Met Office

Coupling between subtropical cloud feedback and the local hydrological cycle in a climate model

Mark Webb and Adrian Lock

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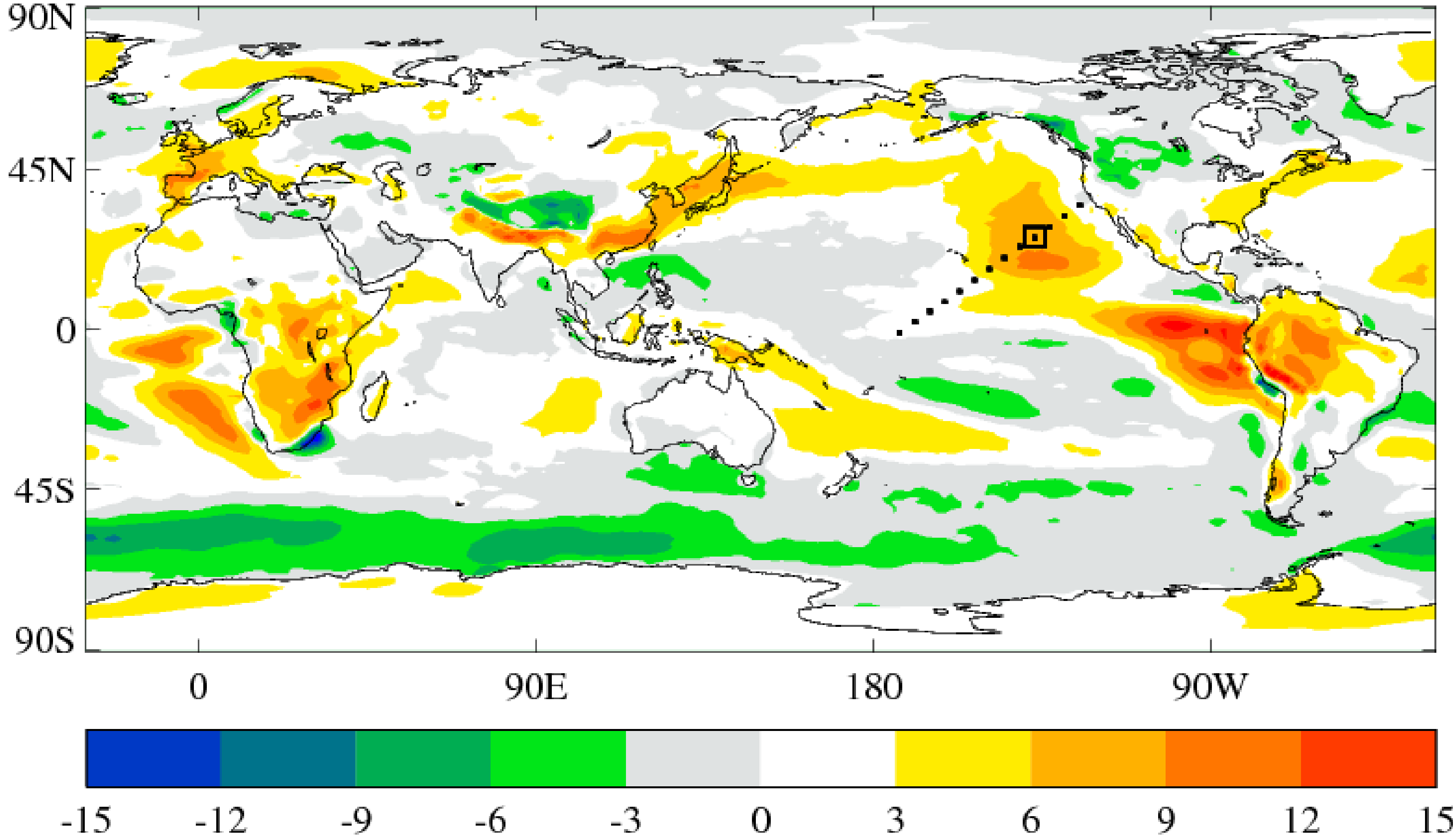
Background and Motivation

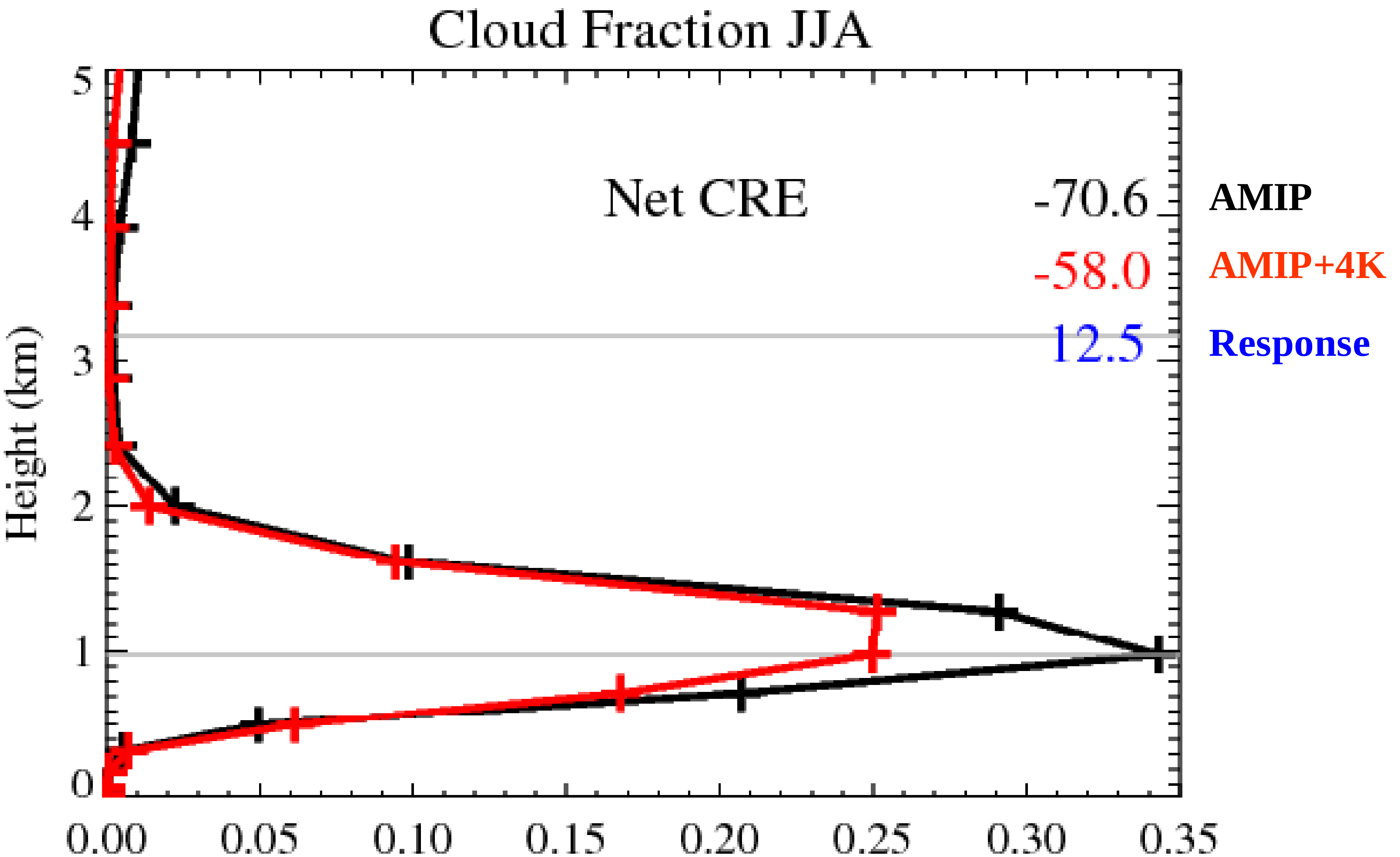
CFMIP-2 provides a suite of SST forced atmosphere-only experiments which are computationally inexpensive compared to coupled slab/AOGCM experiments

This provides an opportunity to develop physical hypotheses for cloud feedback mechanisms and test them using sensitivity experiments

Here we will demonstrate this approach by applying it to the cloud feedback in the subtropical East Pacific in the HadGEM2-A patterned SST experiment

Response of HadGEM2-A Net Cloud Radiative Effect in CFMIP-2 patterned +4K SST experiment



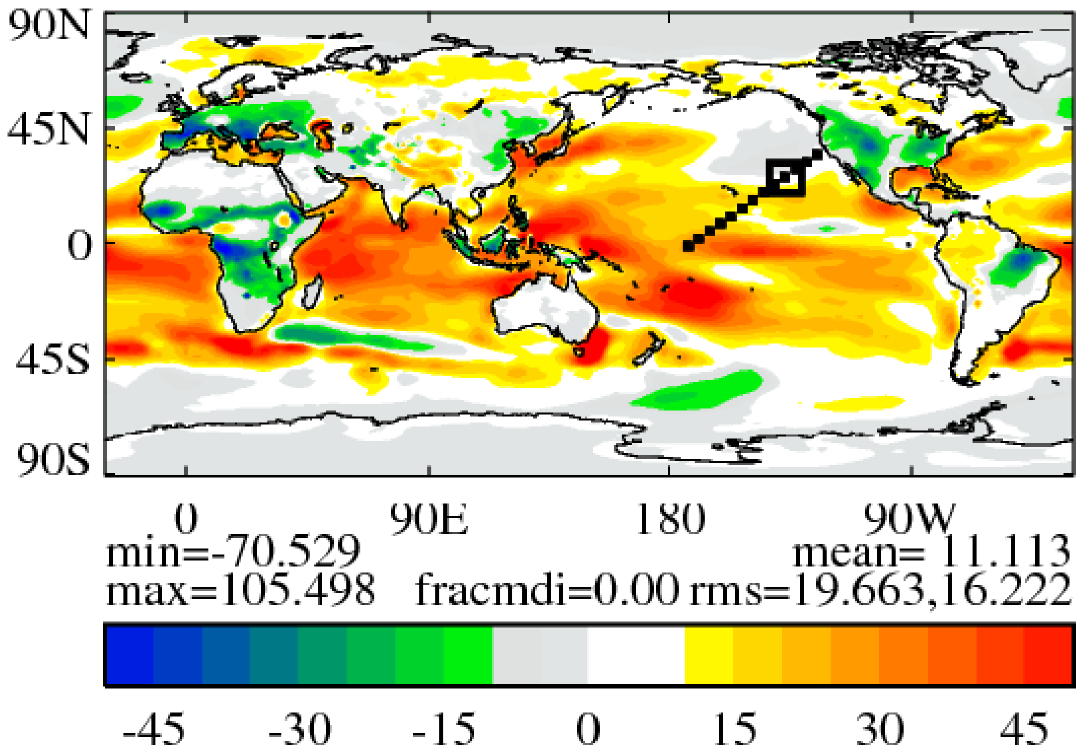


30 Year JJA Mean 1979-2008

Hypotheses we have considered and ruled out for this particular case

- Cloud reductions due to increased entrainment of warm, dry air through the inversion (Lock 2009, Brient and Bony 2012, Rieck et al 2012)
- Deeper, drier boundary layer due to reduced subsidence (Vecchi and Soden 2008)
- Increases in upper level cloud/humidity inhibit longwave cloud top cooling/cloud generation (Stevens and Brenguier, 2009)

+4K Patterned SST Surface Latent Heat Flux Response HadGEM2-A



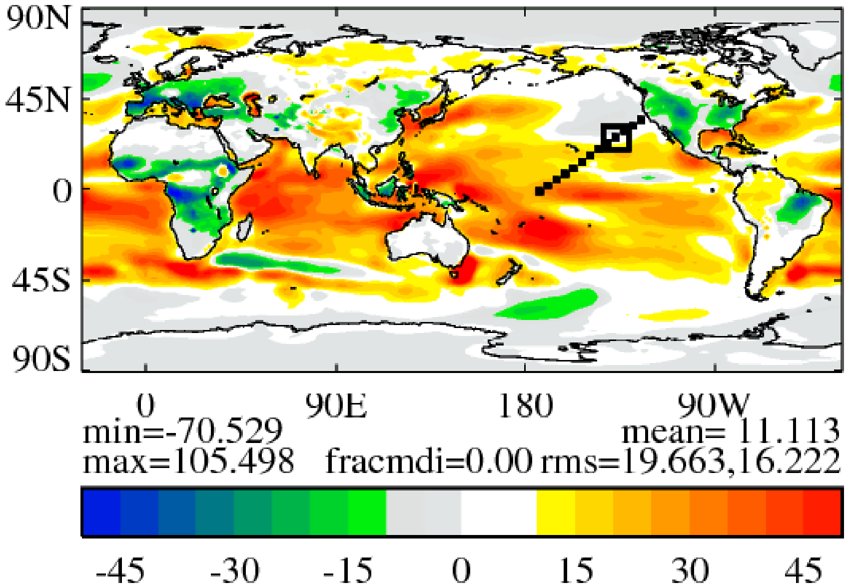
Local surface latent heat flux increases by 0.6%/K compared to 3%/K in the global mean

JJA 1979-2008

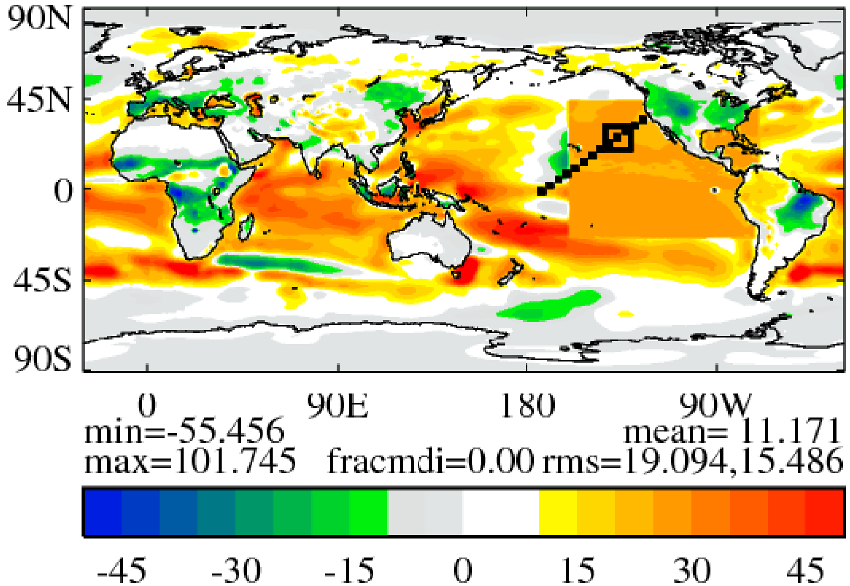
Current working hypothesis

- Clement et al (2009) argued that weakening subsidence in the warmer climate can reduce surface wind speed in this region which results in a reduction in low level cloud
- Richter and Xie (2008) showed that weakening surface winds, reductions in air-sea temperature differences and increases in near-surface relative humidity limit the increase in surface evaporation expected with increasing SSTs in the subtropics
- Rieck et al (2012) showed that increasing SST while keeping surface latent heat fluxes constant dried the boundary layer and reduced cloud fraction a shallow cumulus LES simulation based on the RICO case. They argued that an increasing surface latent heat flux is required to maintain relative humidity in the warmer climate
- Do local effects such as weakening surface winds limit increases in surface evaporation making it harder to maintain boundary layer cloud in the warmer climate in HadGEM2-A?

+4K Patterned SST Surface Latent Heat Flux Response HadGEM2-A



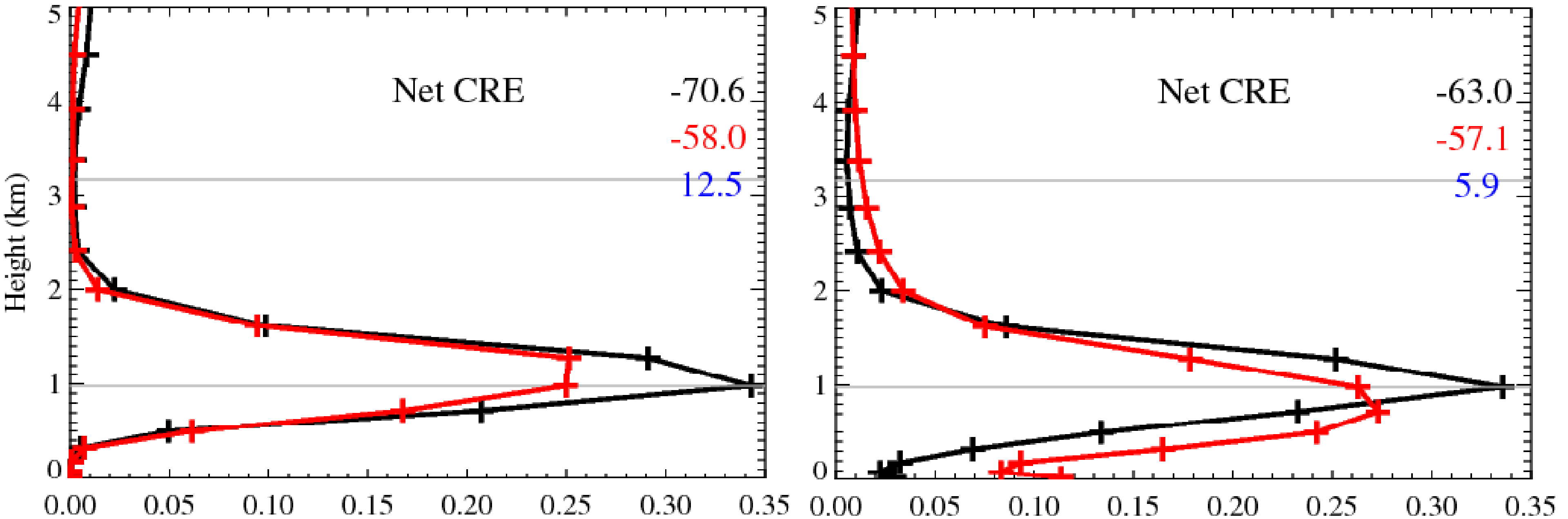
25 Wm^{-2} (5%/K) Forced Increase in Surface Latent Heat Flux



JJA 1979-2008

HadGEM2-A Cloud Fraction

Cloud Fraction with Forced Increase in Surface Latent Heat Flux of 25 Wm^{-2}



JJA 1979-2008

Why is the increase in the latent heat flux so small?

Local surface latent heat flux increases by 0.6%/K

Breakdown of local latent heat flux increase, following Richter and Xie, 2008:

	Change in Surface Latent heat flux
SST increases by 4.1K	6.8 %/K
Surface wind weakens by 10%	-1.8 %/K
Near-surface RH increases by 2.4%	-1.7 %/K
Air-sea temp difference reduces by 19%	-1.4 %/K
All	0.8%/K

Summary

- HadGEM2-A has a strong positive cloud feedback in subtropical stratocumulus/transition regions in +4K SST perturbation experiments
- Over the northeast subtropical Pacific at 137°W/26°N, low level cloud fraction reduces considerably, and surface latent heat flux increases by just 0.6%/K
- Forcing the surface latent heat flux to increase by 5%/K reduces the magnitude of the low cloud feedback, moistening the boundary layer and thickening the cloud
- This suggests that increasing surface latent heat fluxes are required to maintain boundary layer cloud in the warmer climate in HadGEM2-A, consistent with LES results in Rieck et al 2012
- Near surface winds and air-sea temperature differences weaken while near-surface relative humidity increases, consistent with Richter and Xie (2008)
- These local changes limit the ability of the surface latent heat flux to increase sufficiently to maintain the cloud in the boundary layer, contributing to the positive low cloud feedback
- This indicates a coupling between the local hydrological cycle and the subtropical cloud feedback in HadGEM2-A via surface evaporation

Conclusions

- A better understanding of the factors controlling local changes in surface evaporation may be a necessary prerequisite for understanding the reasons for inter-model differences in subtropical cloud feedbacks

- An organised SCM/LES inter-comparison based on different surface latent heat flux forcing (e.g. based on Rieck et al 2012 or CGILS) would help us to understand wider model sensitivities to surface latent heat flux forcing