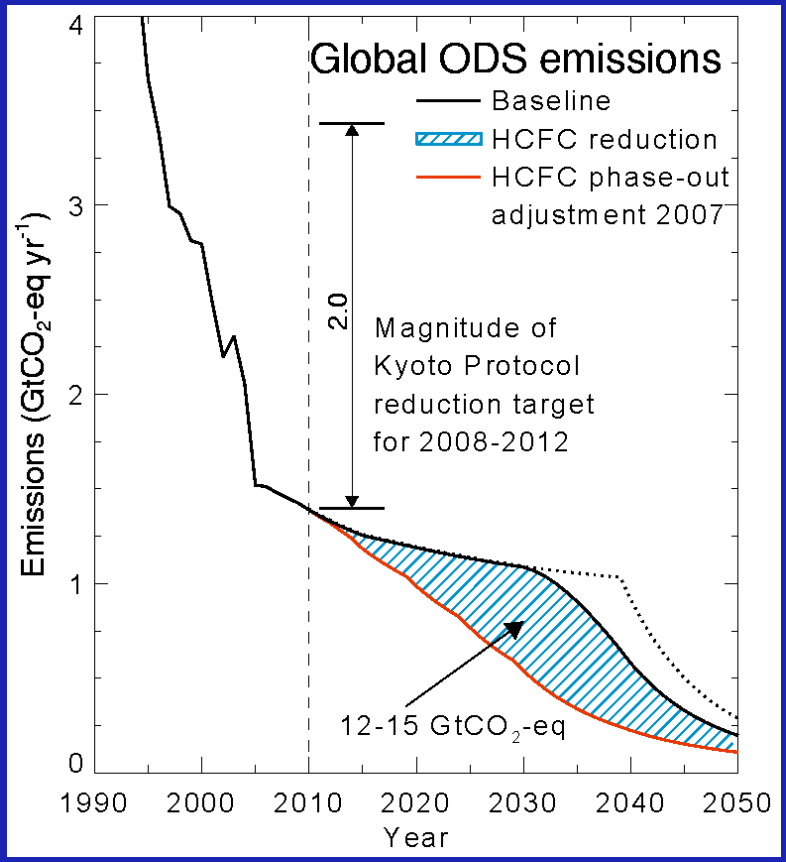
World avoided by the Montreal Protocol?

Reduction to date by Montreal Protocol of ~11 $GtCO_2$-eq/yr

➔5-6 times global Kyoto target

Role of ozone depletion cooling due to CFCs? Could reduce this by perhaps a third but….

Montreal Sep 2007 adjustment: HCFC early phase-out



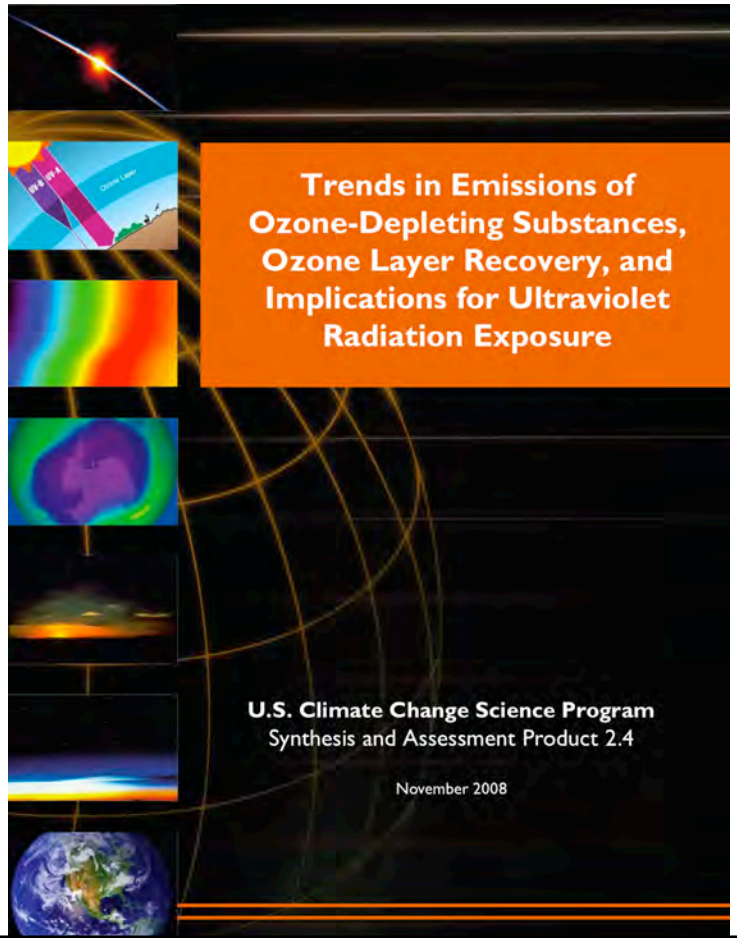
Reduction in future emissions:

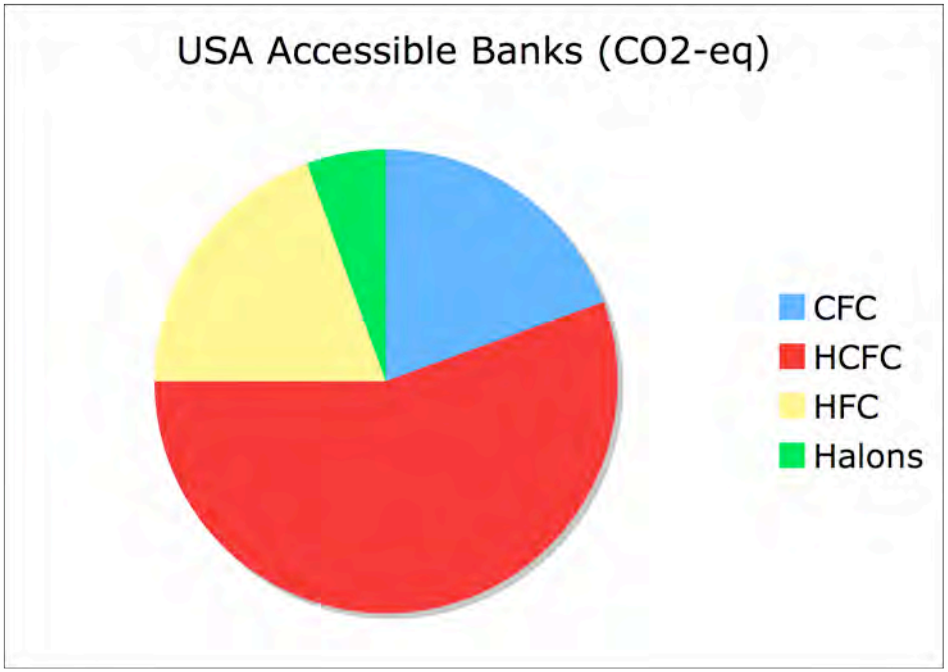
- HCFCs 'transition' speedup
- 12-15 $GtCO_2$-eq potential reduction if replaced with low-GWP alternatives or reduced through conservation/recycling.

SAP 2.4: Trends In Emissions of Ozone Depleting Substances, Ozone Layer Recovery, and Implications for Ultraviolet Radiation Exposure

CCSP: Connecting with our national process

SAP 2.4 (2008) NOAA key contributors: Ravishankara (lead), Montzka, Daniel, Fahey





CCSP: Connecting with our national process

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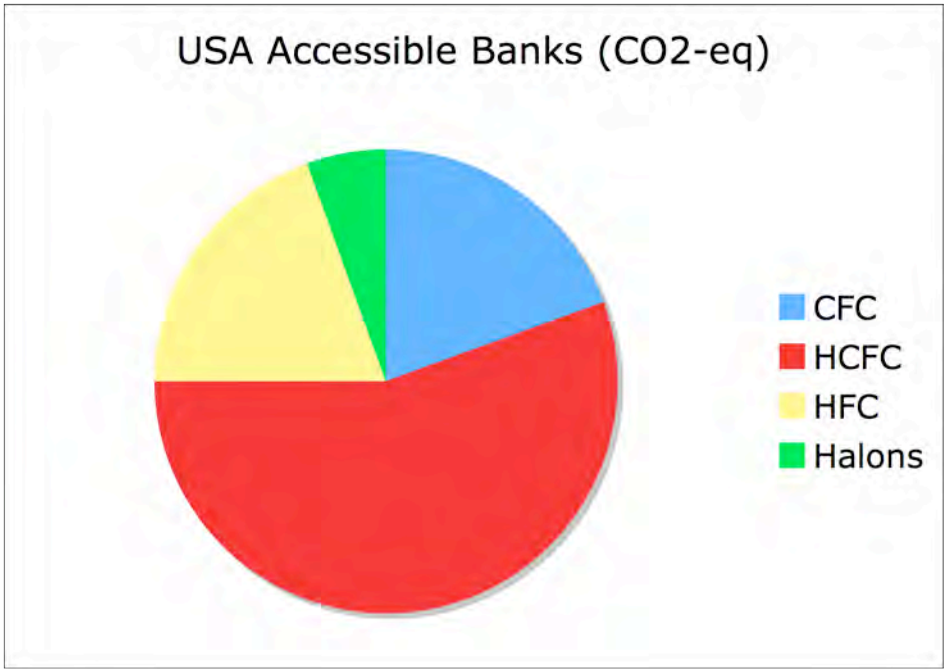
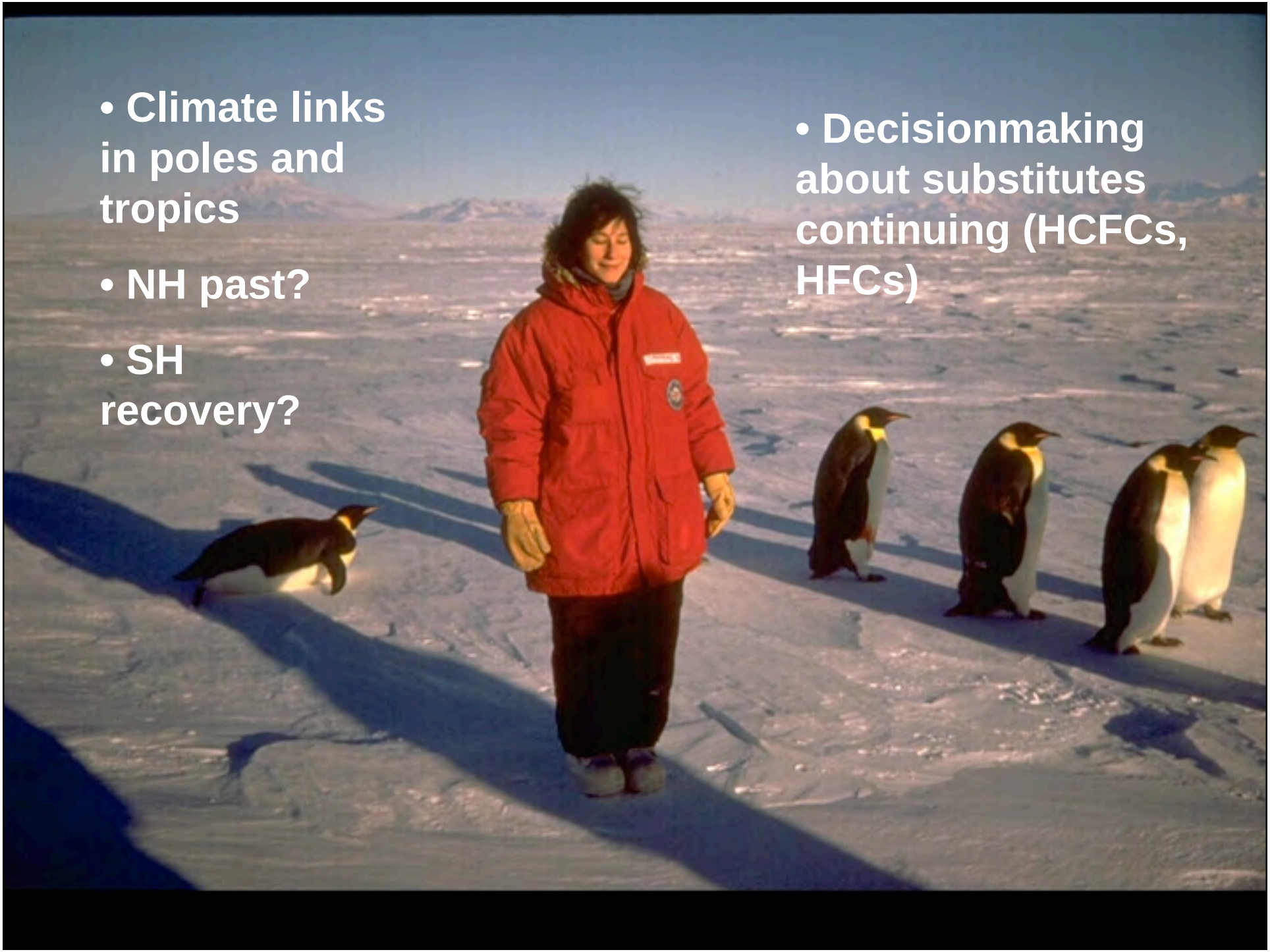
US Banks: 1.9 Gt CO2-eq in all, about 1 Gt in HCFCs (AC, refrigeration). Possible future actions to recover/destroy banks would represent several years of 'Kyoto-equivalent' for US.




• Climate links in poles and tropics
• NH past?
• SH recovery?
• Decisionmaking about substitutes continuing (HCFCs, HFCs)