Iris Effect, Negative Feedback and Climate Sensitivity

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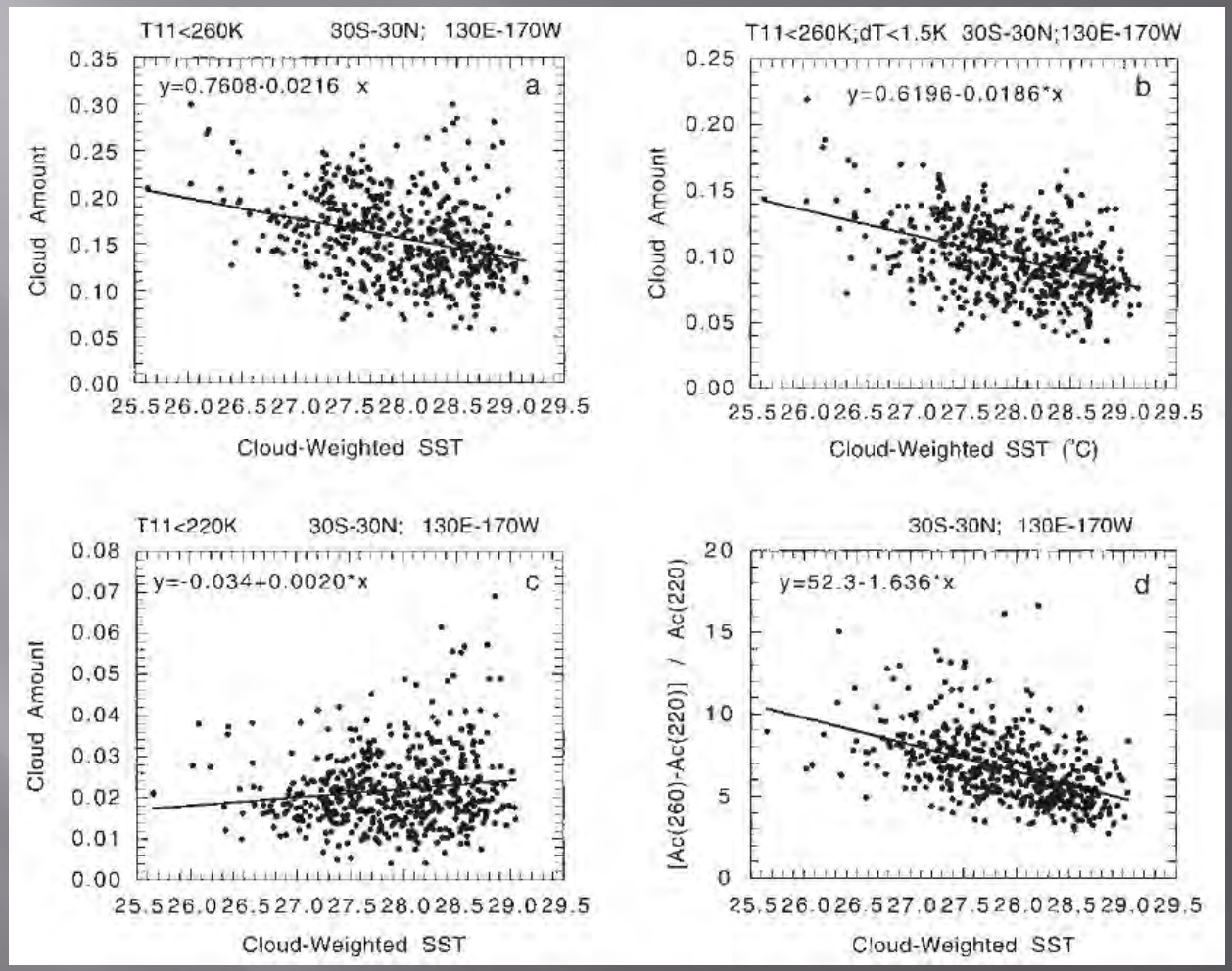
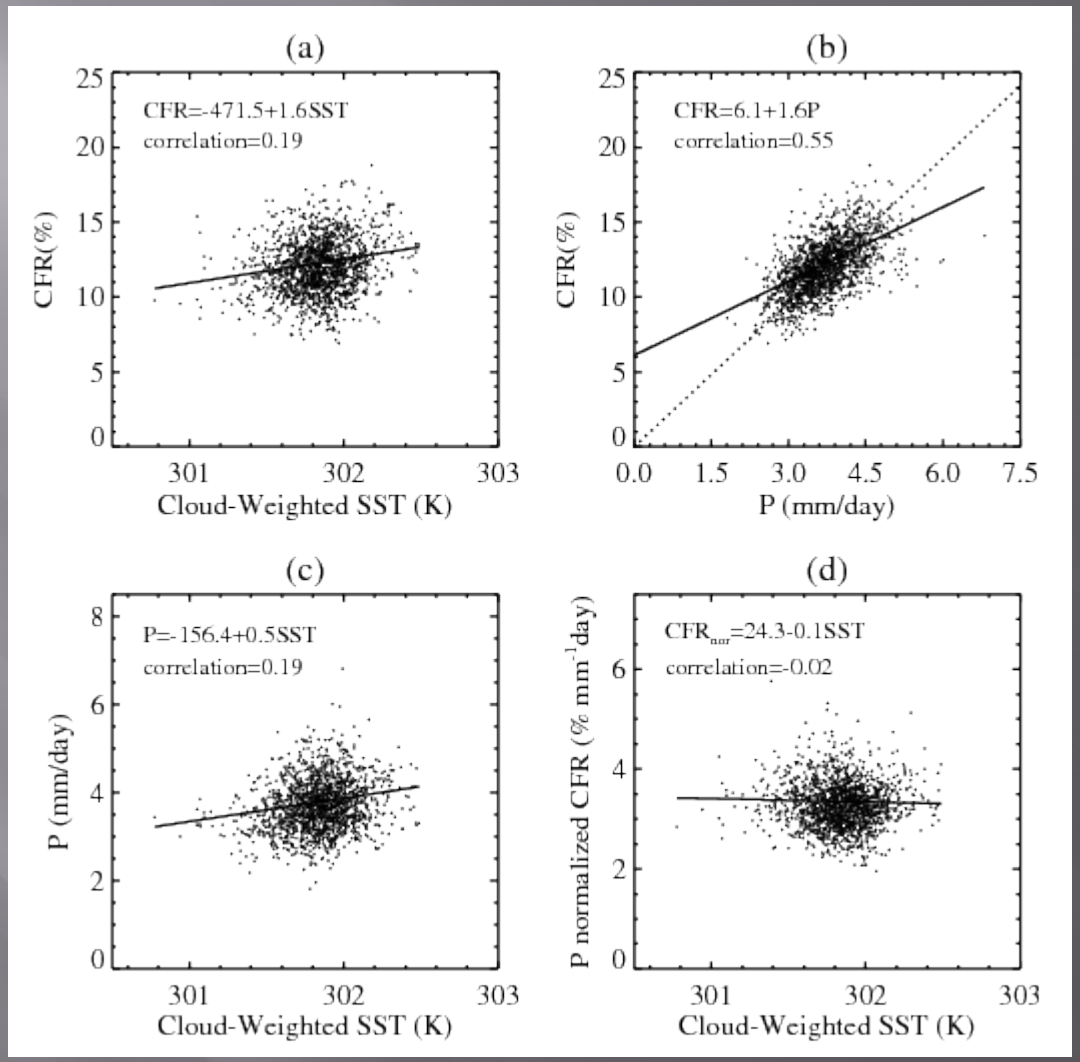
The Iris Hypothesis (2001)



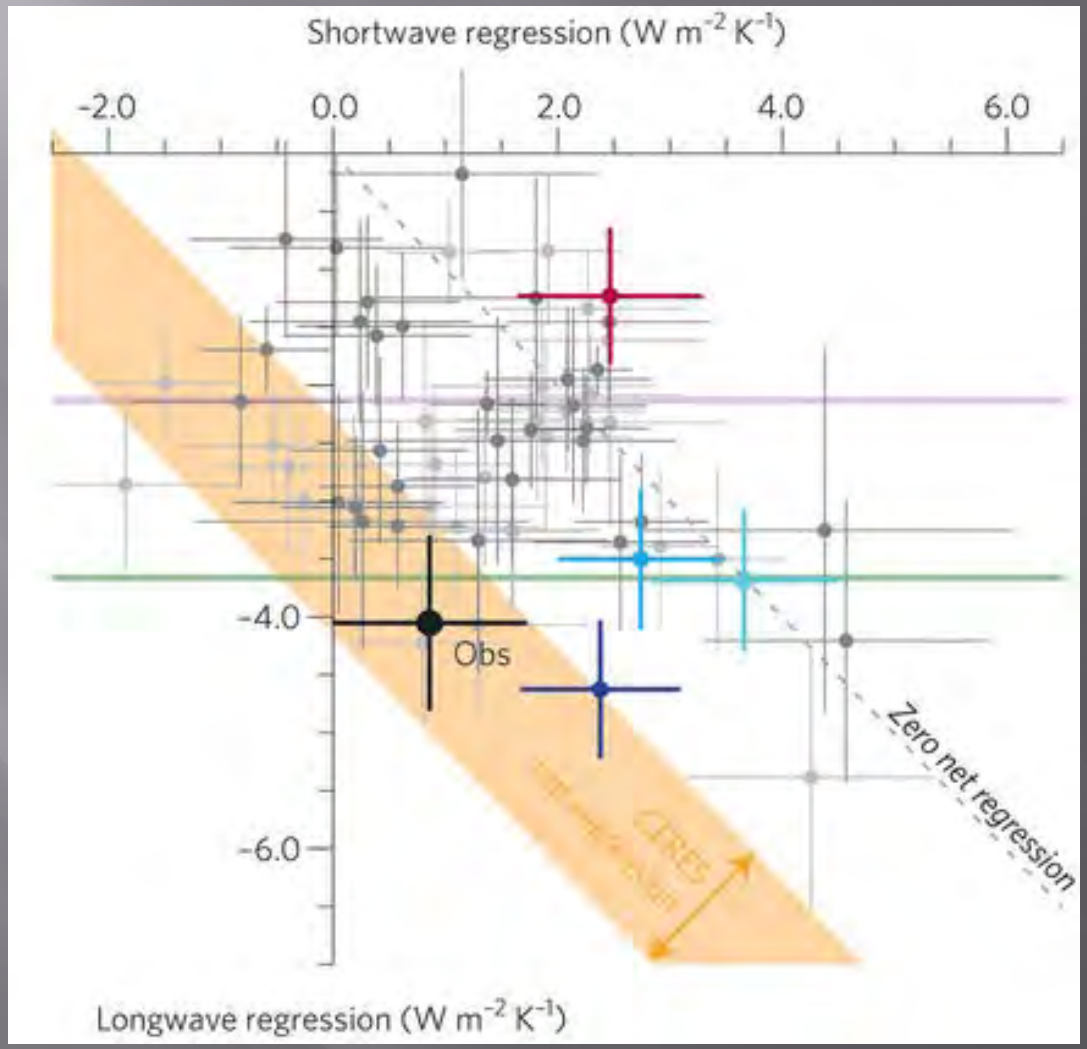
Lindzen et al. **(2001, BAMS) suggested that cirrus cloud coverage normalized by a measure of cumulus coverage decreases about 22% per degree increase of SST, implying a negative climate feedback that would more than cancel all the positive feedbacks in current climate models.**

Lack of Evidence for Iris (2008)



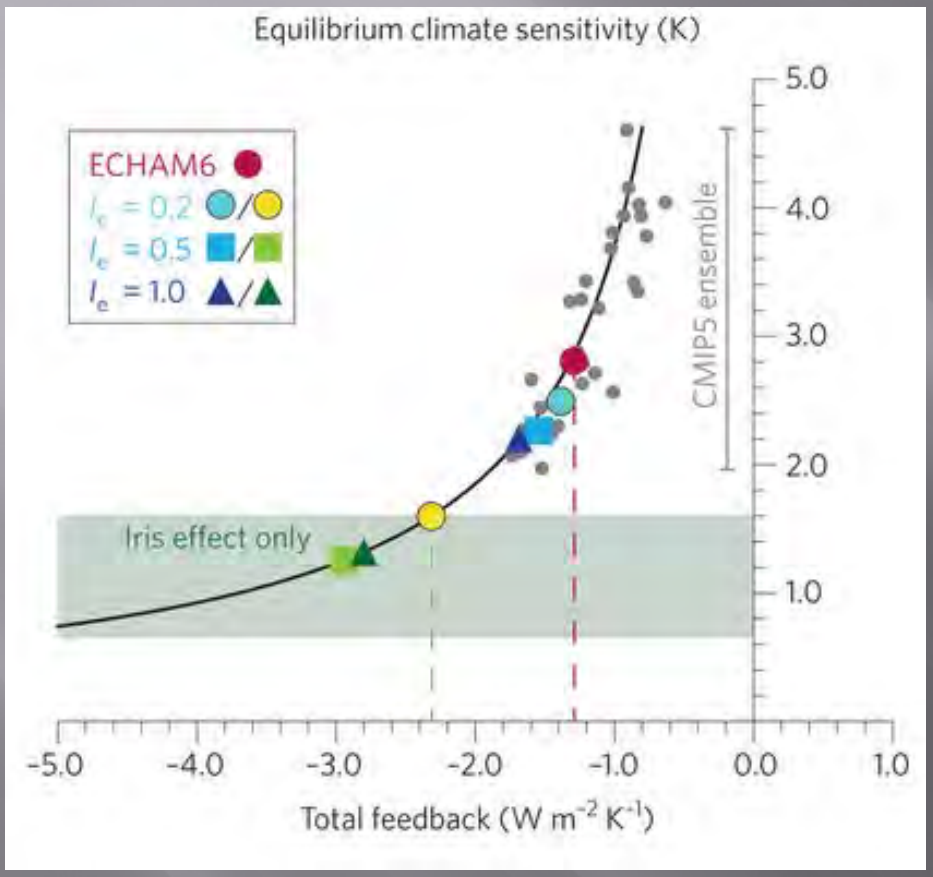
Su et al. (2008) **showed that tropical (15°S-15°N) upper tropospheric (UT, P < 300 hPa) cloud fraction increases with cloud-weighted SST based on AIRS daily data from September 1, 2002 to September 30, 2006.**

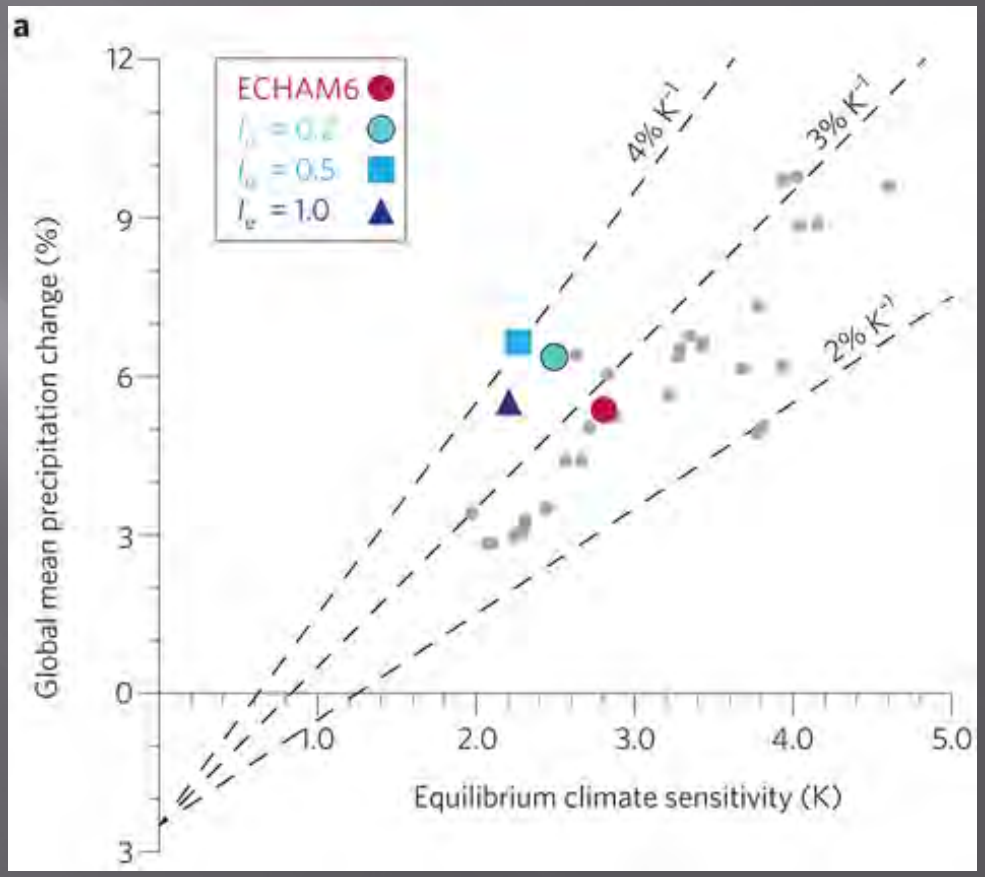
The Return of Interest in Iris Effect (2015)



Mauritsen and Stevens (2015, *Nature. Geo.*)

Iris Effect Relevance to Climate Sensitivity and Hydrological Sensitivity





Mauritsen and Stevens (2015, *Nature. Geo.*)

Big Questions

- Is there missing negative feedback in the models?
- From where is the negative feedback missing?
- What processes are responsible for the missing negative feedback in models?
- Does the missing negative feedback account for the inter-model spread in climate sensitivity?

Data and Models

- CERES-EBAF 2.8 (January 2001- December 2013)
  - Top-of-atmosphere (TOA) radiative fluxes for clear-sky and all-sky

- AIRS (September 2002 to June 2015)
  - TOA outgoing longwave radiation (OLR) for clear-sky and all-sky
  - High-cloud fraction, Level 3, Version 6

- CloudSat/CALIPSO cloud fraction and cloud class (June 2006 to December 2010)

- MLS water vapor (September 2004 to December 2013)

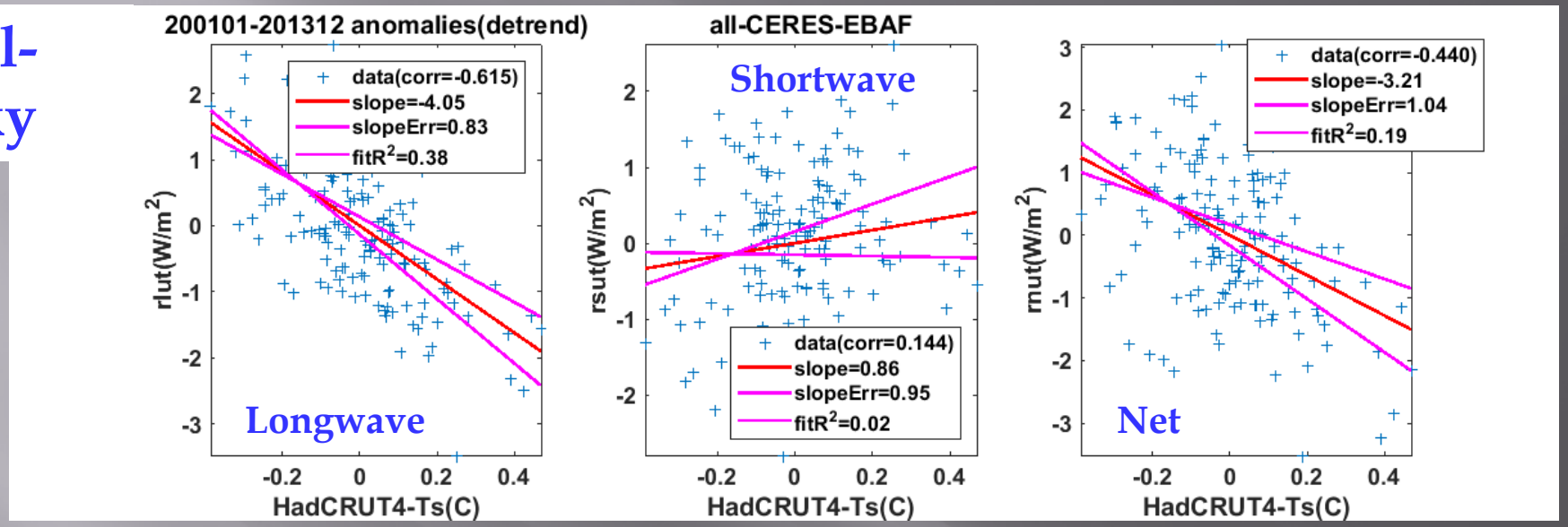
- ISCCP (January 1995 to December 2005)
  - TOA radiative fluxes for clear-sky and full-sky
  - High-cloud fraction

- HadCRUT4 surface temperature (T_s) (1995 to 2015)

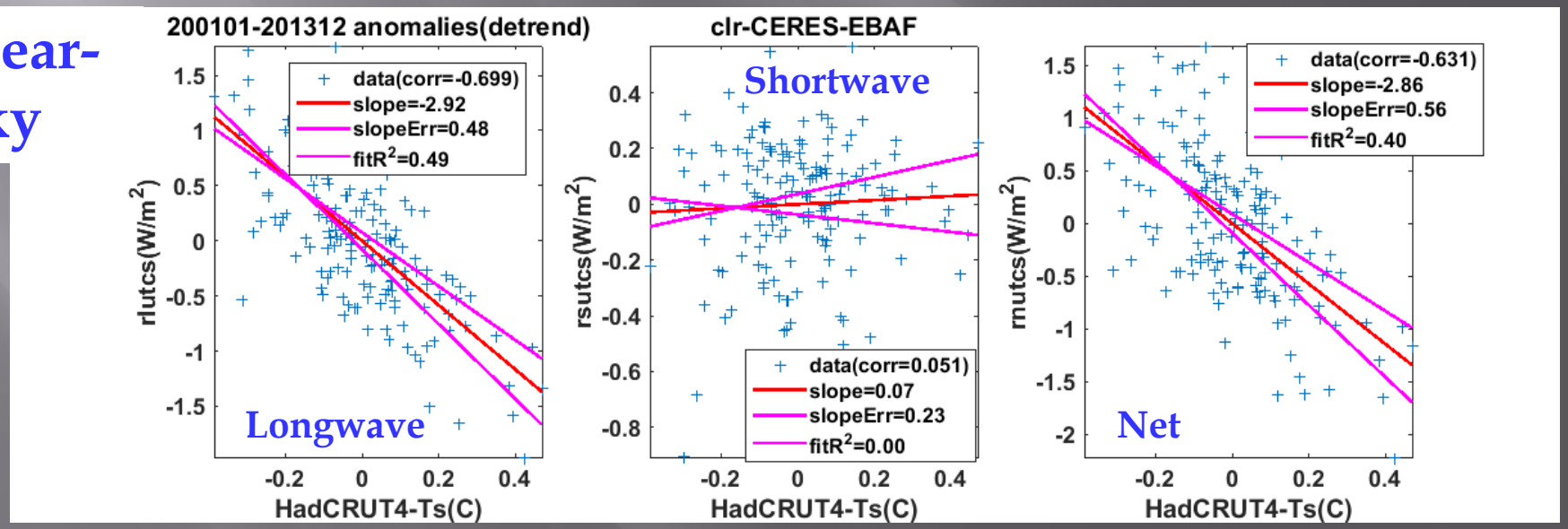
- 13 CMIP5 AMIP-type model simulations (1995-2005)

Observed TOA Radiation Sensitivity to T_s

All-Sky

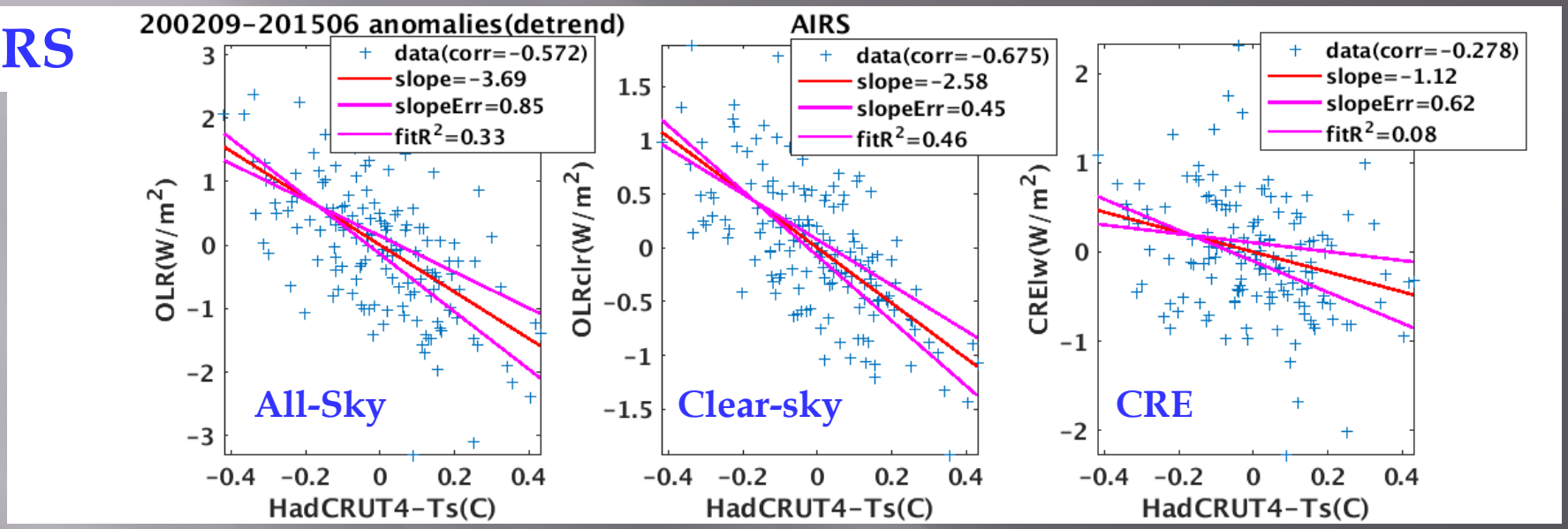


Clear-Sky

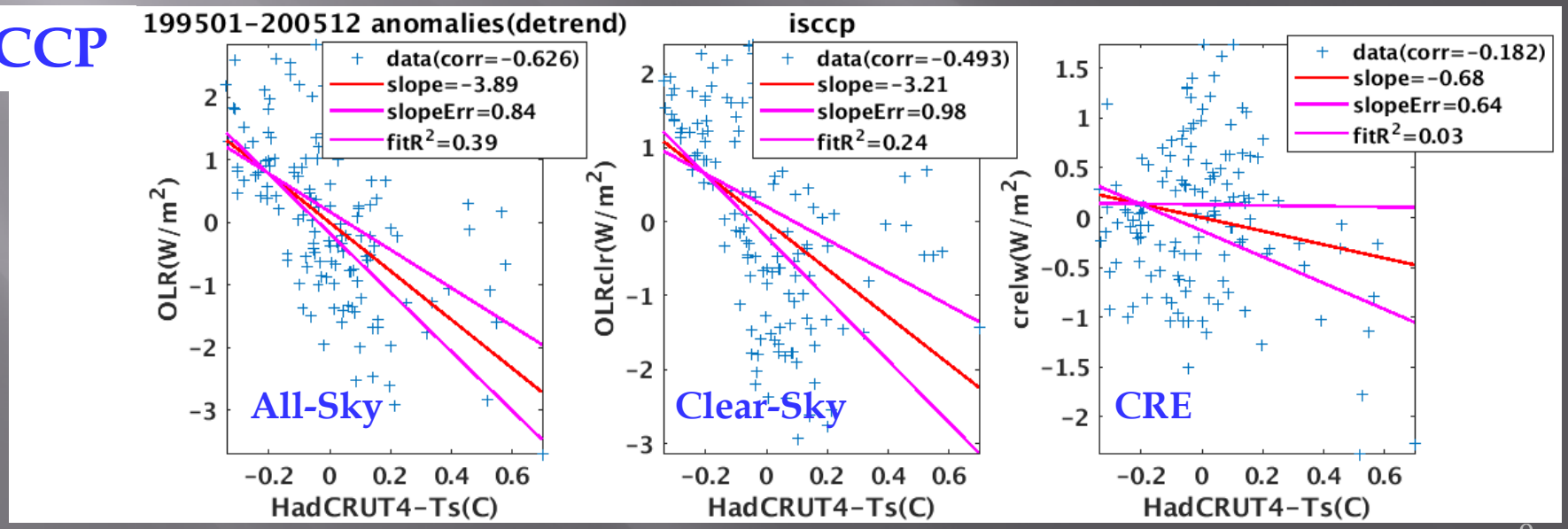


Negative Longwave Feedbacks

AIRS



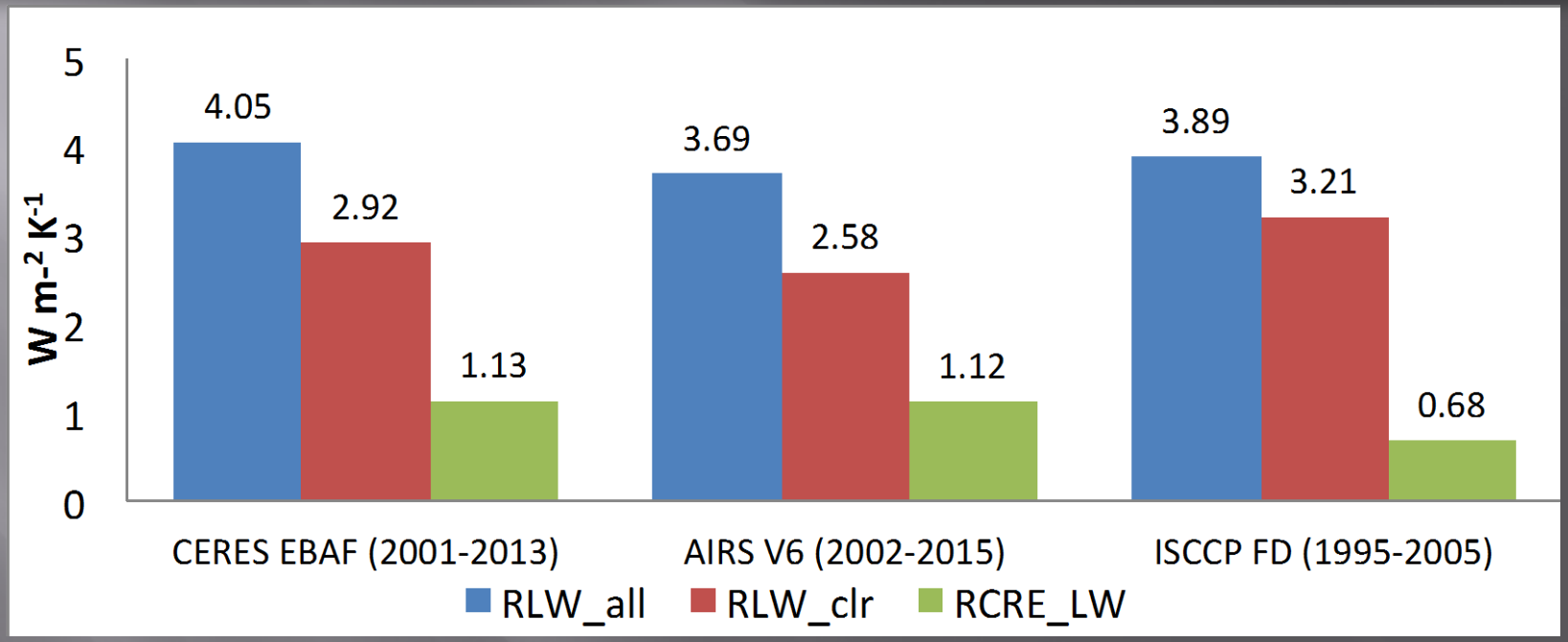
ISCCP



Discrepancy in Observations

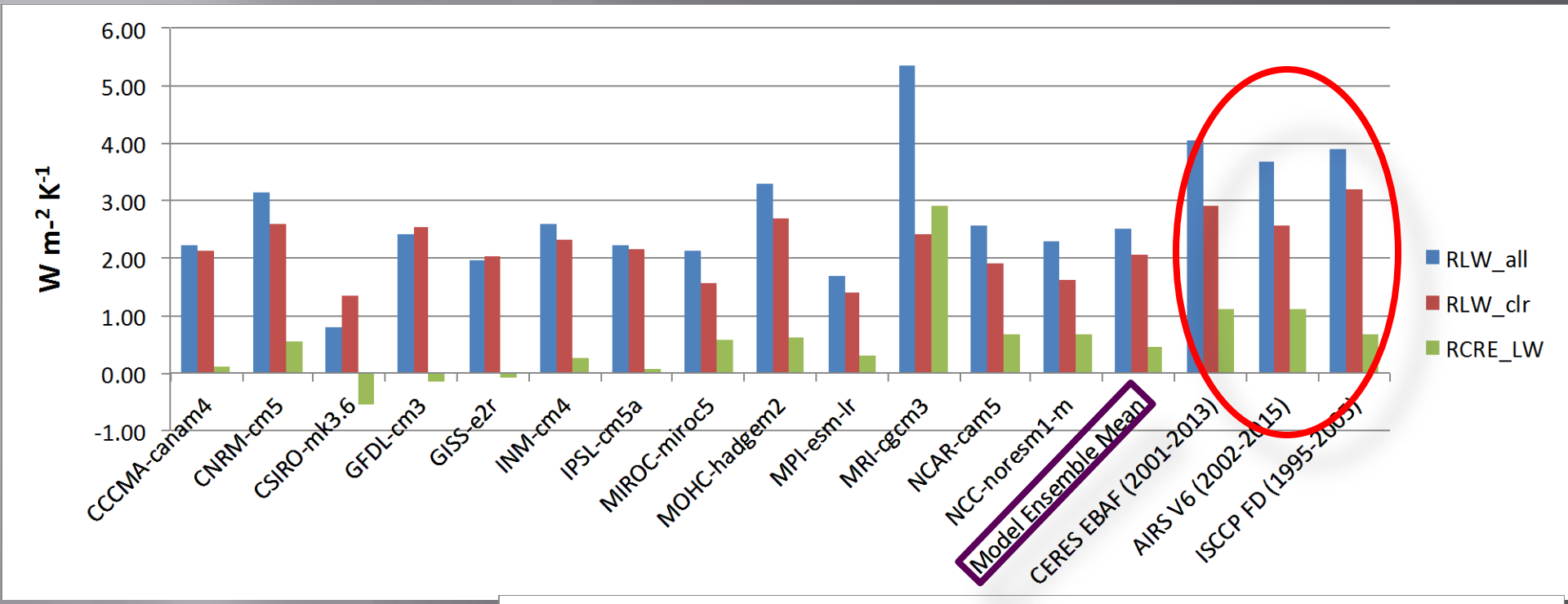
Regression slopes of monthly outgoing longwave radiation (OLR) and CRE against surface temperature (20°S-20°N) in W m^{-2} K^{-1}

unit: W m^{-2} K^{-1}	R_{LW_all}	R_{LW_clr}	R_{CRE-LW}
CERES EBAF (2001-2013)	4.05	2.92	1.13
AIRS V6 (2002-2015)	3.69	2.58	1.12
ISCCP FD (1995-2005)	3.89	3.21	0.68

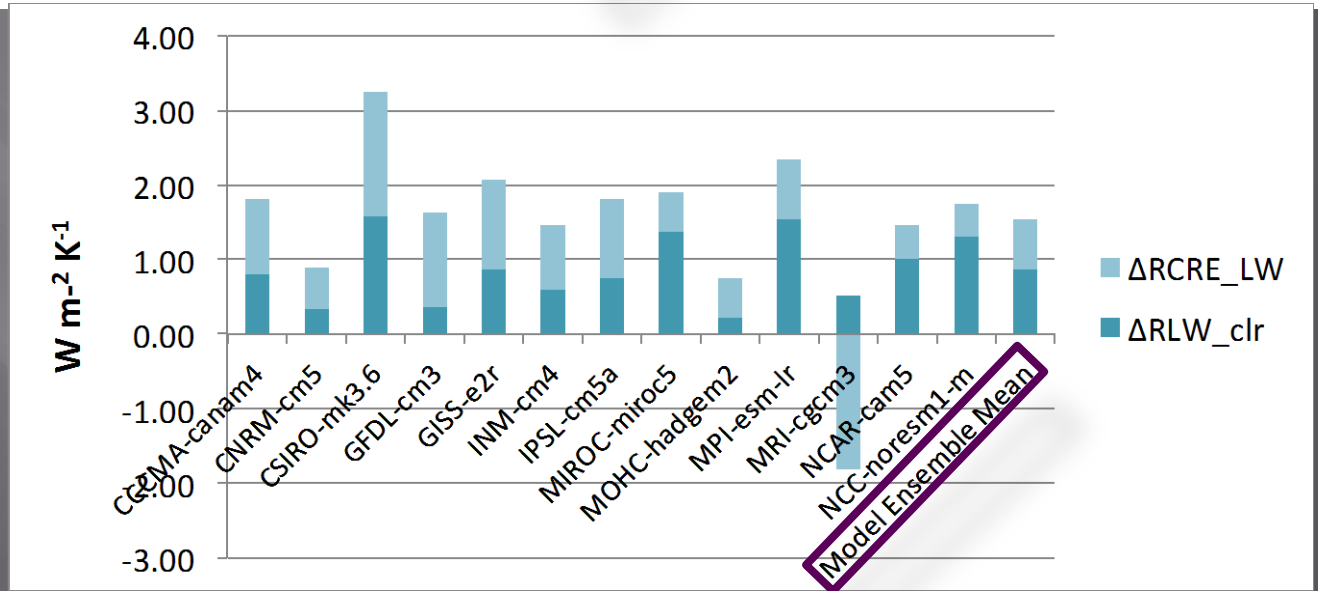


$$R_{LW_all} = R_{LW_clr} + R_{CRE_LW}$$

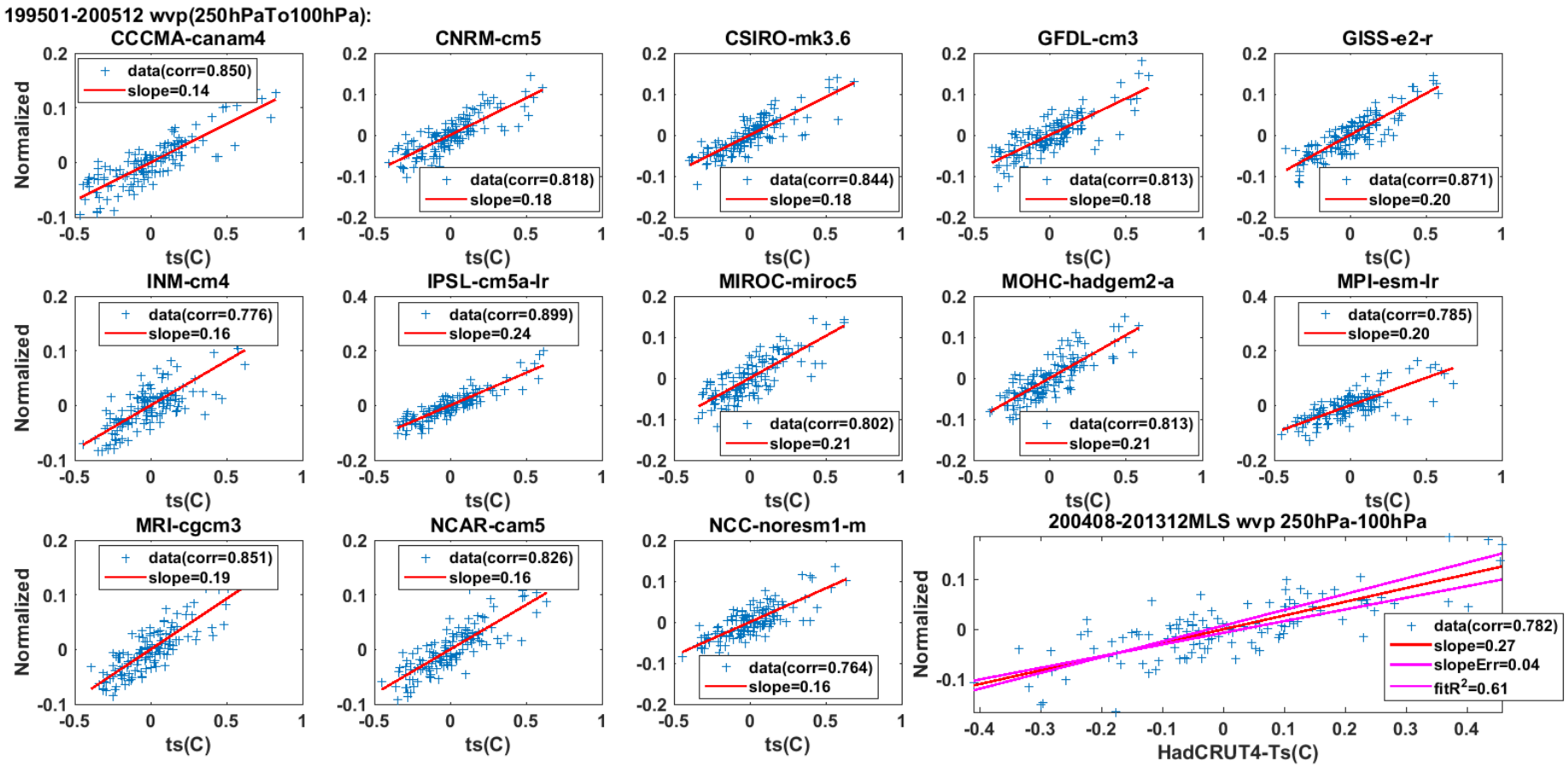
Missing Negative Feedback in Models



Differences between obs. and models



UT Water Vapor Sensitivity to T_s



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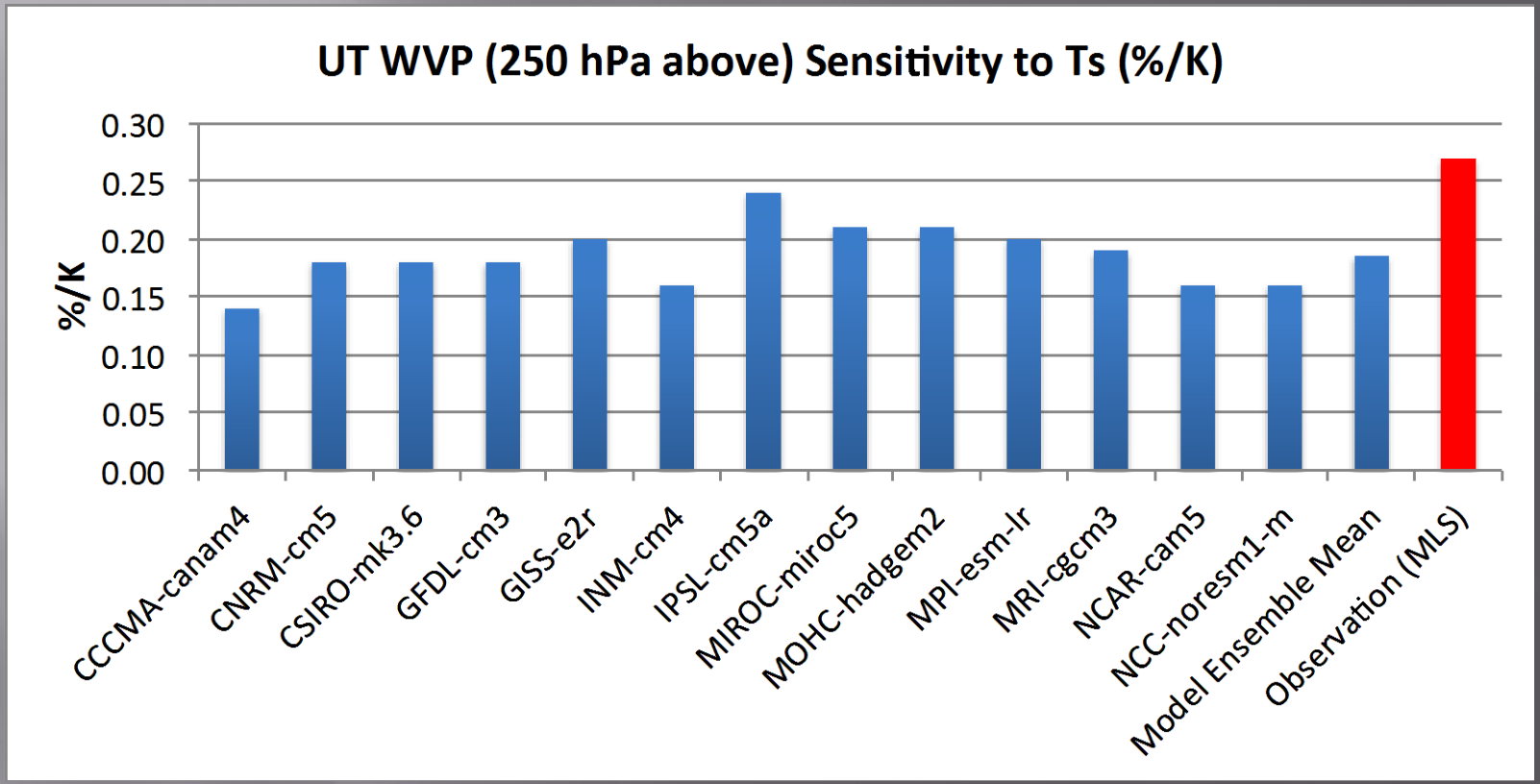
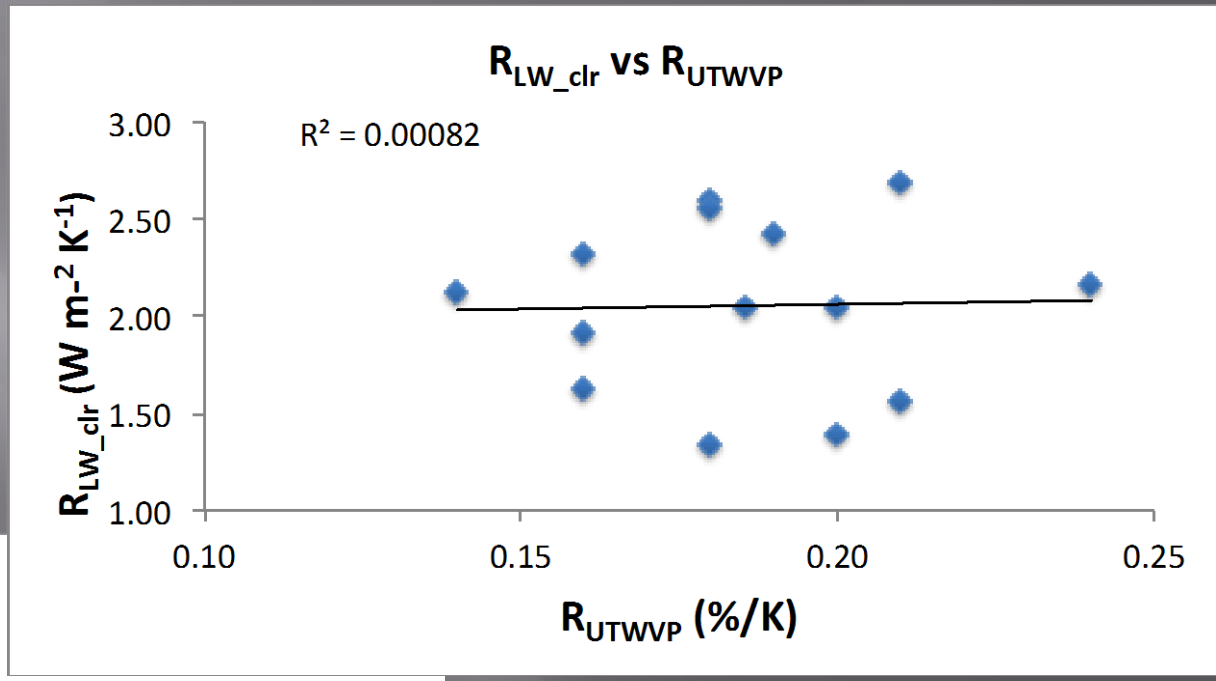
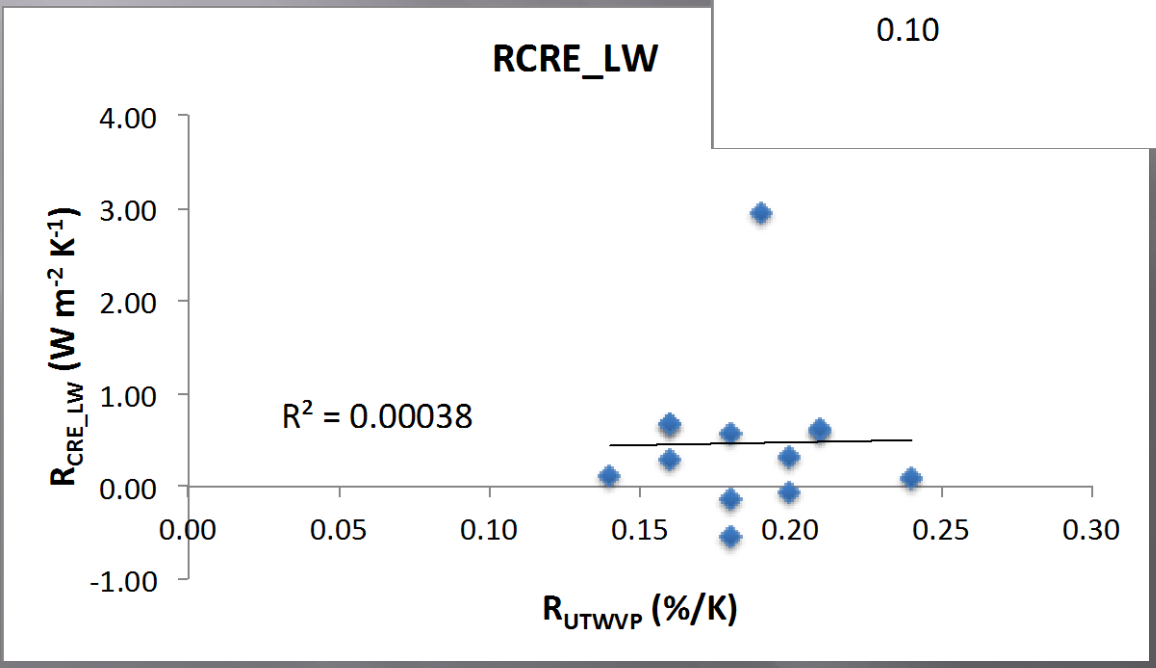
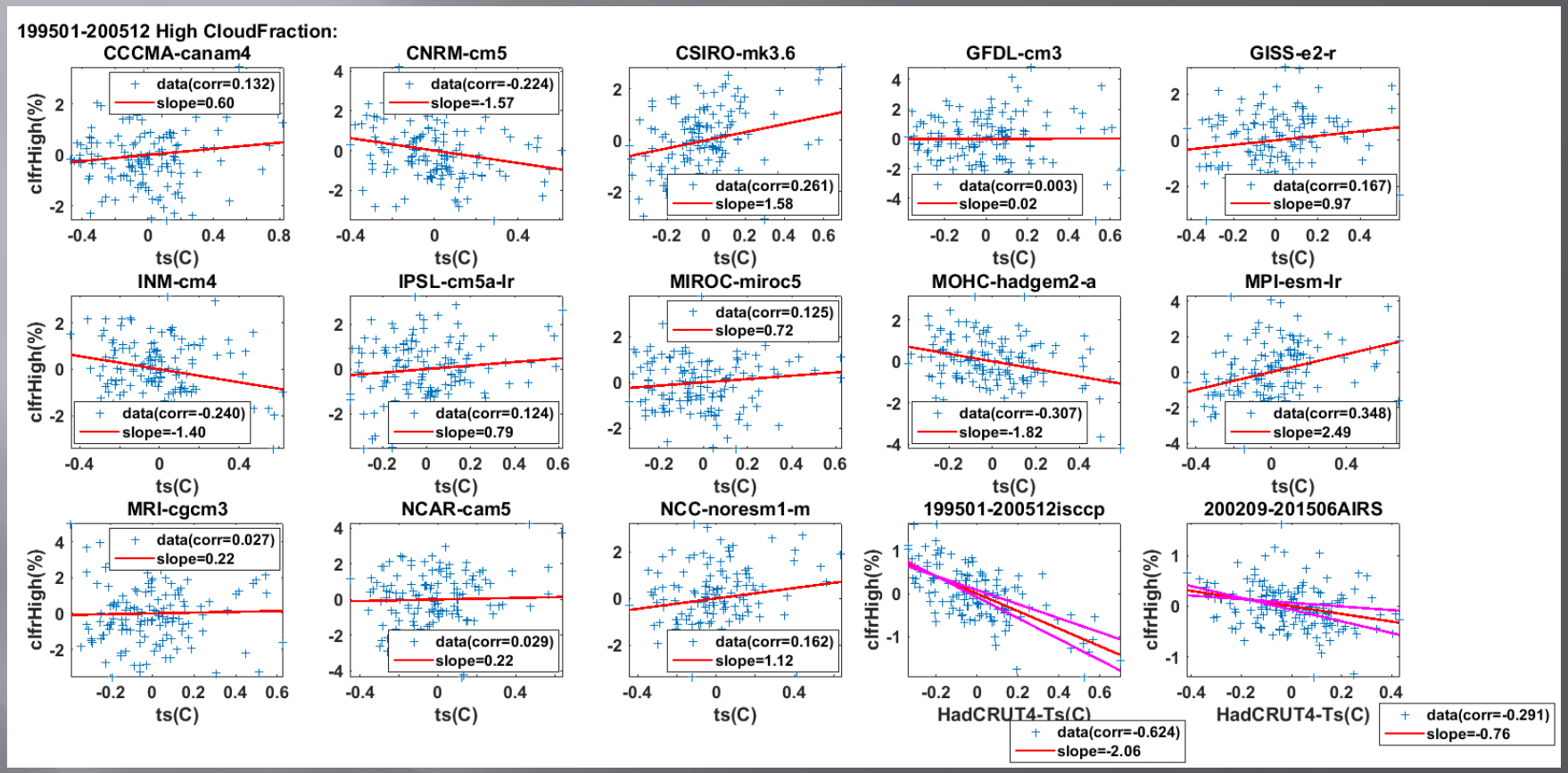


Contribution of UT Water Vapor



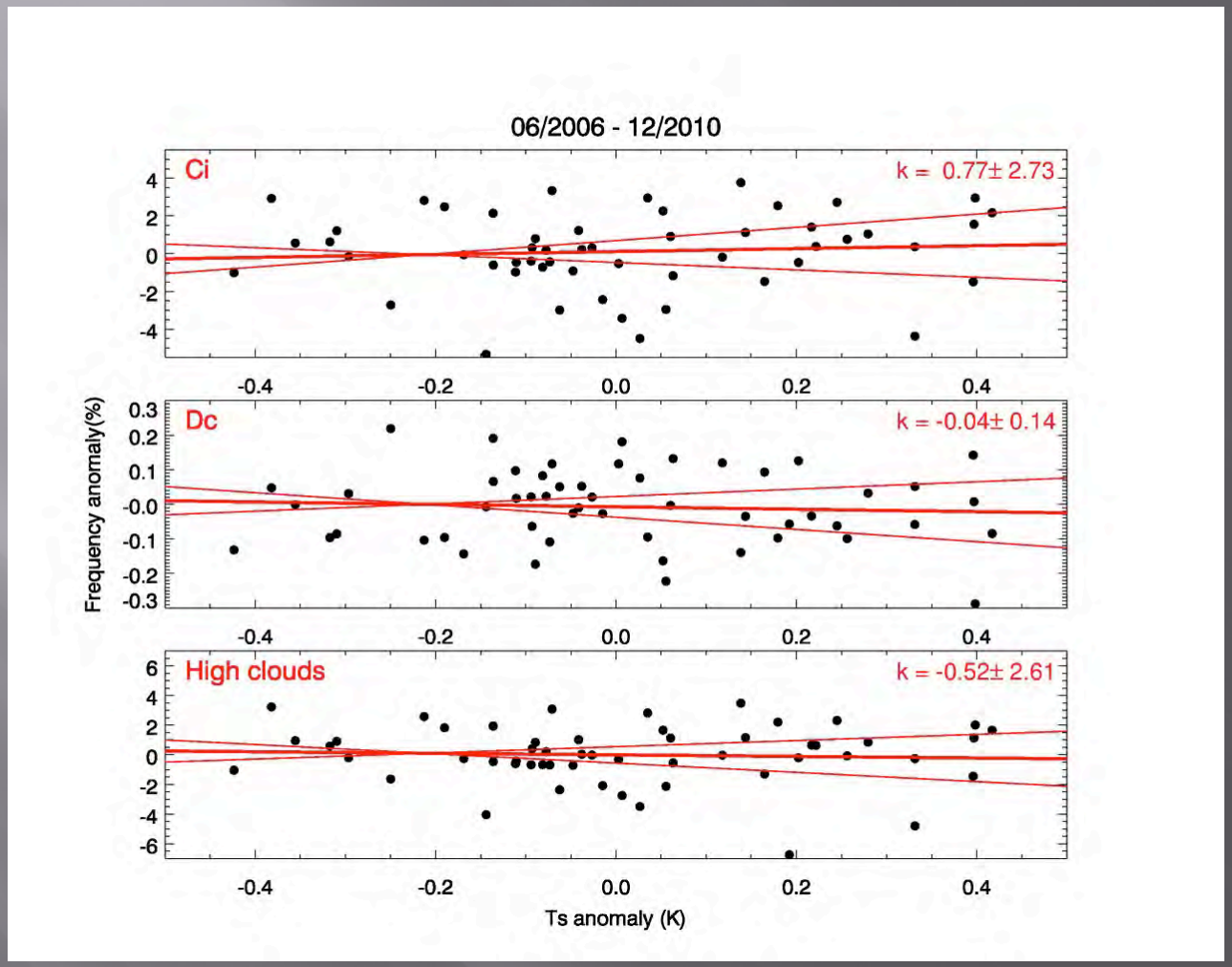


UT Cloud Fraction Sensitivity to T_s

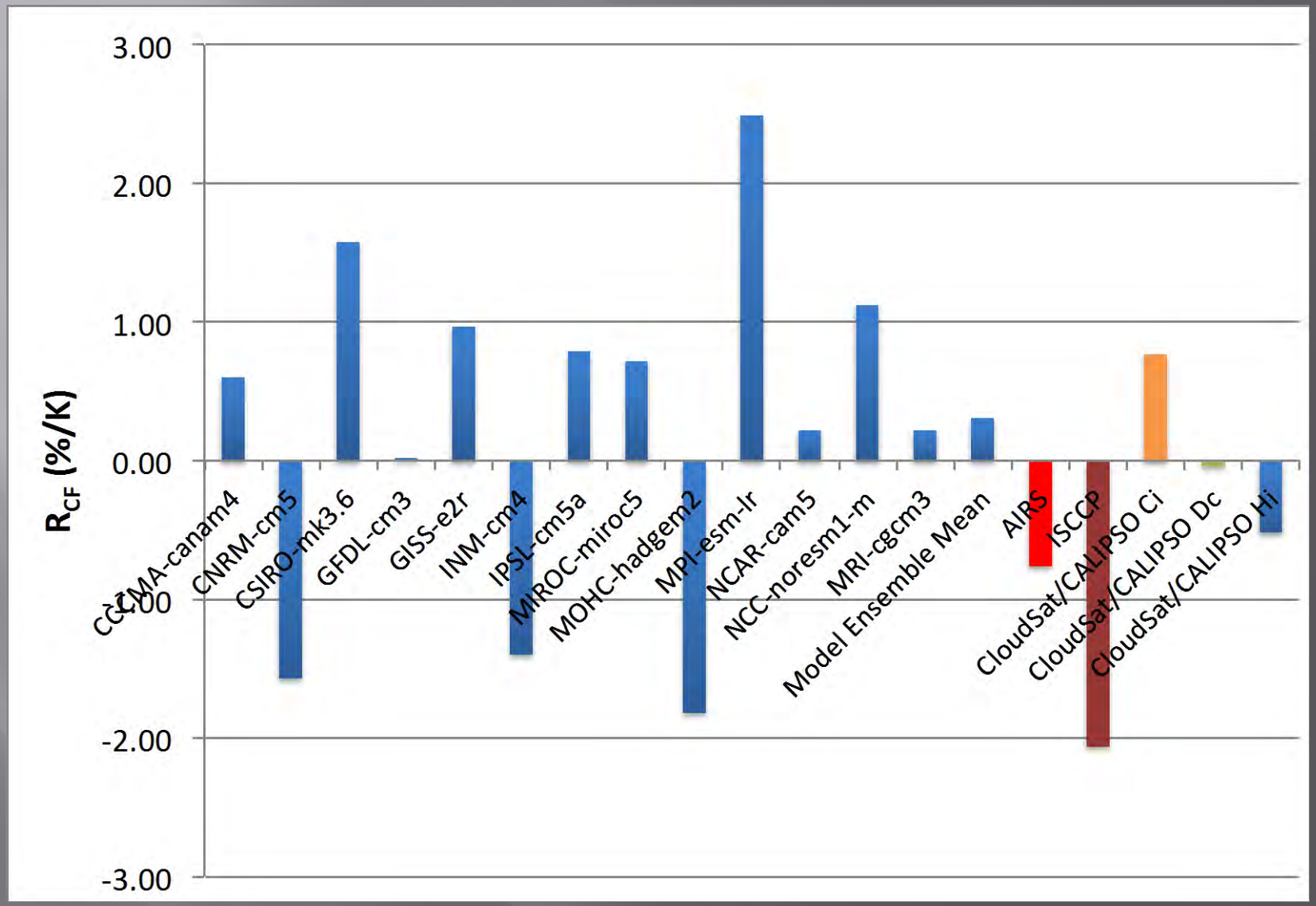


Large Spread in Observational Data

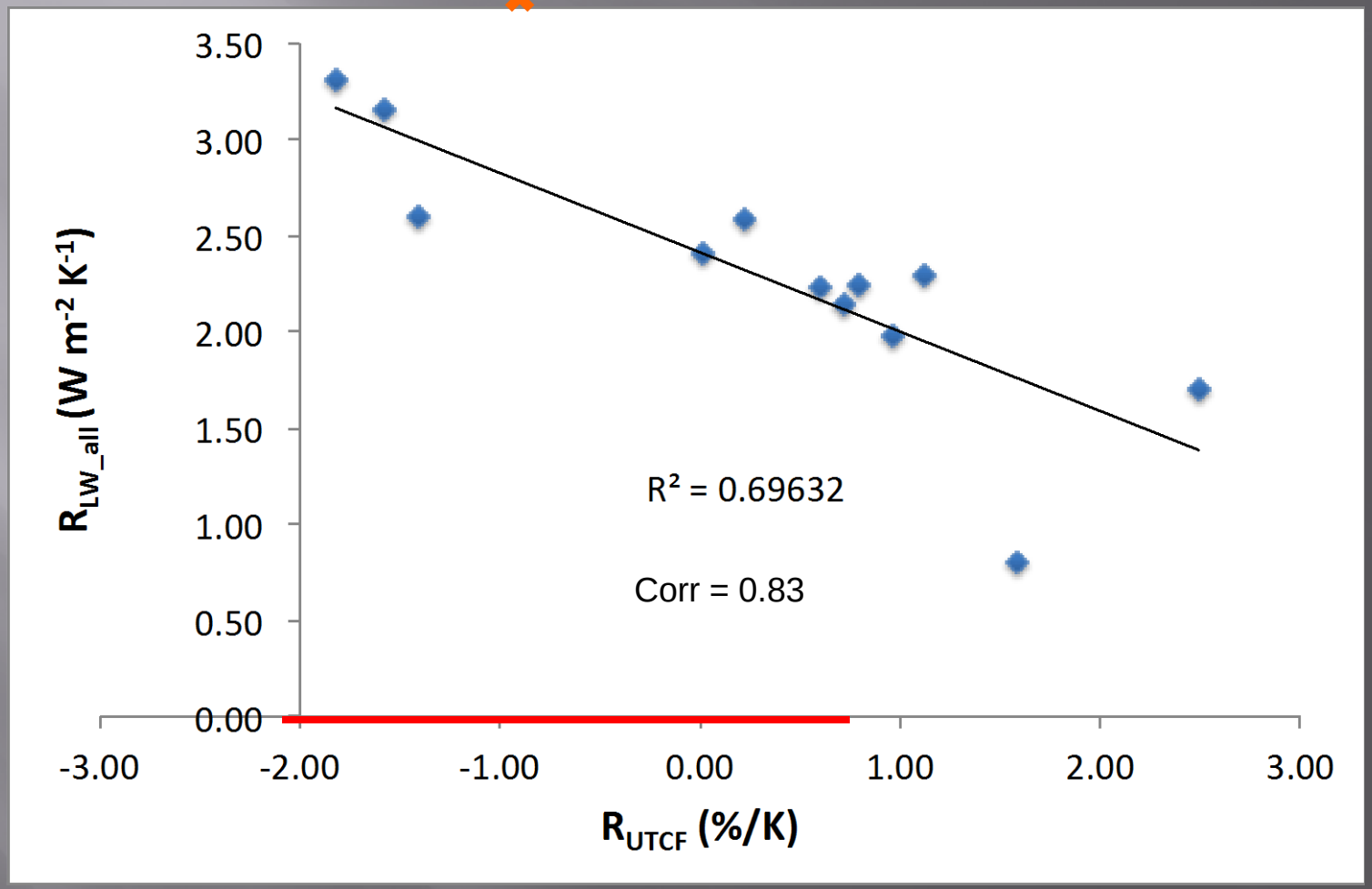
CloudSat/CALIPSO June 2006 to December 2010



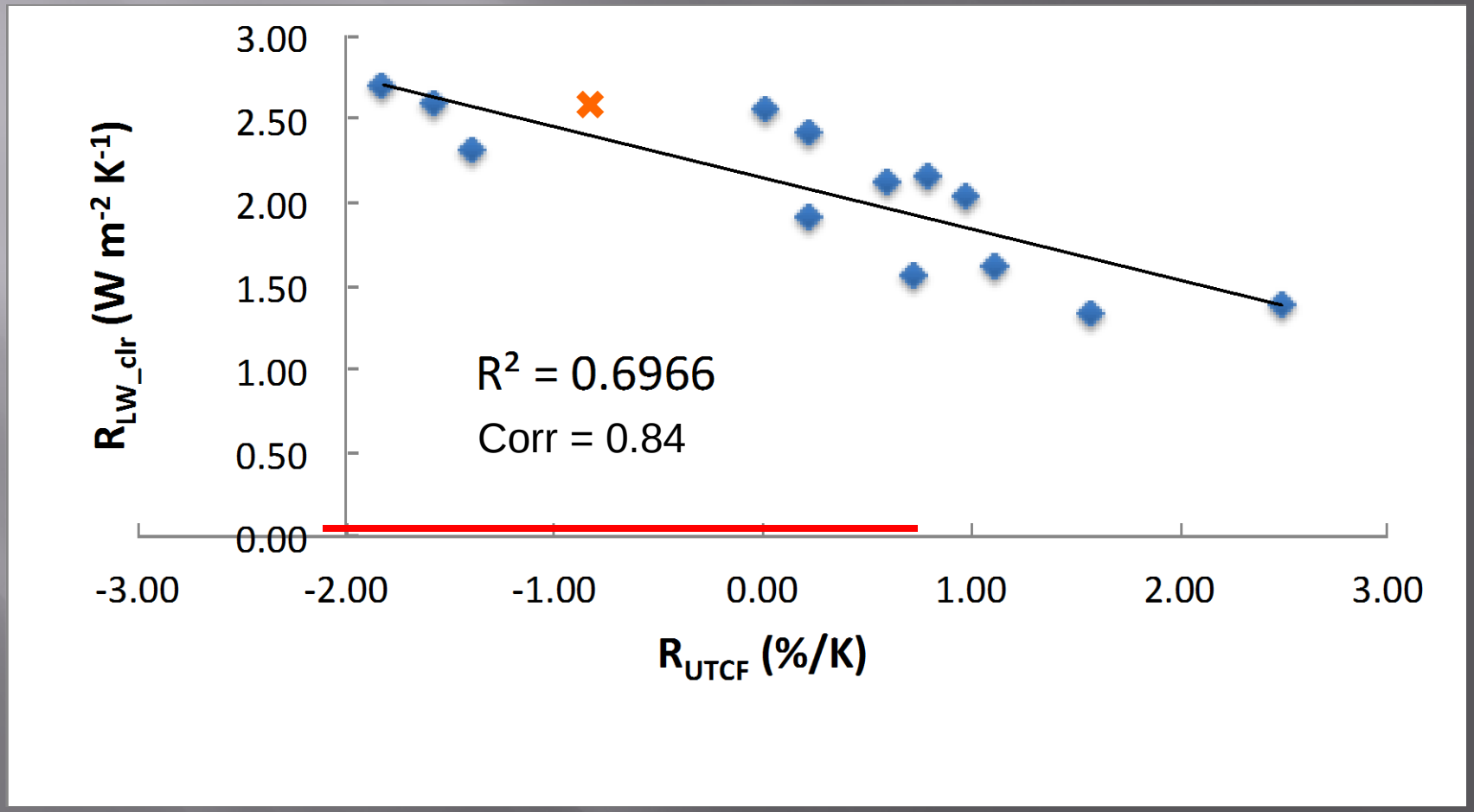
UT Cloud Fraction Sensitivity to T_s



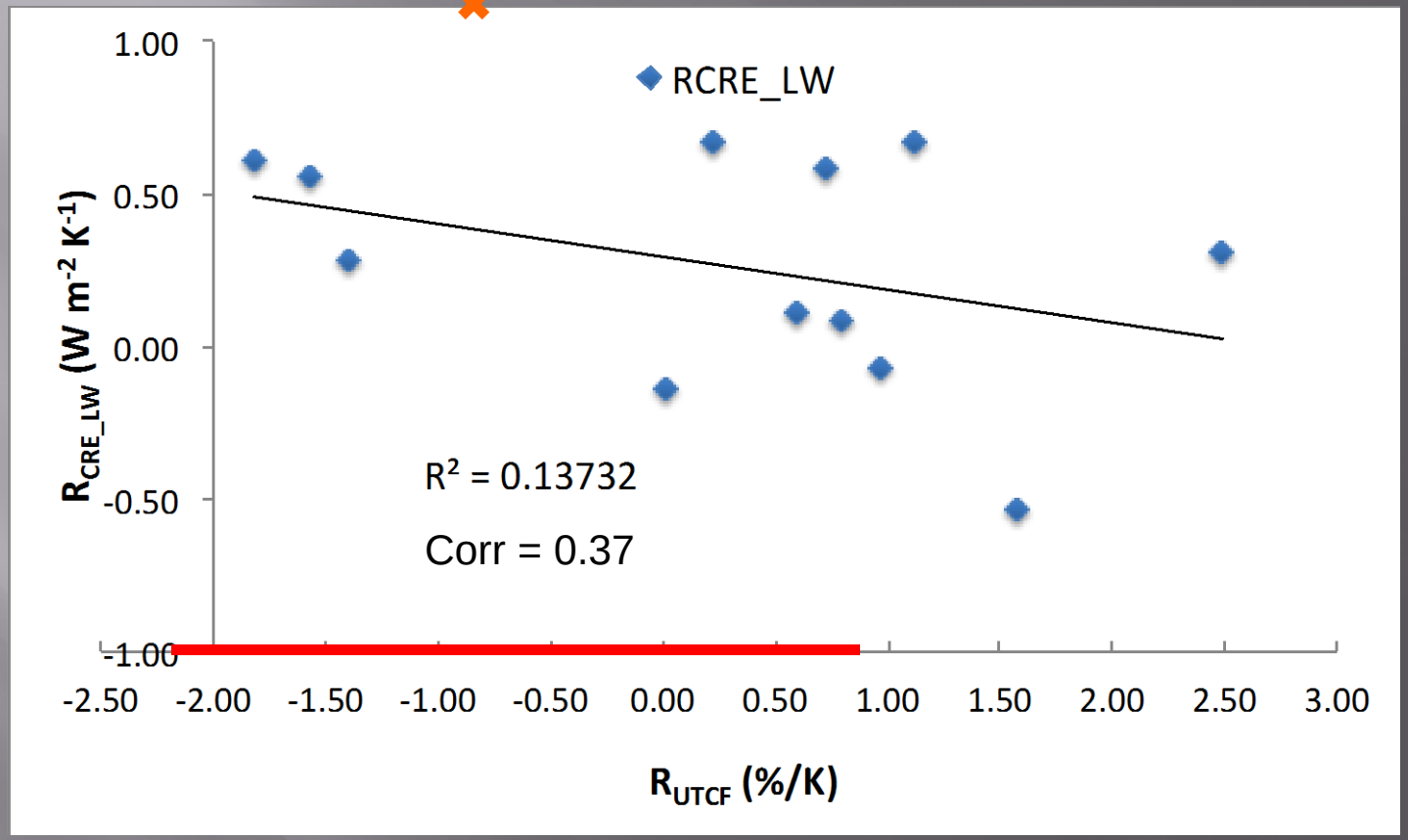
Contribution of the Iris Effect to the All-sky OLR



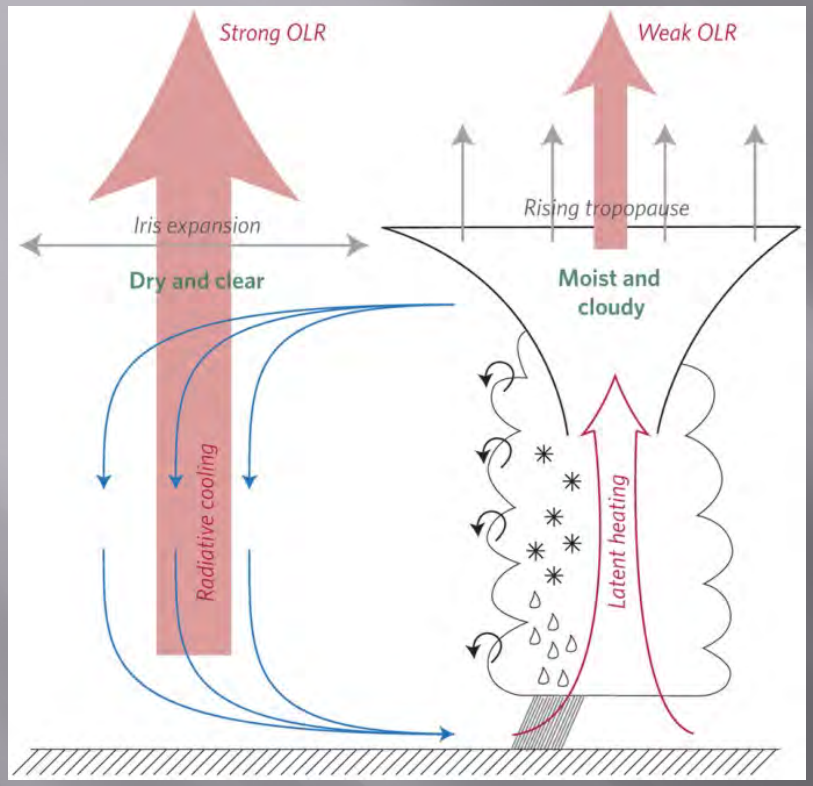
Contribution of the Iris Effect to Clear-sky OLR



Contribution of the Iris Effect



Coupling Between High Clouds and Clear-Sky Radiation



Mauritsen and Stevens (2015, *Nature. Geo.*)

$$OLR_{all} = OLR_{clr} + CRE$$

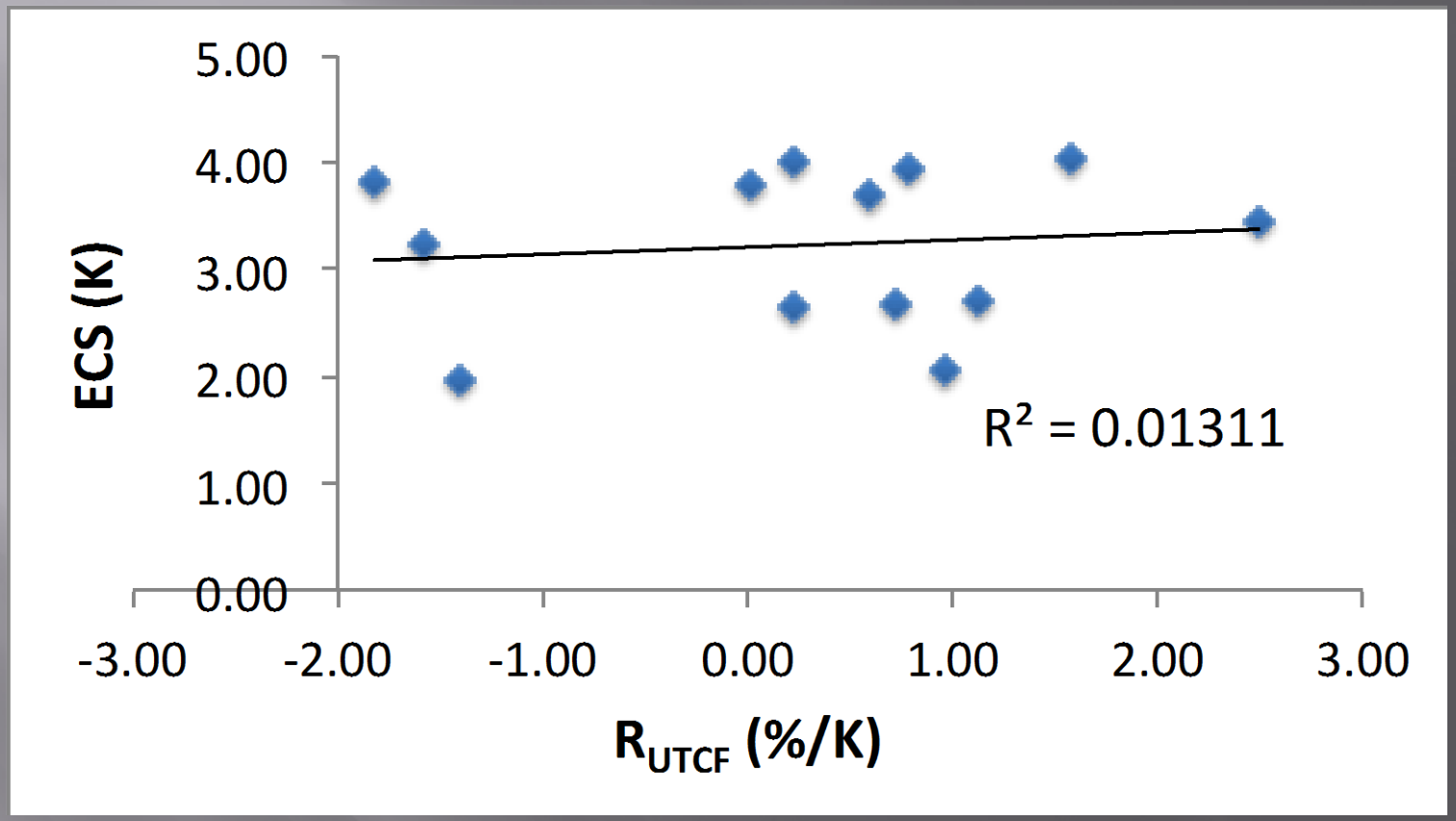
$$\frac{dOLR_{all}}{dT_s} = \frac{dOLR_{clr}}{dT_s} + \frac{dCRE}{dT_s}$$

~4 ~3 ~1 W m^{-2} K^{-1}

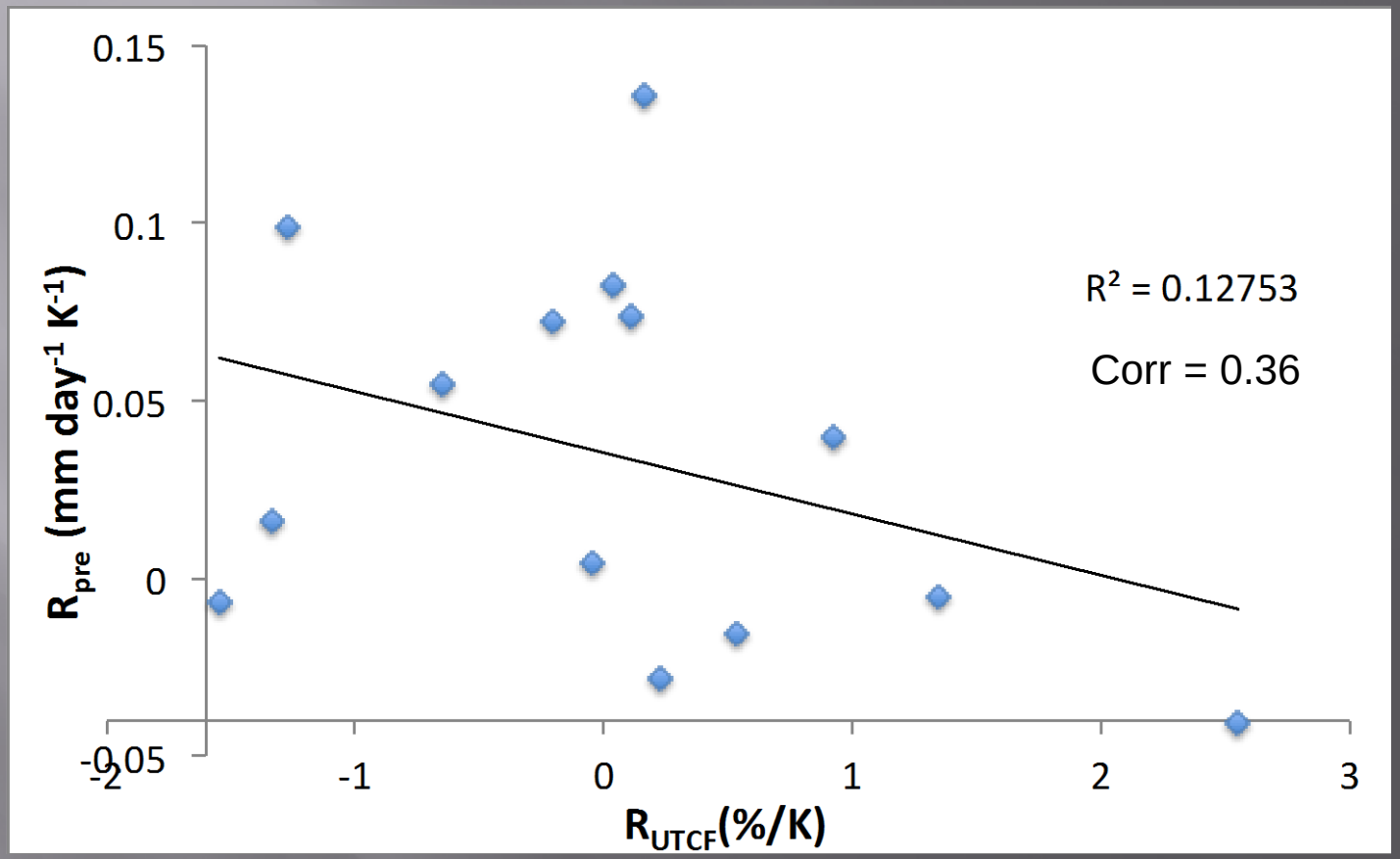
$$OLR_{clr} = A(OLR^m) + (1 - A)OLR^d$$

$$\frac{dOLR_{clr}}{dT_s} = \boxed{\frac{dA}{dT_s}\left(OLR^m - OLR^d\right)} + A\frac{dOLR^m}{dT_s} + (1 - A)\frac{dOLR^d}{dT_s}$$

Iris Effect and Climate Sensitivity



Iris Effect and Hydrological Sensitivity



Summary

- Nearly all CMIP5 models underestimate the increasing OLR with increasing surface temperature.
- Clear-sky OLR and longwave cloud radiative effects contribute comparably to the total missing negative feedback.
- Iris effects explains about 70% of the inter-model spread in the clear-sky longwave radiative feedback.
- The missing negative feedback does not explain the inter-model spread in climate sensitivity, but it has a stronger correlation with hydrological sensitivity in the models.