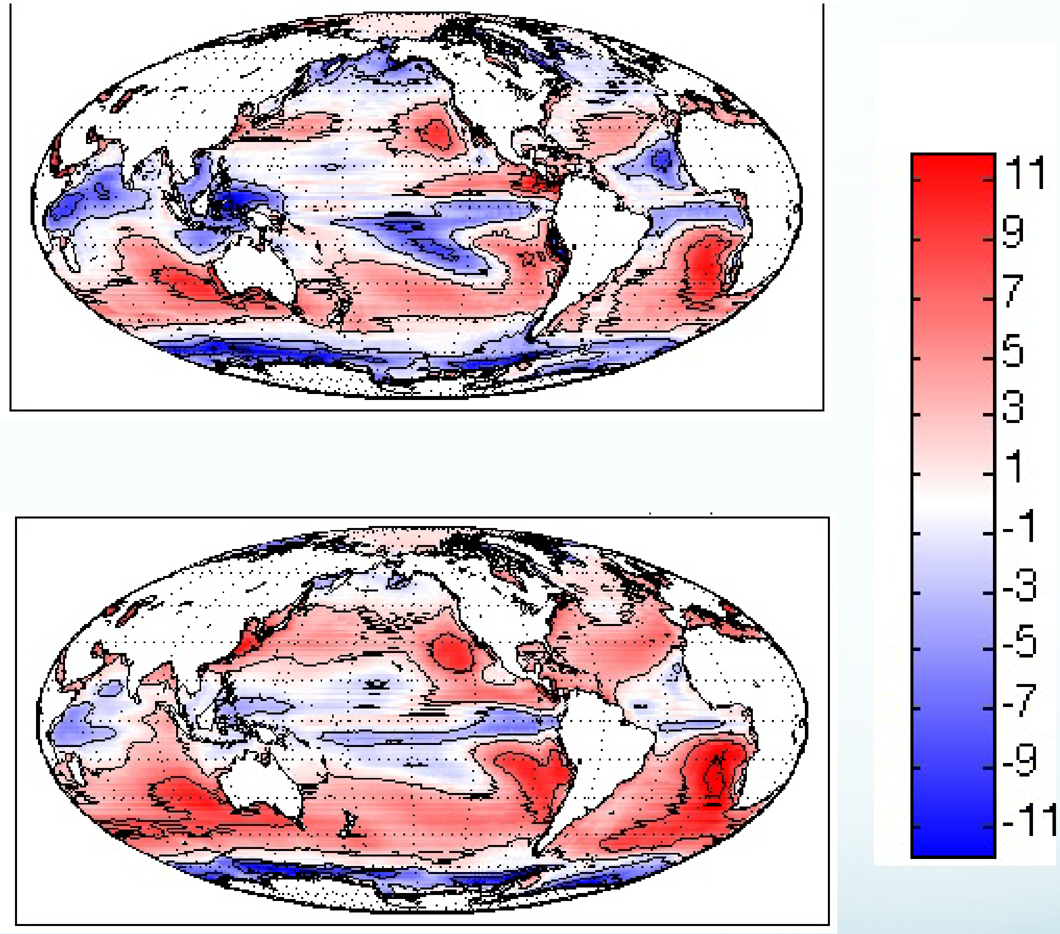
Biases in means, variability, and trends of air-sea fluxes and SST in the CCSM4

J. Climate Special Issue Paper
S. Bates, W. Large, and S. Yeager (NCAR)
B. Fox-Kemper and S. Stevenson (UC-Boulder/CIRES)
S. Jayne (WHOI)

Shortwave radiation bias relative to CORE (W/m^2)

CCSM3-CORE (1980-1999)

CCSM4-CORE (1986-2005)



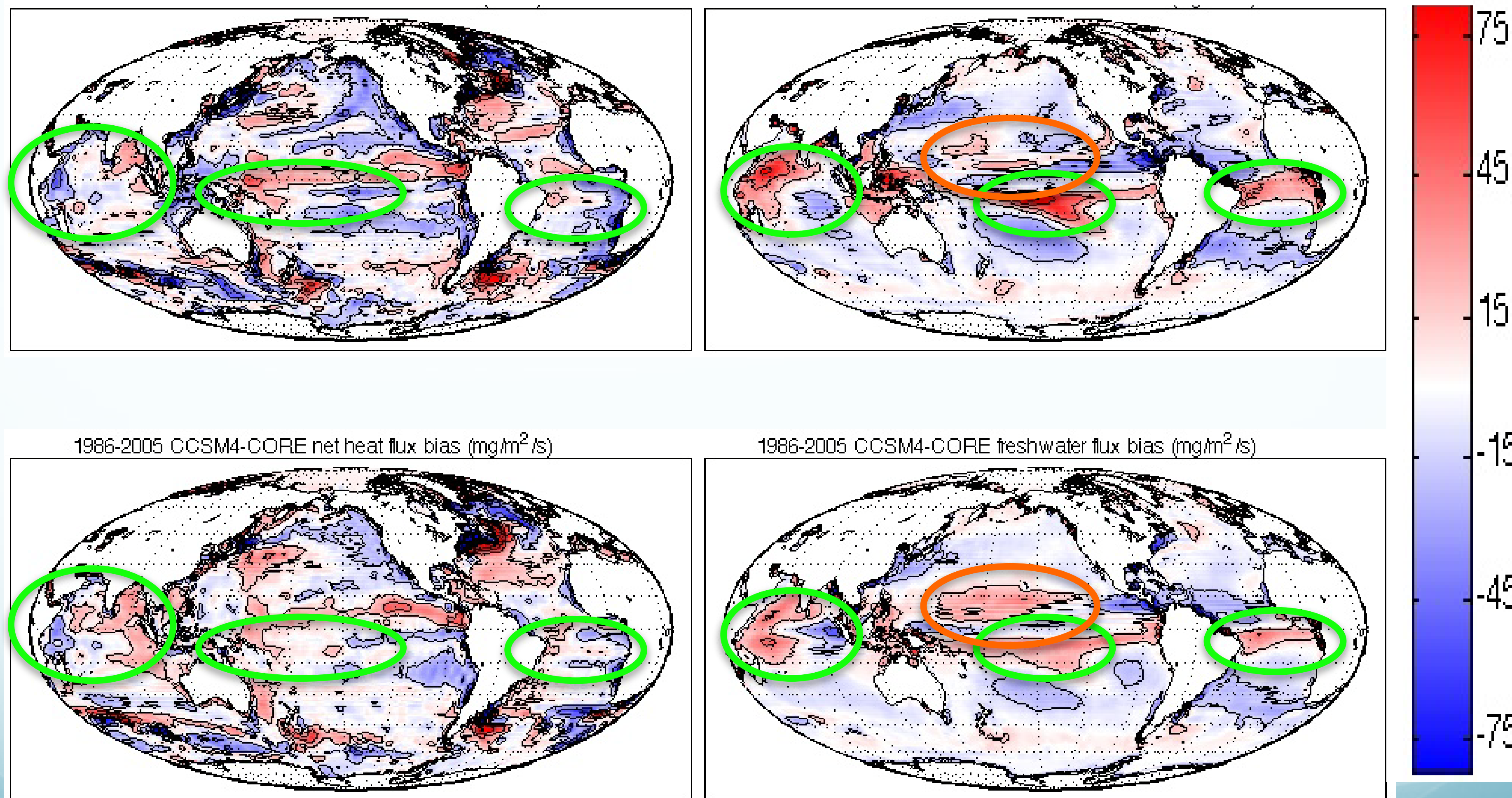
Net flux biases relative to CORE

Net heat flux bias (W/m^2)

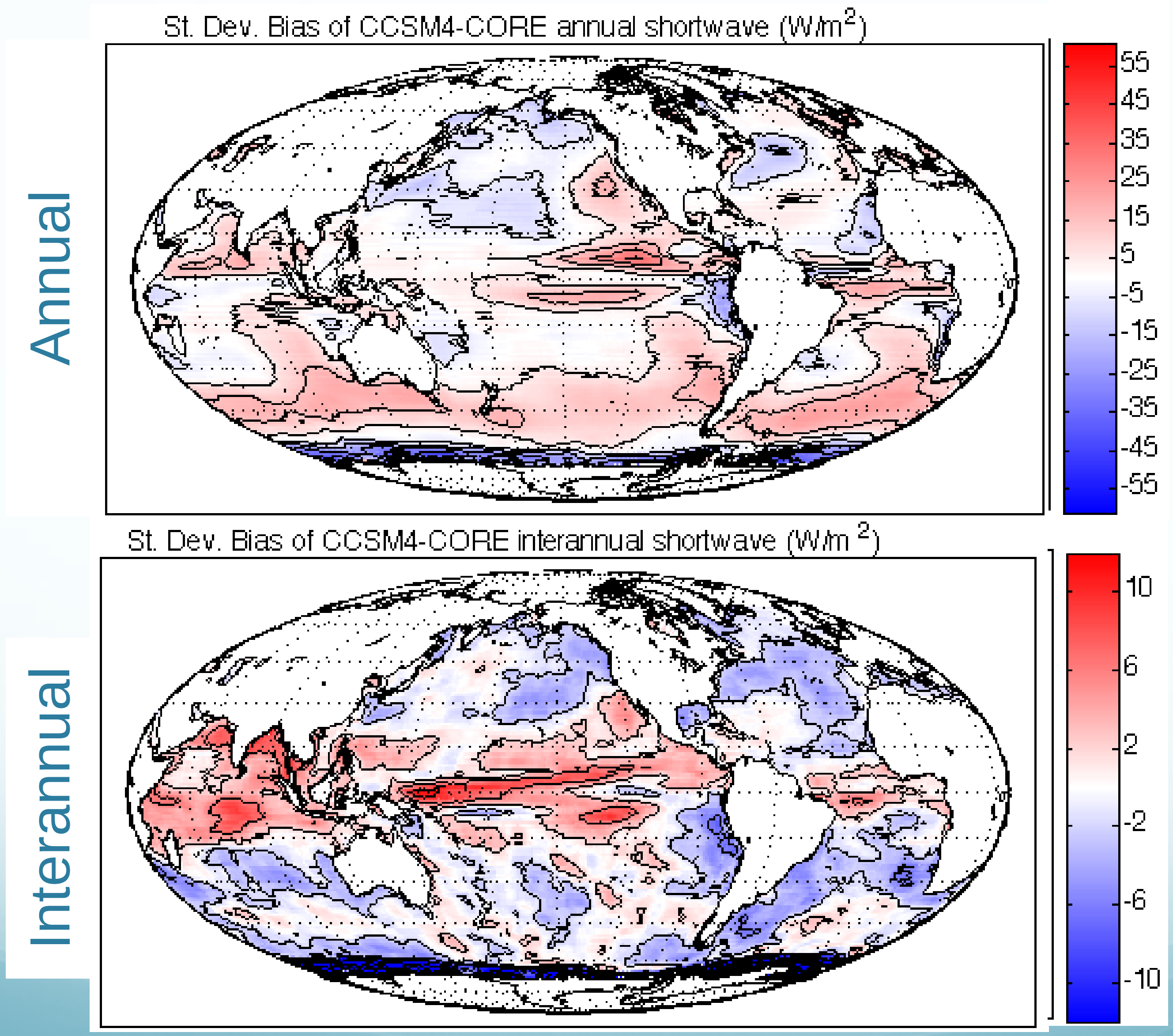
Net freshwater flux bias (mg/m^2/s)

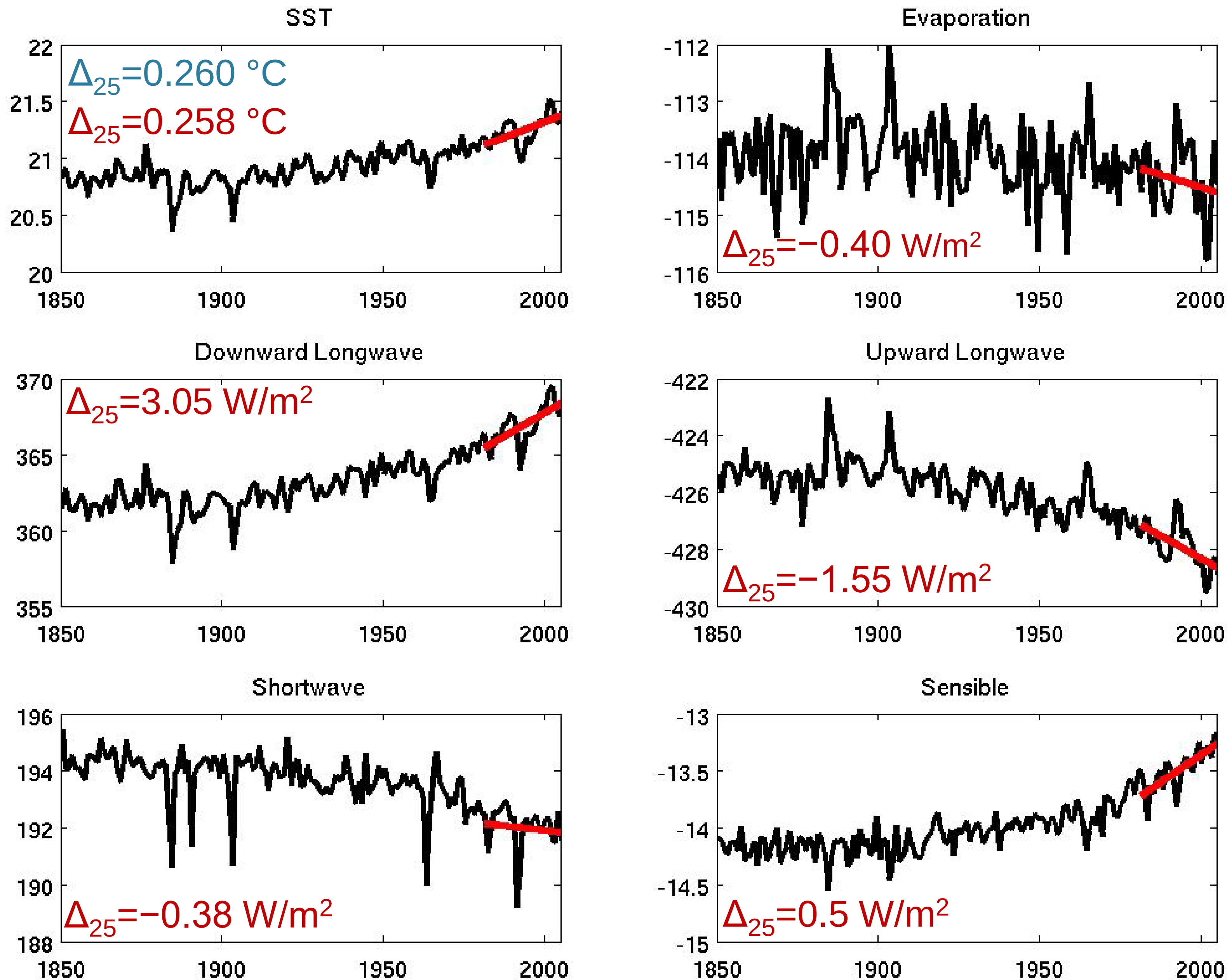
CCSM3-CORE

CCSM4-CORE

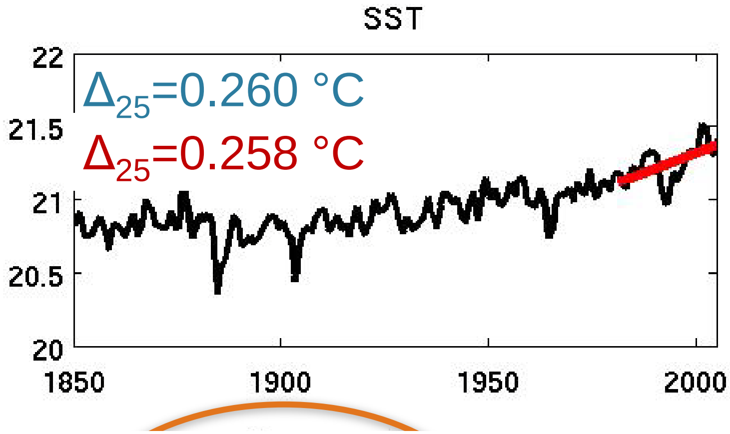


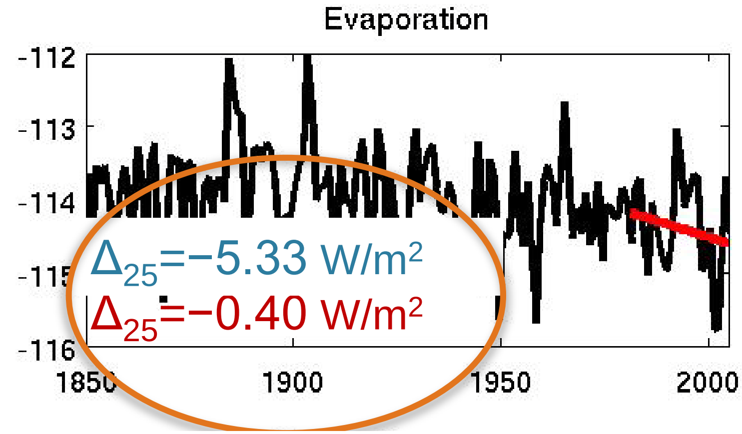
CCSM4 Shortwave Variability Bias
Standard Deviation Bias (W/m^2)





SST
Δ25=0.260 °C
Δ25=0.258 °C
Evaporation
Δ25=−0.40 W/m2
Downward Longwave
Δ25=3.05 W/m2
Upward Longwave
Δ25=−1.55 W/m2
Shortwave
Δ25=−0.38 W/m2
Sensible
Δ25=0.5 W/m2
1850
1900
1950
2000





CORE

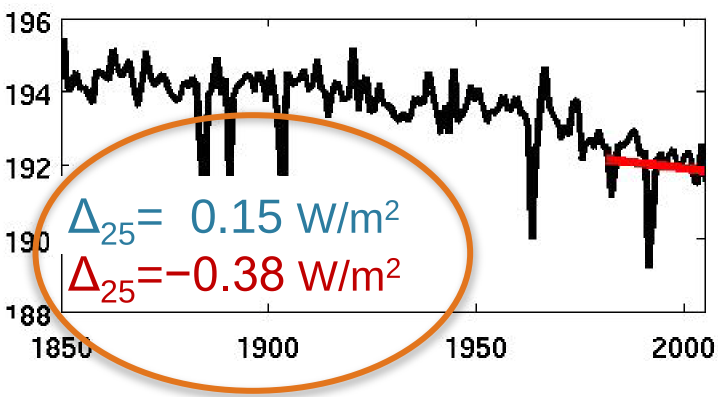
CCSM4

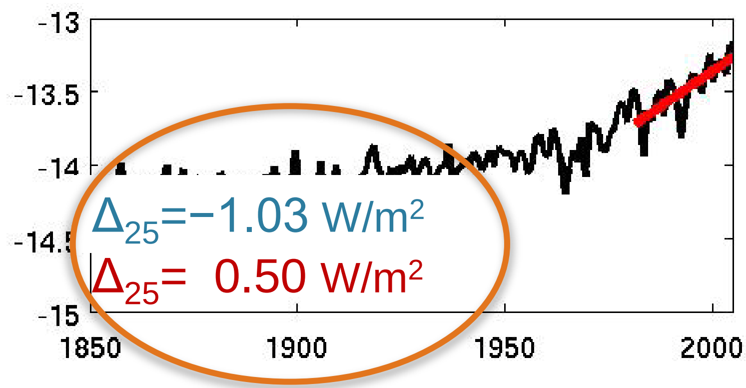
CORE

CCSM4

$\Delta_{25}Q_{pbl}$ = − 7.88 W/m^2

$\Delta_{25}Q_{pbl}$ = −1.48 W/m^2





CORE

CCSM4

Boundary Layer Processes

$$Q_E + Q_H = \rho\, C10\, U10\, (C_p\, \Delta_T + \Lambda\, \Delta_q)$$

Q_E = latent heat flux

Q_H = sensible heat flux

C10 = transfer coefficient

U10 = 10m wind speed

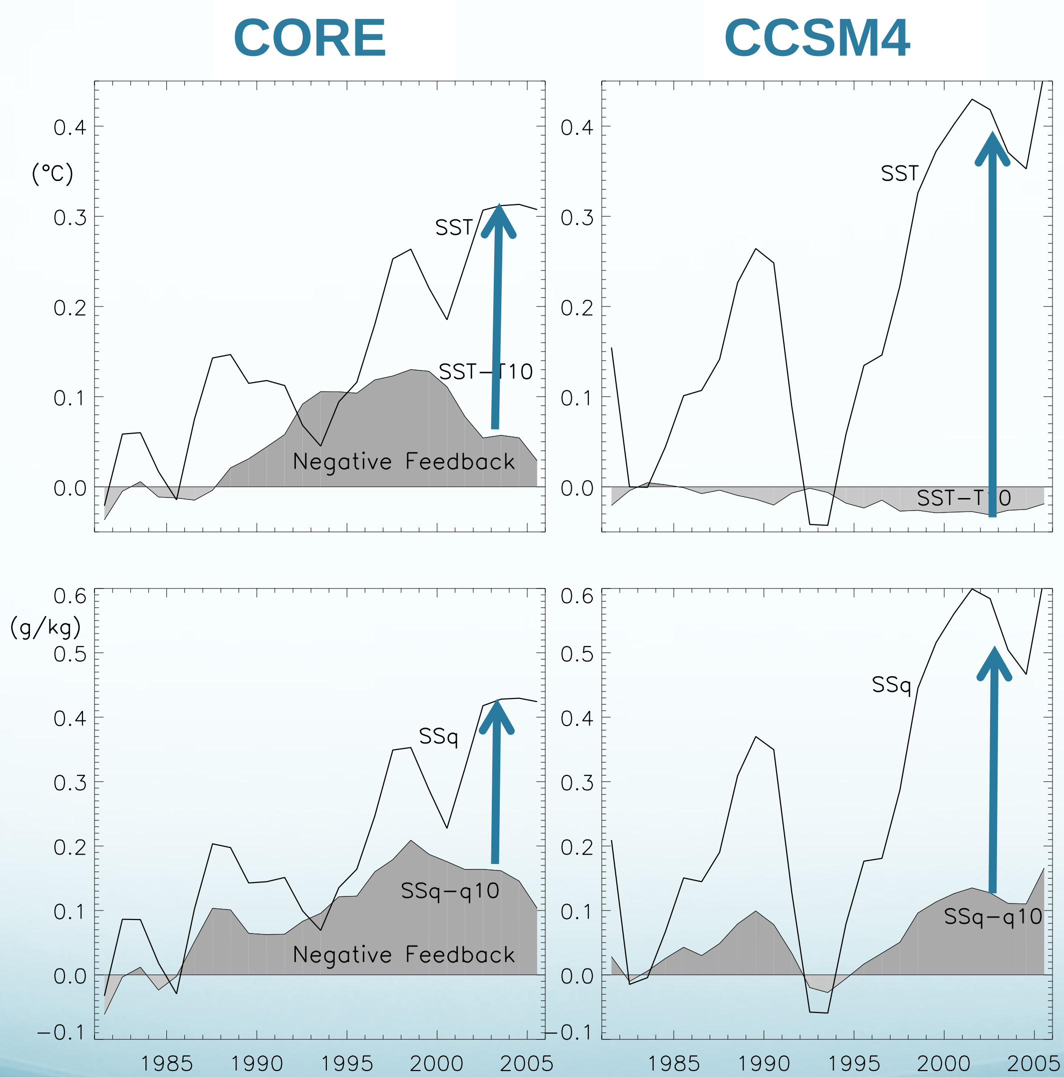
$\Delta_T = T_{air} - SST$

$\Delta_q = q_{air} - SSq$

Considering wind speed, there is still have a 3.3 W/m^2 discrepancy

SST and Sea-Air Temperature Difference Between 40˚N and 40˚S

Why is CCSM4 behavior so different from “Observations” ?



Summary

- Mean biases
  - Solar radiation bias is larger in higher latitudes
  - Net bias is smaller: improvements due to improved precipitation and evaporation biases
- Variability
  - Patterns of bias in mean, annual, and interannual are different
  - Annual bias leaves room for improvement
- Trends
  - The late 20th Century trends are not analogous to CORE.
  - The forcing of SST and the flux response during this time period behave differently from CORE.
  - C_{pbl} as a metric for assessing a model's boundary layer

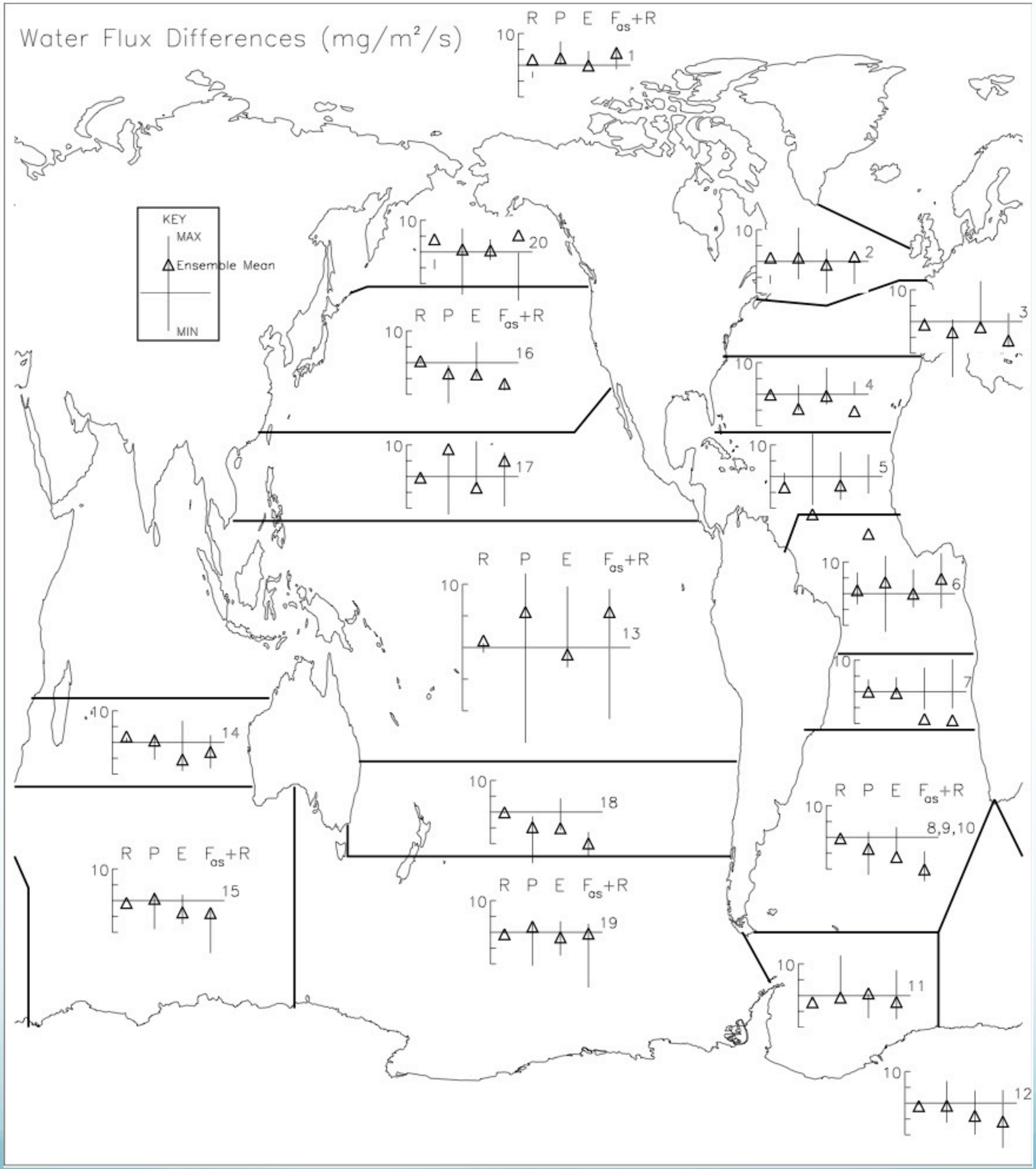
	CCSM4	CORE
$\Delta_{25}\, Q_{pbl}$	−1.48 W/m^2	−7.88 W/m^2
Δ_{25} U10	$O(10^{-4})$	0.13 m/s
Q_{pbl} change		−3.1 W/m^2
Q_{pbl} remaining	−1.48 W/m^2	−4.78 W/m^2

Boundary Layer Processes

$$Q_{pbl} = LW_{up} + Q_E + Q_H$$

$$C_{pbl} = \frac{\Delta Q_{pbl}}{\Delta SST}$$

Geographical Region	CORE C_{pbl}	CCSM4 C_{pbl}	Ratio
Global	-28	-14	2
North Atlantic	-18	-7	2.6
Equatorial Atlantic	-29	-14	2.1
Indian	-46	-9	5.1
North Pacific	-18	-6	3
Equatorial Pacific	-35	-8	4.4
South Pacific	-33	-9	3.7



Water Flux Differences (mg/m²/s)
KEY
MAX
Ensemble Mean
MIN
R P E Fas+R
10
1
2
3
4
5
6
7
8,9,10
11
12
13
14
15
16
17
18
19
20