Variations in ERA-Interim and CERES-Terra Fluxes and Cloud Properties with SST Anomalies for Low Cloud Regions

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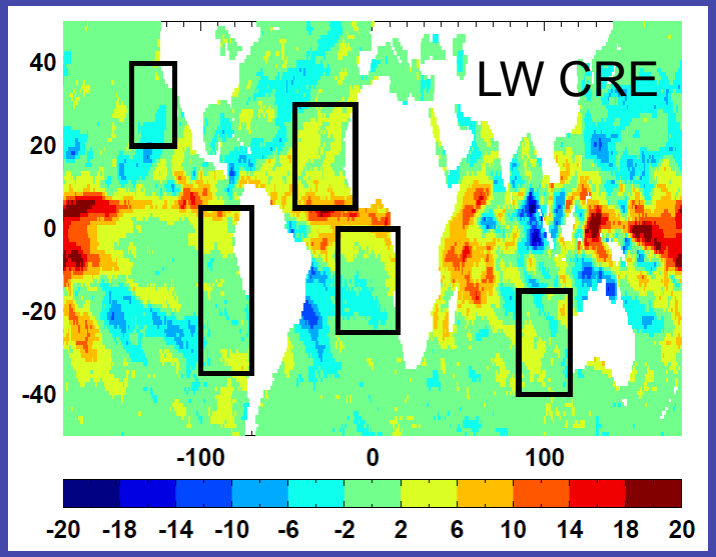
Motivation

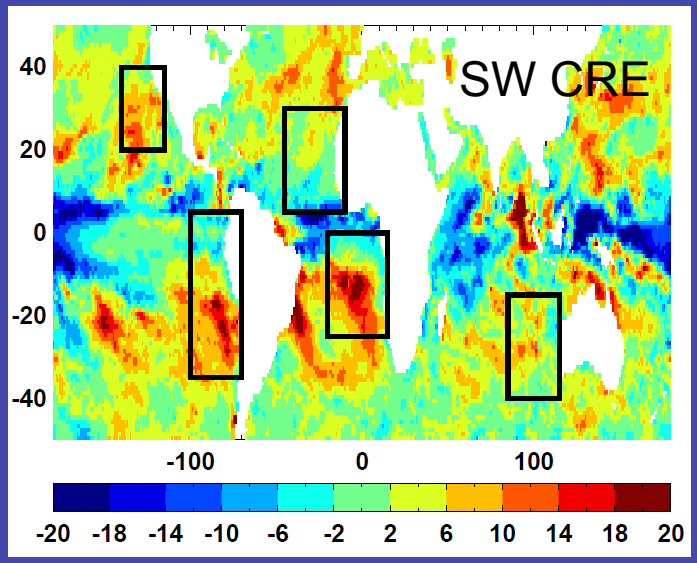
- Recent authors (e.g., Wagner et al. (2008, Atmos Chem Phys) have used satellite data to examine cloud properties and their changes with SST anomaly.
- Others (e.g., Bony et al. 2004, Klein and Hartmann 1993, Wood and Bretherton 2006) have studied how clouds change with dynamical regime and lower-tropospheric stability.
- Here, we look at changes in cloud properties with SST anomaly, and attempt to quantify the portion of that change that is due to shifts in stability within a given dynamical regime.

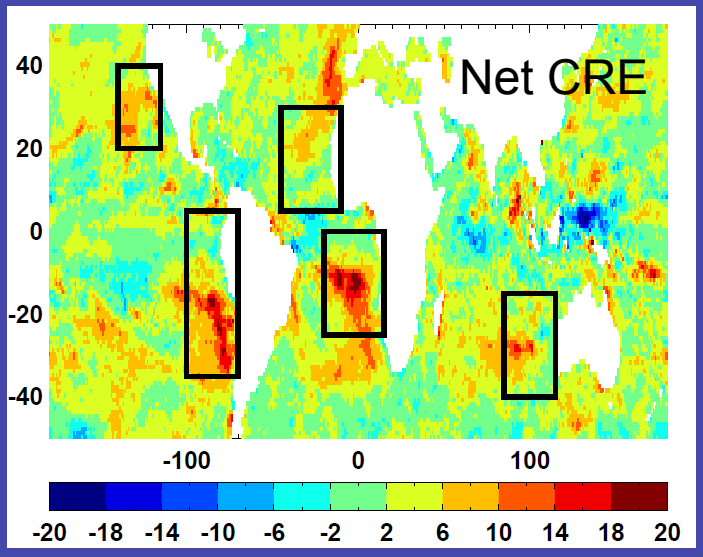
Data Sources

- All data is from March 2000-Feb 2005.
- Monthly mean 1x1 degree CERES-EBAF data is used for radiative fluxes.
- Monthly mean 1x1 degree CERES Terra SRBAVG Non-GEO data is used for LWP and cloud.
- Monthly mean Reynolds SSTs from NOAA.
- ECMWF-Interim data is used for meteorological data, including ω_{700} and Estimated Inversion Strength (EIS).
- Anomalies are calculated by subtracting each month's value from the five-year mean for that month.

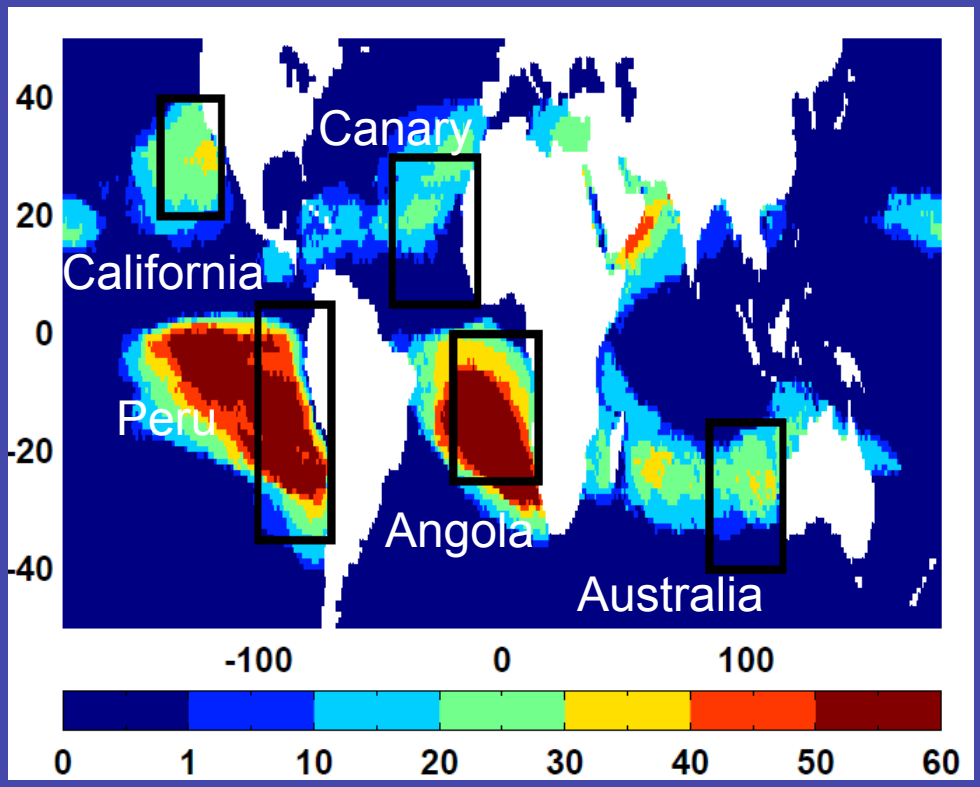
Change in LW, SW and Net CRE with SST (W m^{-2} K^{-1})





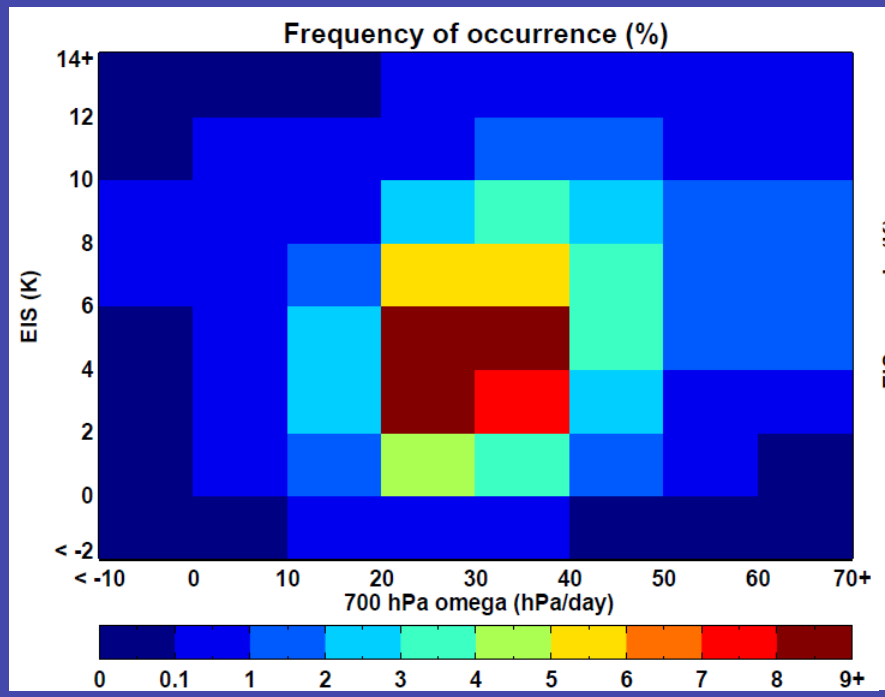


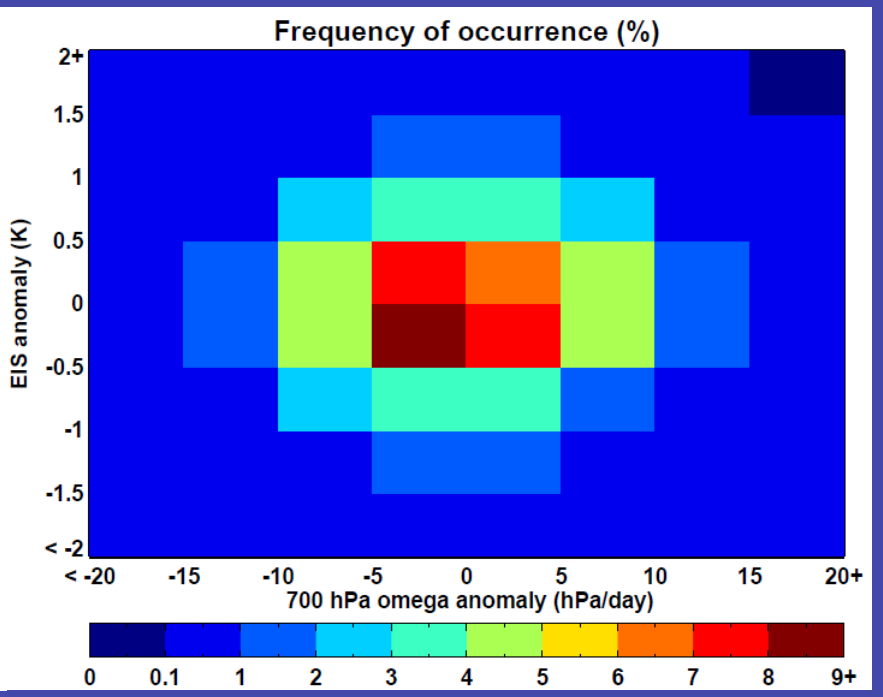
Low cloud regions defined by Jensen et al. (2008)



The number of months (out of 60) with a combined middle and high cloud fraction less than 0.10 are contoured.

Frequencies of occurrence

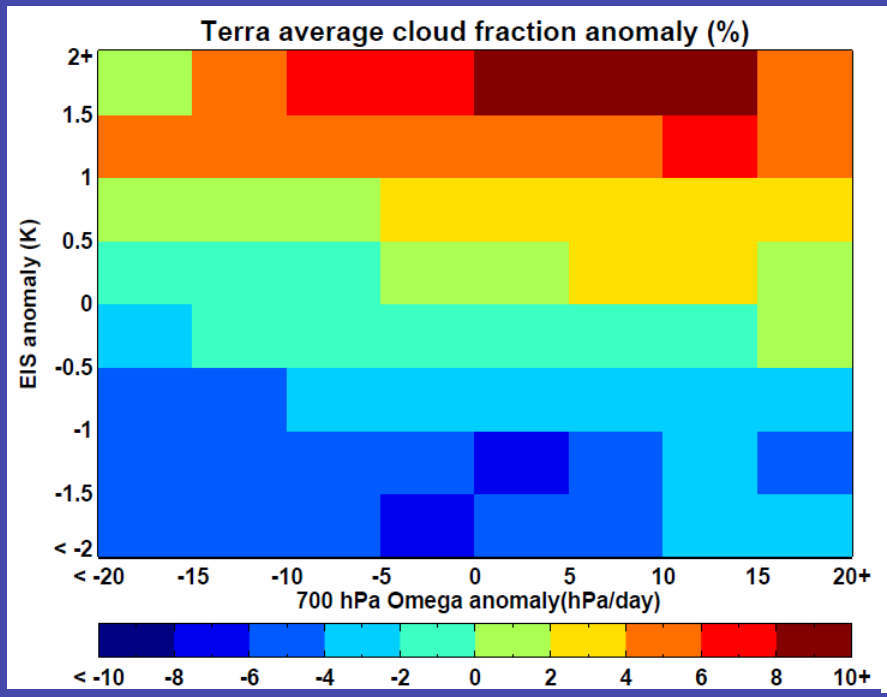


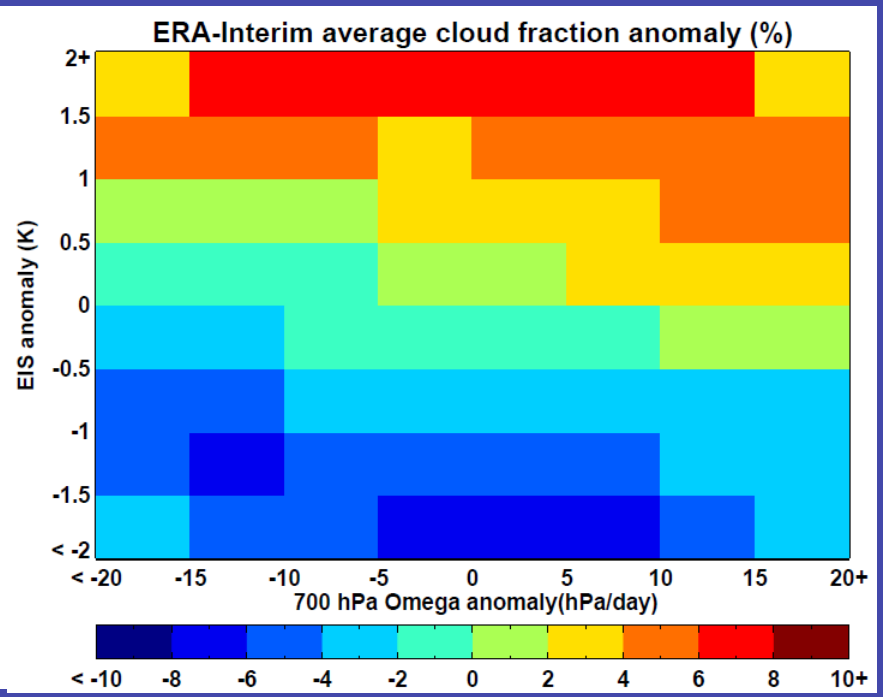


ω_{700}-EIS regimes

ω_{700} anomaly-EIS anomaly regimes

Average low cloud fraction anomalies

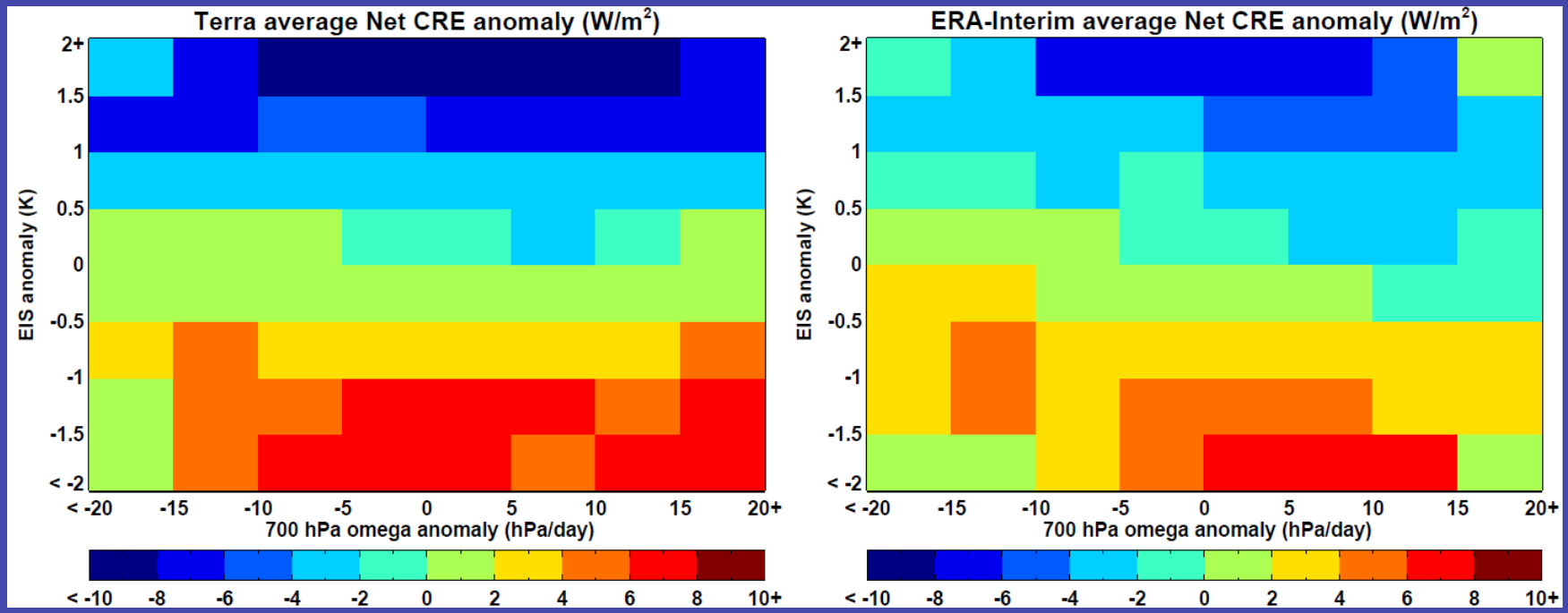




Terra

ERA-Interim

Average Net CRE anomalies



Terra

ERA-Interim

Estimation of thermodynamic and dynamic effects

If C is a cloud or radiative property (cloud fraction, Net CRE, etc.), it can be expressed as:

$$\frac{\partial C}{\partial (SST)} = \sum_{\omega} \left(\frac{\partial C}{\partial (EIS)}\right)\left(\frac{\partial (EIS)}{\partial (SST)}\right) P_{\omega} + \sum_{EIS} \left(\frac{\partial C}{\partial \omega}\right)\left(\frac{\partial \omega}{\partial (SST)}\right) P_{EIS} + R$$

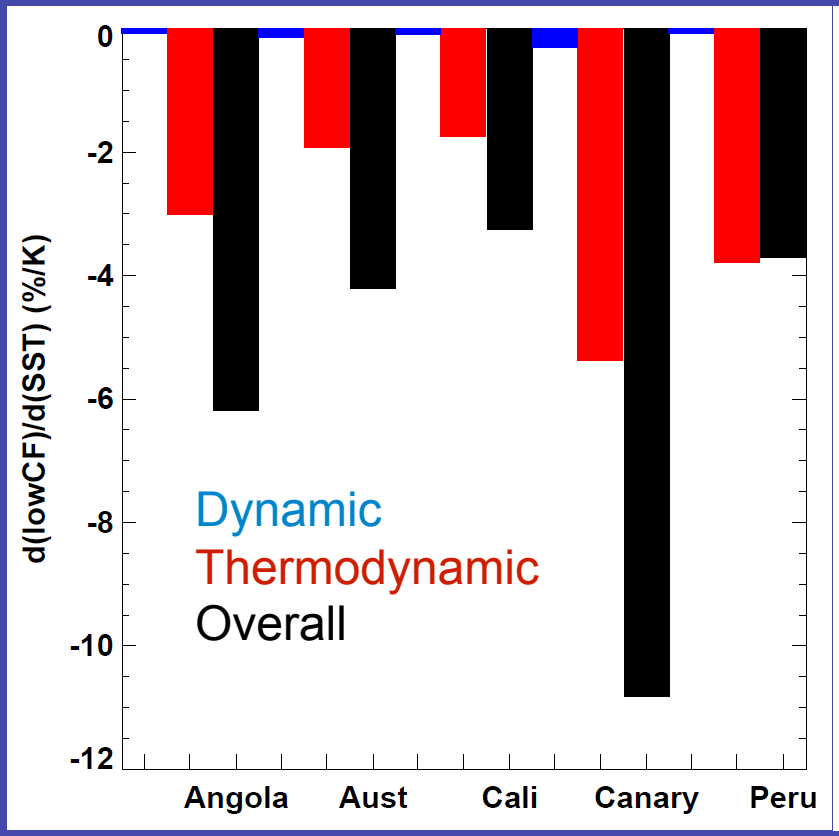
The first term represents thermodynamic effects, the second dynamic, and the third, the residual.

Changes in properties with SST for low cloud regions

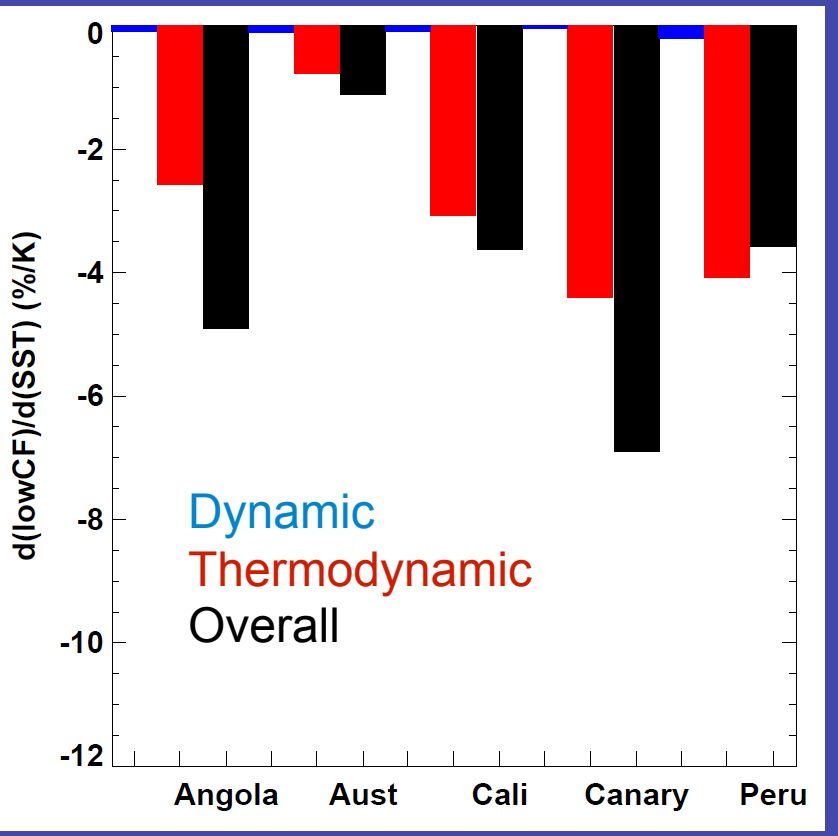
	Total	Thermodyn	Dynamic	Residual
Terra low cld fraction (%/K)	-5.22	-3.18	-0.06	-1.97
ERA low cld fraction (%/K)	-4.35	-3.24	-0.11	-1.00
Terra LWP ($g\ m^{-2}\ K^{-1}$)	-6.83	-4.13	-0.10	-2.60
ERA LWP ($g\ m^{-2}\ K^{-1}$)	-2.74	-3.90	-0.12	1.28
Terra SW CRE ($W\ m^{-2}\ K^{-1}$)	7.33	3.68	0.02	3.35
ERA SW CRE ($W\ m^{-2}\ K^{-1}$)	3.35	3.26	0.10	-0.01
Terra Net CRE ($W\ m^{-2}\ K^{-1}$)	6.86	3.52	0.04	3.30
ERA Net CRE ($W\ m^{-2}\ K^{-1}$)	3.21	2.97	0.09	0.15

Regional differences in changes in low-cloud fraction with SST

Terra observations

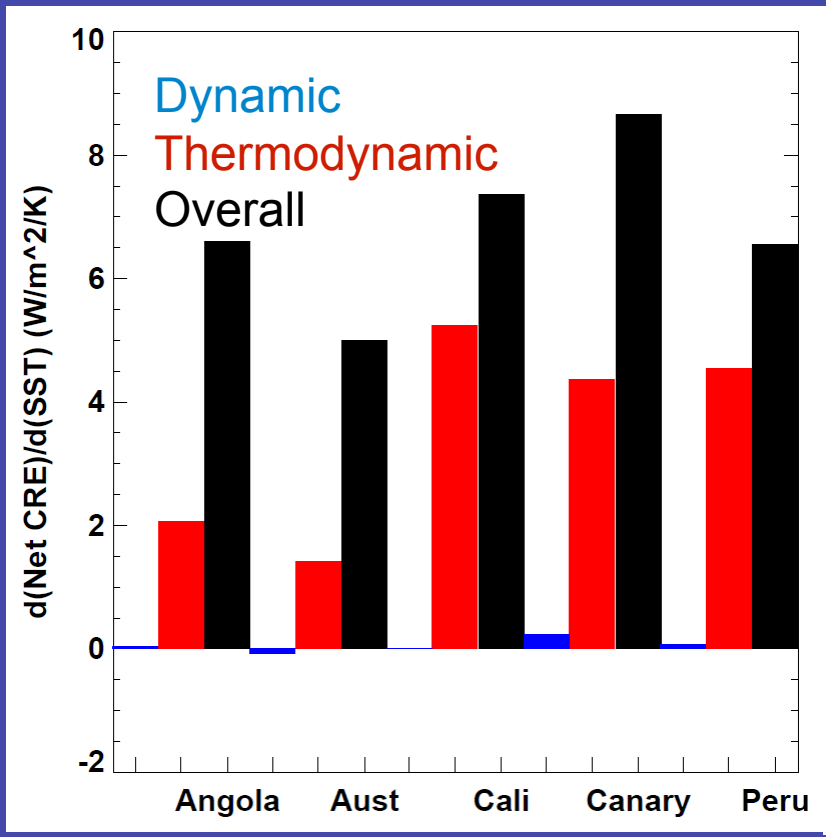


ERA-Interim data

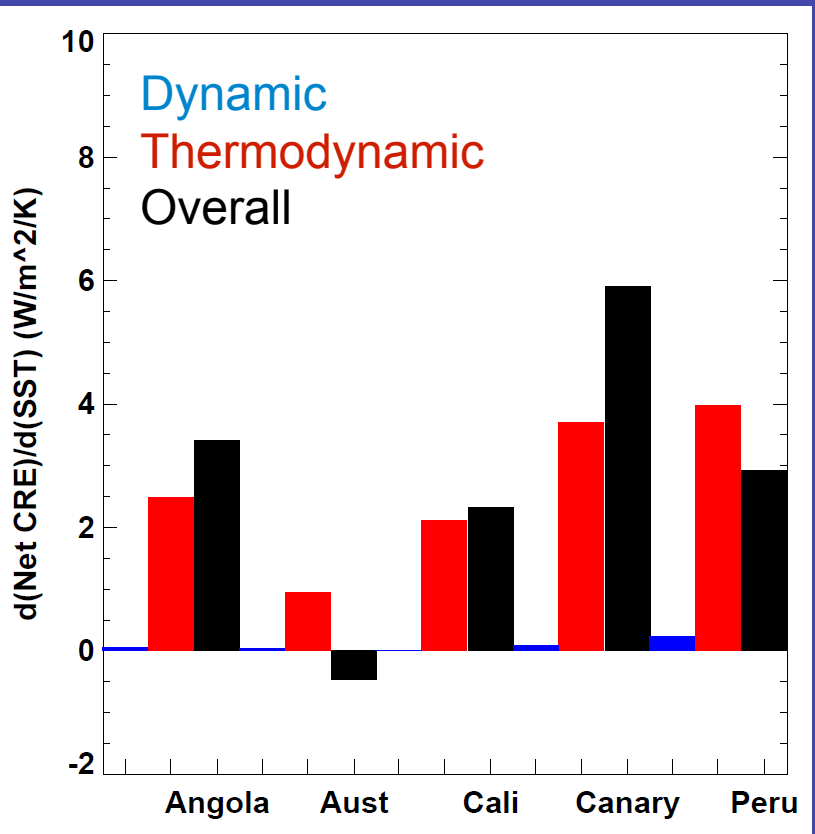


Regional differences in changes in Net CRE with SST

Terra observations



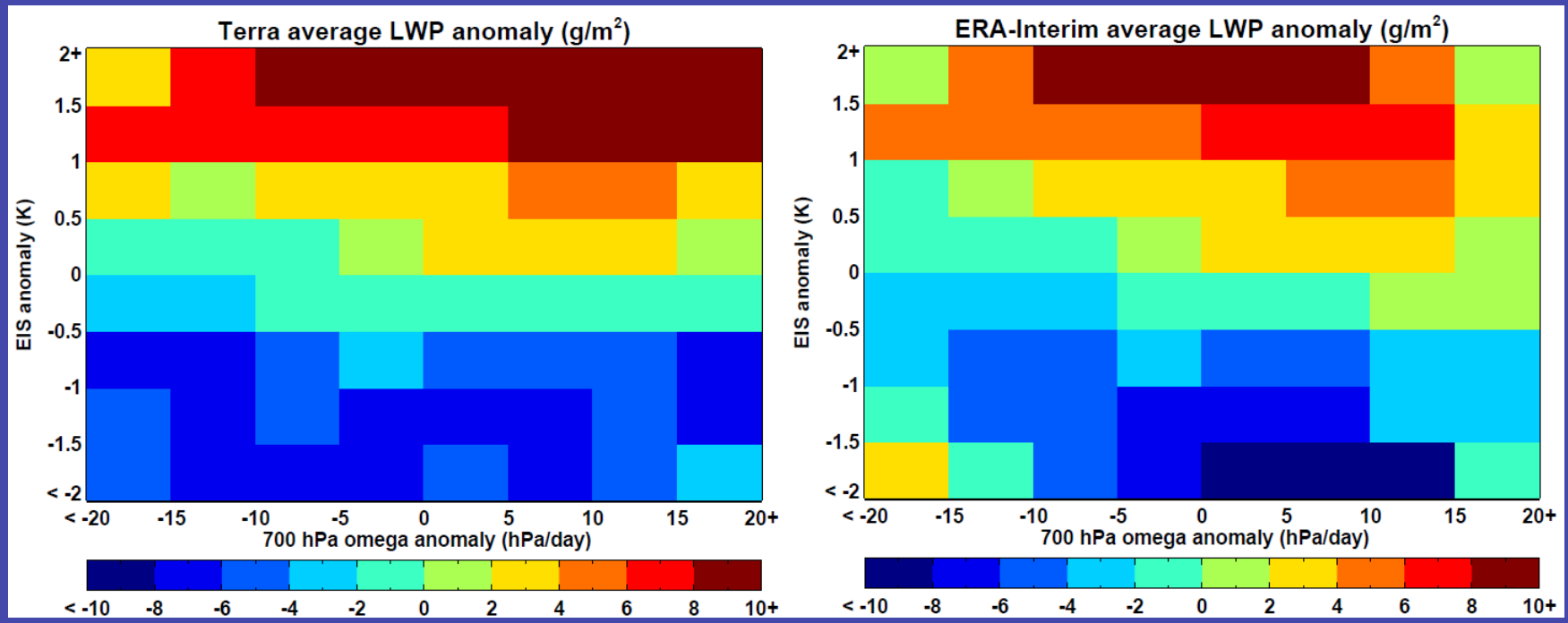
ERA-Interim data



Summary

- In subtropical boundary-layer cloud regions, cloud fraction and liquid water path decrease with SST, leading to a net warming in both the Terra observations and ERA-Interim analyses.
- These variations with SST tend to be somewhat weaker (especially for LWP) in the ERA analyses.
- Changes in cloud and radiative properties with SST have a strong association with changes in EIS within each dynamical regime. If the stabilities of low cloud regions do not change much with long-term climate change, these results suggest that the cloud feedback in these regions may be weak.
- The above trends have the same signs in individual basins for the most part, but magnitudes differ between basins. The Canary region has the strongest variations with SST for both the observations and analyses.

Average LWP anomalies

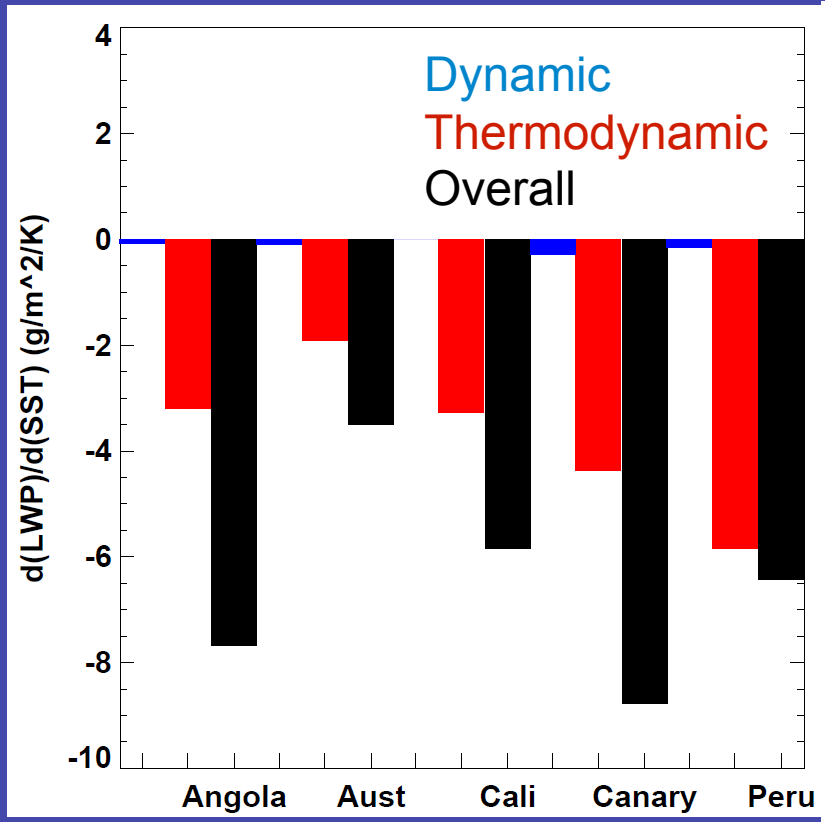


Terra

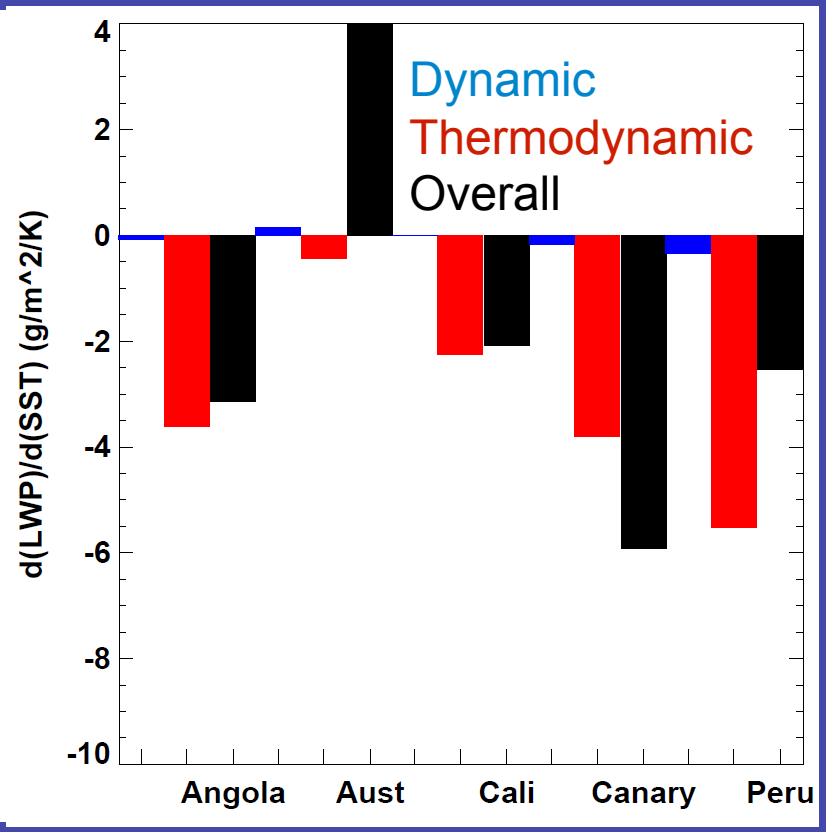
ERA-Interim

Regional differences in changes in LWP with SST

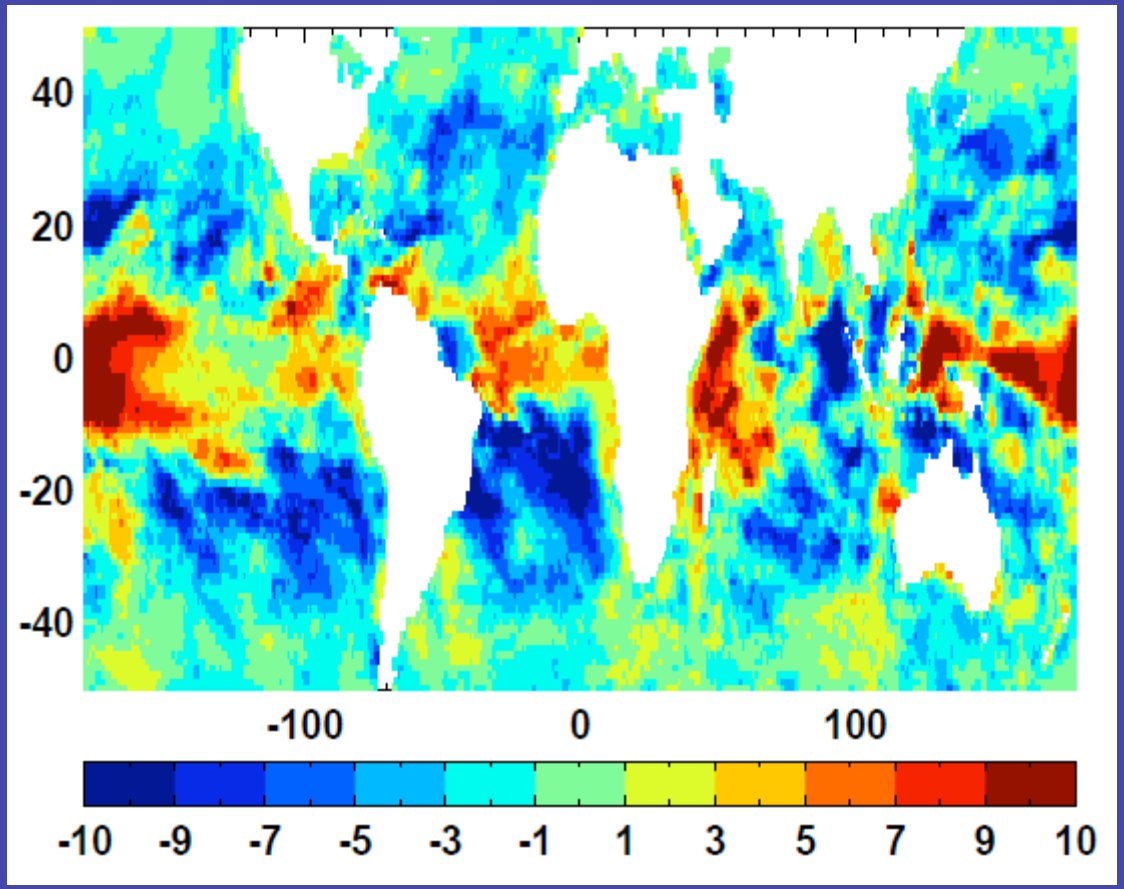
Terra observations



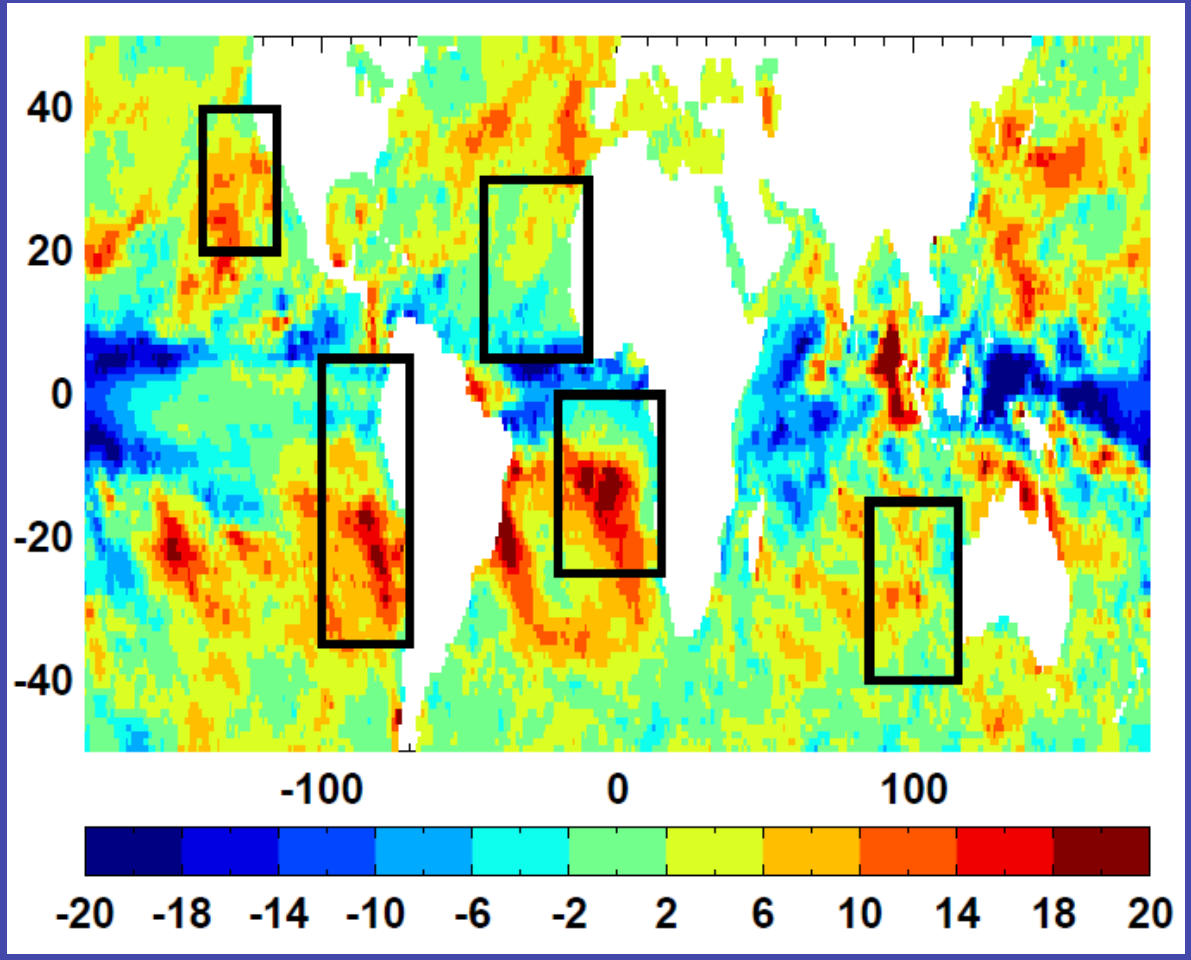
ERA-Interim data



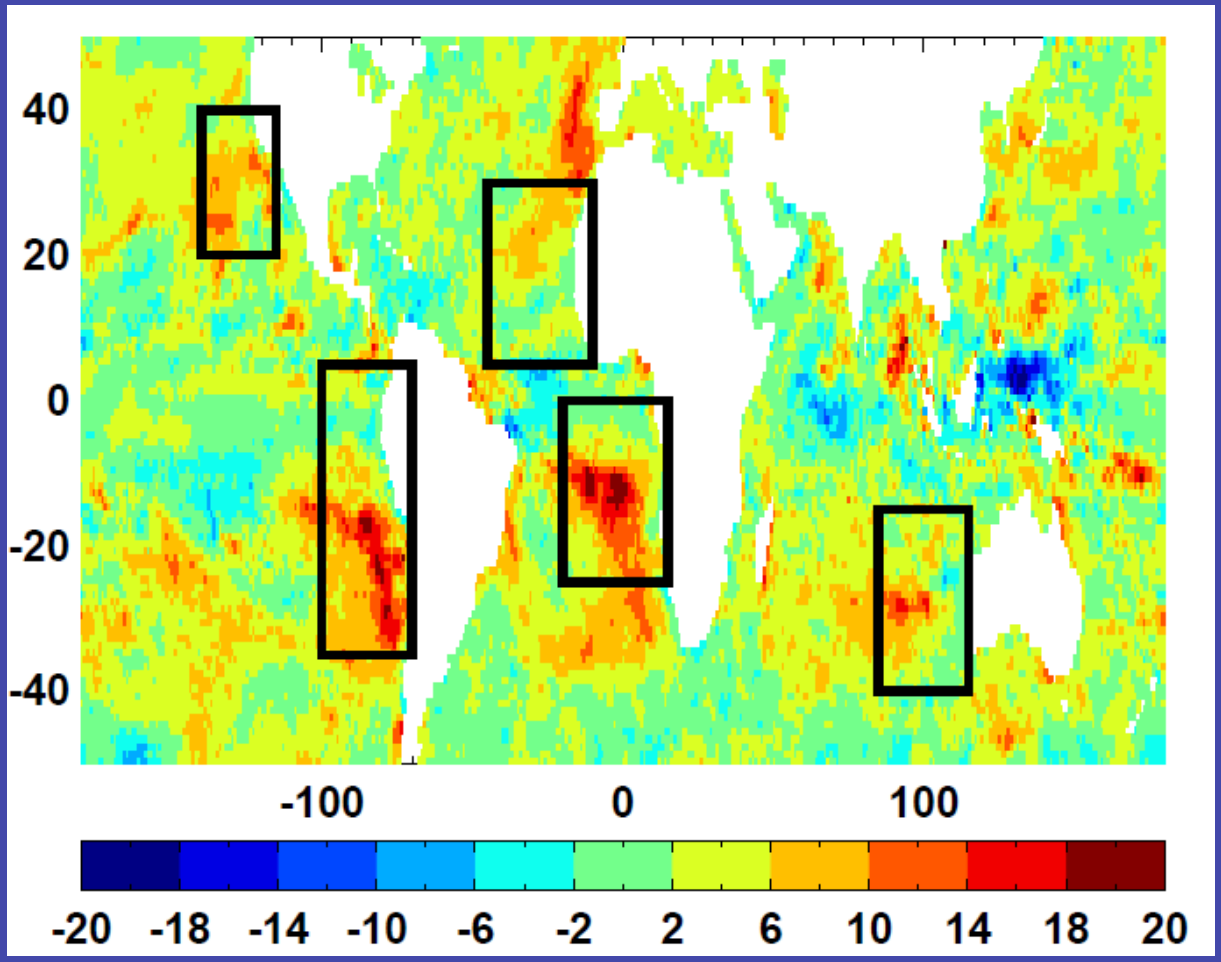
Change in total cloud fraction with SST (%/K)



Change in SW CRE with SST (W m^{-2} K^{-1})



Change in Net CRE with SST (W m^{-2} K^{-1})



Changes in properties with SST for low cloud regions