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Using stochastic sampling of parametric uncertainties to quantify relationships between CAM3.1 bias and climate sensitivity

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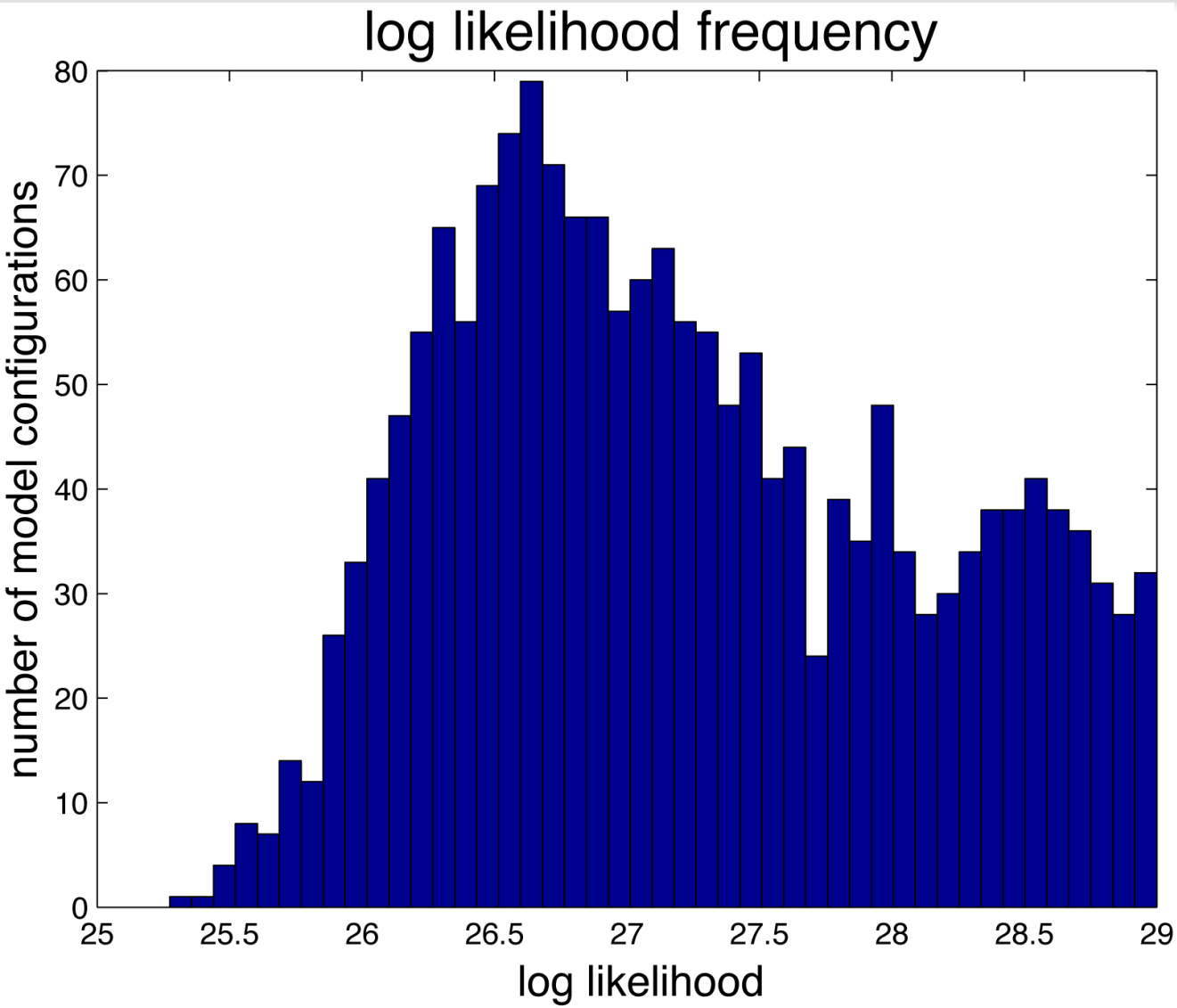
Climate and Earth System Modeling PI Meeting
September 19 – 22, 2011

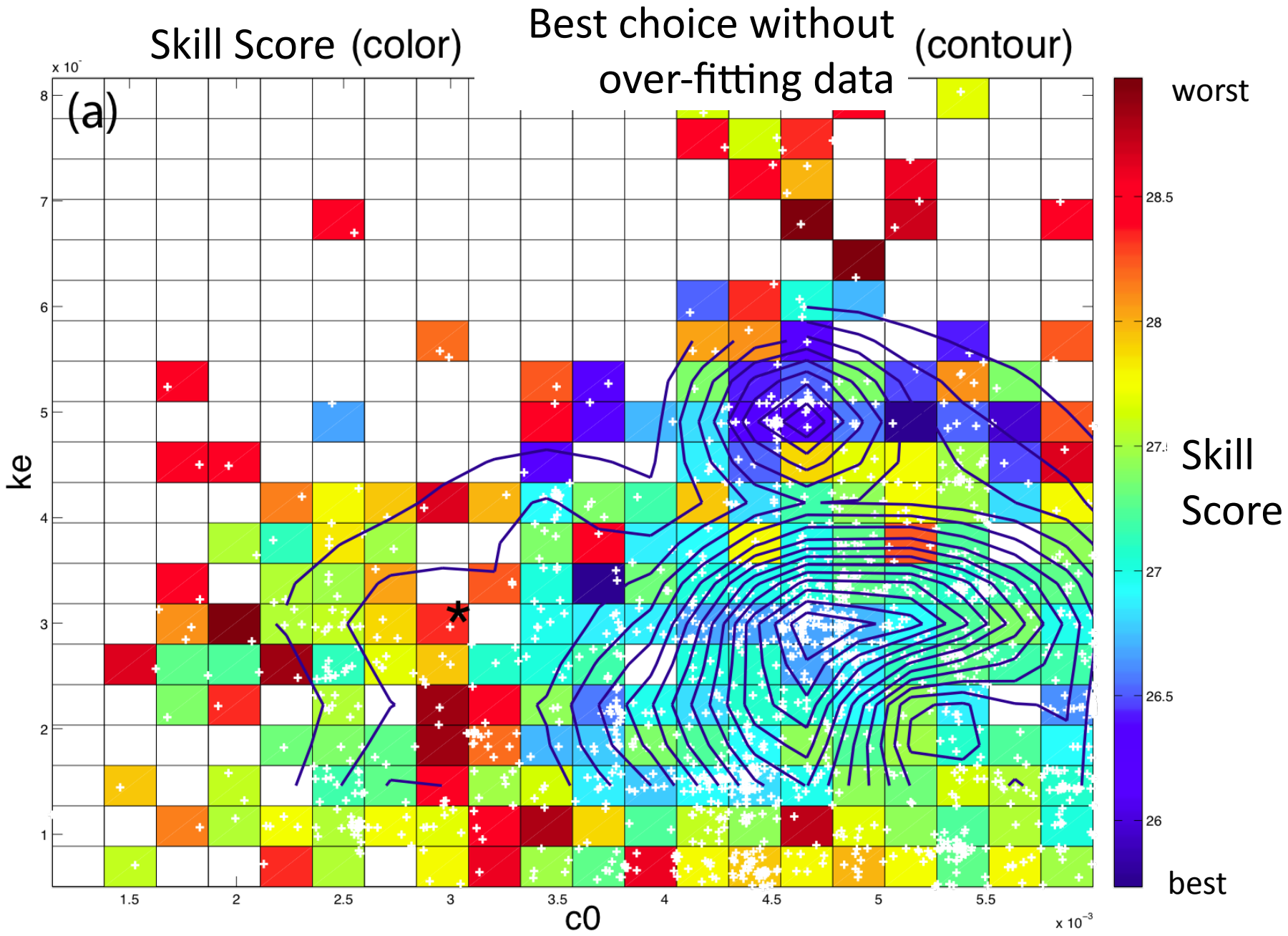
Bayesian formulation of climate model parameter uncertainty

$$PPD\left(\mathbf{m} \mid \mathbf{d}_{obs}, g(\mathbf{m})\right) \propto \exp\left[-\frac{1}{2}\left(g(\mathbf{m}) - \mathbf{d}_{obs}\right)^{T} \mathbf{C}_{noise}^{-1}\left(g(\mathbf{m}) - \mathbf{d}_{obs}\right)\right] \cdot prior(\mathbf{m})$$

Likelihood test of model acceptability


log likelihood frequency
number of model configurations
log likelihood
0
10
20
30
40
50
60
70
80
25
25.5
26
26.5
27
27.5
28
28.5
29

Result summary of how 2 model parameters affect model skill



The problem:

- It is not clear what quantifying uncertainties mean when large systematic differences exist between a model and observations (i.e. biases).
- If biases do not affect feedbacks, they would not add to spread in predictions. Biases are removed by looking only at predicted changes.
- If biases do affect predictions, the information about biases should be taken into account when measuring model likelihood.

Correlation between model bias and scatter in level of warming when CO2 is doubled.

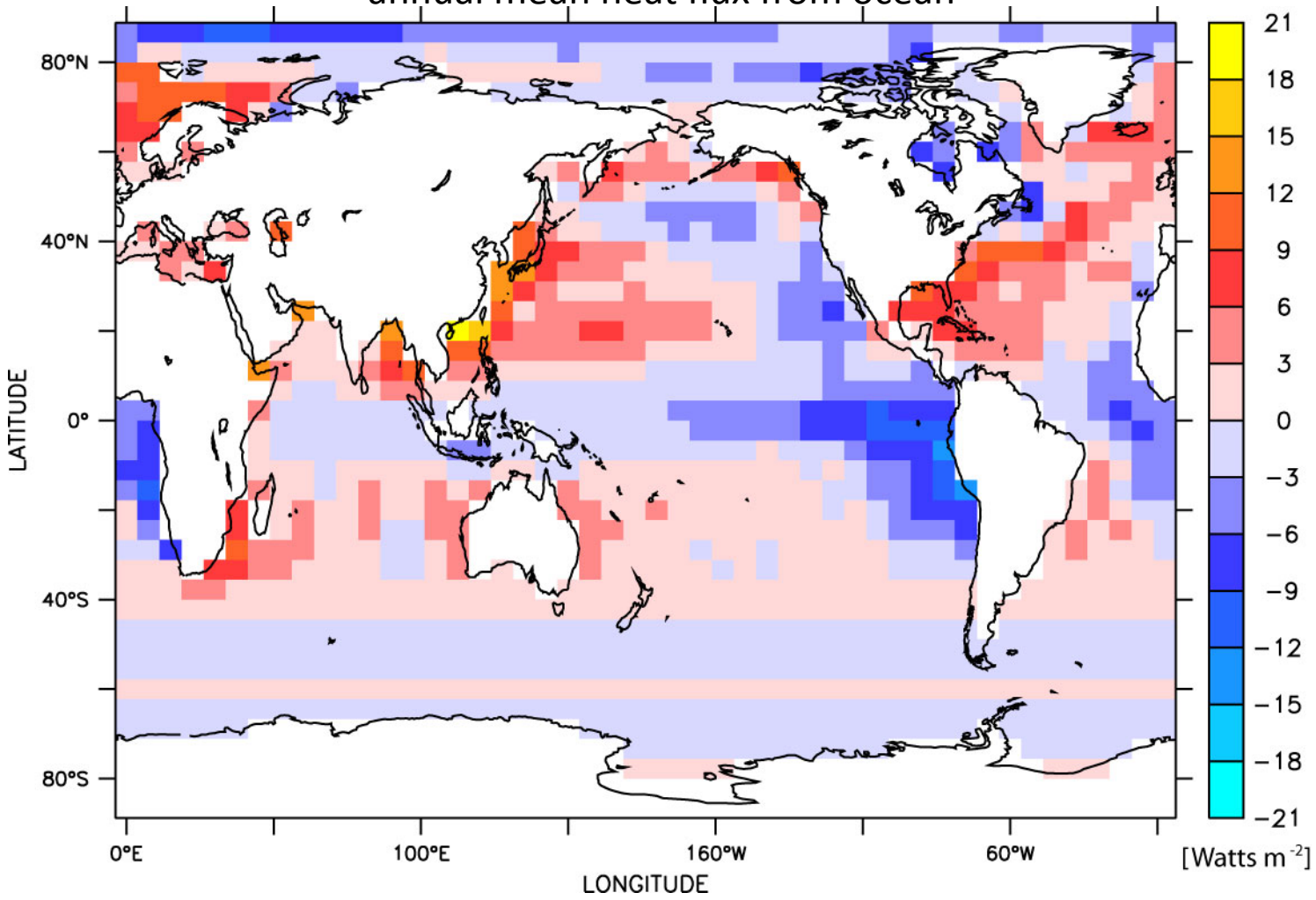
$$Corr\left(\phi,\theta\right)=\frac{1}{N_m}\sum_{i=1}^{N_m}\frac{\left(g_i^{1x}\left(\phi,\theta\right)-obs^{1x}\left(\phi,\theta\right)\right)\cdot\left(R\left(g_i^{2x}\right)-R\left(obs^{2x}\right)\right)}{\sigma^{1x}\sigma^{2x}}$$

If biases do not affect feedbacks, correlation should be 0.

Global warming experiments

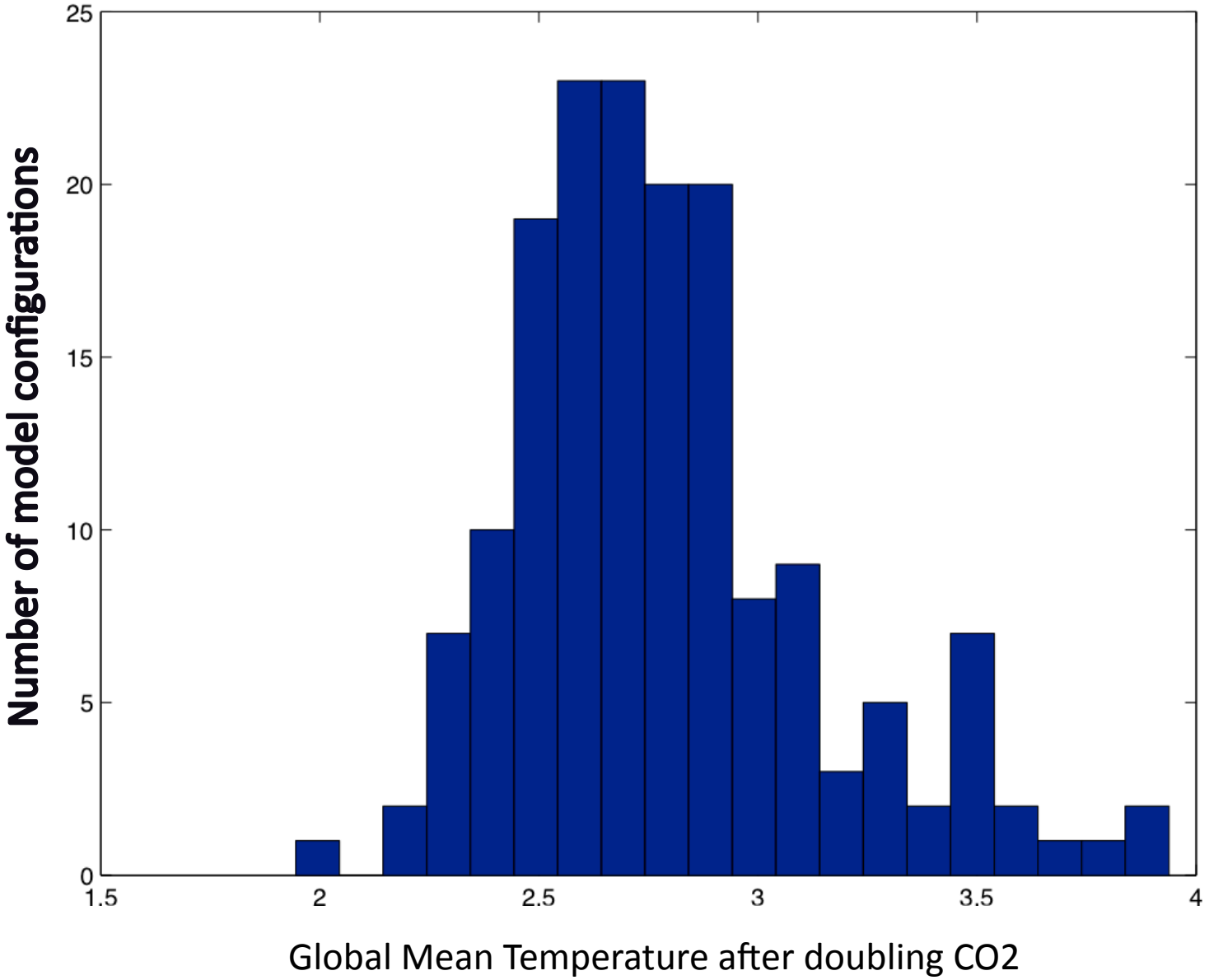
- Couple cam3 to a “slab” ocean
- Calculate ocean effects of ocean heat transports, apply as heat flux to base of slab ocean. Allows model to reproduced observed SSTs.
- We chose to keep this heat flux field the same in all global warming experiments.

annual mean heat flux from ocean



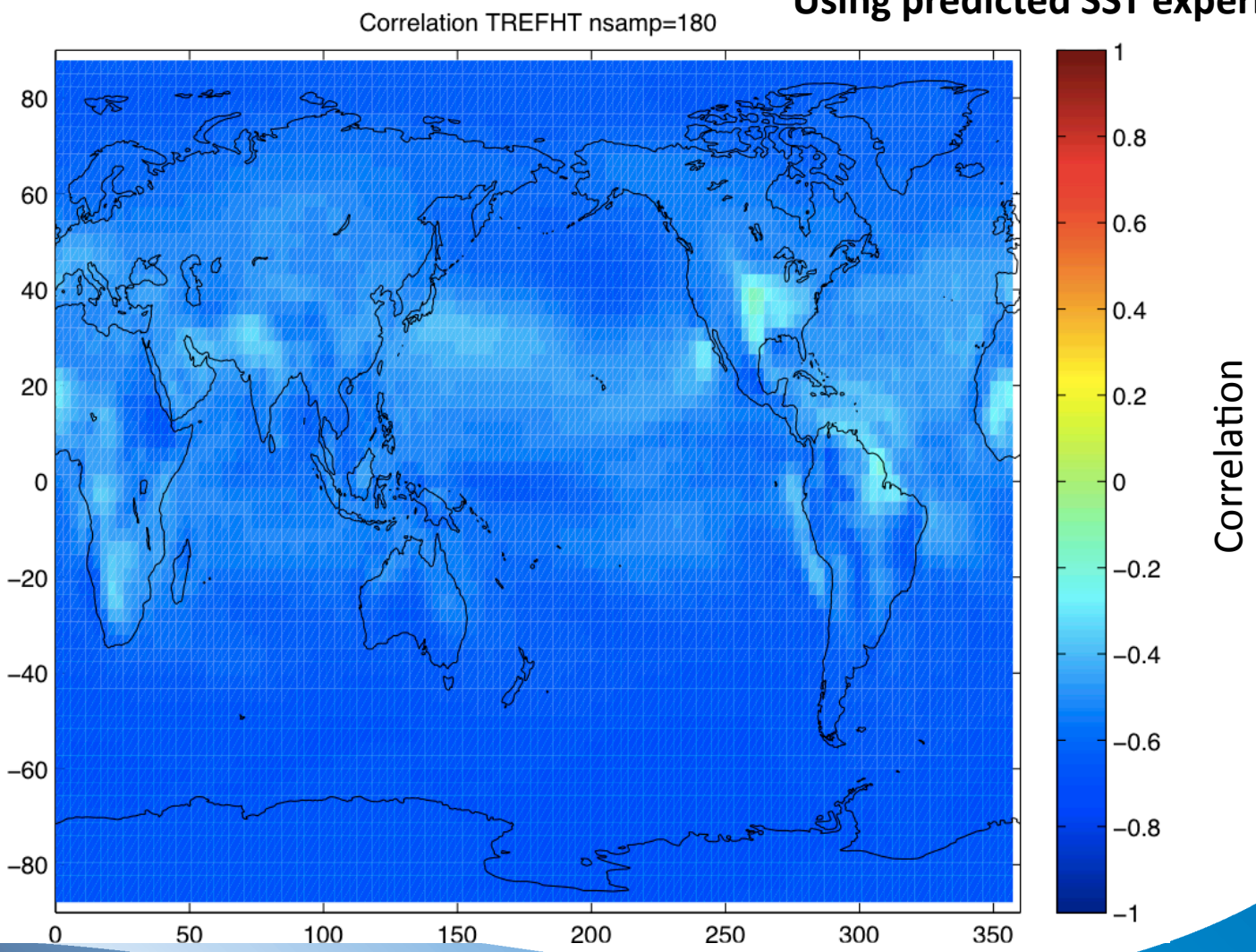
Jackson 2006

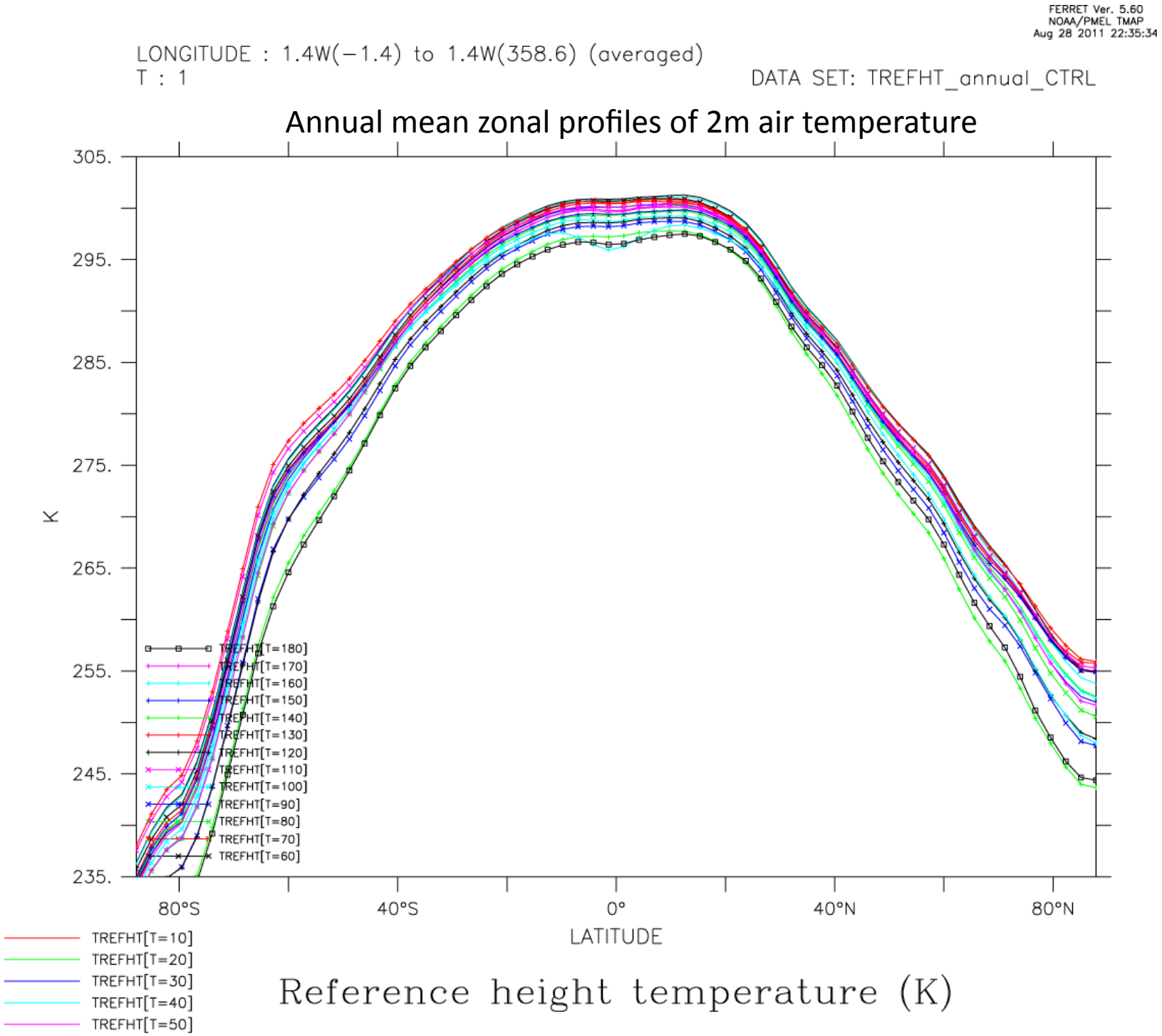
Impact of parameter uncertainties on equilibrium sensitivity to 2xCO2

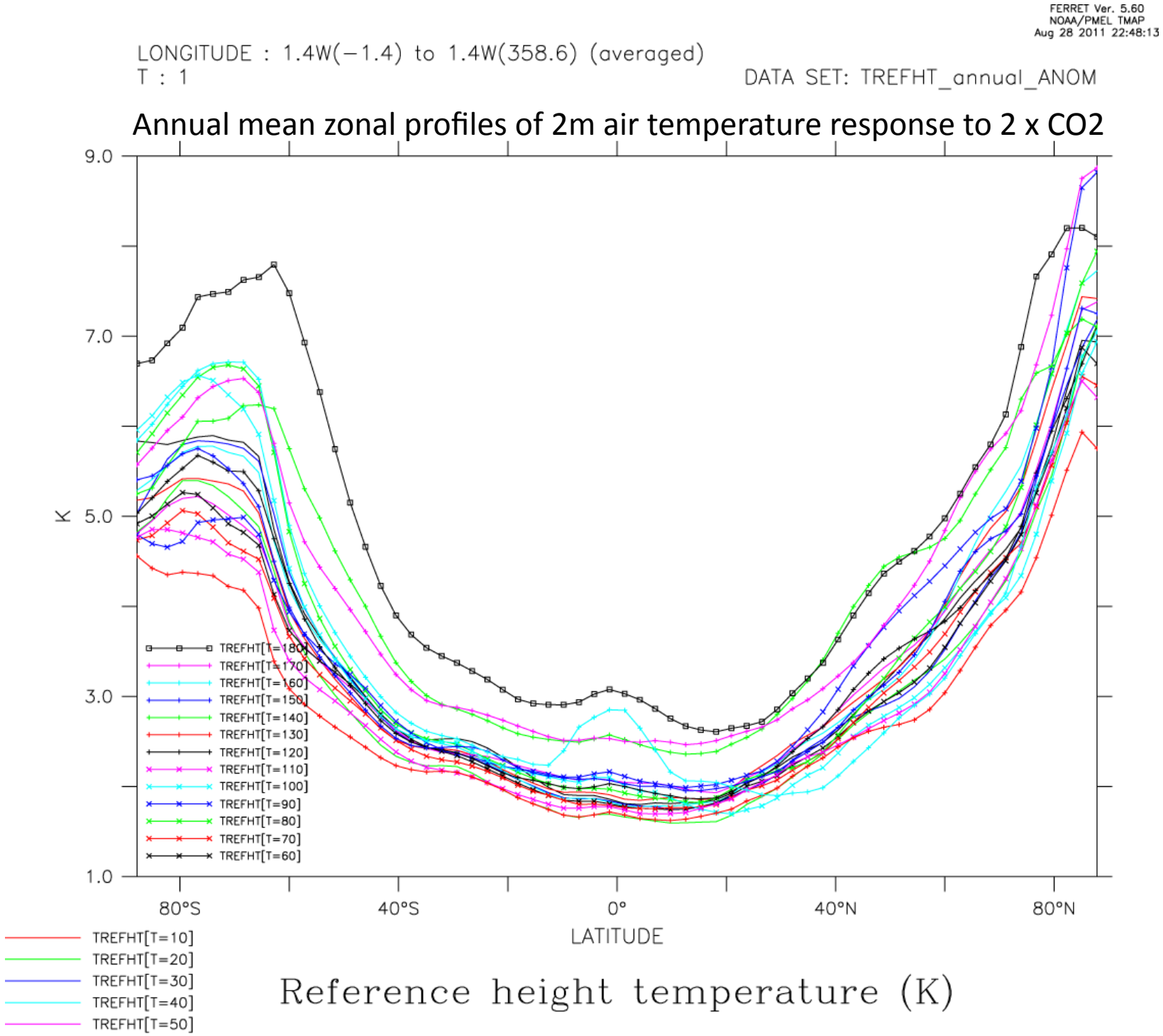


Correlation between scatter in control 2m air temperature and climate sensitivity

Using predicted SST experiments

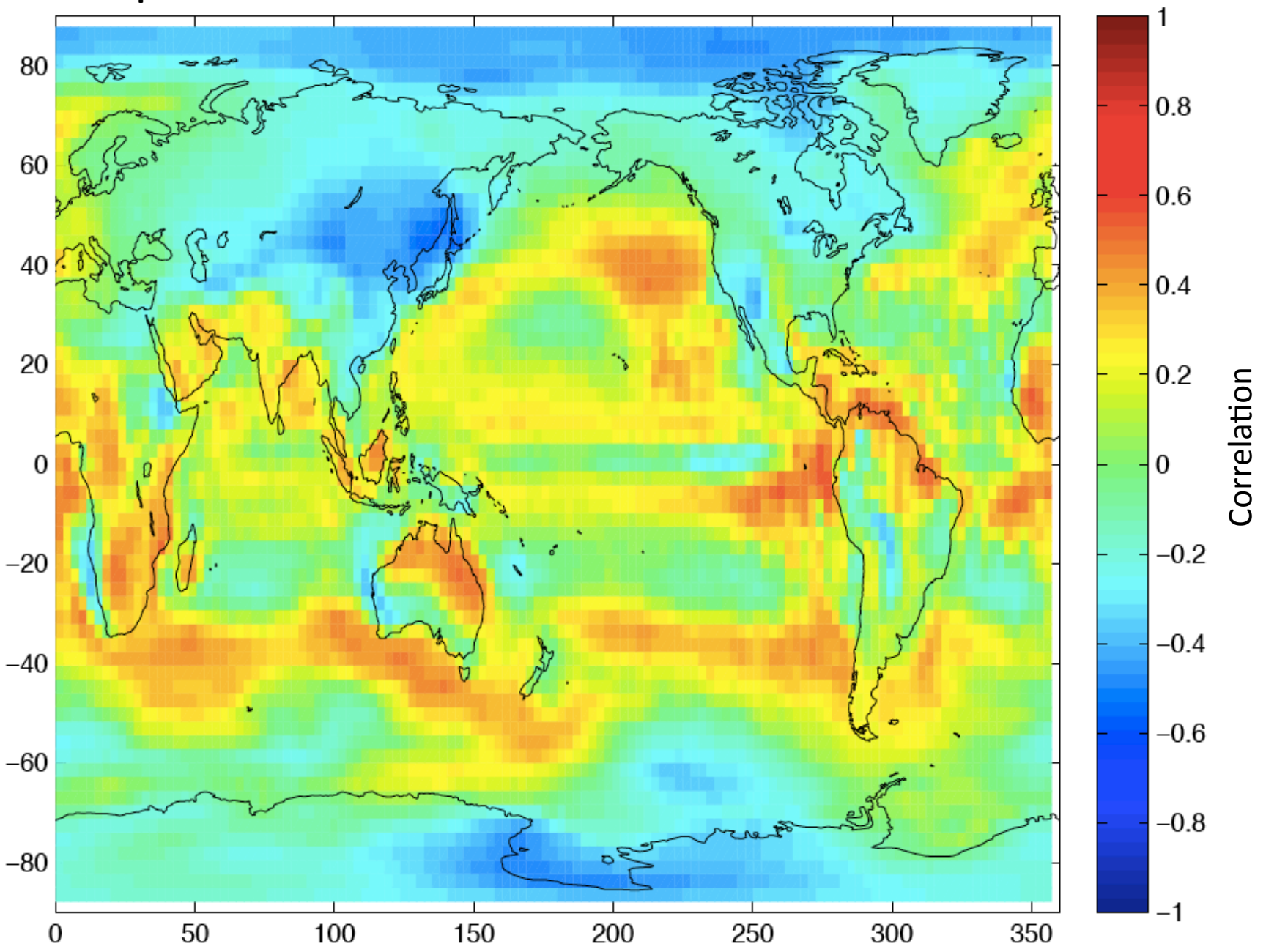



FERRET Ver. 5.60
NOAA/PMEL TMAP
Aug 28 2011 22:35:34
LONGITUDE : 1.4W(−1.4) to 1.4W(358.6) (averaged)
T : 1
DATA SET: TREFHT_annual_CTRL
Annual mean zonal profiles of 2m air temperature
305.
295.
285.
275.
265.
255.
245.
235.
K
TREFHT[T=180]
TREFHT[T=170]
TREFHT[T=160]
TREFHT[T=150]
TREFHT[T=140]
TREFHT[T=130]
TREFHT[T=120]
TREFHT[T=110]
TREFHT[T=100]
TREFHT[T=90]
TREFHT[T=80]
TREFHT[T=70]
TREFHT[T=60]
80°S
40°S
0°
40°N
80°N
LATITUDE
TREFHT[T=10]
TREFHT[T=20]
TREFHT[T=30]
TREFHT[T=40]
TREFHT[T=50]
Reference height temperature (K)

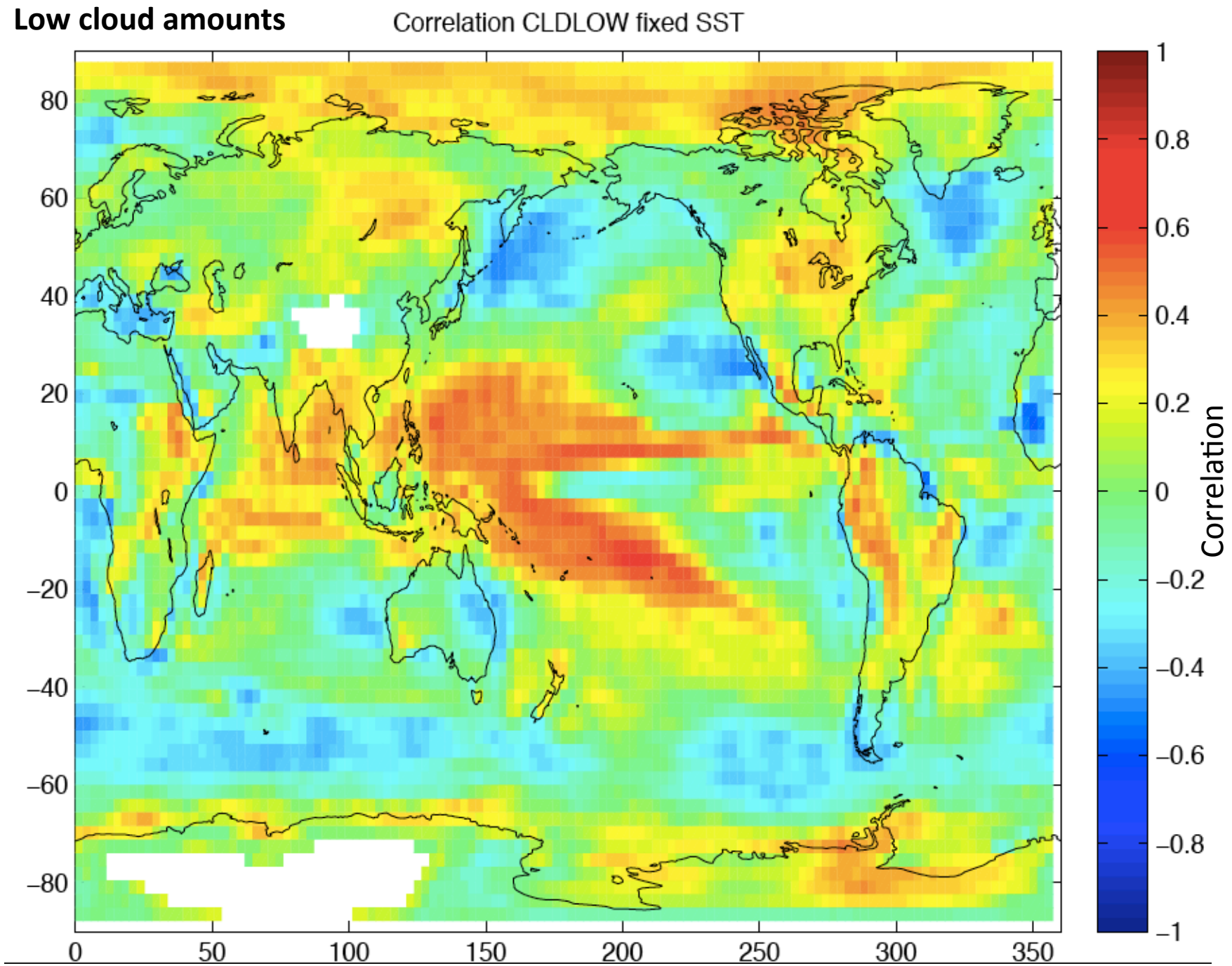

FERRET Ver. 5.60
NOAA/PMEL TMAP
Aug 28 2011 22:48:13
LONGITUDE : 1.4W(−1.4) to 1.4W(358.6) (averaged)
T : 1
DATA SET: TREFHT_annual_ANOM
Annual mean zonal profiles of 2m air temperature response to 2 x CO2
9.0
7.0
5.0
3.0
1.0
K
80°S
40°S
0°
40°N
80°N
LATITUDE
TREFHT[T=180]
TREFHT[T=170]
TREFHT[T=160]
TREFHT[T=150]
TREFHT[T=140]
TREFHT[T=130]
TREFHT[T=120]
TREFHT[T=110]
TREFHT[T=100]
TREFHT[T=90]
TREFHT[T=80]
TREFHT[T=70]
TREFHT[T=60]
TREFHT[T=10]
TREFHT[T=20]
TREFHT[T=30]
TREFHT[T=40]
TREFHT[T=50]
Reference height temperature (K)

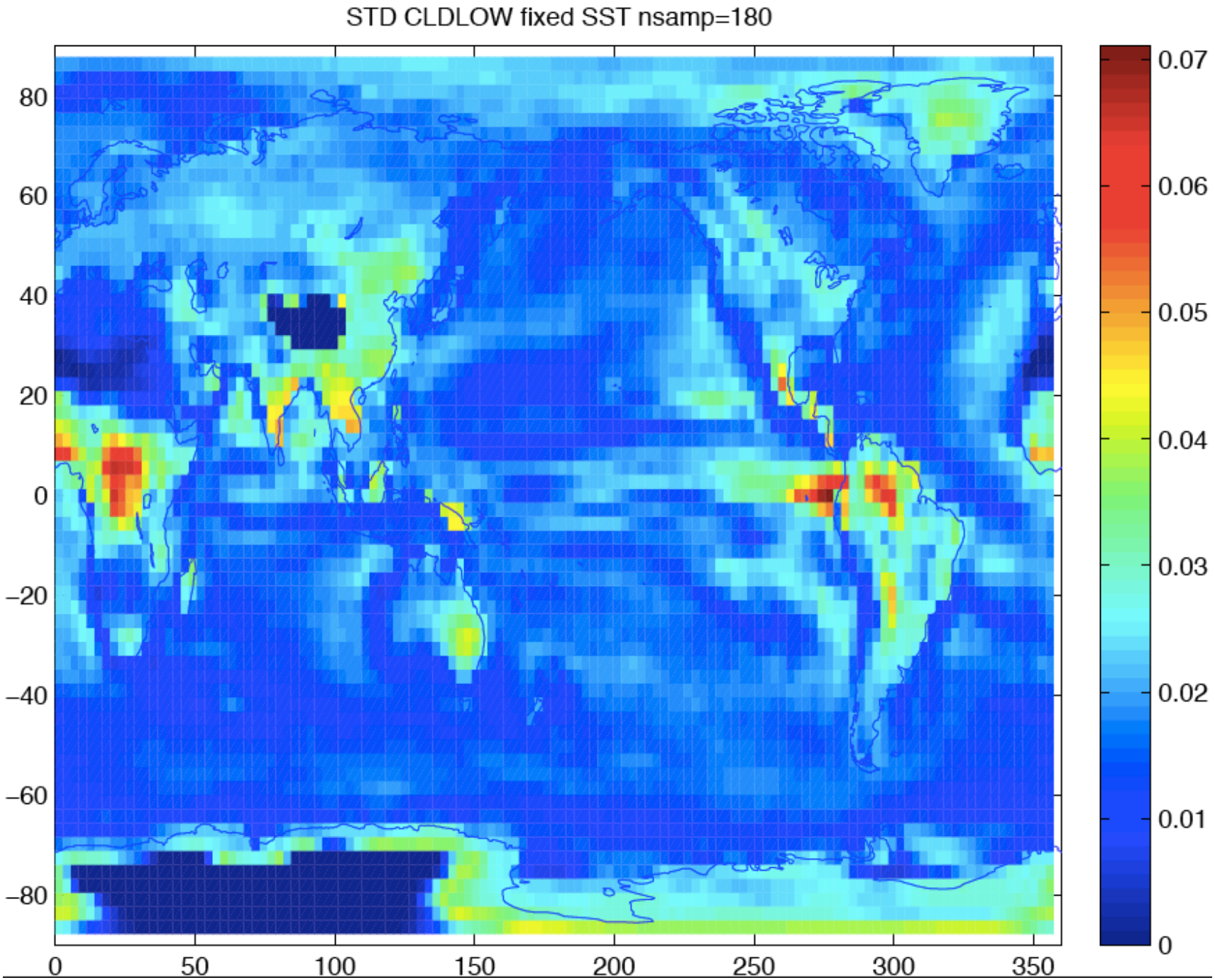
2m air temperature

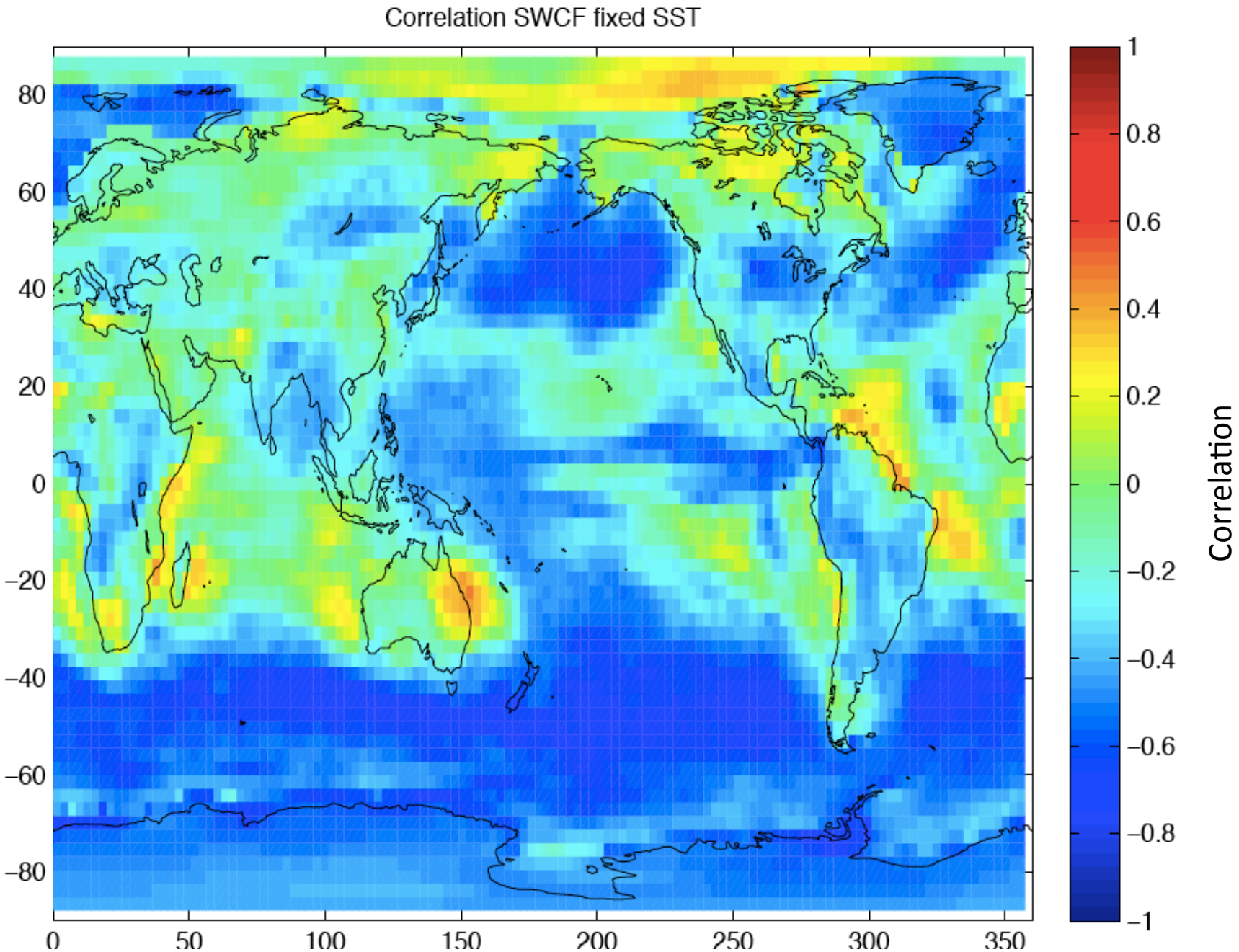
using fixed SST experiments



Low cloud amounts




STD CLDLOW fixed SST nsamp=180
80
60
40
20
0
−20
−40
−60
−80
0
50
100
150
200
250
300
350
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0


Correlation SWCF fixed SST
80
60
40
20
0
−20
−40
−60
−80
0
50
100
150
200
250
300
350
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
Correlation

conclusions

- Biases important to take into account when calculating model likelihood.
- Need to know which biases affect predictions.
- Surprising level of interaction with ocean heat fluxes to maintain atmospheric model skill.
- We need a new strategy to test how models can be tested against data. Current strategy allows significant errors to emerge after testing.