WACCM Whole Atmosphere Community Climate Model

NCAR

Downward coupling in CESM1(WACCM)

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AMWG/ WAWG Joint Session - 11 February 2013

Outline

- Review important differences between WACCM and CCSM4
- Compare CCSM4 and WACCM in two areas where downward coupling is important:
  - NH winter
  - Influence of the antarctic ozone hole

Important differences from CCSM4 used for CMIP5

- Model top at ~140 km (66 levels) vs. ~40 km (26 levels)
- Horizontal (lat x lon) resolution: 1.9° x 2.5° vs. 0.94° x 1.25°
- Fully-interactive chemistry
- Nudged Quasi-Biennial Oscillation (QBO)
- Forced with daily varying spectral irradiance rather than annual mean TSI
- Thermospheric processes - aurora, ion chemistry, molecular diffusion
- Additional parameterization for gravity waves from convection and fronts (same orographic parameterization)
- "Turbulent mountain stress" (TMS) turned on

How then to investigate the influence of a ‘high-top’?

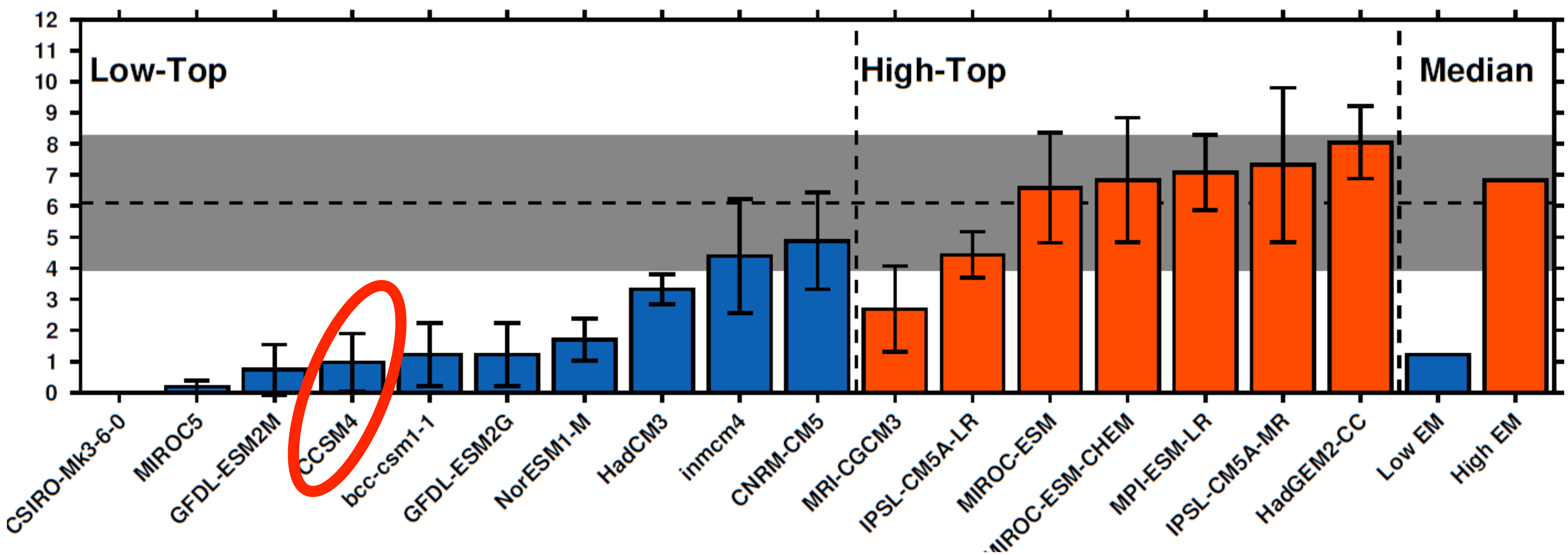
- Parallel simulations of CCSM4 configured in a similar manner to WACCM
  - Horizontal (lat x lon) resolution: 1.9° x 2.5°
  - Daily TSI
  - TMS turned on
- We term this model CCSM4-WSET
- Note: all simulations (WACCM, CCSM4 1°, and CCSM4-WSET) run with the same POP2 active ocean at 1°

Model name	horizontal resolution	model top (hPa)	# levels	TMS	QBO	Interactive chemistry
WACCM	$1.9° \times 2.5°$	5.96×10^{-6}	66	ON	YES	YES
WACCM NO-TMS	$1.9° \times 2.5°$	5.96×10^{-6}	66	OFF	YES	YES
CCSM4	$0.95° \times 1.25°$	3.54	26	OFF	NO	NO
CCSM4-WSET	$1.9° \times 2.5°$	3.54	26	ON	NO	NO

NH variability

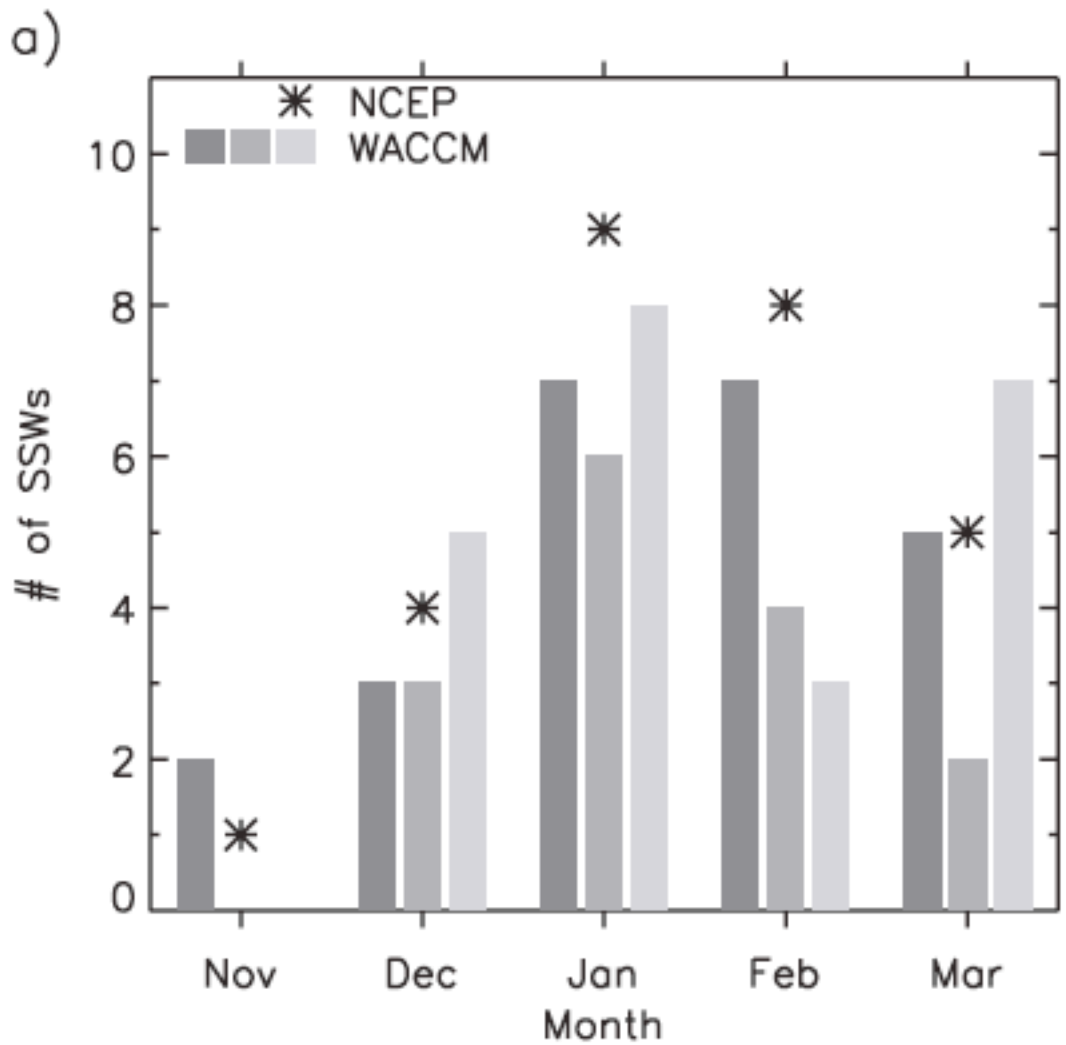
SSW counts in CMIP5 models

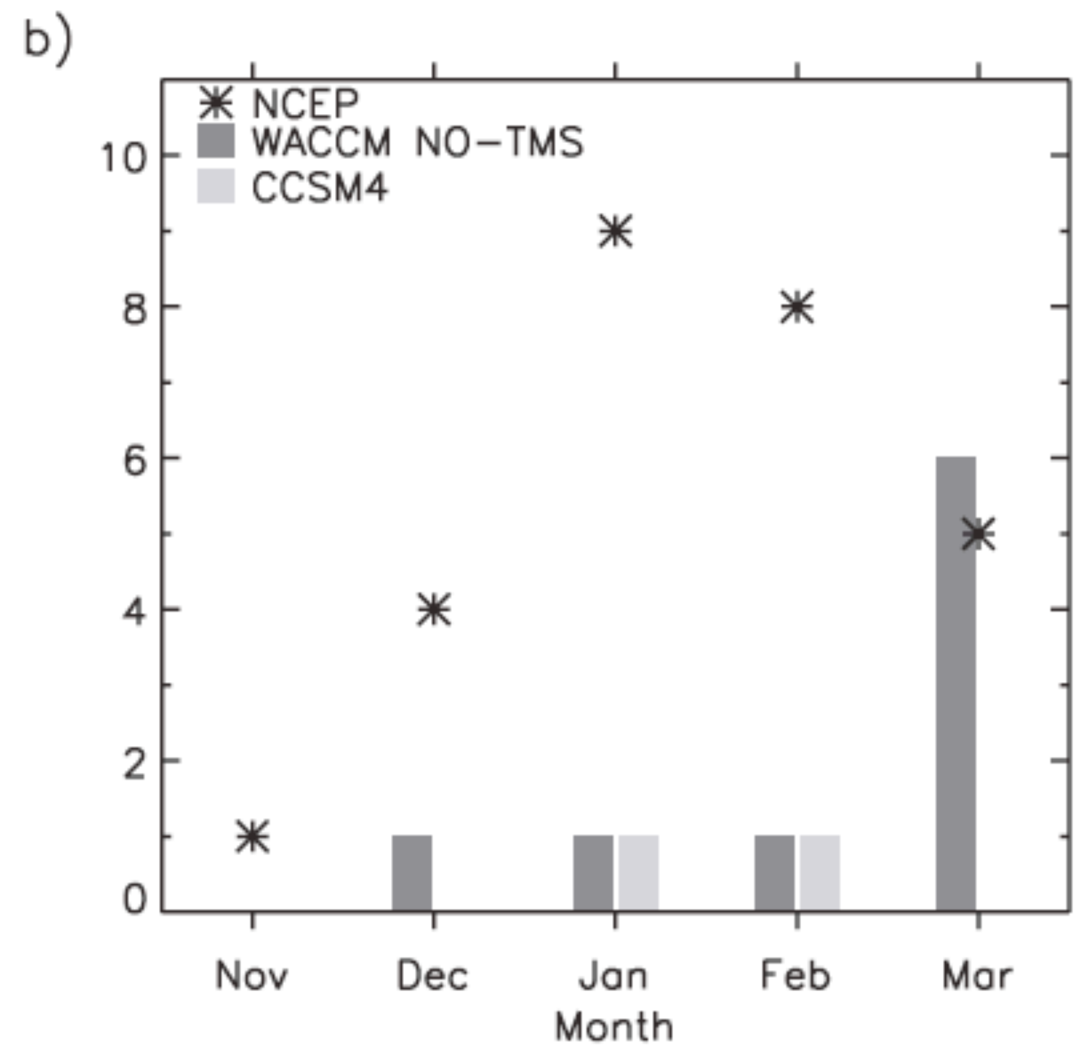
WACCM 3.3-5.3 / decade (4.6 on average)



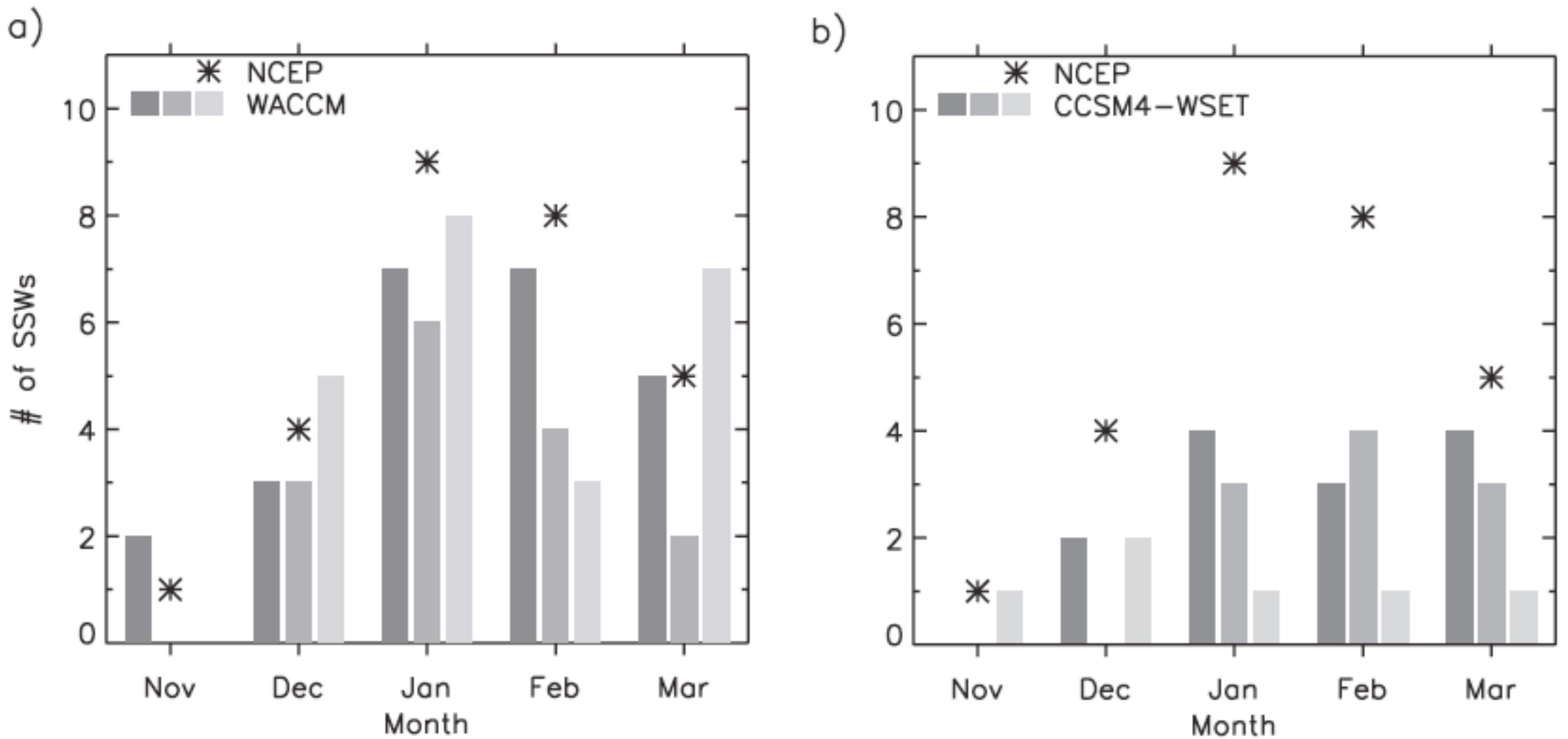
A. Charlton-Perez et al., JGR, 2013

Stratospheric Sudden Warmings 1960 to 2004

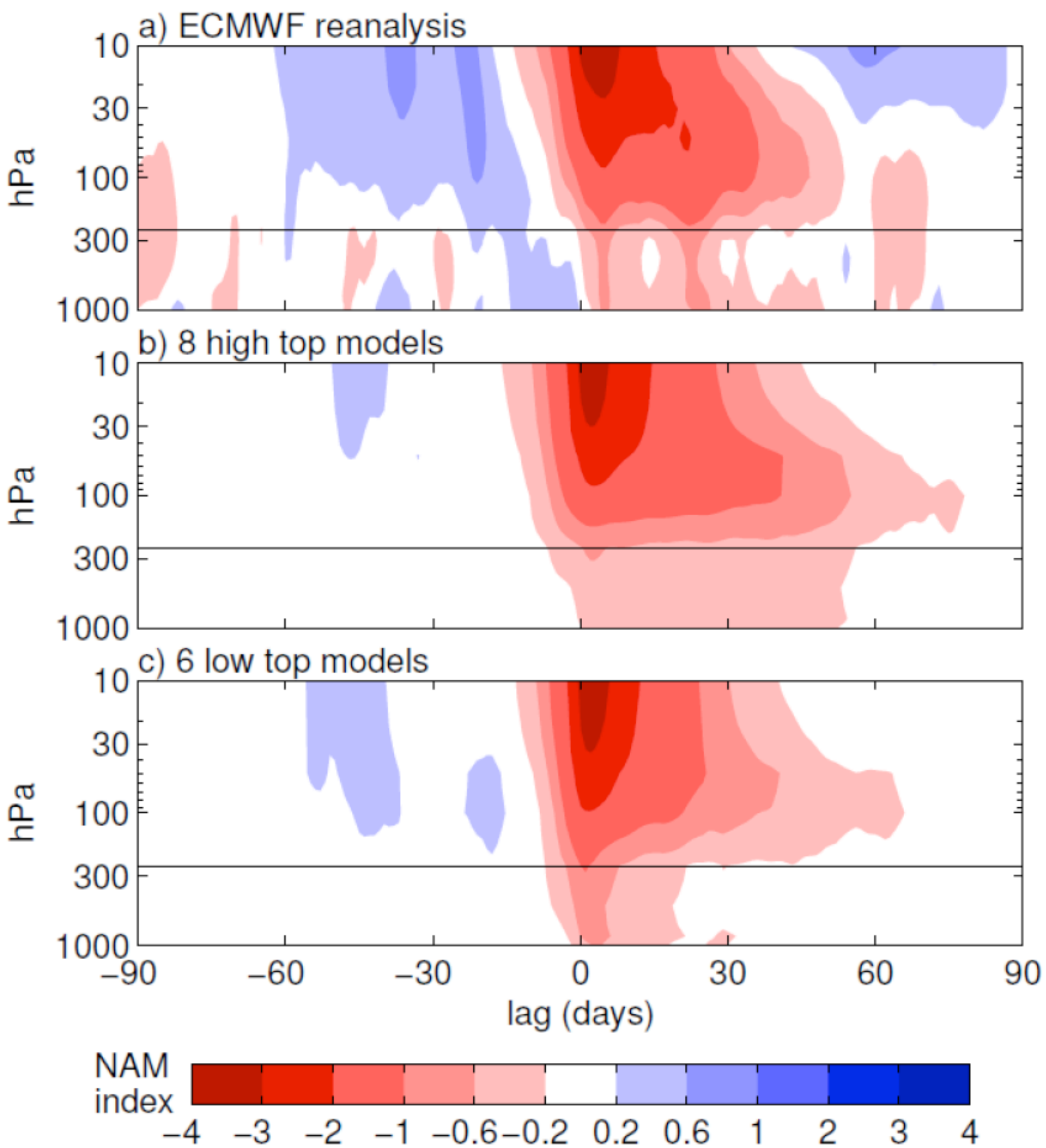




Stratospheric Sudden Warmings
1960 to 2004



NAM index composite for winters with SSWs



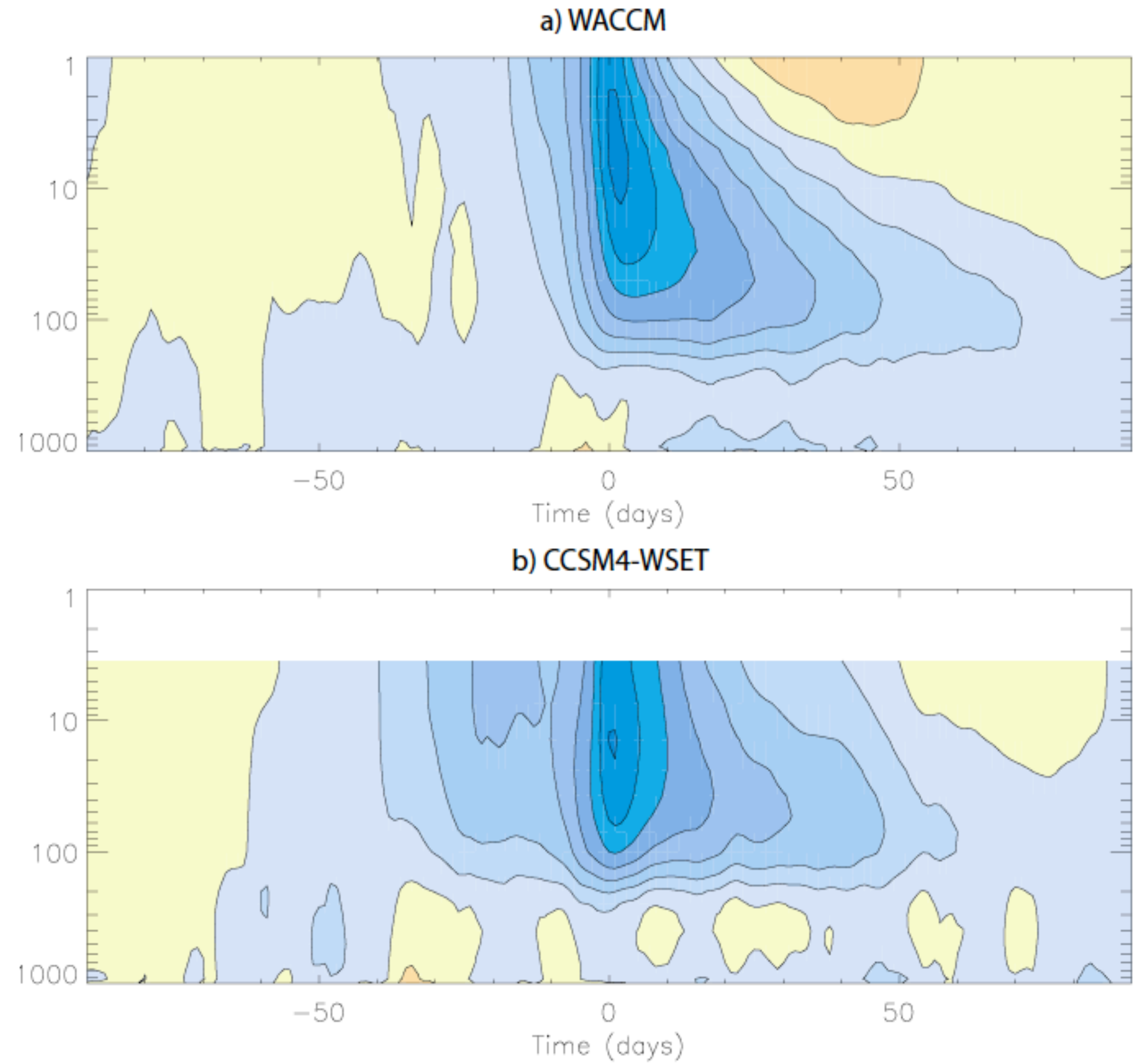
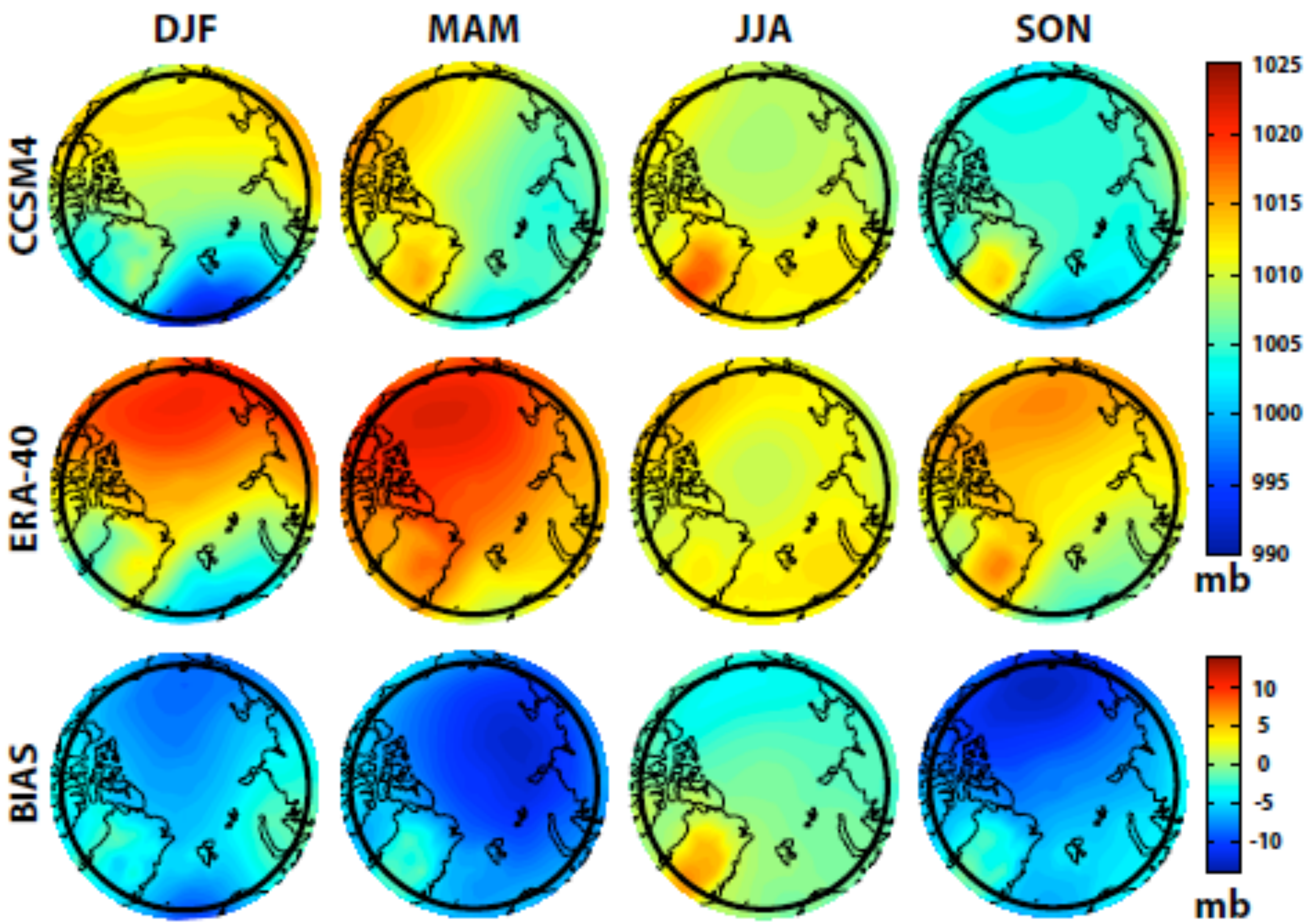
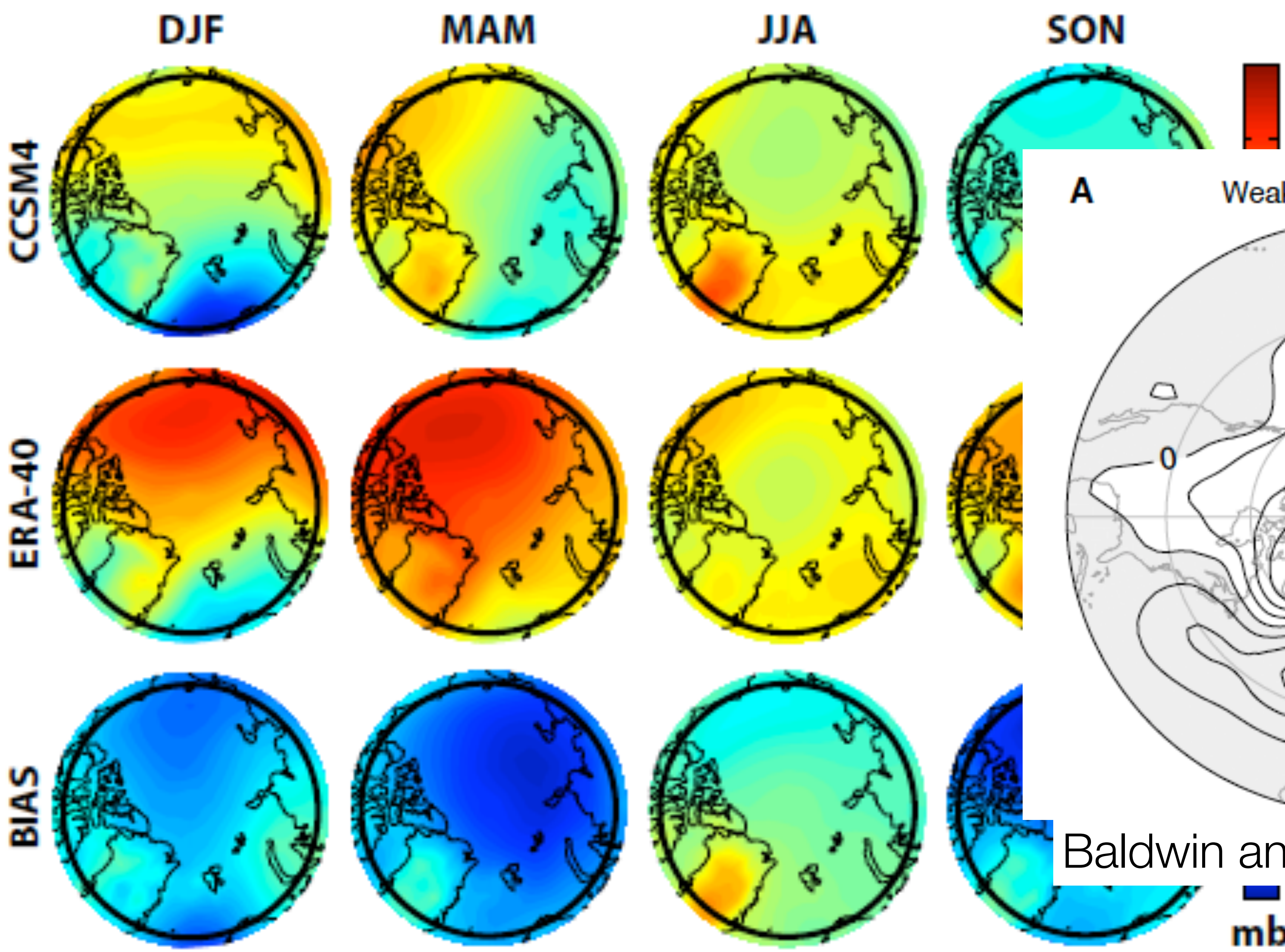


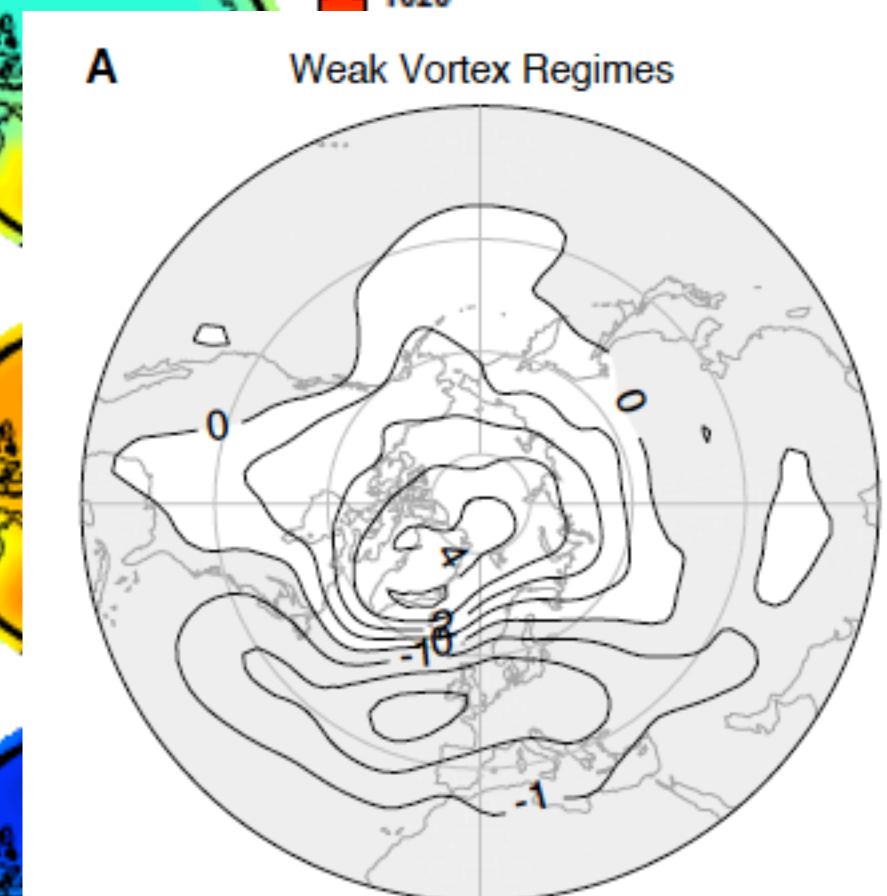
FIG. 4. NAM index composite constructed from winters with major SSWs for the ensemble of (a) WACCM and (b) CCSM4-WSET simulations. Day 0 is the central date of each SSW. Contours every 0.5. Blue is negative, yellow postive.

CCSM4 Sea level pressure bias (de Boer et al., 2013)



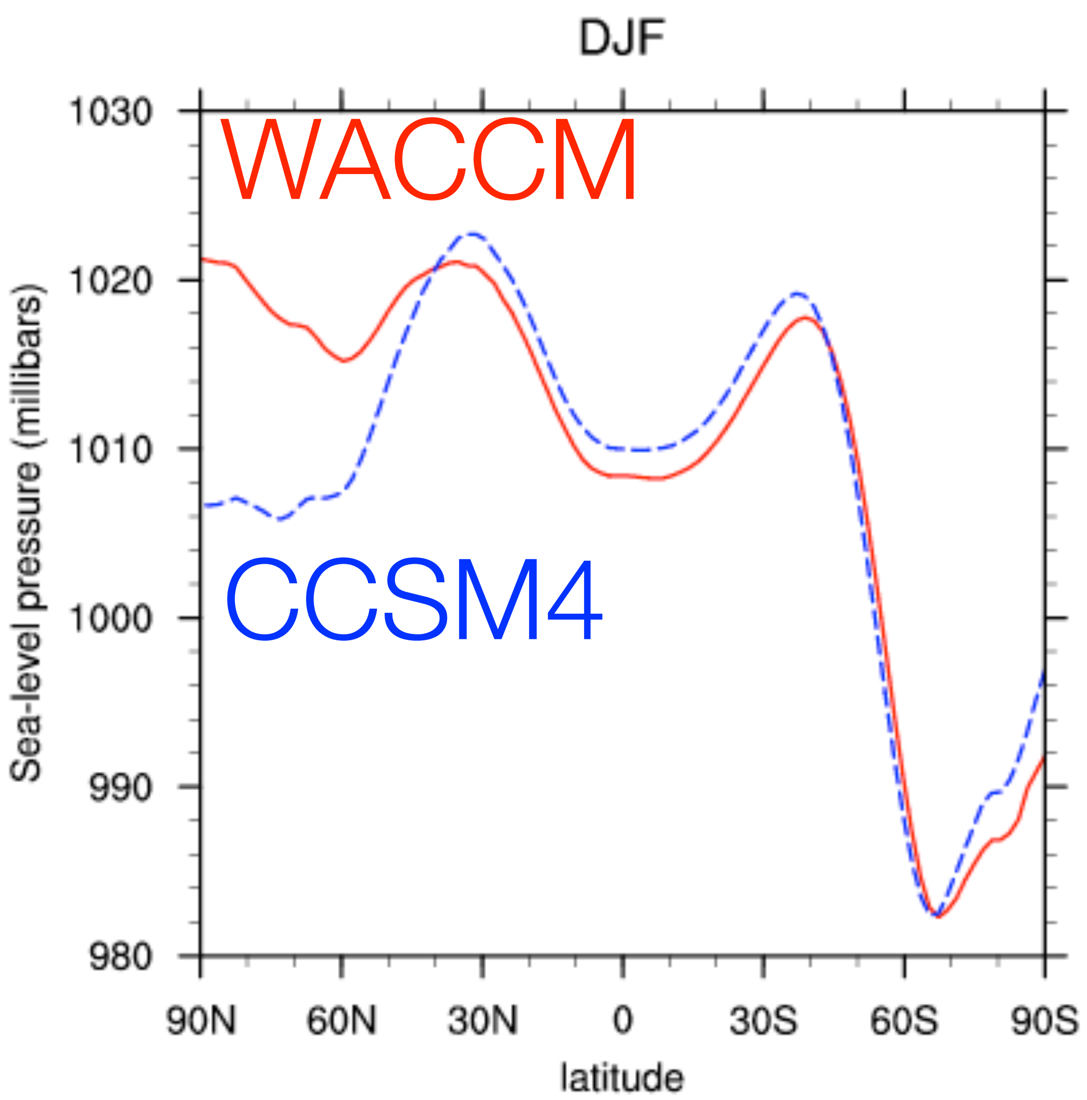
CCSM4 Sea level pressure bias (de Boer et al., 2013)



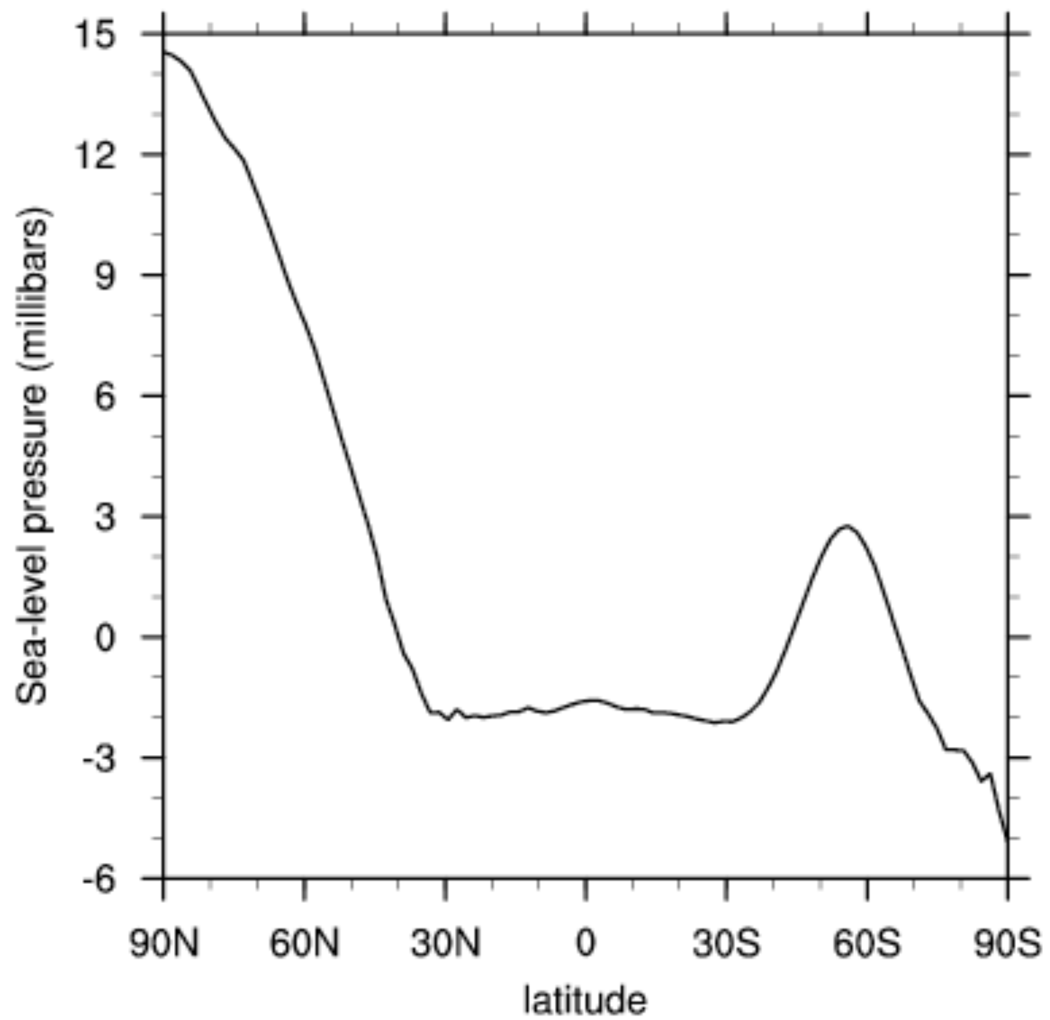


Baldwin and Dunkerton, 2001

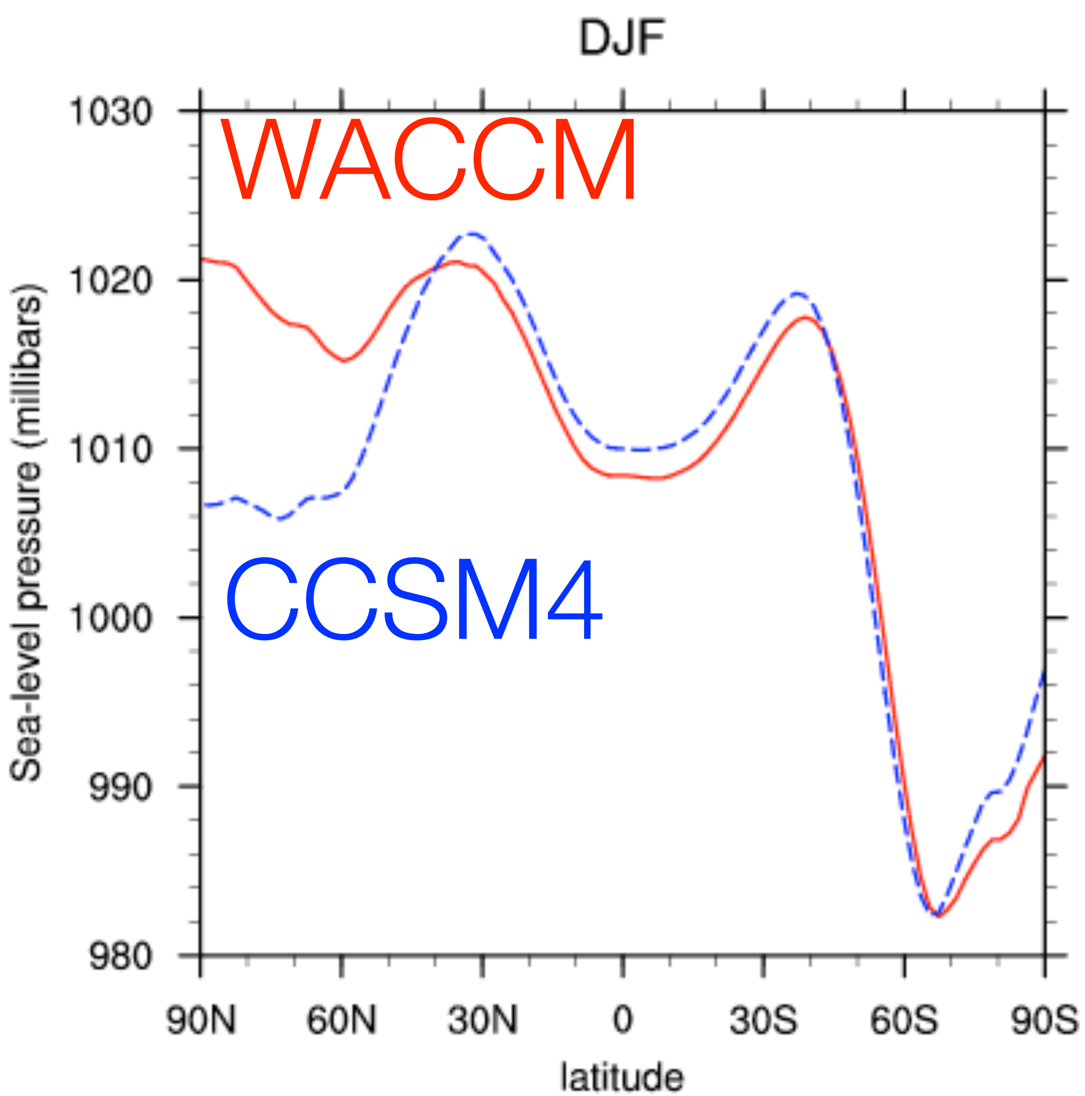
DJF Sea Level Pressure



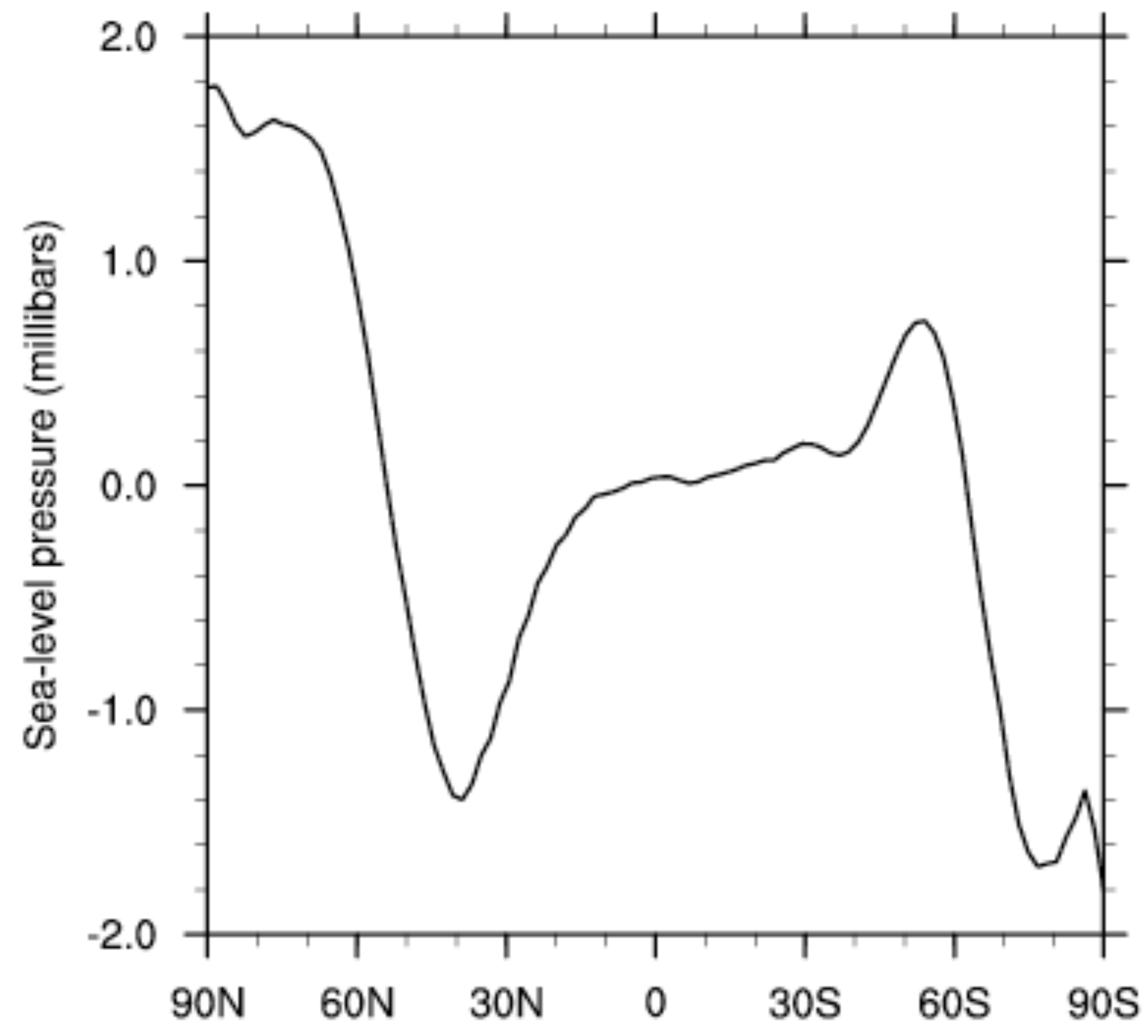
WACCM-CCSM4



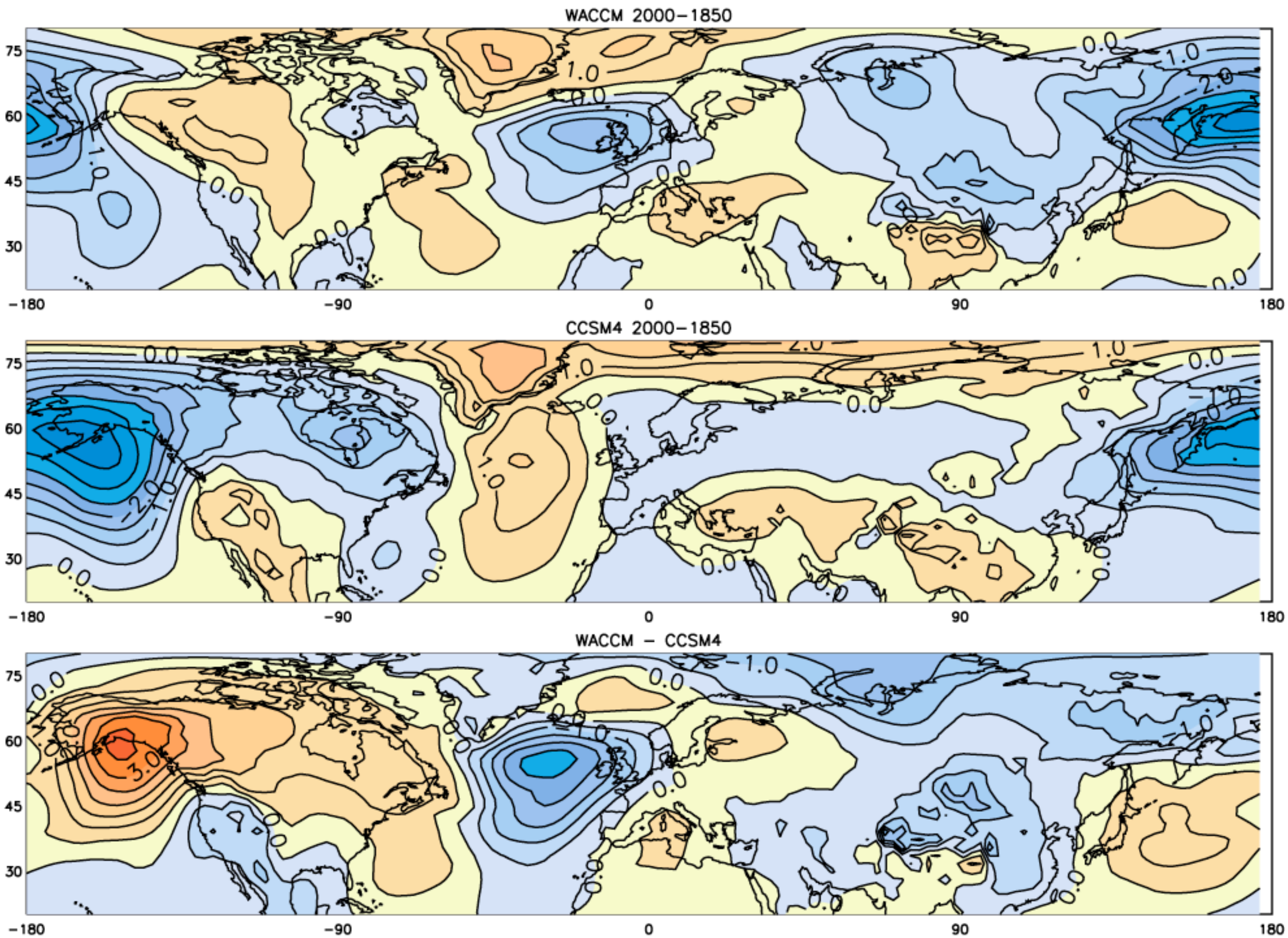
DJF Sea Level Pressure



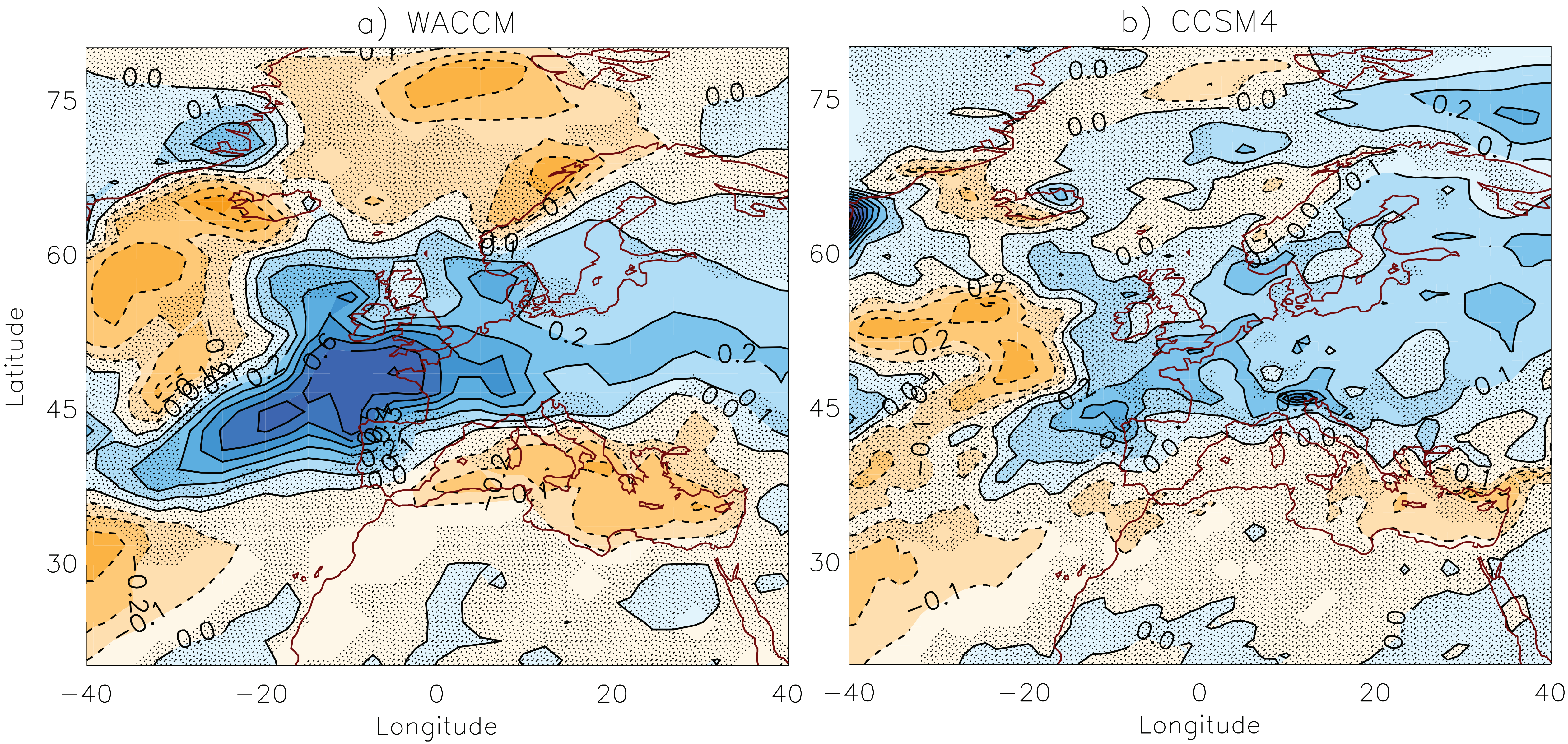
WACCM-CCSM4-WSET



Sea level pressure change PI to present



Precipitation change PI to present over Europe



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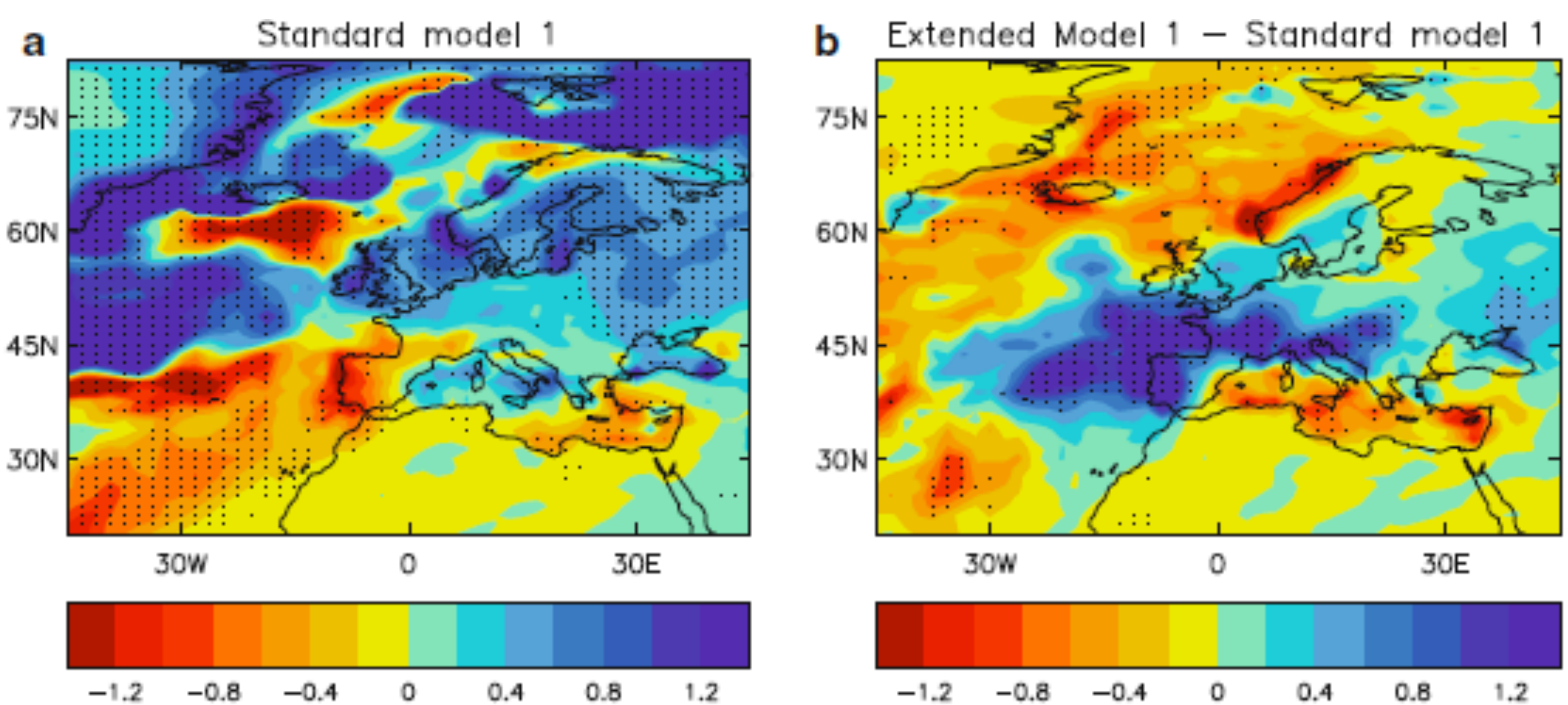
NH surface response

Clim Dyn
DOI 10.1007/s00382-011-1080-7

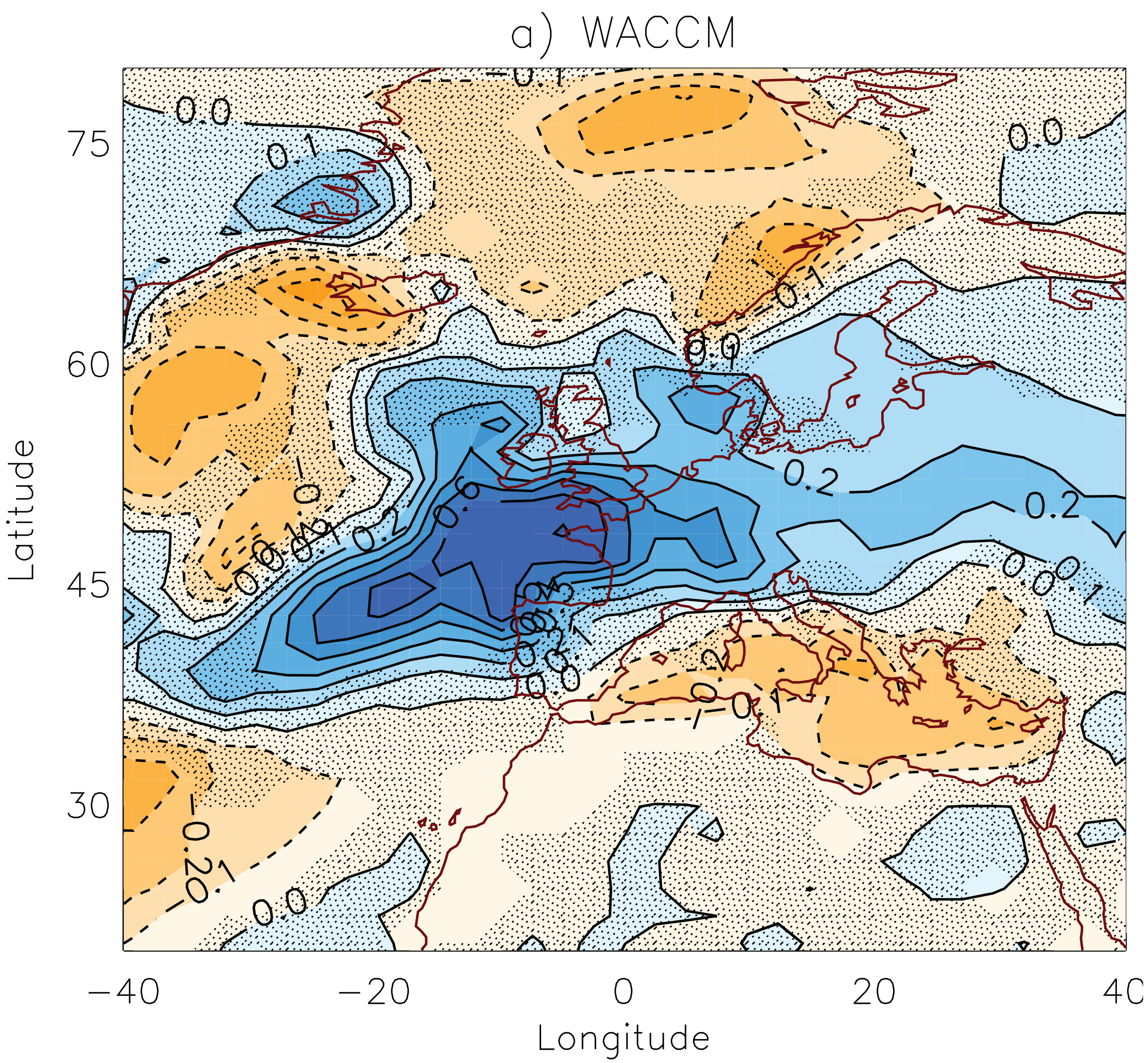
Climate change projections and stratosphere–troposphere interaction

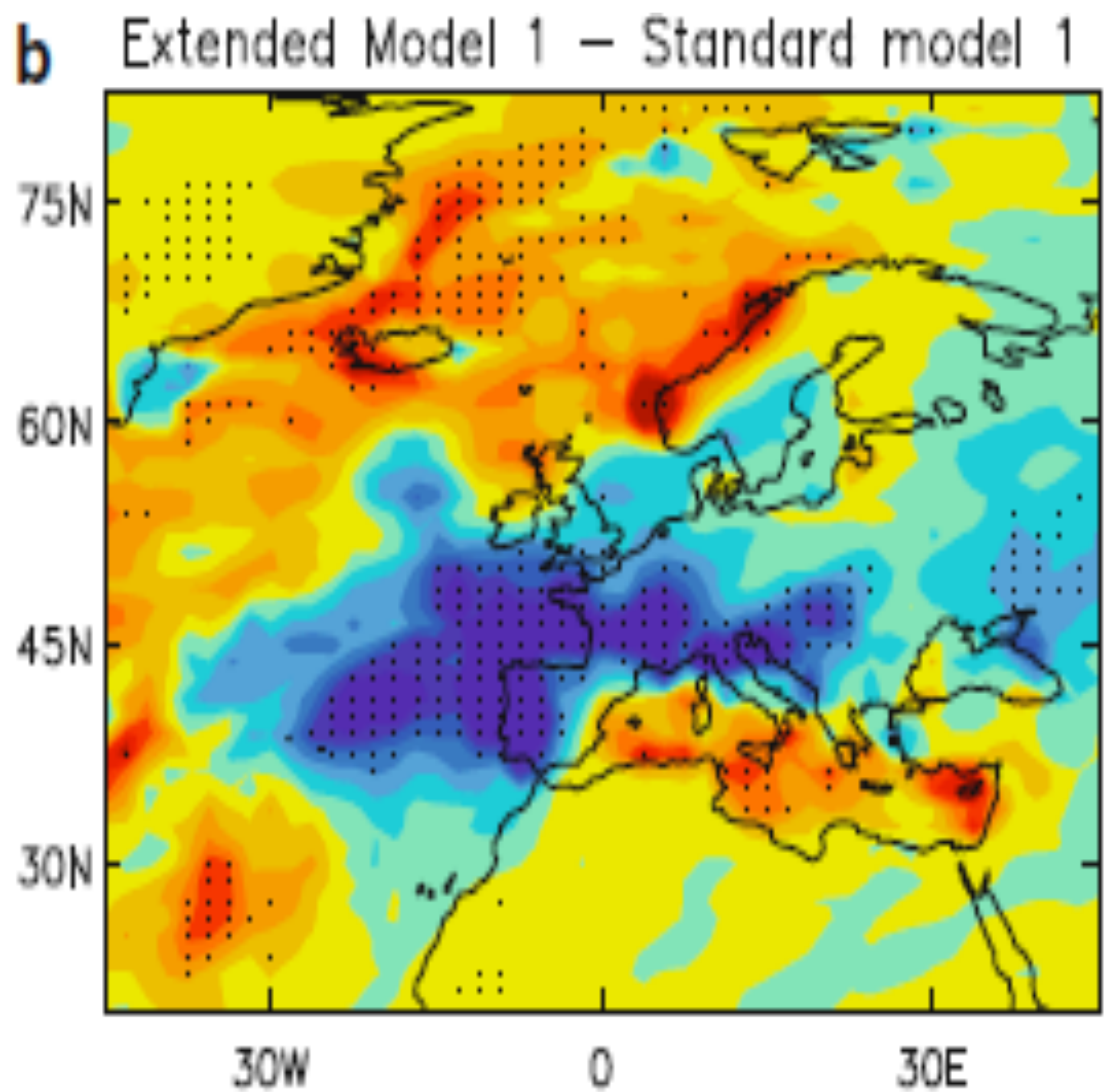
Adam A. Scaife · Thomas Spangehl · David R. Fereday · Ulrich Cubasch · Ulrike Langematz · Hideharu Akiyoshi · Slimane Bekki · Peter Braesicke · Neal Butchart · Martyn P. Chipperfield · Andrew Gettelman · Steven C. Hardiman · Martine Michou · Eugene Rozanov · Theodore G. Shepherd



Winter Mean Rainfall
$(4 \times CO_2)$-$(1 \times CO_2)$

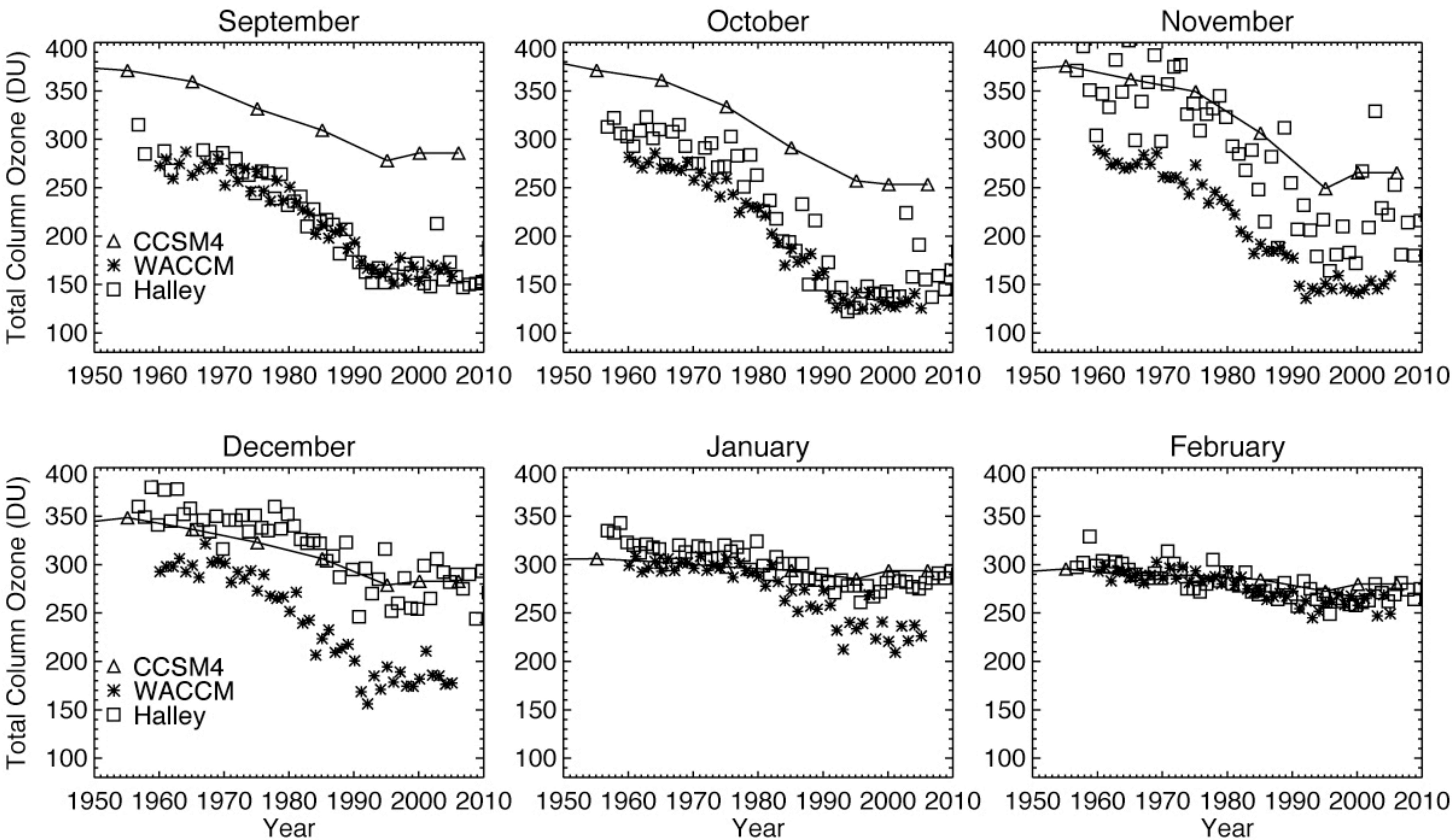
Precipitation change PI to present



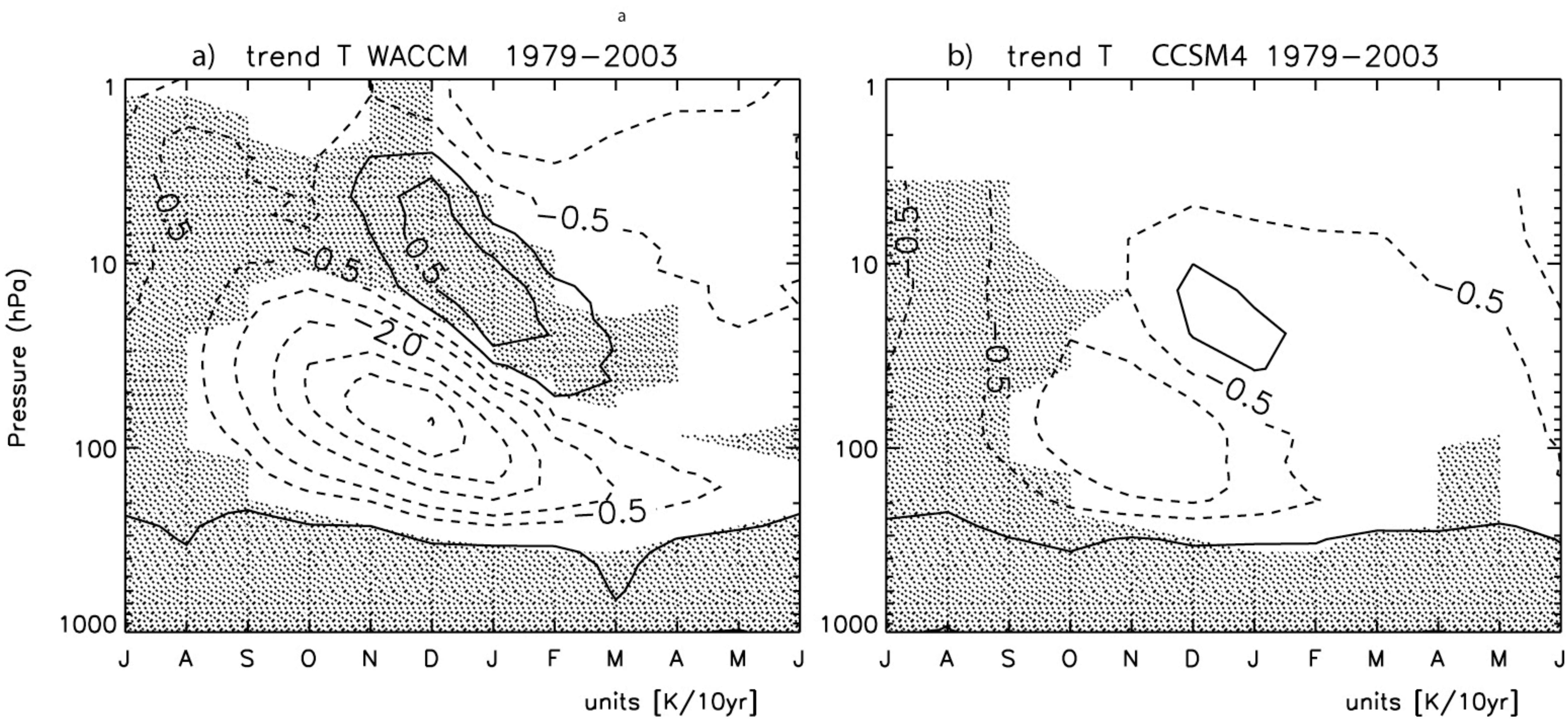


SH response to the development of the stratospheric ozone hole

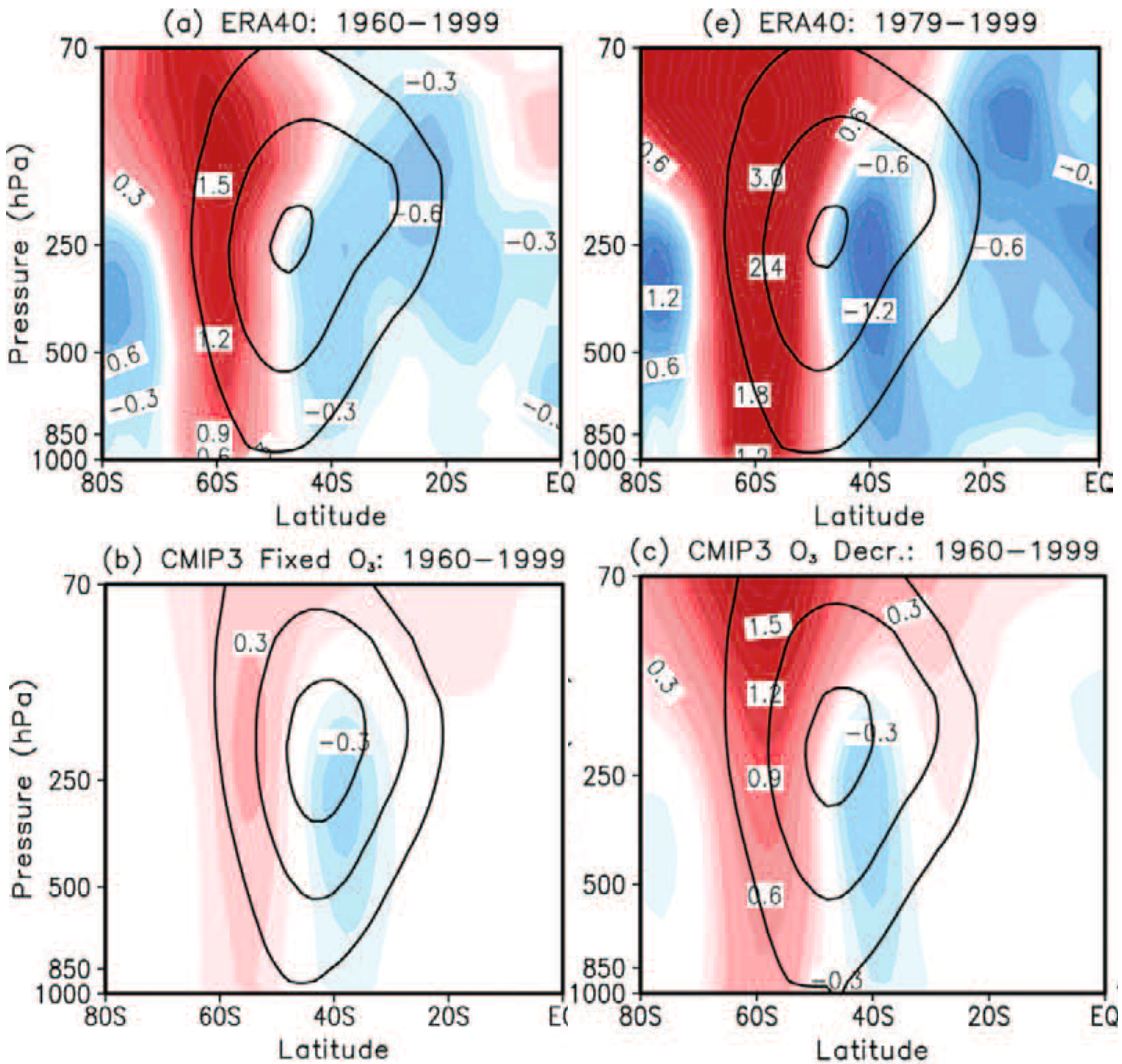
Total Column Ozone - Halley Bay



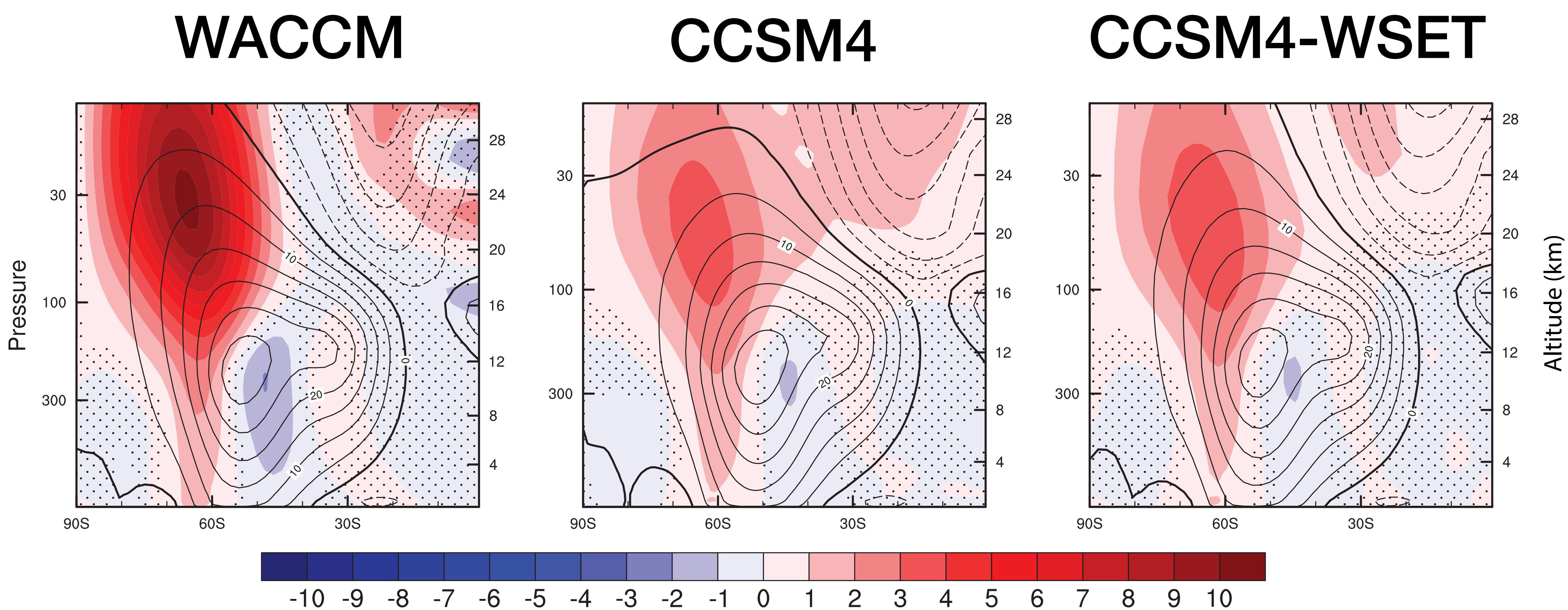
SH polar cap temperature trends (K/decade)



DJF zonal mean wind trends (m/s/decade)



DJF zonal wind (m/s)



Colors: 1986-2005 average minus 1960-79 average.
Lines: 1960-79 average.

Ozone more important than GHG

Stratospheric Ozone Depletion: The Main Driver of Twentieth-Century Atmospheric Circulation Changes in the Southern Hemisphere

By specifying ozone and greenhouse gas forcings independently, and performing long, time-slice integrations, it is shown that the impacts of ozone depletion are roughly 2–3 times larger than those associated with increased greenhouse gases, for the Southern Hemisphere tropospheric summer circulation.

Detecting Ozone- and Greenhouse Gas–Driven Wind Trends with Observational Data

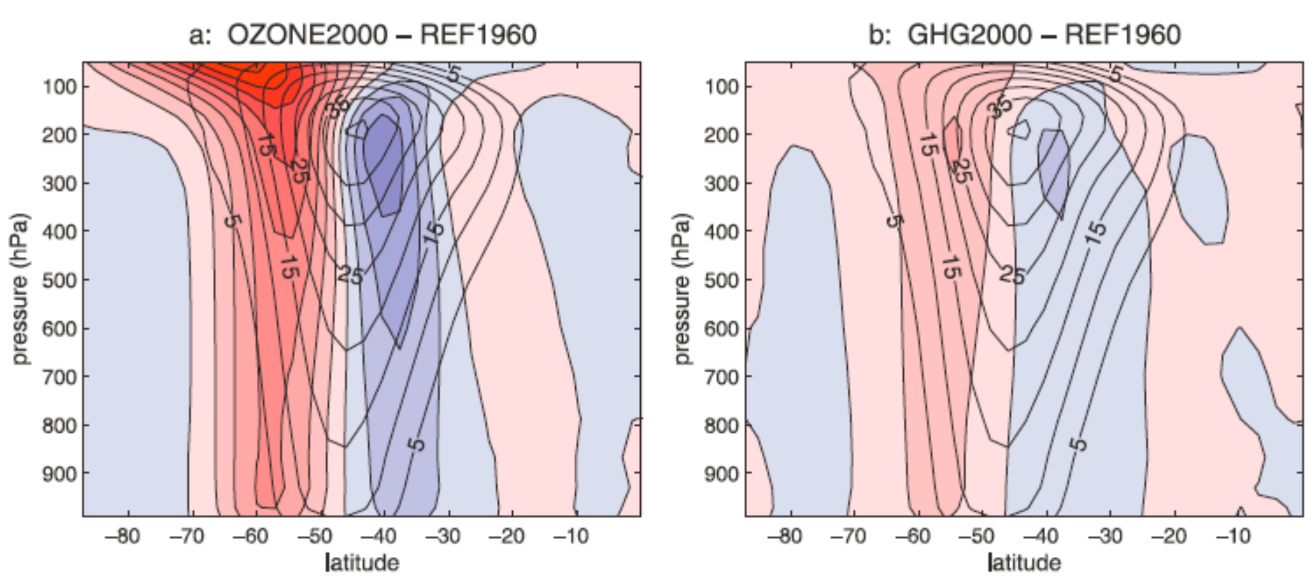
Sukyoung Lee[1]* and Steven B. Feldstein[1]

Modeling studies suggest that Antarctic ozone depletion and, to a lesser degree, greenhouse gas (GHG) increase have caused the observed poleward shift in the westerly jet during the austral summer. Similar studies have not been performed previously with observational data because of difficulties in separating the two contributions. By applying a cluster analysis to daily ERA-Interim data, we found two 7- to 11-day wind clusters, one resembling the models' responses to GHG forcing and the other resembling ozone depletion. The trends in the clusters' frequency of occurrence indicate that the ozone contributed about 50% more than GHG toward the jet shift, supporting the modeling results. Moreover, tropical convection apparently plays an important role for the GHG-driven trend.

Throughout the late 20th century, the Southern Hemisphere (SH) westerlies have undergone a poleward shift (1–3), especially during the austral summer (December through February; DJF hereafter) (Fig. 1A). This change affects weather and climate not only by altering the

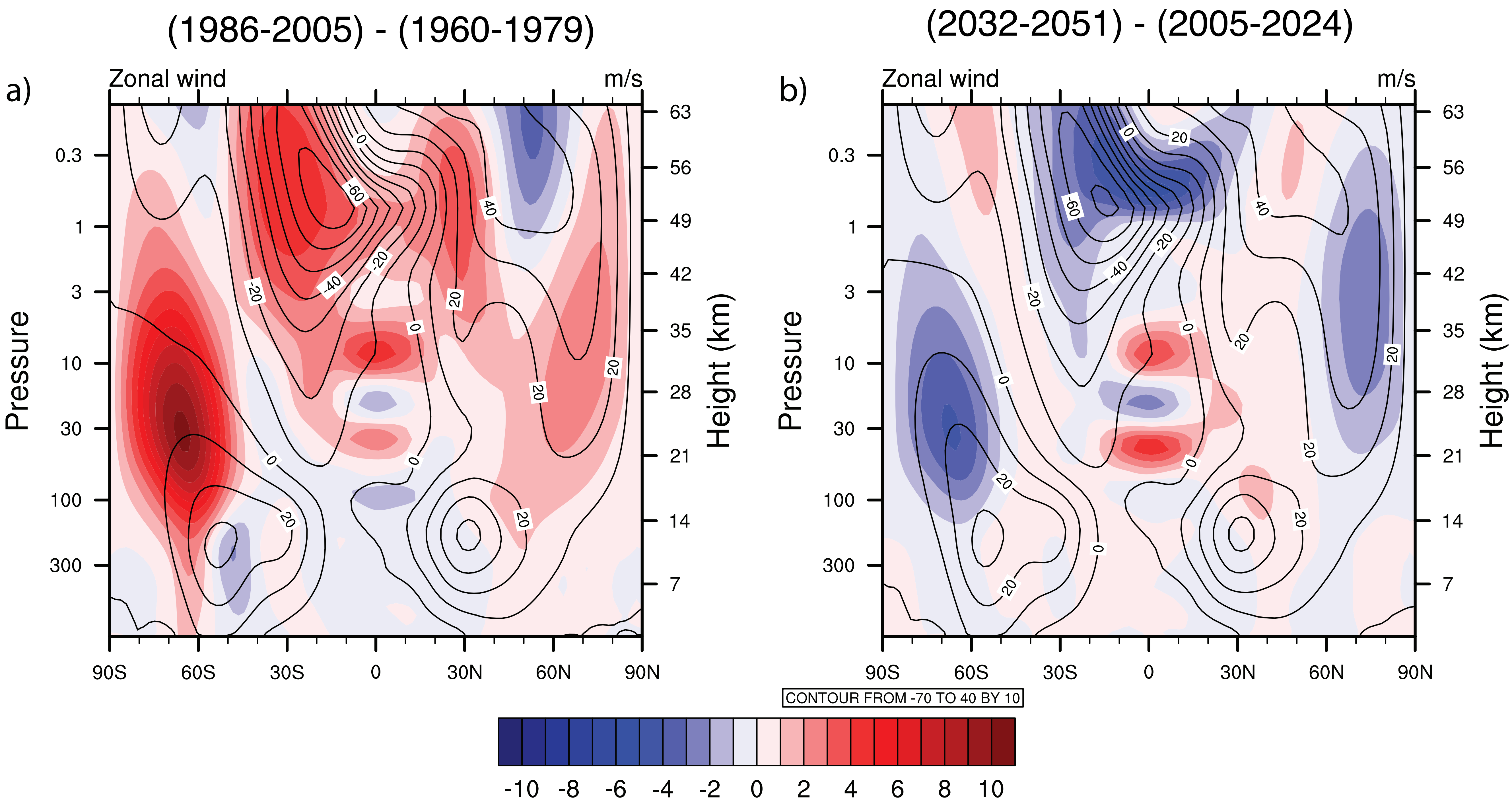
:emag.org SCIENCE VOL 339 1 FEBRUARY 2013 563

1 February 2011 POLVANI ET AL.



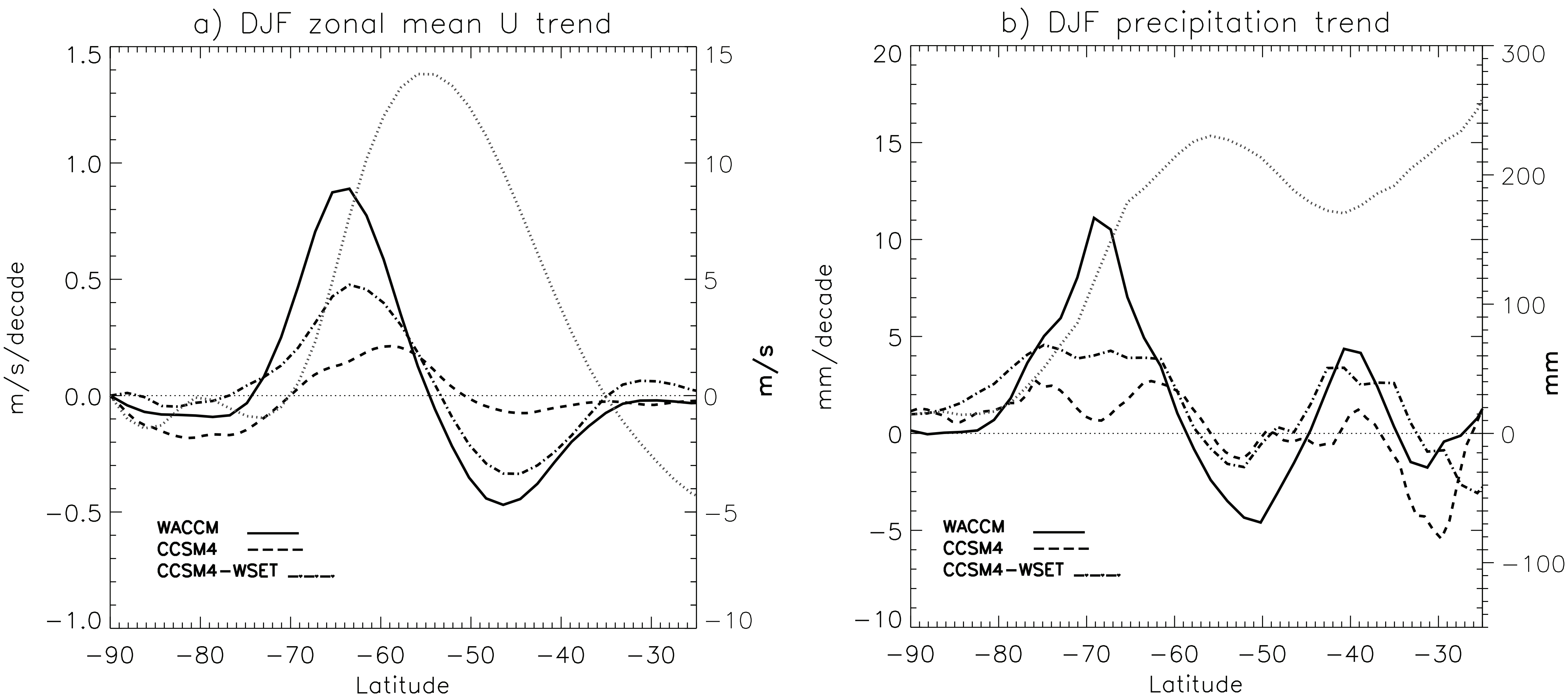
"...ozone contributed about 50% more than GHG toward the jet shift..."

Trend reverses going into the future



Hurrell et al., BAMS, 2013

Zonal wind and precipitation trends 1975-1995



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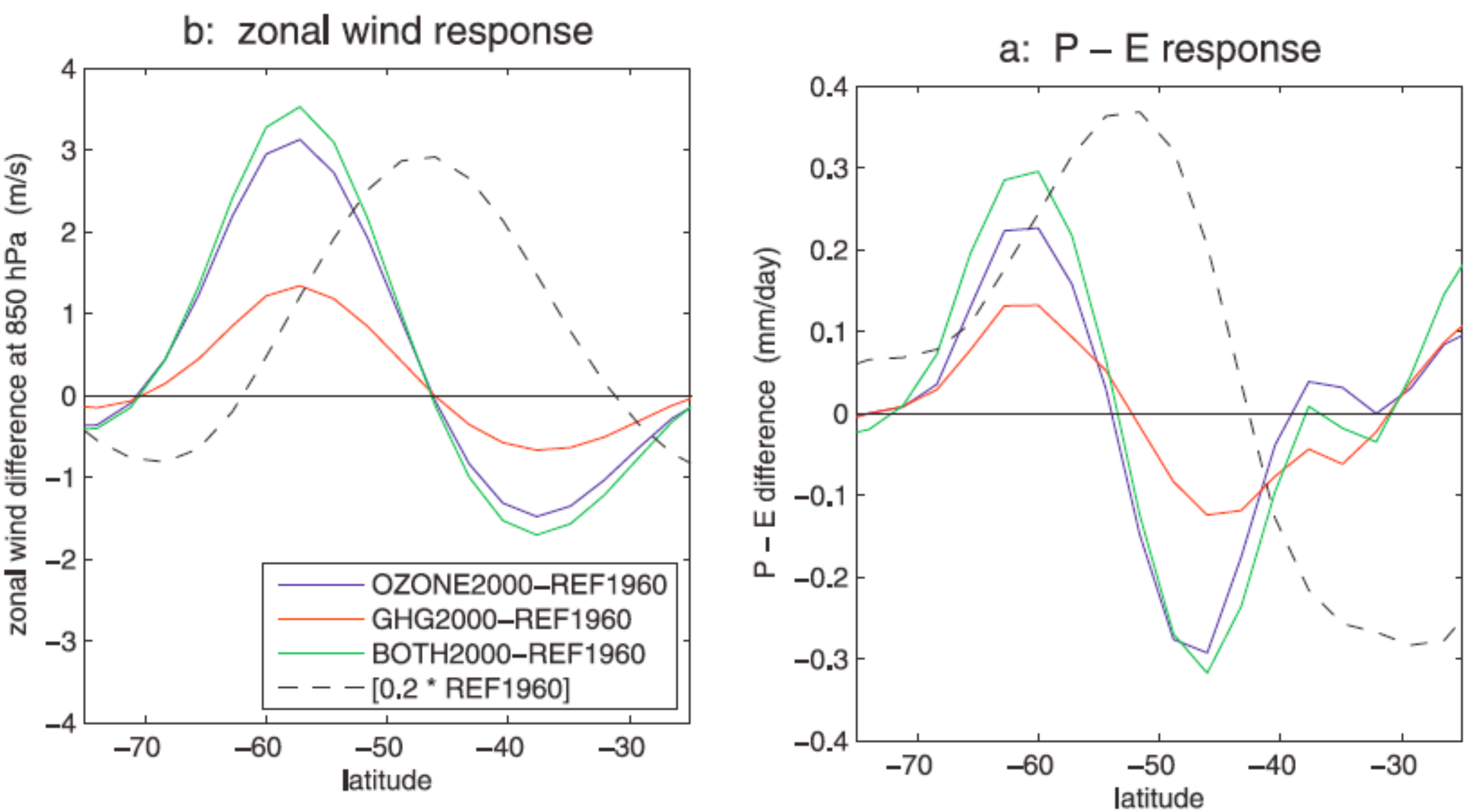
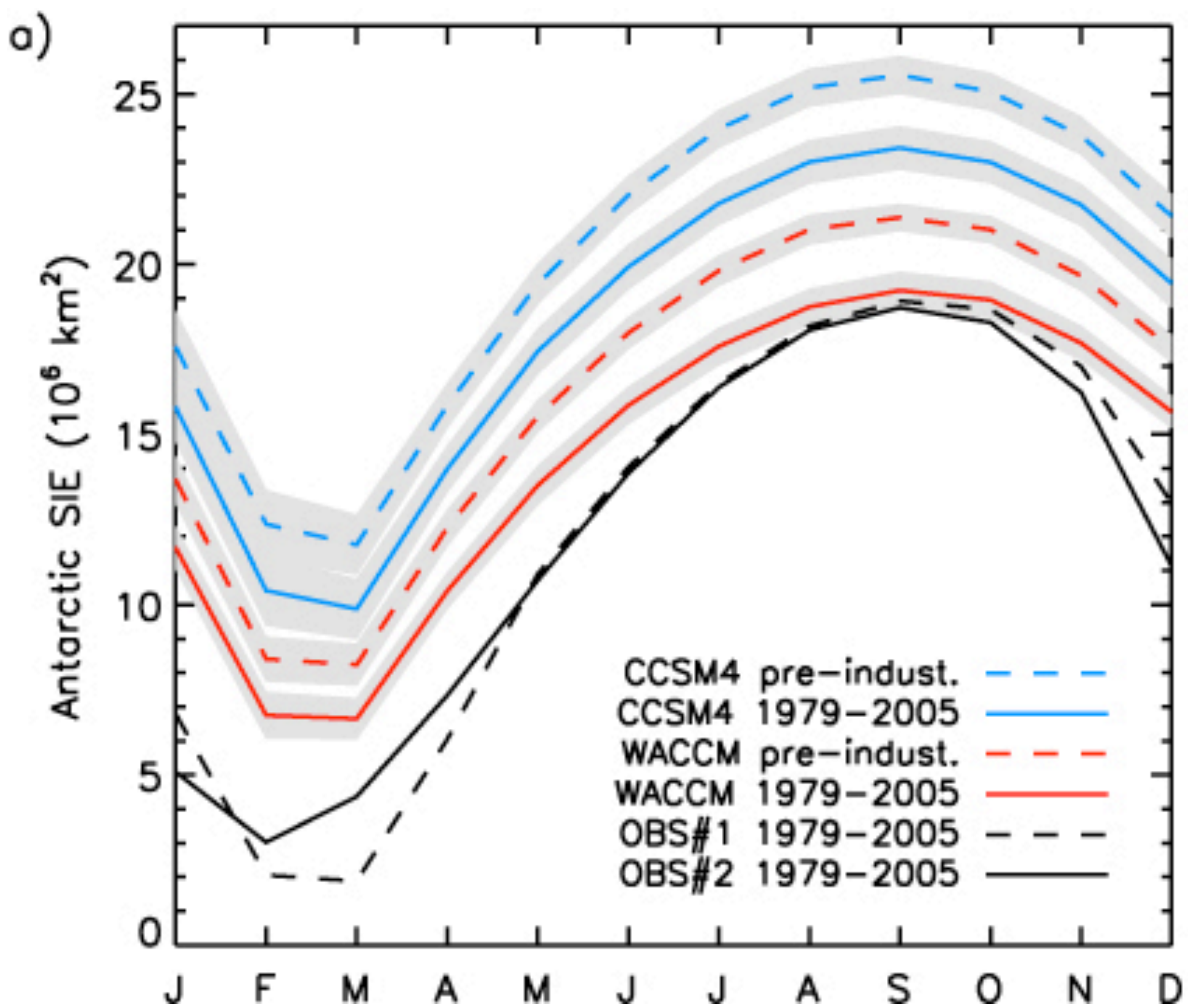
Polvani et al., 2011

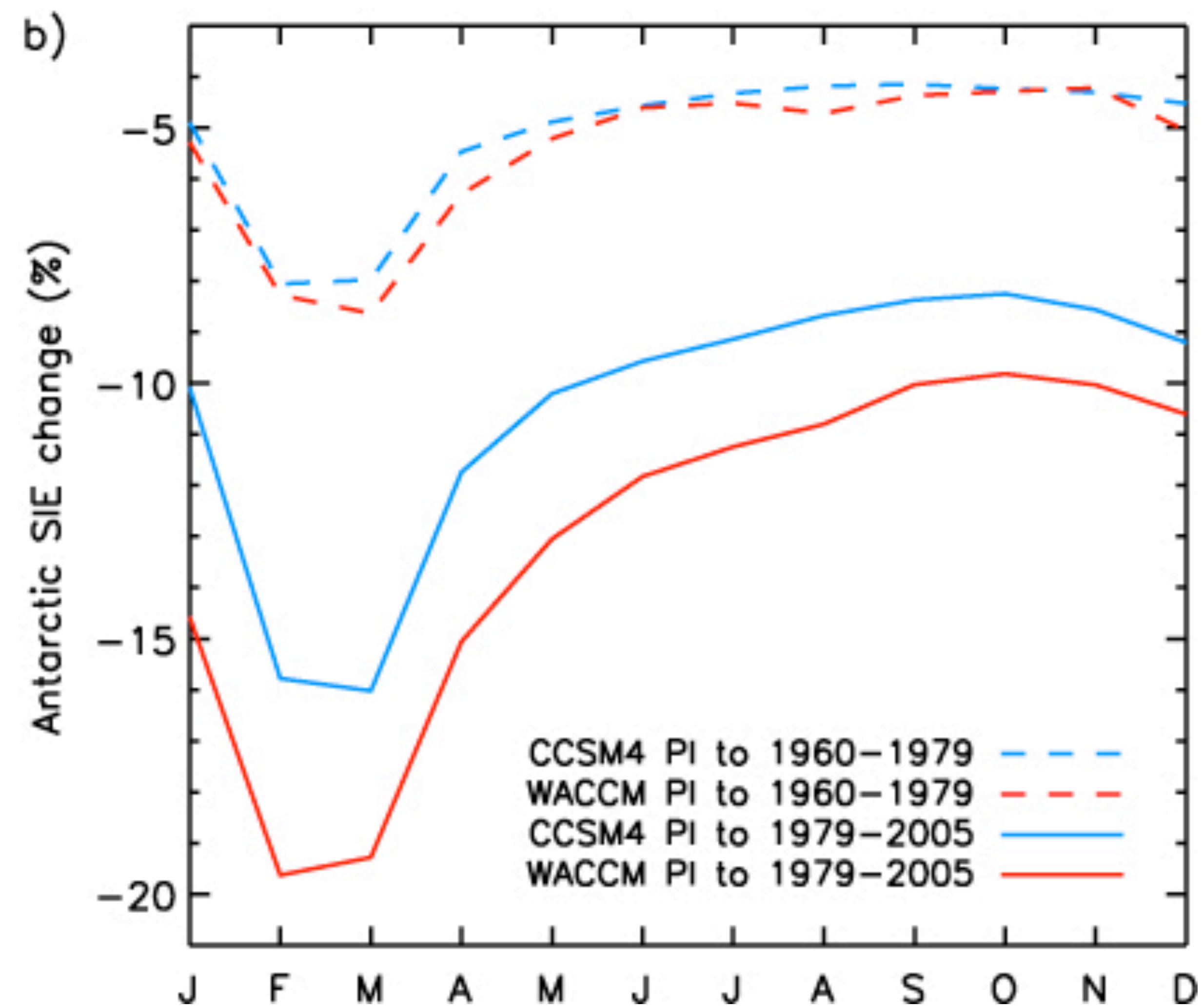


Antarctic Sea Ice Extent

SIE (10^6 km^2)



% change from PI



Summary

- SSWs are practically absent in standard CCSM4 - there is no NAM signal propagating into the troposphere.
- TMS leads to a reasonable SSW occurrence in WACCM and a substantial increase (~50% obs.) in CCSM4. NH polar SLP bias reduced. It also improves N3.4 power amplitude (not shown).
- PI to present change in NH European SLP and precip. are different between WACCM and CCSM4 - pattern remarkably consistent with prior studies.
- Correct ozone changes in the stratosphere are critical to getting trends correct there. These trends lead to differences in surface winds and precip.
- WACCM and CCSM4 show an **acceleration** of SEI loss with the development of the ozone hole - contrary to observations, which show flat or slightly positive trends.