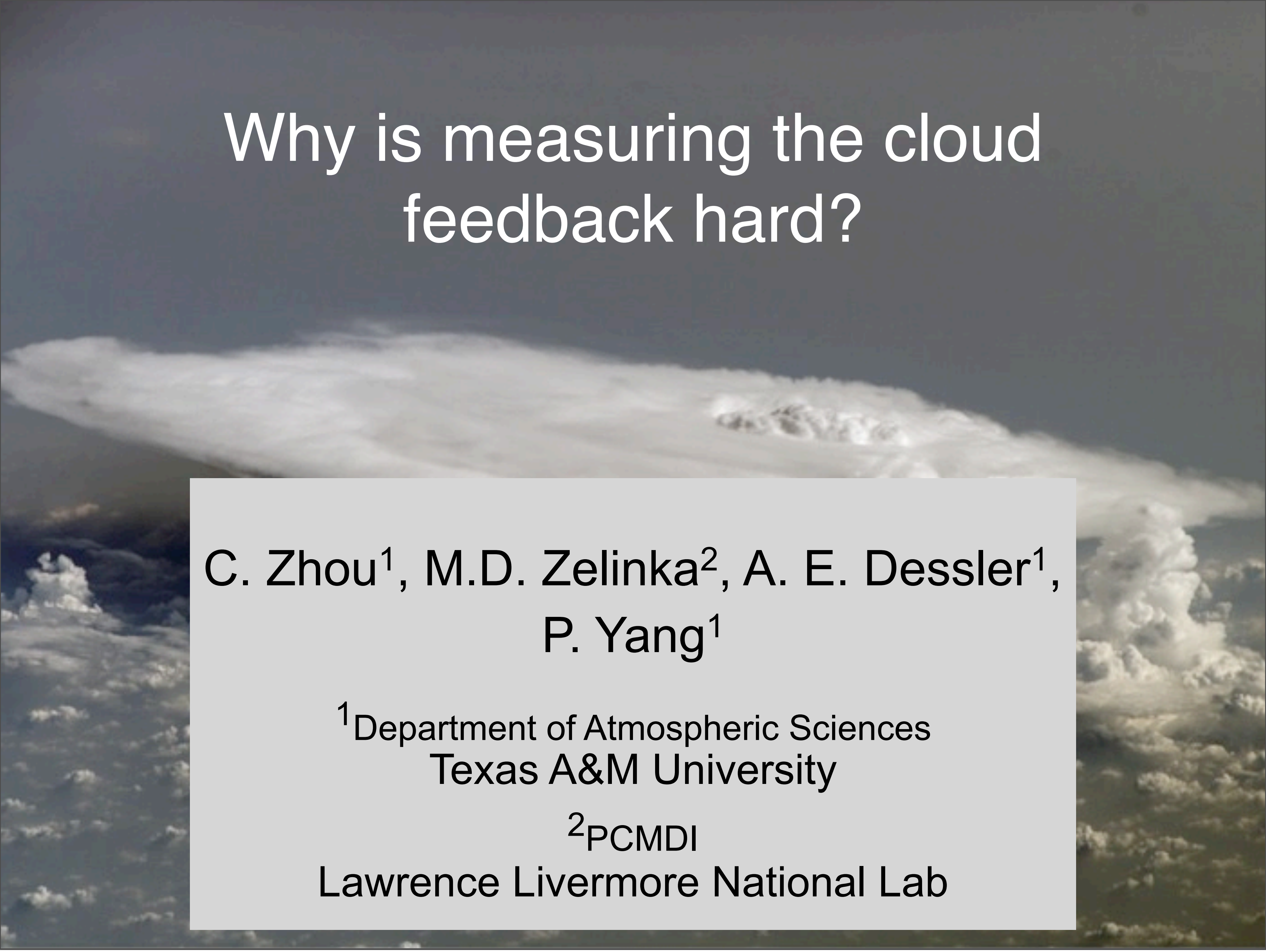
Why is measuring the cloud feedback hard?



Why is measuring the cloud feedback hard?

C. Zhou[1], M.D. Zelinka[2], A. E. Dessler[1], P. Yang[1]

[1]Department of Atmospheric Sciences
Texas A&M University

[2]PCMDI
Lawrence Livermore National Lab

$$\Delta R_{\text{all-sky}} = \Delta R_T + \Delta R_q + \Delta R_{\text{albedo}} + \Delta R_{\text{cloud}} + \Delta F$$

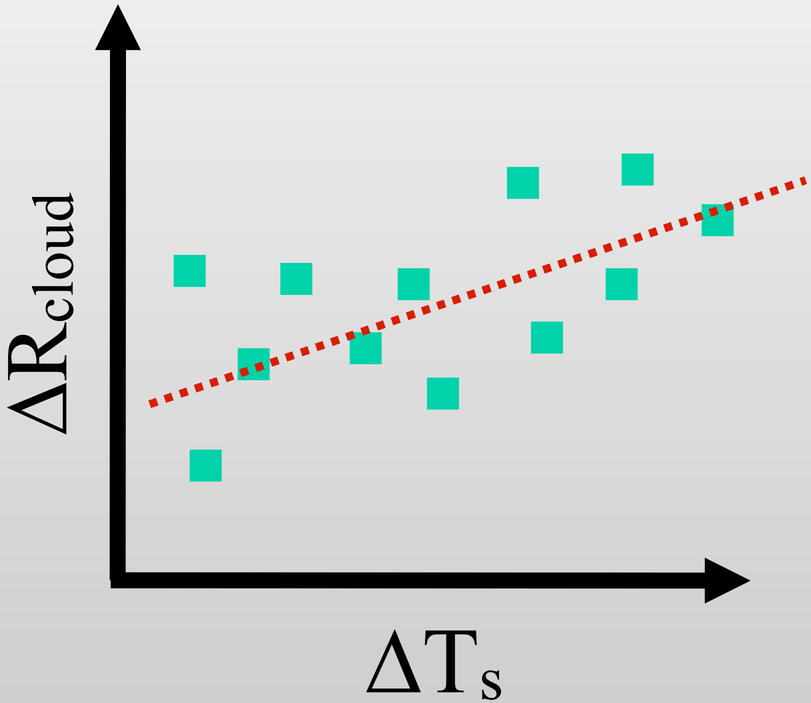
$$\Delta R_{\text{all-sky}} = \Delta R_T + \Delta R_q + \Delta R_{\text{albedo}} + \Delta R_{\text{cloud}} + \Delta F$$

"CERES method":

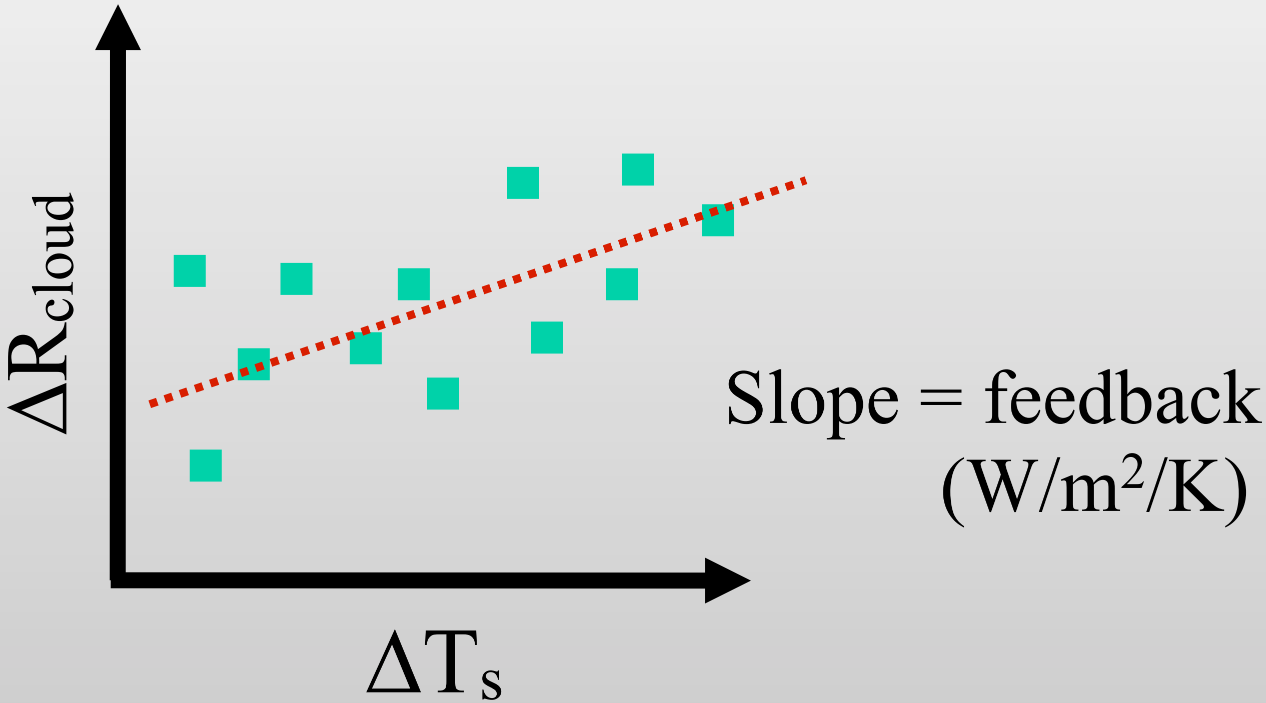
$$\Delta R_{\text{cloud}} = \Delta R_{\text{all-sky}} - \Delta R_T + \Delta R_q + \Delta R_{\text{albedo}} + \Delta F$$

Dessler, 2010, 2013

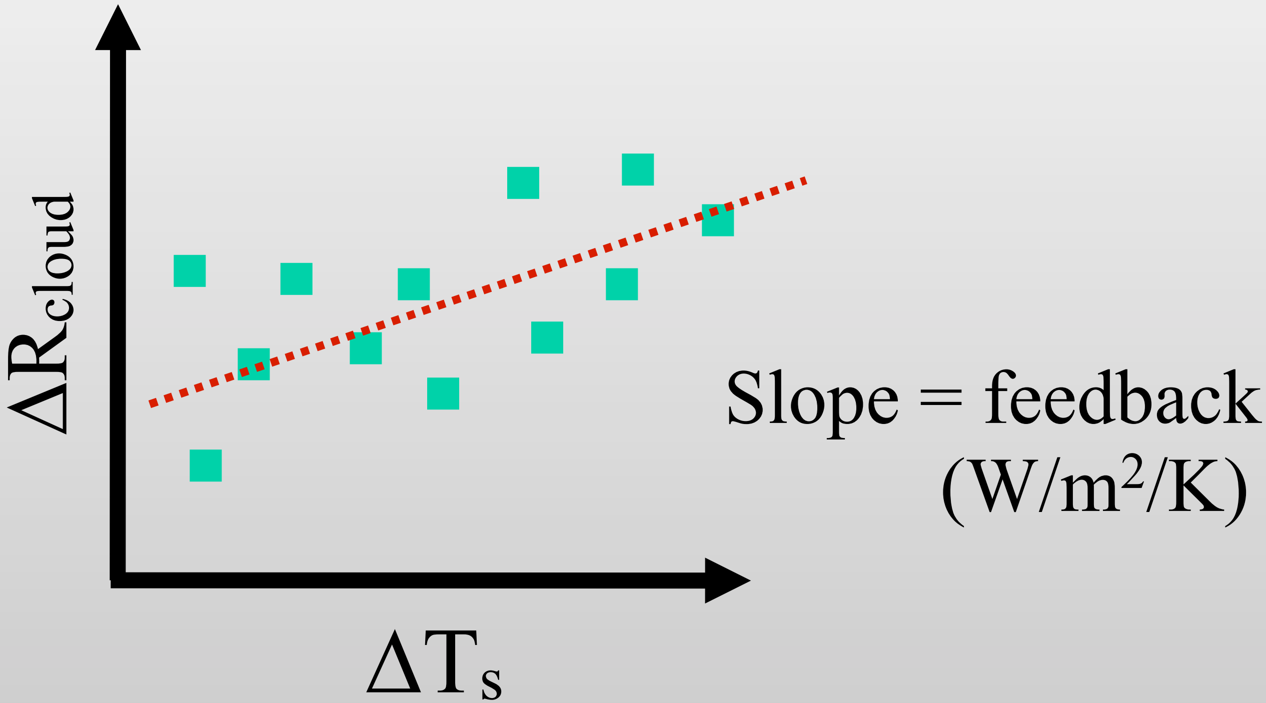
Regress ΔR_{cloud} vs. ΔT_s



Regress ΔR_{cloud} vs. ΔT_s



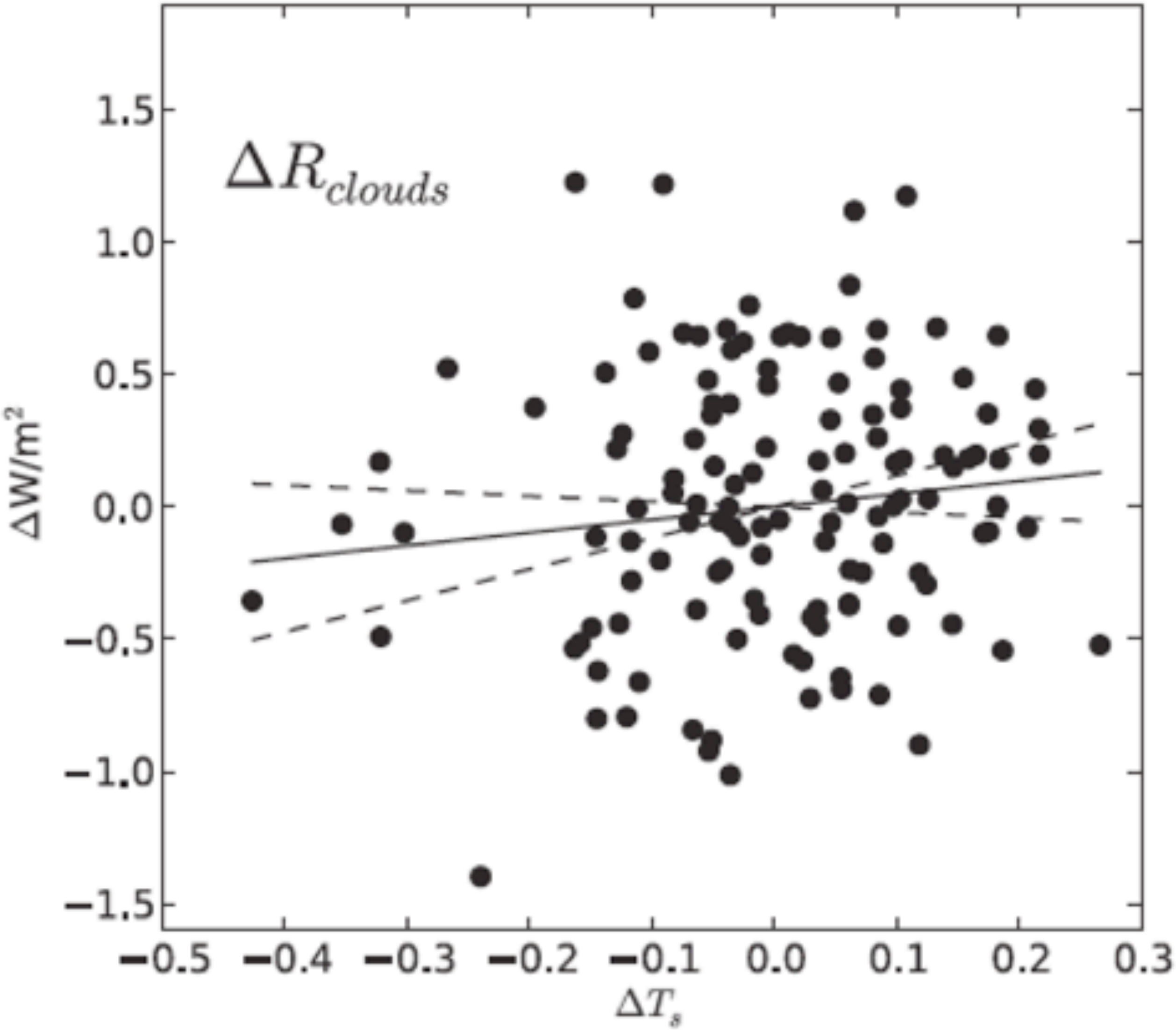
Regress ΔR_{cloud} vs. ΔT_s



ΔT_s is from ENSO

Dessler 2013 J. Climate

adjusted CERES data



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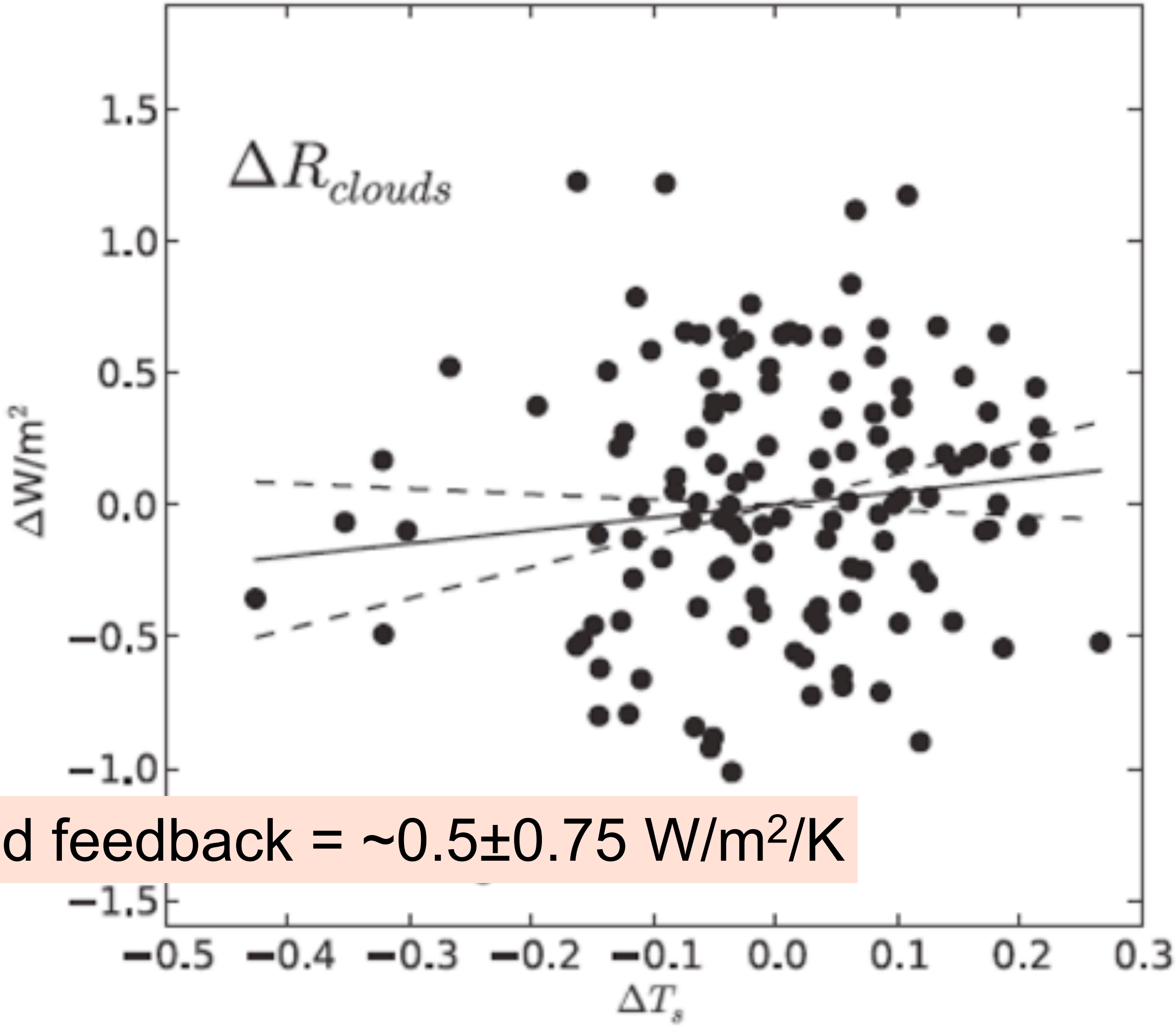
Dessler 2013 J. Climate

adjusted CERES data

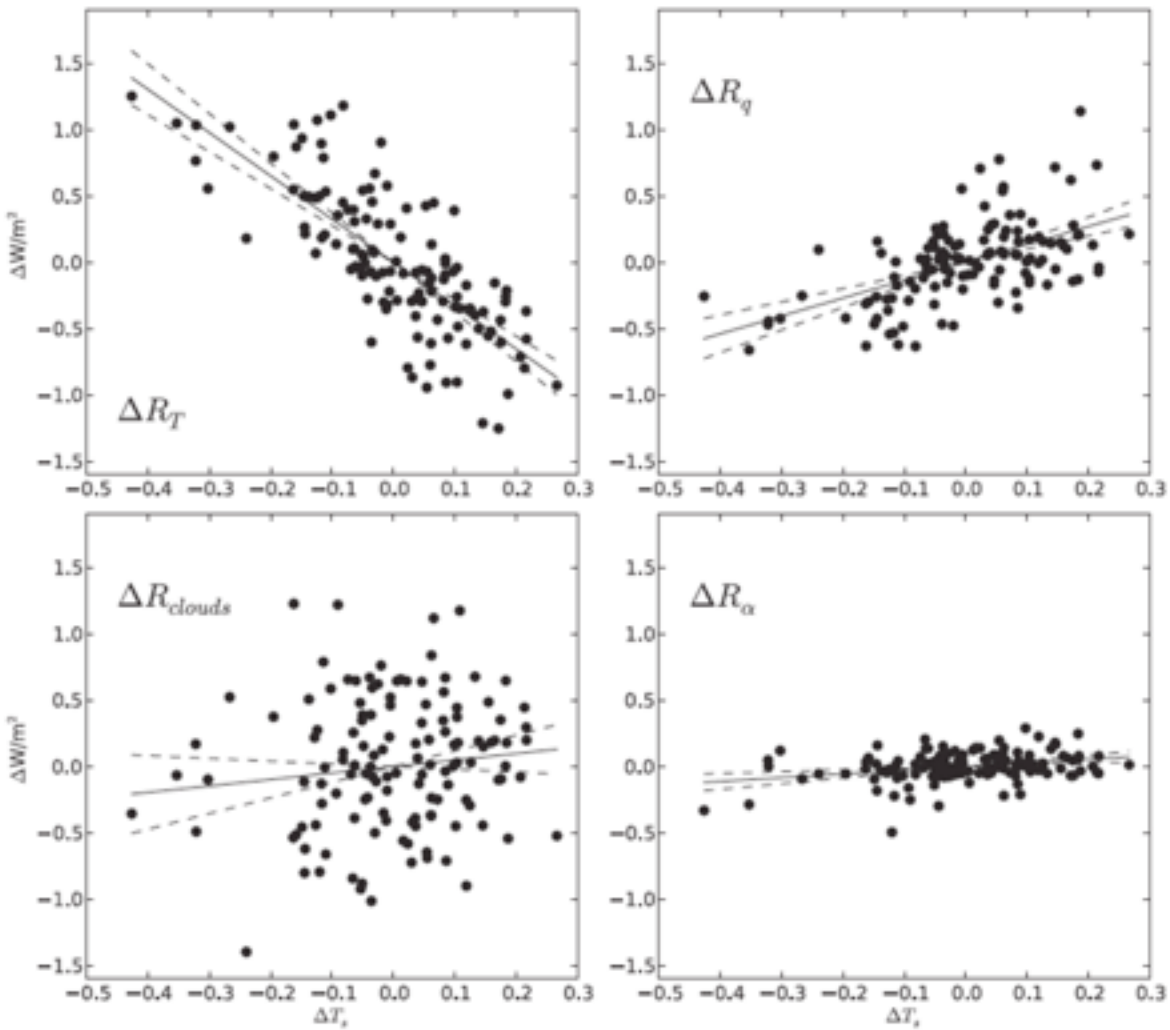


cloud feedback = ~0.5±0.75 W/m^2/K

$$\Delta R_{all\text{-}sky} = \Delta R_T + \Delta R_q + \Delta R_{albedo} + \Delta R_{cloud} + \Delta F$$

2000-2011

$\Delta R_{all\text{-}sky} = \Delta R_T + \Delta R_q + \Delta R_{albedo} + \Delta R_{cloud} + \Delta F$



2000-2011

Dessler, J. Climate, 2013

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Why is there scatter?

- Bad data
- Clouds are not controlled by T_s
- The effect of clouds is a net difference of two large, canceling terms

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If what controls clouds correlates with Ts, then you'll see a correlation
If not, then the cloud feedback is zero

Why is there scatter?

- Bad CERES data
- Clouds are not controlled by T_s
- The effect of clouds is a net difference of two large, canceling terms

$$\Delta R_{\text{all-sky}} = \Delta R_T + \Delta R_q + \Delta R_{\text{albedo}} + \Delta R_{\text{cloud}} + \Delta F$$

"CERES method":

$$\Delta R_{\text{cloud}} = \Delta R_{\text{all-sky}} - \Delta R_T + \Delta R_q + \Delta R_{\text{albedo}} + \Delta F$$

Dessler, 2010, 2012

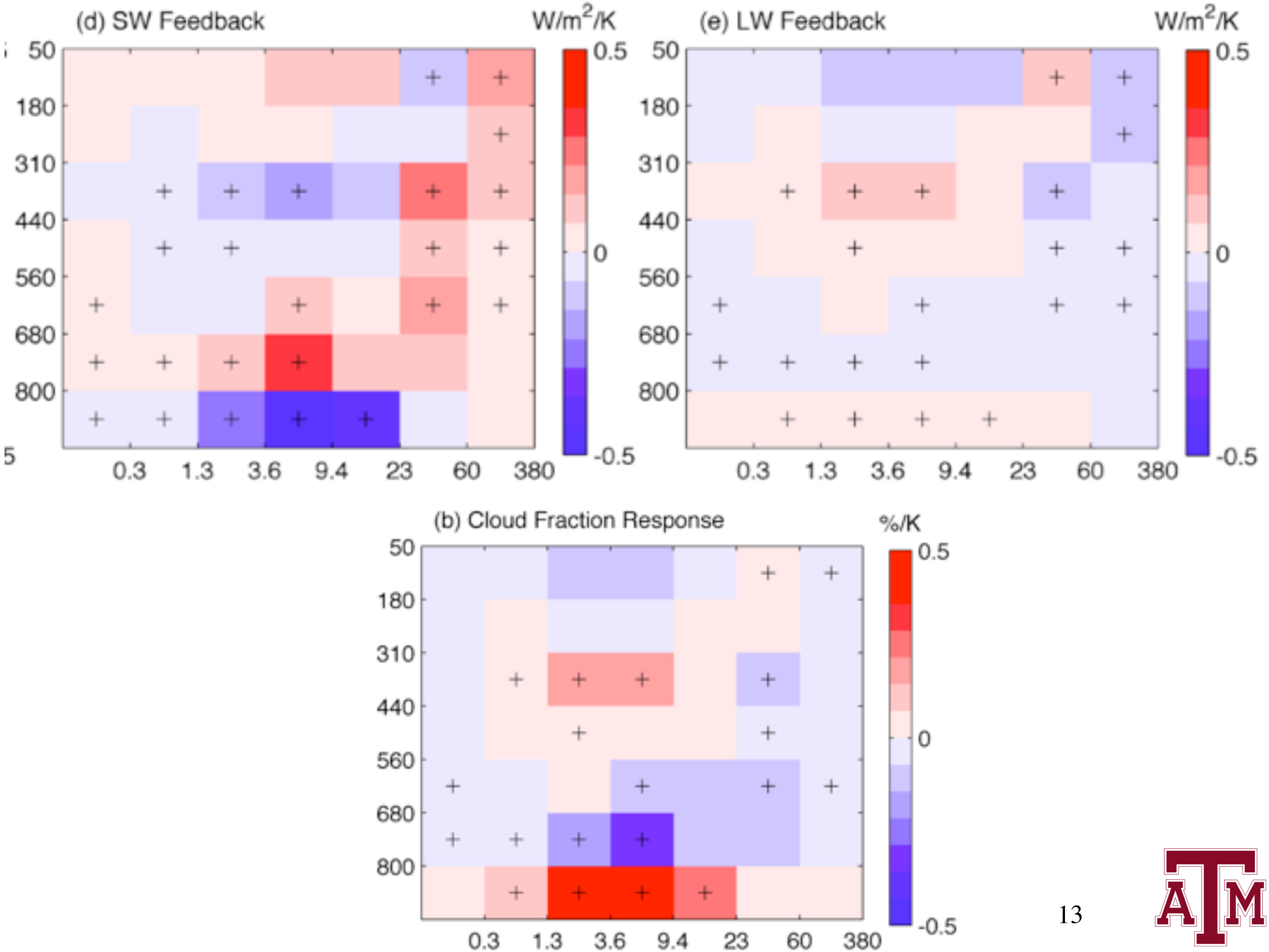
$$\Delta R_{all\text{-}sky} = \Delta R_T + \Delta R_q + \Delta R_{albedo} + \Delta R_{cloud} + \Delta F$$

"MODIS method":
direct observations of clouds + radiative transfer calculations

"CERES method":
$\Delta R_{cloud} = \Delta R_{all\text{-}sky} - \Delta R_T + \Delta R_q + \Delta R_{albedo} + \Delta F$
Dessler, 2010, 2012

MODIS method

- MODIS cloud measurements
- Calculate the changes as T_s changes
- apply Zelinka radiative transfer calculations


(d) SW Feedback
W/m2/K
50
180
310
440
560
680
800
0.3
1.3
3.6
9.4
23
60
380
0.5
0
-0.5
(e) LW Feedback
W/m2/K
(b) Cloud Fraction Response
%/K

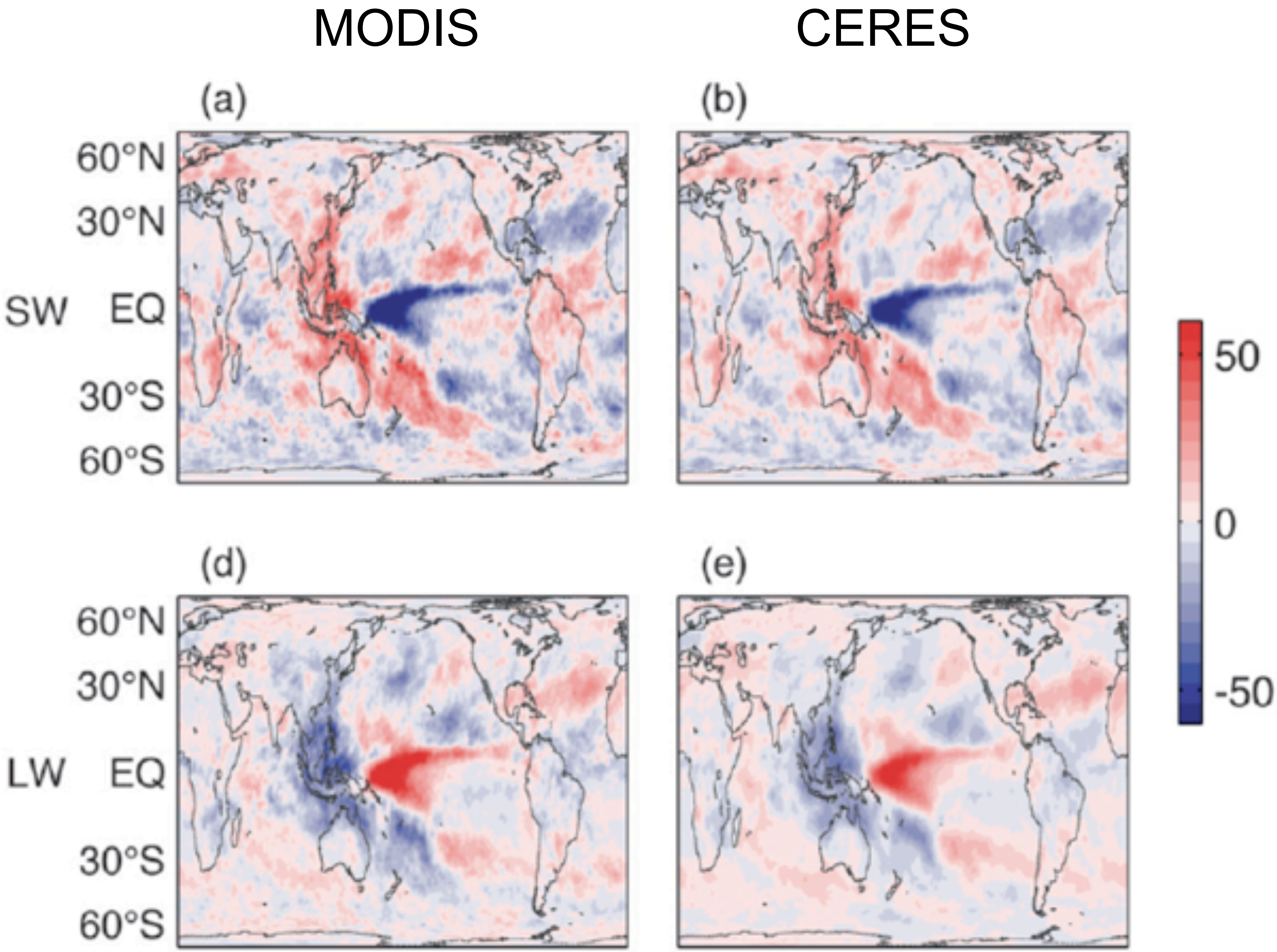


Fig. 4

Feedback(lat,lon)

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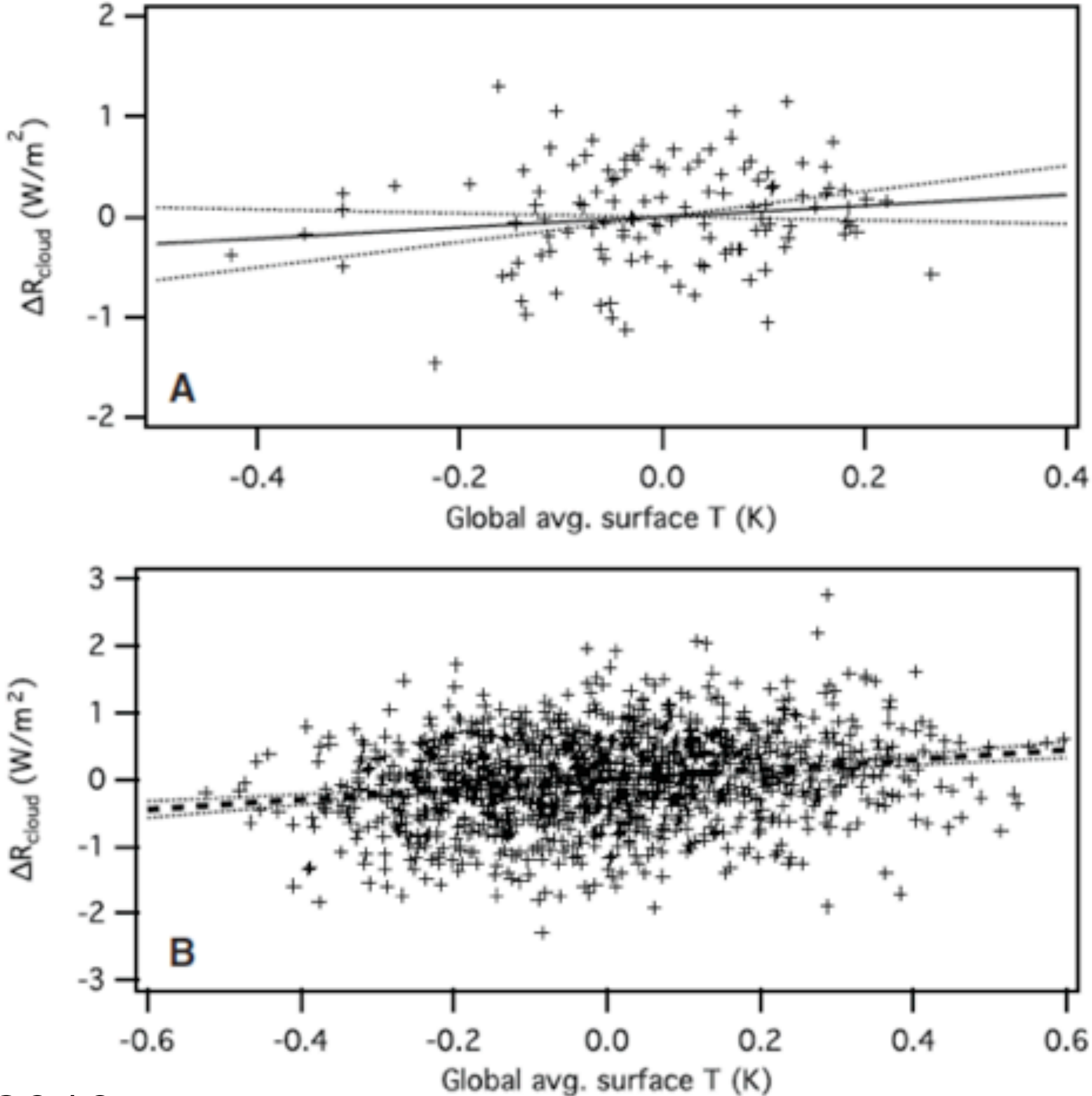
Fig. 2. (**A**) Scatter plot of monthly average values of ΔR_{cloud} versus ΔT_s using CERES and ECMWF interim data. (**B**) Scatter plot of monthly averages of the same quantities from 100 years of a control run of the ECHAM/MPI-OM model. In all plots, the solid line is a linear least-squares fit and the dotted lines are the 2σ confidence interval of the fit.



Dessler, 2010

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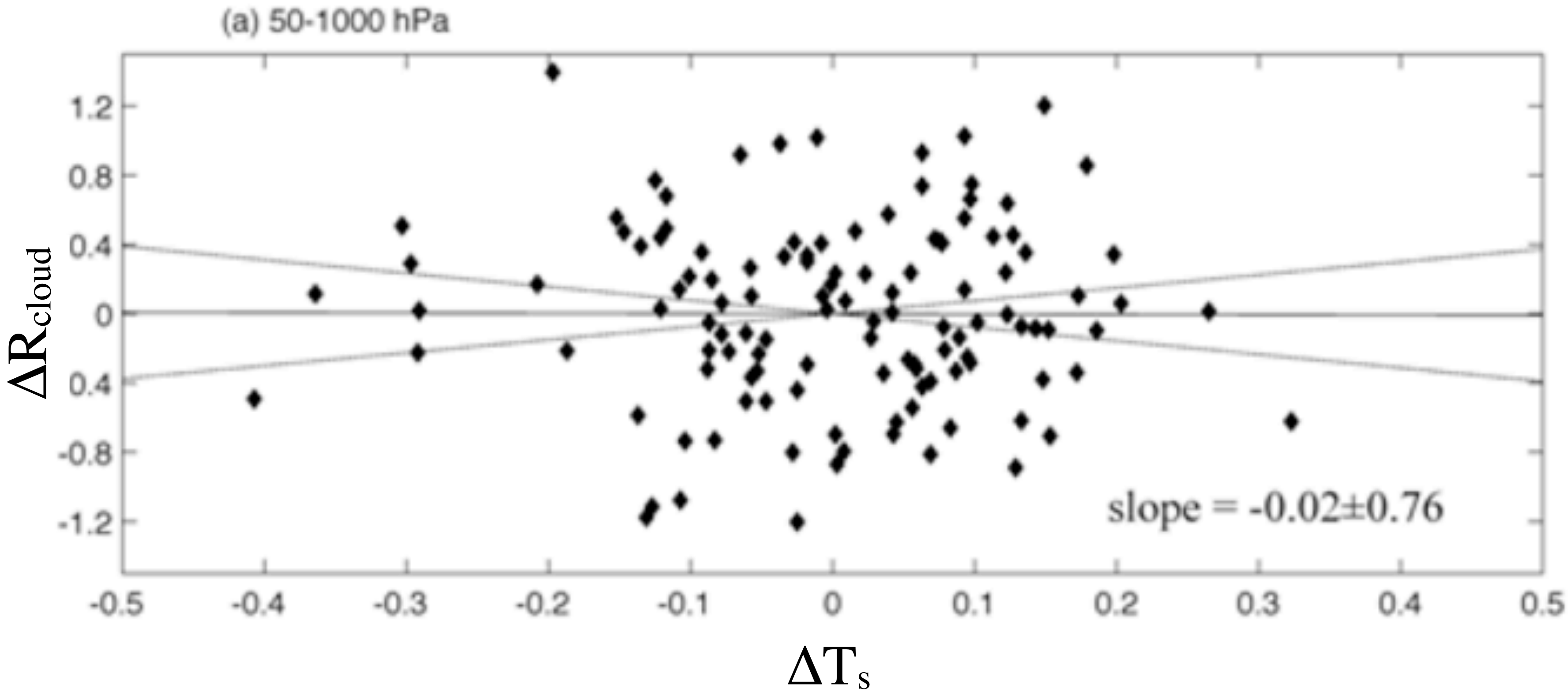
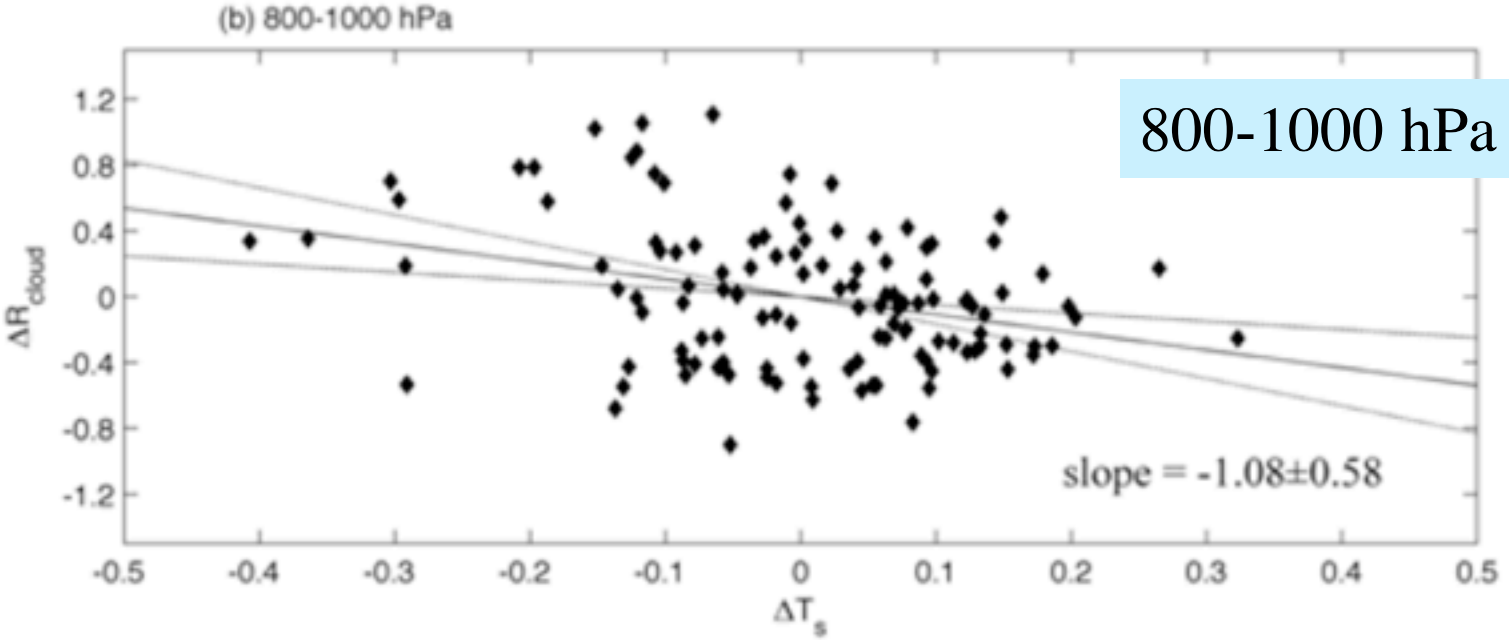
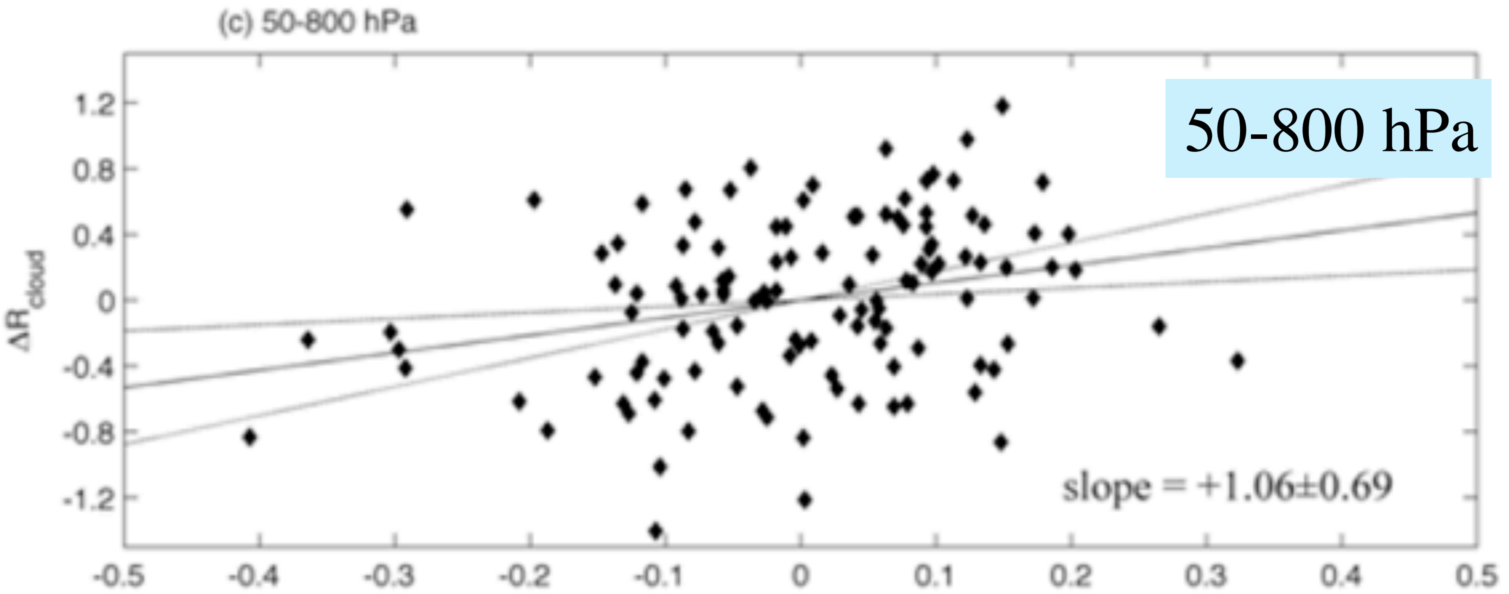


(a) 50-1000 hPa
1.2
0.8
0.4
0
0.4
-0.8
-1.2
ΔR_{cloud}
slope = -0.02±0.76
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
ΔT_s

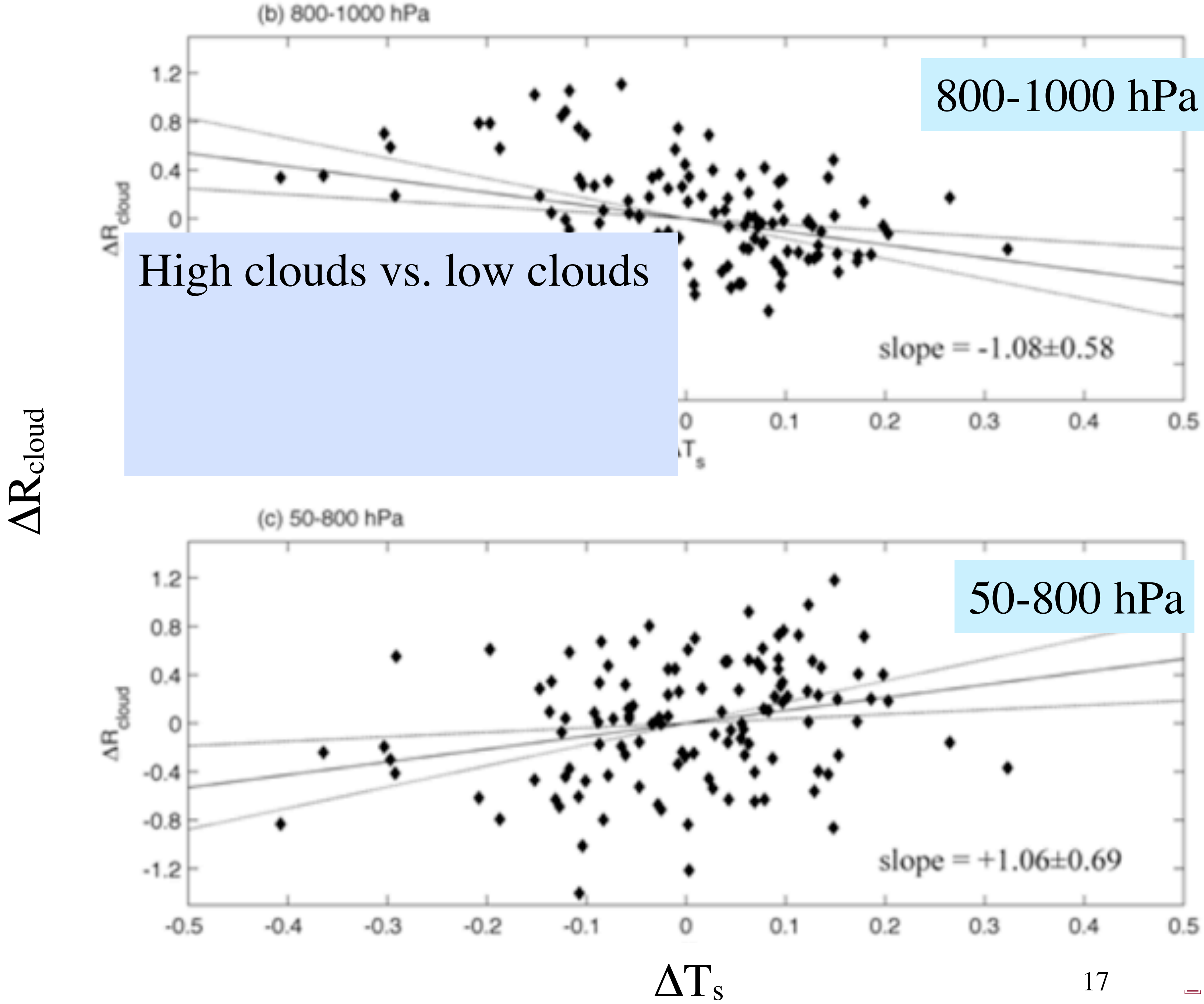




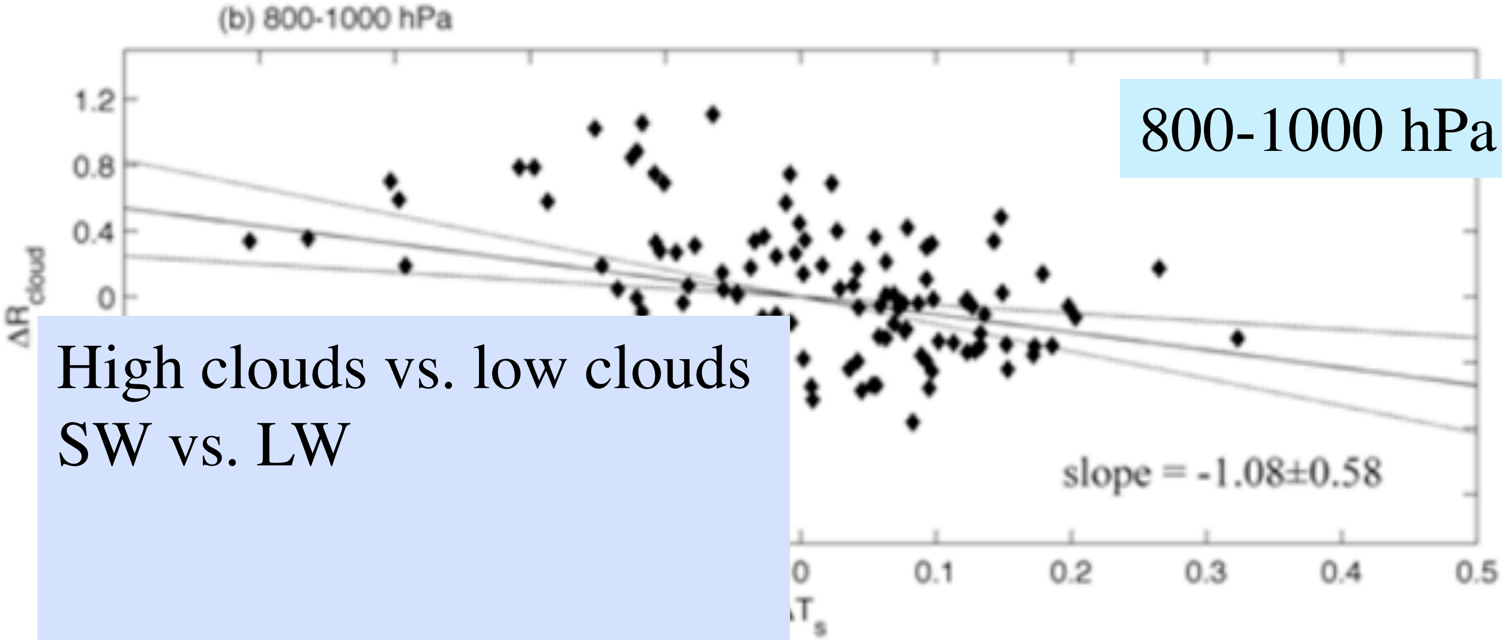
ΔR_{cloud}

ΔT_s

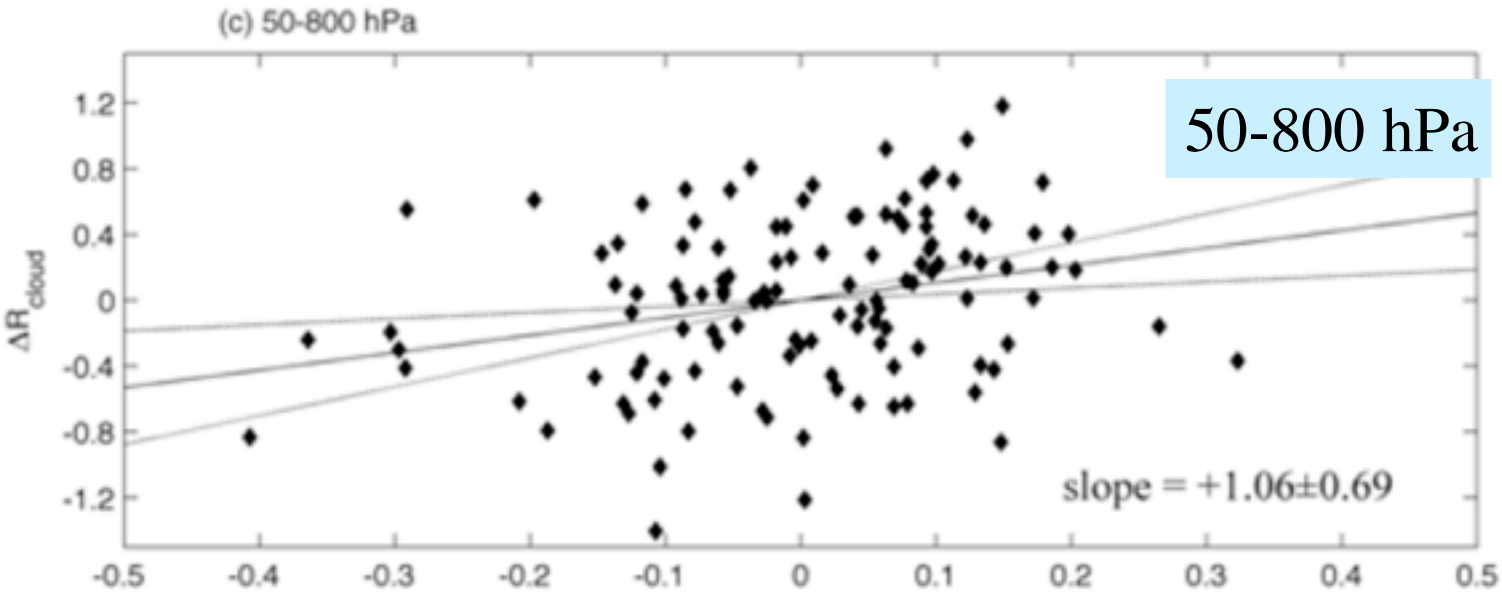
High clouds vs. low clouds



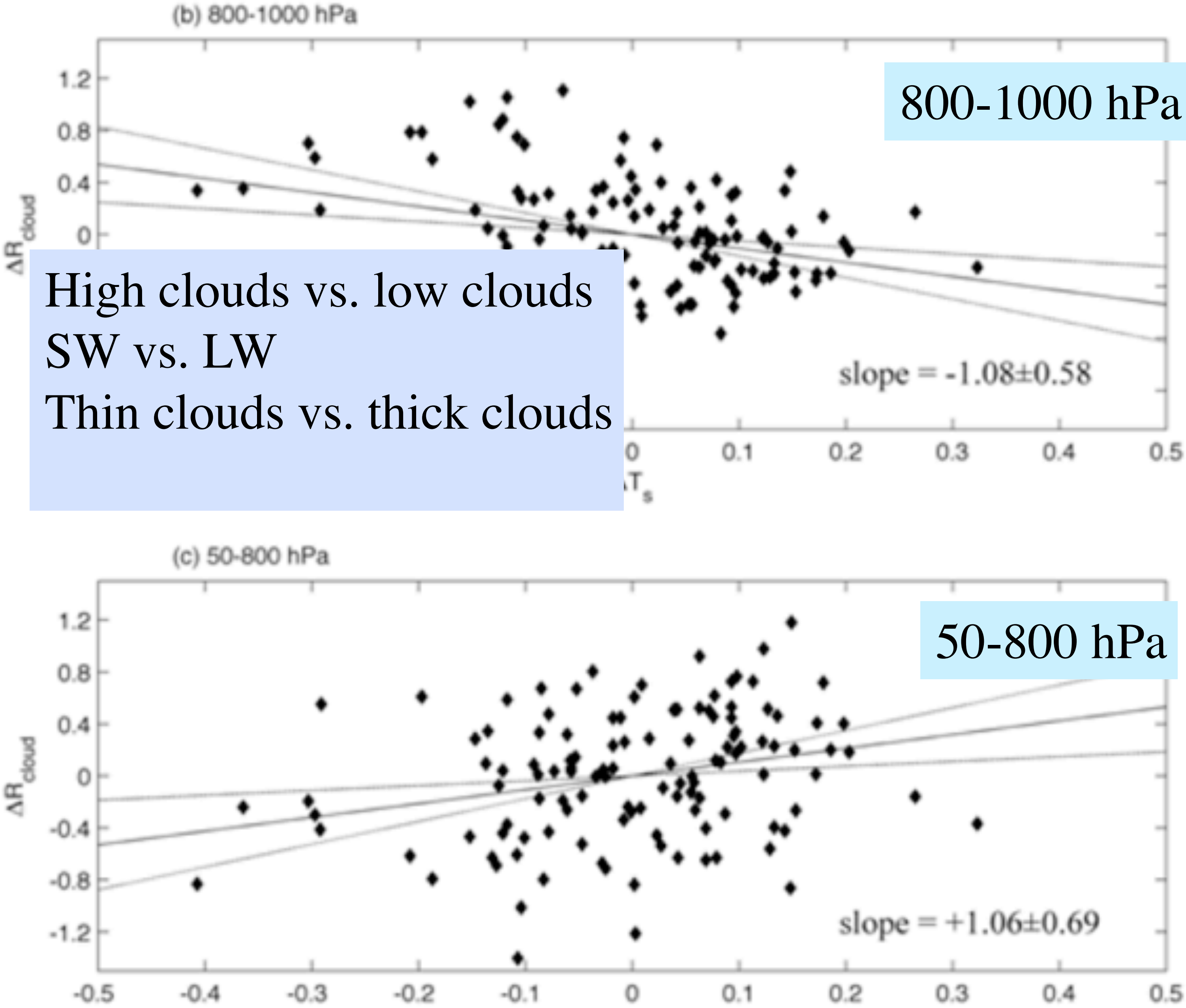
High clouds vs. low clouds
SW vs. LW



ΔR_{cloud}



ΔT_s



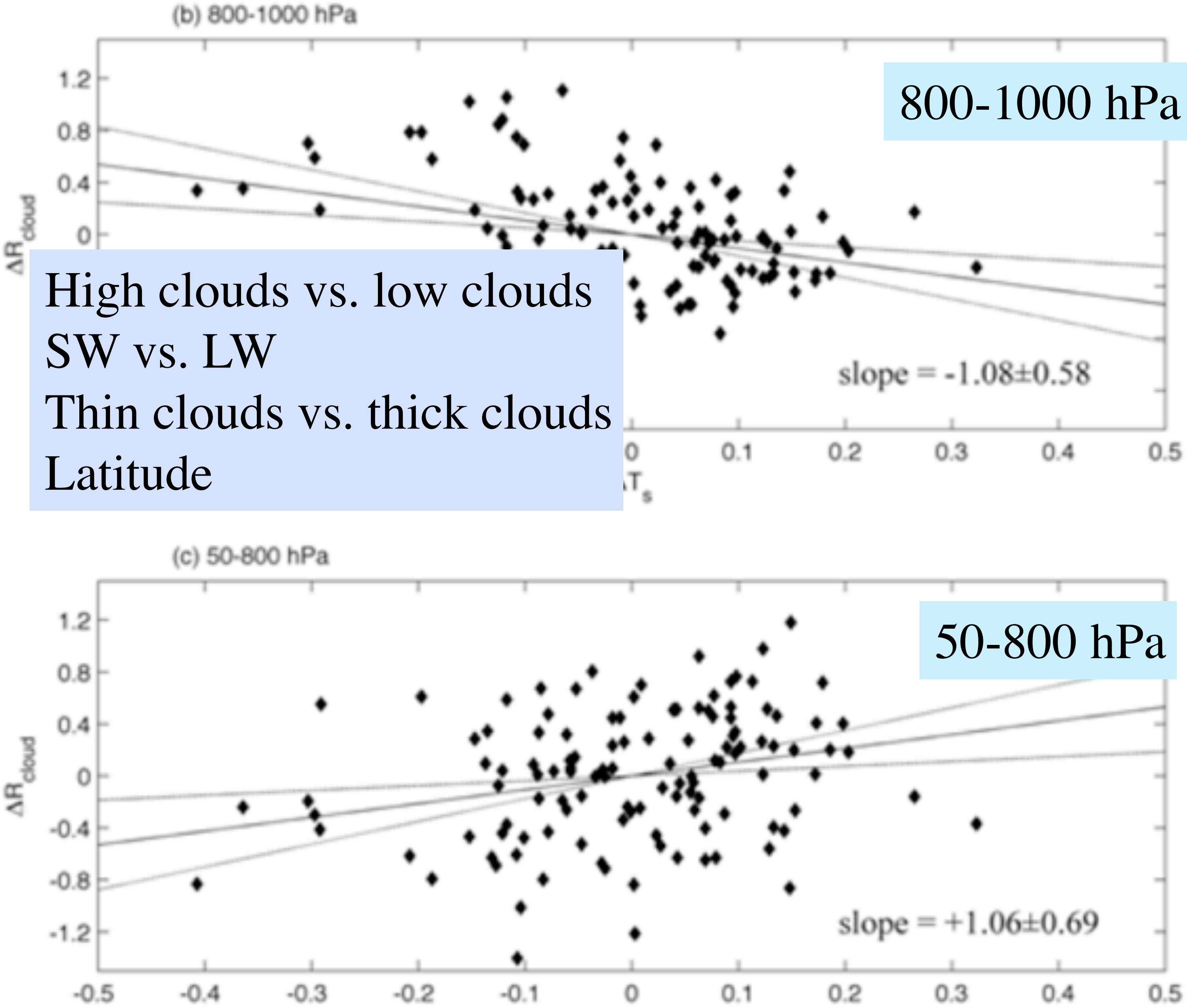
800-1000 hPa

High clouds vs. low clouds
SW vs. LW
Thin clouds vs. thick clouds

50-800 hPa

ΔR_{cloud}

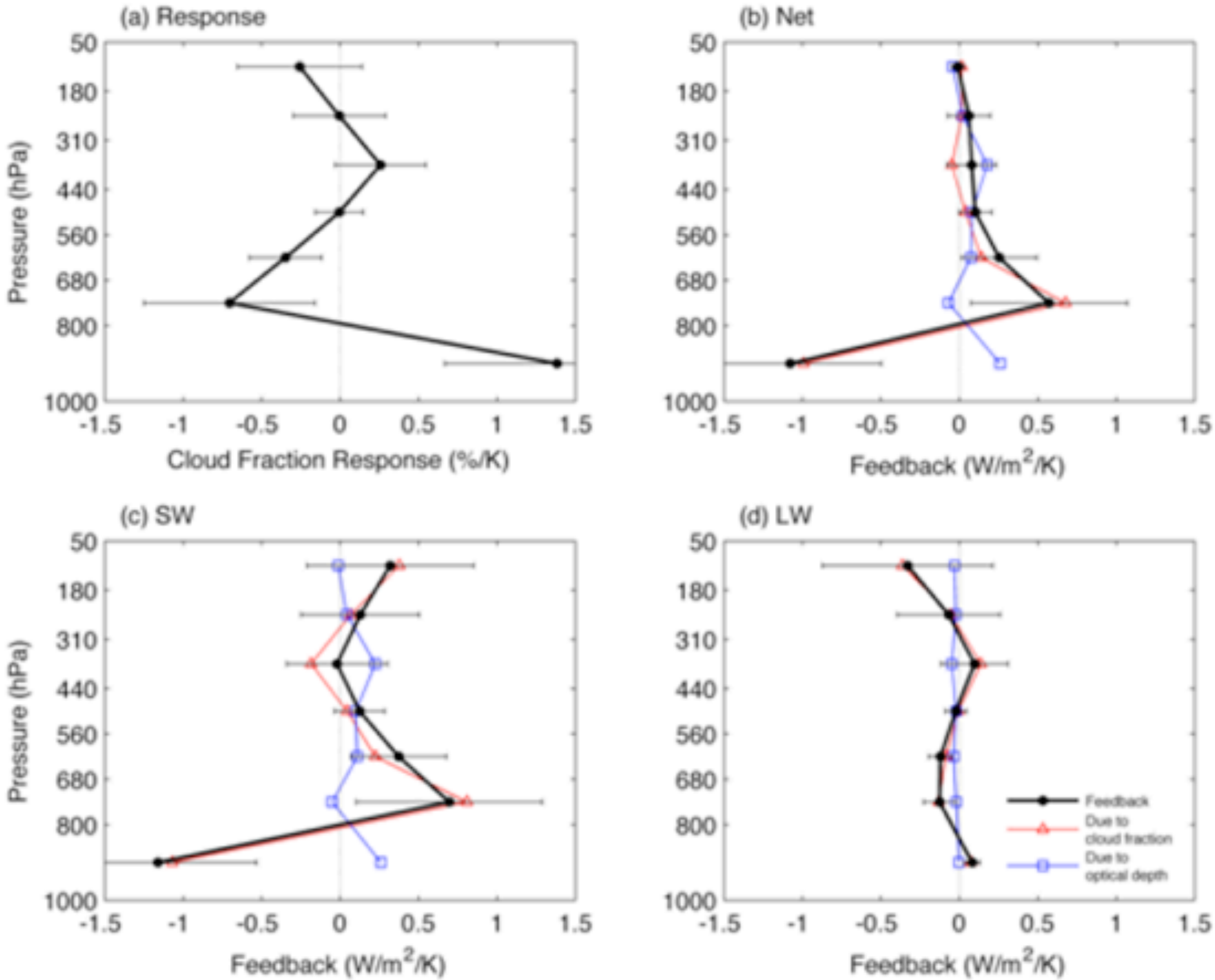
ΔT_s



High clouds vs. low clouds
SW vs. LW
Thin clouds vs. thick clouds
Latitude

ΔR_{cloud}

ΔT_s



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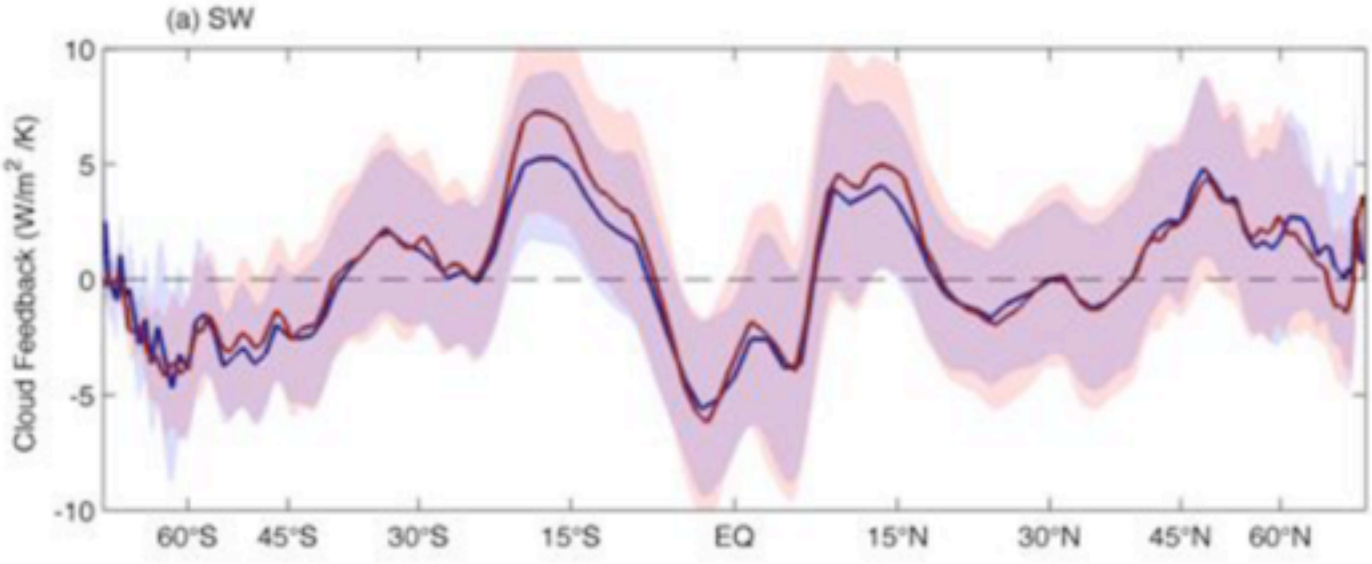
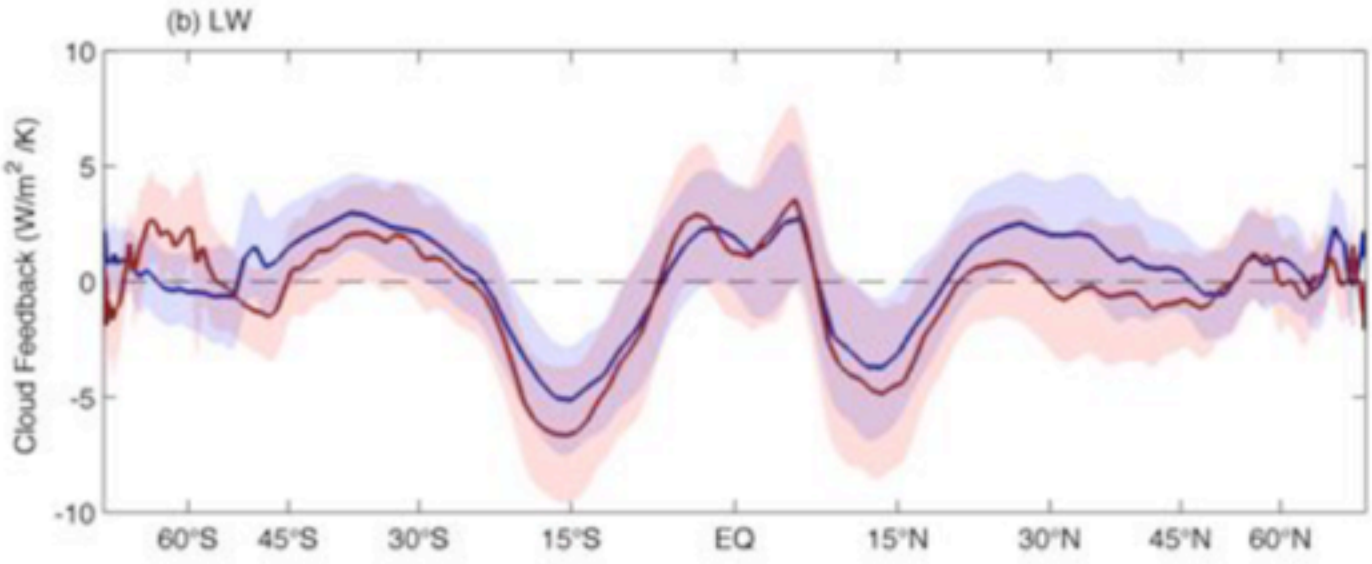
Monday, June 10, 13


(a) SW
Cloud Feedback (W/m^2 /K)
10
5
0
-5
-10
60°S
45°S
30°S
15°S
EQ
15°N
30°N
45°N
60°N


(b) LW
Cloud Feedback (W/m^2 /K)
10
5
0
-5
-10
60°S
45°S
30°S
15°S
EQ
15°N
30°N
45°N
60°N

Conclusions

- Response of short-term ΔR_{cloud} and ΔT_s variations is an important test of our models
- Cloud feedback is intrinsically uncertain due to scatter between ΔR_{cloud} and ΔT_s.
- Scatter arises because ΔR_{cloud} is a balance between canceling terms — this is a fundamental property of the problem
- Zhou et al., J. Climate, in press (preprint on my website)

Table 1. Summary of global avg. cloud feedbacks
All values have units of $W/m^2/K$

	LW	SW	Total (LW+SW)
MODIS all clouds	-0.48±0.68	+0.36±1.03	-0.12±0.78

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CERES			
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MERRA	+0.53±0.47	+0.11±0.74	+0.64±0.69

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MODIS ~0.2-0.3 $W/m^2/K$
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Difference in NH subtropics + midlatitudes

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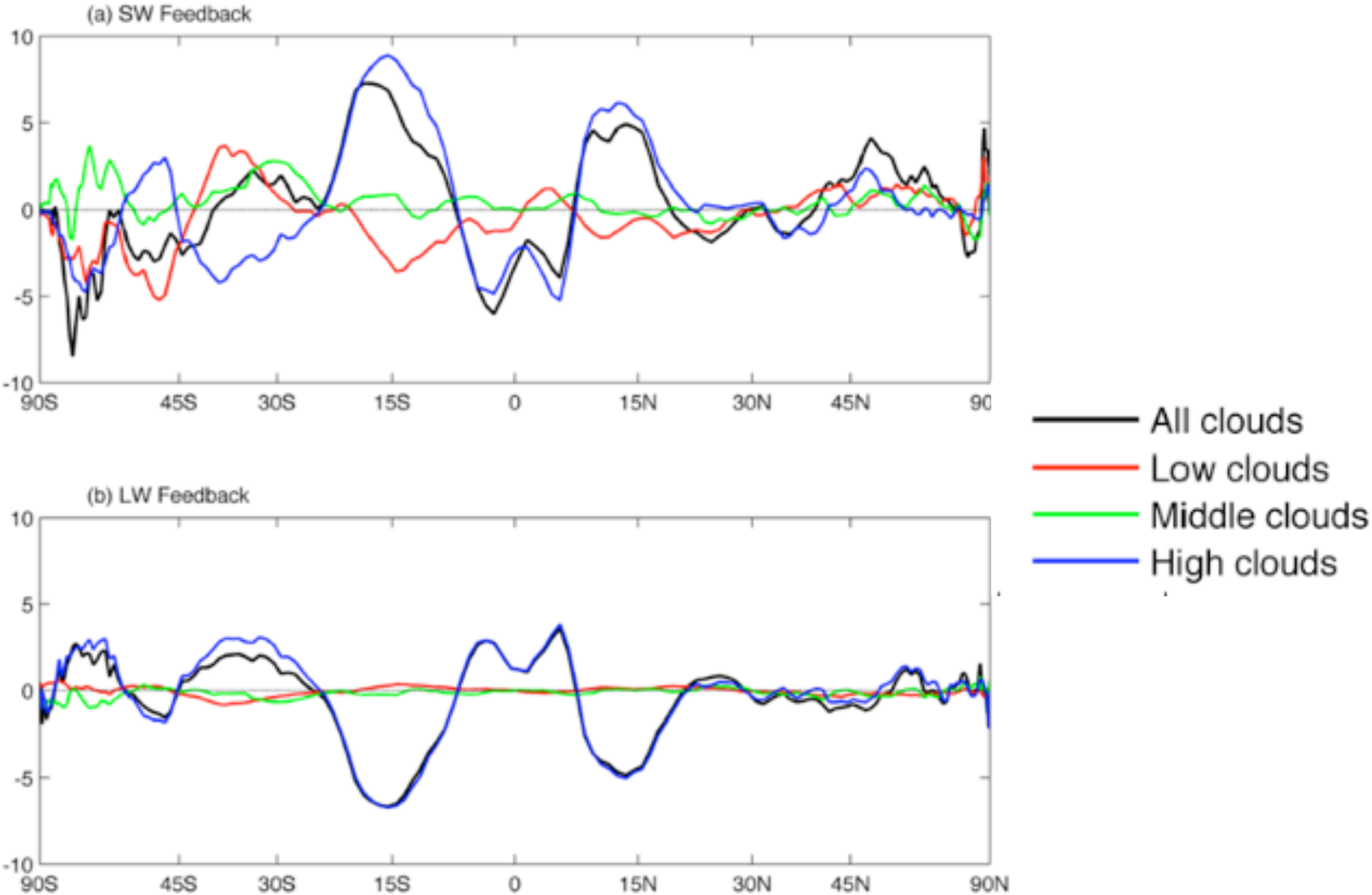
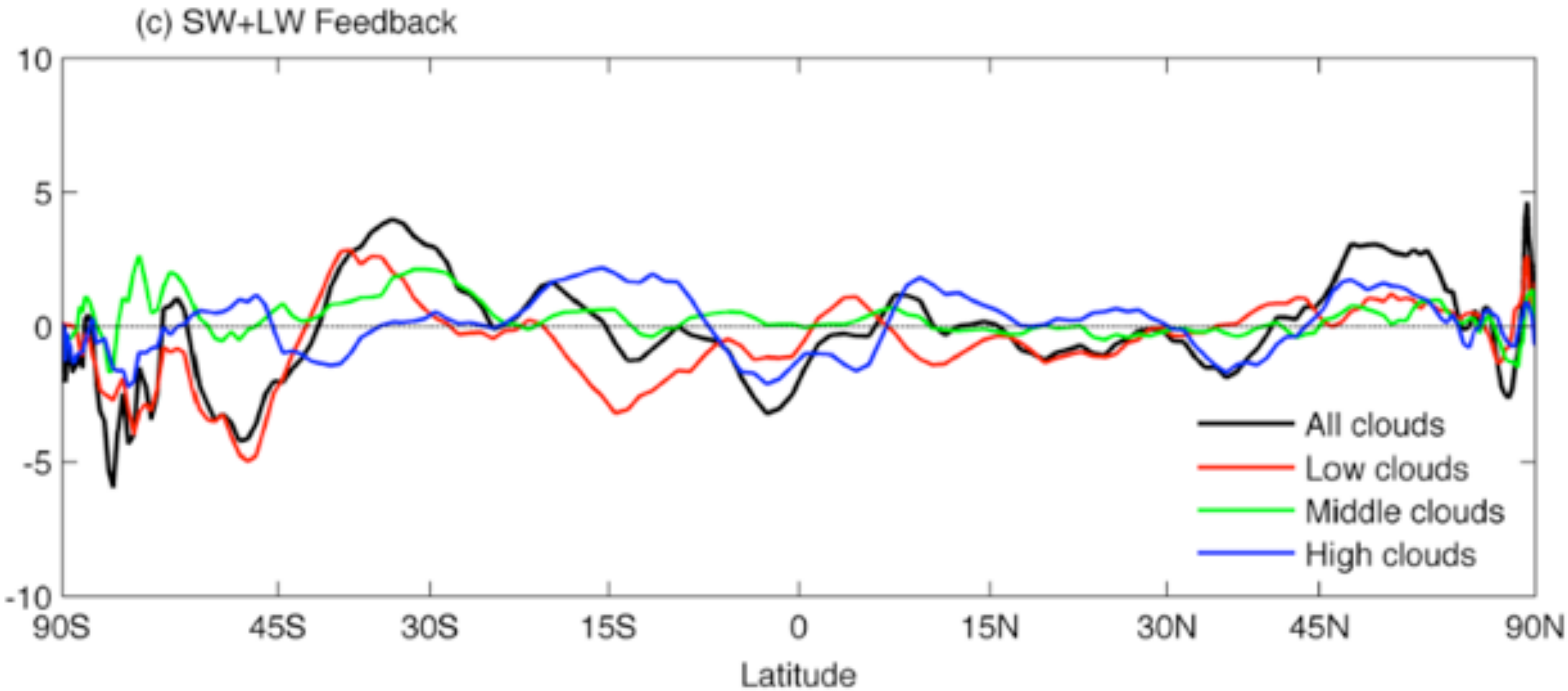
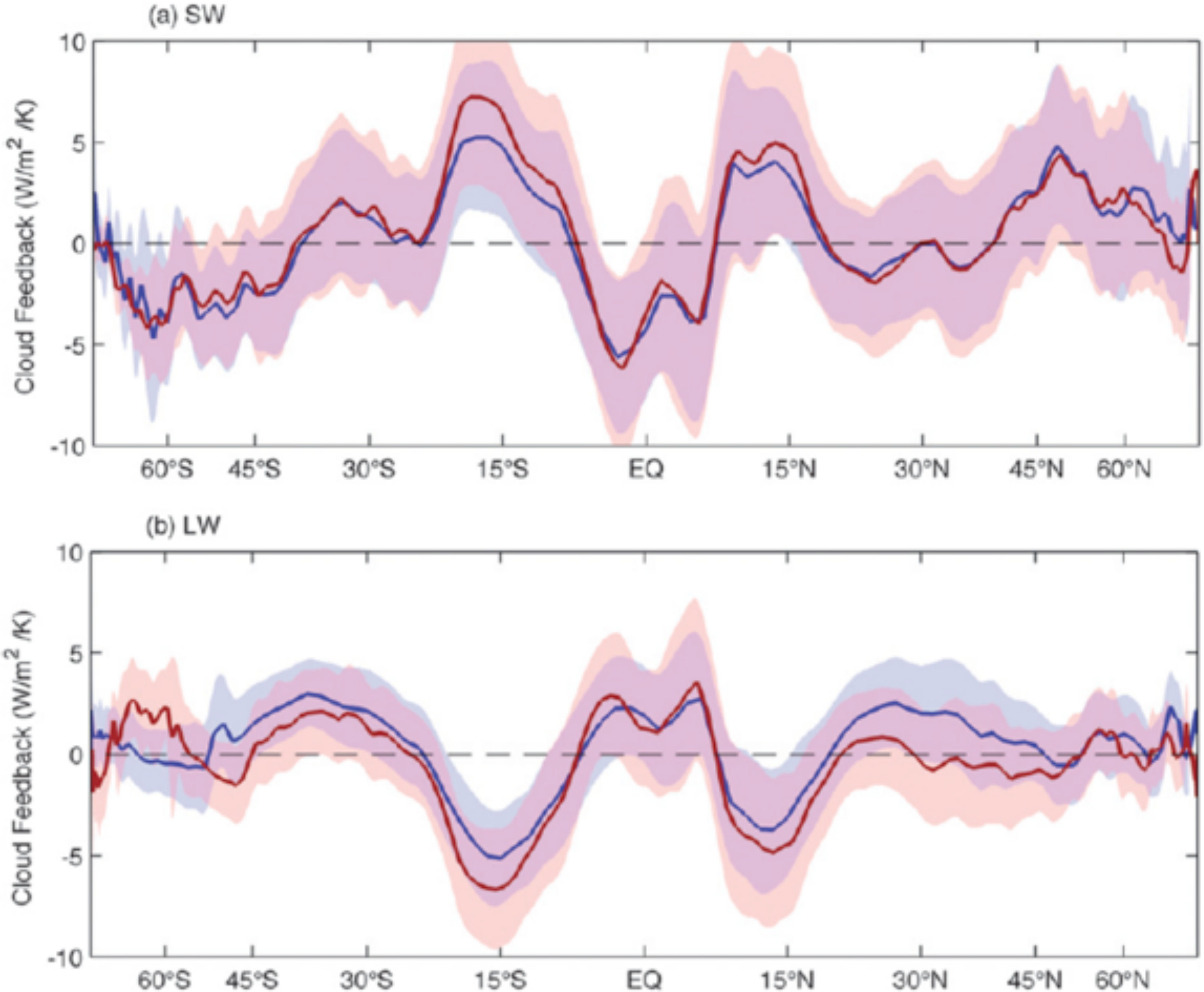


High: P < 440 hPa; Low: P > 680 hPa



breakdown into cloud height (low: P > 680 hPa, high: P < 440 hPa)


(a) SW
Cloud Feedback (W/m2 /K)
10
5
0
-5
-10
60°S
45°S
30°S
15°S
EQ
15°N
30°N
45°N
60°N
(b) LW
Cloud Feedback (W/m2 /K)
10
5
0
-5
-10
60°S
45°S
30°S
15°S
EQ
15°N
30°N
45°N
60°N

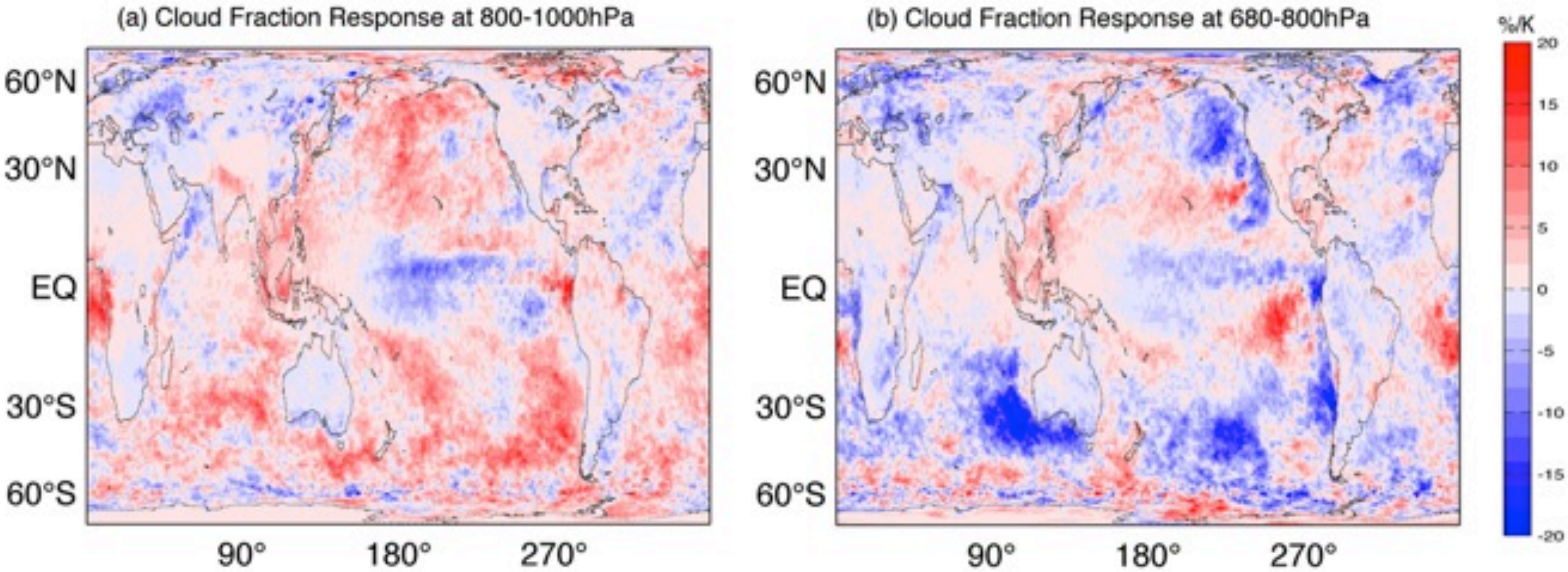

(a) Cloud Fraction Response at 800-1000hPa
(b) Cloud Fraction Response at 680-800hPa
60°N
30°N
EQ
30°S
60°S
90°
180°
270°
%/K
20
15
10
5
0
-5
-10
-15
-20

Fig. 2

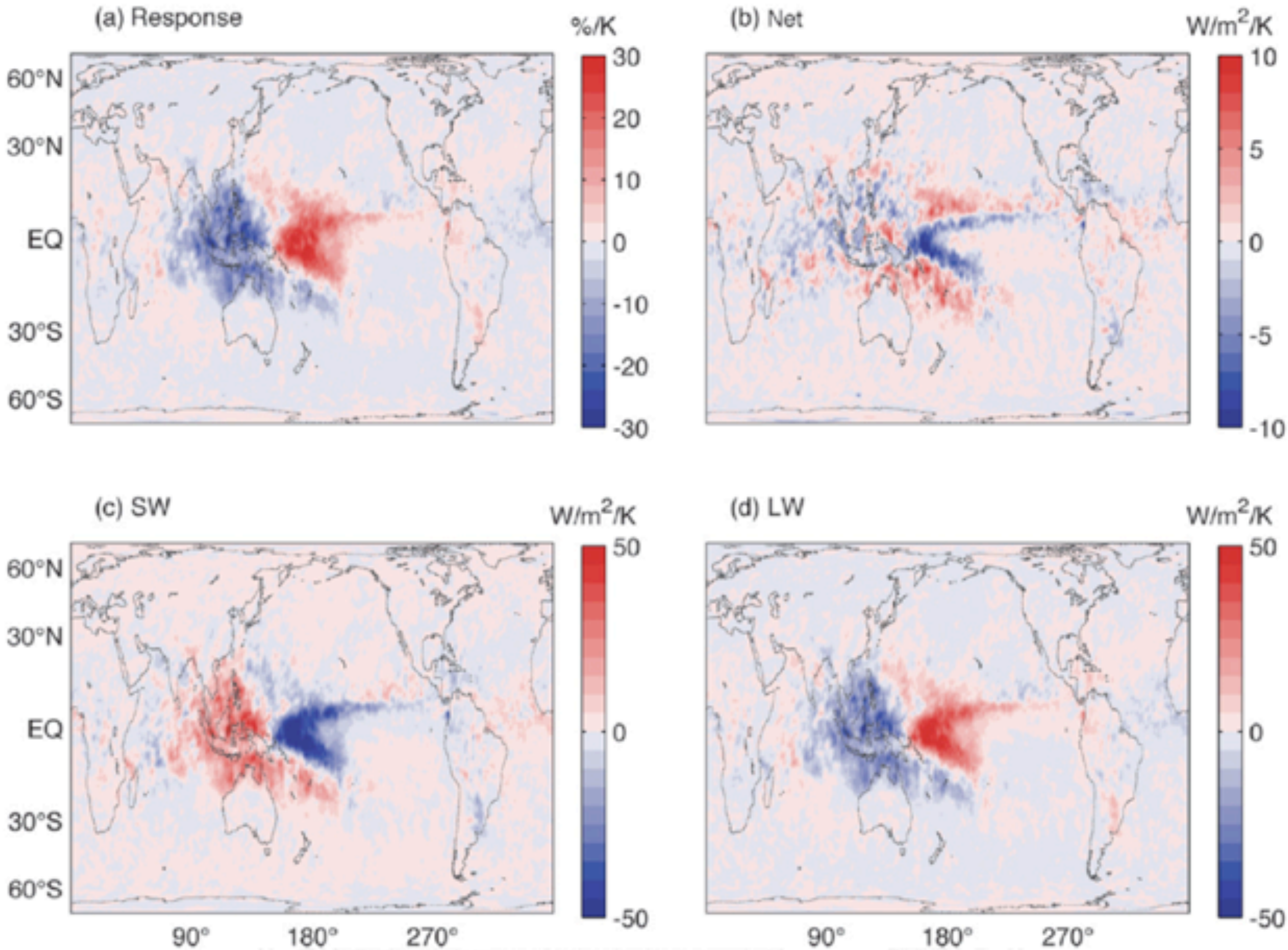
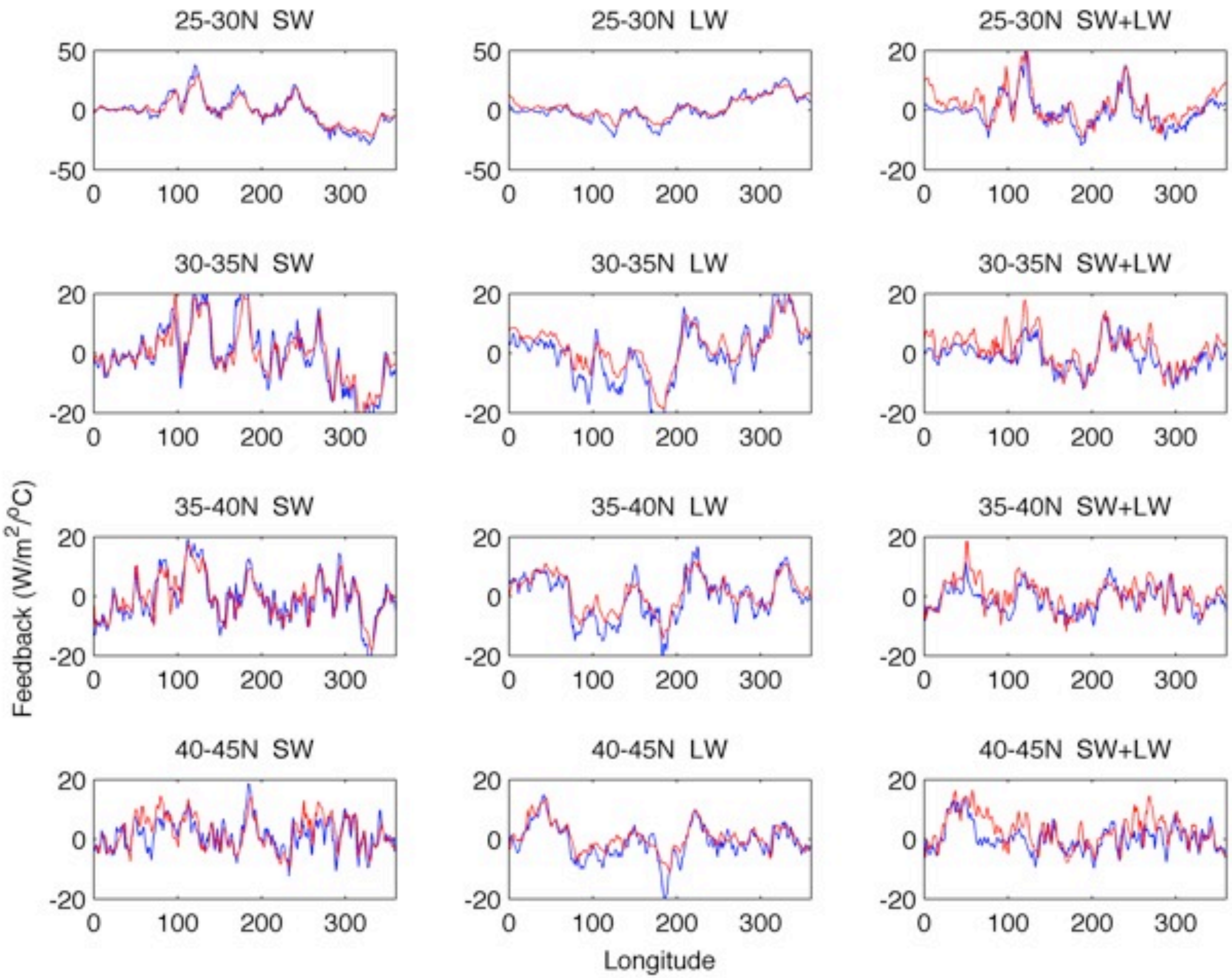
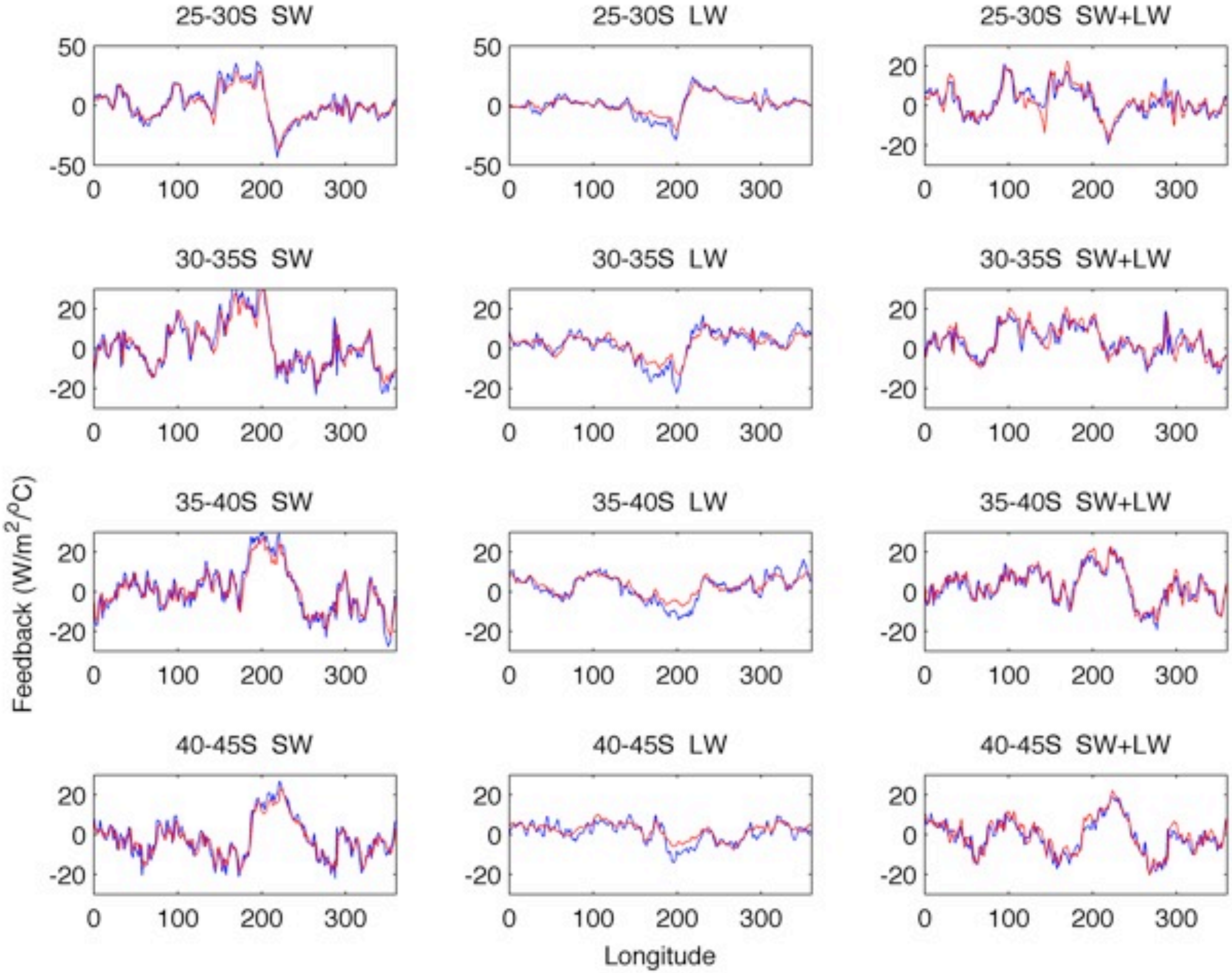

(a) Response
%/K
30
20
10
0
-10
-20
-30
(b) Net
W/m2/K
10
5
0
-5
-10
(c) SW
W/m2/K
50
0
-50
(d) LW
W/m2/K
50
0
-50
60°N
30°N
EQ
30°S
60°S
90°
180°
270°

Fig. 6


25-30N SW
25-30N LW
25-30N SW+LW
30-35N SW
30-35N LW
30-35N SW+LW
35-40N SW
35-40N LW
35-40N SW+LW
40-45N SW
40-45N LW
40-45N SW+LW
Feedback (W/m^2/^{o}C)
Longitude


25-30S SW
25-30S LW
25-30S SW+LW
30-35S SW
30-35S LW
30-35S SW+LW
35-40S SW
35-40S LW
35-40S SW+LW
40-45S SW
40-45S LW
40-45S SW+LW
Feedback (W/m^2/^{o}C)
Longitude