Rapid cloud adjustments, cloud feedbacks and large-scale forcings

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Outline

Met Office
Hadley Centre

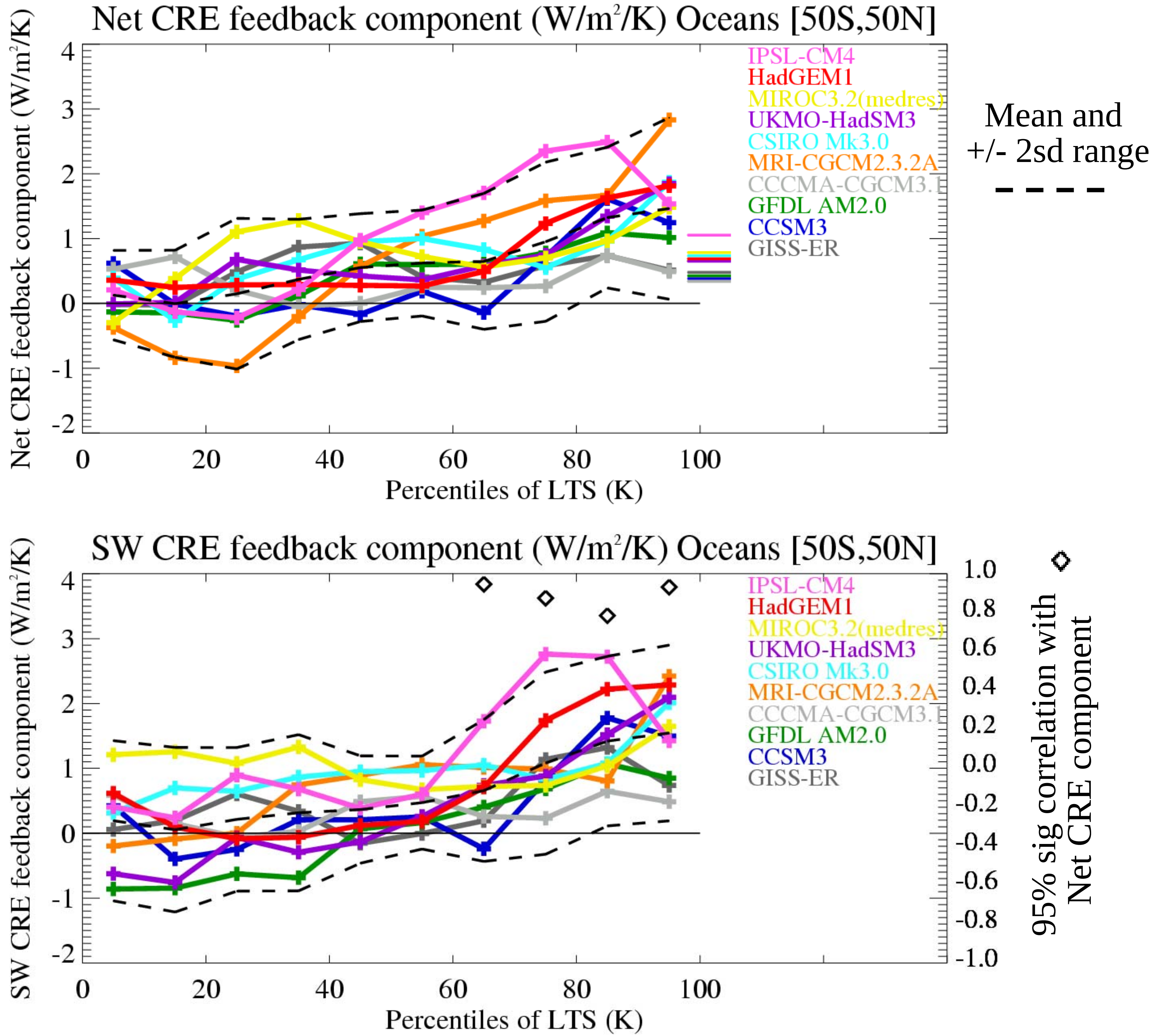
Gregory and Webb (2008) found evidence of rapid cloud adjustments in direct response to CO_2 doubling in the AR4/CFMIP-1 slab models

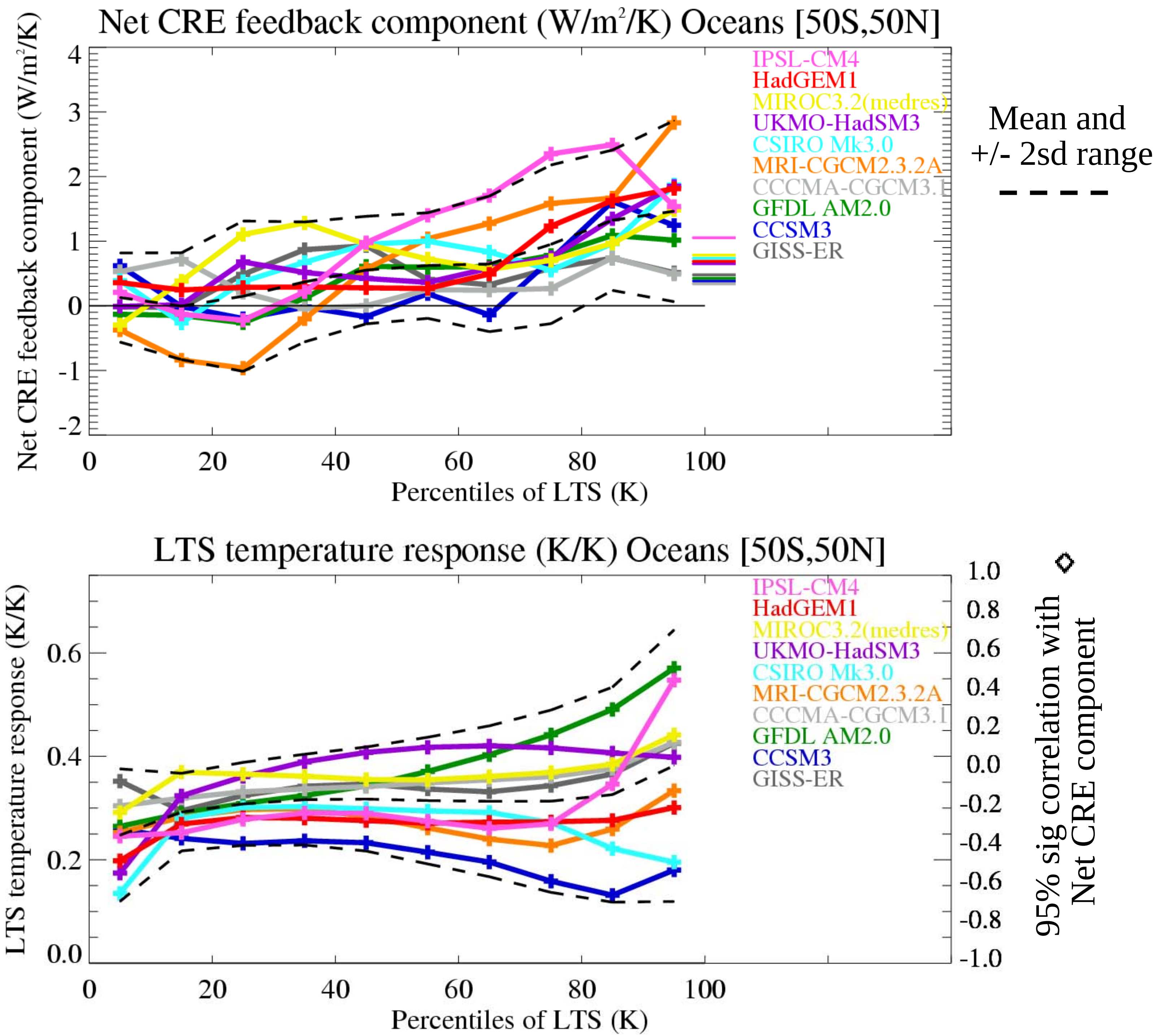
Here we diagnose forcings and feedbacks using the Gregory method in an enlarged ensemble with four additional AR4 slab models

We separate shallow vs deep cloud regimes by sorting cloud components of forcing and feedback into percentiles of lower tropospheric stability (LTS) over ocean points using the method of Wyant, Bretherton and Blossey (2009)

We examine CO_2 and temperature dependent responses in LTS and EIS (Estimated Inversion Strength, Wood and Bretherton, 2006) to see whether these are consistent between the models. If they are substantially different, then inter-model feedback and forcing differences are unlikely to be due solely to differences in local moist physics

Early results from CFMIP-2 rapid cloud adjustment experiments will also be shown


Net CRE feedback component (W/m²/K) Oceans [50S,50N]
Net CRE feedback component (W/m²/K)
Percentiles of LTS (K)
IPSL-CM4
HadGEM1
MIROC3.2(medres)
UKMO-HadSM3
CSIRO Mk3.0
MRI-CGCM2.3.2A
CCCMA-CGCM3.1
GFDL AM2.0
CCSM3
GISS-ER
Mean and
+/- 2sd range
SW CRE feedback component (W/m²/K) Oceans [50S,50N]
SW CRE feedback component (W/m²/K)
Percentiles of LTS (K)
95% sig correlation with
Net CRE component



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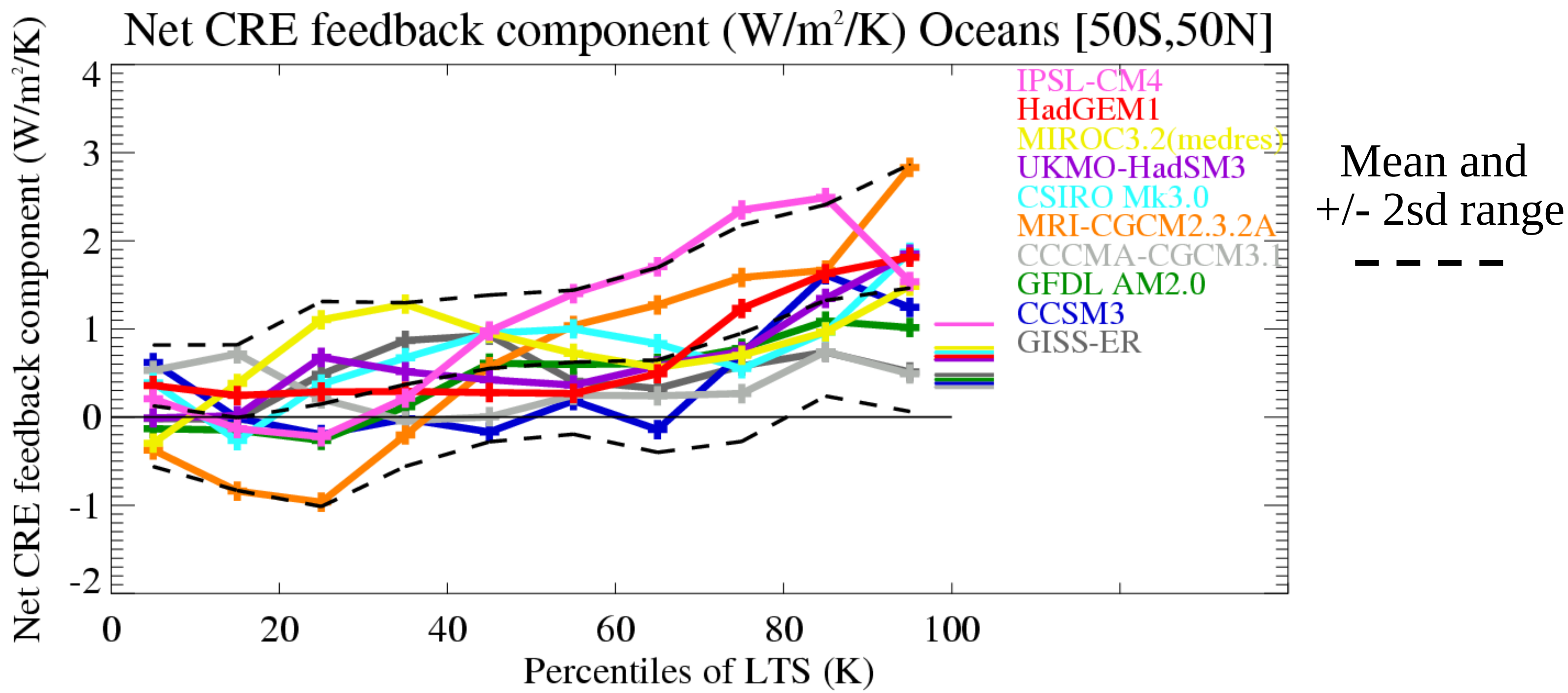
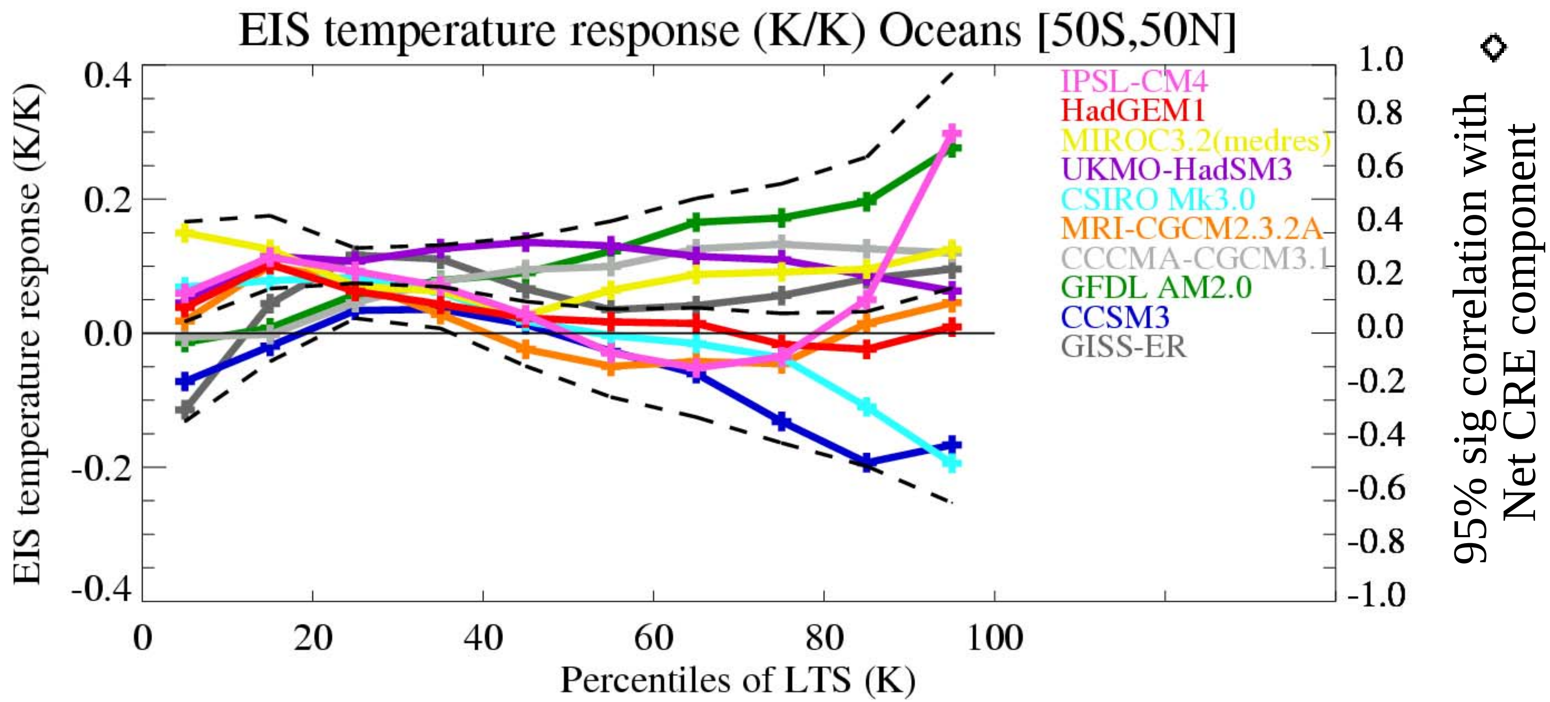
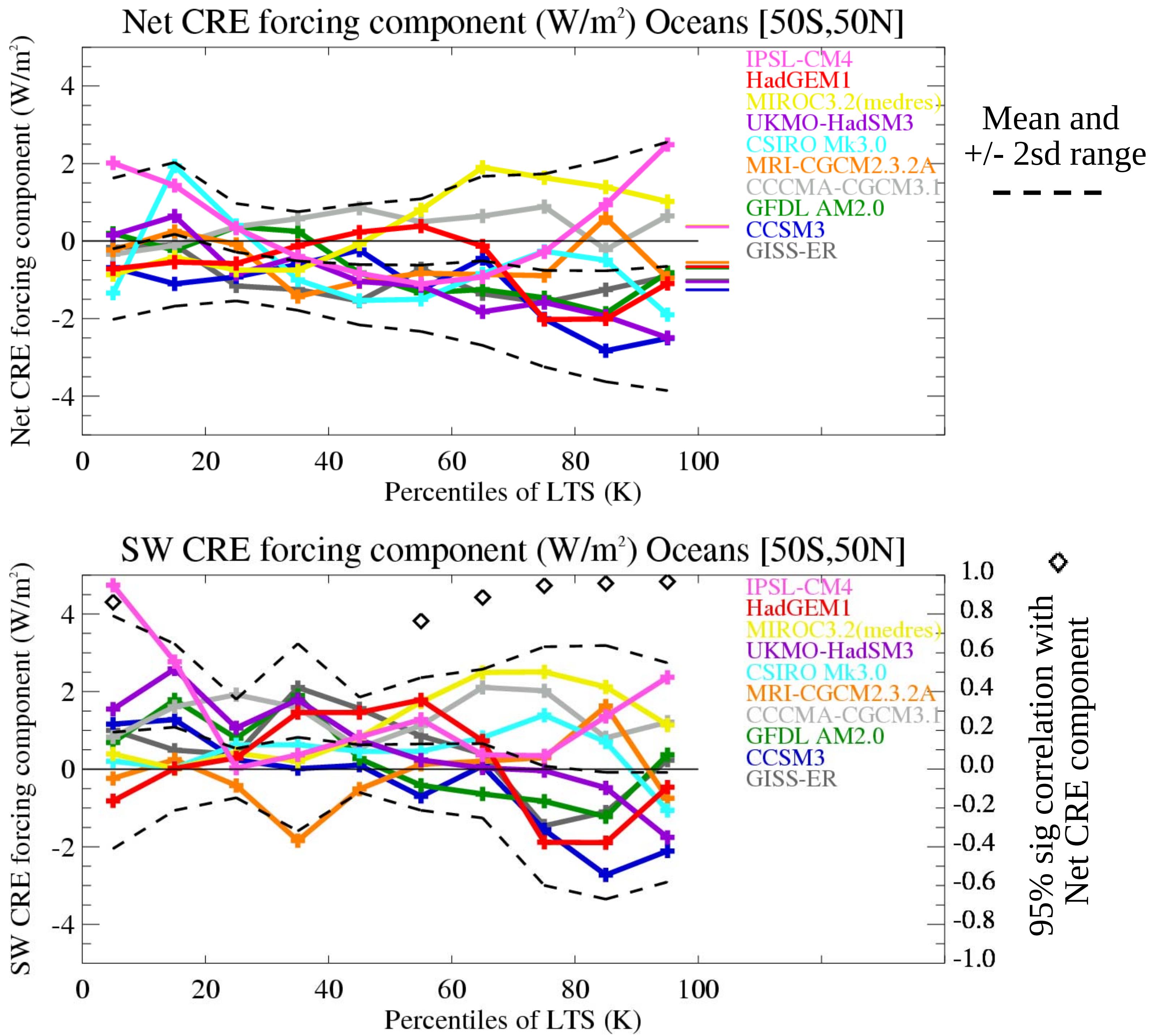
CCCMA-CGCM3.1
GFDL AM2.0
CCSM3
GISS-ER
Mean and
+/- 2sd range
LTS temperature response (K/K) Oceans [50S,50N]
LTS temperature response (K/K)
Percentiles of LTS (K)
95% sig correlation with
Net CRE component



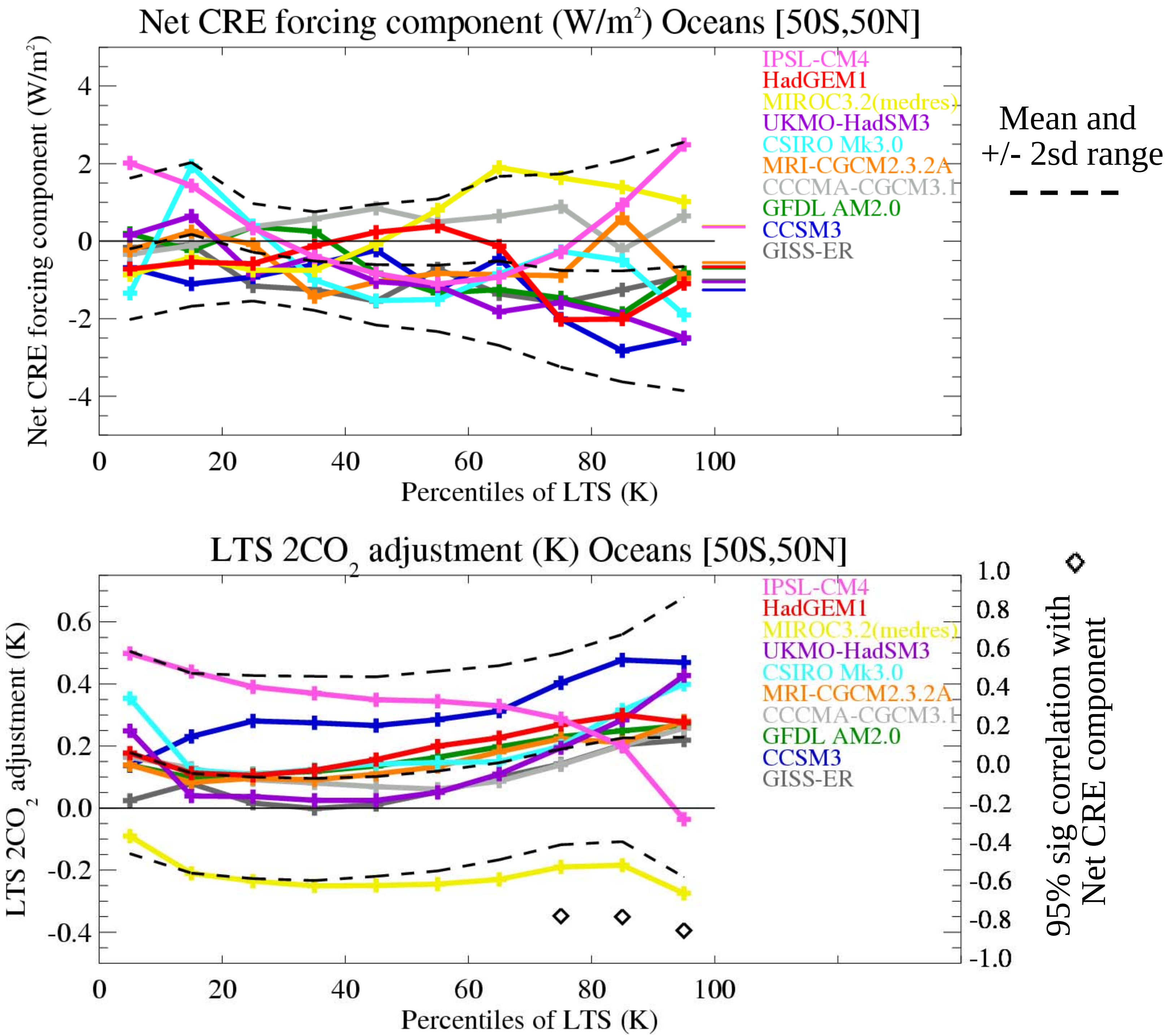
Net CRE feedback component (W/m²/K) Oceans [50S,50N]
Net CRE feedback component (W/m²/K)
4
3
2
1
0
-1
-2
0
20
40
60
80
100
Percentiles of LTS (K)
IPSL-CM4
HadGEM1
MIROC3.2(medres)
UKMO-HadSM3
CSIRO Mk3.0
MRI-CGCM2.3.2A
CCCMA-CGCM3.1
GFDL AM2.0
CCSM3
GISS-ER
Mean and
+/- 2sd range



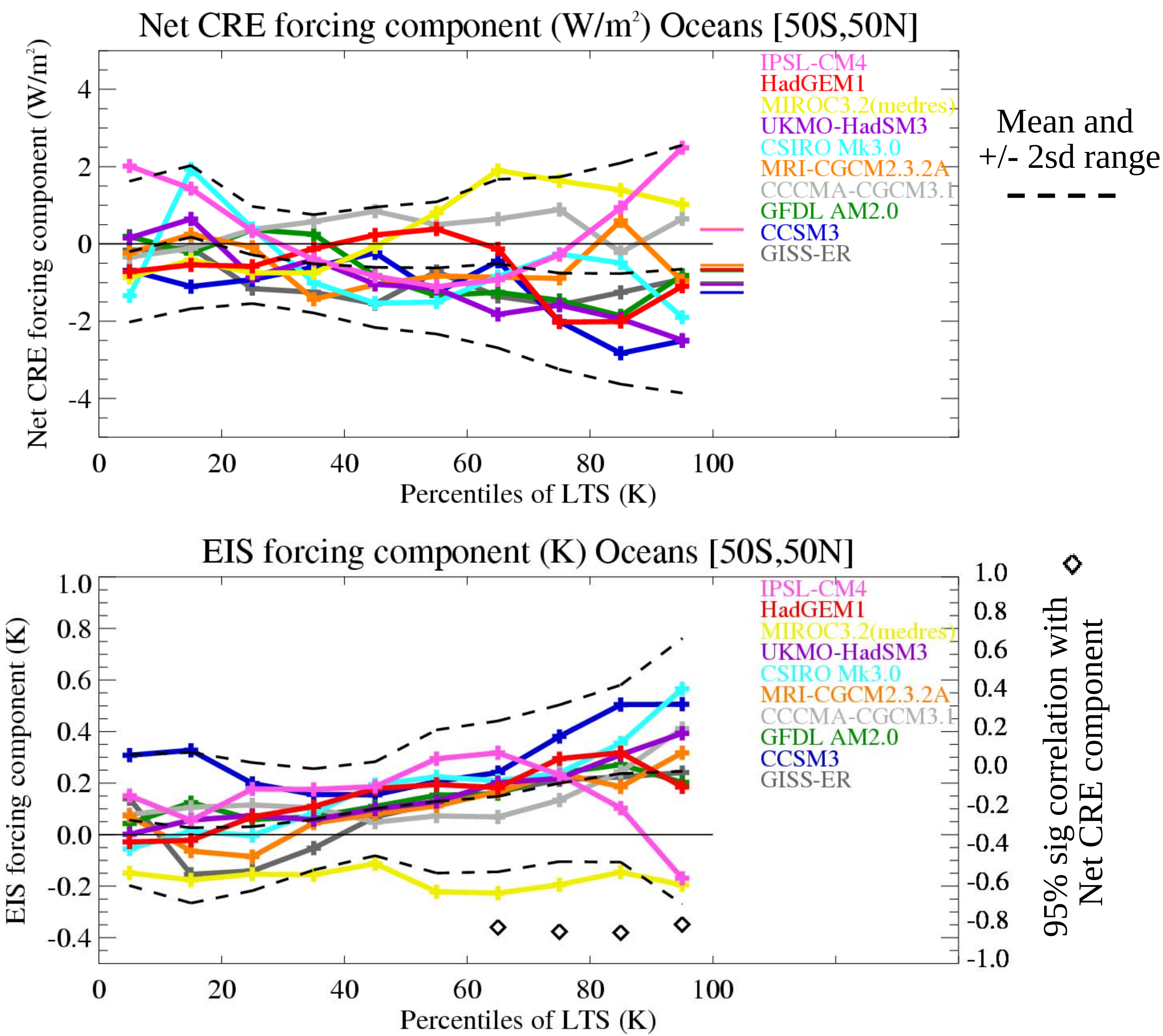
EIS temperature response (K/K) Oceans [50S,50N]
EIS temperature response (K/K)
0.4
0.2
0.0
-0.2
-0.4
0
20
40
60
80
100
Percentiles of LTS (K)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
95% sig correlation with
Net CRE component
IPSL-CM4
HadGEM1
MIROC3.2(medres)
UKMO-HadSM3
CSIRO Mk3.0
MRI-CGCM2.3.2A
CCCMA-CGCM3.1
GFDL AM2.0
CCSM3
GISS-ER



Net CRE forcing component (W/m²) Oceans [50S,50N]
Net CRE forcing component (W/m²)
Percentiles of LTS (K)
IPSL-CM4
HadGEM1
MIROC3.2(medres)
UKMO-HadSM3
CSIRO Mk3.0
MRI-CGCM2.3.2A
CCCMA-CGCM3.1
GFDL AM2.0
CCSM3
GISS-ER
Mean and
+/- 2sd range
SW CRE forcing component (W/m²) Oceans [50S,50N]
SW CRE forcing component (W/m²)
95% sig correlation with
Net CRE component

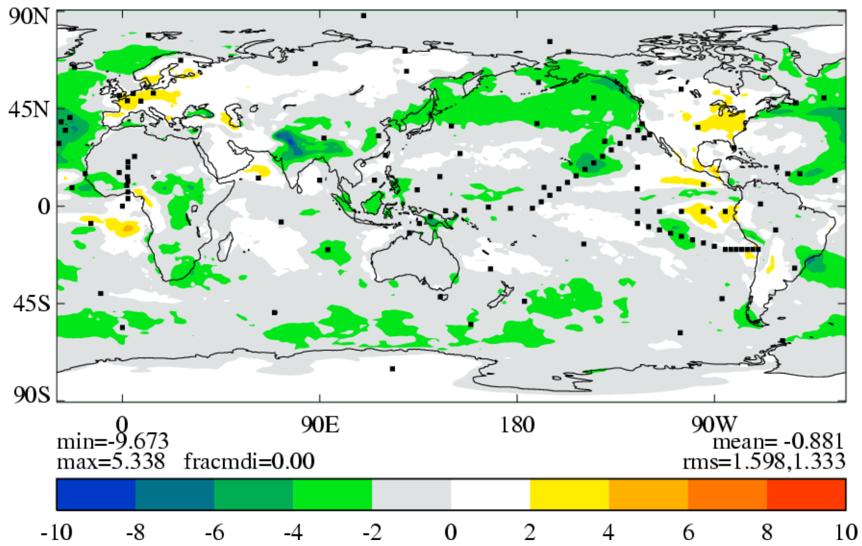


Net CRE forcing component (W/m²) Oceans [50S,50N]
Net CRE forcing component (W/m²)
Percentiles of LTS (K)
IPSL-CM4
HadGEM1
MIROC3.2(medres)
UKMO-HadSM3
CSIRO Mk3.0
MRI-CGCM2.3.2A
CCCMA-CGCM3.1
GFDL AM2.0
CCSM3
GISS-ER
Mean and
+/- 2sd range
LTS 2CO2 adjustment (K) Oceans [50S,50N]
LTS 2CO2 adjustment (K)
Percentiles of LTS (K)
95% sig correlation with
Net CRE component

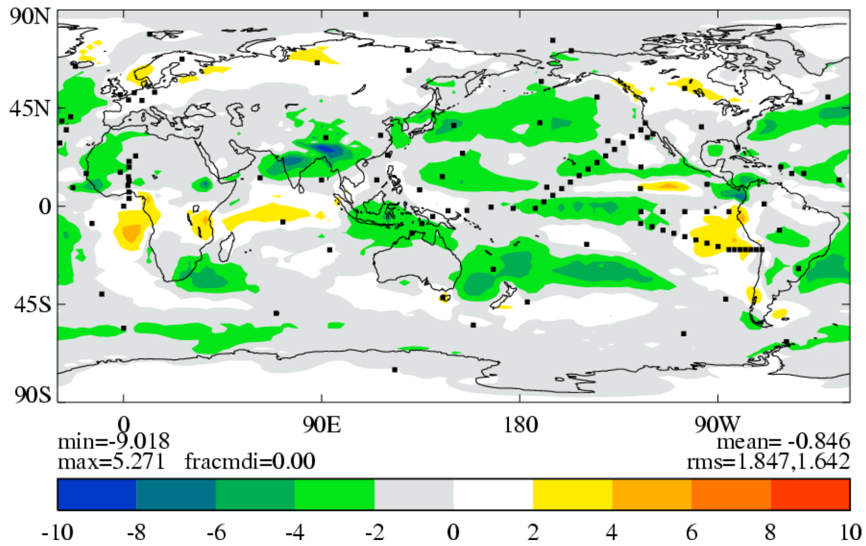


Net CRE forcing component (W/m²) Oceans [50S,50N]
Net CRE forcing component (W/m²)
4
2
0
-2
-4
0
20
40
60
80
100
Percentiles of LTS (K)
IPSL-CM4
HadGEM1
MIROC3.2(medres)
UKMO-HadSM3
CSIRO Mk3.0
MRI-CGCM2.3.2A
CCCMA-CGCM3.1
GFDL AM2.0
CCSM3
GISS-ER
Mean and
+/- 2sd range
EIS forcing component (K) Oceans [50S,50N]
EIS forcing component (K)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
95% sig correlation with
Net CRE component

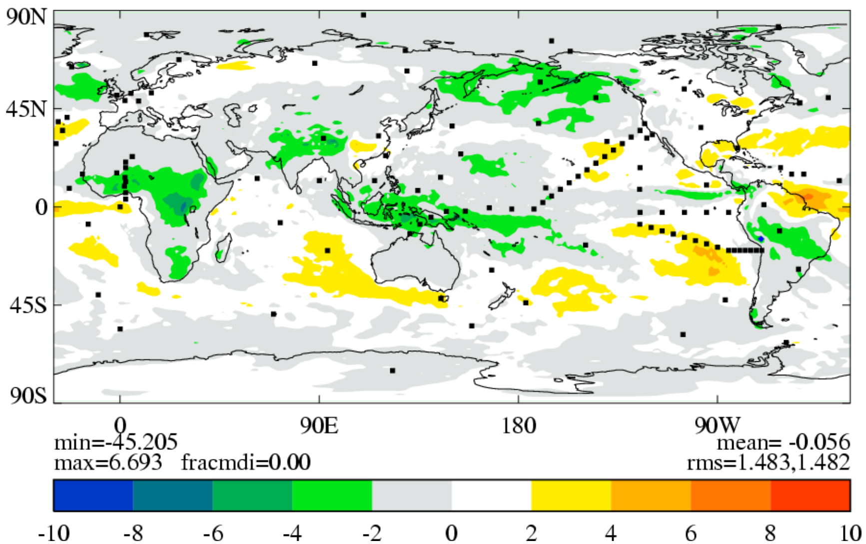
HadGEM2-A 4xCO_2 Fixed SST
Net CRE Response
Global 2xCO_2 Equivalent = -0.44 Wm-2

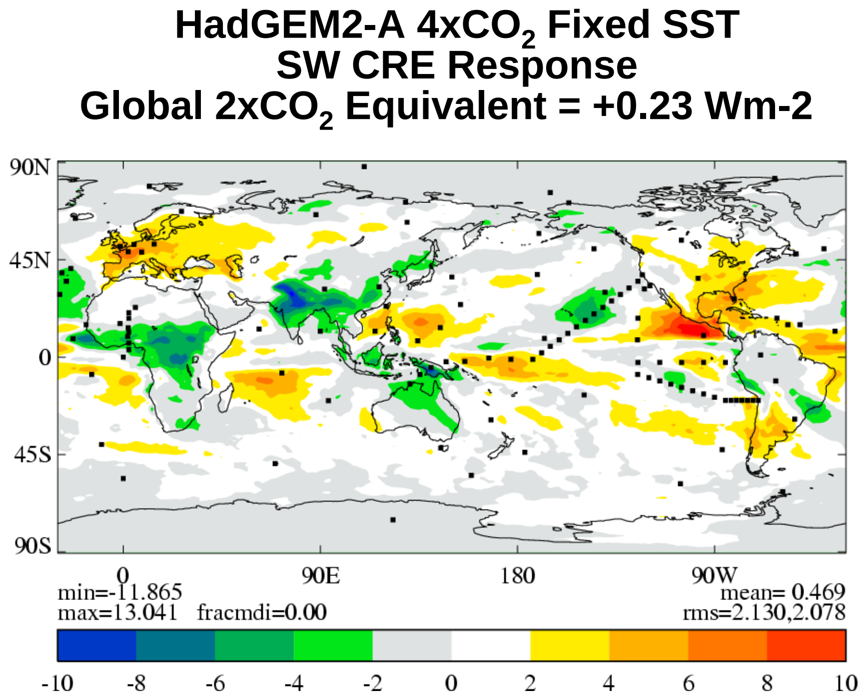


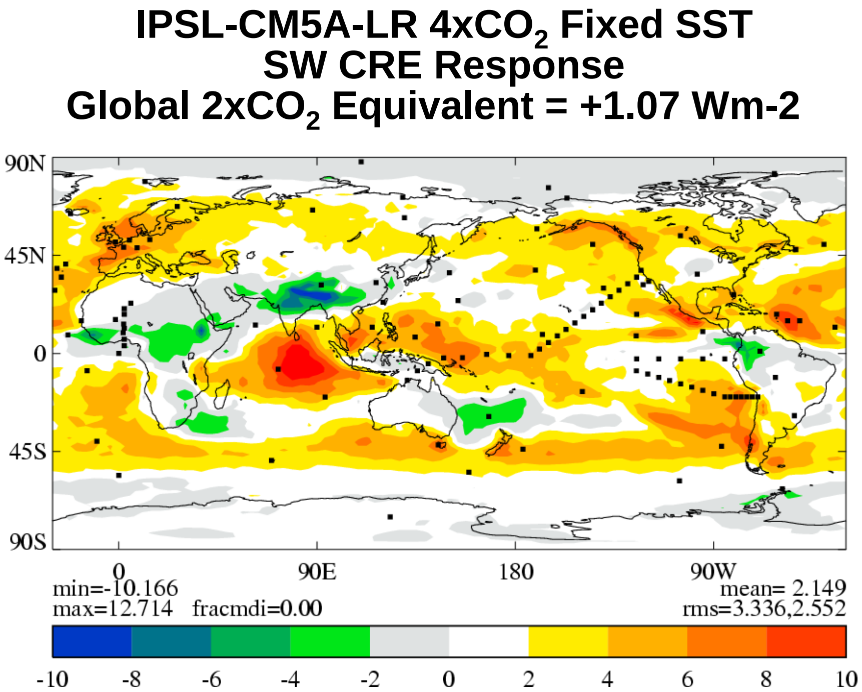
IPSL-CM5A-LR 4xCO_2 Fixed SST
Net CRE Response
Global 2xCO_2 Equivalent = -0.42 Wm-2

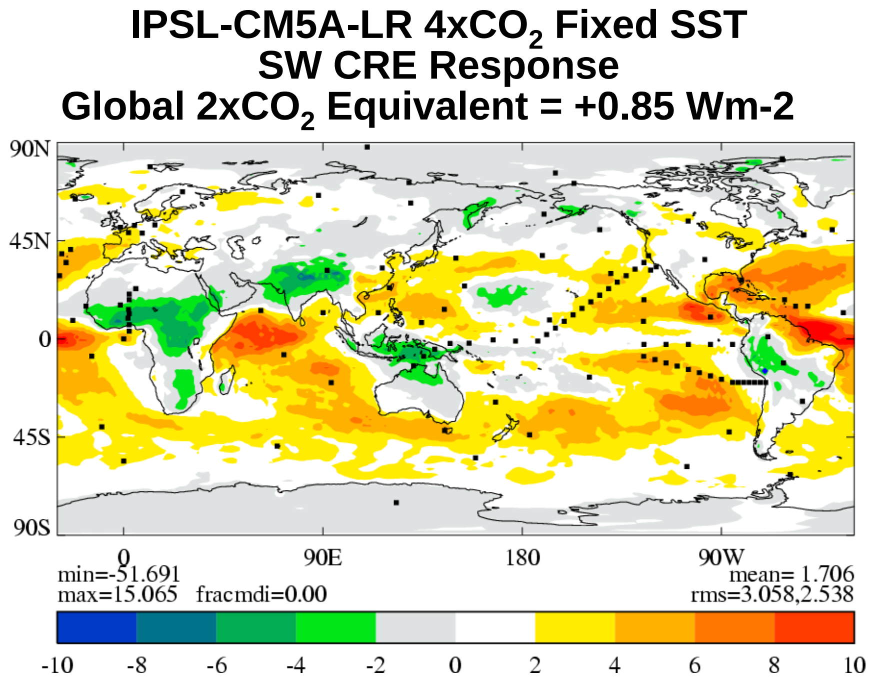


CNRM-CM5 4xCO_2 Fixed SST
SW CRE Response
Global 2xCO_2 Equivalent = +0.03 Wm-2




HadGEM2-A 4xCO$_2$ Fixed SST
SW CRE Response
Global 2xCO$_2$ Equivalent = +0.23 Wm-2
90N
45N
0
45S
90S
0
90E
180
90W
min=-11.865
max=13.041 fracmdi=0.00
mean= 0.469
rms=2.130,2.078
-10 -8 -6 -4 -2 0 2 4 6 8 10


IPSL-CM5A-LR 4xCO$_2$ Fixed SST
SW CRE Response
Global 2xCO$_2$ Equivalent = +1.07 Wm-2
90N
45N
0
45S
90S
0
90E
180
90W
min=-10.166
max=12.714 fracmdi=0.00
mean= 2.149
rms=3.336,2.552
-10 -8 -6 -4 -2 0 2 4 6 8 10


IPSL-CM5A-LR 4xCO$_2$ Fixed SST
SW CRE Response
Global 2xCO$_2$ Equivalent = +0.85 Wm-2
90N
45N
0
45S
90S
0
90E
180
90W
min=-51.691
max=15.065 fracmdi=0.00
mean= 1.706
rms=3.058,2.538
-10 -8 -6 -4 -2 0 2 4 6 8 10

Conclusions (1)

Cloud components of climate feedback are positive in all models in stable oceanic areas, in spite of increases in LTS in all models and increases in EIS in most models

Spread in cloud feedback is largest is stable regions, suggesting that stratocumulus/transition clouds are a leading order cause of spread in climate sensitivity in this ensemble

Large inter-model differences in LTS and EIS responses in stable regions mean that we can not safely assume that differences in feedbacks are due to local moist physics alone

Conclusions (2)

Cloud components of CO_2 forcing take positive and negative values and again show largest differences in stable regions

CAM3 has strong increases in stability in all bins, and the strongest negative cloud component of CO_2 forcing, while MIROC shows the opposite behaviour

The cloud components of the forcings are strongly anti-correlated with changes in LTS and EIS in the stable regions

This suggests that remote processes (e.g. deep convection) may be controlling the different cloud responses via stability changes in some models

Conclusions (3)

Substantial differences in stability responses in stable regions coincident with differing cloud components of CO_2 forcing and feedback suggest a need for studies following on from CGILS to consider a range of stability forcings

Early results from CFMIP-2 experiments with $4xCO_2$ and fixed SSTs show substantial positive shortwave cloud responses over oceans in low and high cloud areas.

Negative SW responses are seen over land are suggestive of a monsoon-like response.