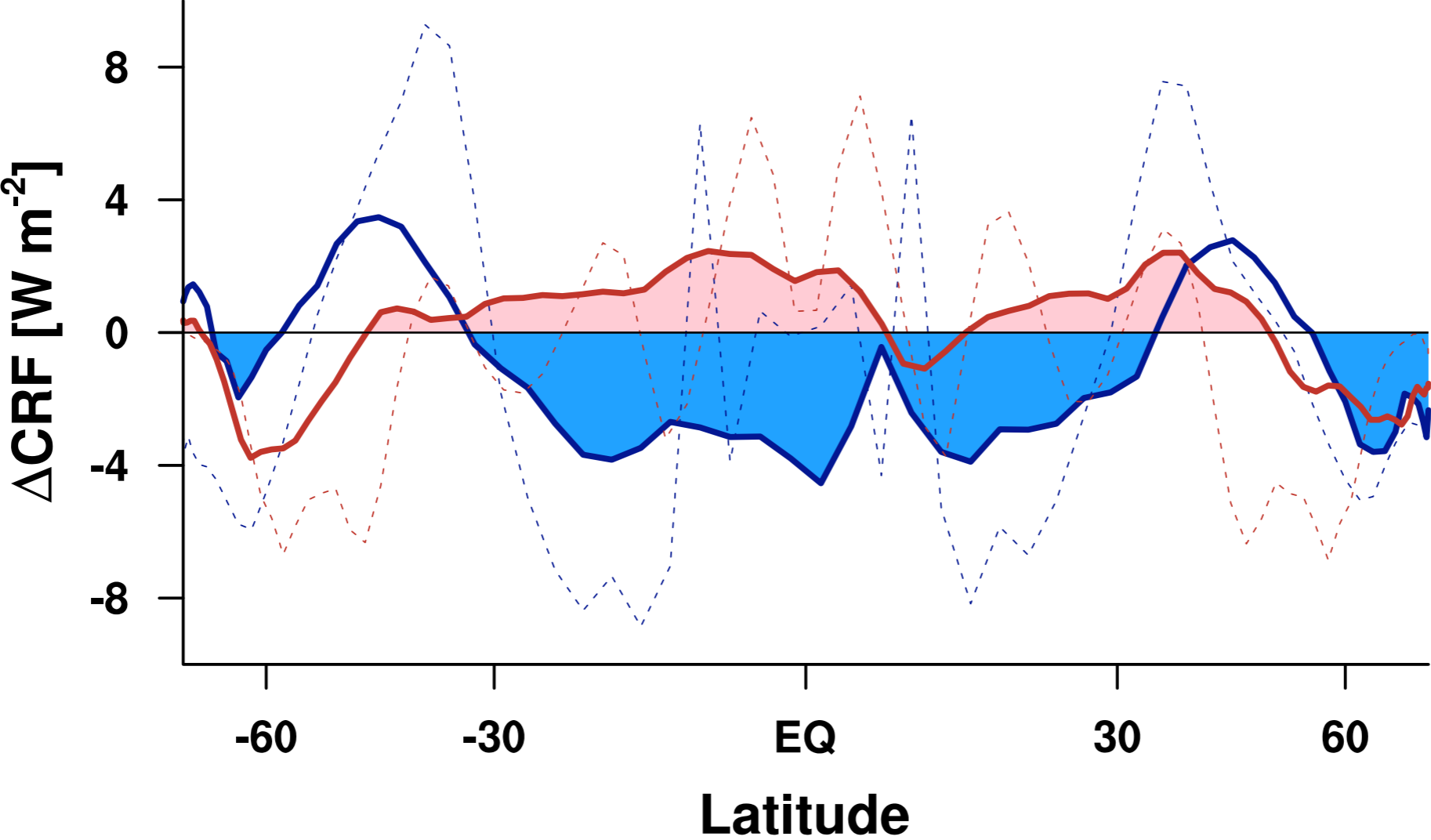


Cloud-climate interactions in GCMs: An aquaplanet perspective

Mostly from: Medeiros, Stevens, Held, Zhao,
Williamson, Olson, and Bretherton, 2008: Aquaplanets,
climate sensitivity, and low clouds. J. Climate In Press.

Climate models disagree



An old story

“It must thus be emphasized that the modeling of clouds is one of the weakest links in the general circulation modeling efforts.”

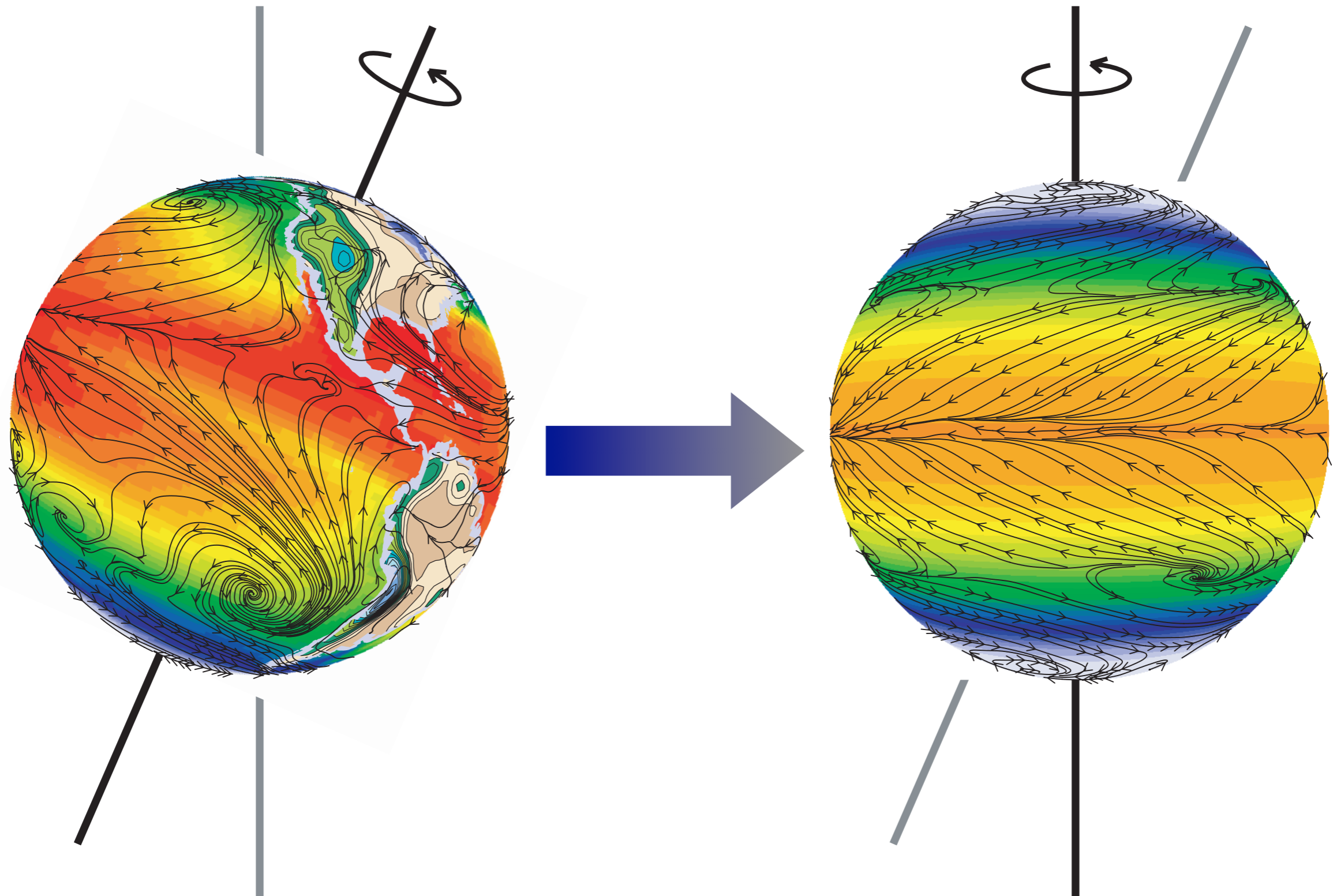
-- National Research Council, Charney et al. (1979)

“... cloud feedbacks remain the largest source of uncertainty in climate sensitivity estimates.”

-- IPCC 4th Assessment Report, Randall et al. (2007)

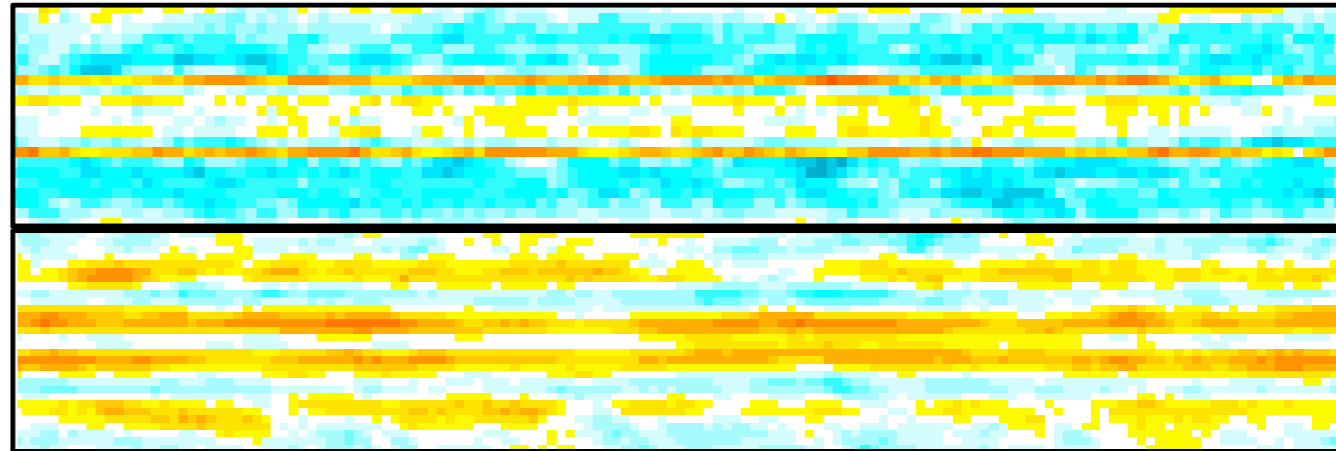
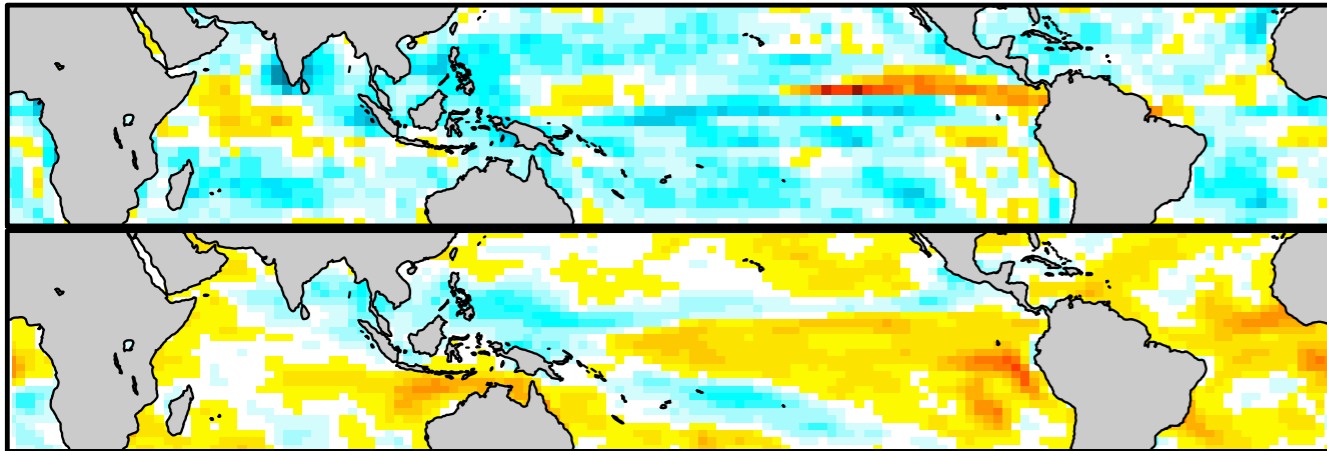


Do aquaplanets predict climate sensitivity?

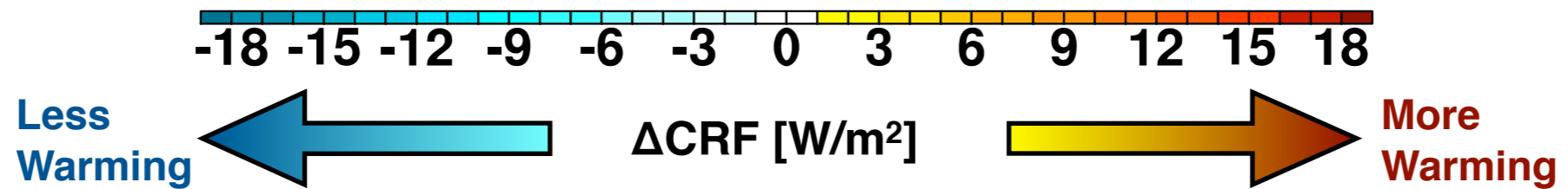


Tropical cloud effects

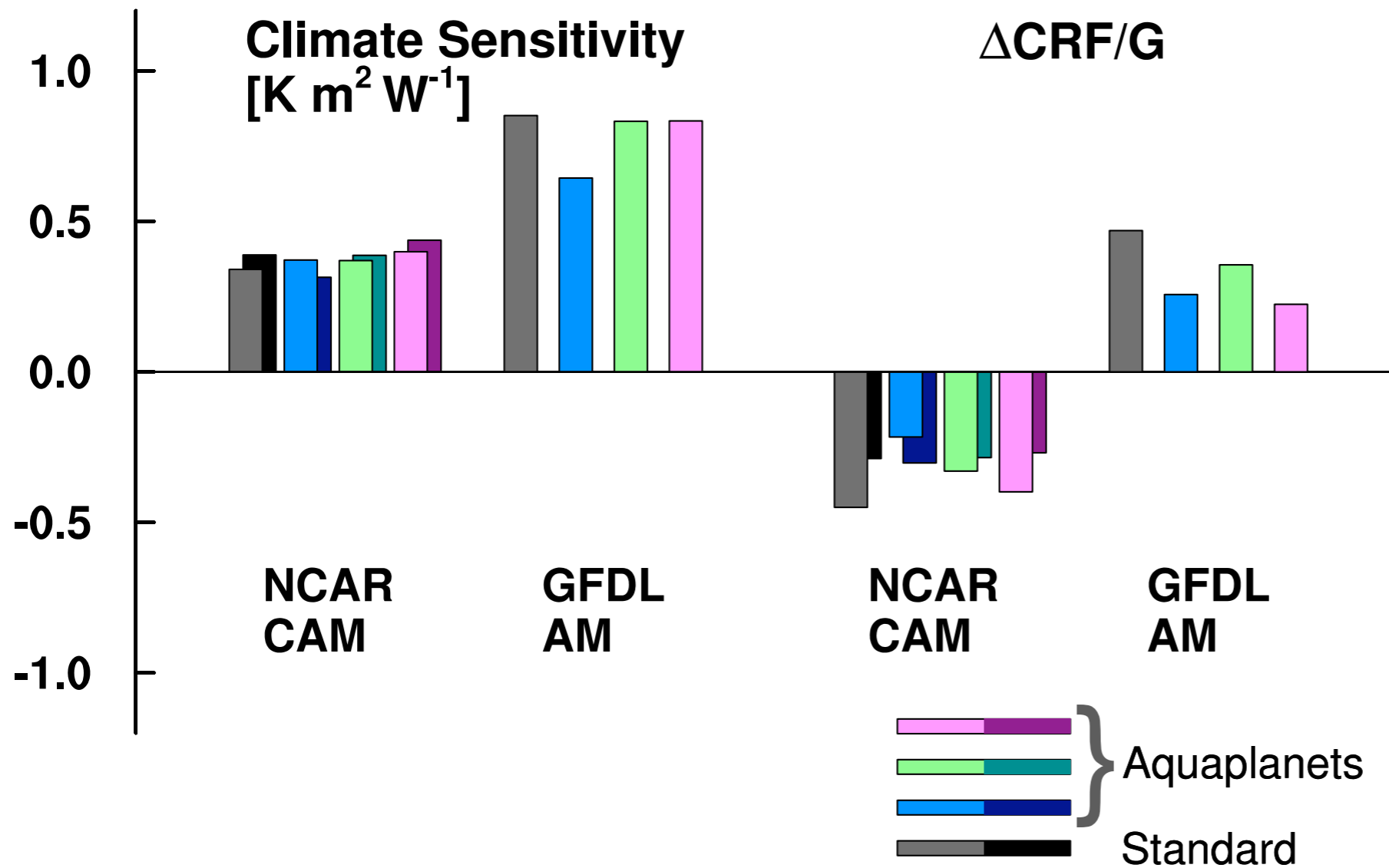
NCAR CAM3



GFDL AM2.0



Climate sensitivity

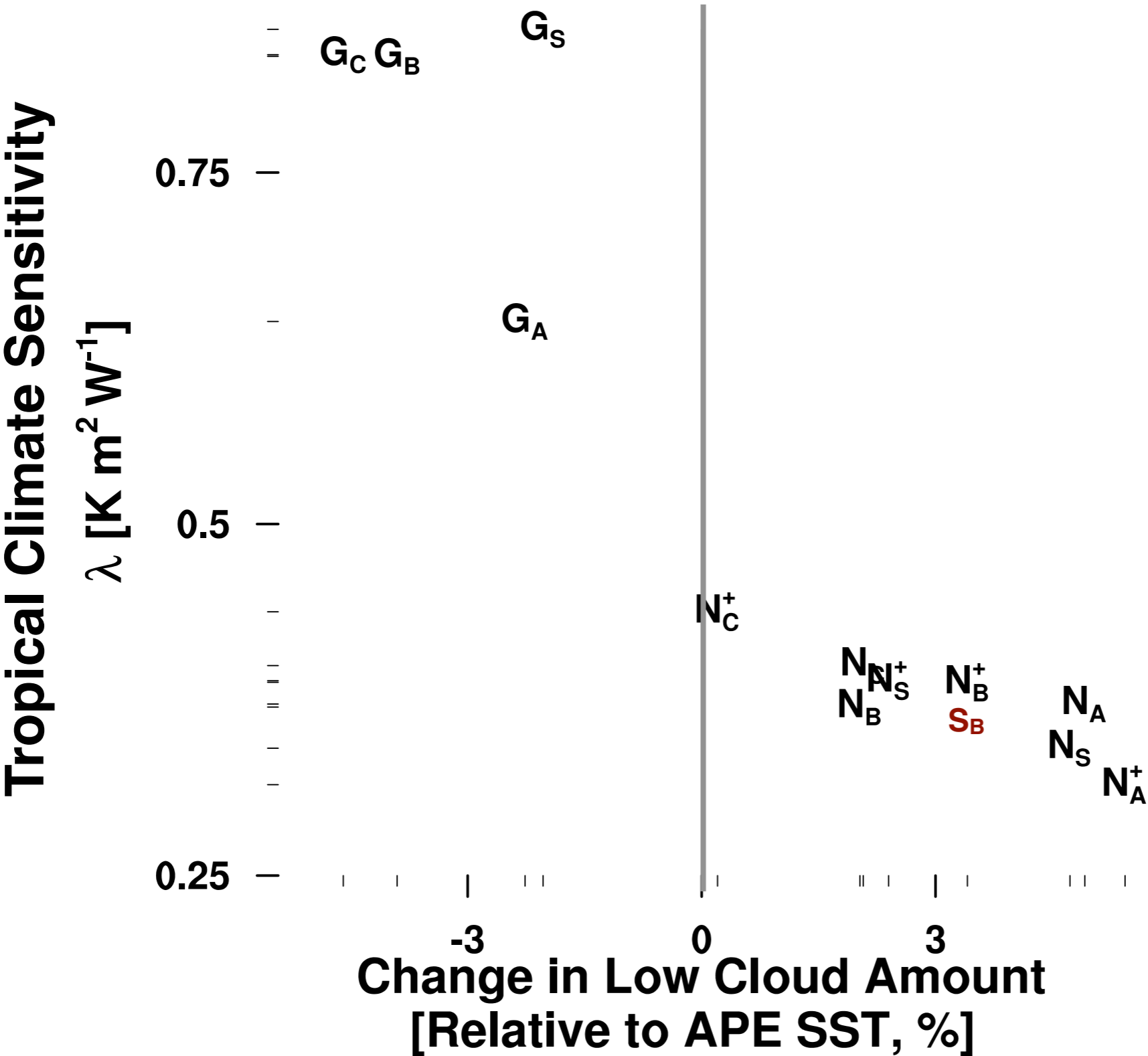


SP-CAM
Standard (*global*)
 $\lambda = .41$,
 $\Delta\text{CRF} = -1.77$
(Wyant et al. 2006)

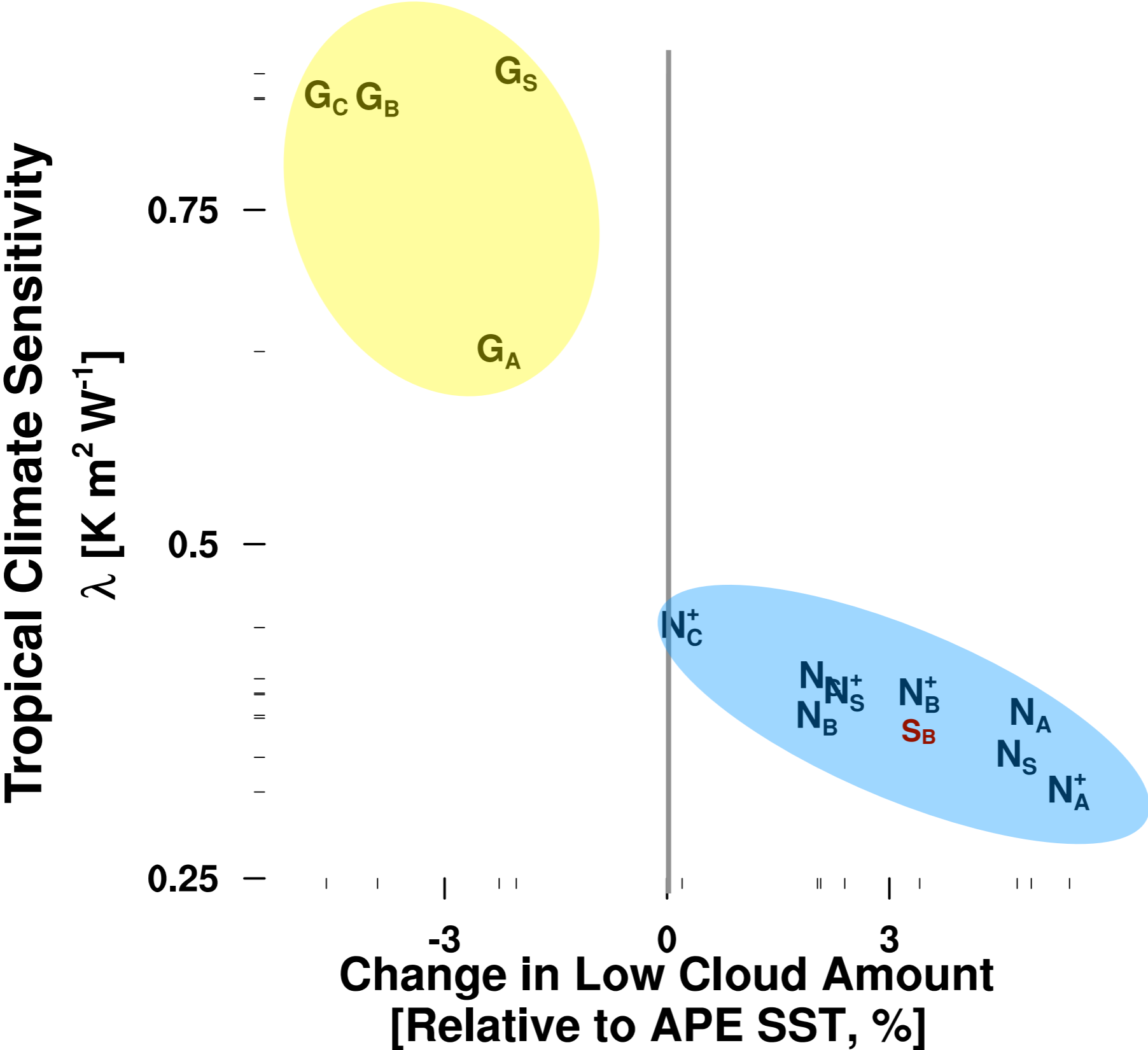
Aquaplanet (B)
 $\lambda = .343$,
 $\Delta\text{CRF/G} = -.269$
(from Marat Khairoutdinov)

NICAM
Aquaplanet (*global*)
 $\lambda = .44$
(Miura et al. 2005)

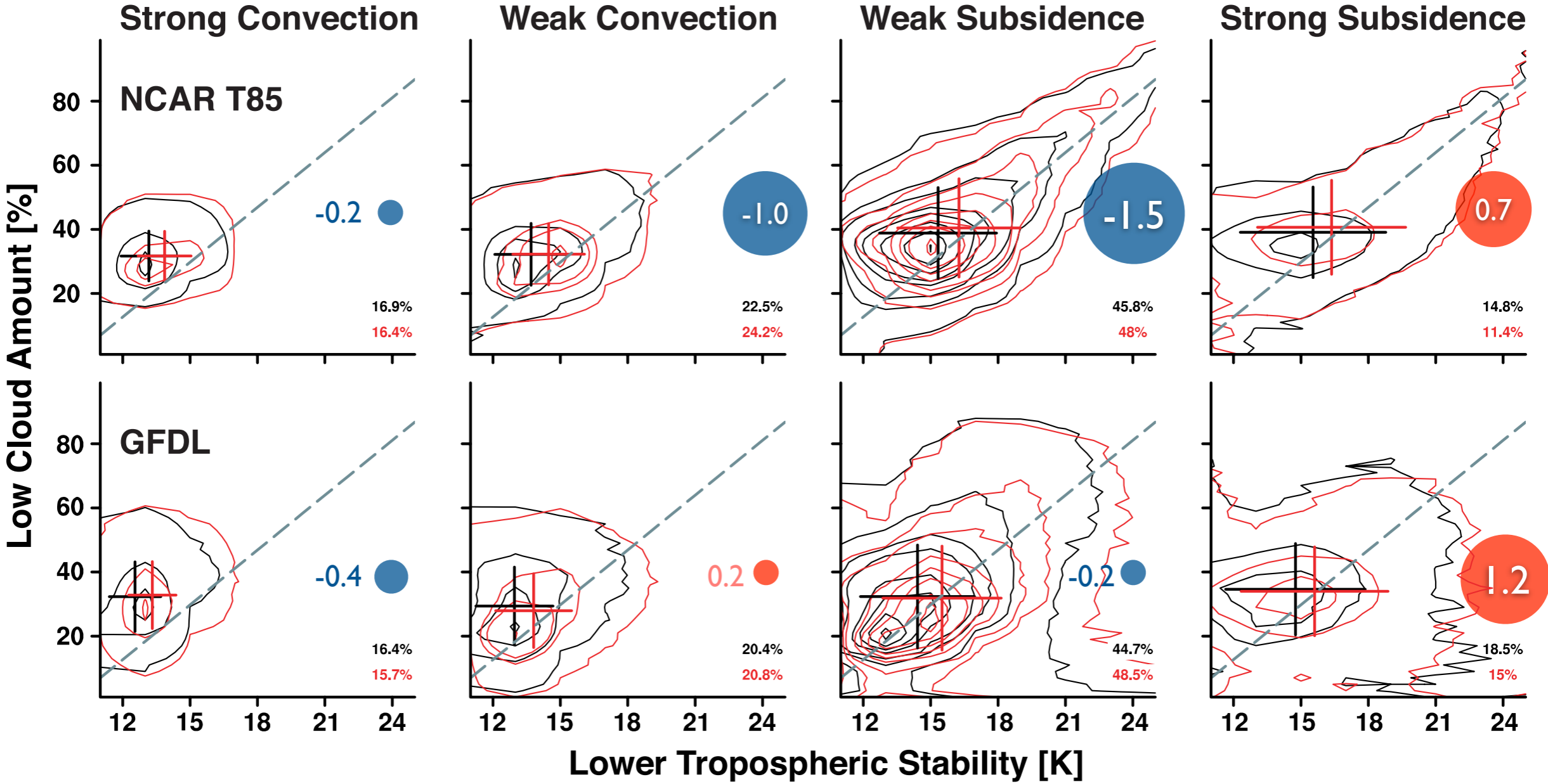
Low clouds



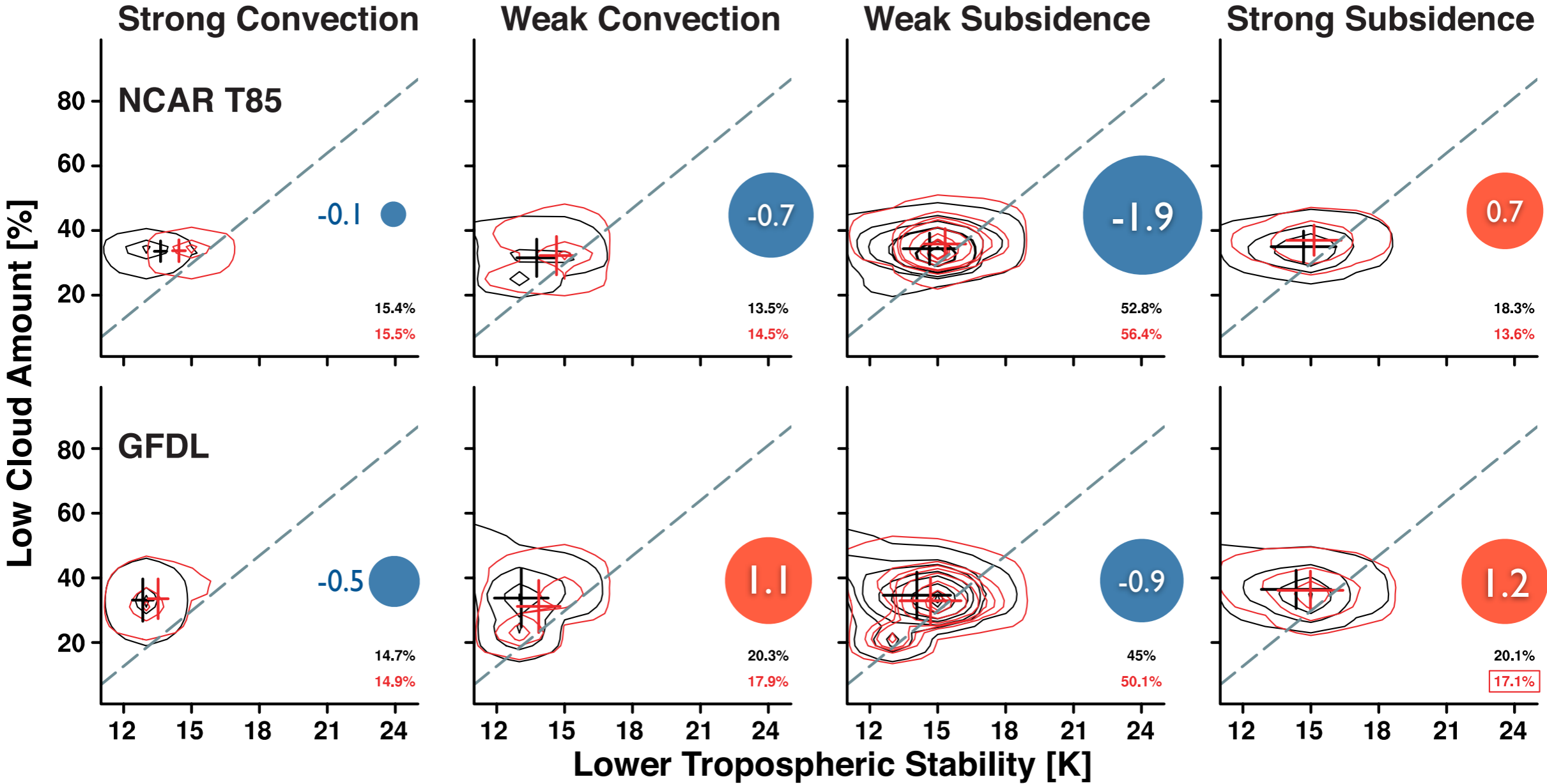
Low clouds



Regimes in Earth simulations



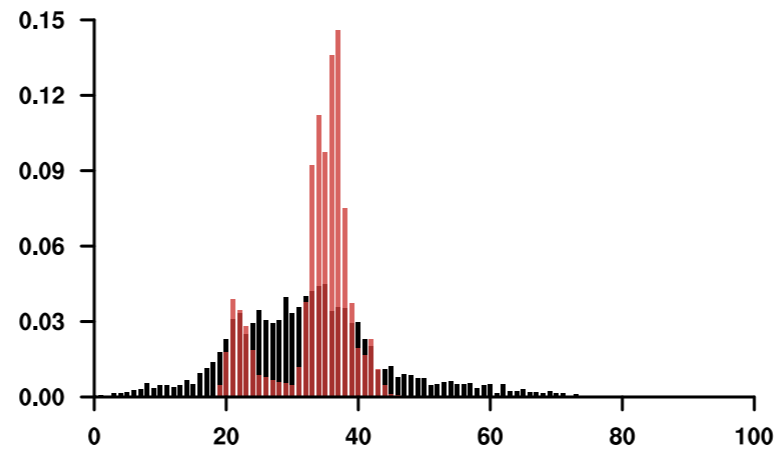
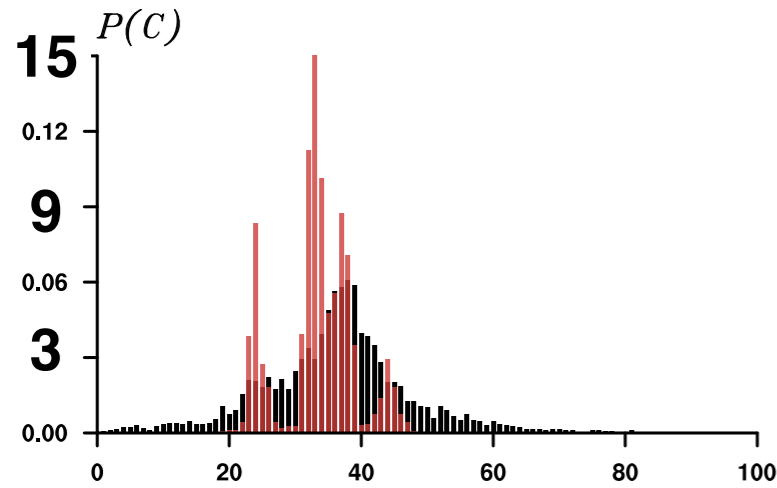
Regimes in aquaplanets



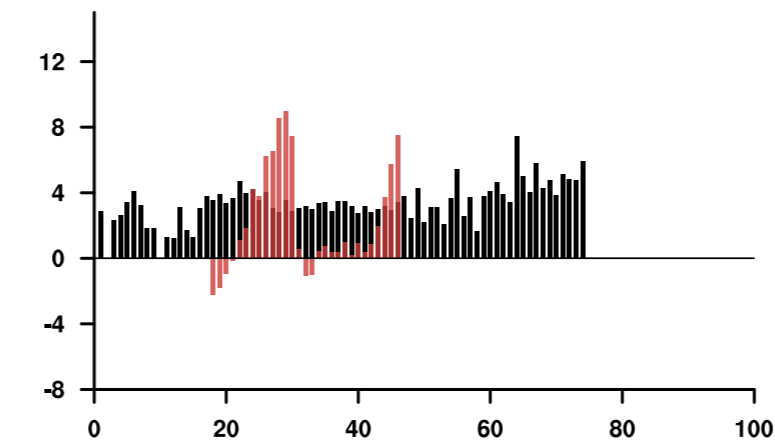
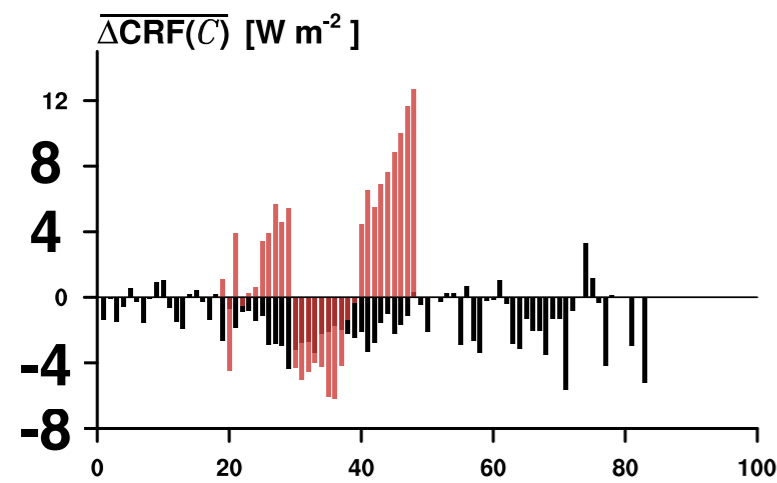
Low cloud distribution and response

NCAR CAM

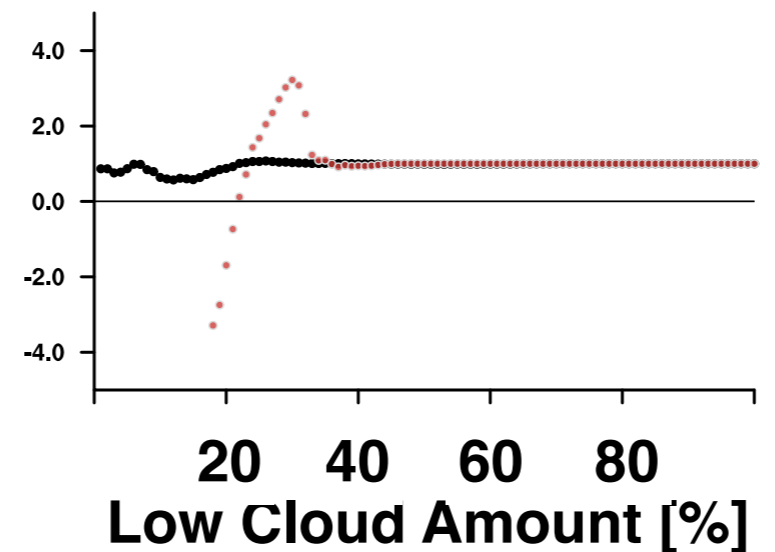
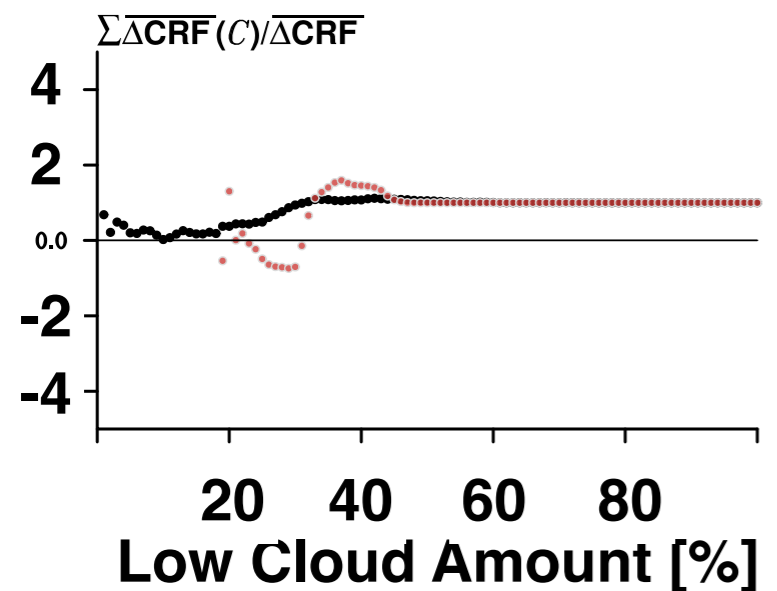
GFDL AM



Histogram of tropical low-cloud amount



Change in CRF with low-cloud amount



Cumulative CRF response with low-cloud

What are these clouds?

- ▶ **Are these really shallow (trade-wind) cumulus?**
- ▶ **Do Earth and aquaplanet simulations produce similar clouds?**
- ▶ **Are the clouds realistic?**

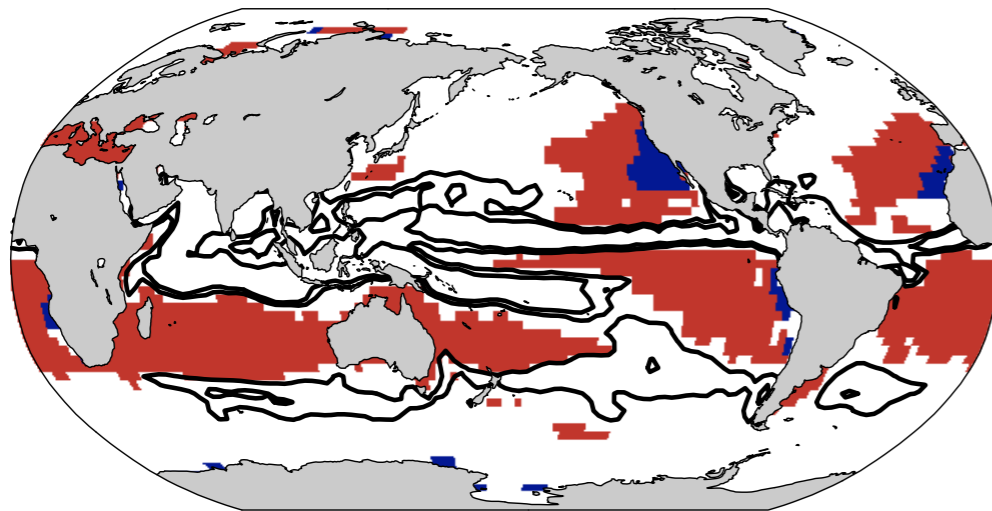
Sample “typical” conditions

- ▶ **Use minimal criteria to sample conditions expected to maintain trade-wind or stratocumulus.**
- ▶ **Dynamic constraint:**
 - subsidence (ω_{500} & $\omega_{700} > 10$ hPa d⁻¹)
- ▶ **Thermodynamic constraint:**
 - lower-tropospheric stability,
 - $\Delta\theta > 18.55\text{K}$ marks “stratocumulus”
(i.e. Klein-Hartmann => stratus > 50 %)
- ▶ **Qualitatively successful in ERA-40, see *poster later*.**

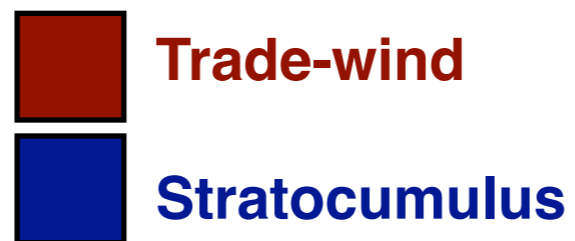
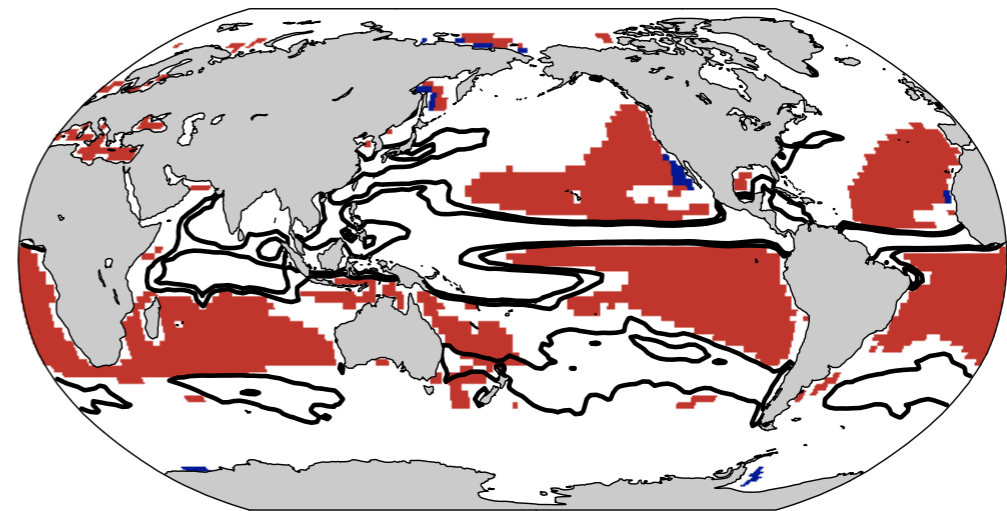
June as an example

- ▶ GCMs underestimate stratocumulus occurrence.
- ▶ Trade-wind points cover almost half of tropics.

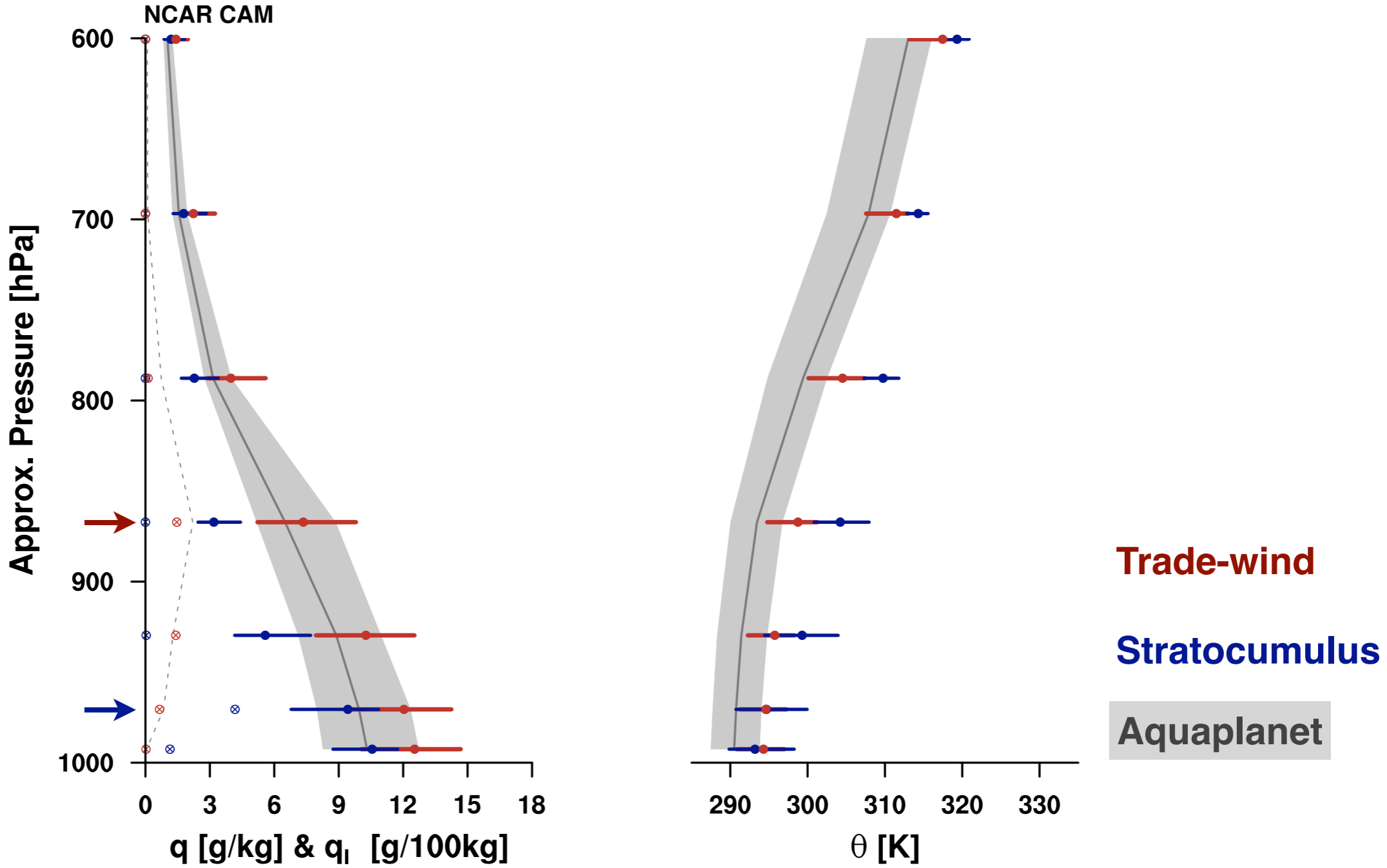
NCAR CAM



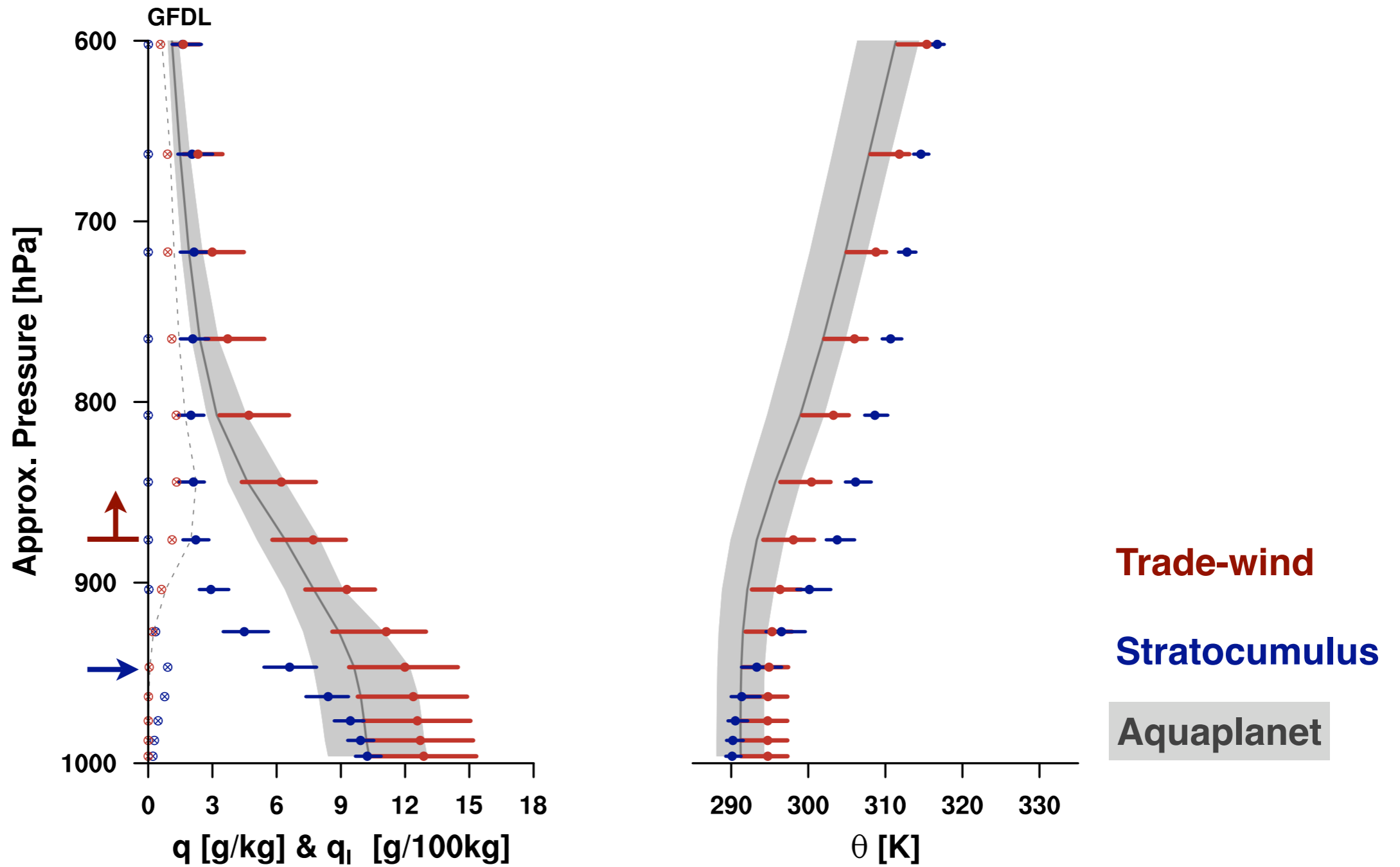
GFDL AM



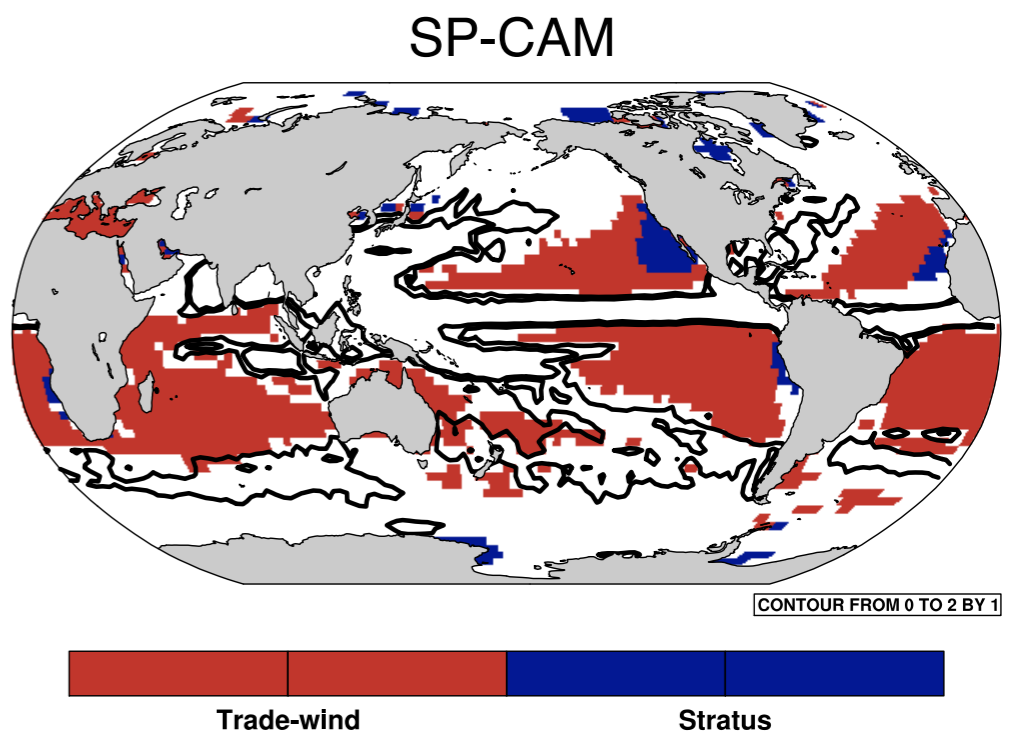
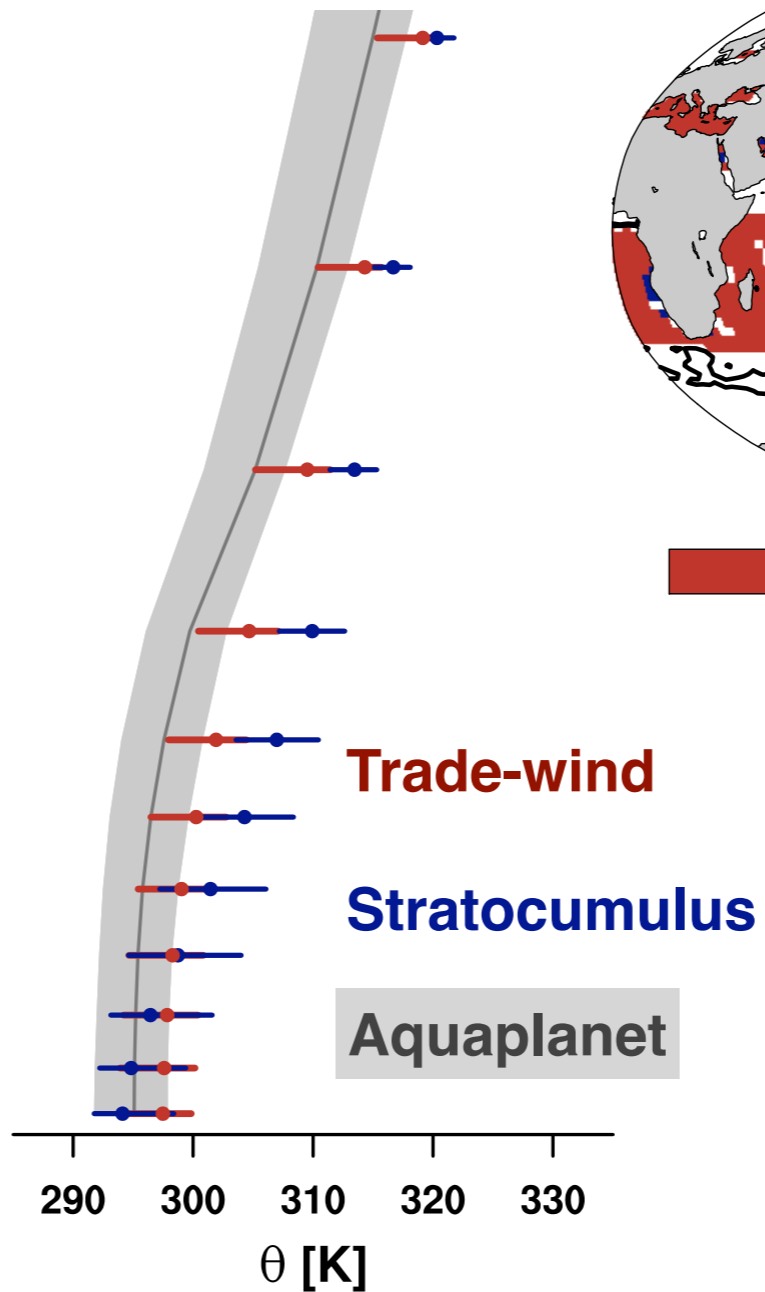
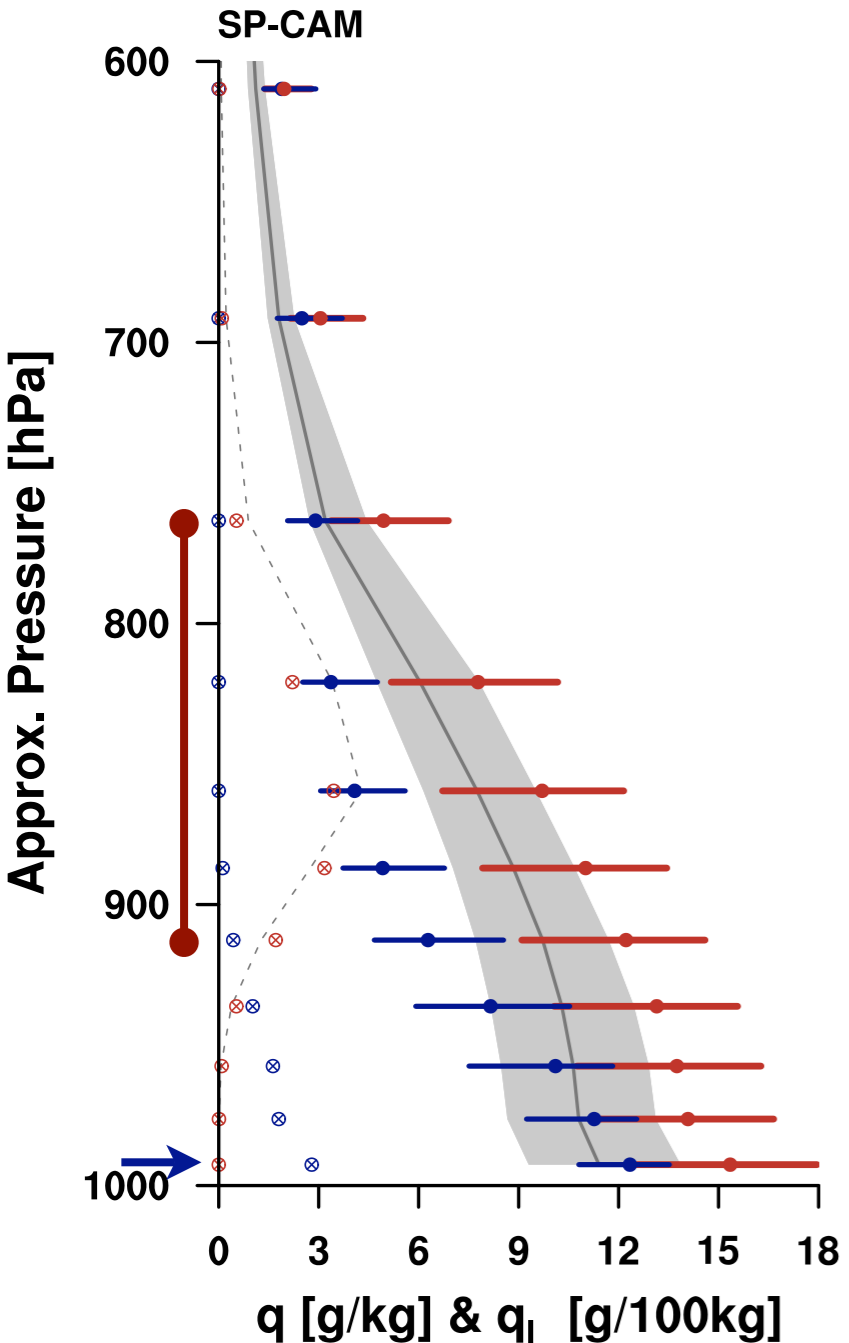
Composite profiles



Composite profiles

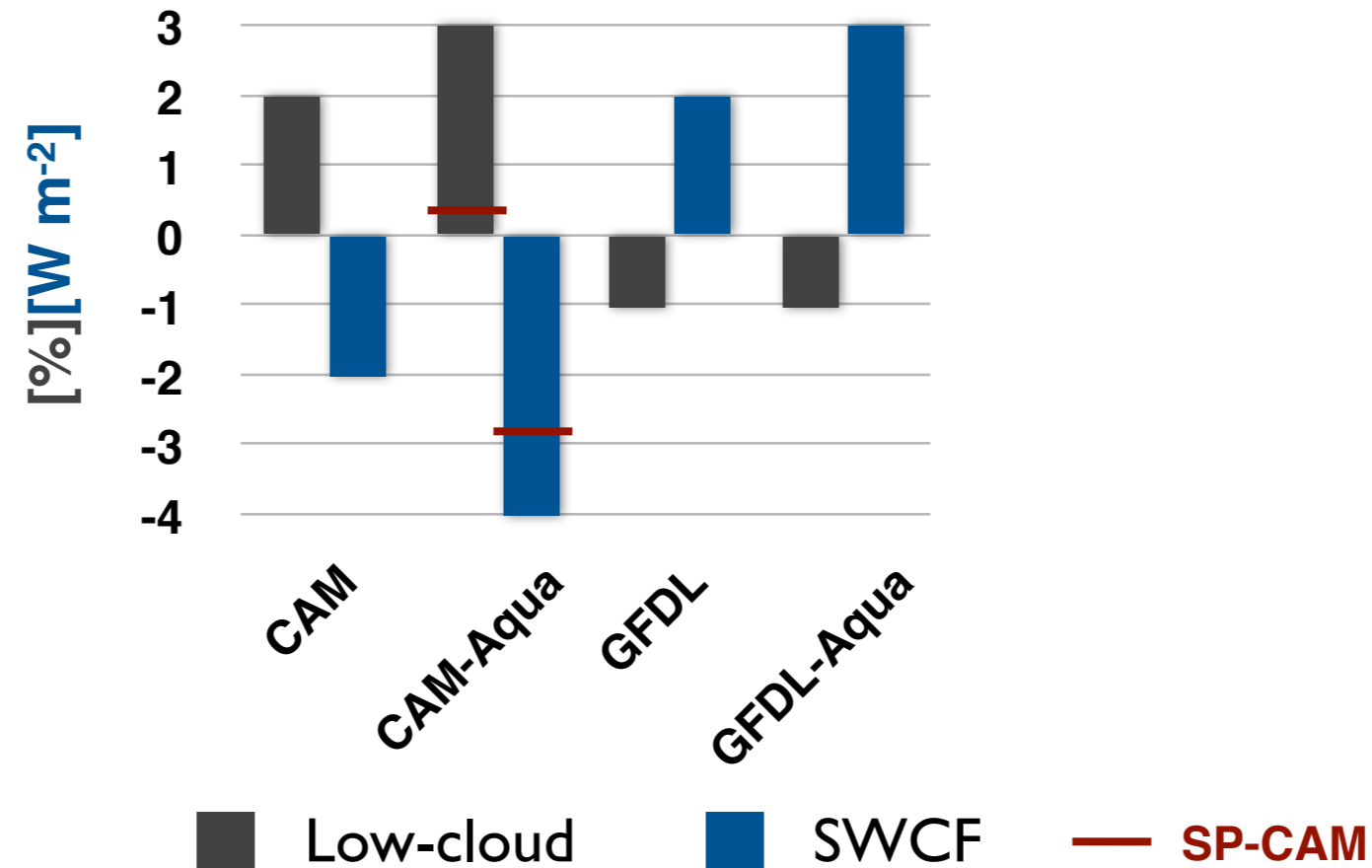


SP-CAM



Climate response

- ▶ Trade-wind/Stratocumulus frequency about the same
- ▶ Warmer, moister tropics (increased LWP, CWV)
- ▶ Cloud amount and short-wave cloud forcing in trade-wind class as in subsidence regimes:



Summary

- ▶ **Aquaplanets reproduce the climate sensitivity of Earth-like configurations,**
- ▶ **by producing similar clouds under given conditions.**
- ▶ **GCMs under-predict stratocumulus (dim stratocumulus?).**
- ▶ **Trade-wind points capture the general behavior of subsidence regimes; shallow cumulus plays an important role in the cloud response.**