



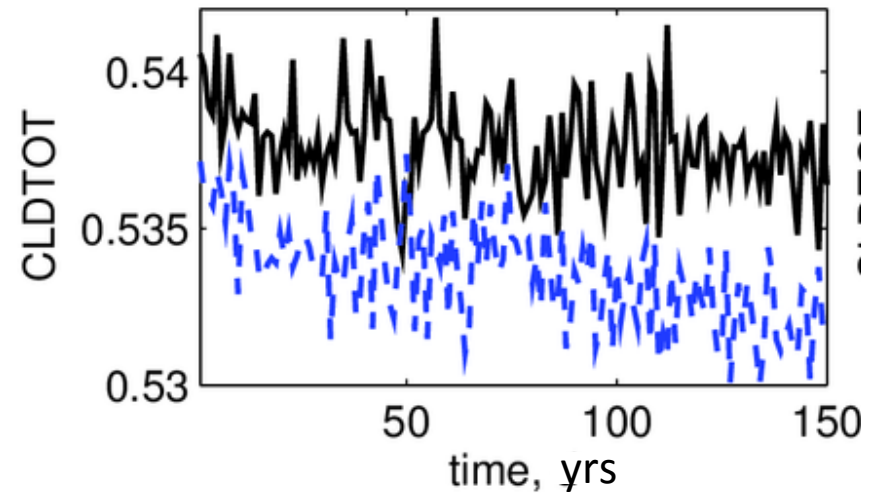
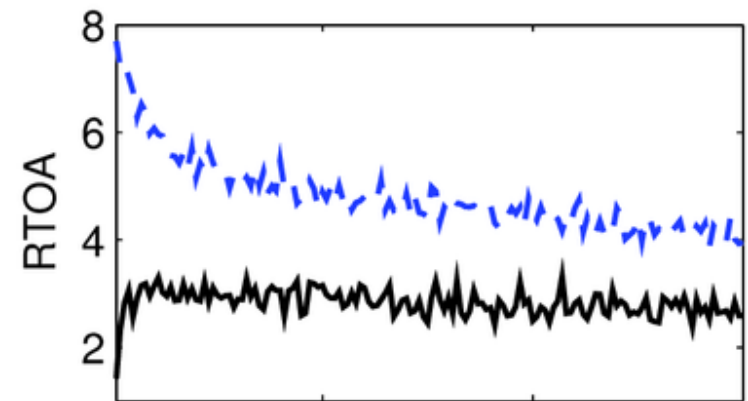
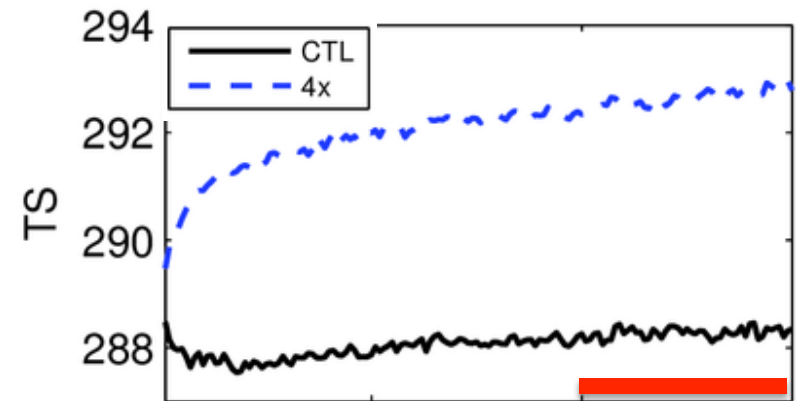
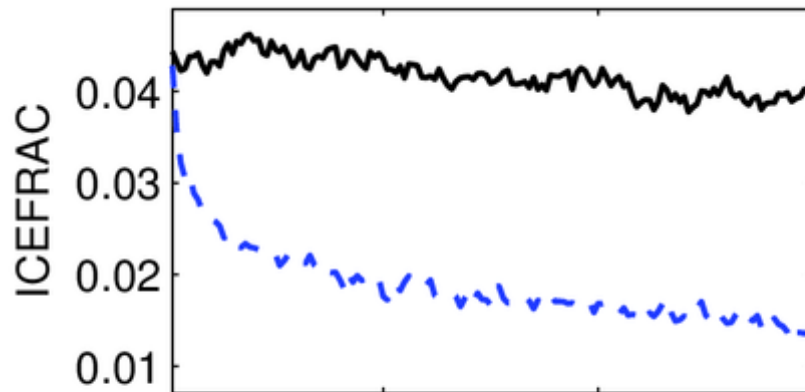
SPCCSM Cloud Feedback Analysis

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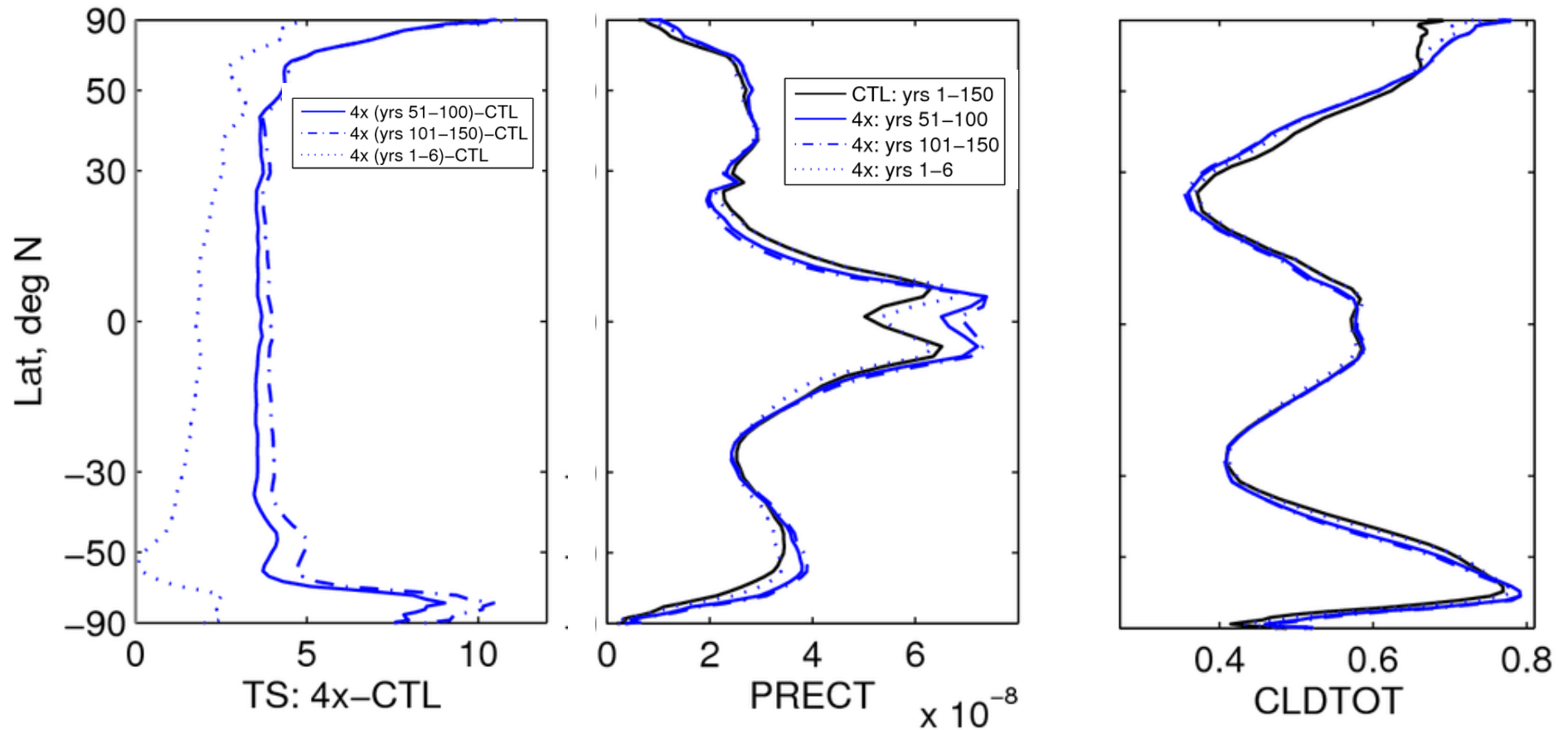
SPCCSM energy flux response to step 4xCO₂

Control run has stable climate
'Rapid adjustment' of CLDTOT (days)
'Fast' surface ocean timescale: 6 yr
'Slow' deep ocean timescale: 200 yr
(Held et al. 2010)



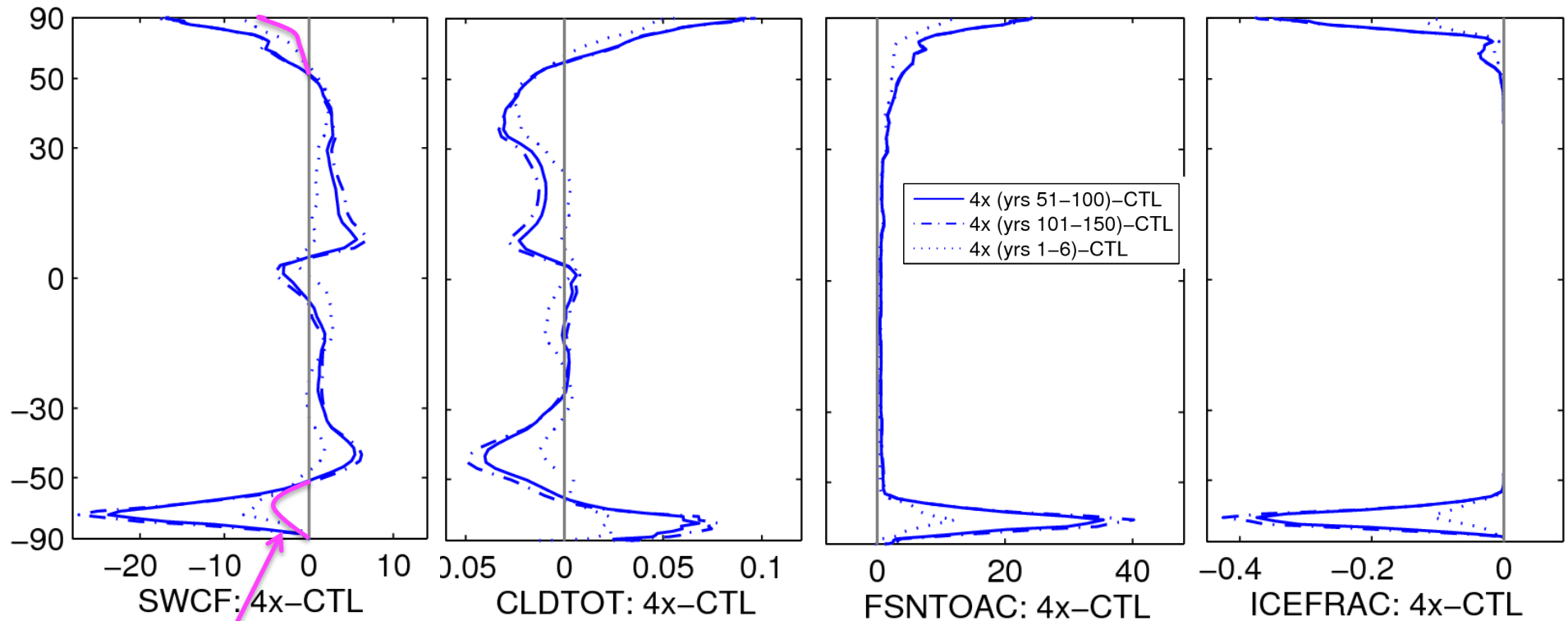
Zonal mean changes

Review from January presentation (updated to 150 yrs)



- Uniform low-latitude warming
- Precip only increases in ITCZ and high lats (poleward storm track shift)
- Cloud decreases slightly in mid lats, increases at high lats.

SWCF vs. cloud cover and snow/ice changes

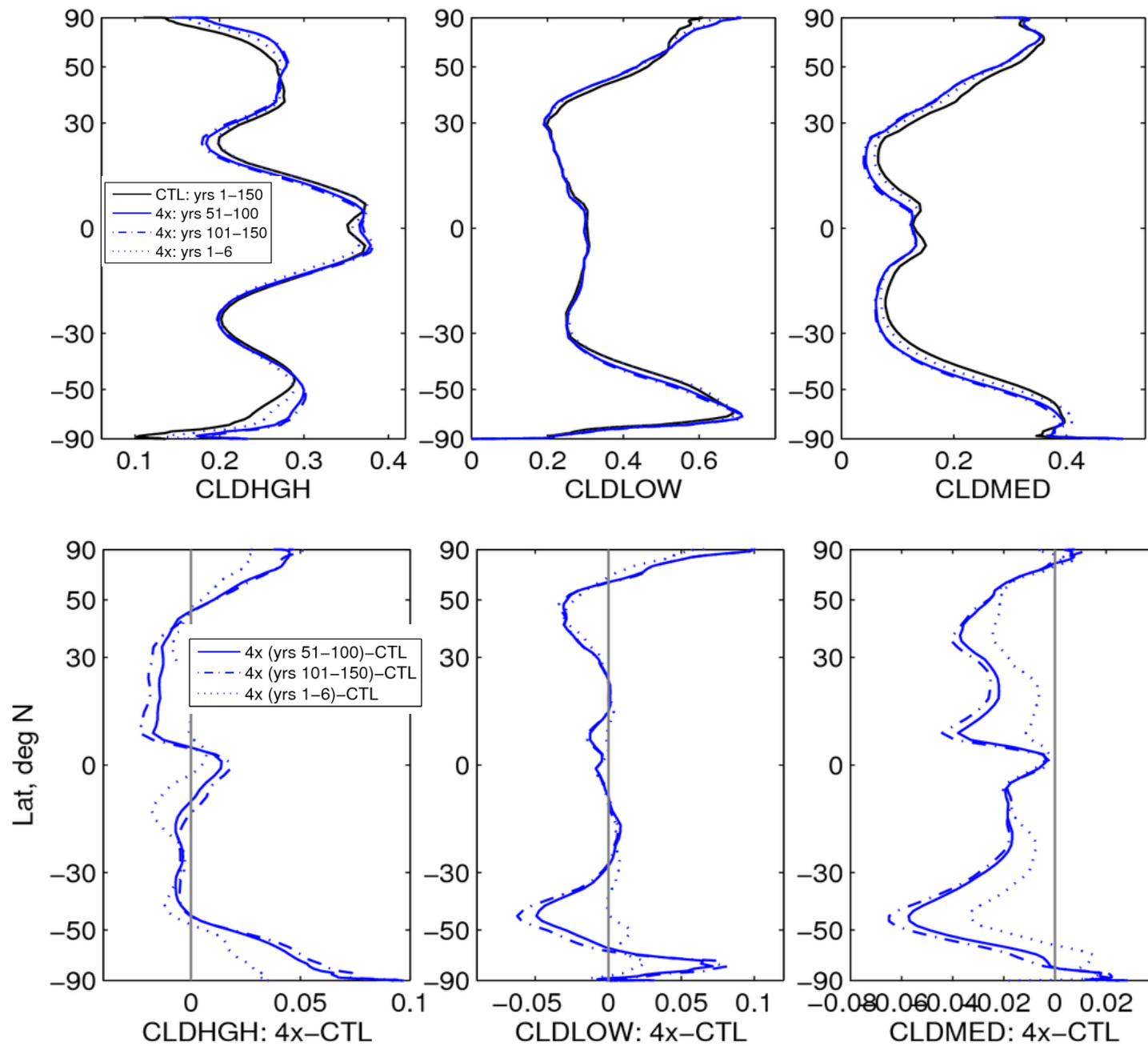


Effect of
cloud
change if
ice-free

In polar regions, Δ SWCF is due mainly to cloud masking of surface albedo decrease due to sea-ice (and snow) reduction, with a small additional contribution from increased cloud

Elsewhere, $-1\% \Delta$ CLDTOT $\approx 1 \text{ W m}^{-2} \Delta$ SWCF

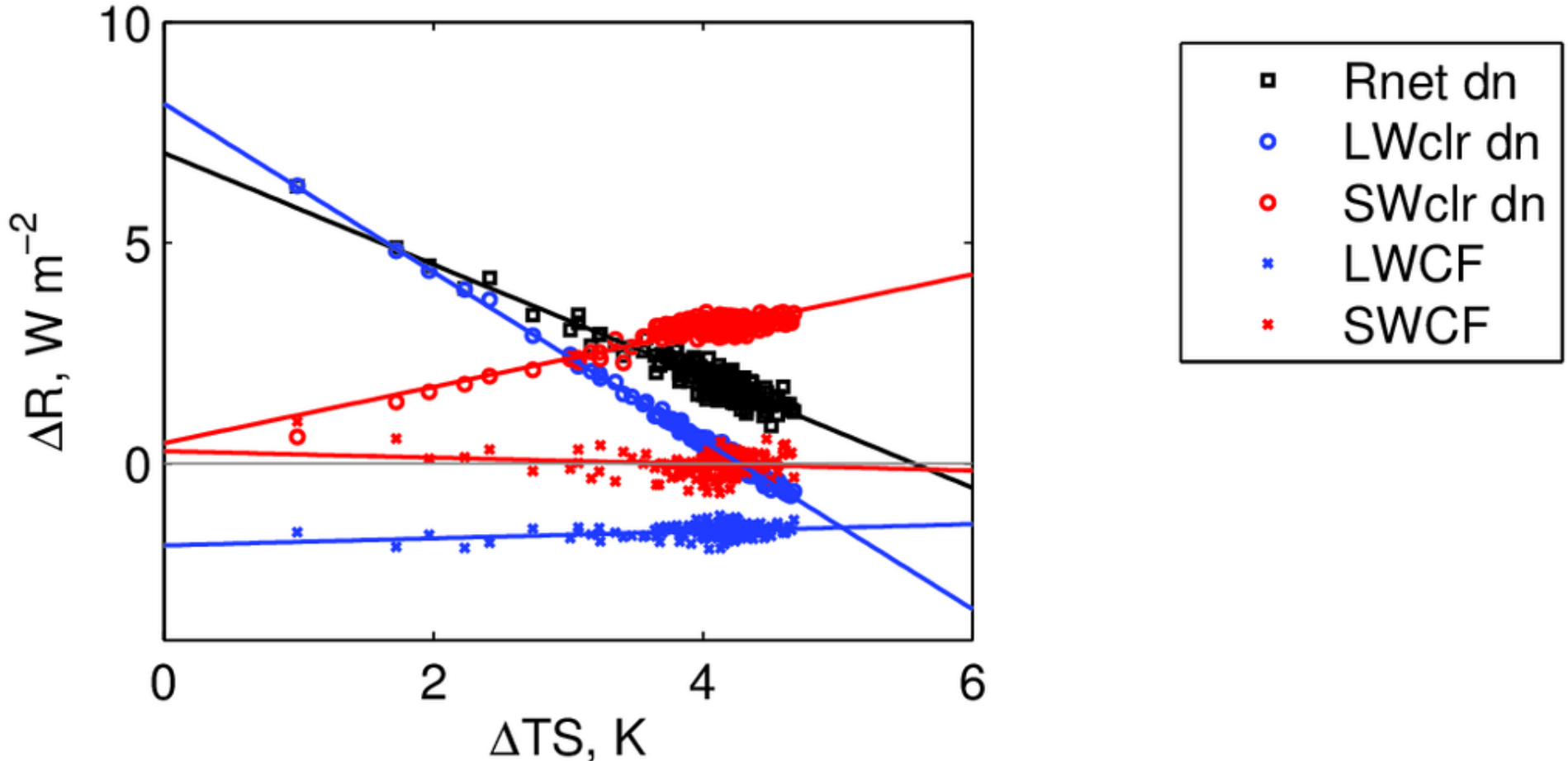
Ubiquitous decrease of midlevel (400-700 hPa) cloud



Net mid/low cloud reduction suggests weak positive SW cloud feedback

Linearity of temperature-mediated response

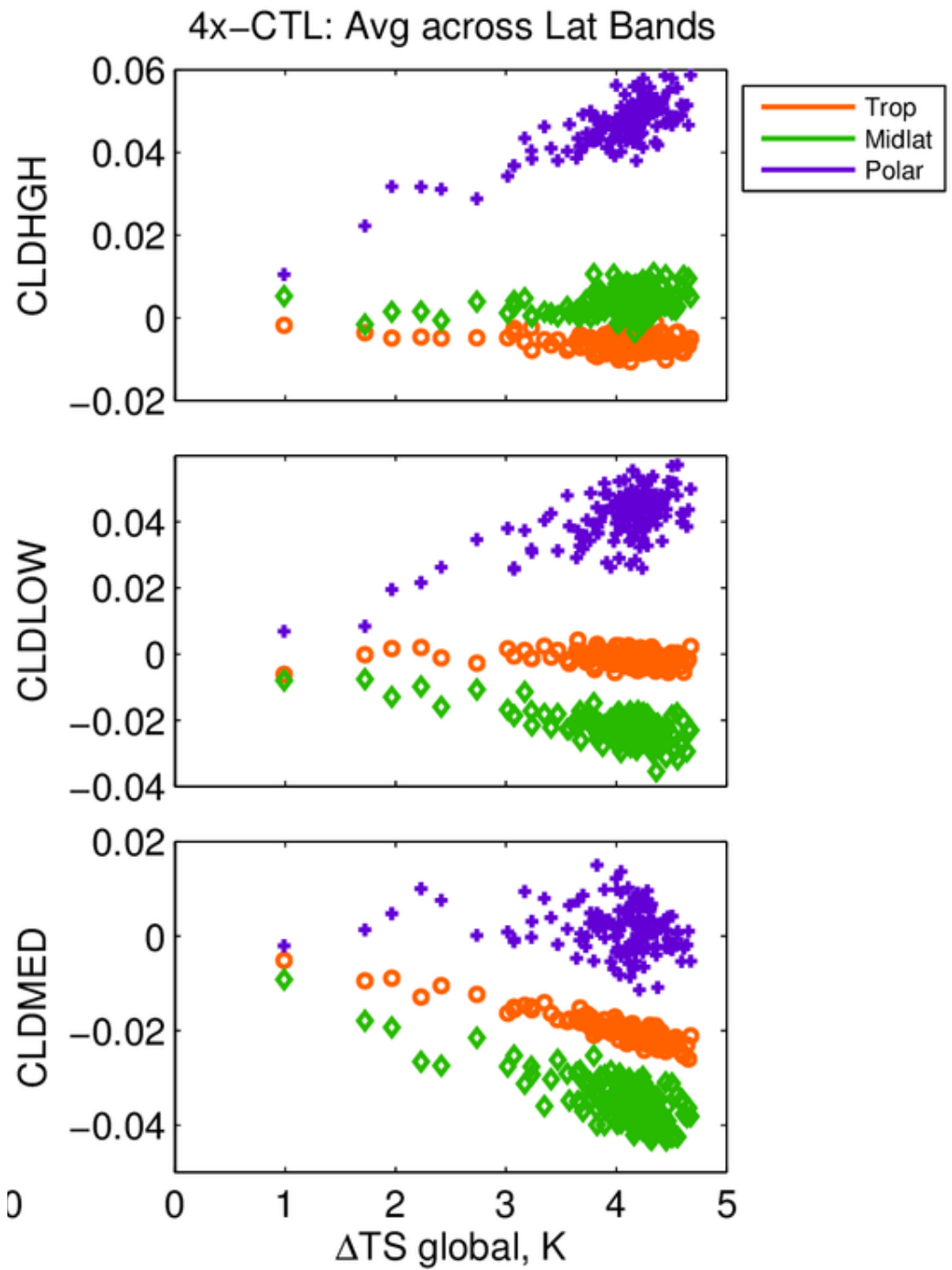
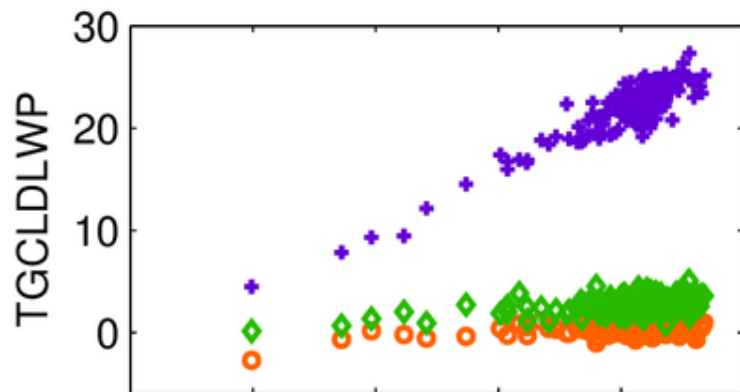
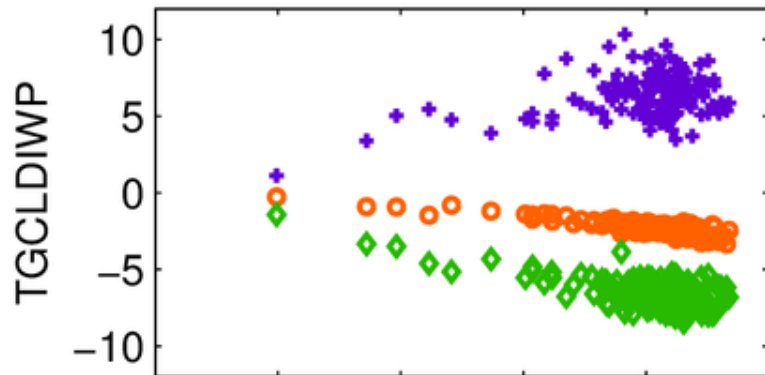
Gregory plot: Global-averages



- Good linearity out to 150 yr \rightarrow 2xCO₂ climate sensitivity \sim 2.8 K
- Slight rapid CO₂-forced cloud decrease \rightarrow positive SWCF intercept.
- CO₂ masking \rightarrow negative LWCF intercept
- Snow/ice feedback \rightarrow positive $\Delta SW_{clr}/\Delta T_s$

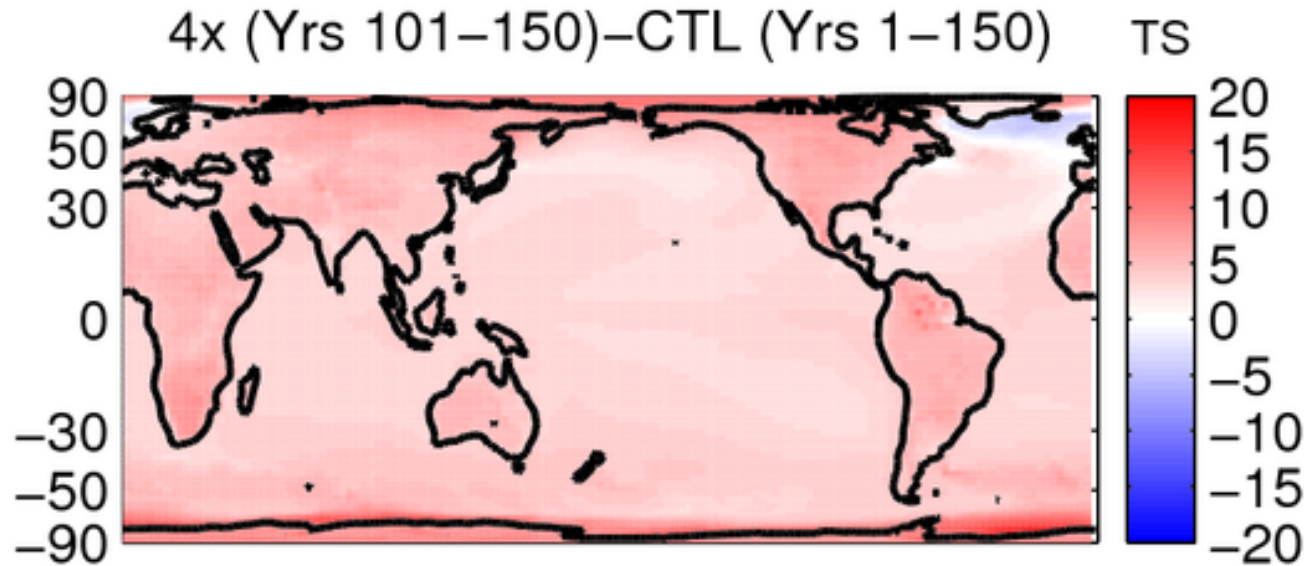
Linearity of cloud trends

Polar cloud increase/thickening

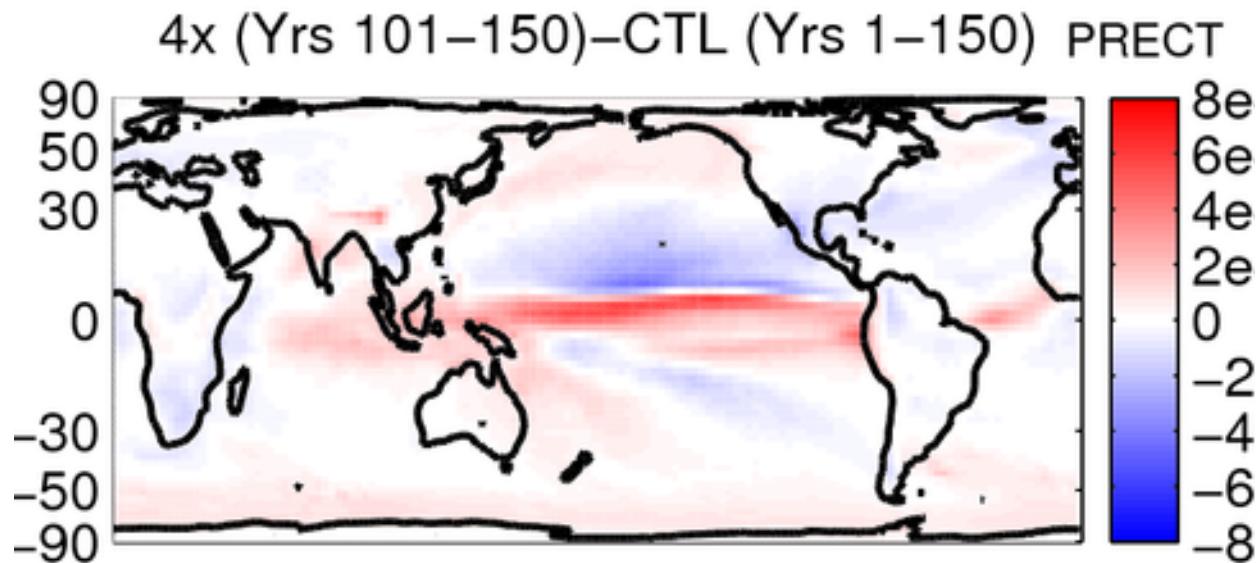


Geographical changes

Surface temperature and precipitation change



More land
warming

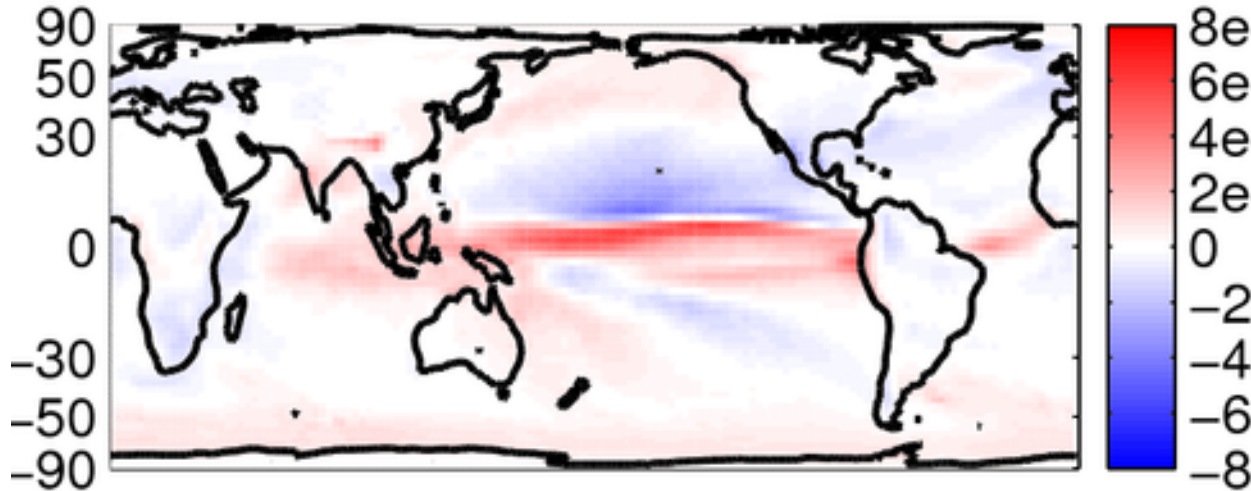


Reduced
equatorial
upwelling
focuses ITCZ
onto equator

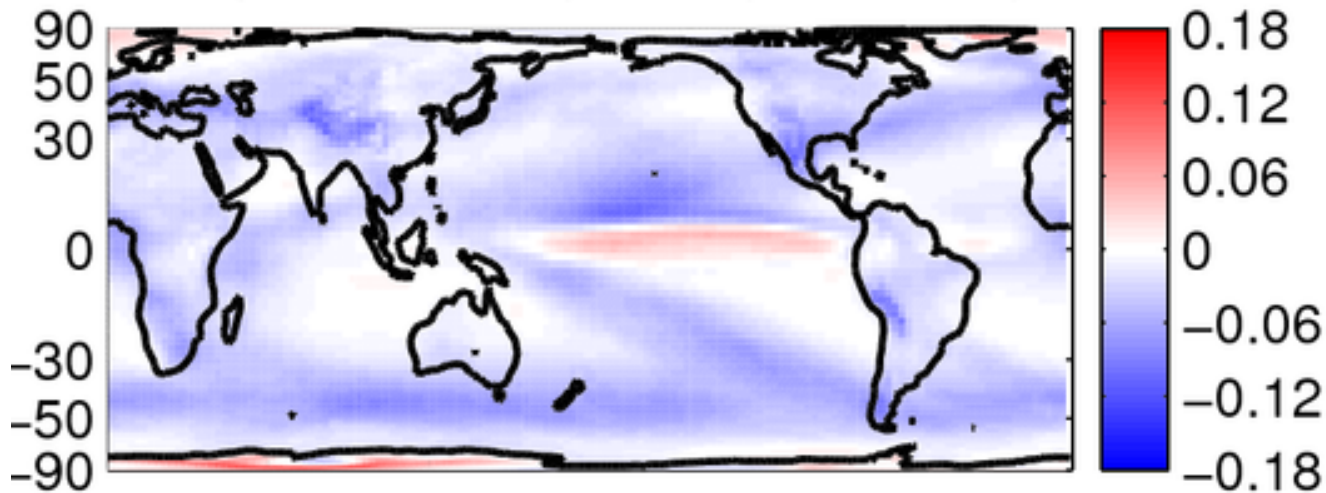
Weak rainfall
decrease over
most low-lat
land

Midlevel cloud reduction

4x (Yrs 101–150)–CTL (Yrs 1–150) PRECT



4x (Yrs 101–150)–CTL (Yrs 1–150) CLDMED



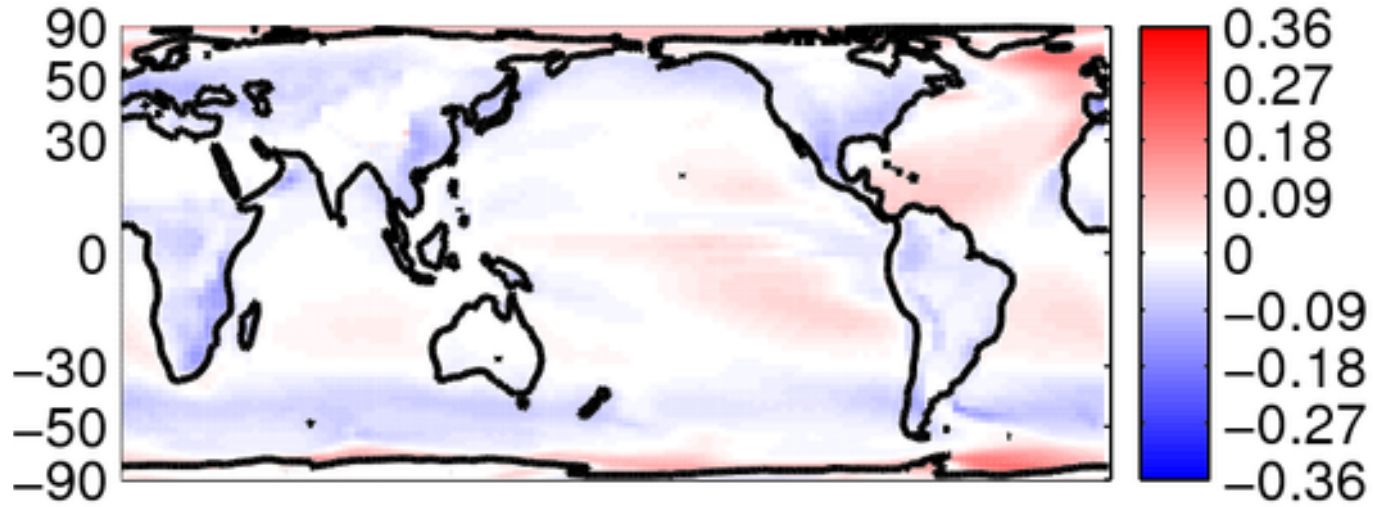
Reduction almost everywhere except Eq Pac, modulated by precipitation changes (slowdown of diabatically-driven overturning).

Low cloud trends

4x (Yrs 101–150)–CTL (Yrs 1–150)RHREFHT



4x (Yrs 101–150)–CTL (Yrs 1–150)CLDLOW



Decrease over land (coupled to lower RH) and most ocean regions

Westward extension of subtropical Sc zones

Conclusions

- Cloud analysis done thru 150 yrs for instant 4CO_2 SPCCSM.
- The temperature, precipitation and cloud responses of SPCCSM are within the ranges expected from CMIP5.
- Middle-level clouds decrease over most of the planet.
- Low clouds decrease over land and midlat oceans.
- Cloud increases in high lats. at all levels.
- Weakly positive global shortwave cloud feedbacks, consistent with 2.8 K 2xCO_2 equilibrium climate sensitivity.