

The battle over the future direction of the Southern Annular Mode *Ozone recovery or greenhouse warming?*

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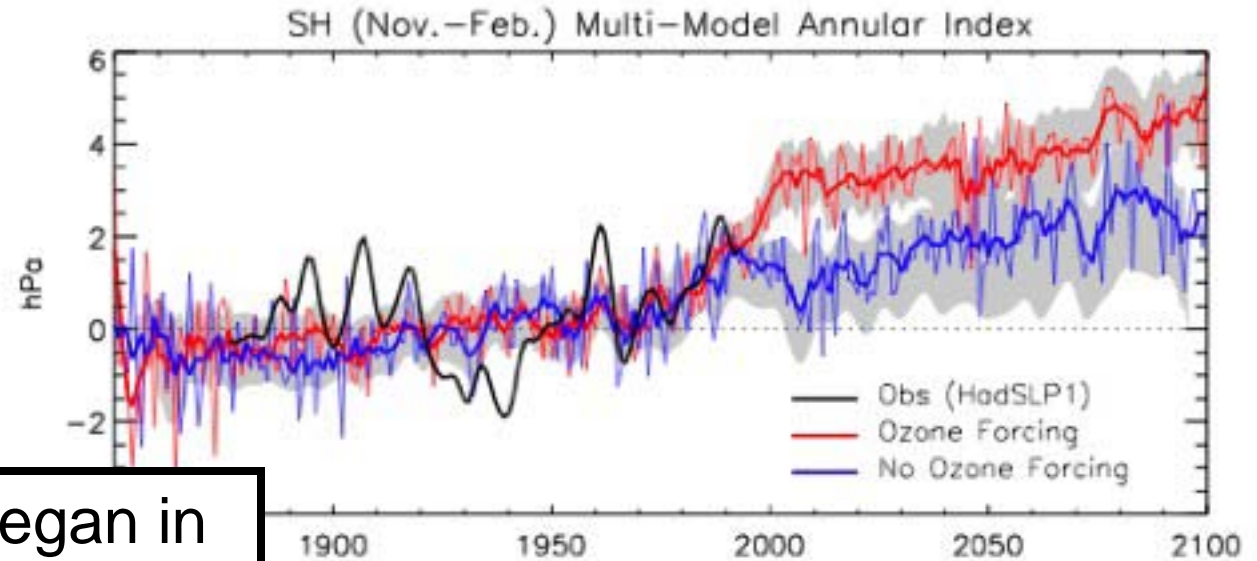
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³University of Melbourne

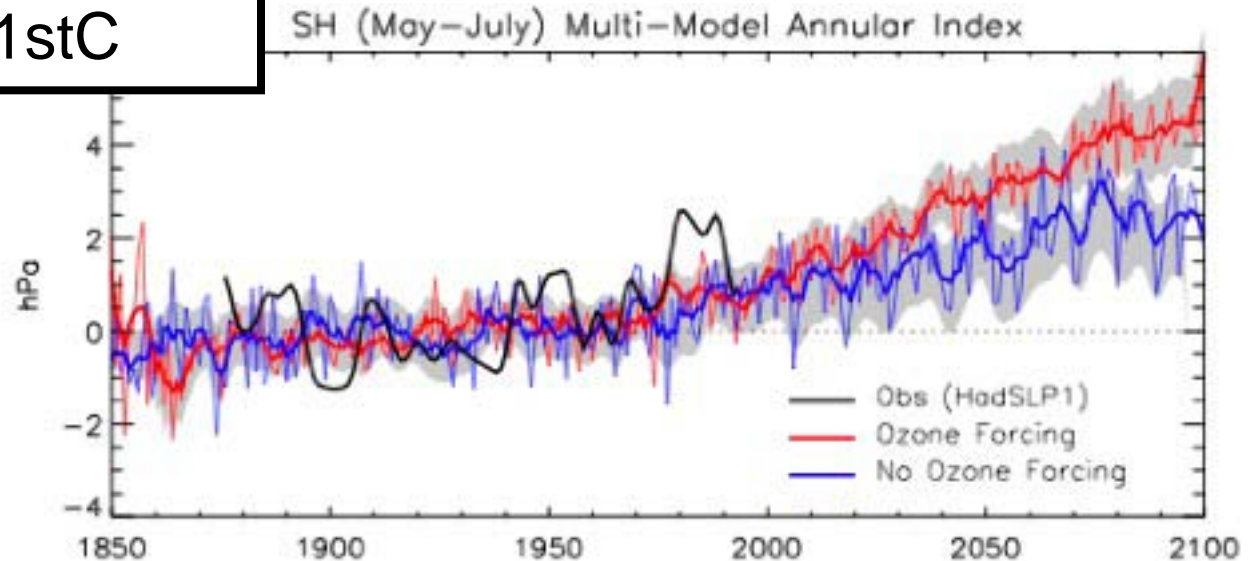
Multi-model SAM index from CMIP3 models

NDJF

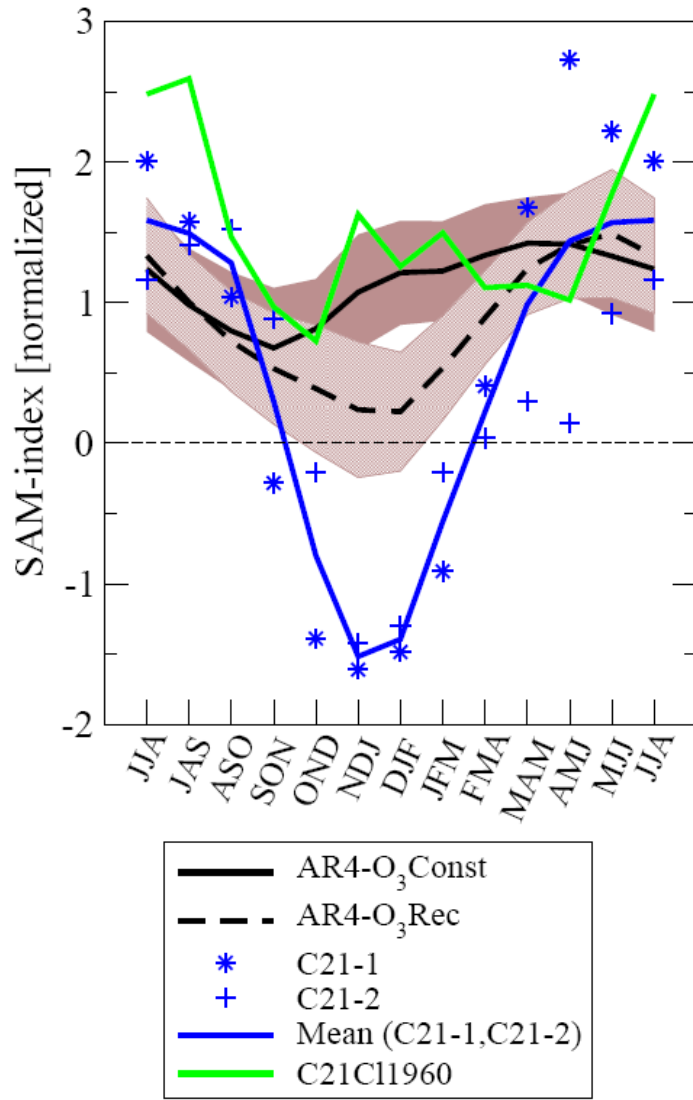


SAM trends that began in late 20thC, expected to continue into 21stC

MJJ



SAM index from CMIP3 & CCMVals models

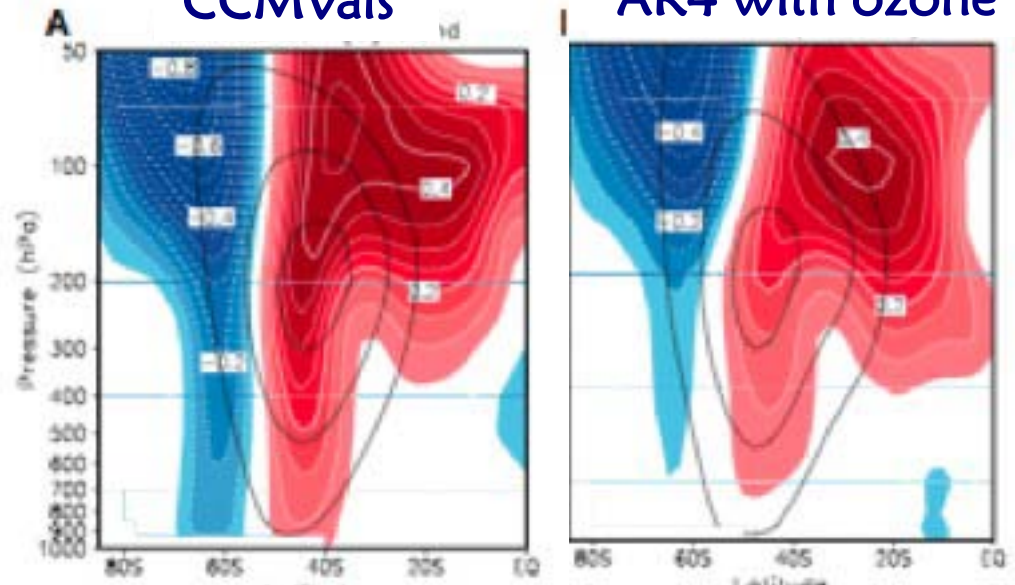


**Perlwitz et al. 2008, GRL
and Son et al, 2008, Science**

Chemistry-climate models suggest negative DJF trend in SAM over 21stC, opposite to IPCC AR4 multi-model mean

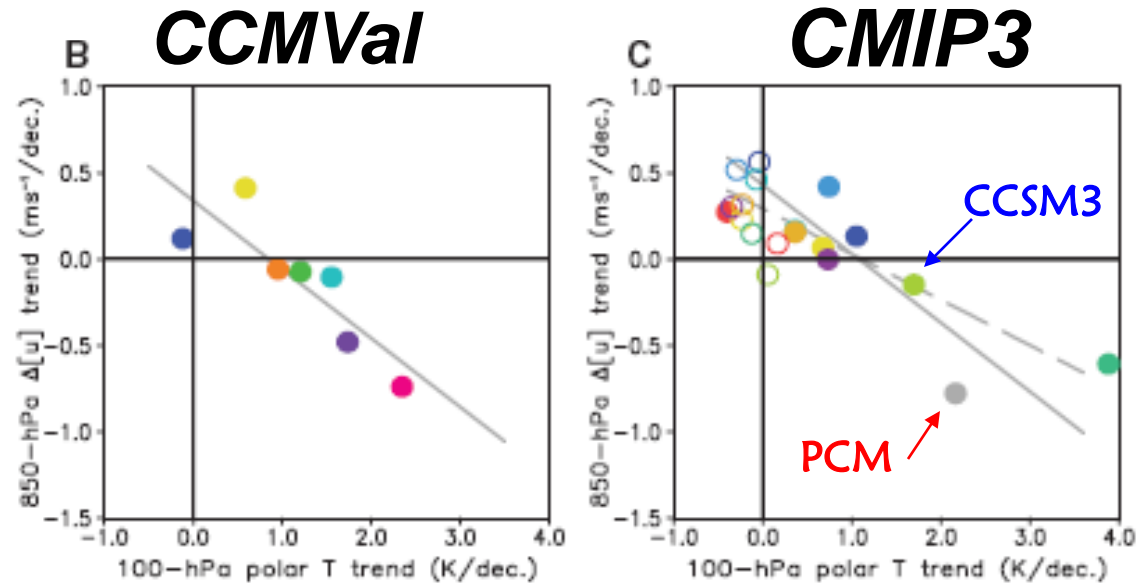
CCMVals

AR4 with ozone



SAM index from CMIP3 & CCMVals models

CCMval models show a strong relationship between 100 hPa polar cap winds and changes in SAM.

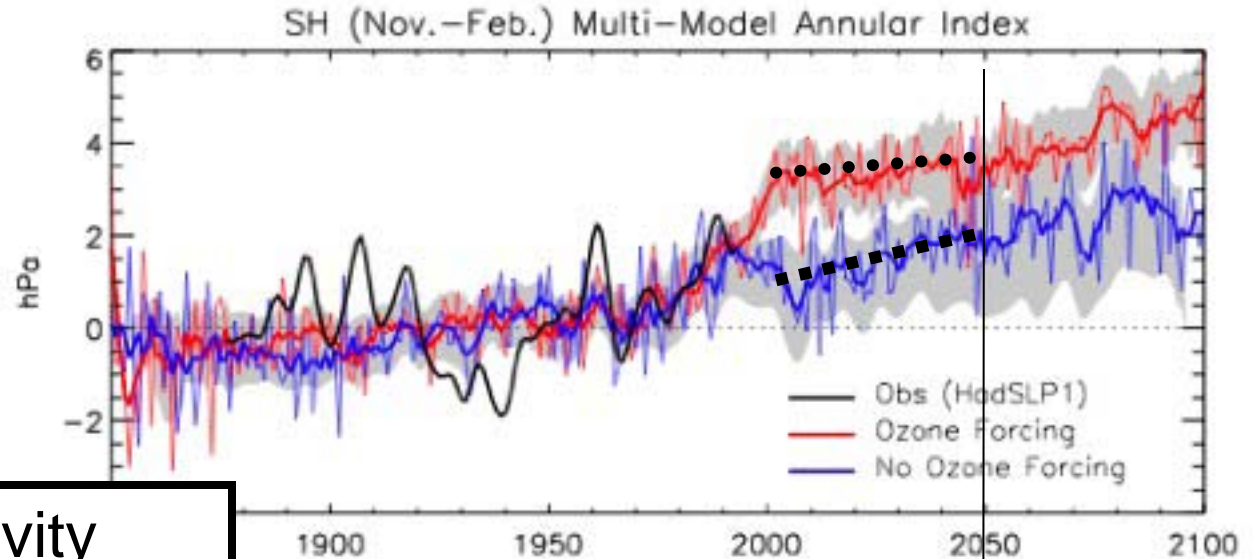


Son et al 2008

AR4 models with ozone recovery show a similar, while weaker relationship.

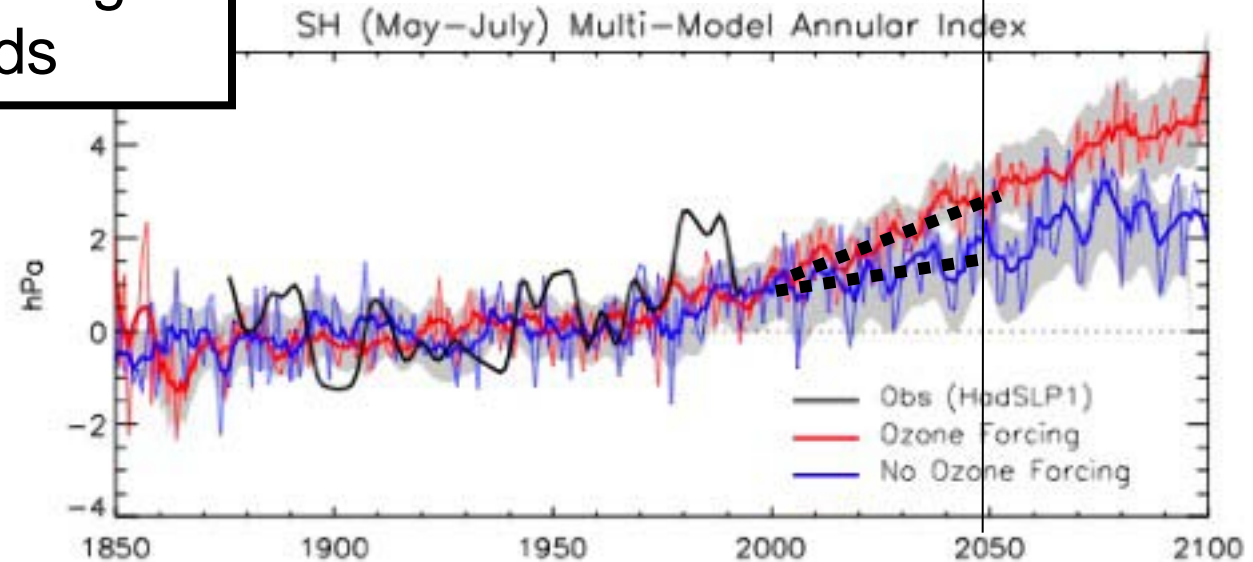
Multi-model SAM index from CMIP3 models

NDJF



Climate sensitivity strongly affects strength of 21stC trends

MJJ



Motivation

⇒ Greenhouse gas increases and ozone depletion have additive affect on SAM in 20thC => +ve SAM trend

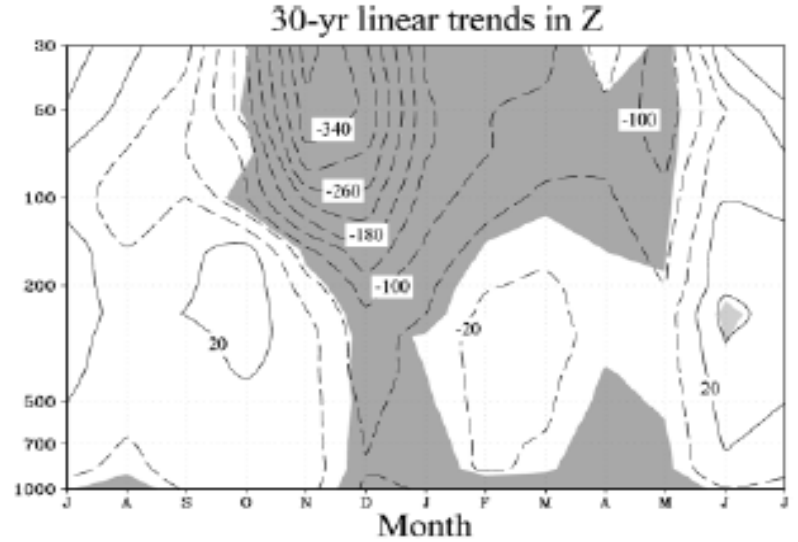
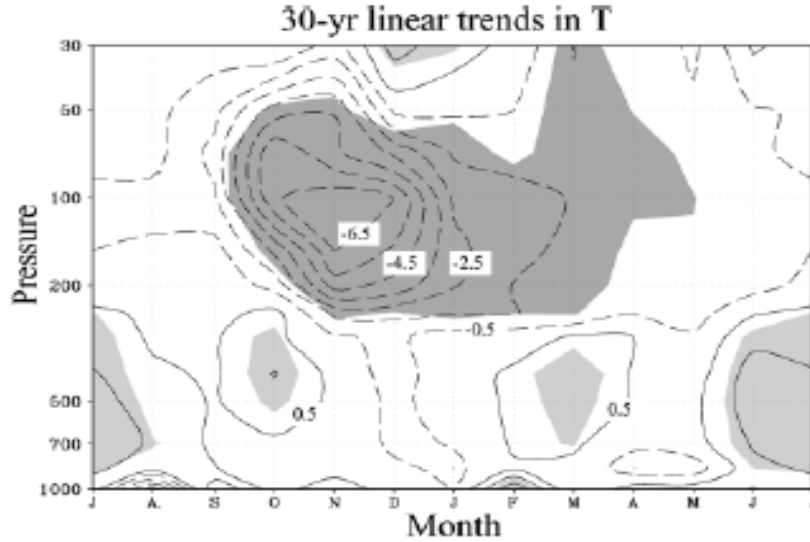
⇒ Greenhouse gas increases and ozone recovery have opposing affect on SAM in 21stC => ? SAM trend

⇒ Chem-Climate (high-top) and coupled (low-top) models give opposite trends, but comparing sets of models is complicated by different forcing datasets

⇒ *can look more closely at two models with known forcings to understand differences*

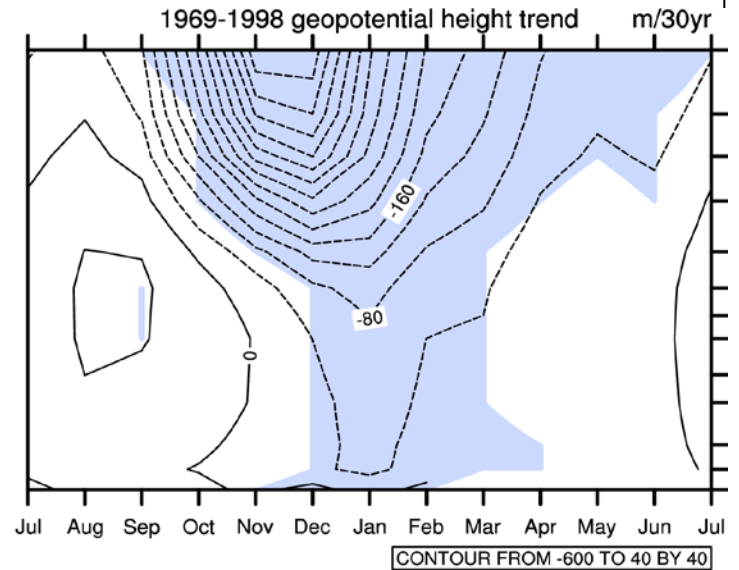
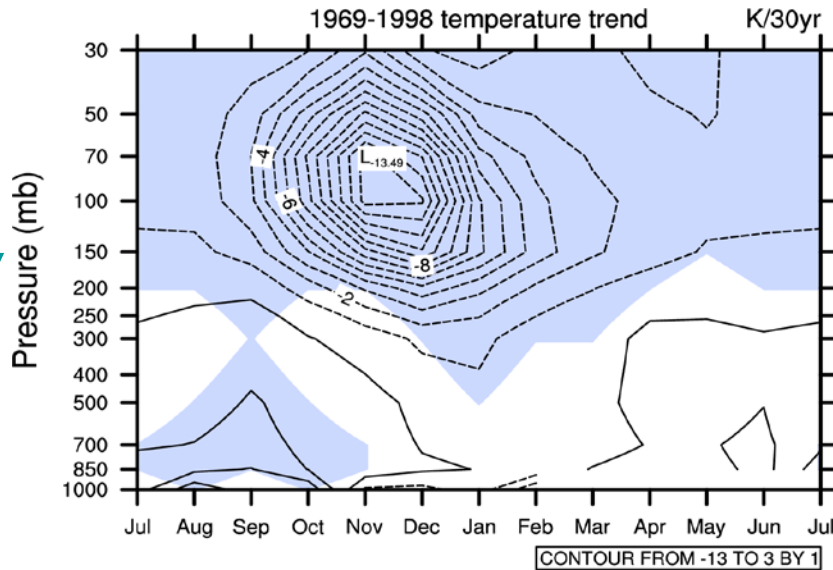
20thC Trends over Antarctic cap in NCAR PCM

Obs



[Thompson & Solomon, *Science*, May 2002]

Pcm
"All"



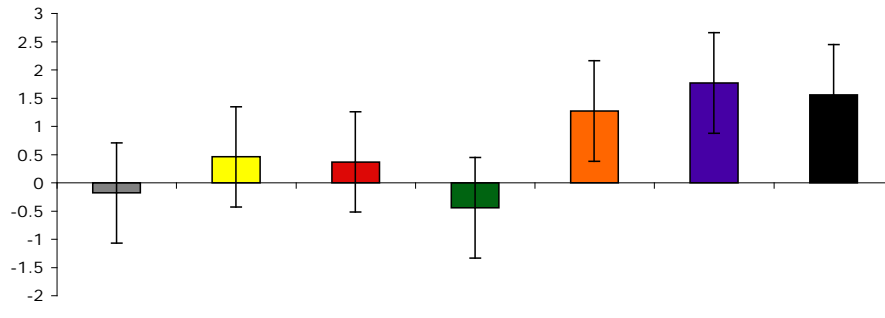
volc+solar+ghg+sulfate+ozone

Arblaster & Meehl, 2006

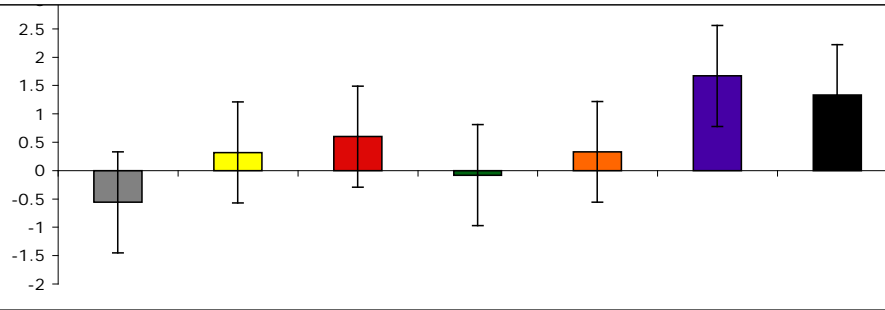
PCM SAM Trends: 1958-1999

V S G Su Oz All Obs

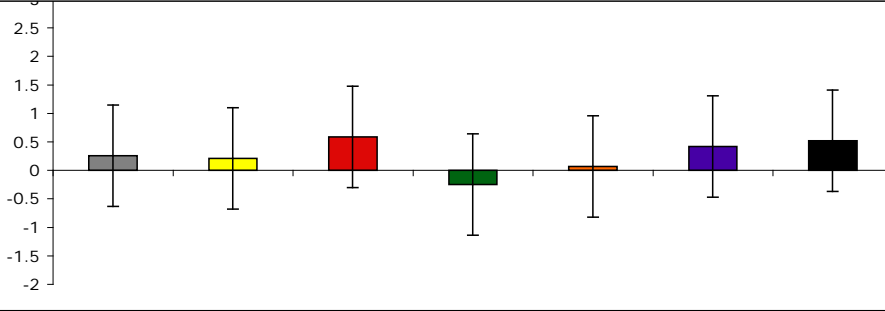
DJF



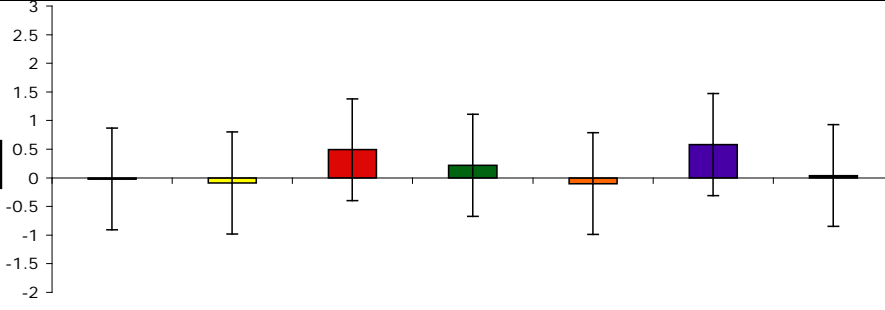
MAM



JJA



SON

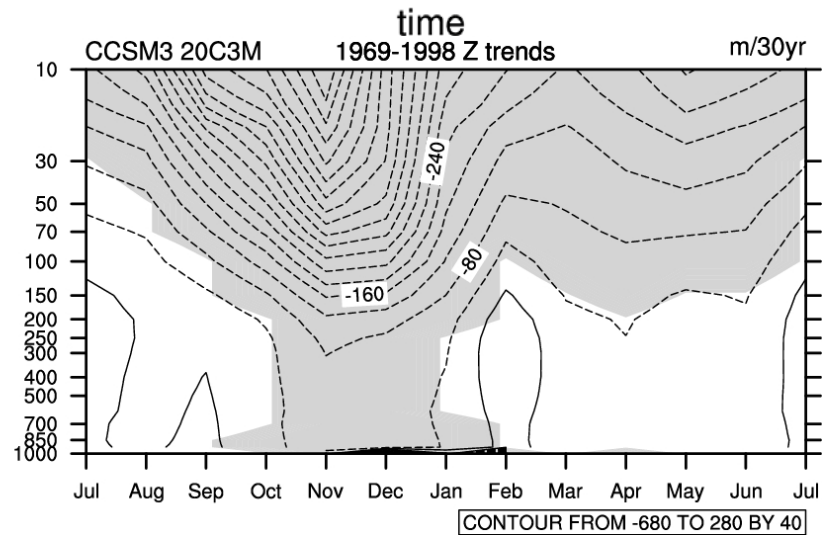
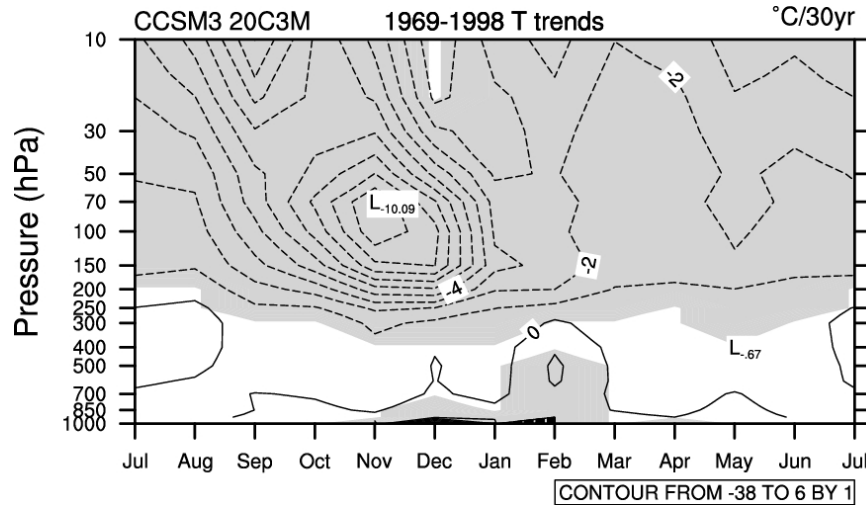
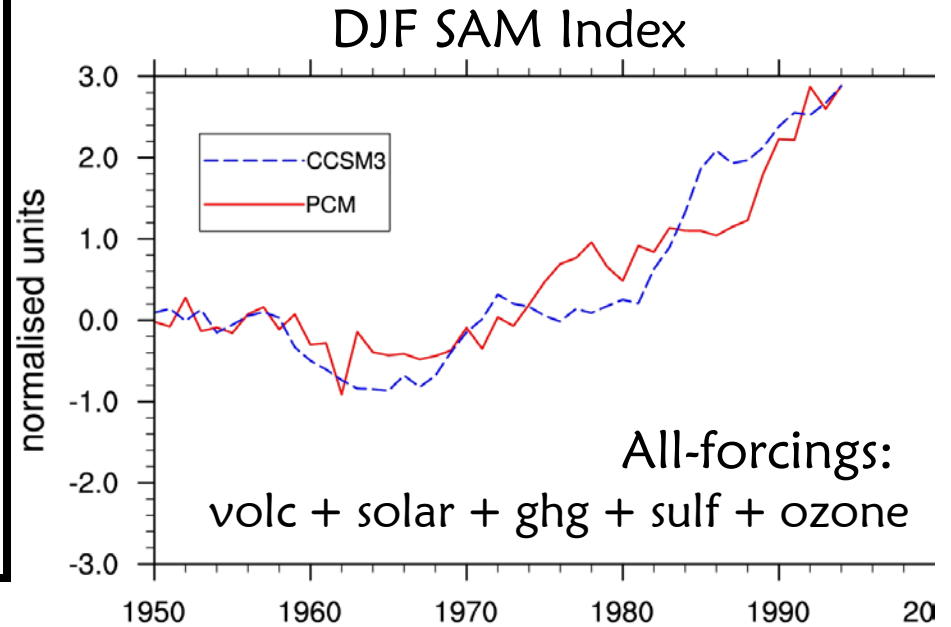


Trends from 1958-1999 of the SAM index (normalized units/30yr). The SAM index is defined as the difference in normalized zonally averaged sea level pressure between 40°S and 65°S. The error bars indicate the 95% confidence intervals obtained from the PCM 1000 year control run

Trends in NCAR models over late 20th Century

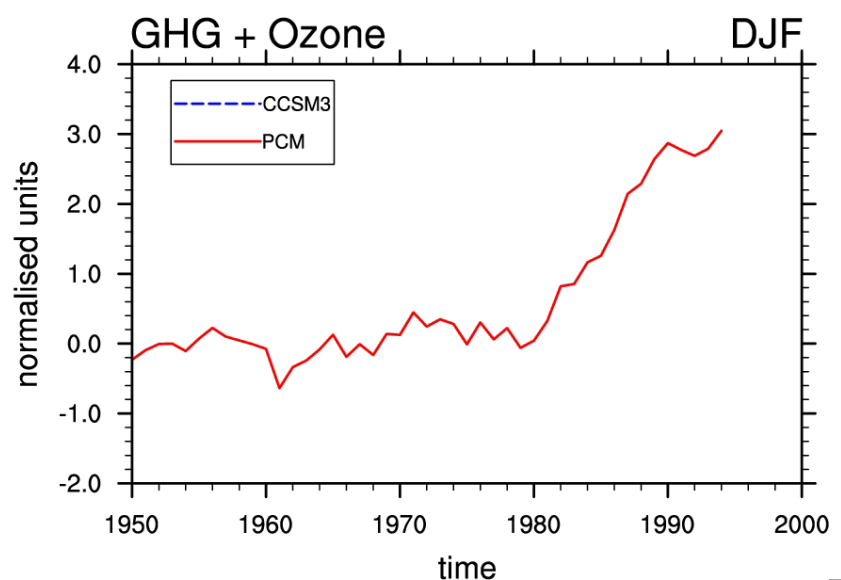
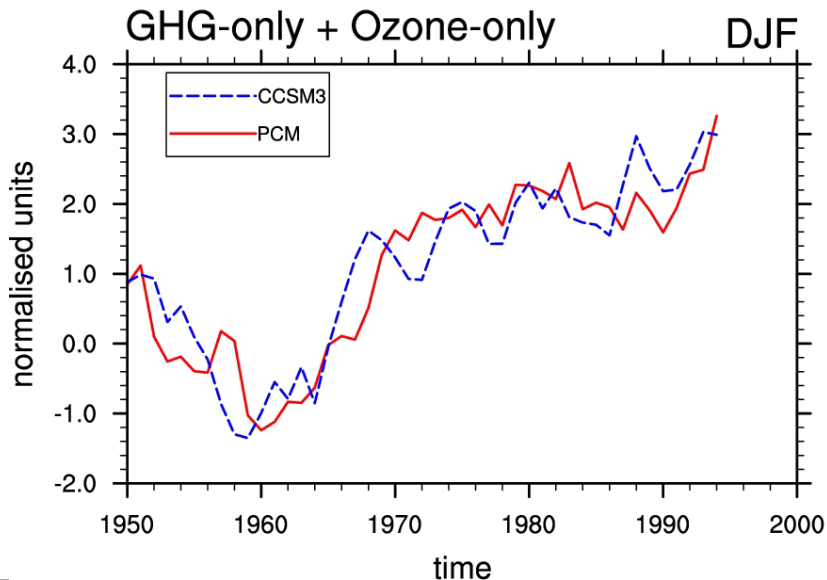
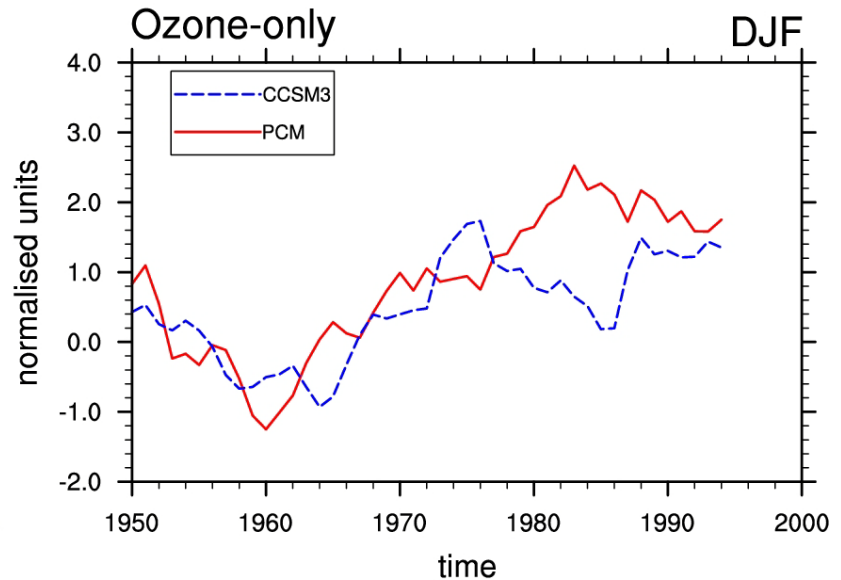
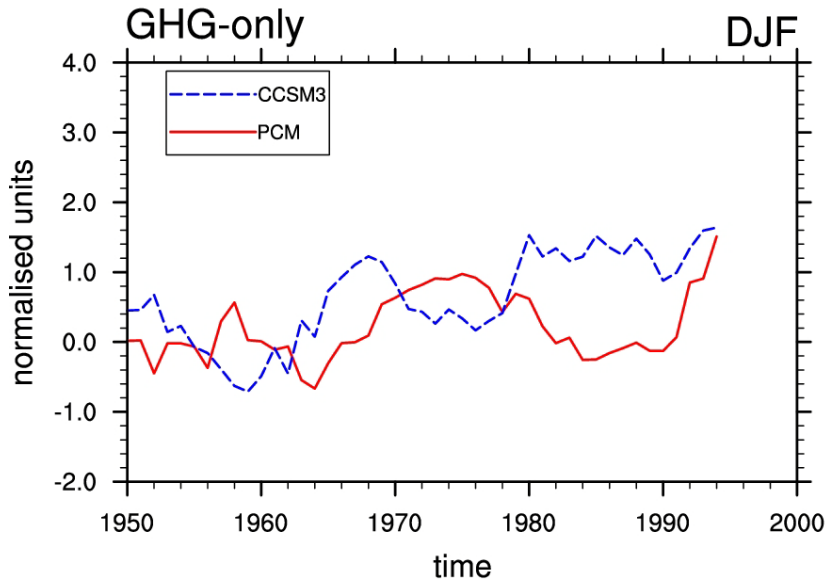
Similar SAM trends over second half of 20thC in all-forcing runs of NCAR models

Both models capture downward progression of height trends in austral summer

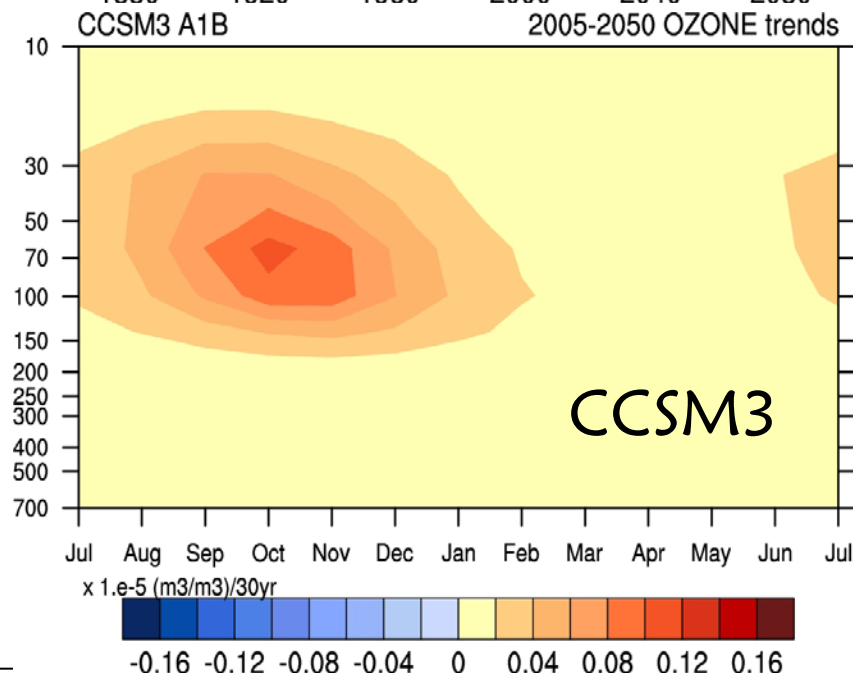
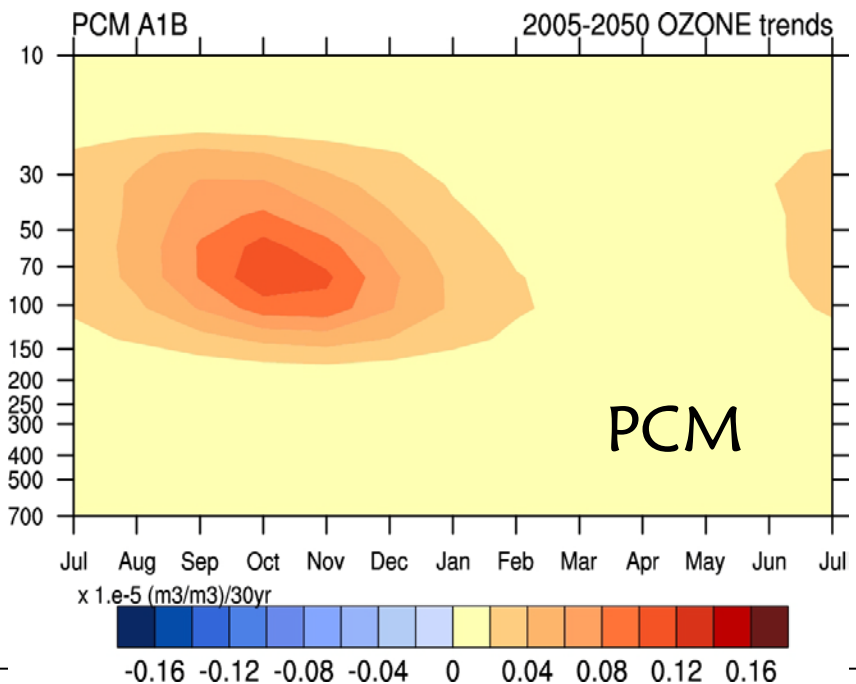
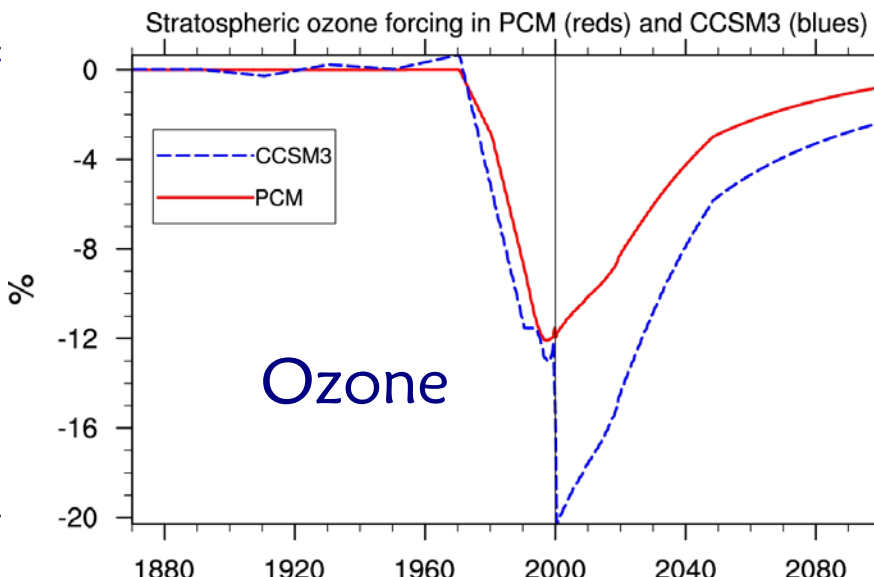
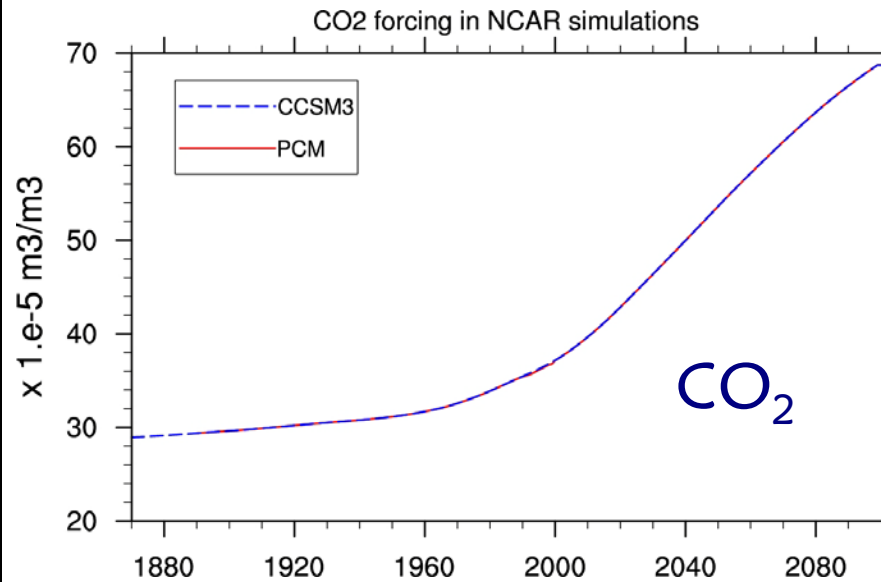


SAM in NCAR AR4 models over 20th Century

SAM Index: NCAR 20th Century simulations

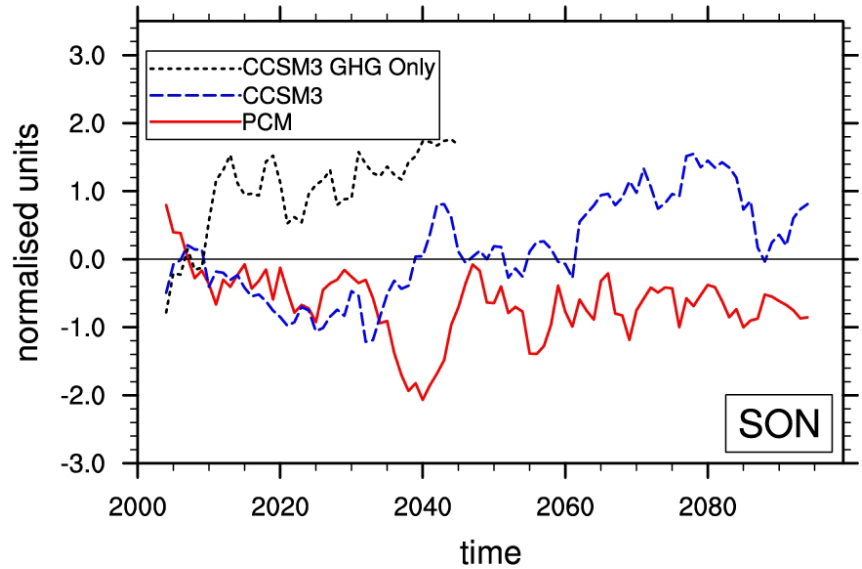
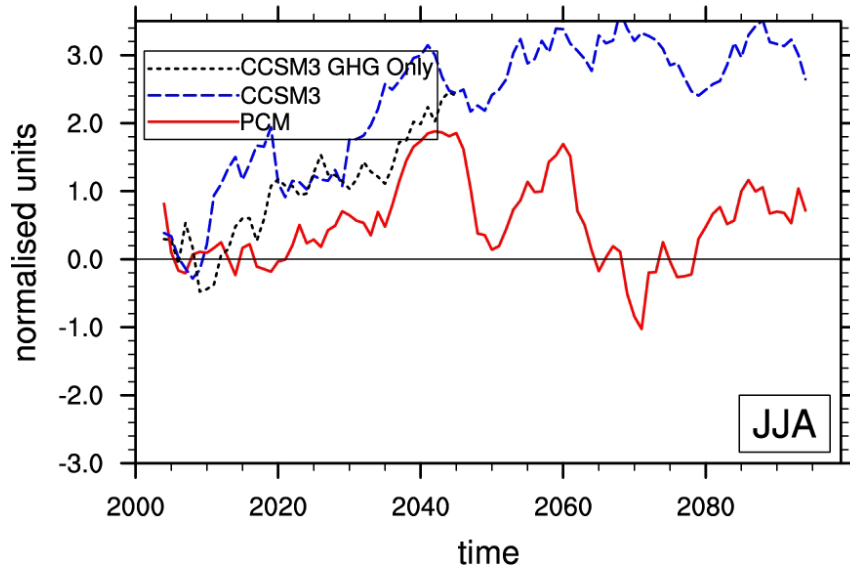
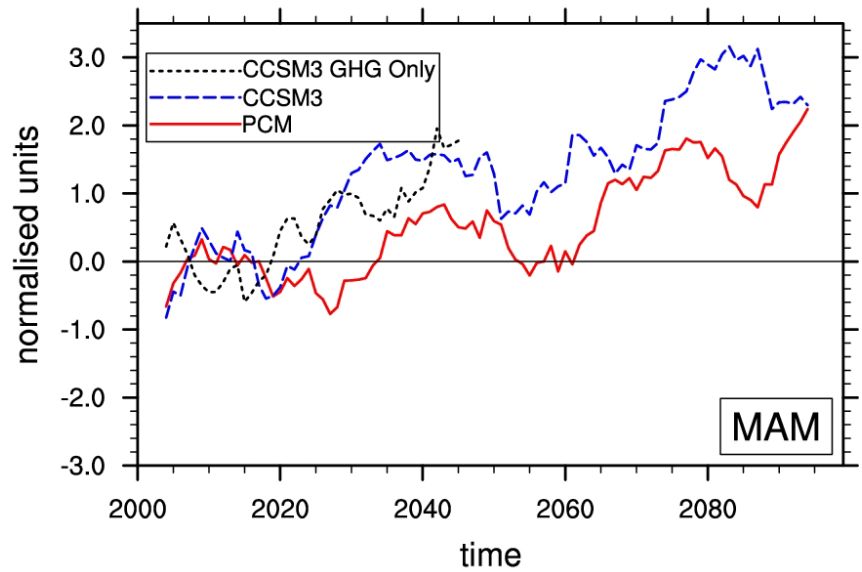
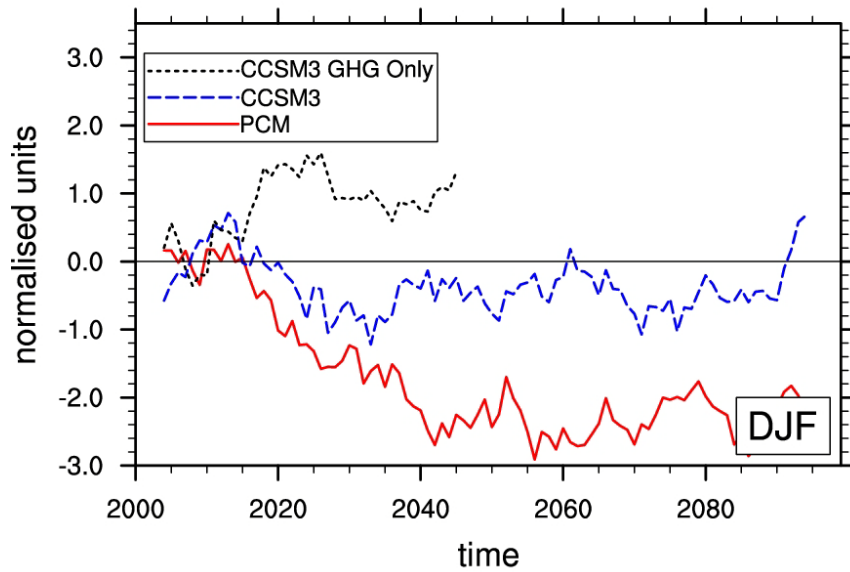


21stC forcing used in NCAR AR4 models



SAM index from NCAR A1B runs

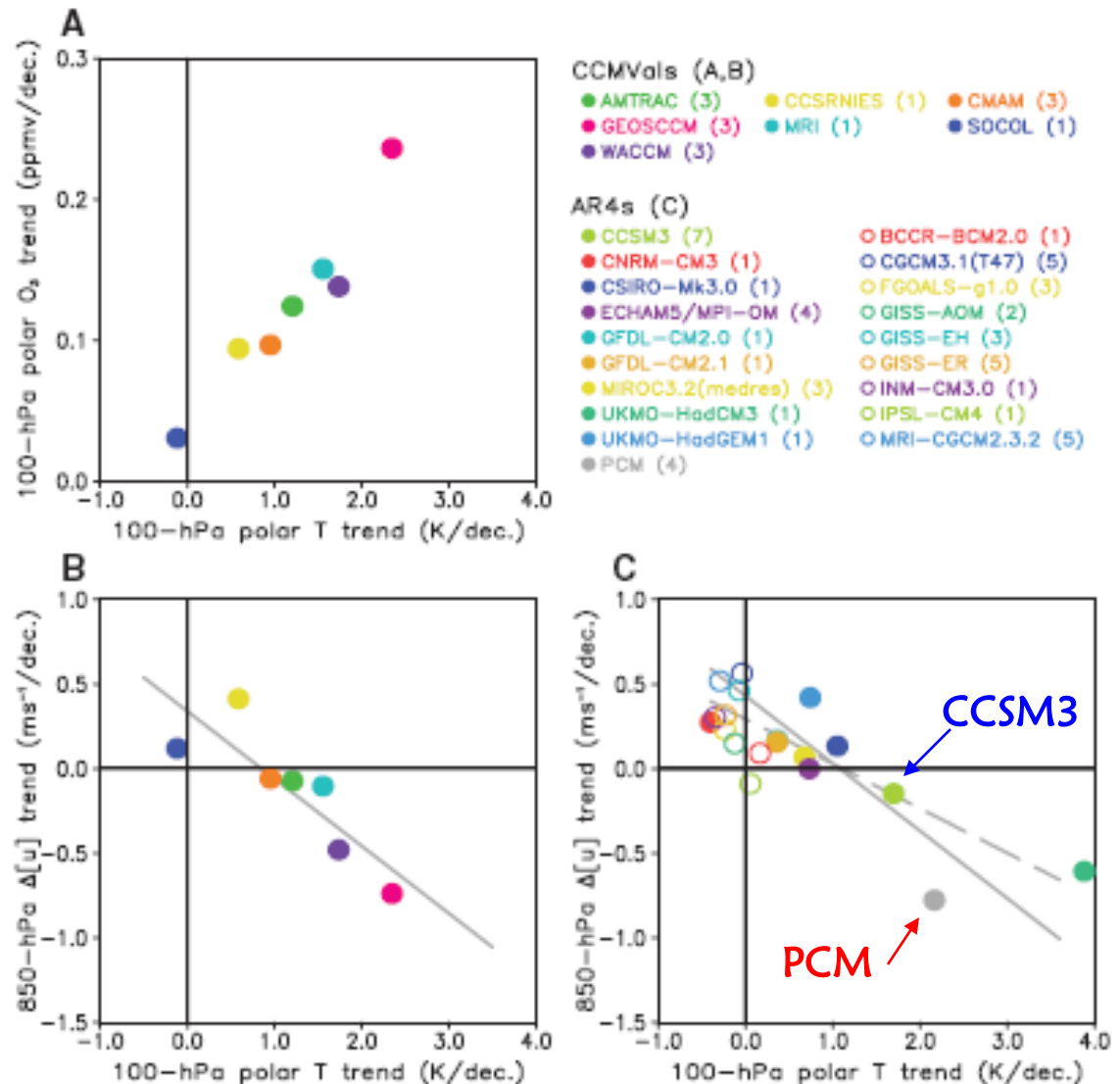
SAM Index: NCAR SRES A1B simulations



SAM index from CMIP3 & CCMVals models

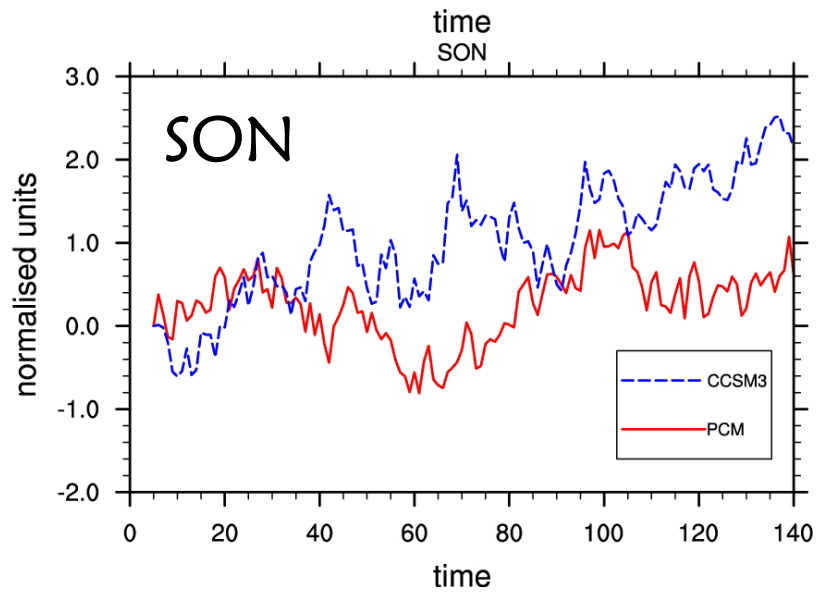
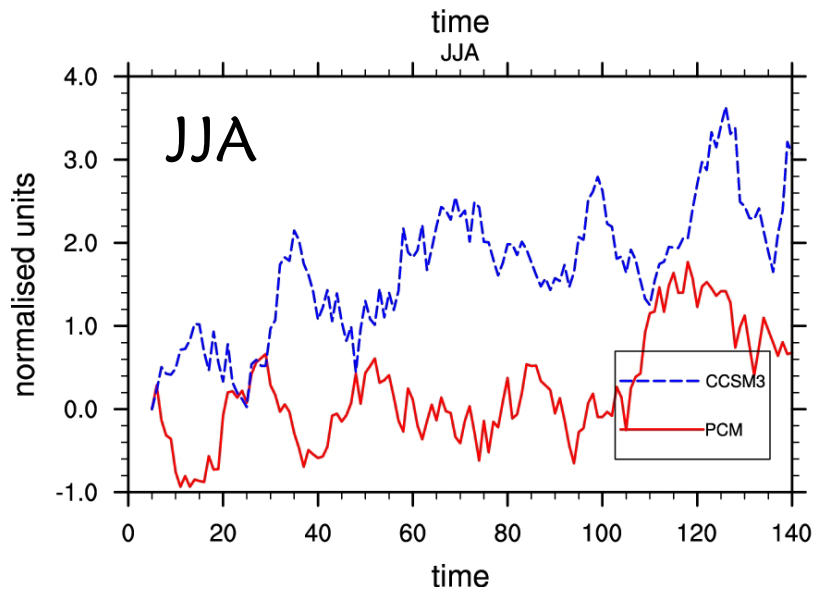
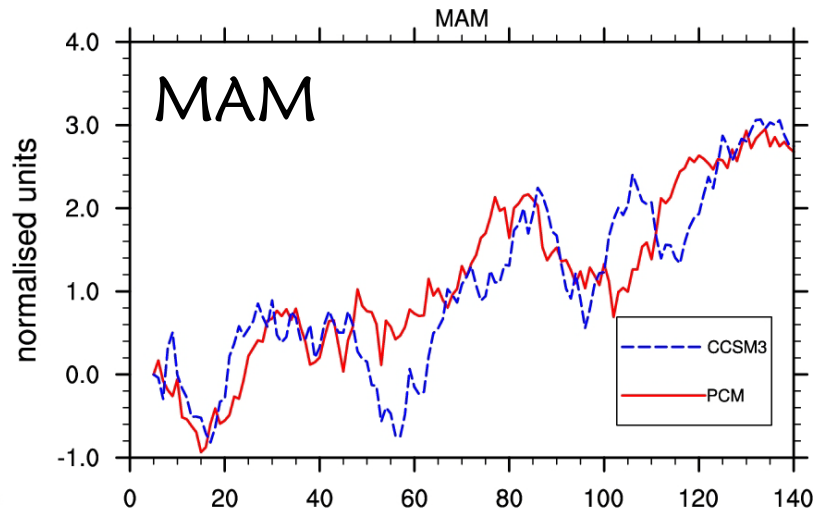
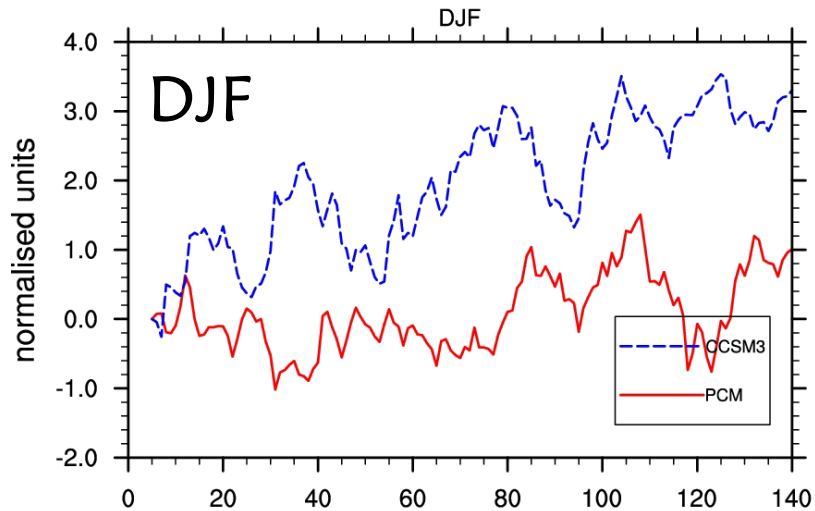
Is difference between CCSM3 & PCM due mostly to climate sensitivity?

How does this impact comparison between CCMVals and CMIP3 models?



SAM index from NCAR 1%/yr CO₂ incr runs

1% per year CO₂ increase to 4xCO₂

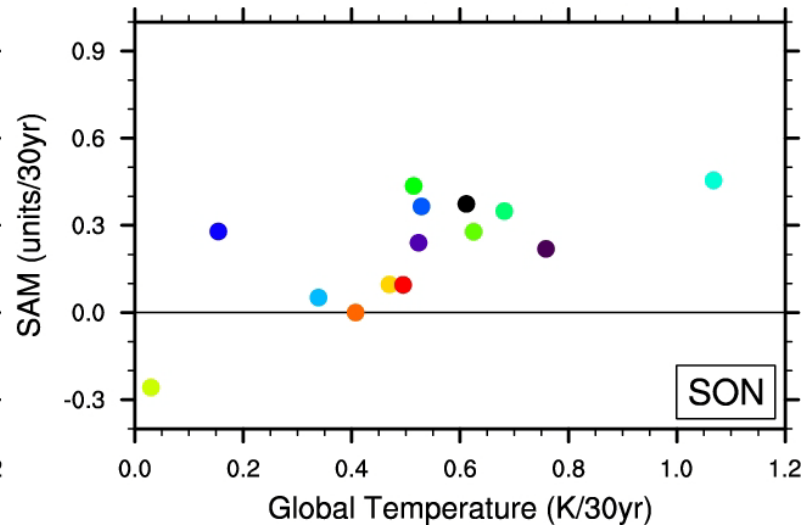
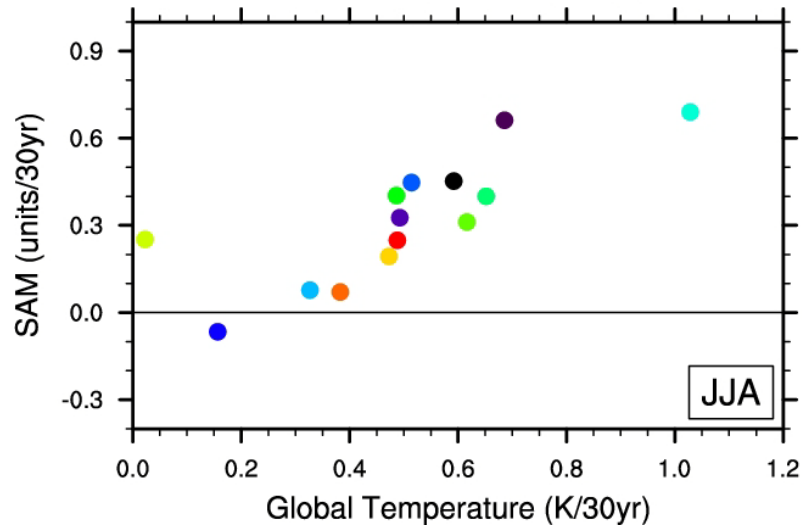
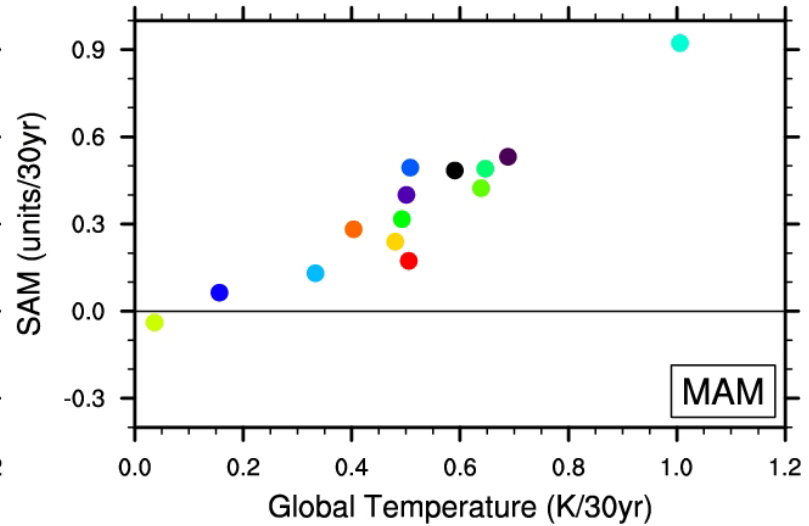
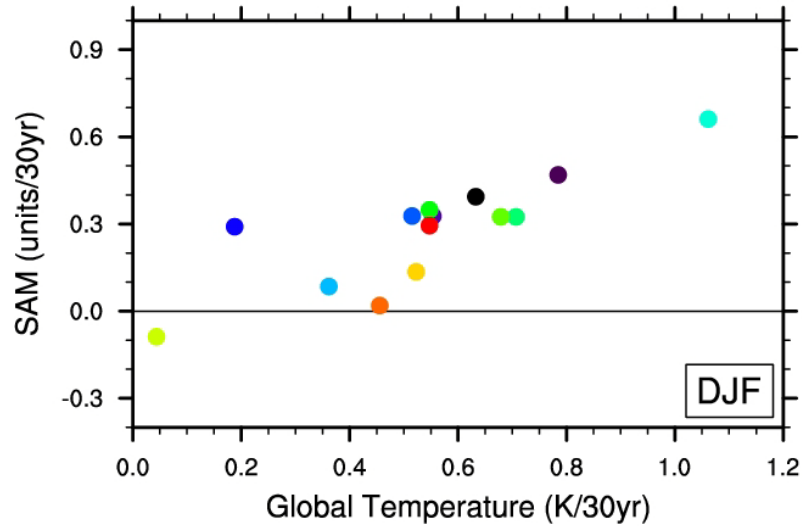


Trends in Southern Annular Mode in NCAR models over 21st Century

- ⇒ Negative SAM trend over first half of 21st Century in both NCAR low-top models under SRES A1B prescribed forcings, ozone recovery wins
- ⇒ Difficult to attribute cause of difference between models without single ozone forcing runs, however 1%/yr CO₂ runs indicate SAM in CCSM3 is more sensitive than PCM to CO₂
- ⇒ Different climate sensitivity likely explains the different SAM trends between the NCAR 21stC simulations

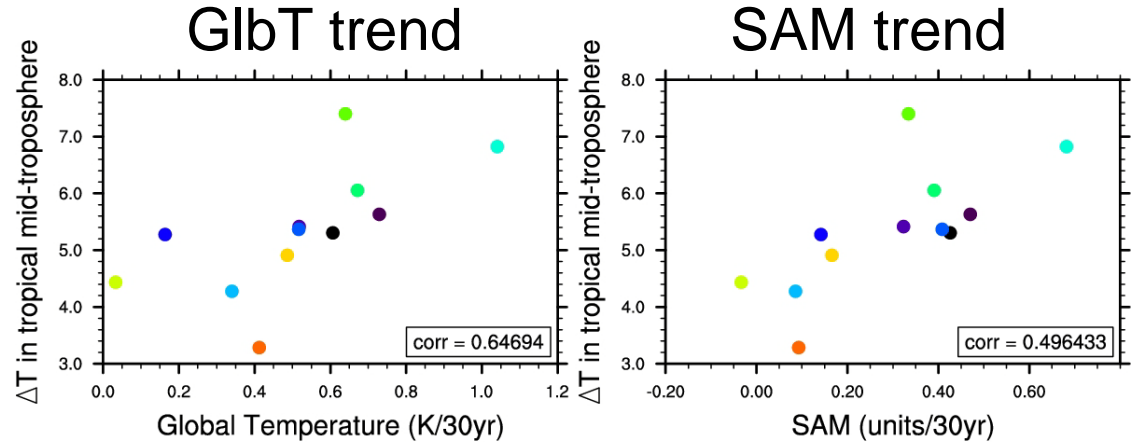
Global temperature trends vs SAM in 1%/yr runs

Trends in global temperature vs SAM from CMIP3 1%/yr CO₂ runs

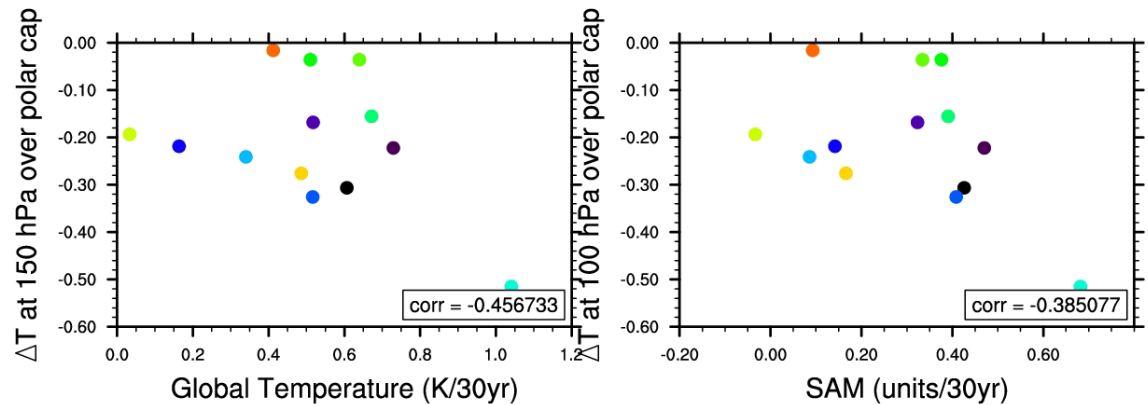


CMIP3 relationships with temperature regions in strat/trop

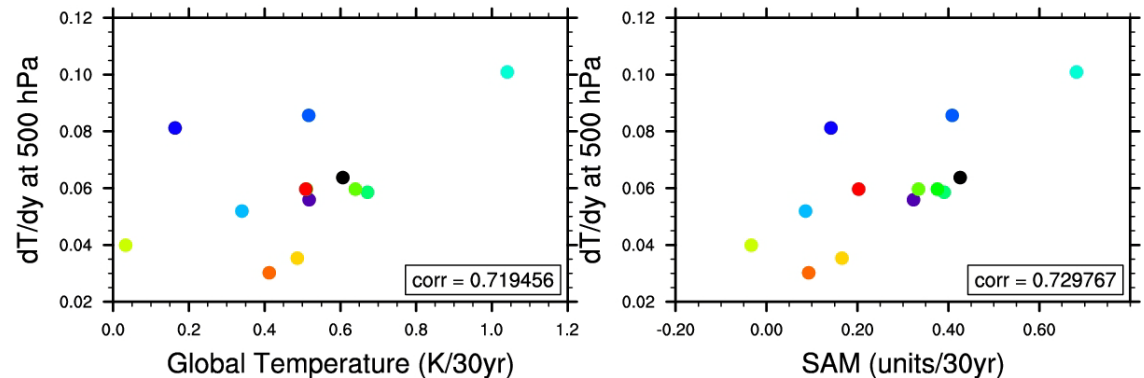
ΔT in tropical mid-troposphere



ΔT at 150 hPa over Antarctic cap



$\delta T/\delta y$ at 500 hPa



1%/yr incr CO2 runs

Conclusions

⇒ Main drivers of extratropical climate change in the Southern Hemisphere are likely to be increasing greenhouse gases and ozone recovery. These two forcings drive opposing trends in the Southern Annular Mode (SAM) in the 21st Century

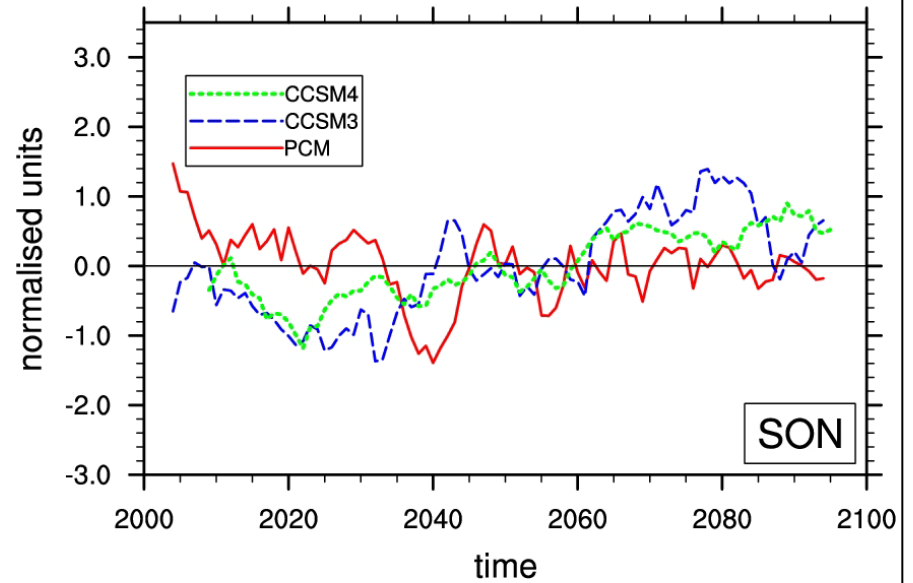
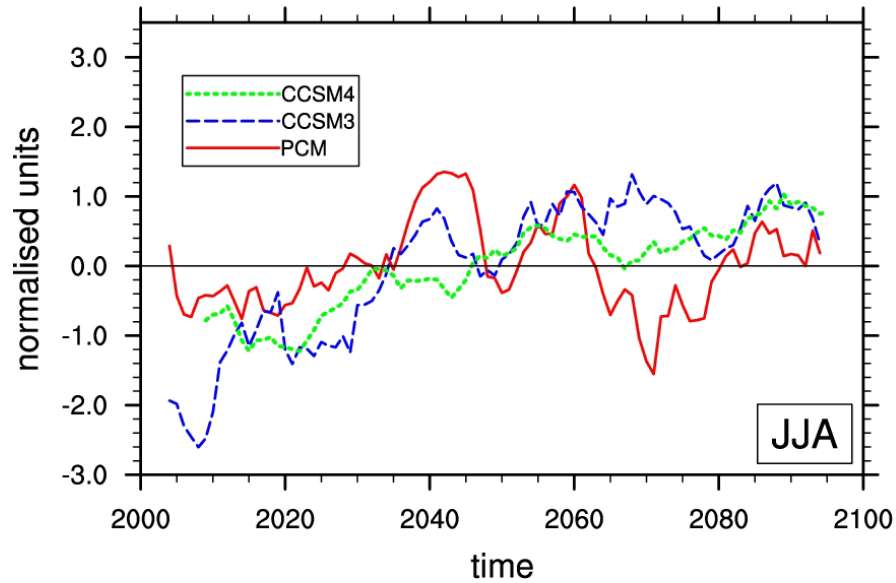
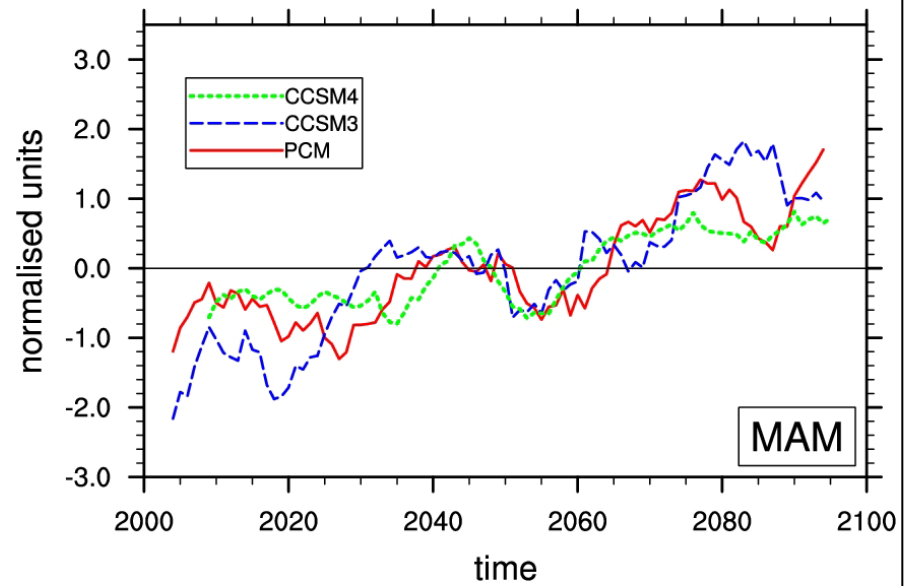
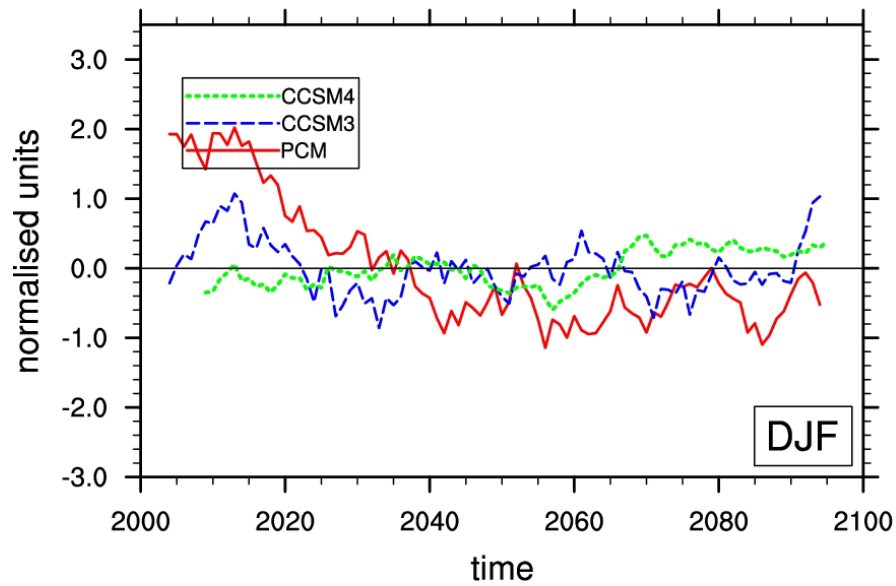
⇒ Investigated SAM trends in NCAR climate models where forcings are known. Climate sensitivity appears to play a strong role in variation between the two models

⇒ SAM trends strongly correlated with climate sensitivity in AR4 models

⇒ Need to be very careful when comparing A1B simulations between sets of models as climate sensitivity could impact trends

SAM Index in CCSM4 RCP8.5

SAM Index: NCAR simulations



Internal variability of SAM trends in NCAR models

50 year trends from CCSM3 (solid) and PCM (hatched) Plcntrl run

