Unforced Surface Air Temperature Variability and Its Contrasting Relationship with the Anomalous TOA Energy Flux at Local and Global Spatial Scales*

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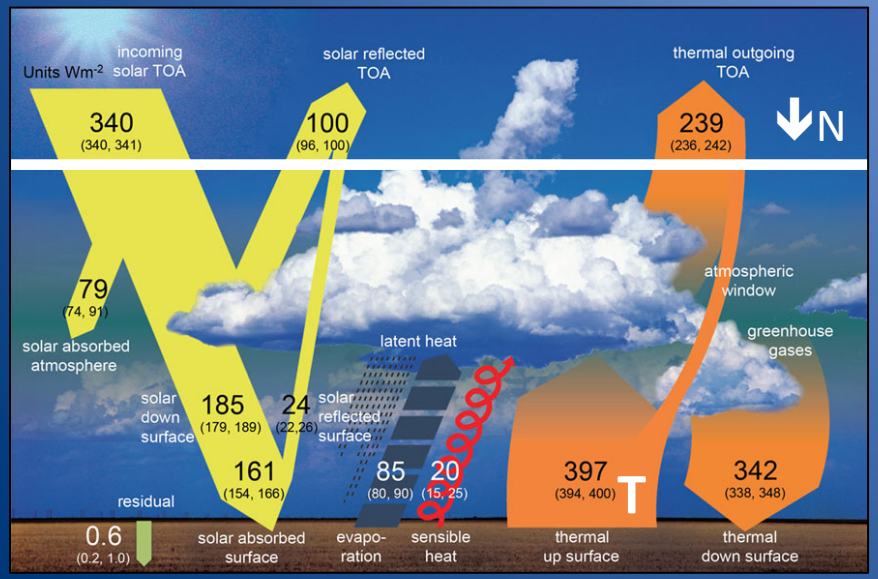
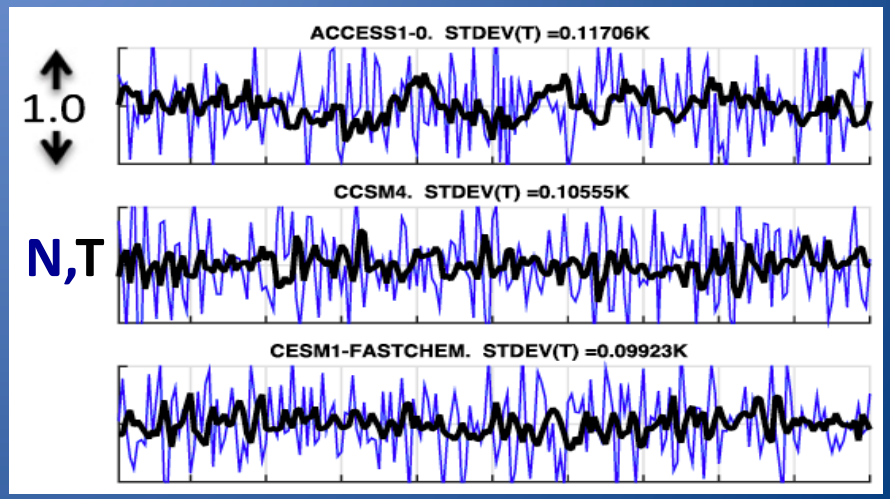
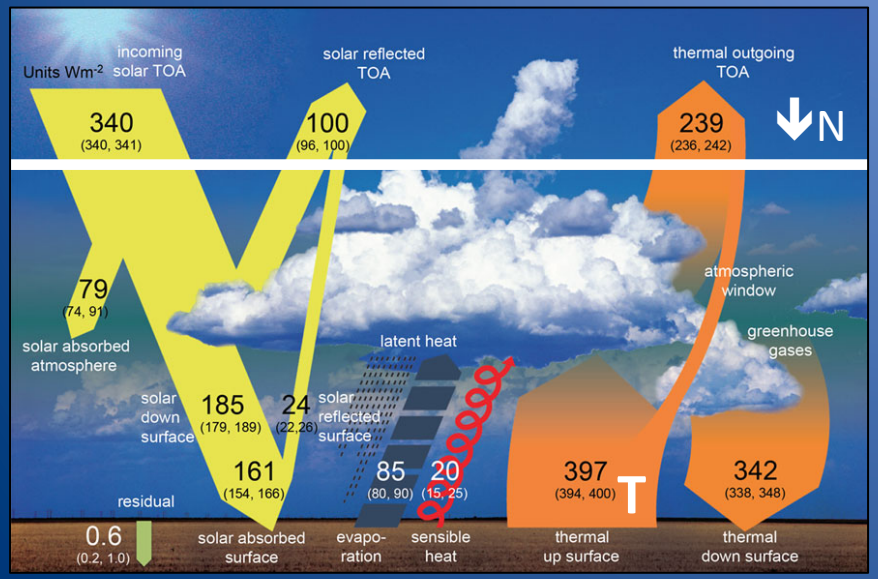
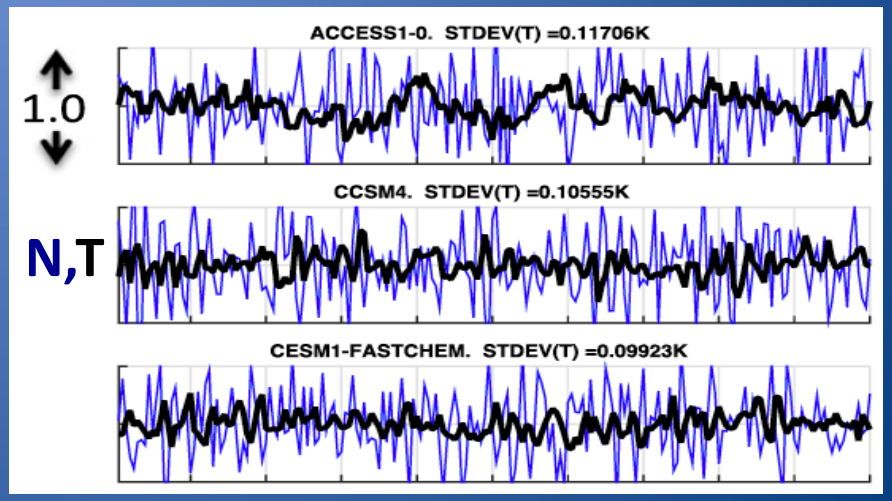




200 years

- In the absence of external radiative forcings, global mean temperature (T) should be stable in the long run

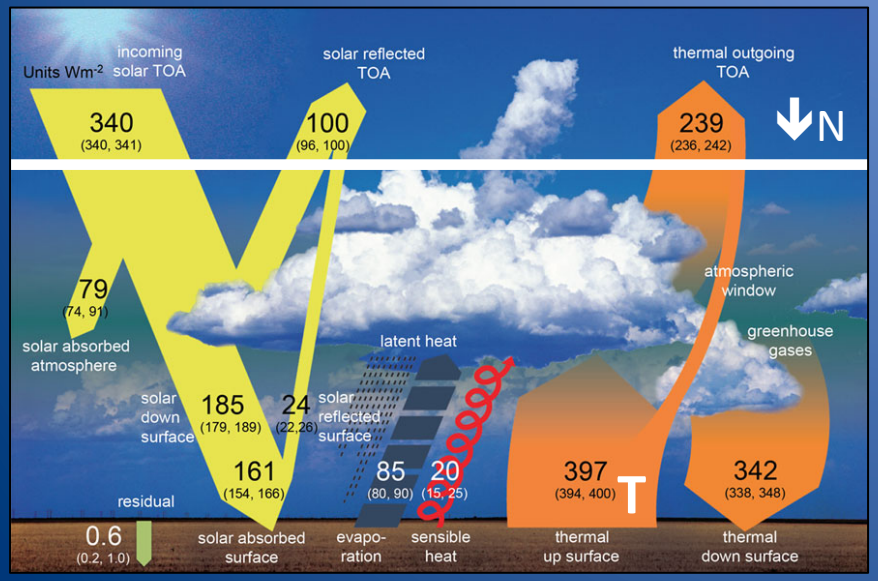


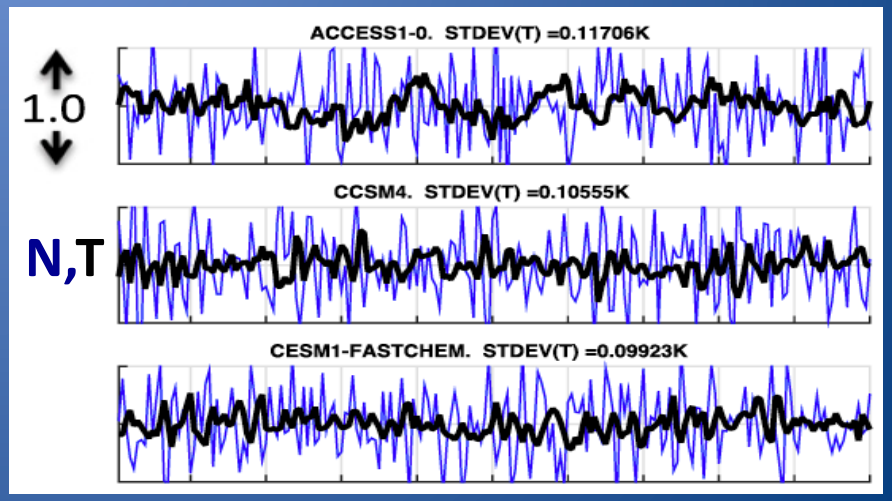


200 years

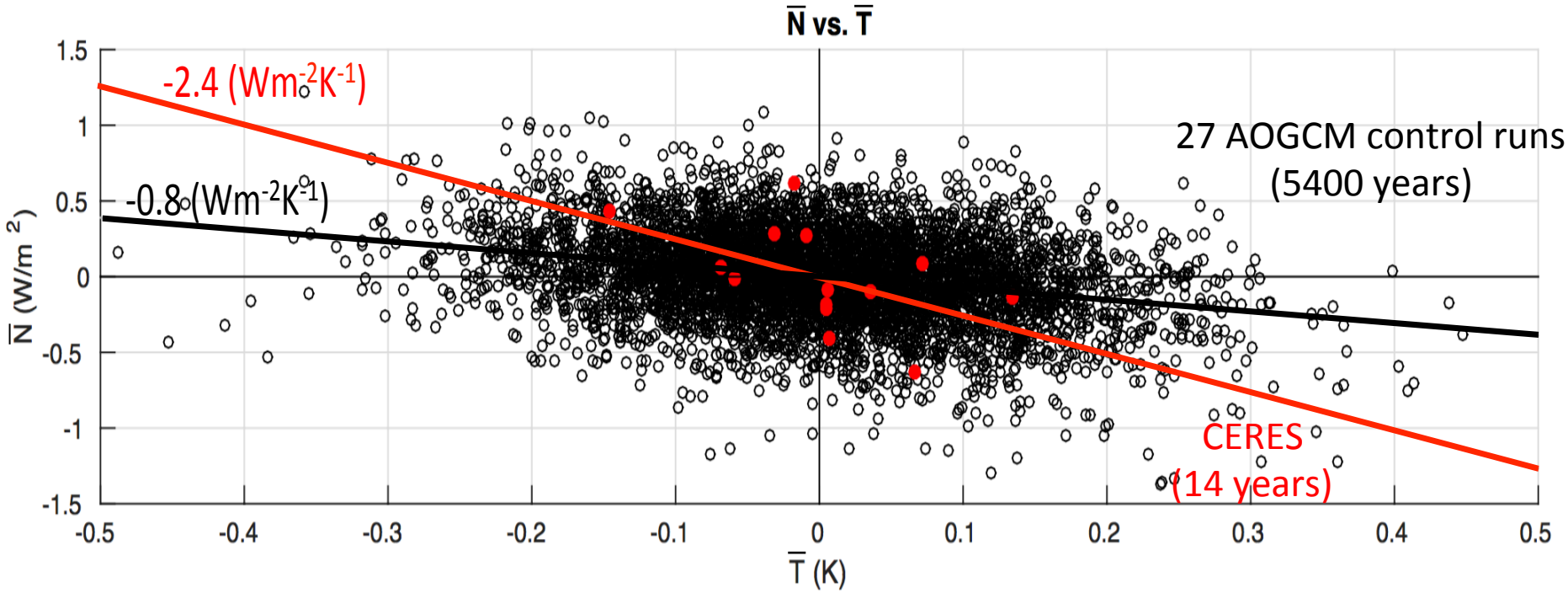
- In the absence of external radiative forcings, global mean temperature (T) should be stable in the long run
- Why? Because of the 'Planck Response':

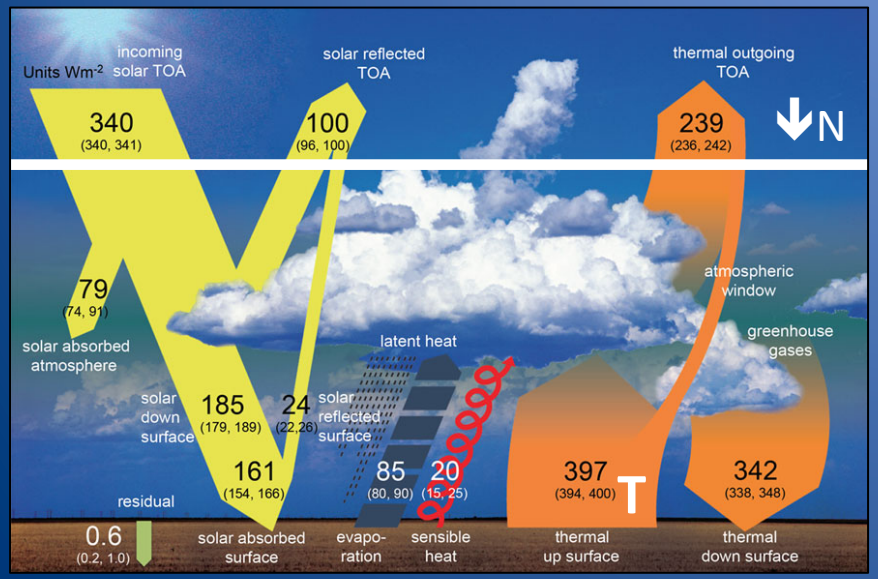
$$\lambda_{Planck} = -4\sigma T_e^3 \approx 3.2\ Wm^{-2}K^{-1}$$

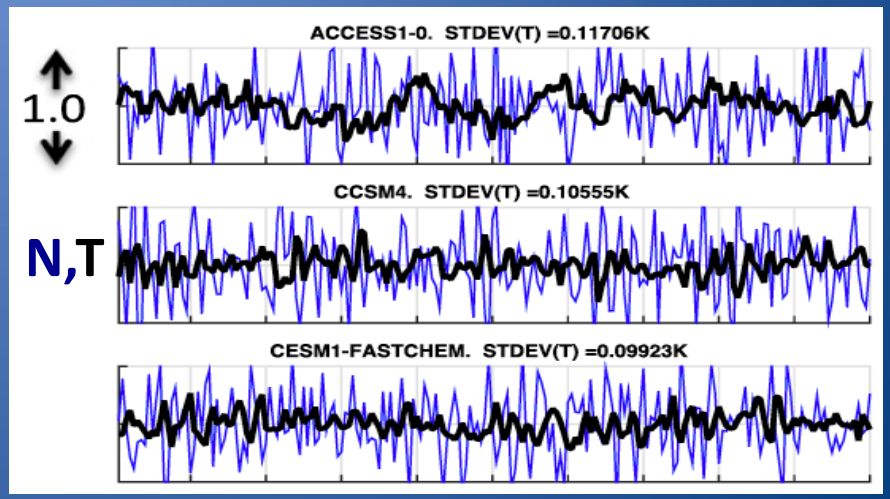




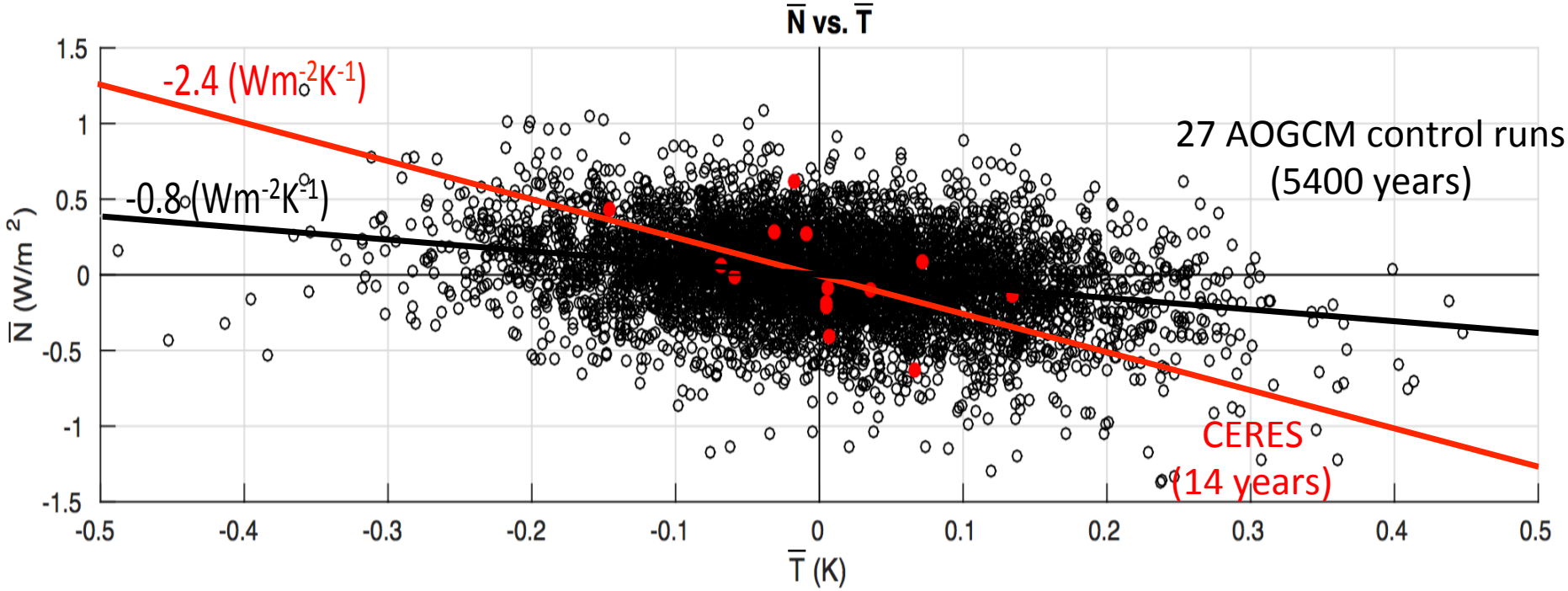
200 years


N̄ vs. T̄
-2.4 (Wm-2K-1)
-0.8 (Wm-2K-1)
27 AOGCM control runs
(5400 years)
CERES
(14 years)
N̄ (W/m 2)
T̄ (K)
1.5
1
0.5
0
-0.5
-1
-1.5
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

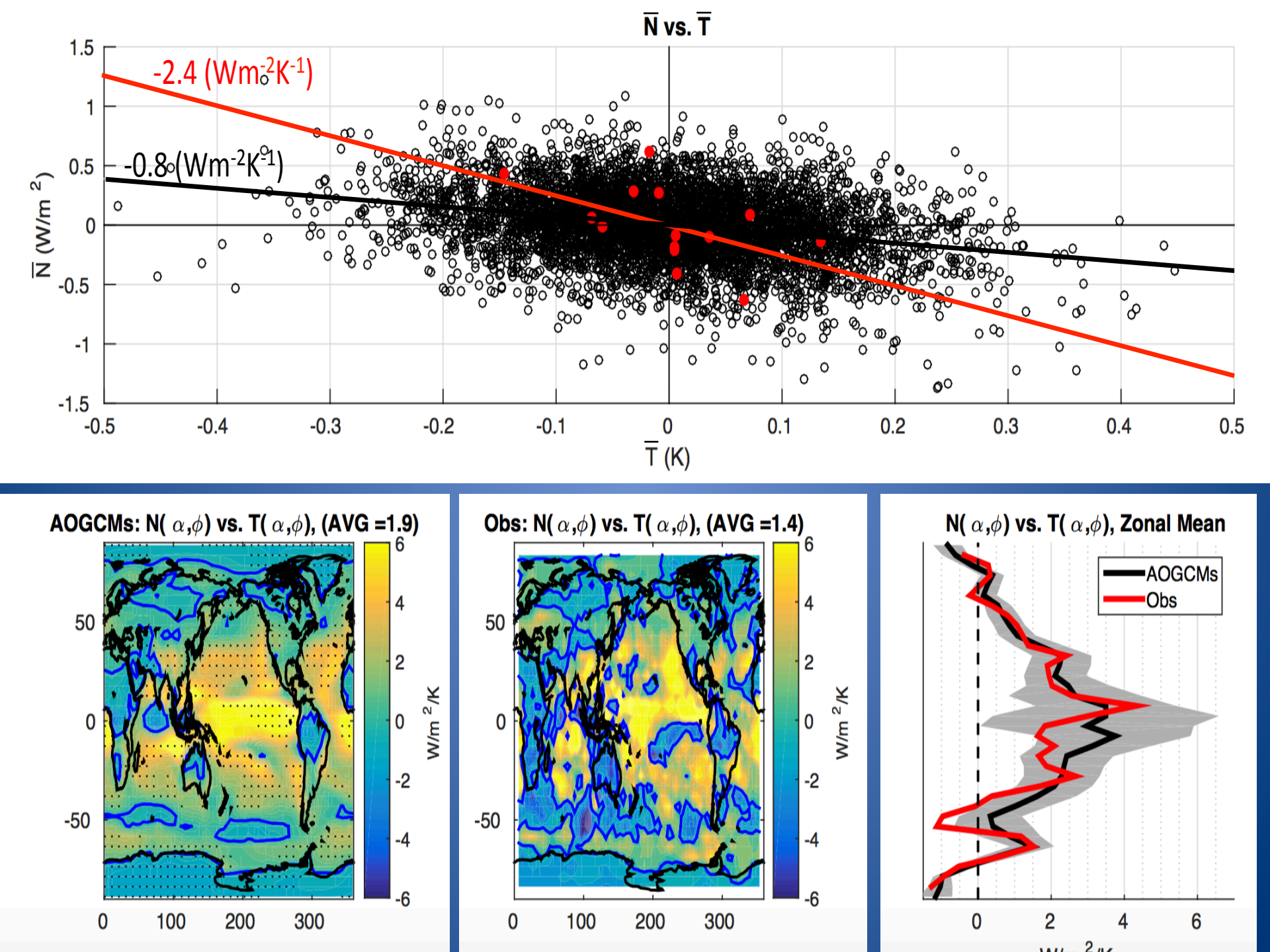

Units Wm-2
incoming solar TOA
340
(340, 341)
solar reflected TOA
100
(96, 100)
thermal outgoing TOA
239
(236, 242)
N
79
(74, 91)
solar absorbed atmosphere
solar down surface
185
(179, 189)
24
(22,26)
solar reflected surface
161
(154, 166)
residual
0.6
(0.2, 1.0)
solar absorbed surface
latent heat
85
(80, 90)
evapo-ration
20
(15, 25)
sensible heat
397
(394, 400)
T
thermal up surface
atmospheric window
greenhouse gases
342
(338, 348)
thermal down surface

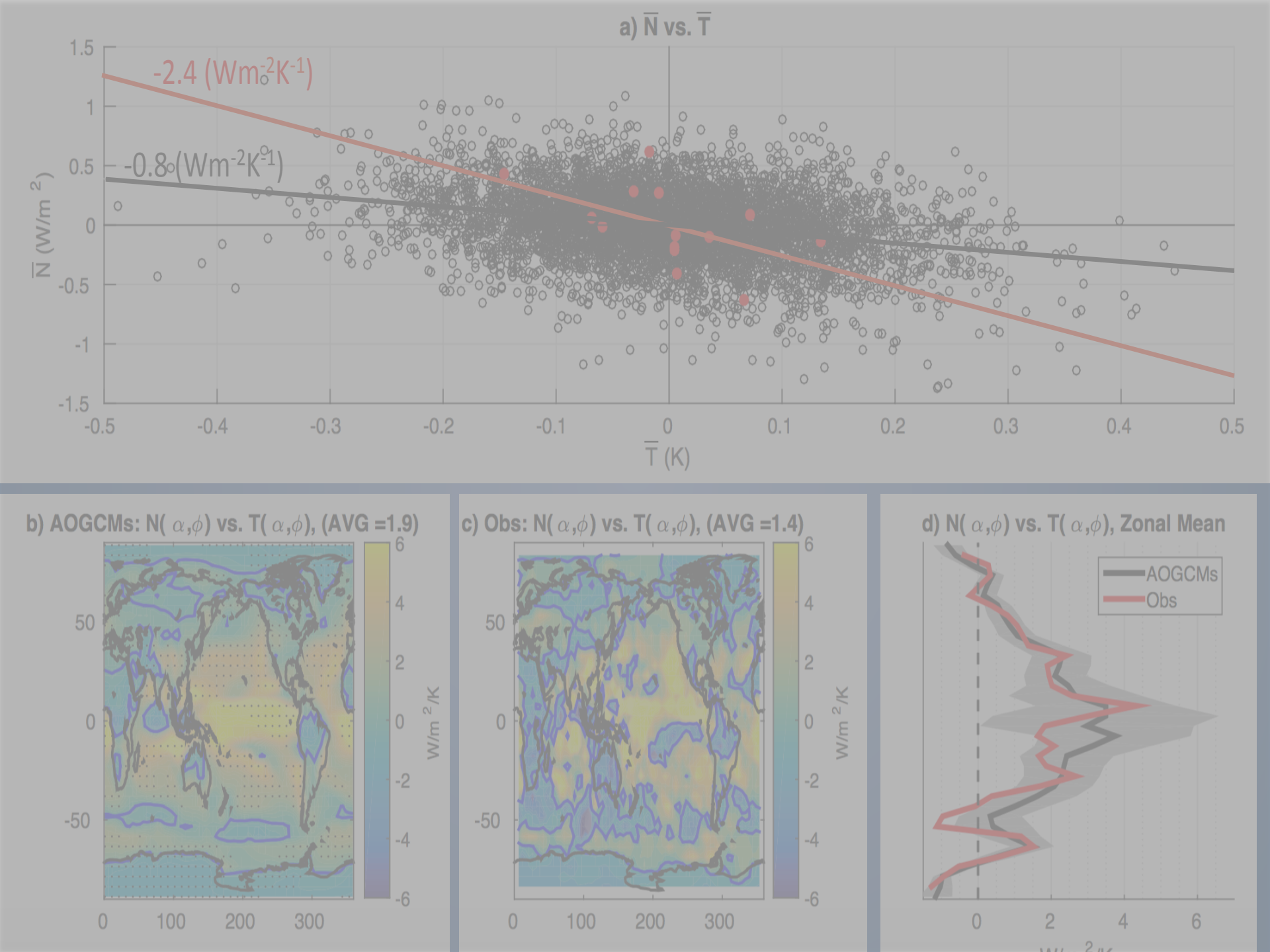

ACCESS1-0. STDEV(T) =0.11706K
1.0
CCSM4. STDEV(T) =0.10555K
N,T
CESM1-FASTCHEM. STDEV(T) =0.09923K

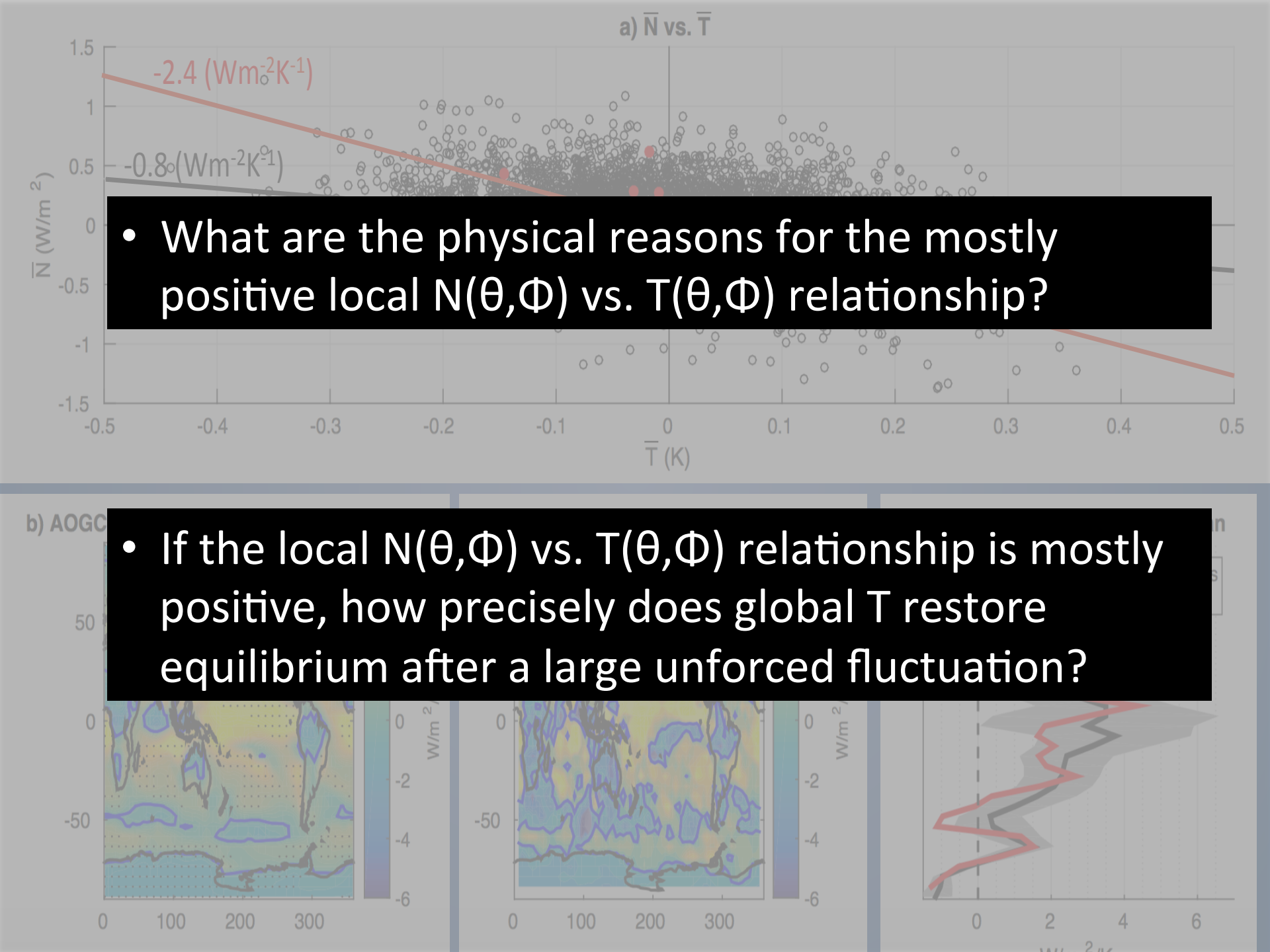
200 years



What does the local relationship [N(θ,Φ) vs. T(θ,Φ)] look like?


N̄ vs. T̄
-2.4 (Wm-2K-1)
-0.8 (Wm-2K-1)
N̄ (W/m 2)
T̄ (K)
AOGCMs: N(α,ϕ) vs. T(α,ϕ), (AVG =1.9)
Obs: N(α,ϕ) vs. T(α,ϕ), (AVG =1.4)
W/m 2/K
N(α,ϕ) vs. T(α,ϕ), Zonal Mean
AOGCMs
Obs

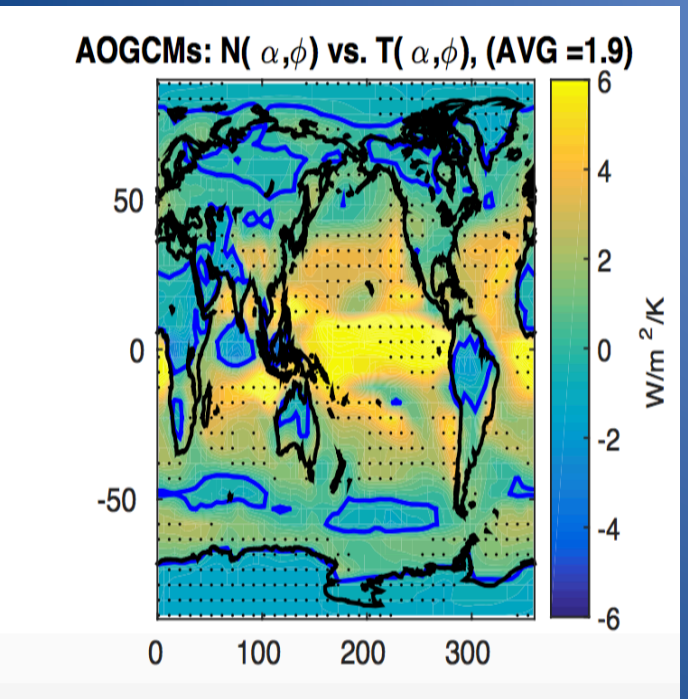

a) $\overline{N}$ vs. $\overline{T}$
-2.4 (Wm-2K-1)
-0.8 (Wm-2K-1)
$\overline{N}$ (W/m 2)
$\overline{T}$ (K)
b) AOGCMs: N(α,ϕ) vs. T(α,ϕ), (AVG =1.9)
c) Obs: N(α,ϕ) vs. T(α,ϕ), (AVG =1.4)
W/m 2/K
d) N(α,ϕ) vs. T(α,ϕ), Zonal Mean
AOGCMs
Obs



- What are the physical reasons for the mostly positive local N(θ,Φ) vs. T(θ,Φ) relationship?

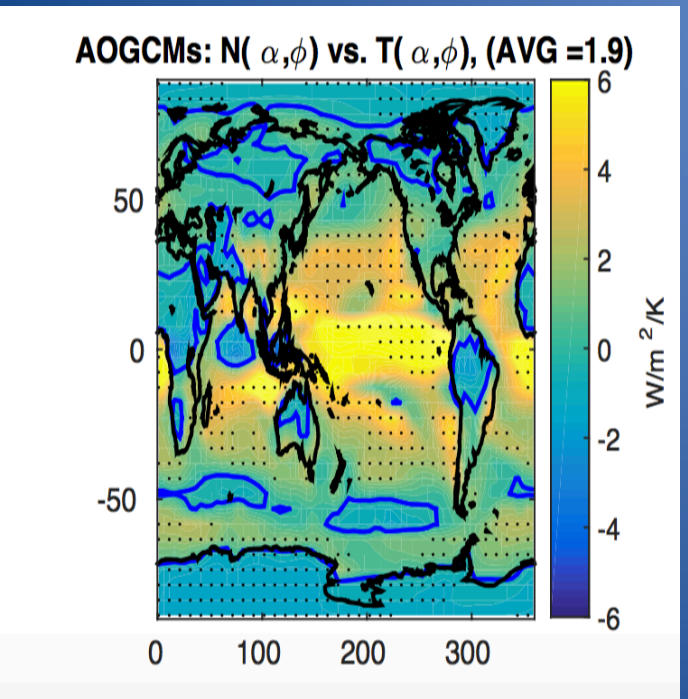
- If the local N(θ,Φ) vs. T(θ,Φ) relationship is mostly positive, how precisely does global T restore equilibrium after a large unforced fluctuation?

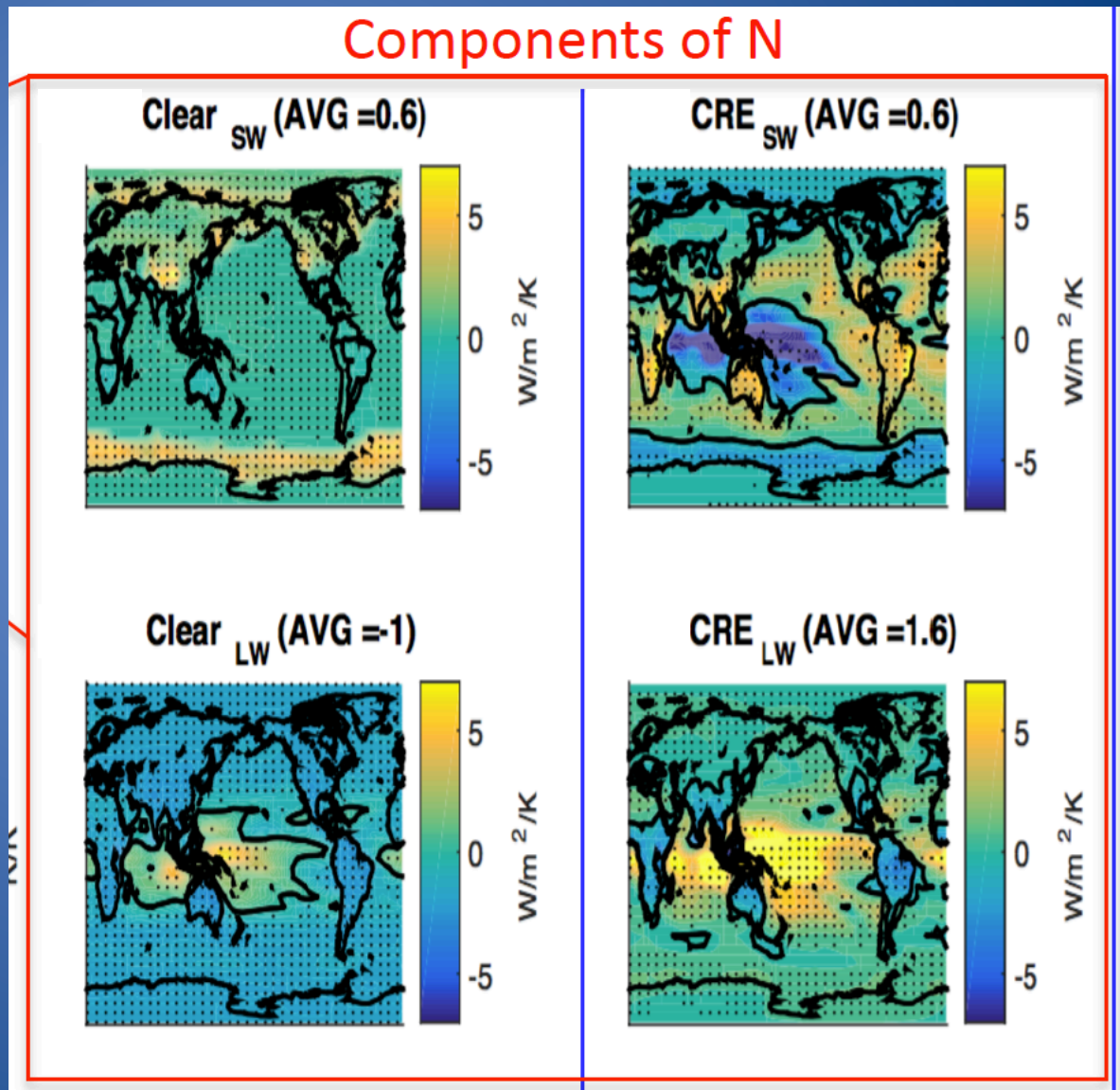
Why is the local N(θ,Φ) vs. T(θ,Φ) relationship mostly positive?



Why is the local N(θ,Φ) vs. T(θ,Φ) relationship mostly positive?

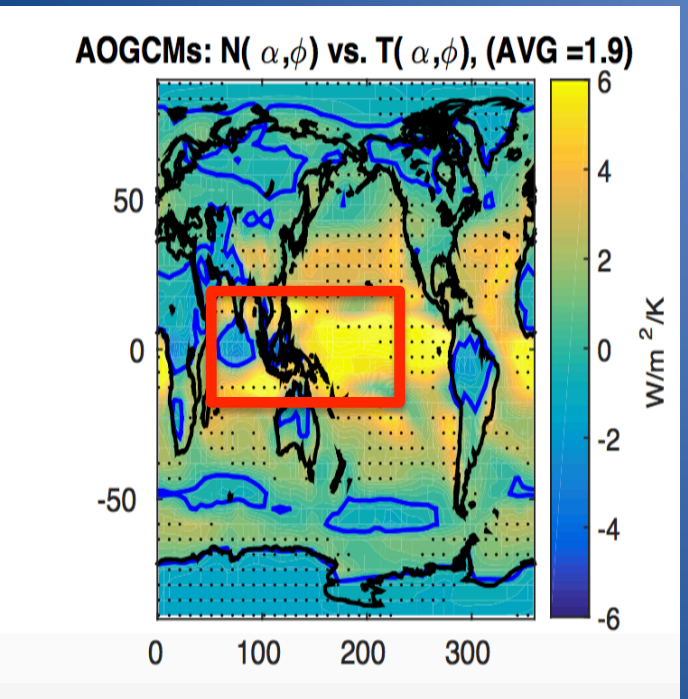
AOGCM control runs

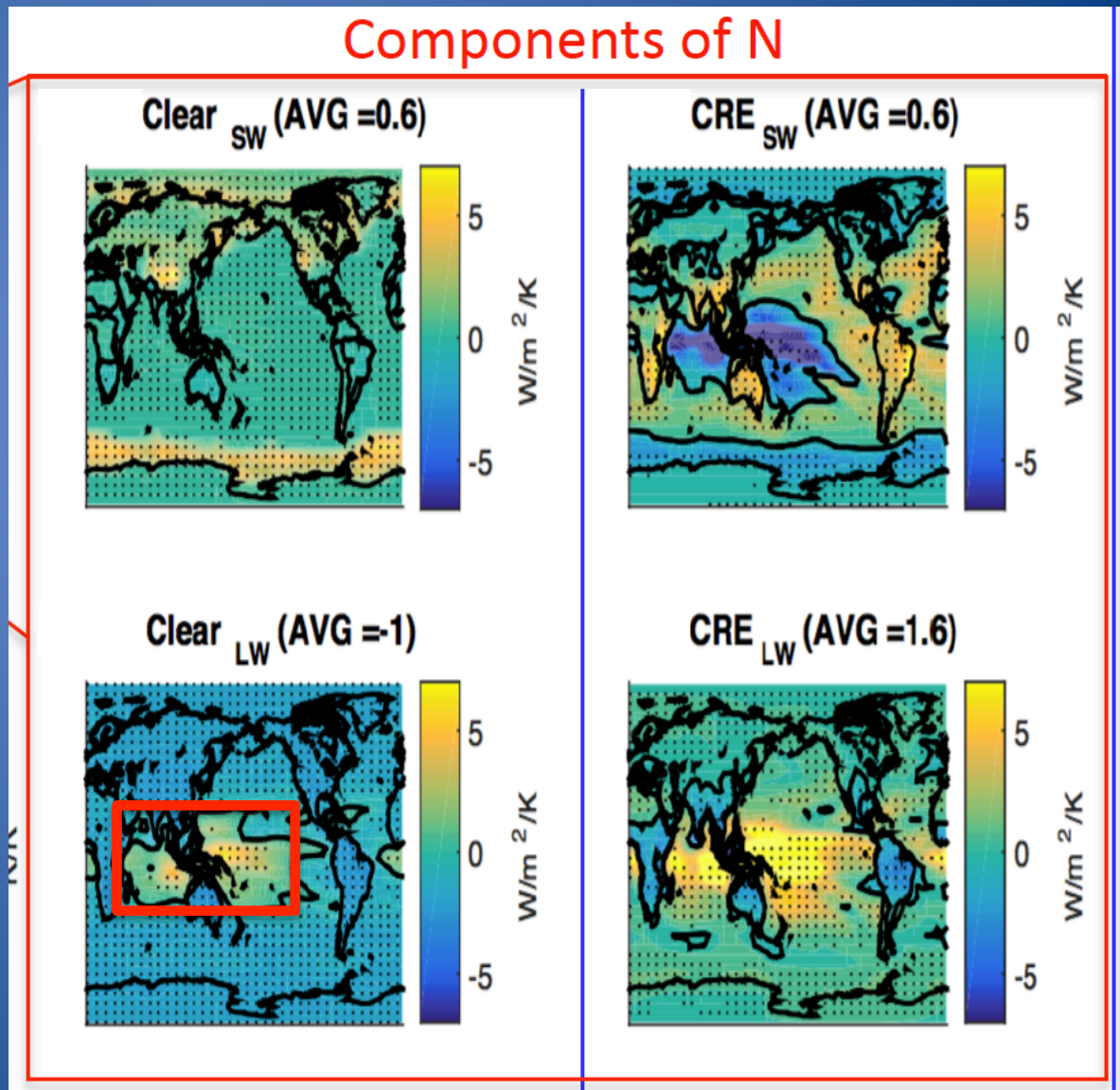




Why is the local N(θ,Φ) vs. T(θ,Φ) relationship mostly positive?

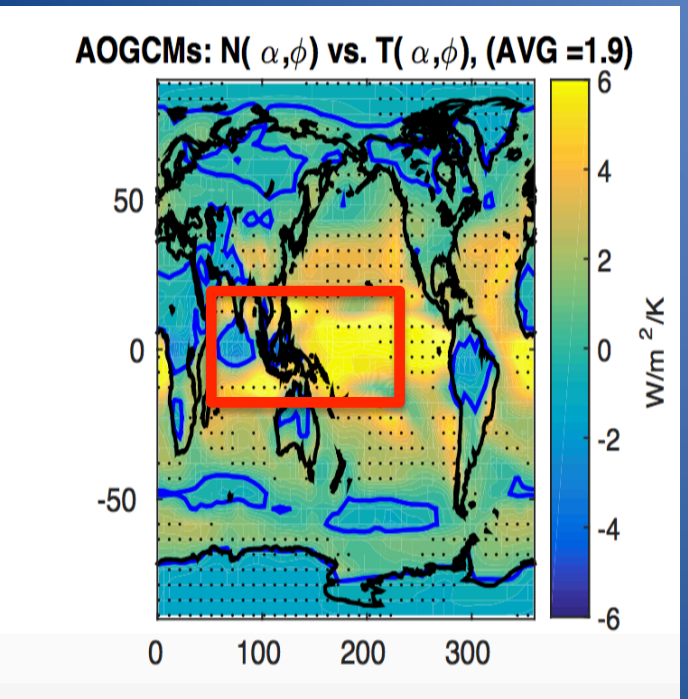
- Due mostly to the longwave water vapor feedback over oceanic regions with the highest climatological T(θ,Φ)

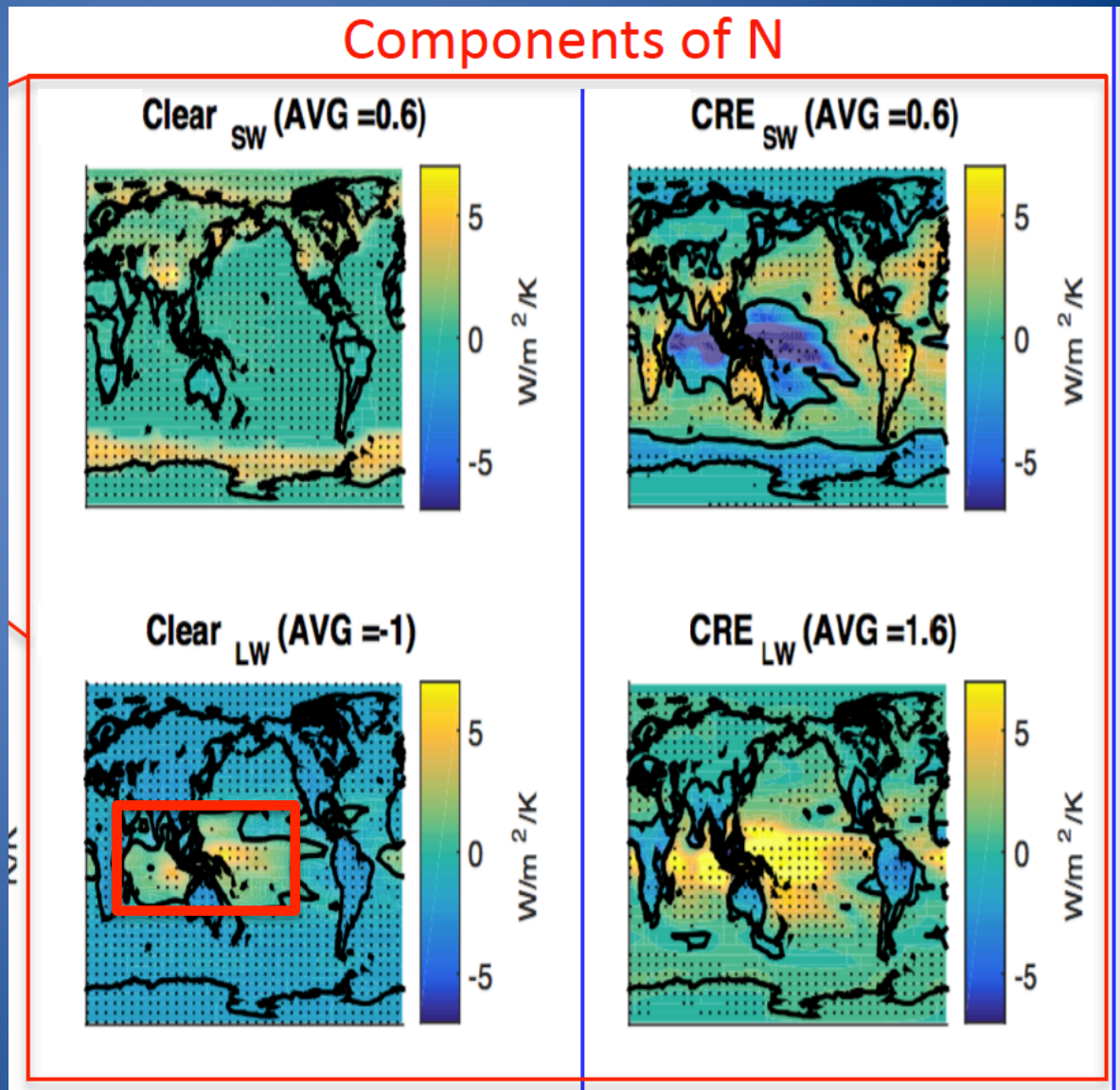




Why is the local N(θ,Φ) vs. T(θ,Φ) relationship mostly positive?

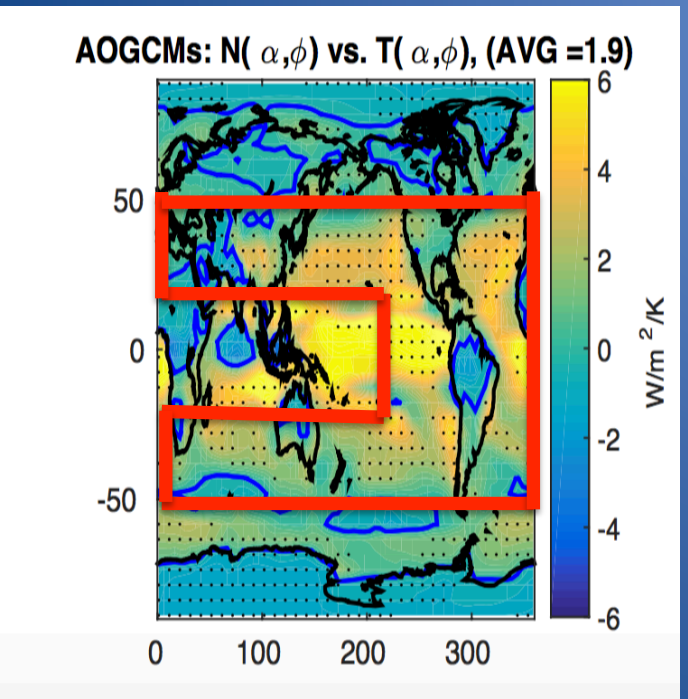
- Planck Response evident in the $Clear_{LW}$ component elsewhere

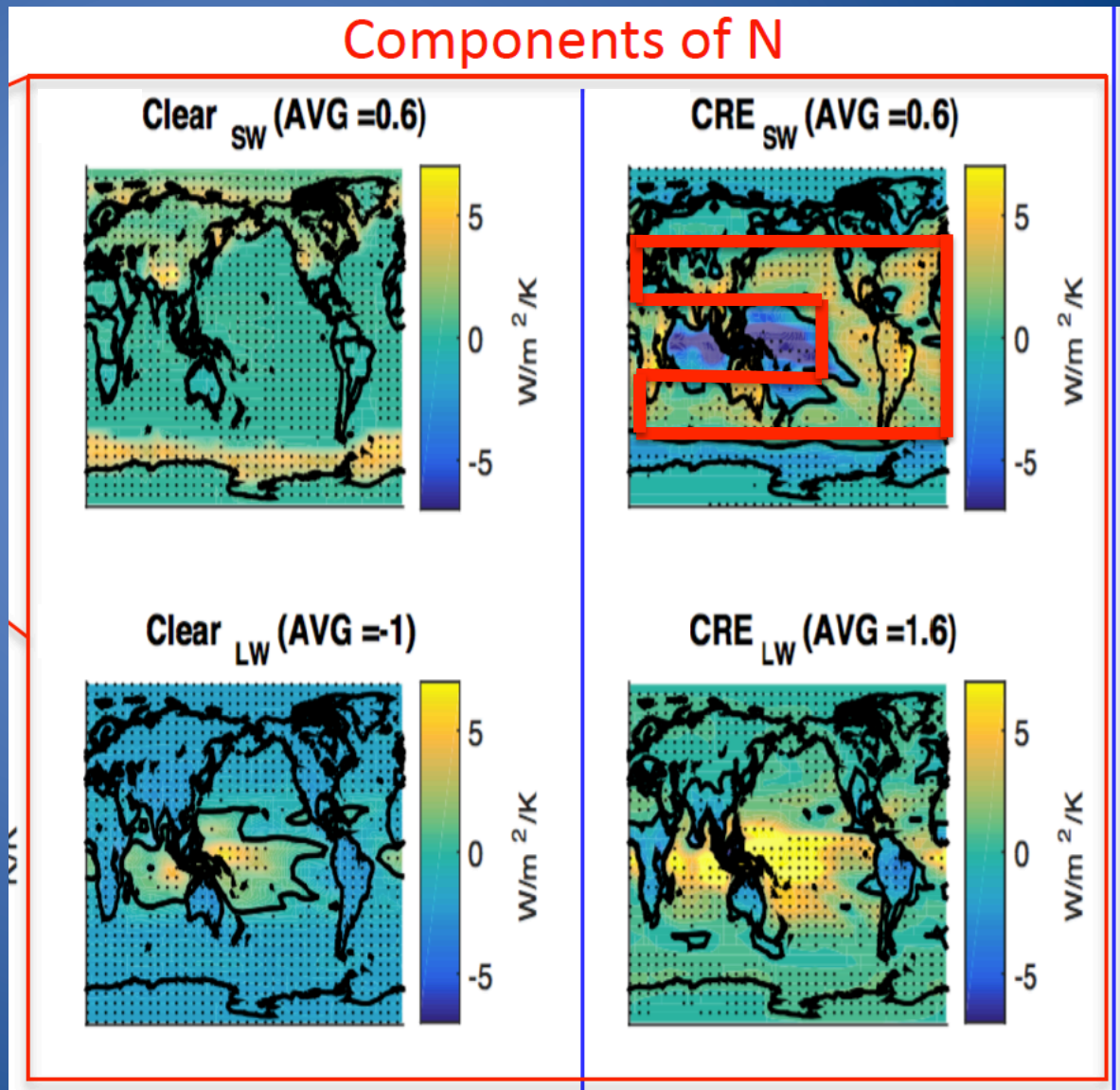




Why is the local N(θ,Φ) vs. T(θ,Φ) relationship mostly positive?

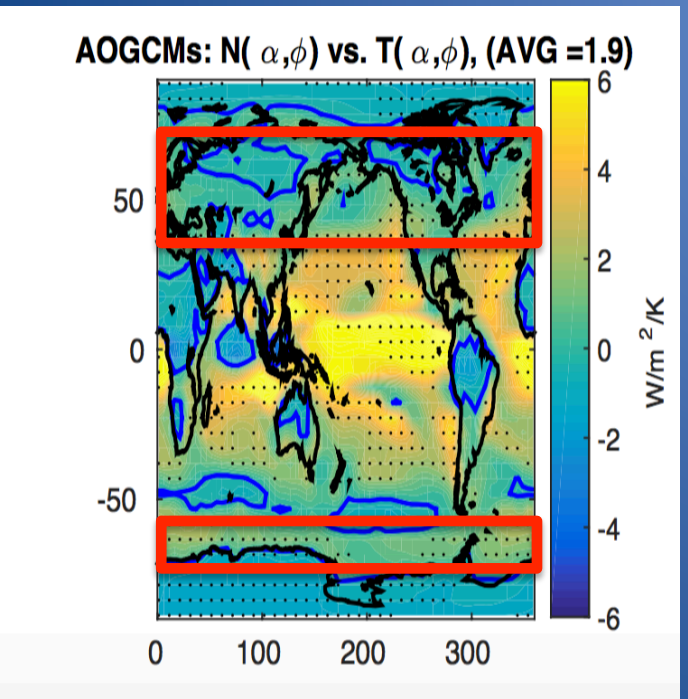
- Due to the cloud shortwave component in regions with intermediate to high climatological T(θ,Φ)

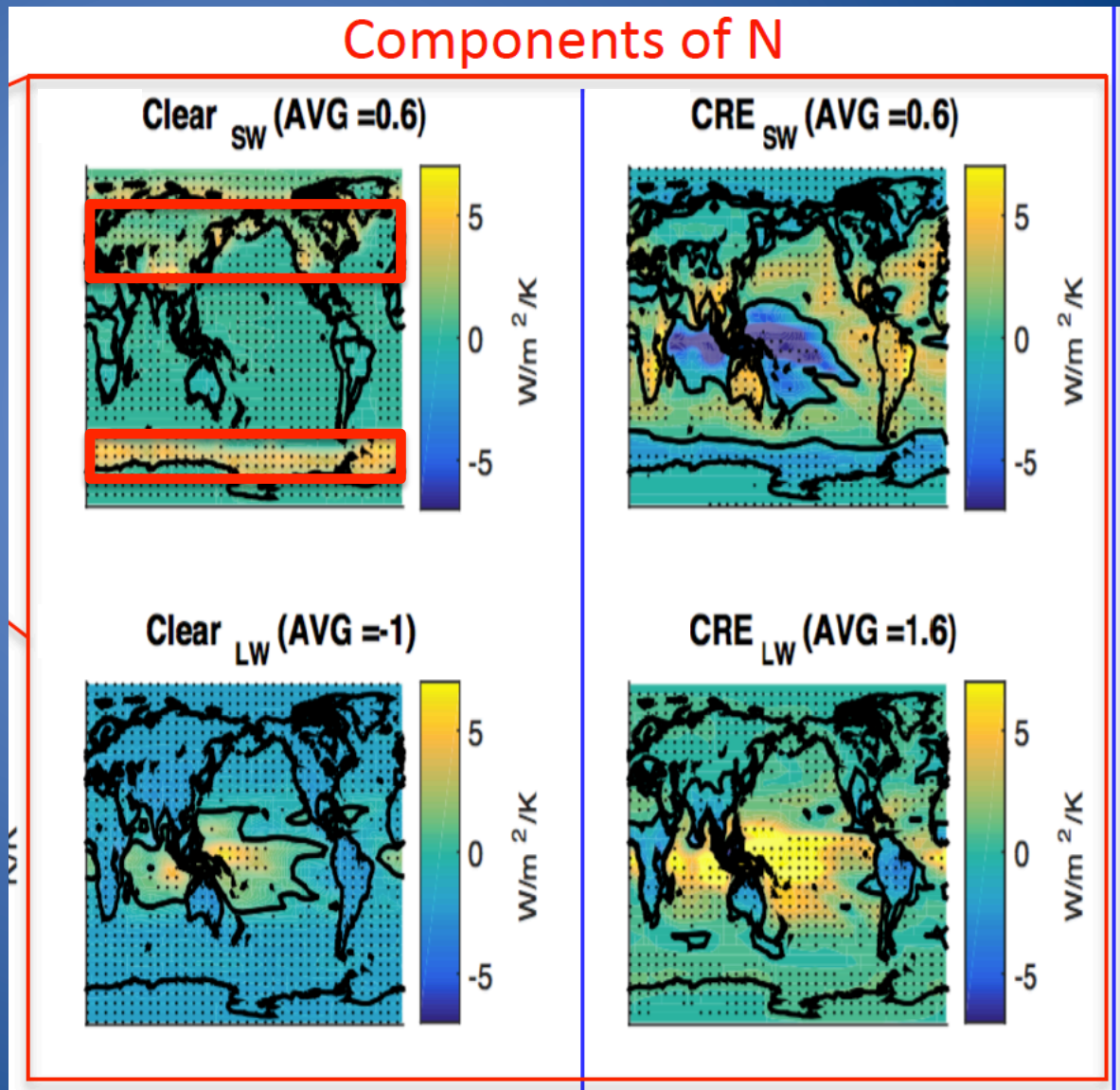




Why is the local N(θ,Φ) vs. T(θ,Φ) relationship mostly positive?

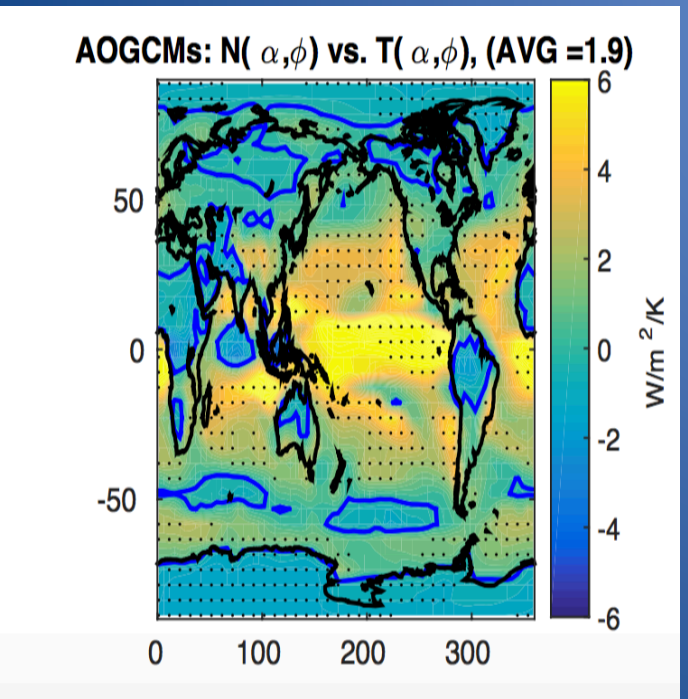
- Due to the surface shortwave component in regions with climatological T(θ,Φ) near the freezing point of water

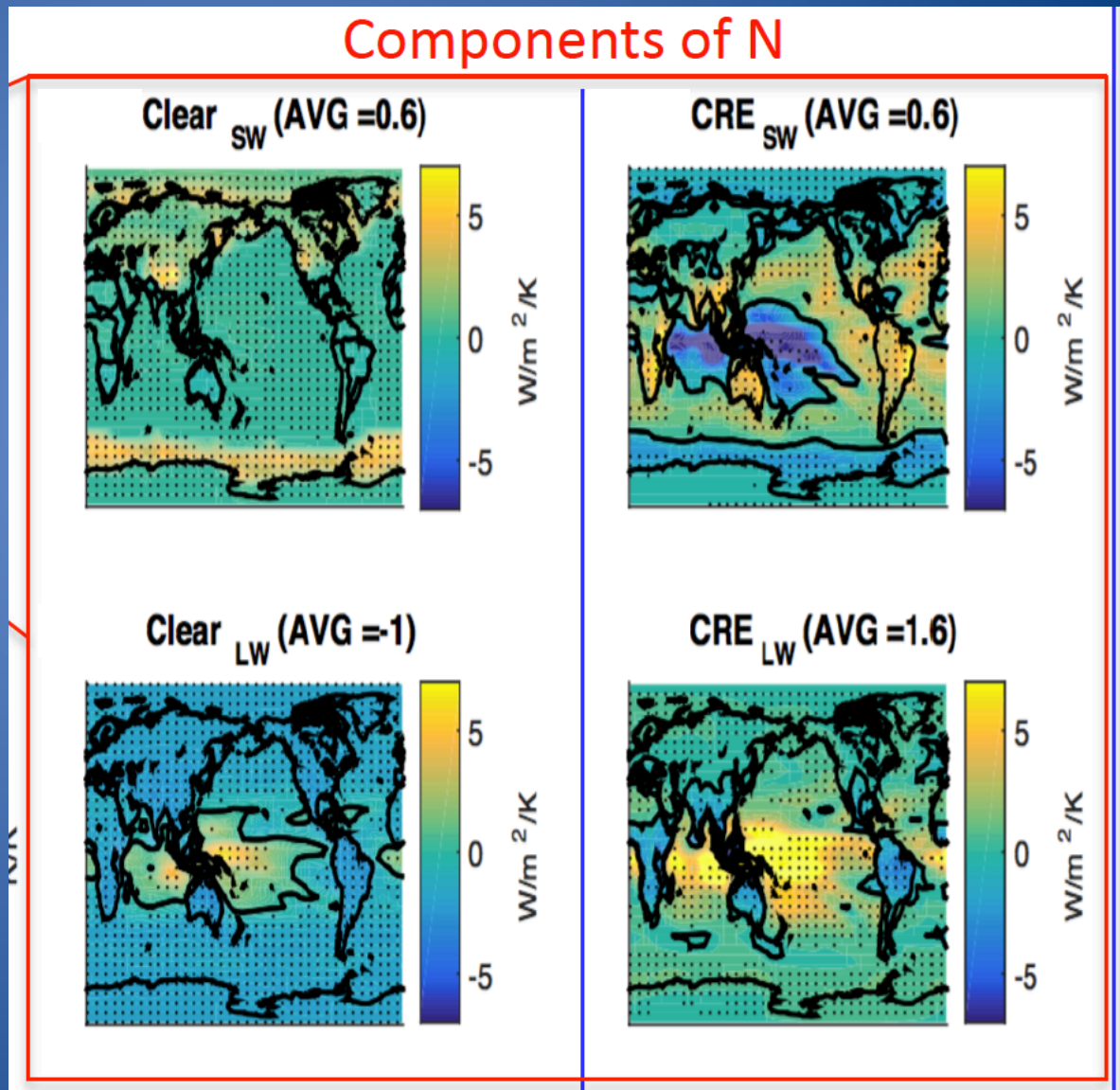




Why is the local N(θ,Φ) vs. T(θ,Φ) relationship mostly positive?

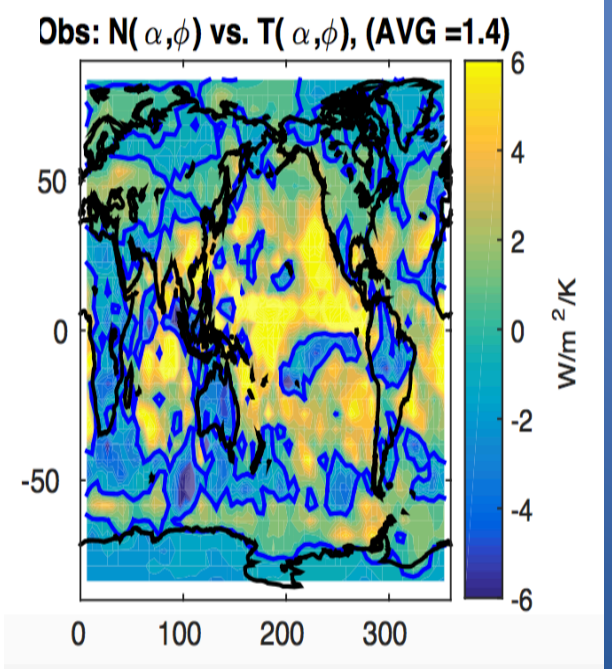
AOGCM control runs

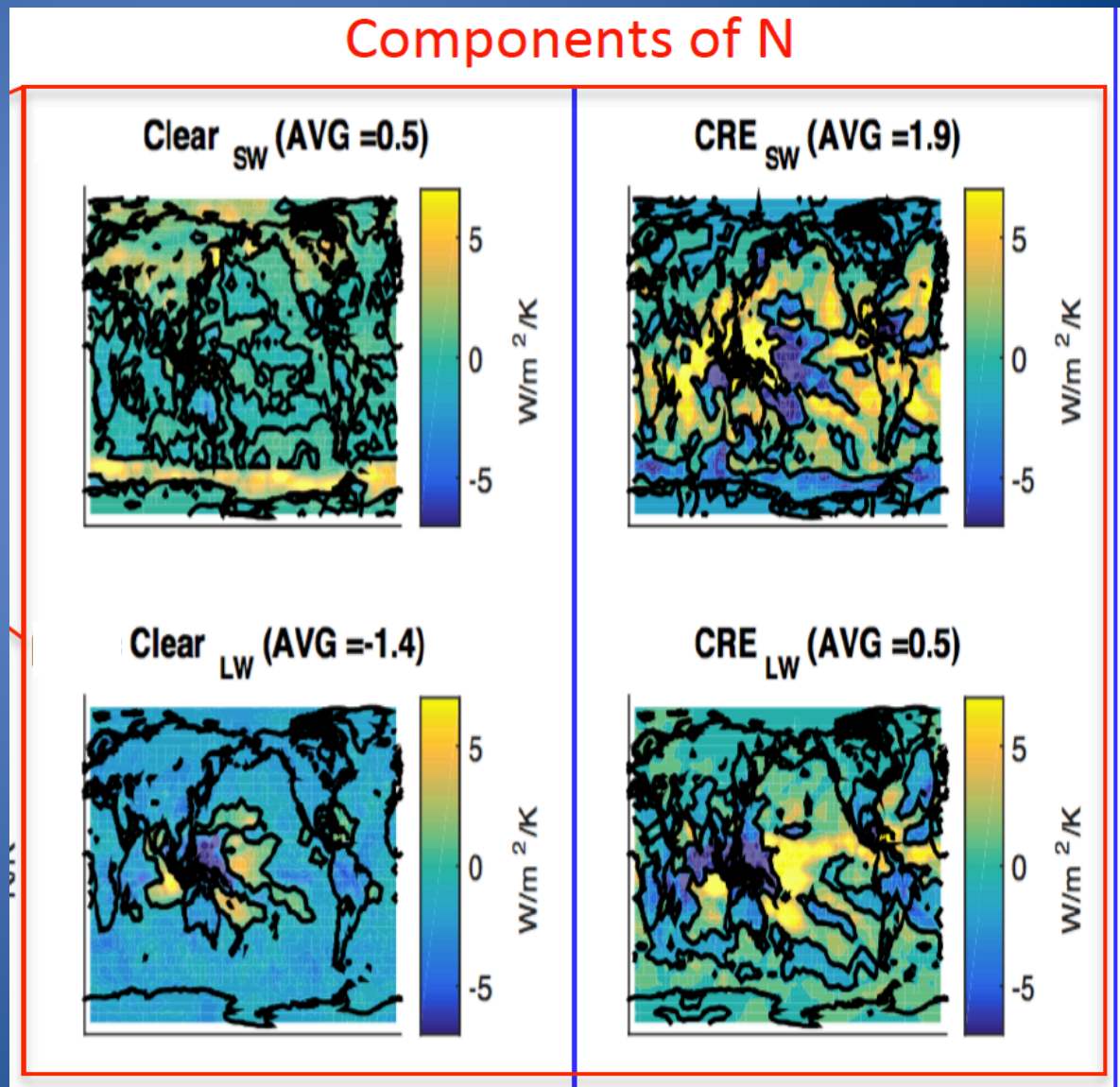


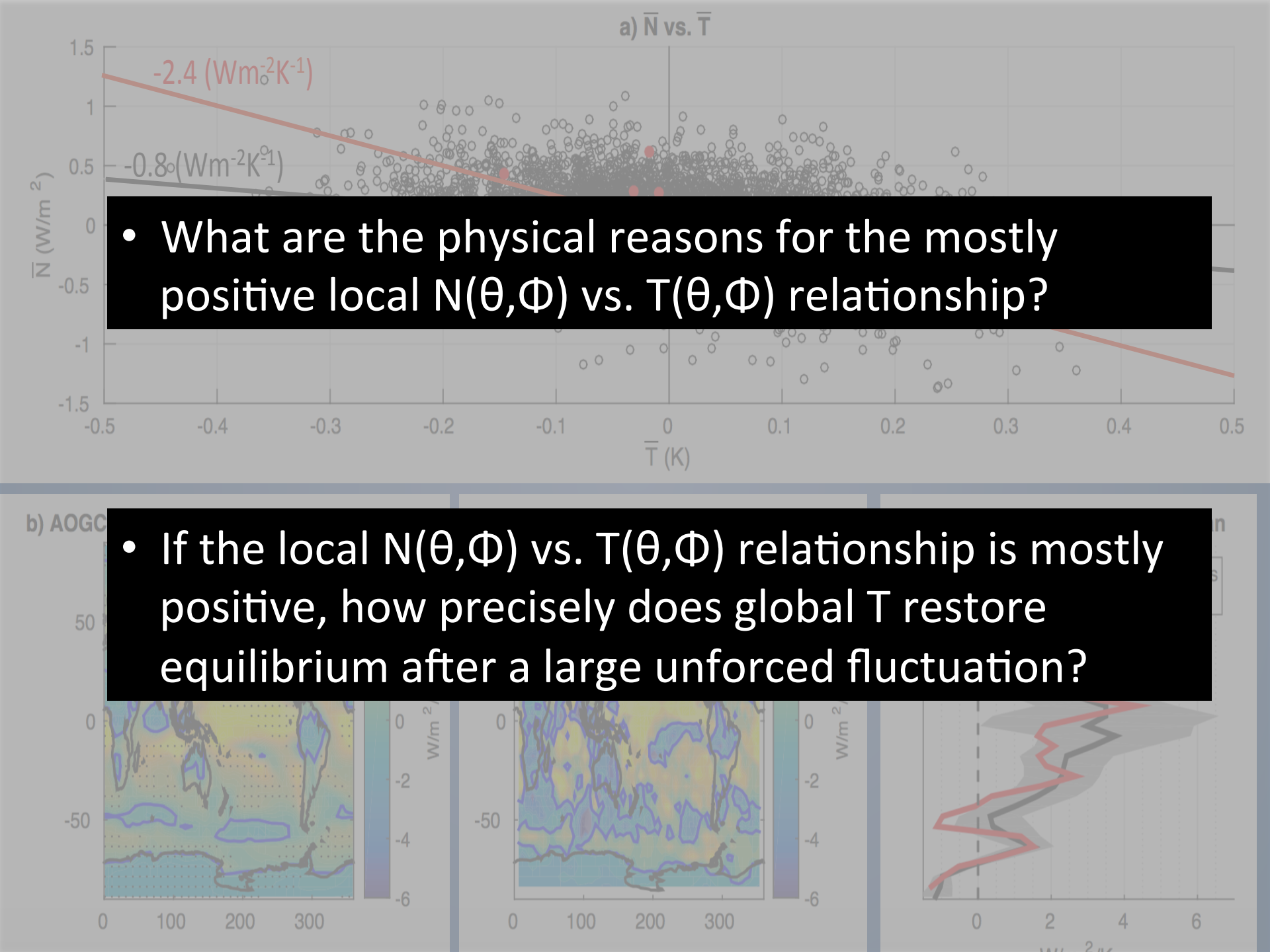


Why is the local N(θ,Φ) vs. T(θ,Φ) relationship mostly positive?

CERES/ERA-I







- What are the physical reasons for the mostly positive local N(θ,Φ) vs. T(θ,Φ) relationship?

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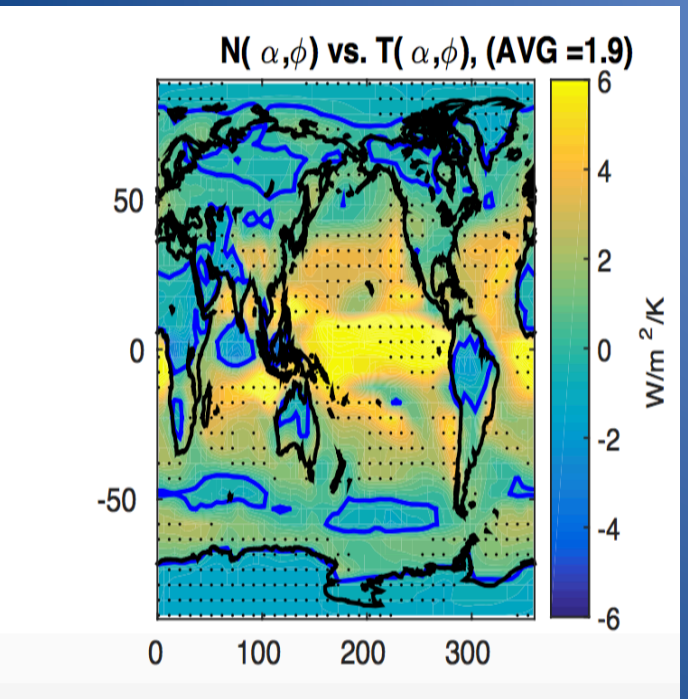
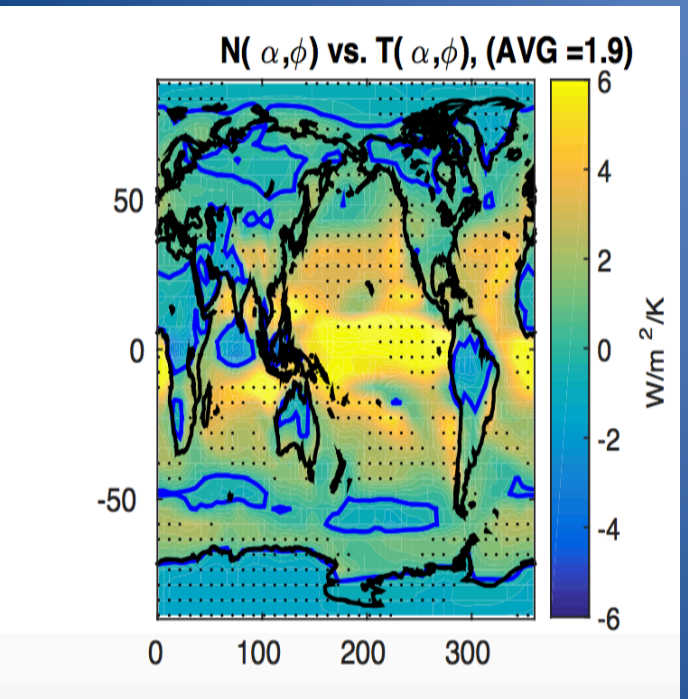
How precisely does global T restore equilibrium after a large unforced fluctuation?



How precisely does global T restore equilibrium after a large unforced fluctuation?

AOGCM control runs

Regression against global T



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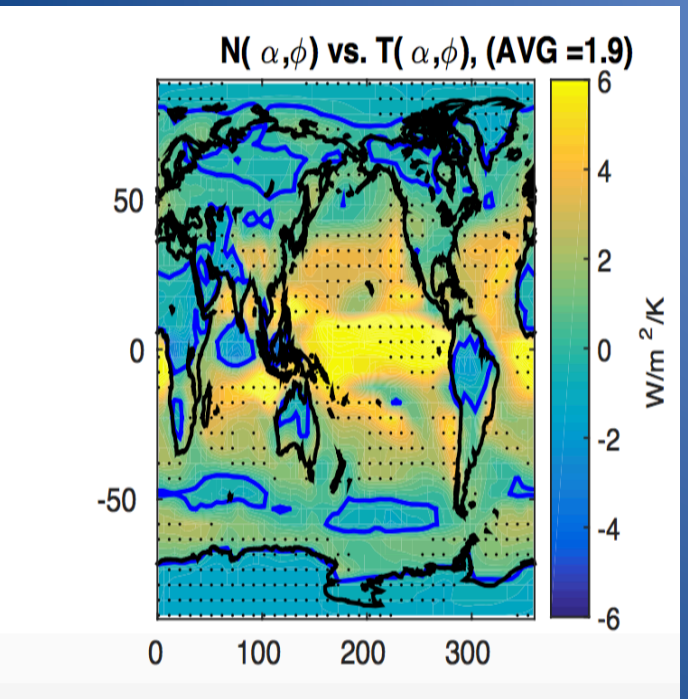
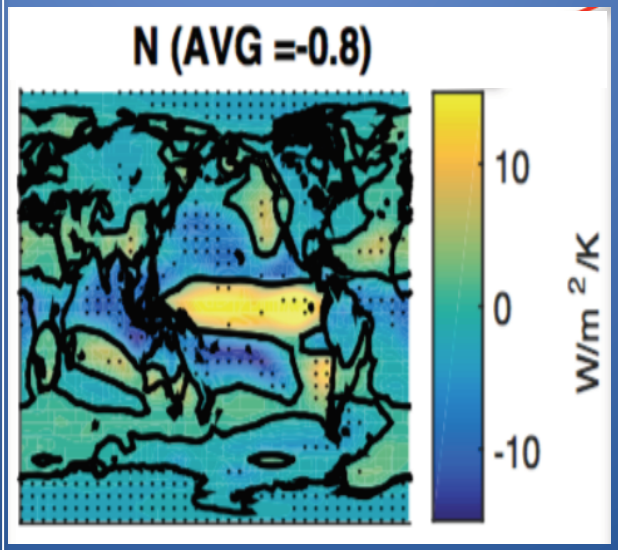
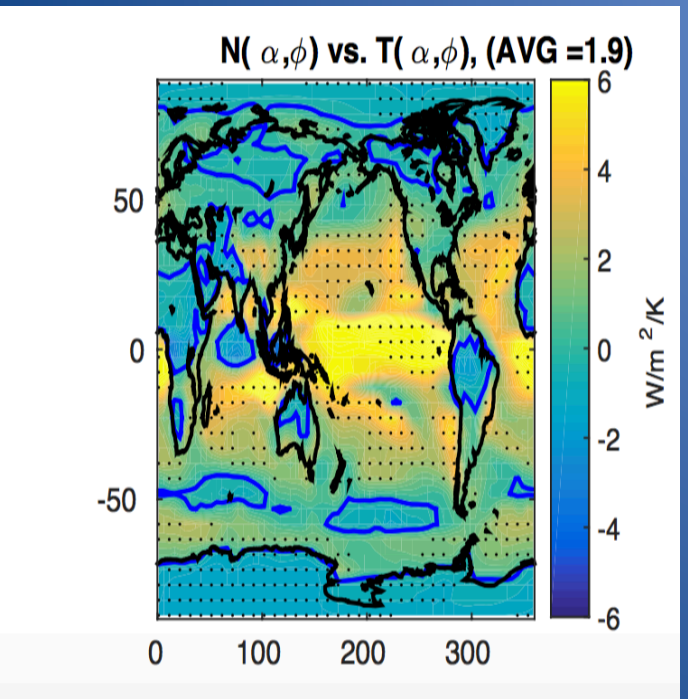


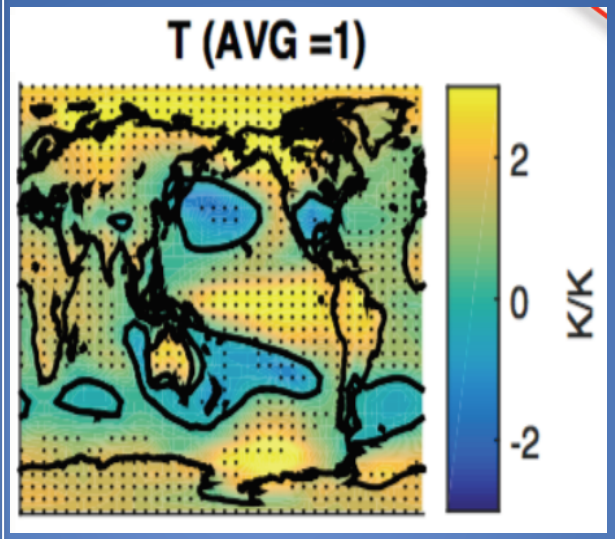


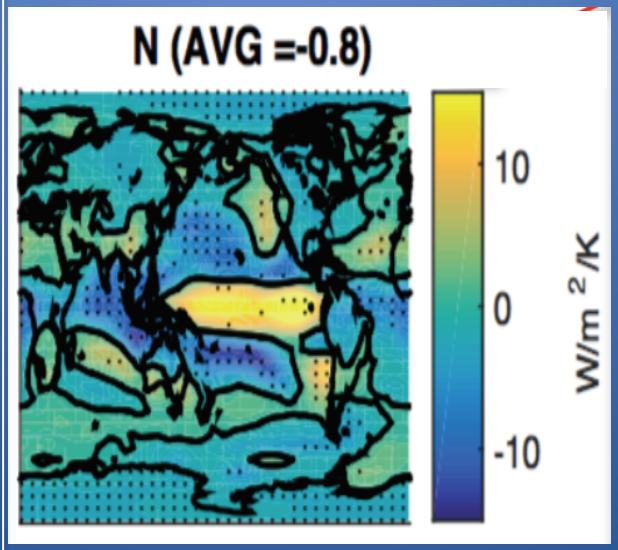
How precisely does global T restore equilibrium after a large unforced fluctuation?

- Positive T anomalies associated with El Niño events



Regression against global T

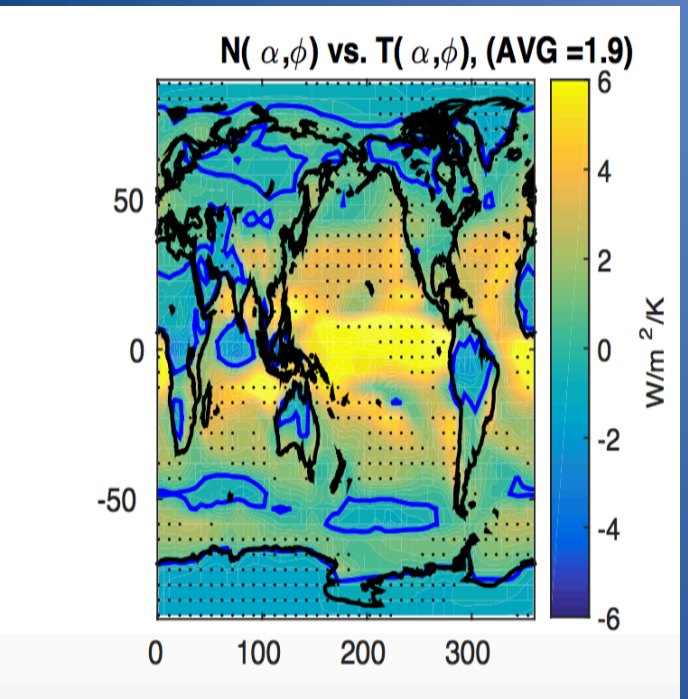




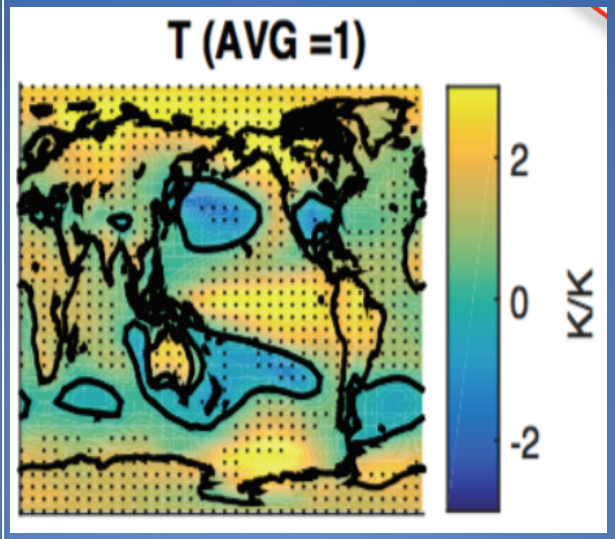
How precisely does global T restore equilibrium after a large unforced fluctuation?

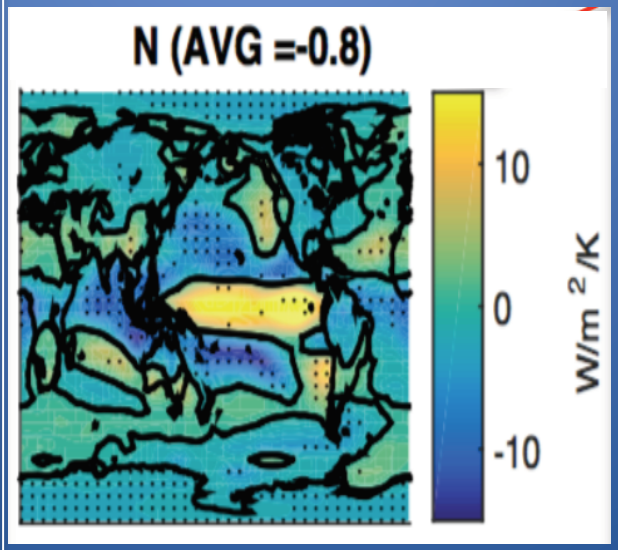
AOGCM control runs

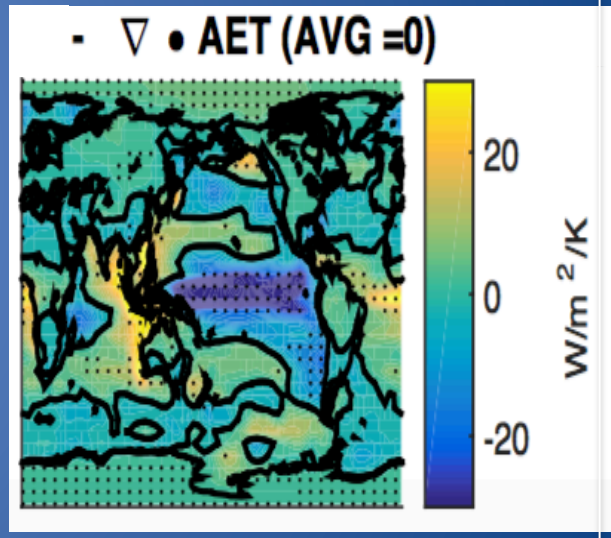
- Large horizontal divergence (convergence) of atmospheric energy transport over the tropical Pacific (high latitudes)



Regression against global T



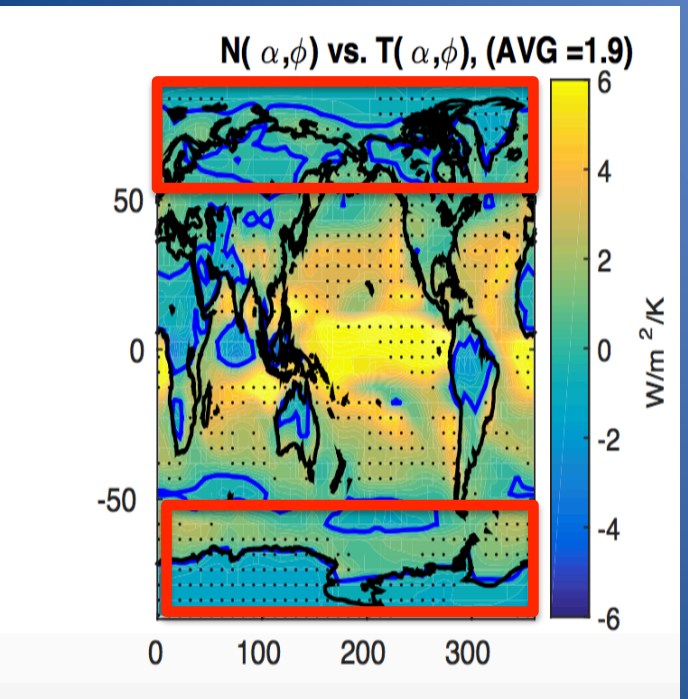




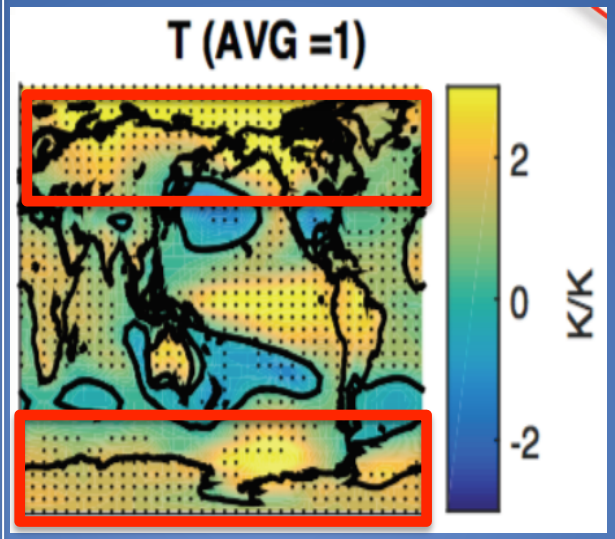
How precisely does global T restore equilibrium after a large unforced fluctuation?

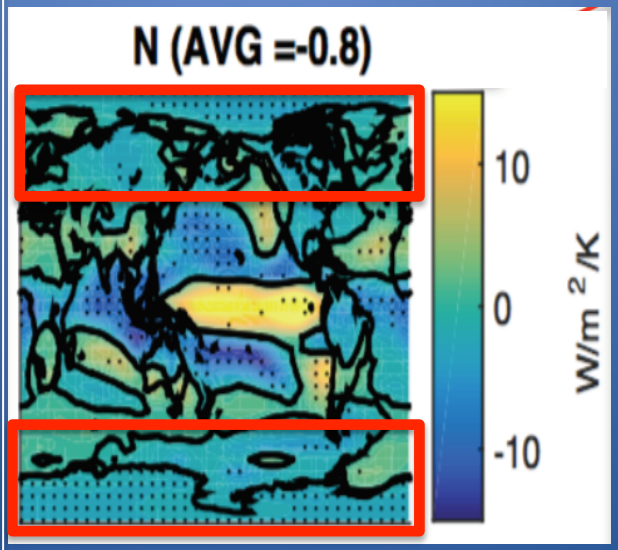
AOGCM control runs

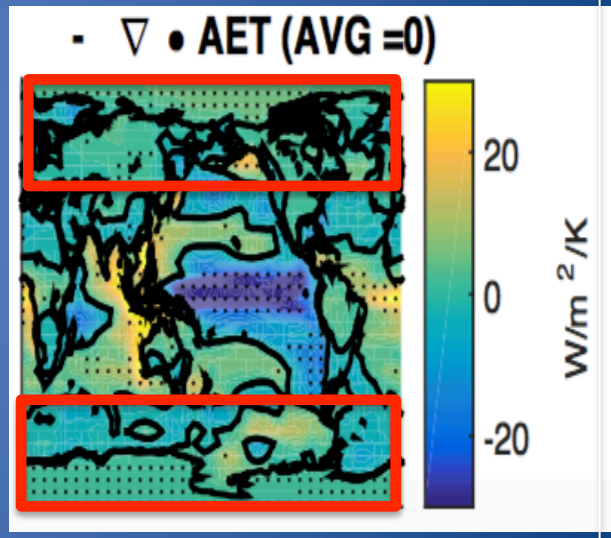
- Characteristic T(θ,Φ) vs. T pattern with a substantial amount of warmth at high latitudes where the temperature anomaly can be easily damped to space



Regression against global T



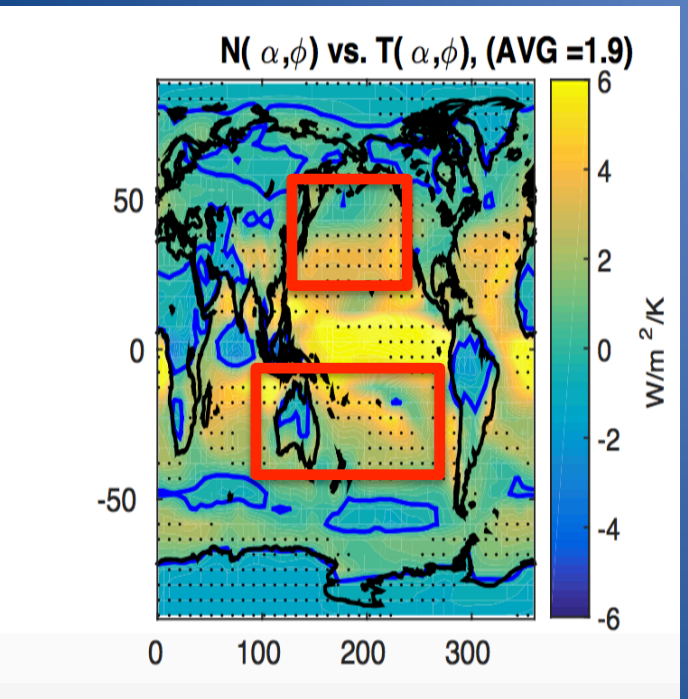




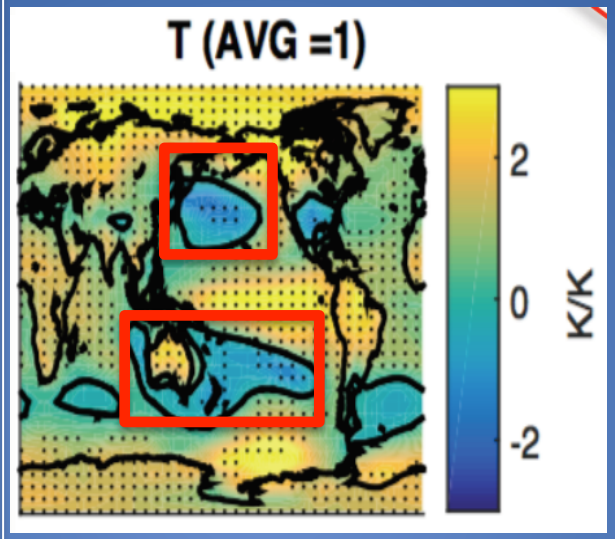
How precisely does global T restore equilibrium after a large unforced fluctuation?

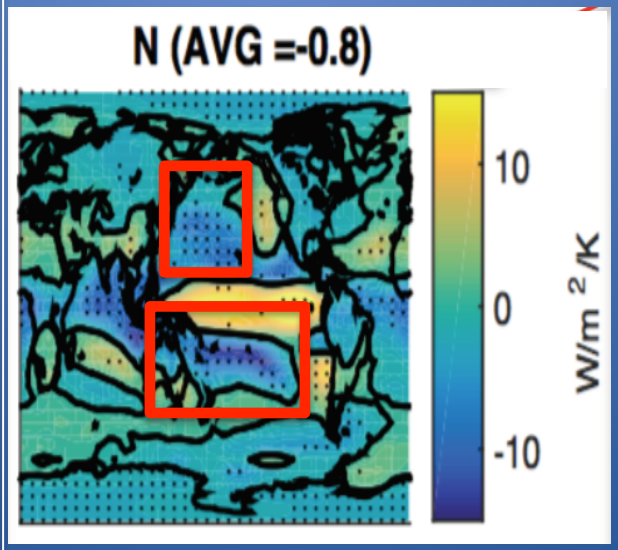
AOGCM control runs

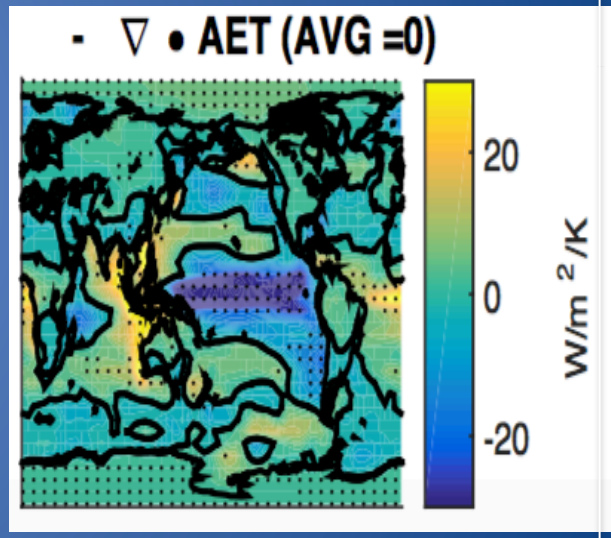
- Characteristic T(θ,Φ) vs. T pattern contains anomalously cool T(θ,Φ) regions where locally positive N(θ,Φ) vs. T(θ,Φ) relationship promotes negative N(θ,Φ)



Regression against global T







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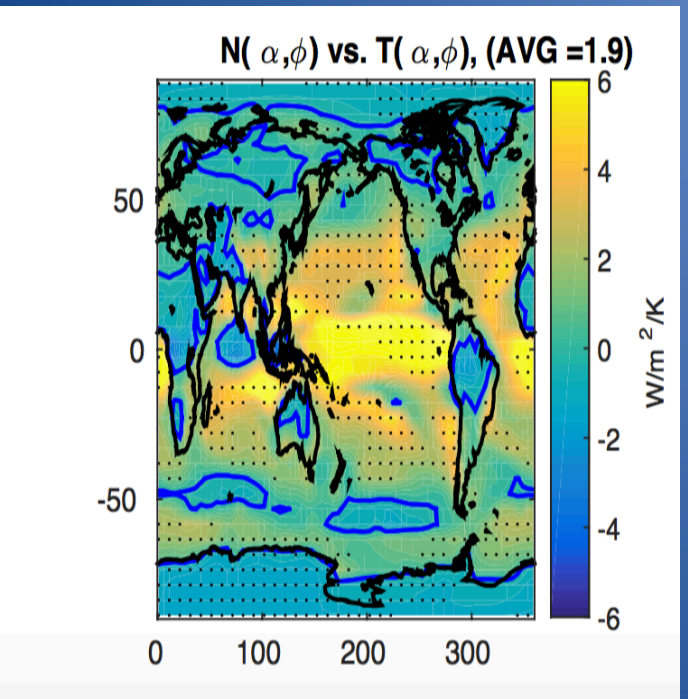
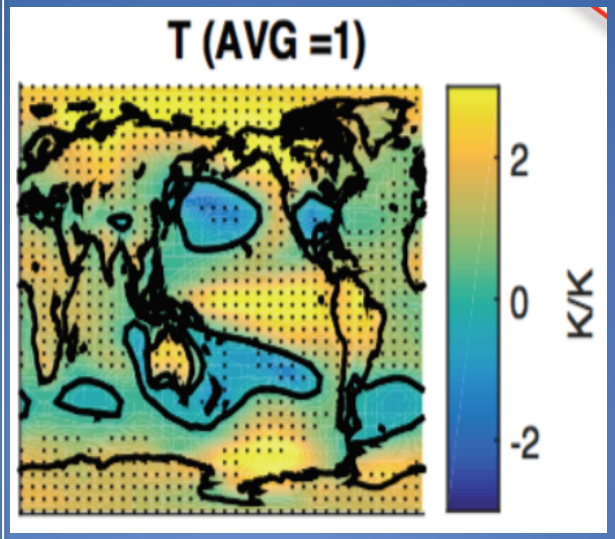
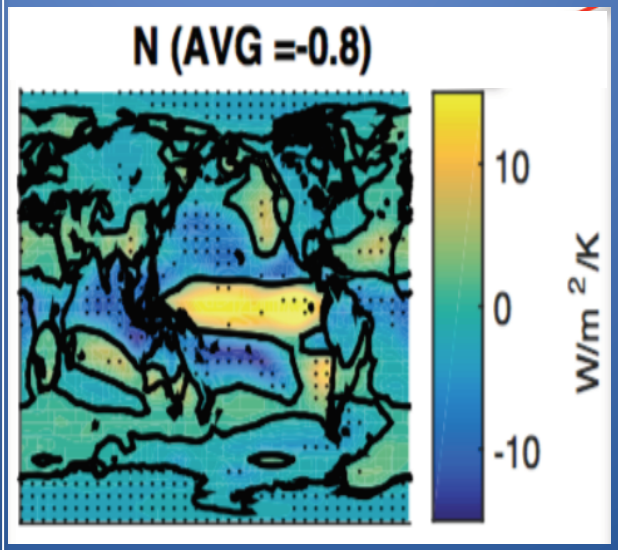
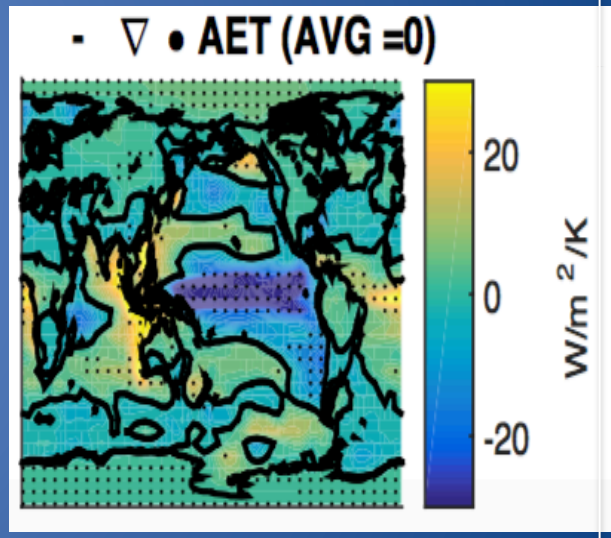
Regression against global T





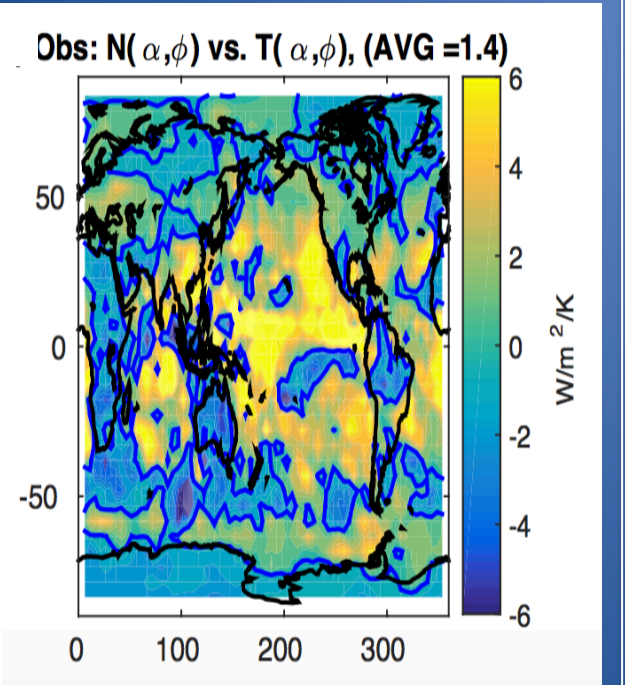


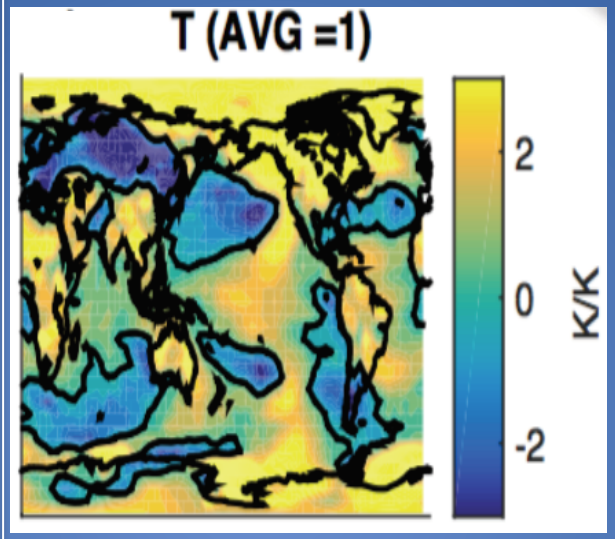


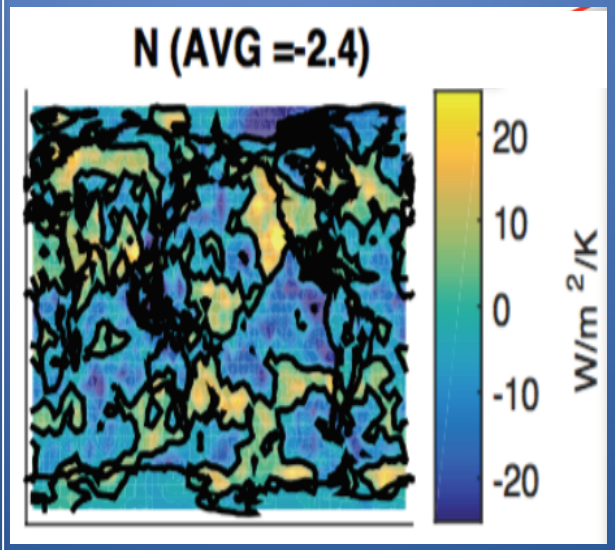
How precisely does global T restore equilibrium after a large unforced fluctuation?

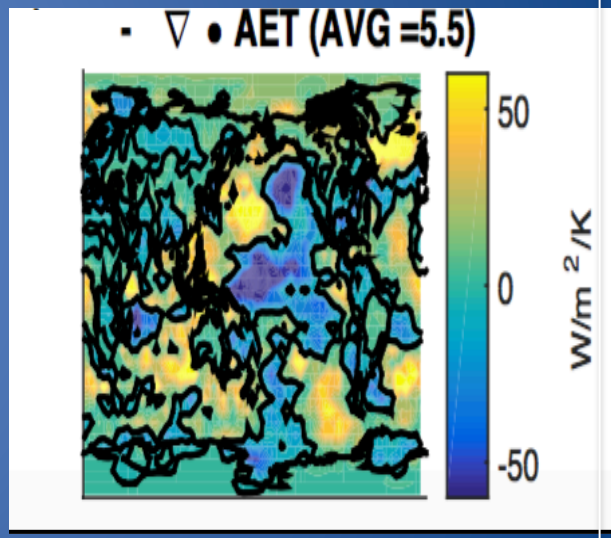
CERES/ERA-I

Regression against global T





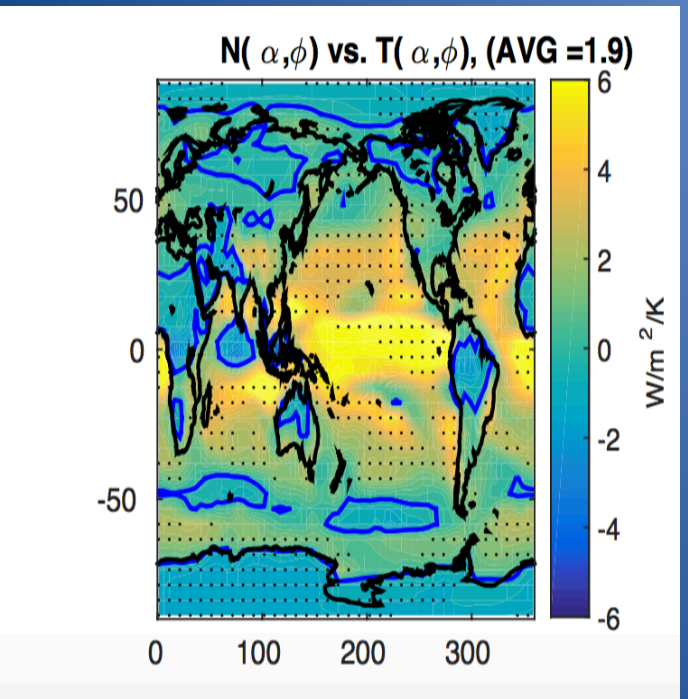


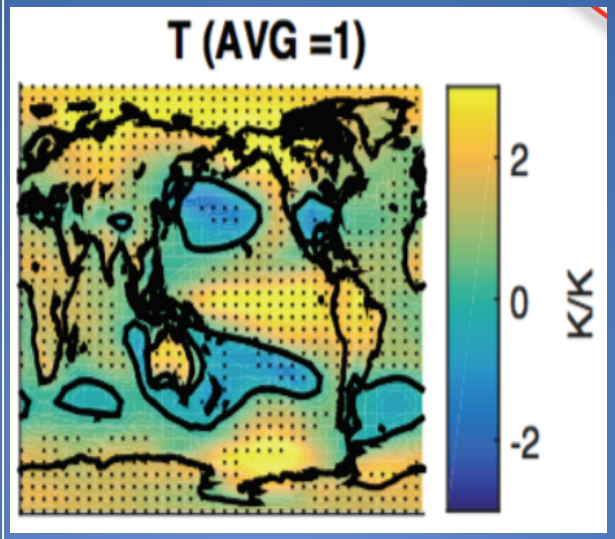


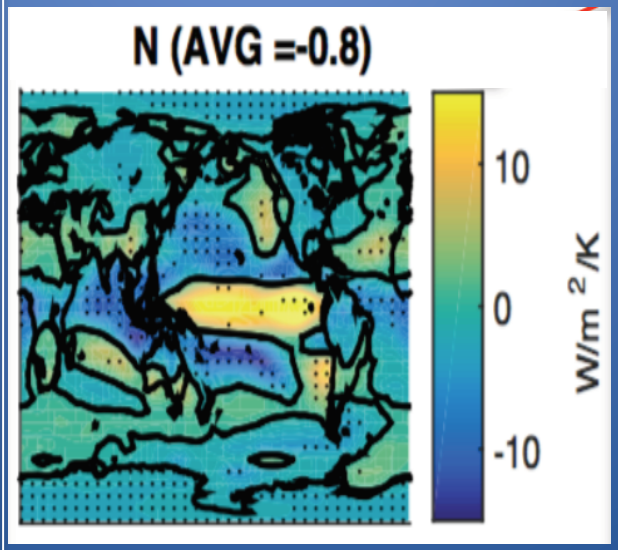
How precisely does global T restore equilibrium after a large unforced fluctuation?

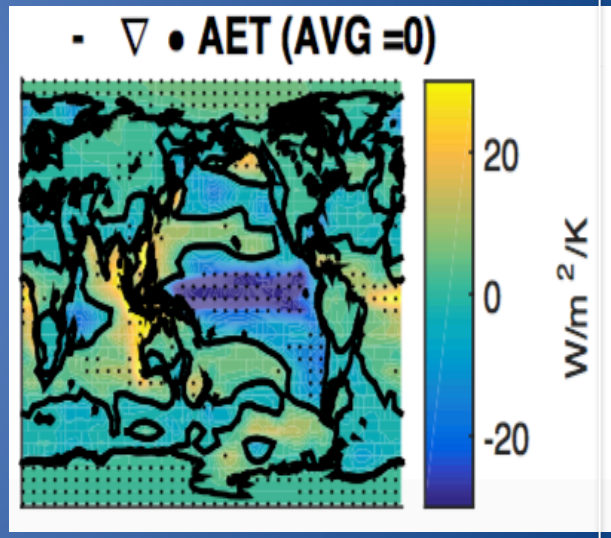
AOGCM control runs

Regression against global T



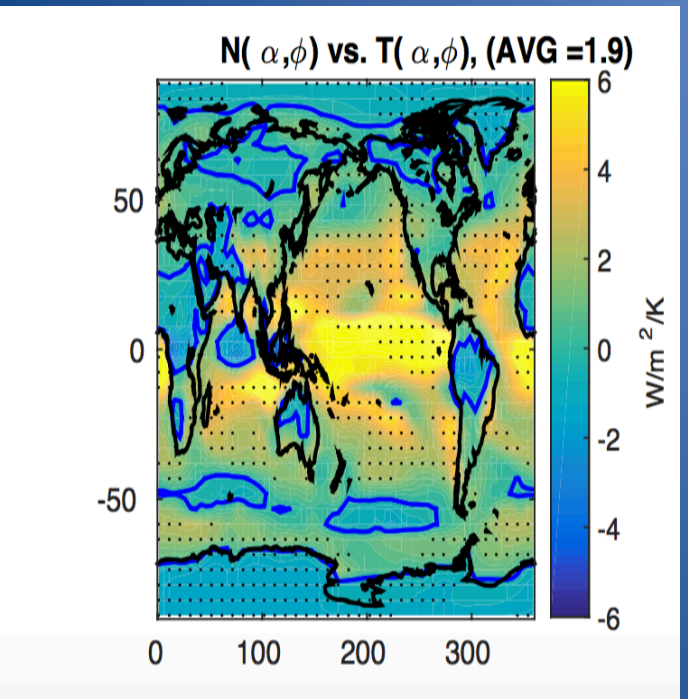






Is the characteristic T(θ,Φ) vs. global T pattern the whole story?

AOGCM control runs



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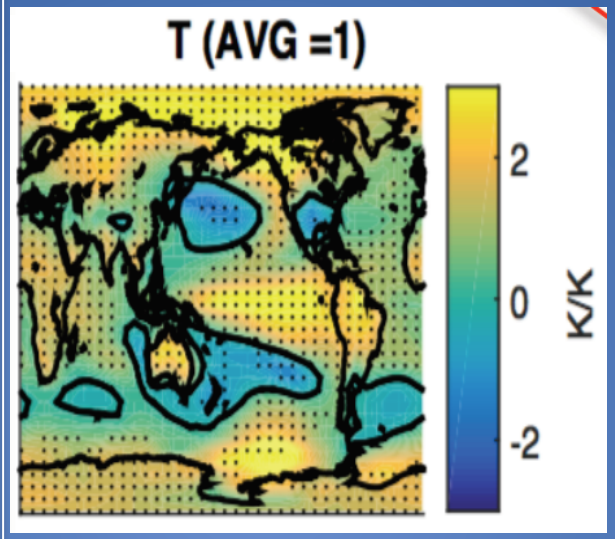

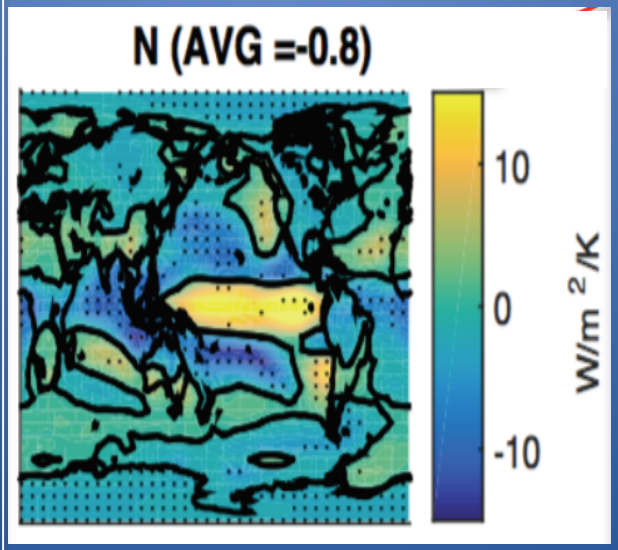

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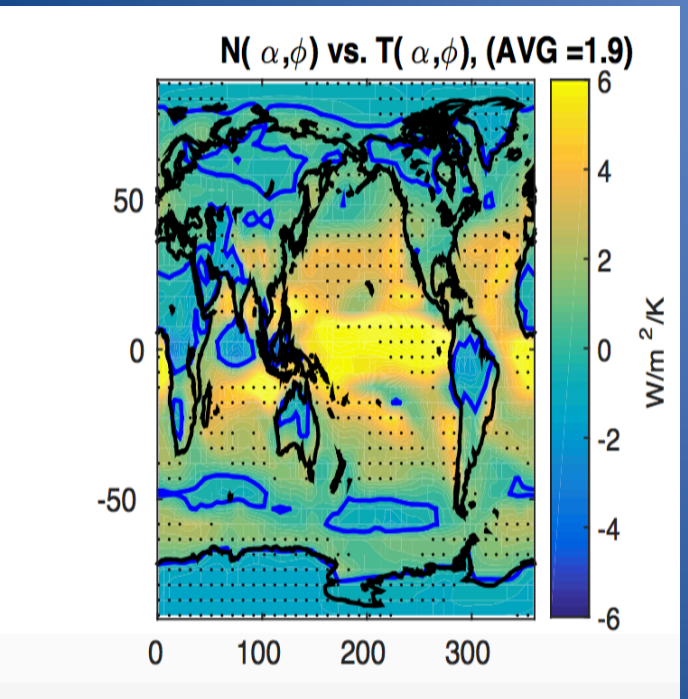
- Test this by multiplying the 'local feedback' relationship by the characteristic surface temperature distribution associated with global T variability…



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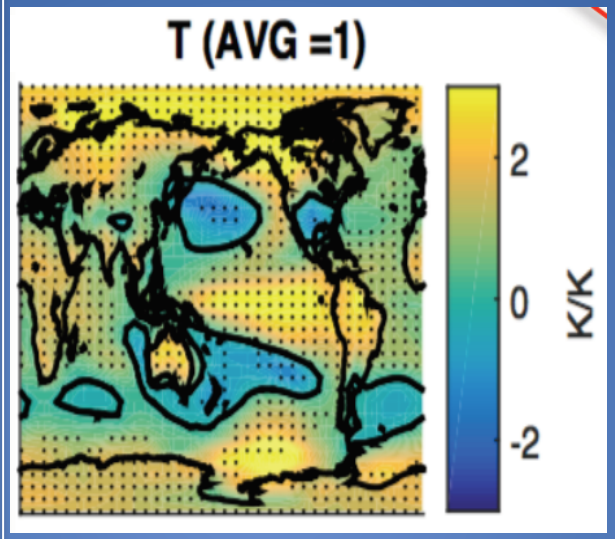

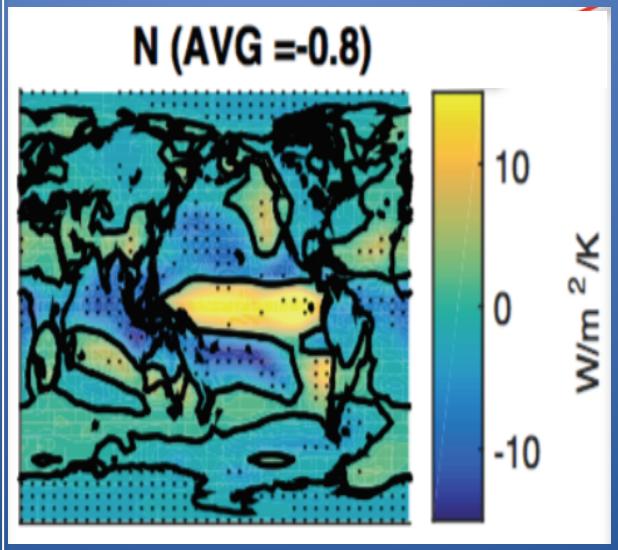

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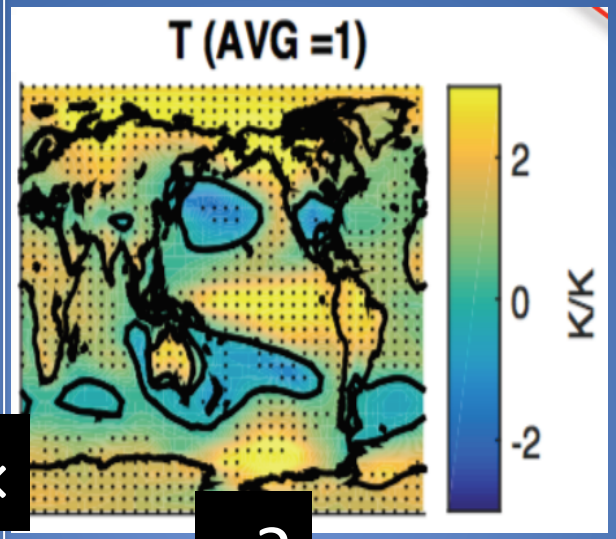

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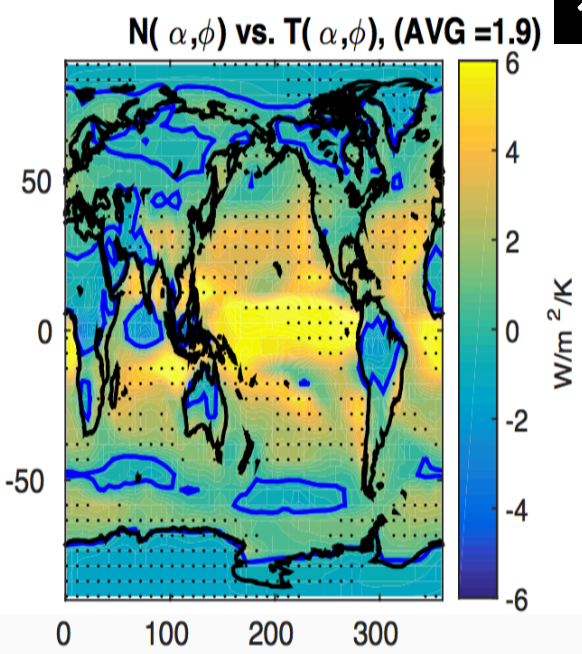

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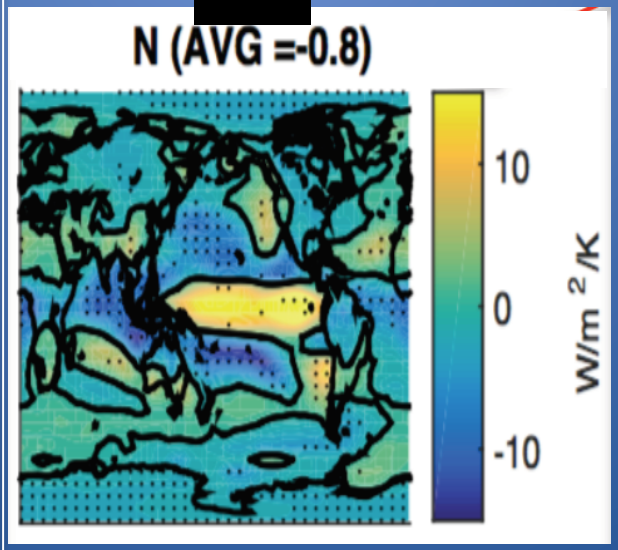

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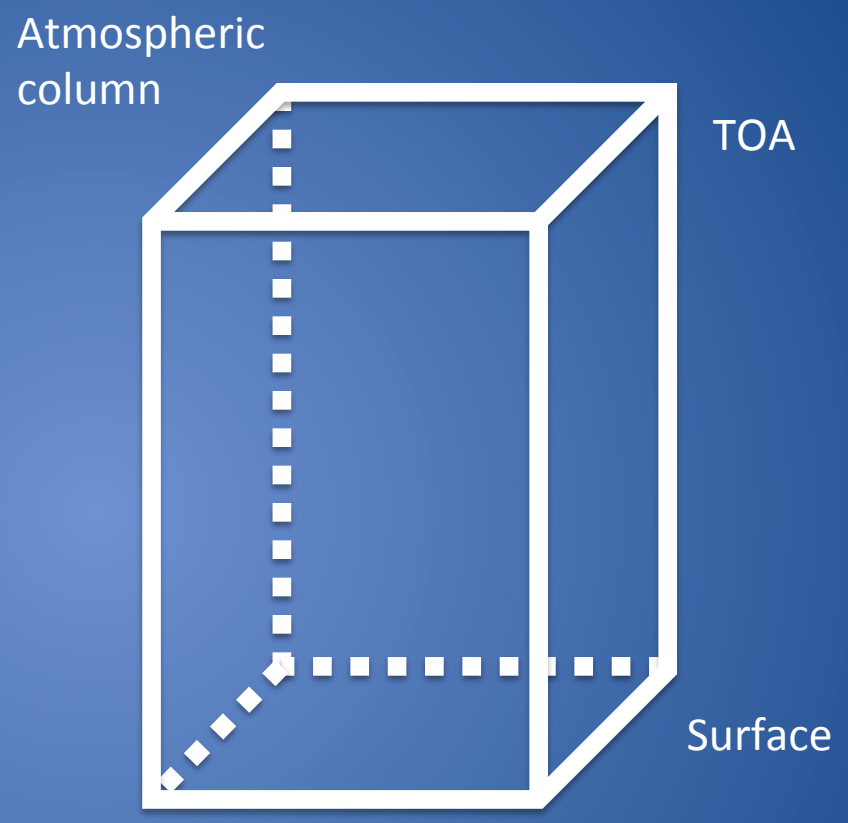

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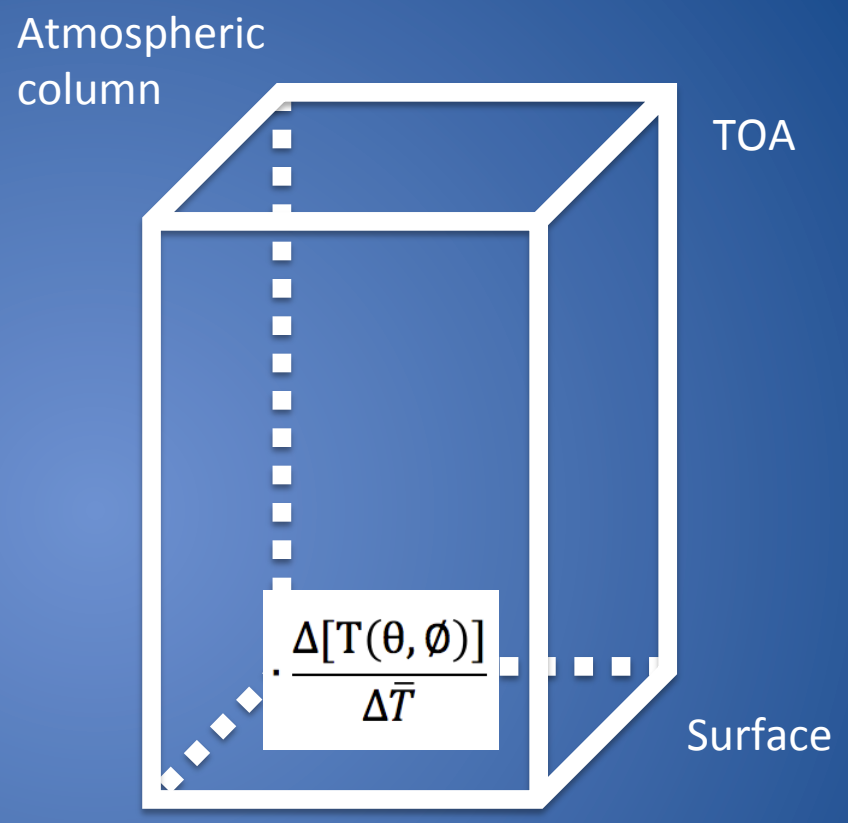

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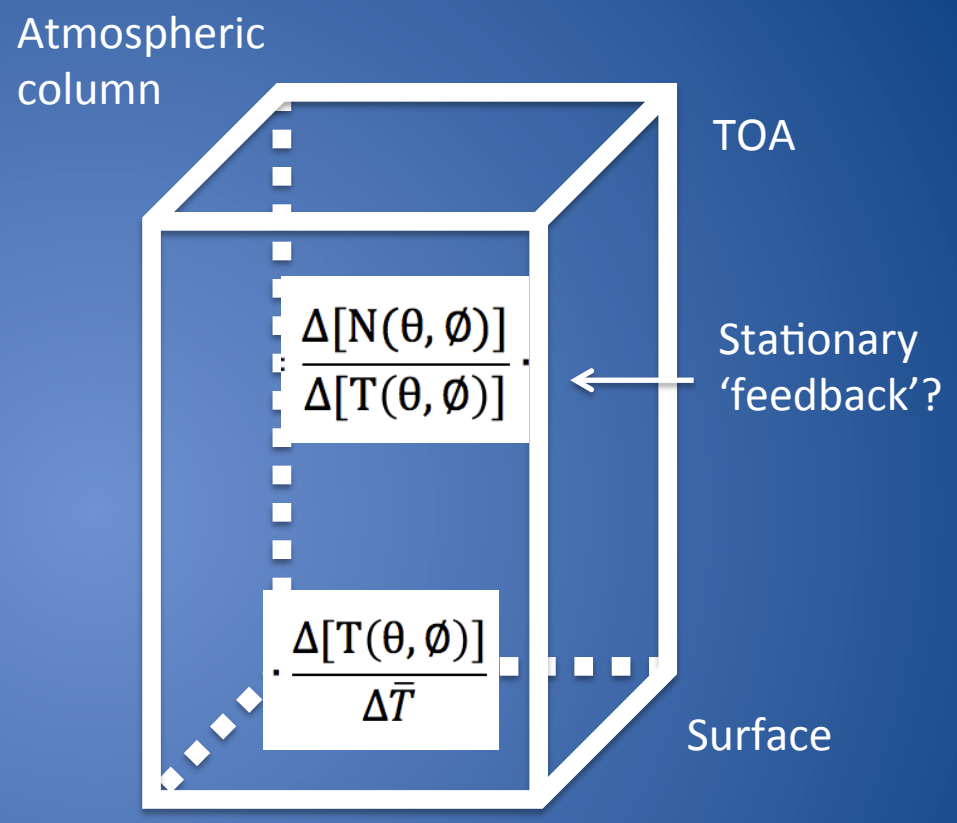

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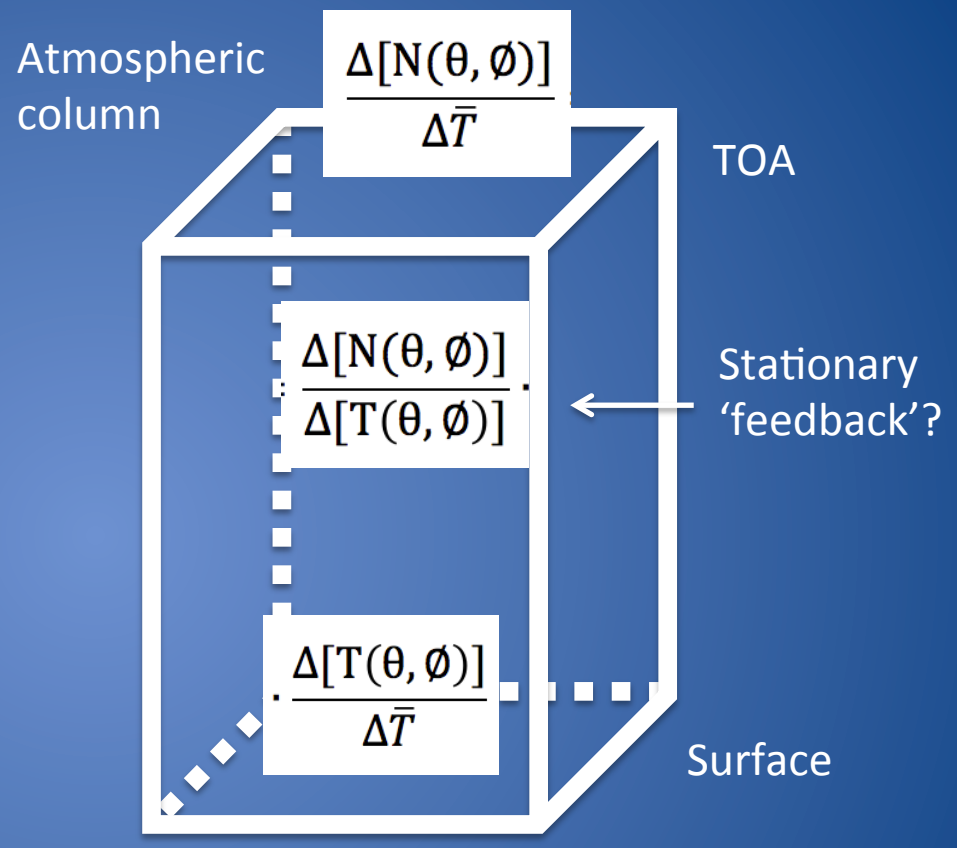

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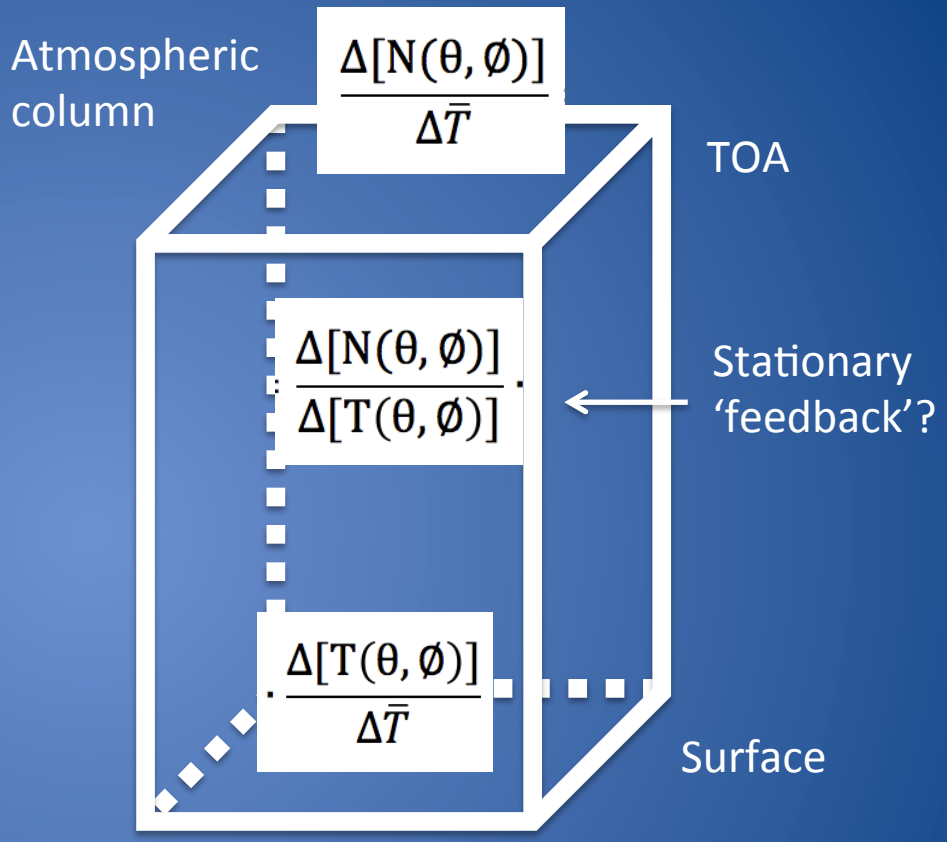

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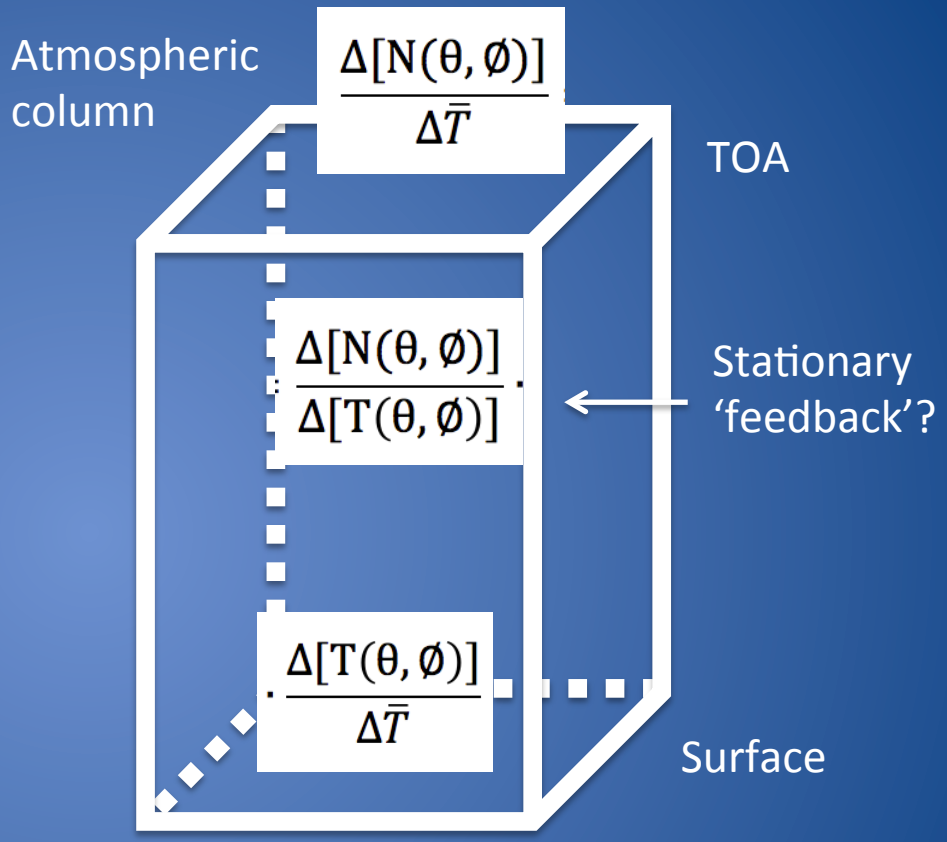

$$\frac{\Delta[N(\theta,\emptyset)]}{\Delta\bar{T}} = \frac{\Delta[N(\theta,\emptyset)]}{\Delta[T(\theta,\emptyset)]} \cdot \frac{\Delta[T(\theta,\emptyset)]}{\Delta\bar{T}}$$

???

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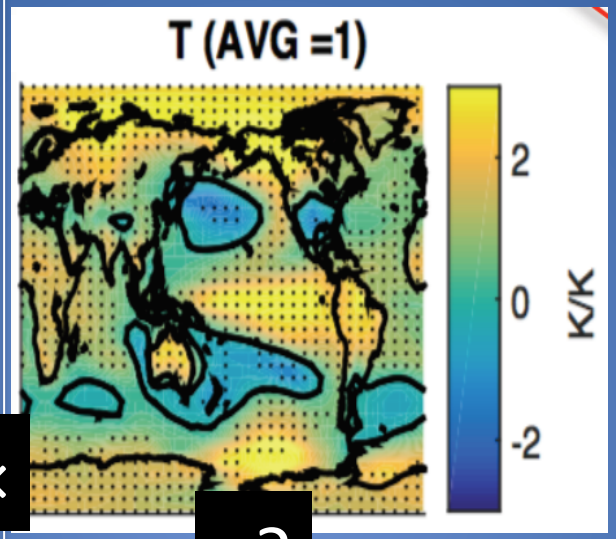
Regression against global T



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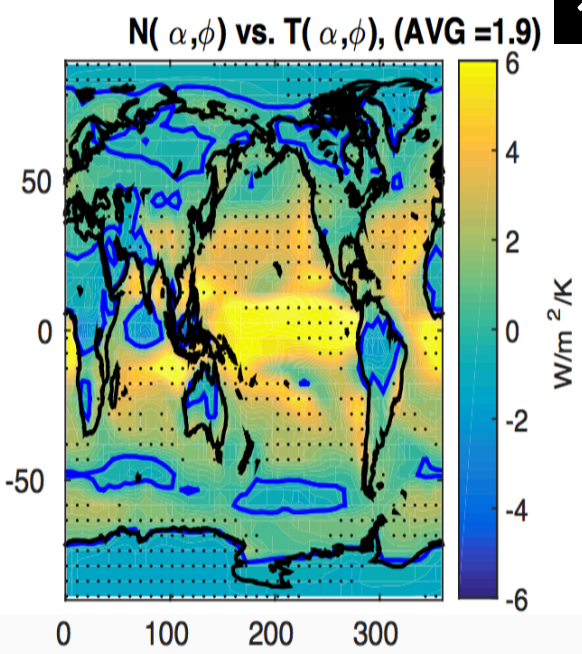

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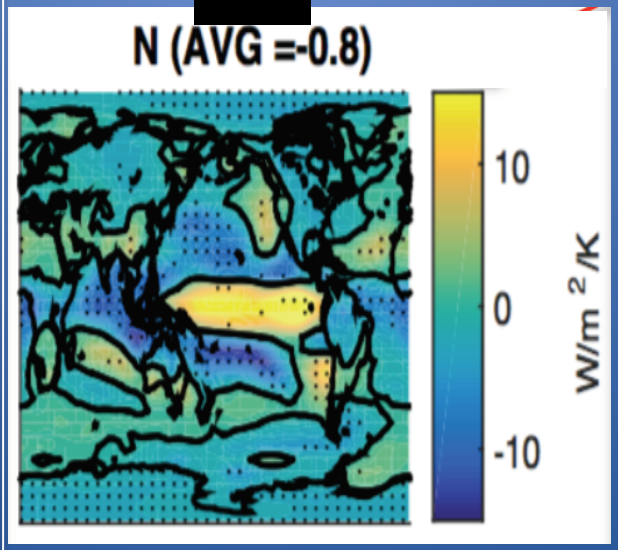

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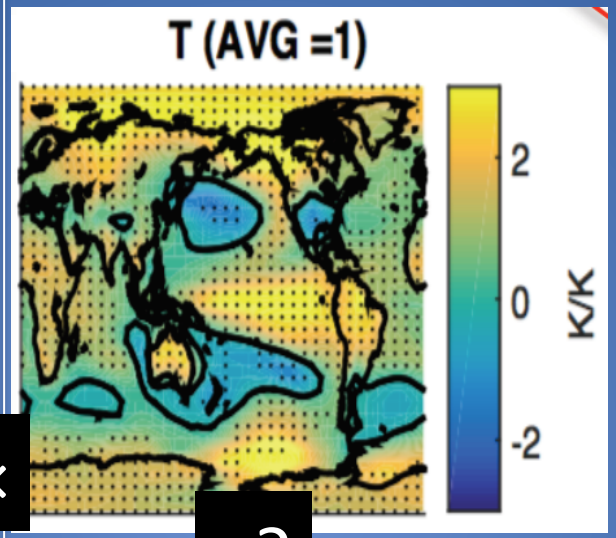

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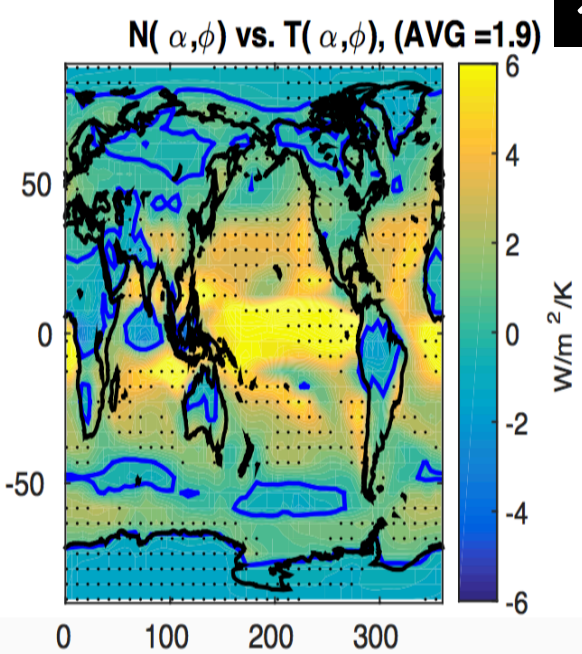

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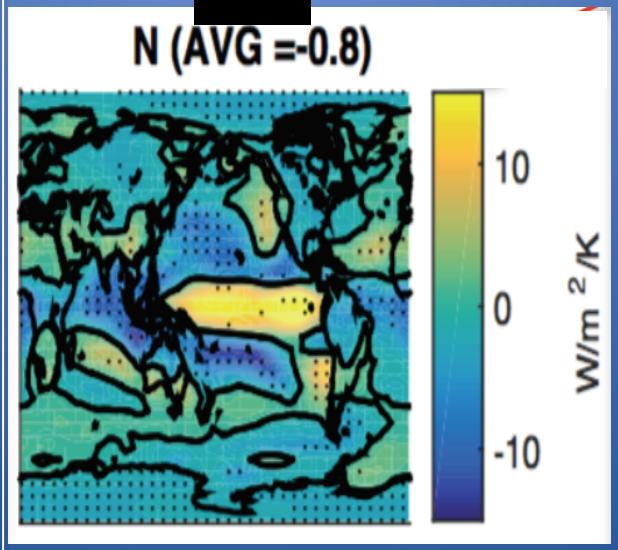

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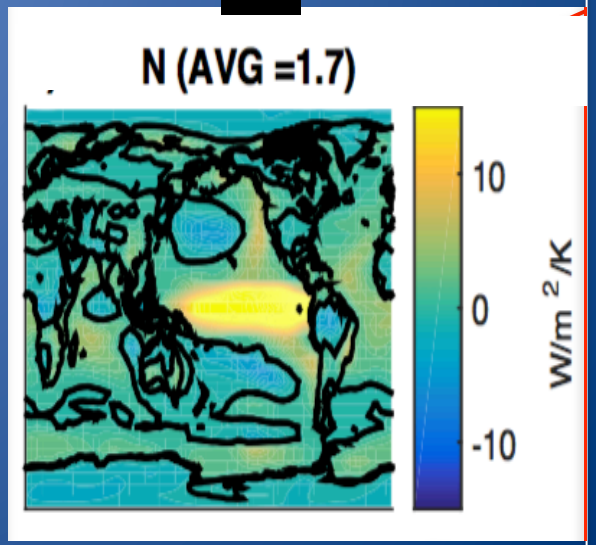
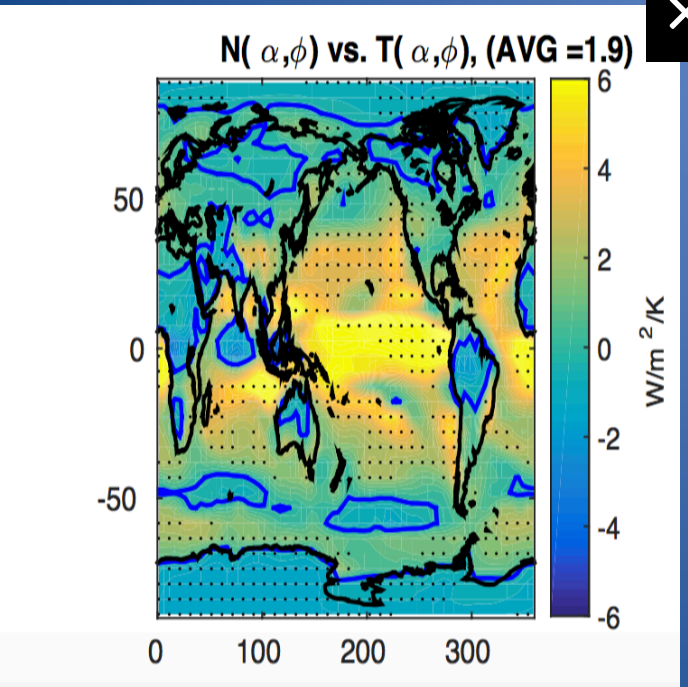


Is the characteristic T(θ,Φ) vs. global T pattern the whole story?

AOGCM control runs

- Test this by multiplying the 'local feedback' relationship by the characteristic surface temperature distribution associated with global T variability…



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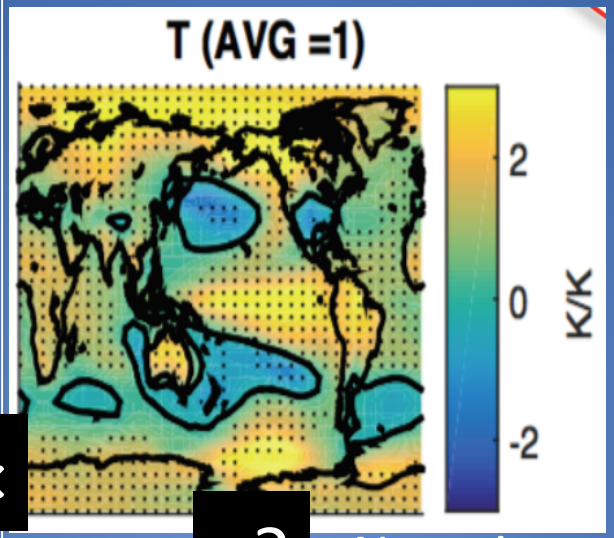
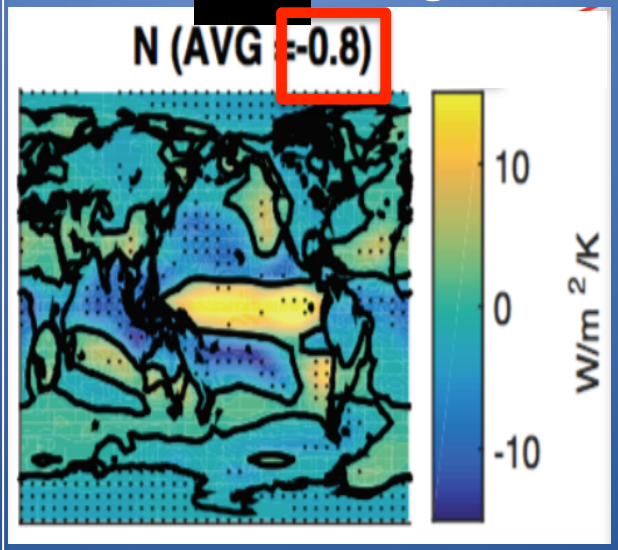
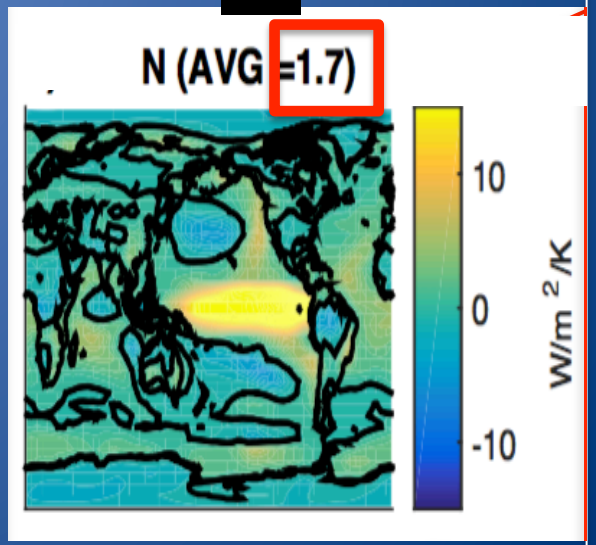
Regression against global T



=? Negative



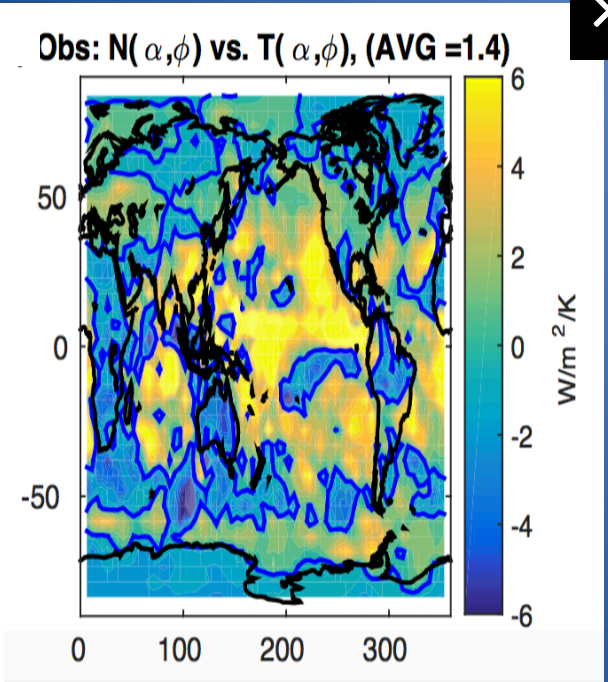
= Positive



Is the characteristic T(θ,Φ) vs. global T pattern the whole story?

CERES/ERA-I

- Test this by multiplying the 'local feedback' relationship by the characteristic surface temperature distribution associated with global T variability…



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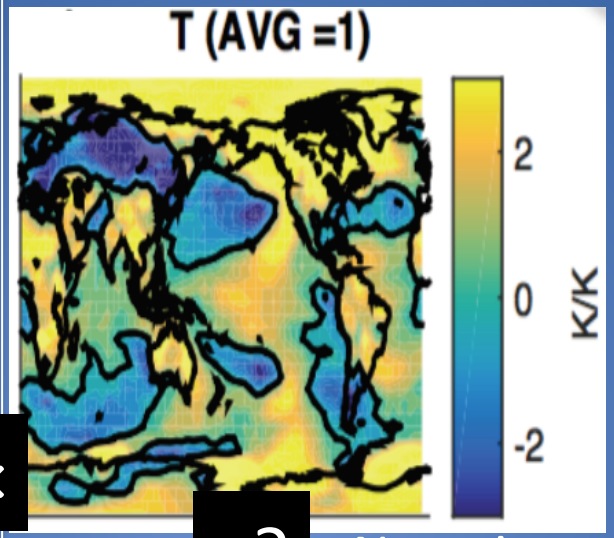
Regression against global T



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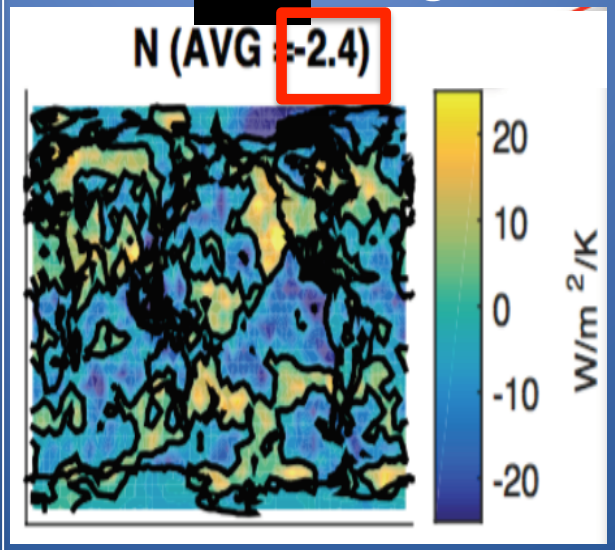

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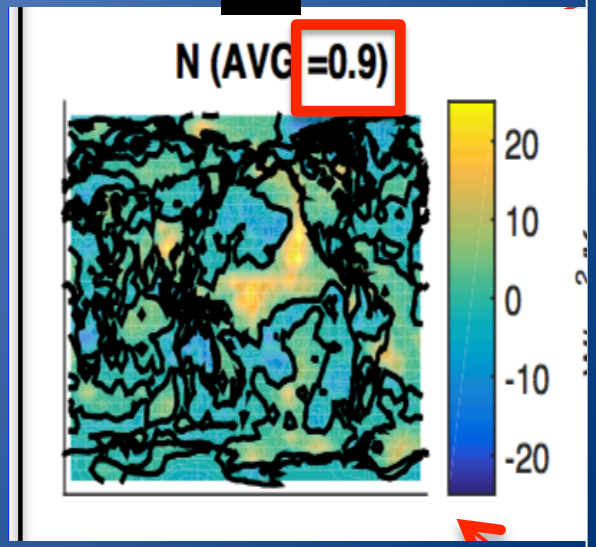

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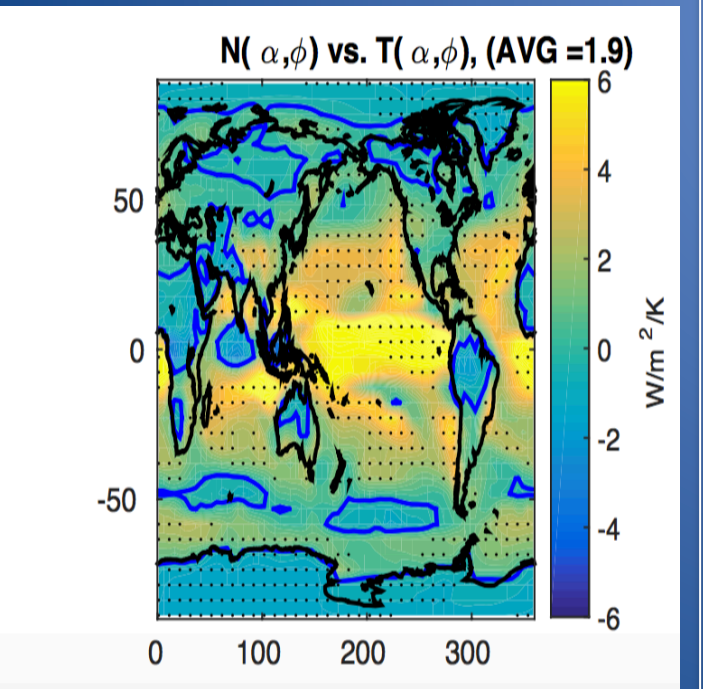
AOGCM control runs

- Test this by multiplying the 'local feedback' relationship by the characteristic surface temperature distribution associated with global T variability…



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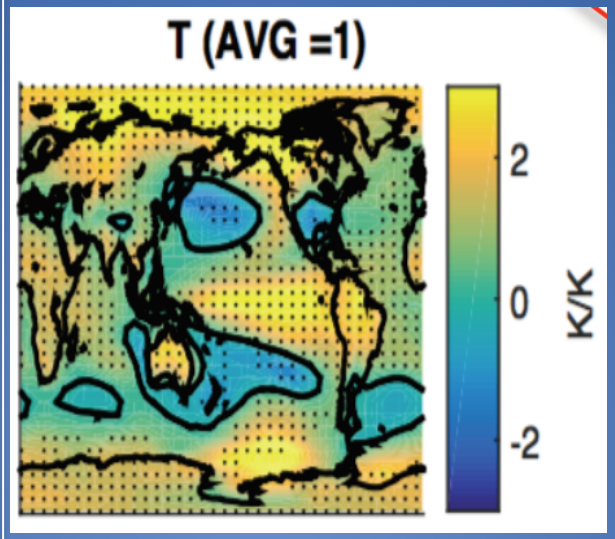
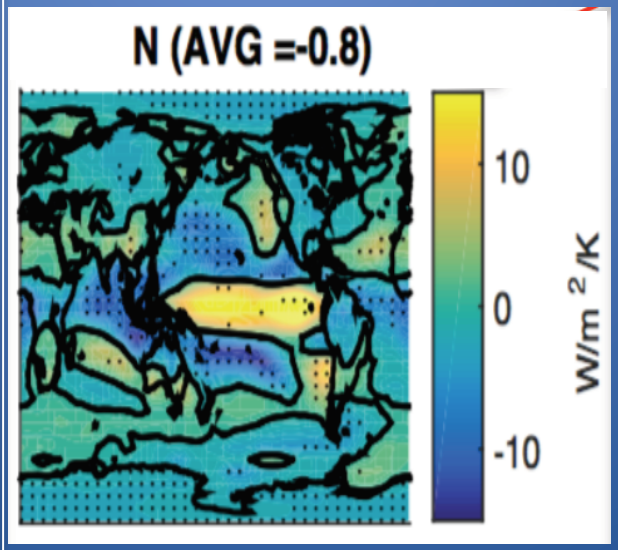
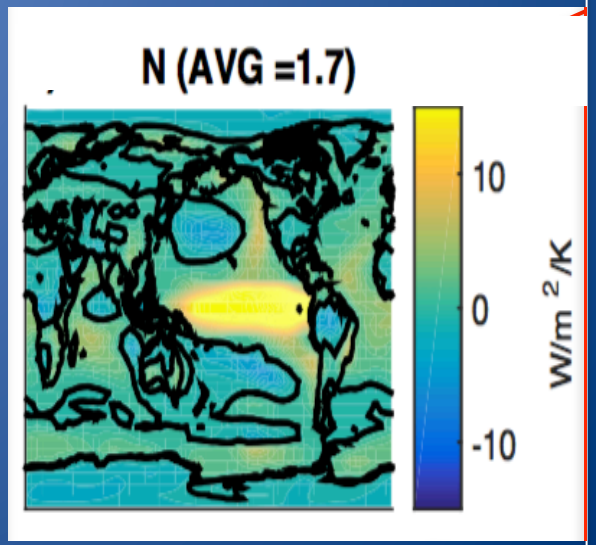
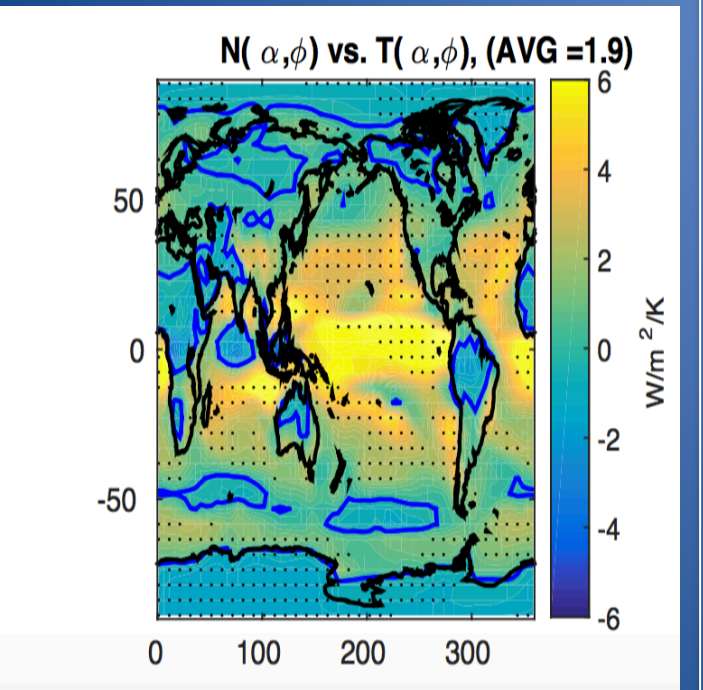




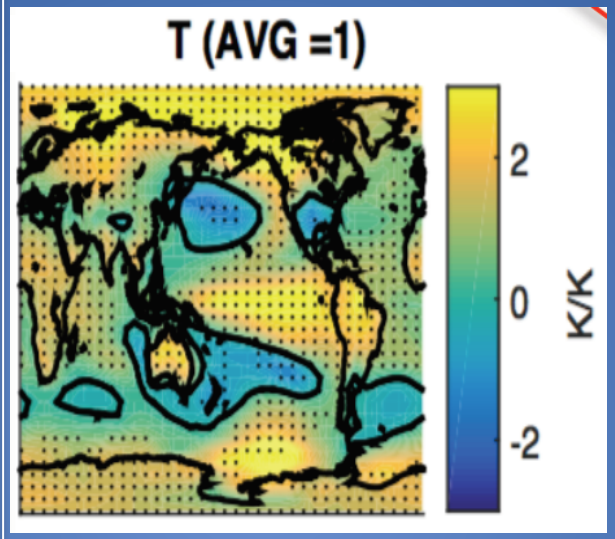


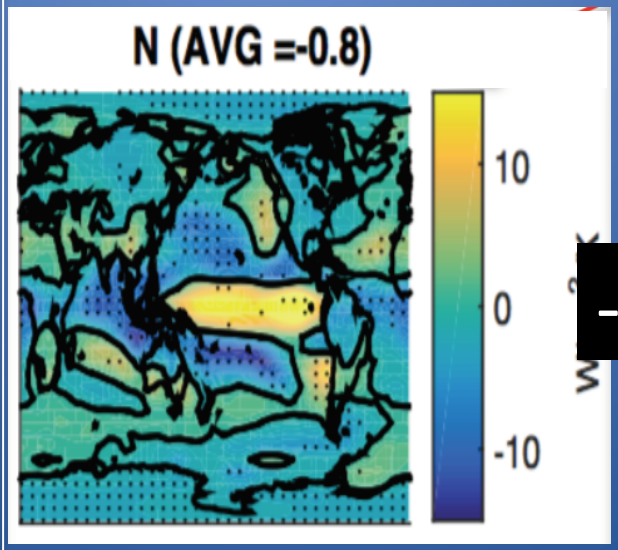
Is the characteristic T(θ,Φ) vs. global T pattern the whole story?

- Subtract to get the contribution to N that is NOT due to the characteristic T(θ,Φ) vs. T pattern



Regression against global T





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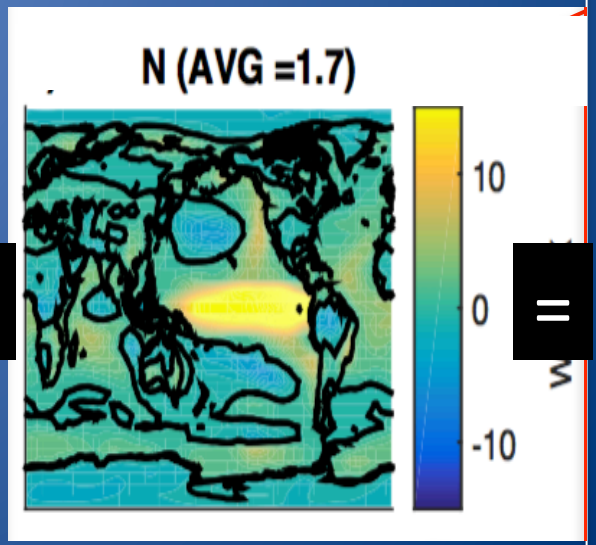

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Why is the global N vs. T relationship negative?

AOGCM control runs

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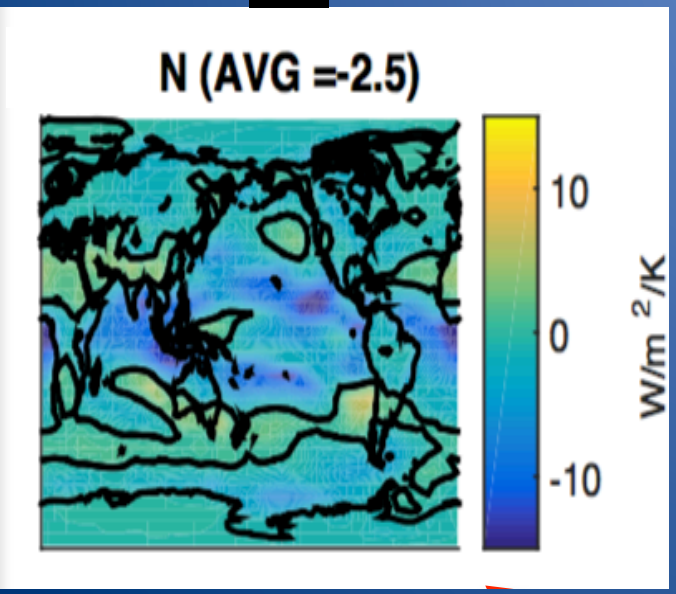

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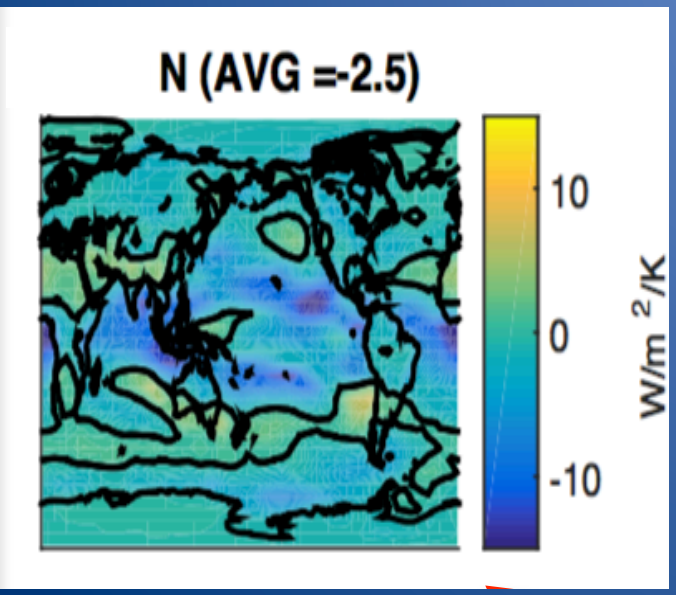
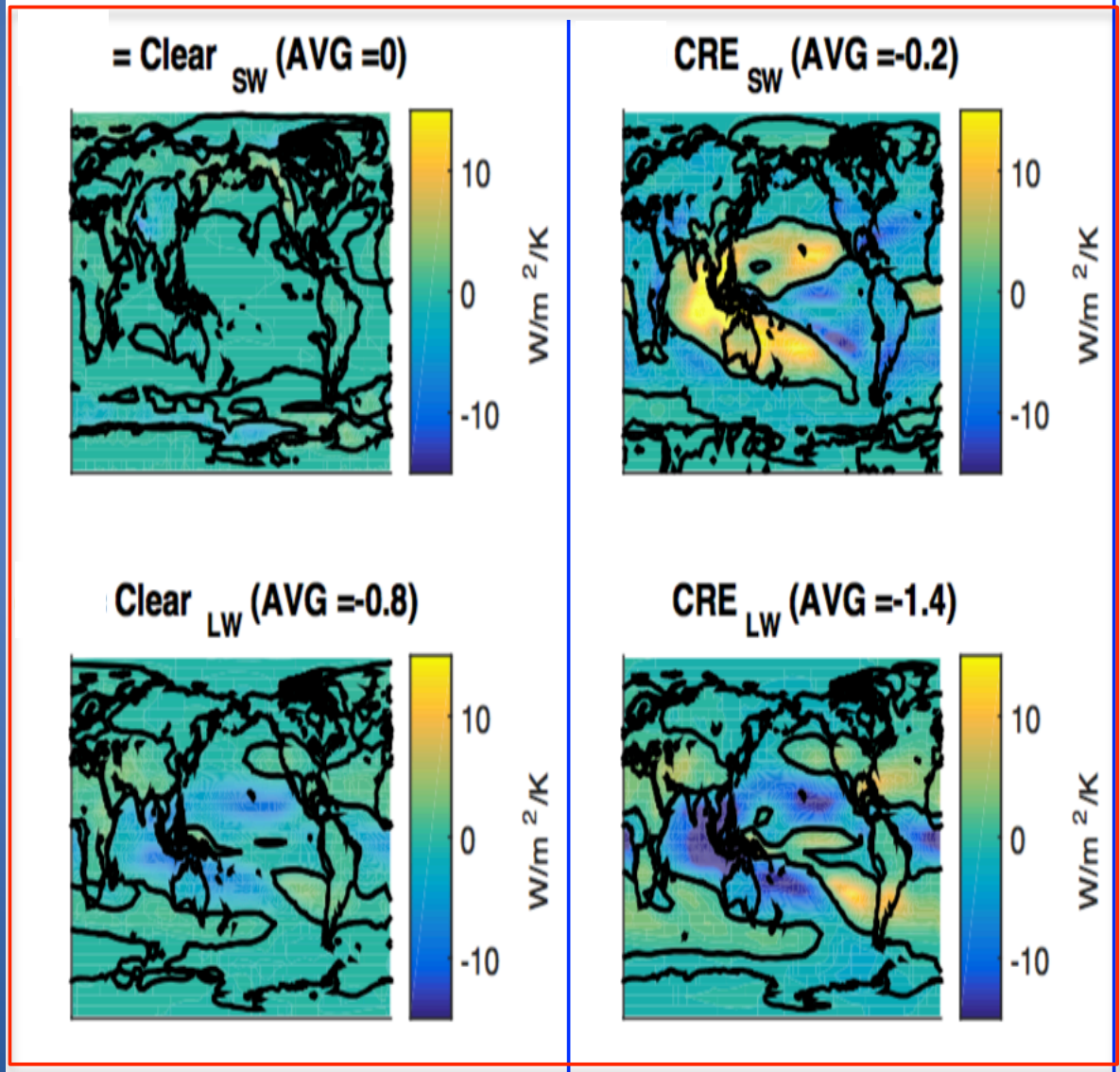


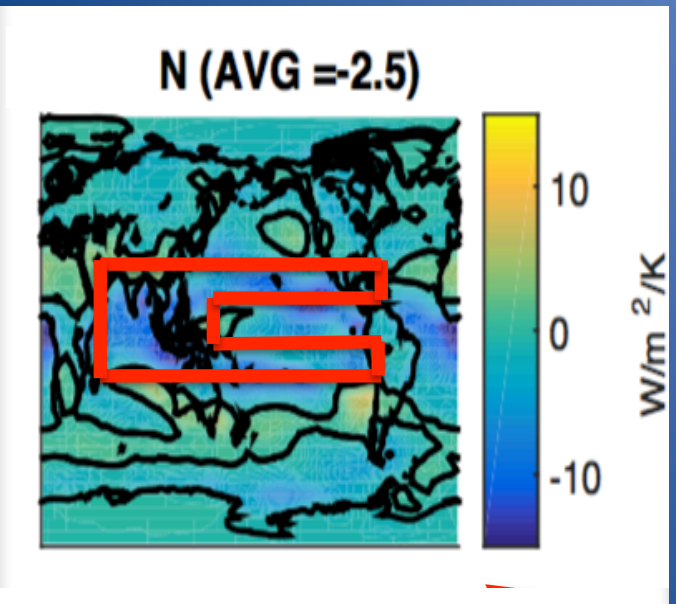
Components of N



Why is the global N vs. T relationship negative?

AOGCM control runs

- Enhanced Hadley circulation and reversed Walker Circulation cause reduced water vapor and cloud fraction/height over large swaths of tropics and subtropics



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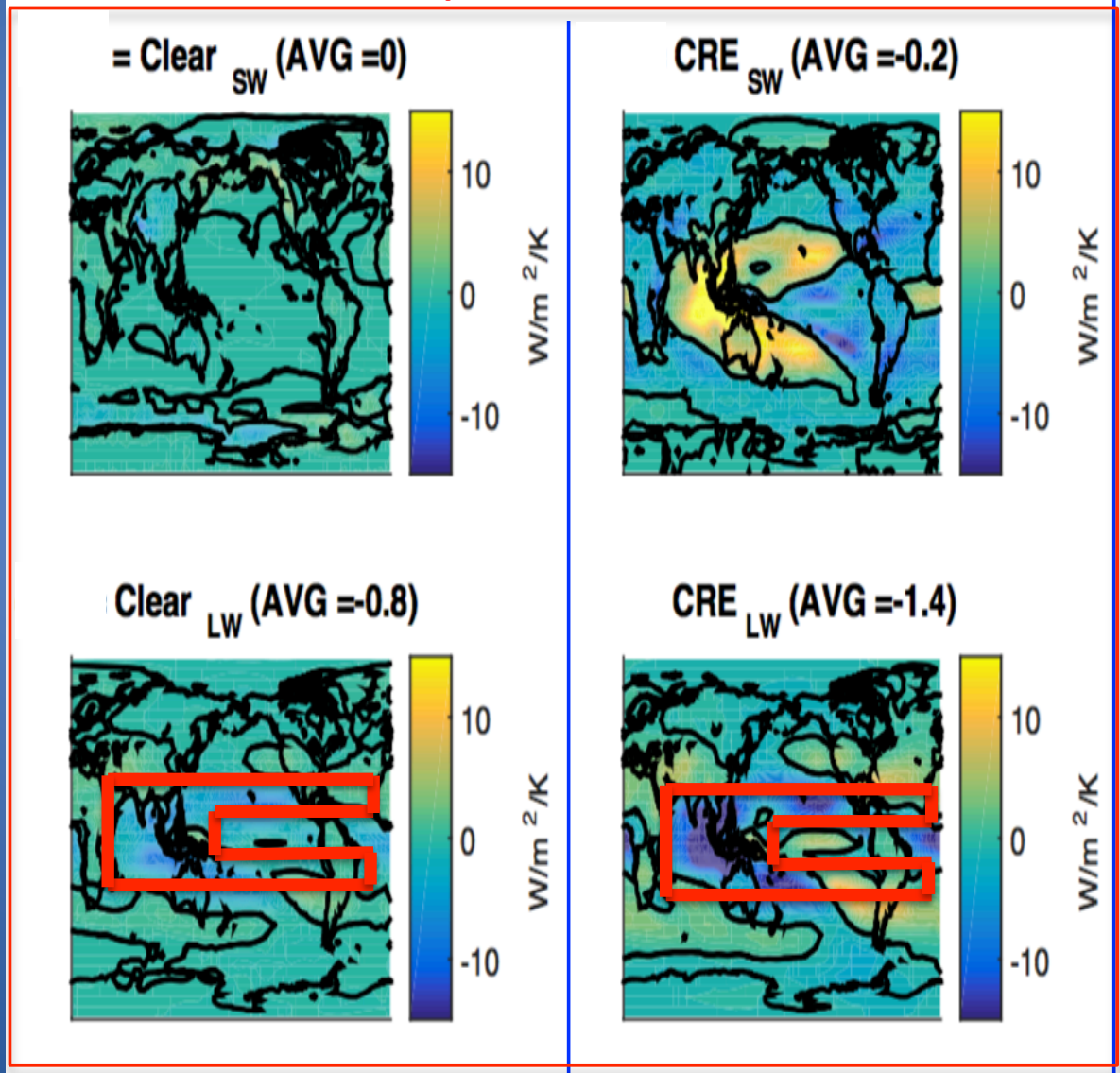
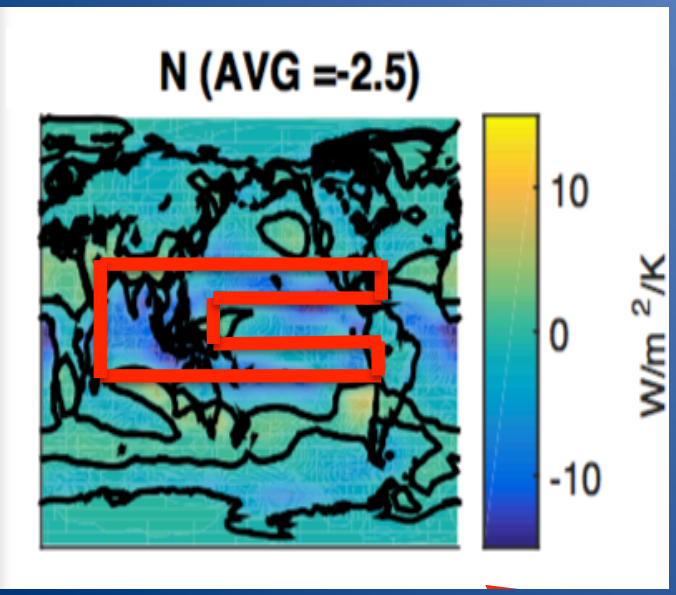


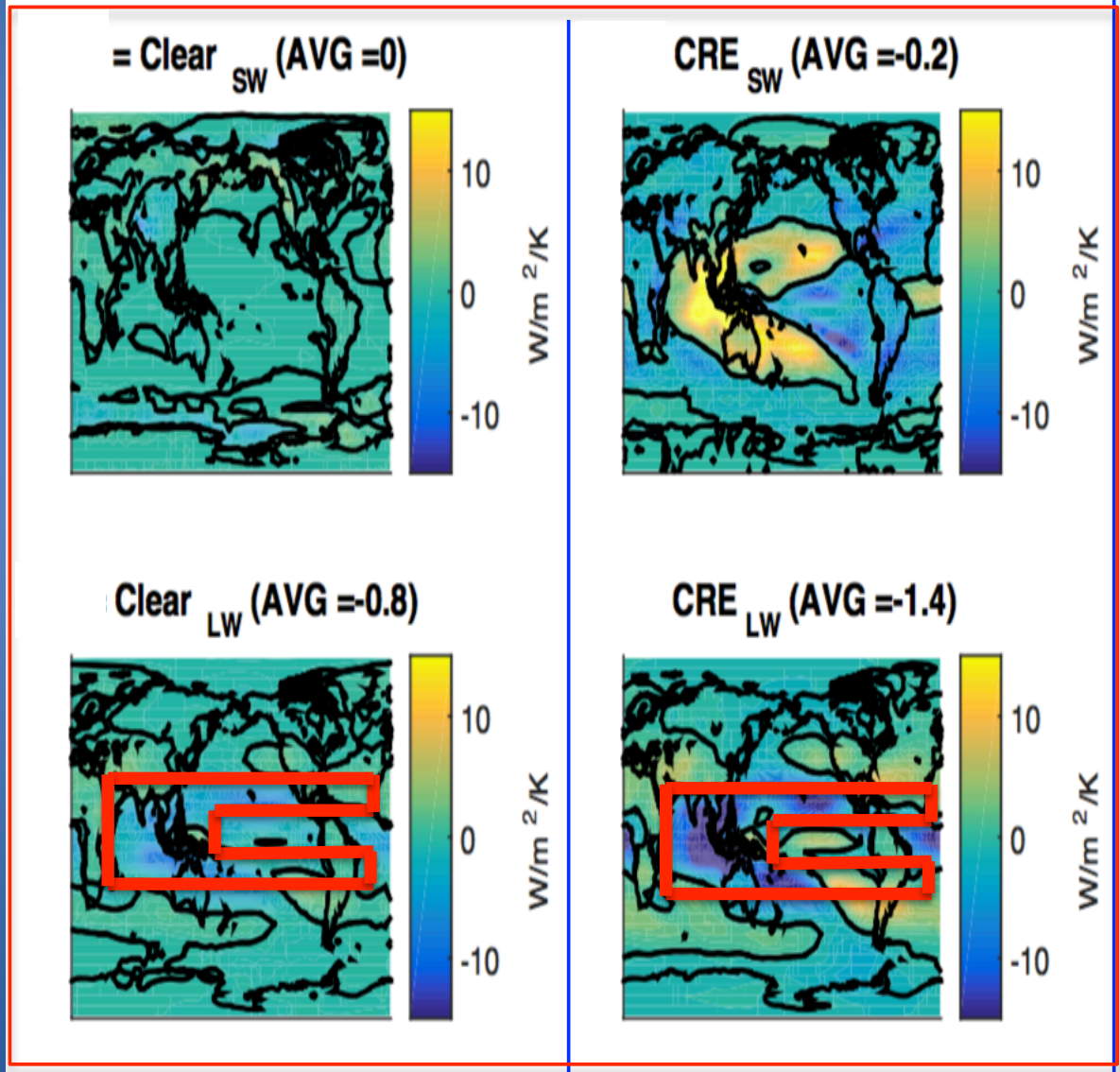
Why is the global N vs. T relationship negative?

AOGCM control runs

- Allows for much more efficient release of LW radiation than would otherwise be expected from the T(θ,Φ) vs. T pattern alone



Components of N



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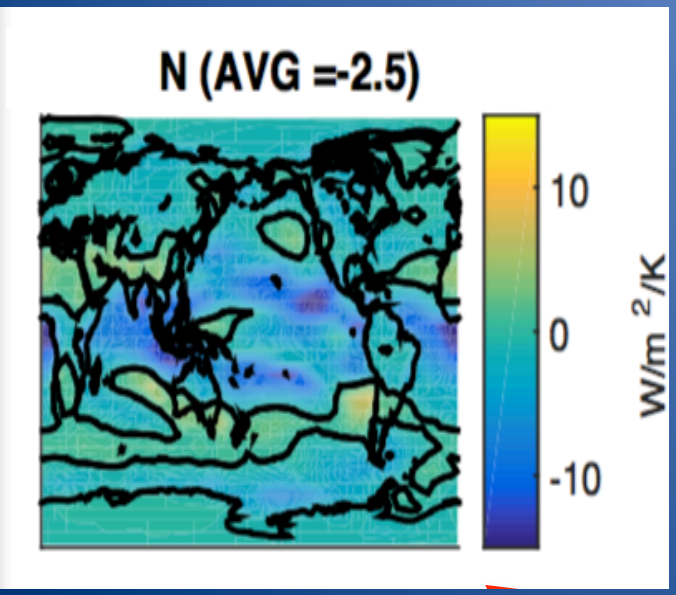
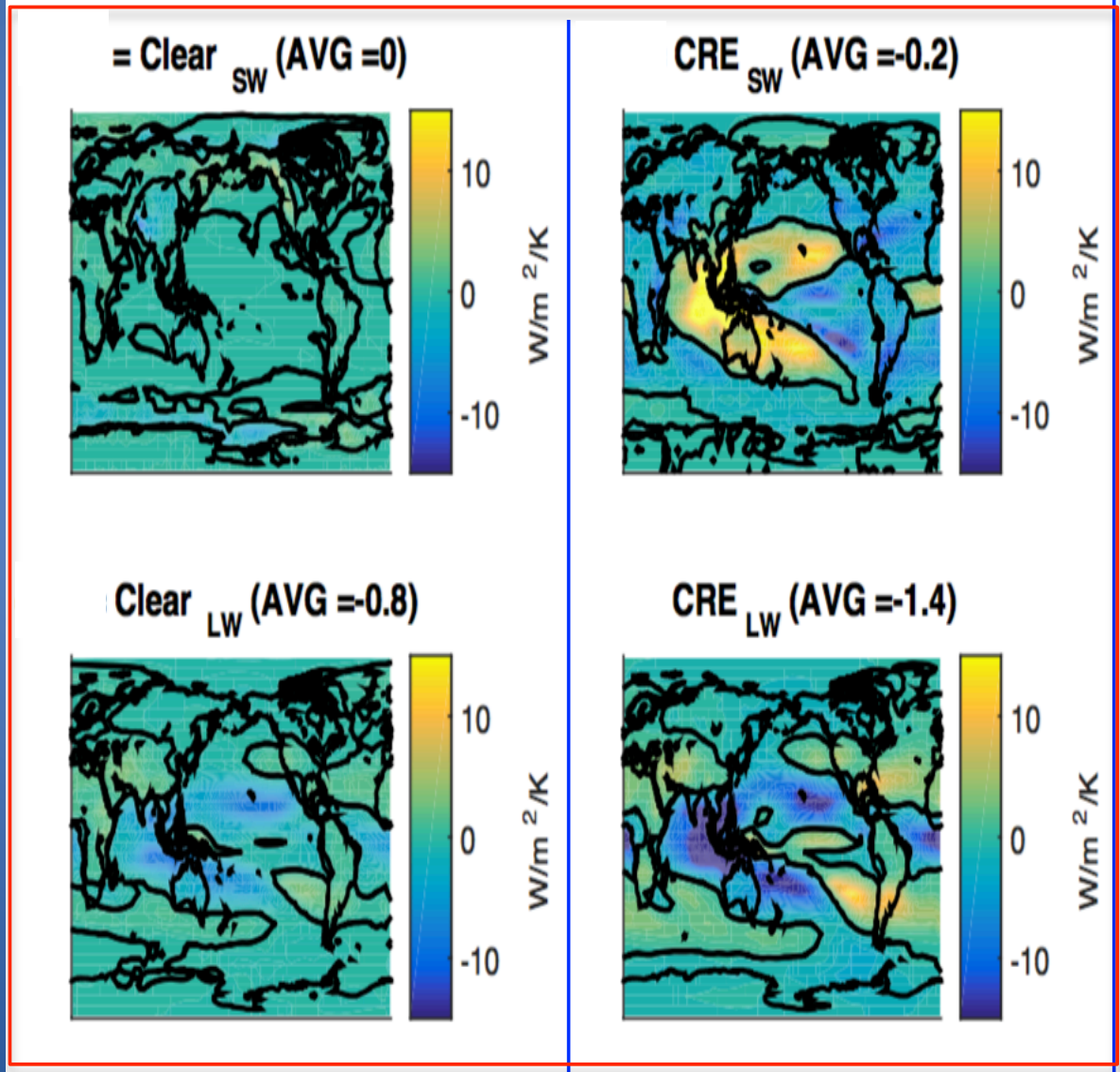


Components of N



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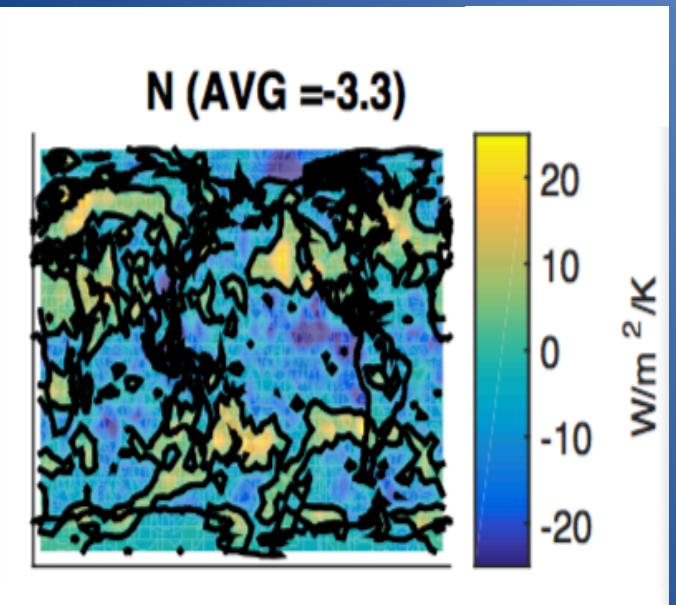
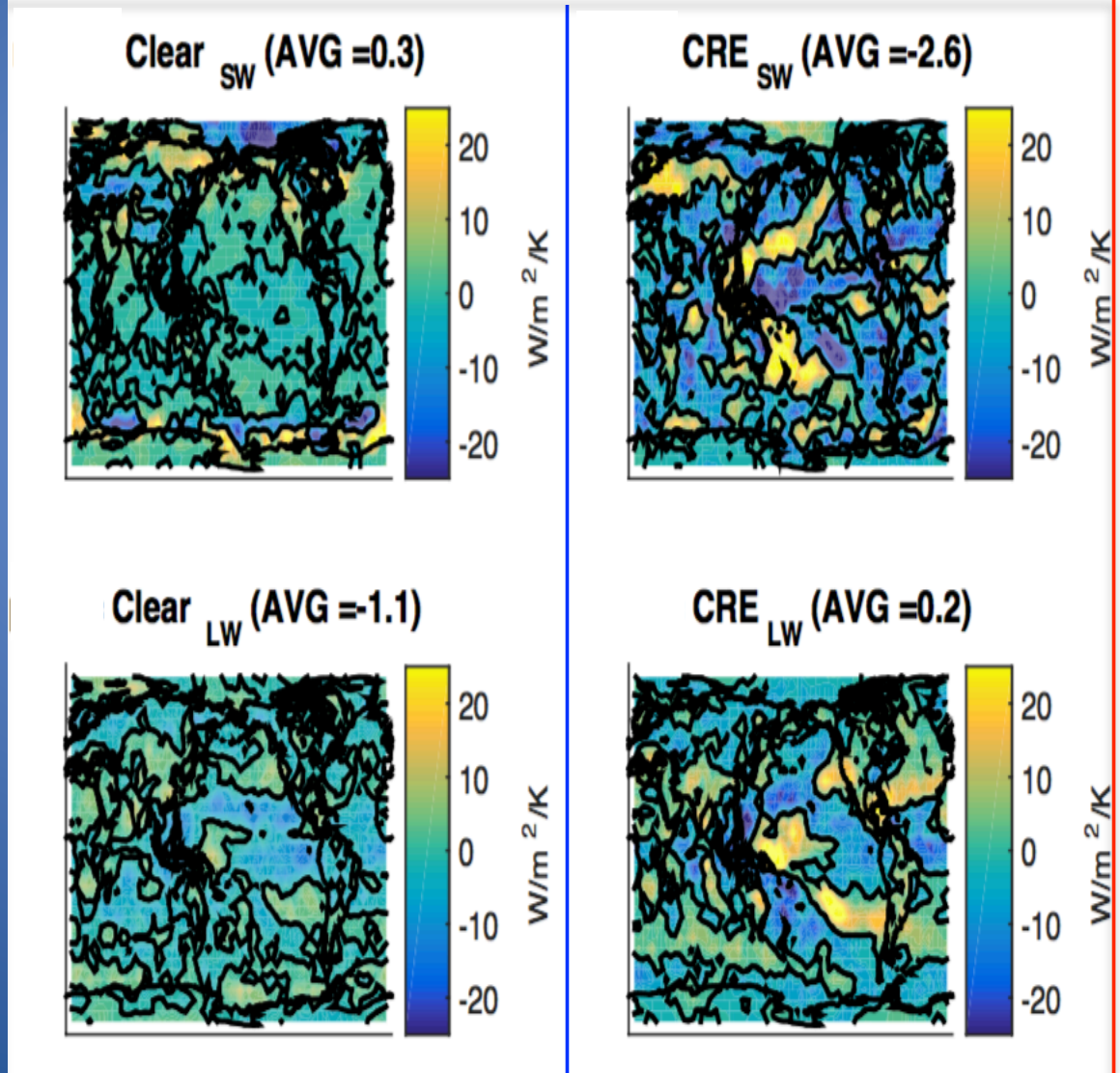
CERES/ERA-I



Components of N



Unforced Surface Air Temperature Variability and Its Contrasting Relationship with the Anomalous TOA Energy Flux at Local and Global Spatial Scales*

PATRICK T. BROWN AND WENHONG LI

Earth and Ocean Sciences, Nicholas School of the Environment, Duke University, Durham, North Carolina

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(Manuscript received 29 May 2015, in final form 6 November 2015)

- The local N(θ, Ø) vs. T(θ, Ø) relationship tends to be positive, despite the Planck Response, because warm T(θ, Ø) is accompanied by:
  - Low surface albedo near sea ice margins and over high elevations
  - Low cloud albedo over much of the middle and low-latitudes
  - Large water-vapor greenhouse effect over the deep Indo-Pacific

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  - Low cloud albedo over much of the middle and low-latitudes
  - Large water-vapor greenhouse effect over the deep Indo-Pacific
- Global T can restore equilibrium after a large fluctuation because warm global T is accompanied by:
  - Large divergence (convergence) of atmospheric energy transport over the Tropical Pacific (high latitudes) which creates large positive T(θ, Ø) anomalies where they can be easily damped to space
  - Large-scale atmospheric circulation changes drive cloud reduction and atmospheric drying over large portions of the tropics and subtropics which allows for greatly enhanced OLR