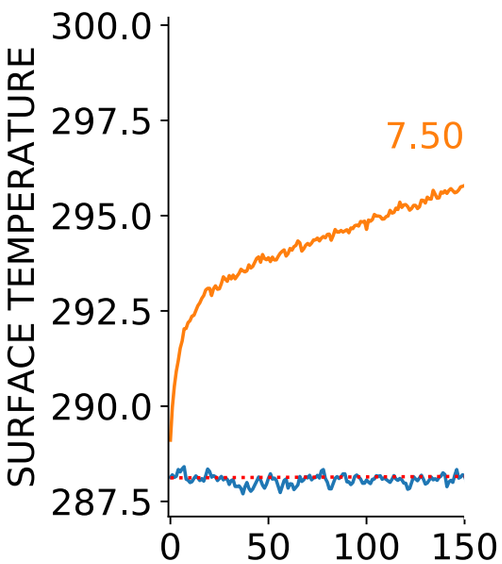
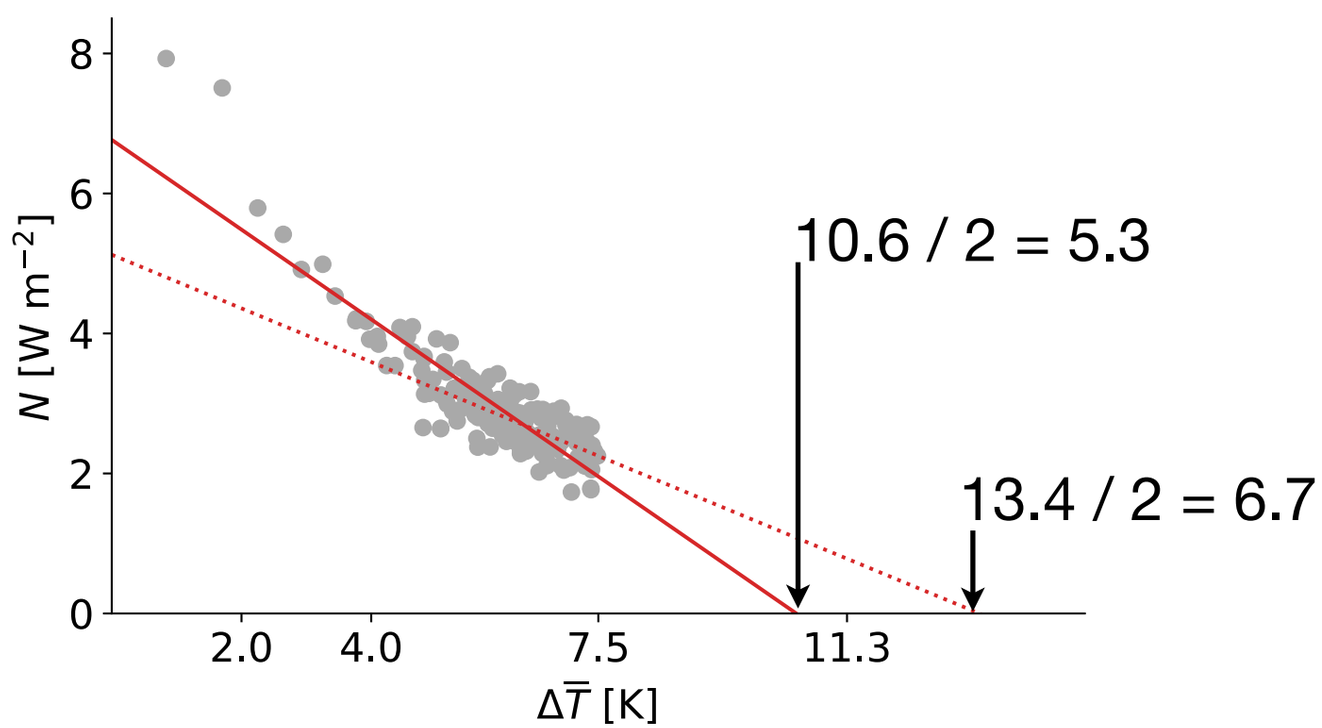
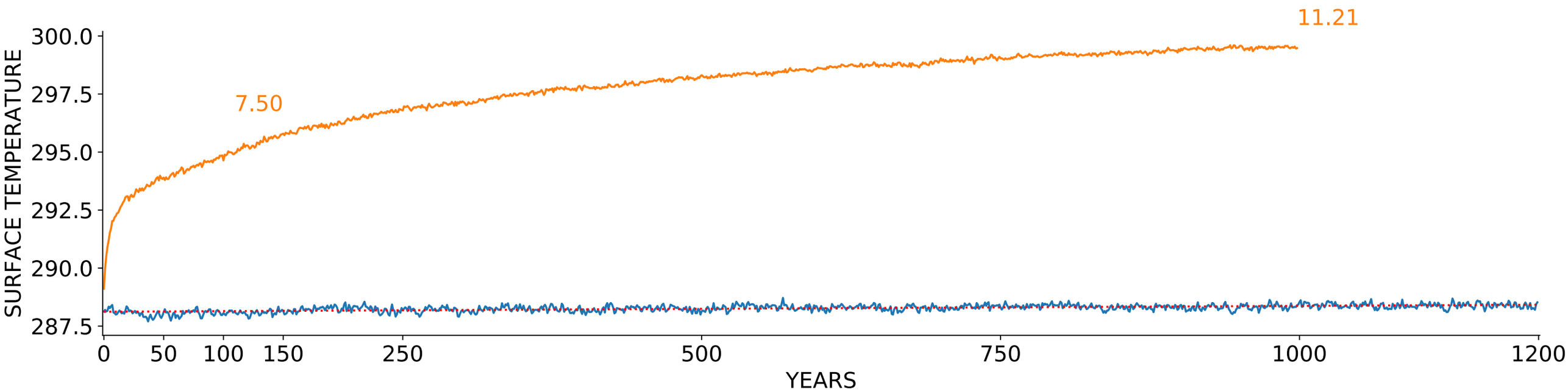
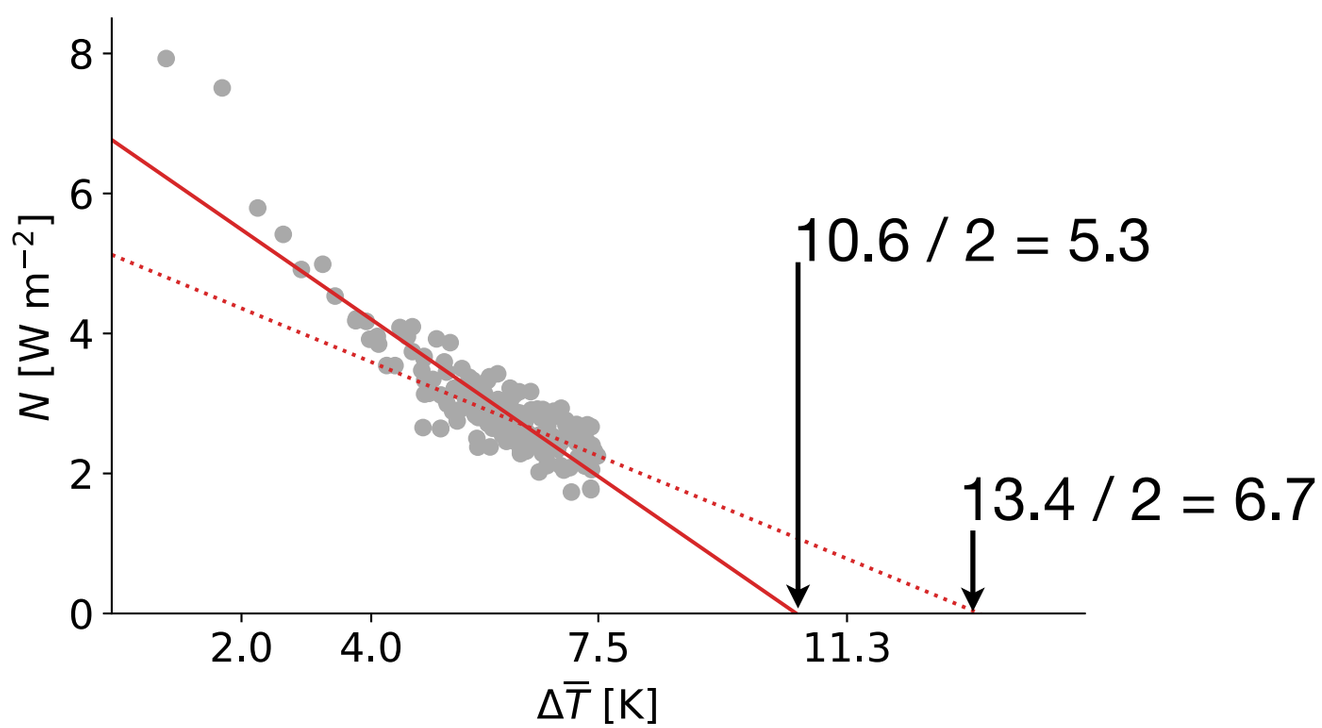
Synthesizing CFMIP experiments to understand CESM2's high climate sensitivity

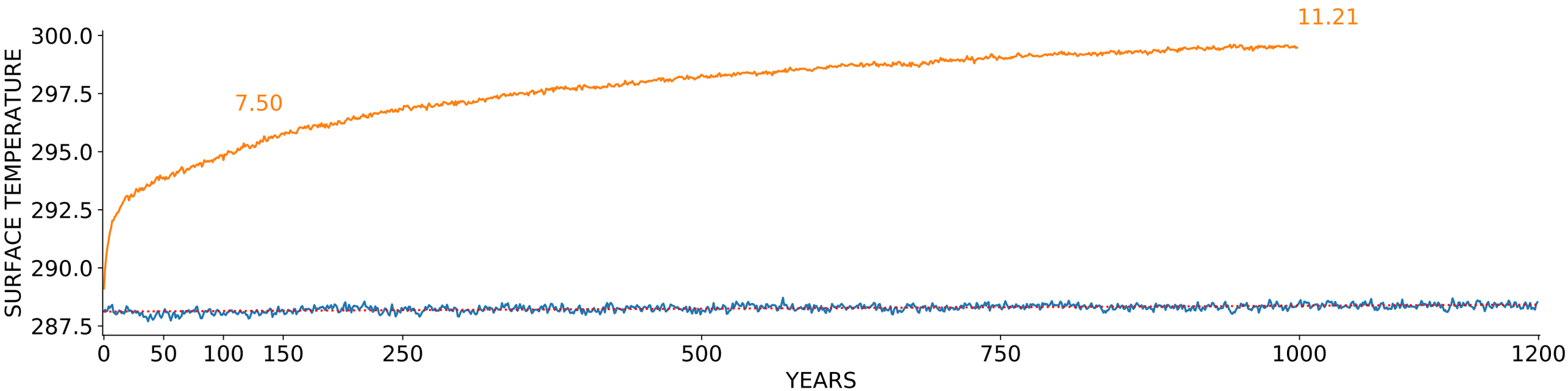
Brian Medeiros
with Jim Benedict, Amy Clement, and Jen Kay


SURFACE TEMPERATURE
300.0
297.5
295.0
292.5
290.0
287.5
7.50
0
50
100
150


N [W m^{-2}]
8
6
4
2
0
2.0
4.0
7.5
11.3
$\Delta\overline{T}$ [K]
10.6 / 2 = 5.3
13.4 / 2 = 6.7


11.21
7.50
300.0
297.5
295.0
292.5
290.0
287.5
SURFACE TEMPERATURE
0
50
100
150
250
500
750
1000
1200
YEARS


8
6
4
2
0
N [W m⁻²]
10.6 / 2 = 5.3
13.4 / 2 = 6.7
2.0
4.0
7.5
11.3
ΔT̄ [K]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7.50
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290.0
287.5
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0
50
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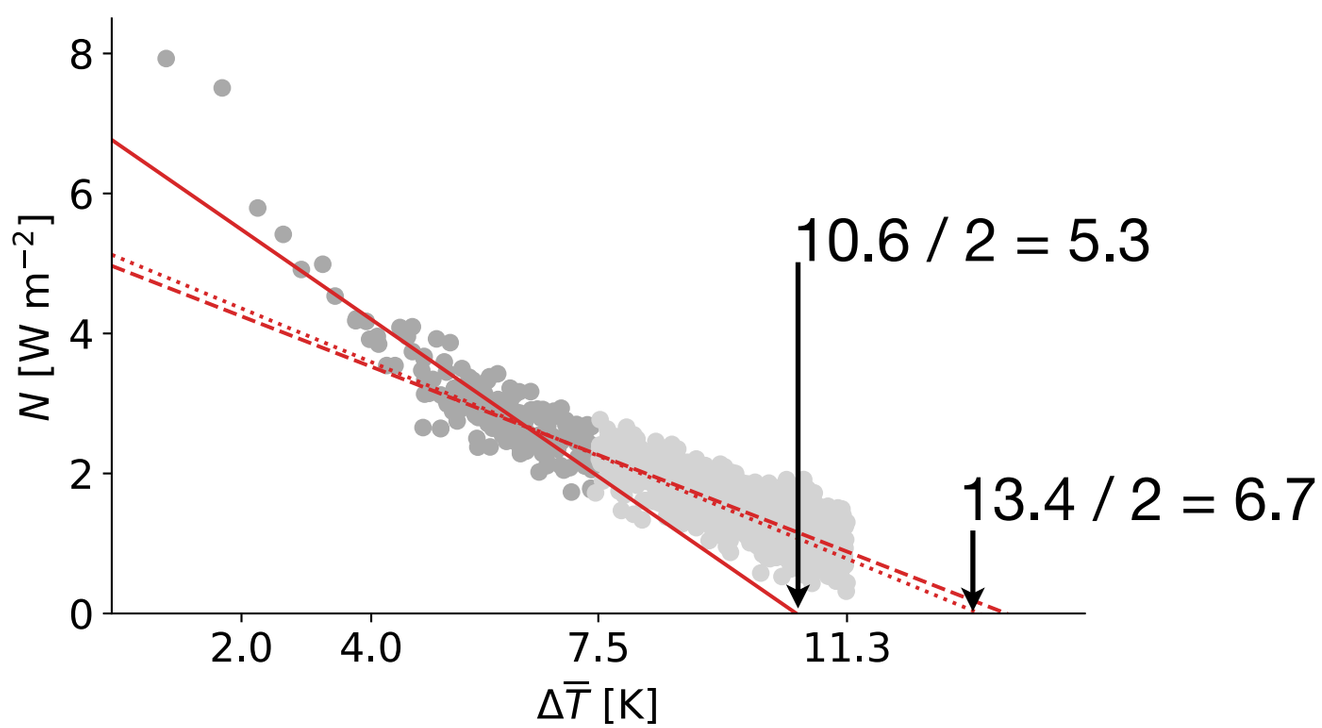
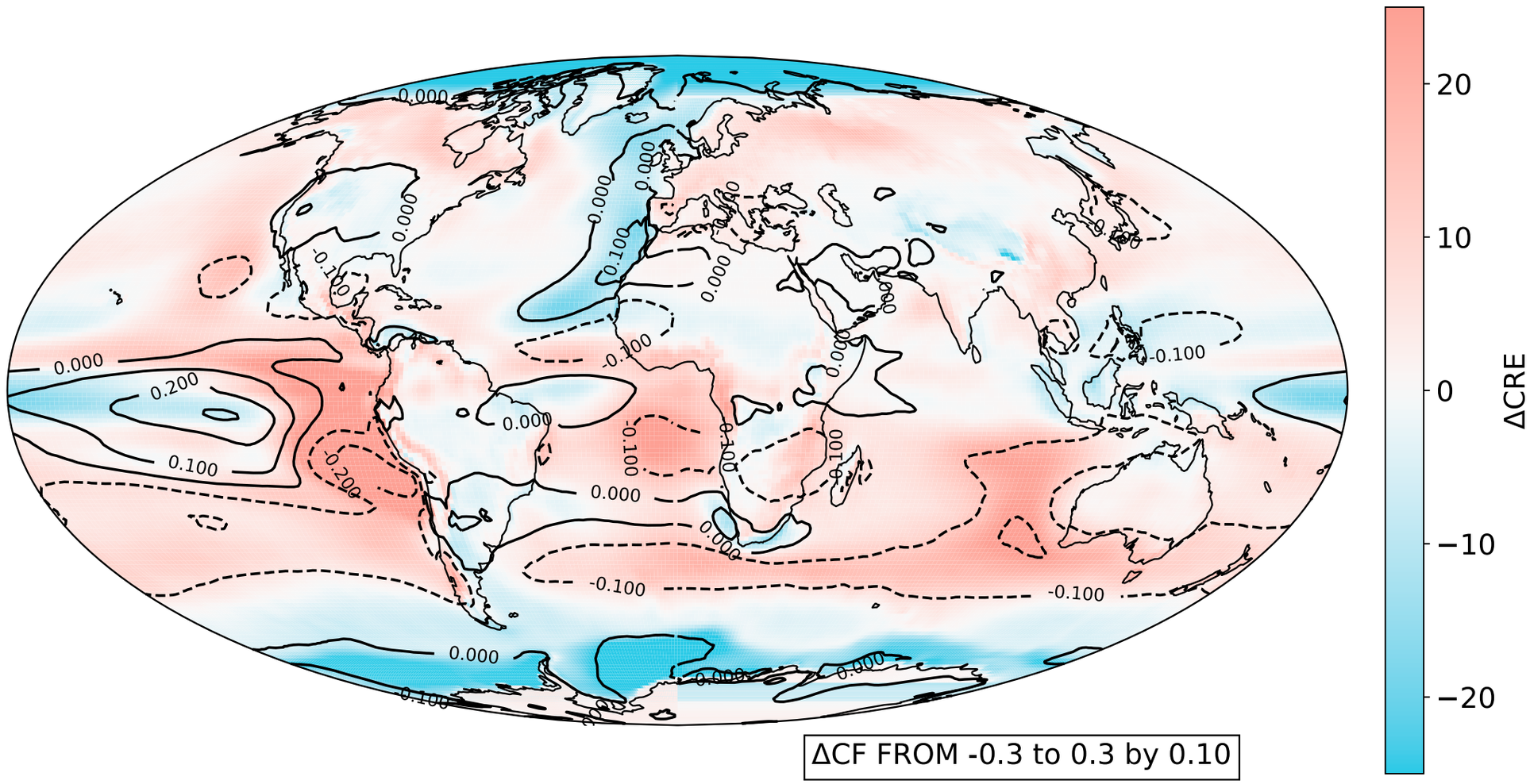
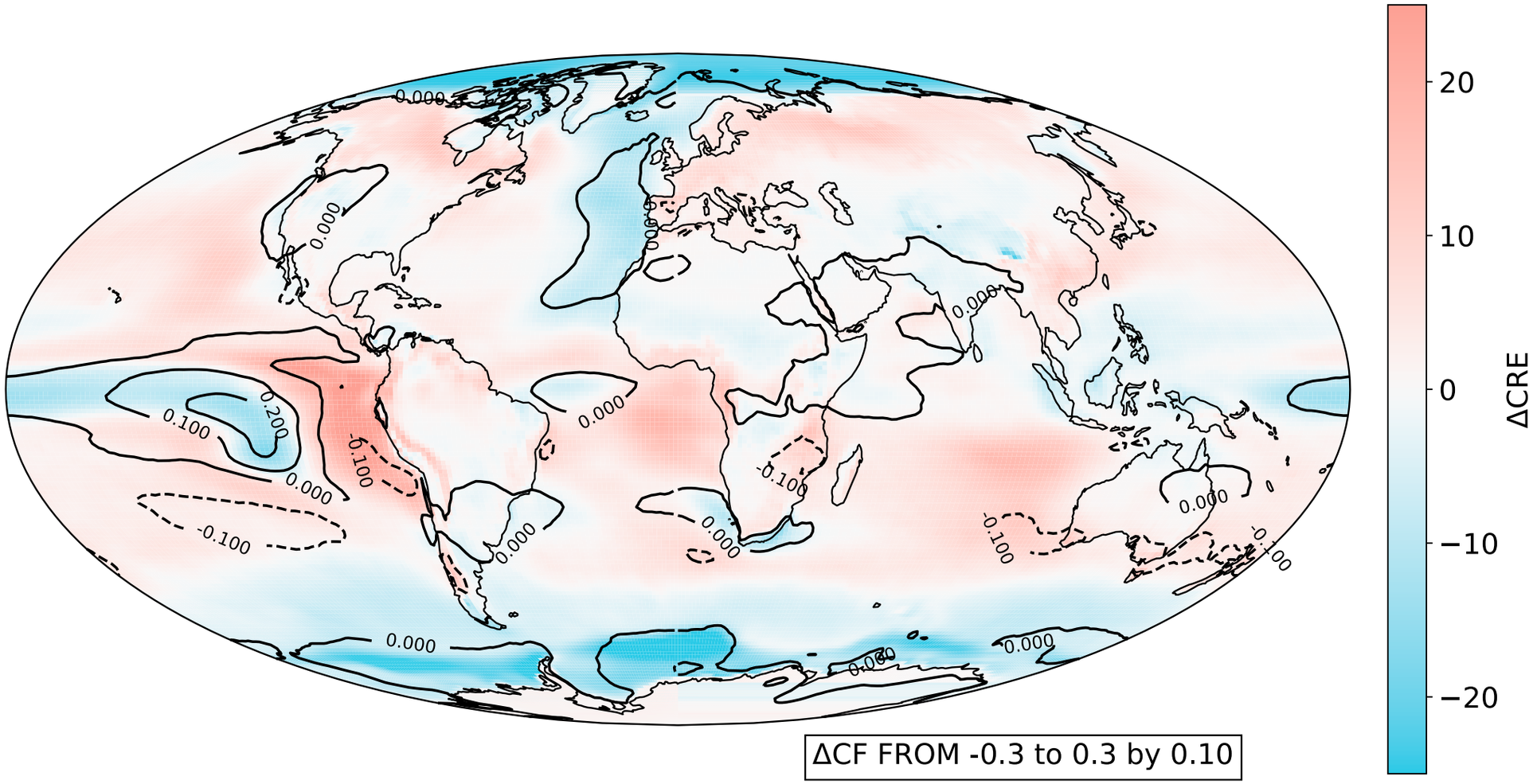
YEARS


10.6 / 2 = 5.3
13.4 / 2 = 6.7
8
6
4
2
0
N [W m⁻²]
2.0
4.0
7.5
11.3
ΔT̄ [K]



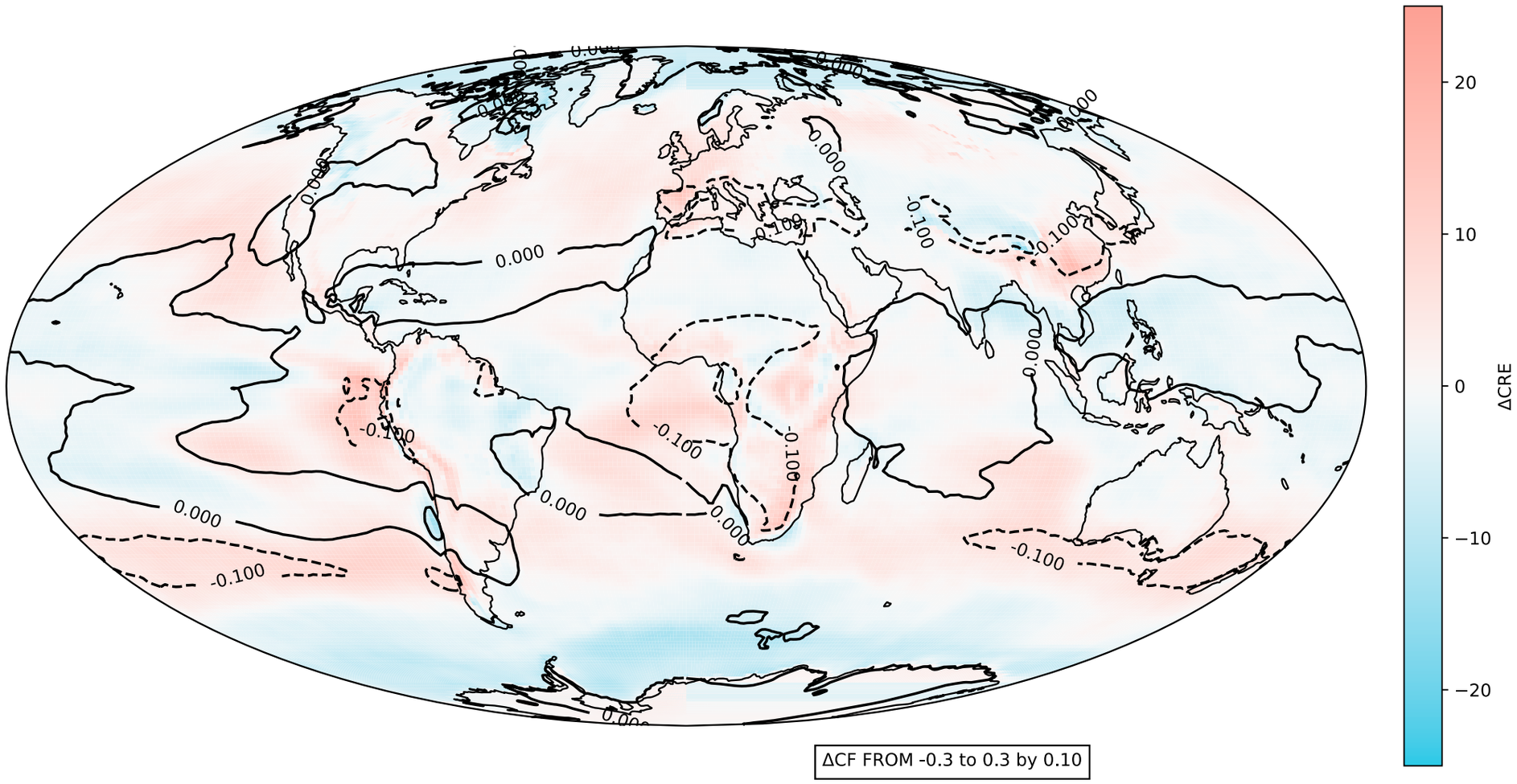
abrupt4x(years 115–145) - picontrol

Earlier in the experiment



abrupt4x(years 015–045) - picontrol

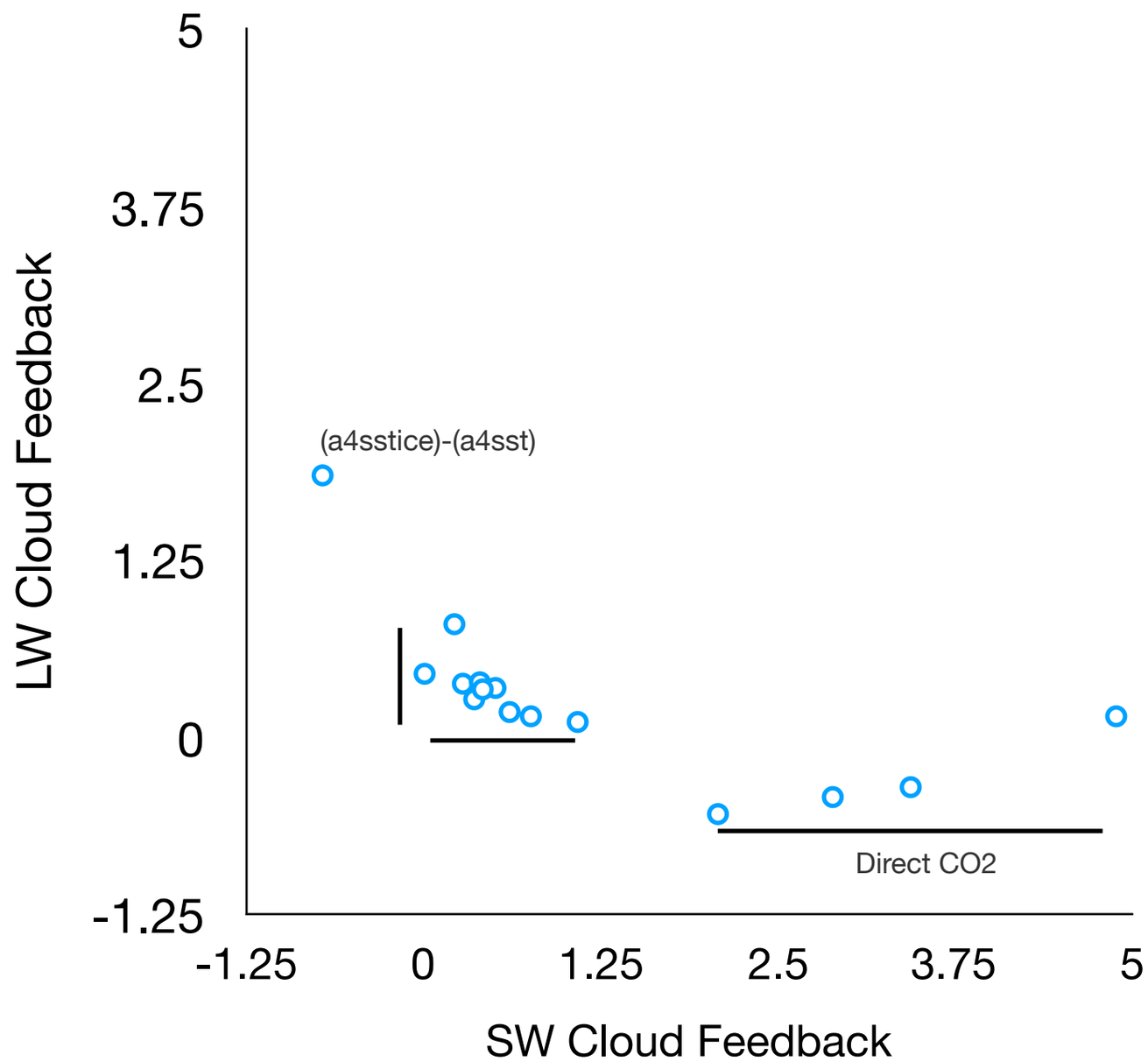
cloud response in fixed-SST experiments

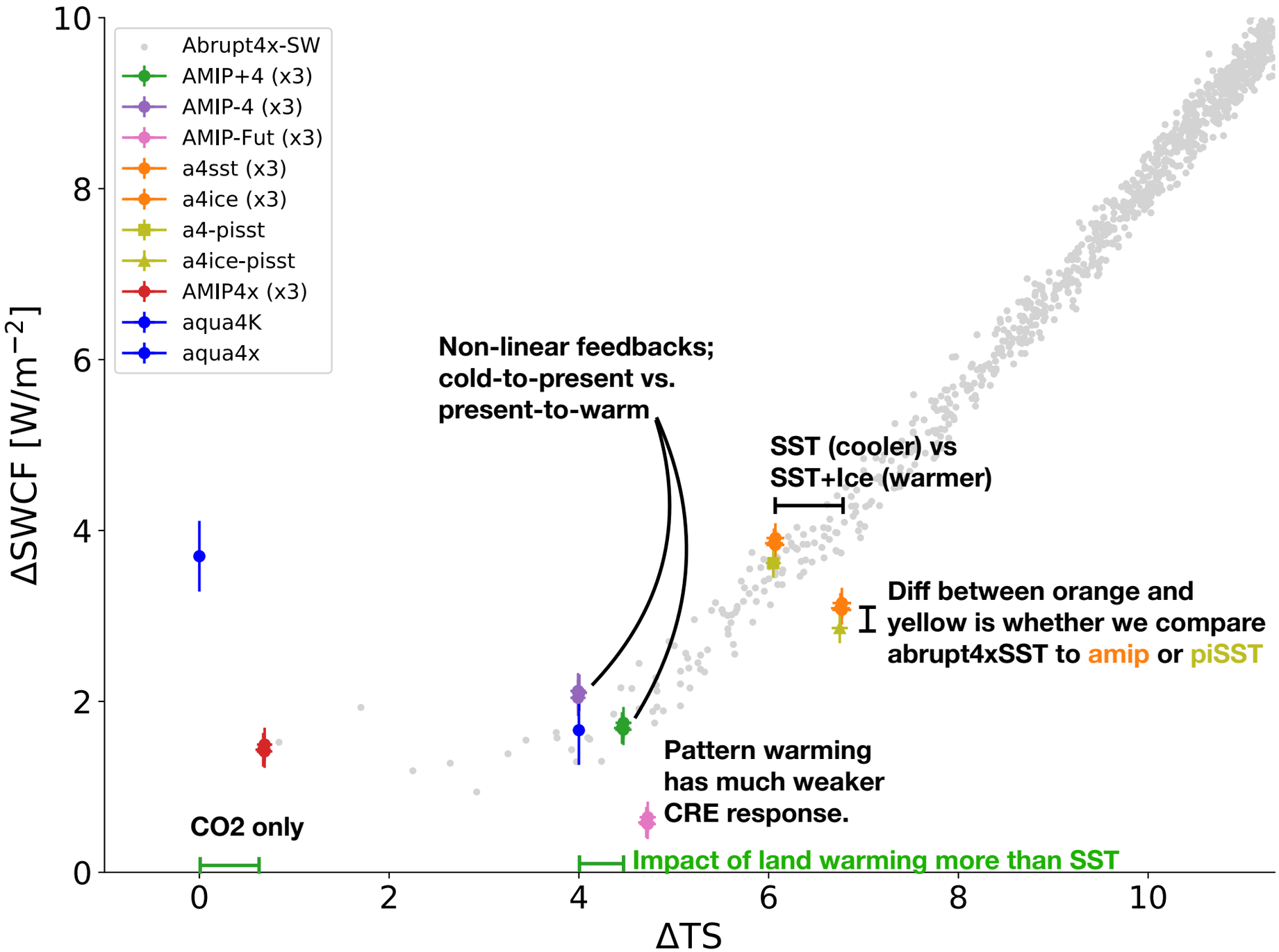


(amip-p4k) - amip

Radiative Kernel analysis

(abrupt4x)-(picontrol)
(p4k)-(amip)
(amip)-(m4k)
(p4k)-(m4k)
(4xco2)-(amip)
(future4k)-(amip)
(a4sst)-(pisst)
(a4sstice)-(pisst)
(a4SSTice-4xCO2)-(pisst)
(piSST-4xCO2)-(pisst)
(piSST-4xCO2-rad)-(pisst)
(a4sstice)-(a4sst)
(a4SSTice-4xCO2)-(a4sst)
(a4SSTice-4xCO2)-(a4sstice)
(piSST-4xCO2-rad)-(piSST-4xCO2)
(aqua4k)-(aqua)
(aqua4x)-(aqua)

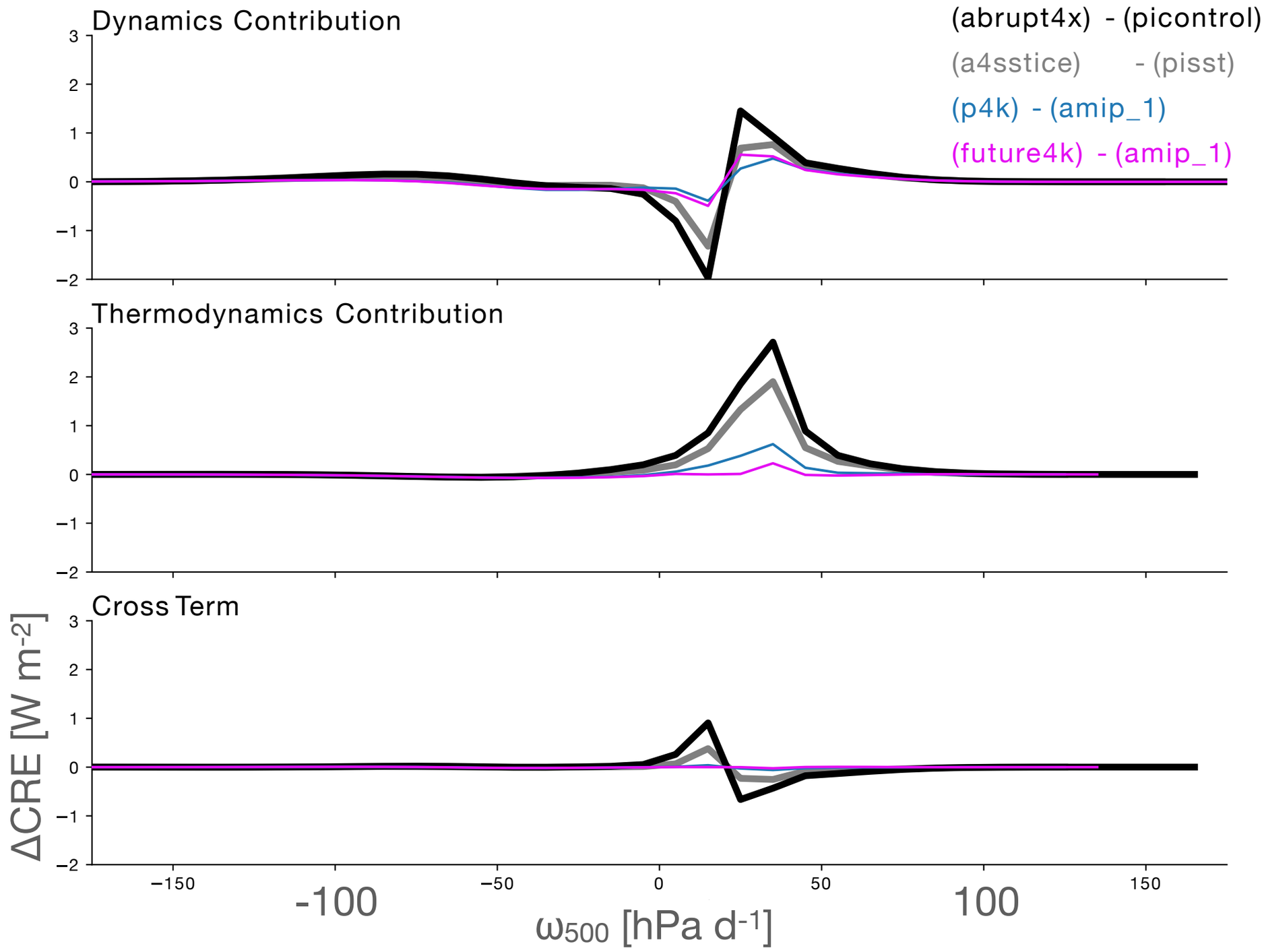




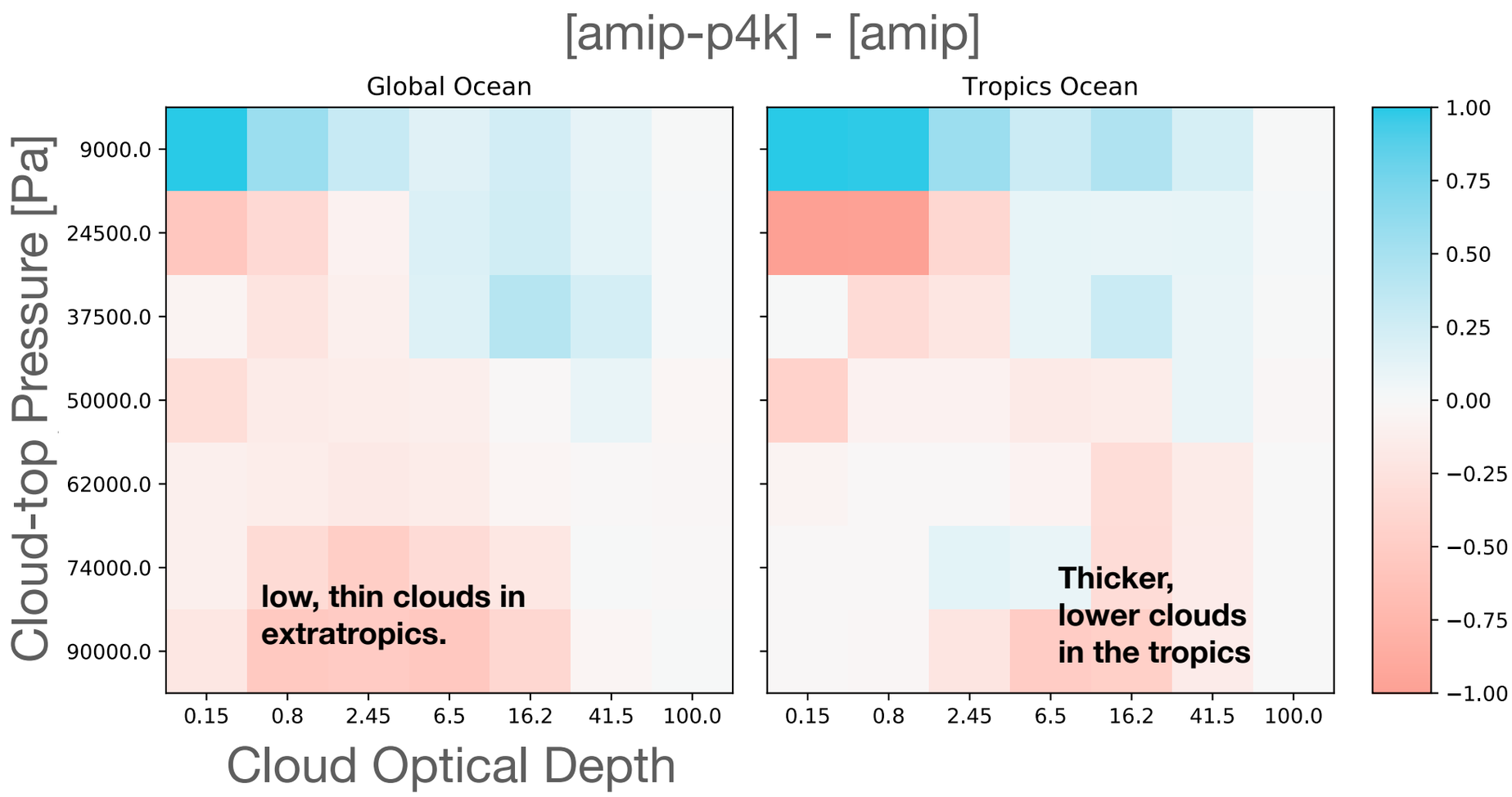
Error bars show 90% confidence interval

Dynamical regimes analysis

$$\overline{\delta c} = \int c_\omega dP_\omega d\omega + \int \delta c_\omega P_\omega d\omega + \int dc_\omega dP_\omega d\omega$$



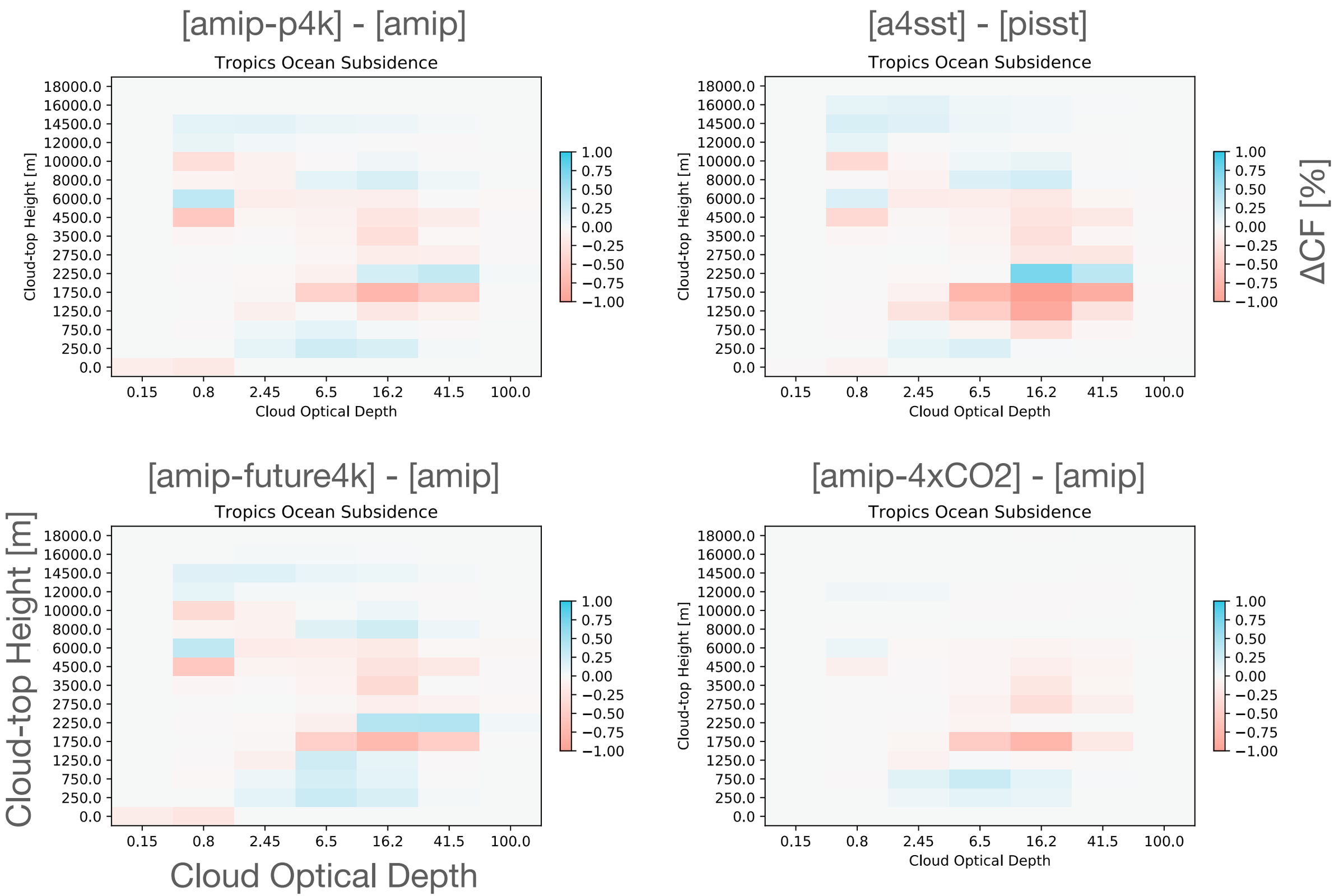
What kinds of clouds are changing?

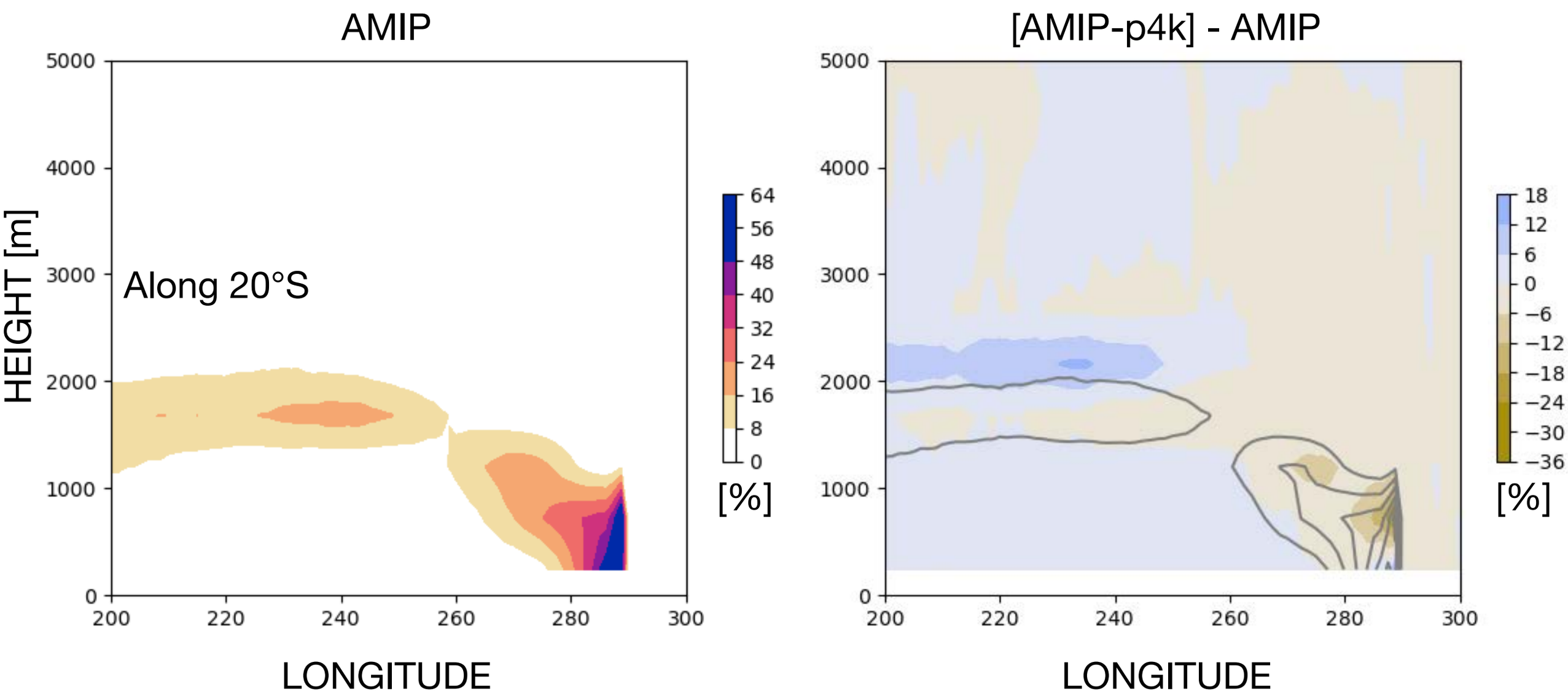


Ocean+Land is nearly identical.

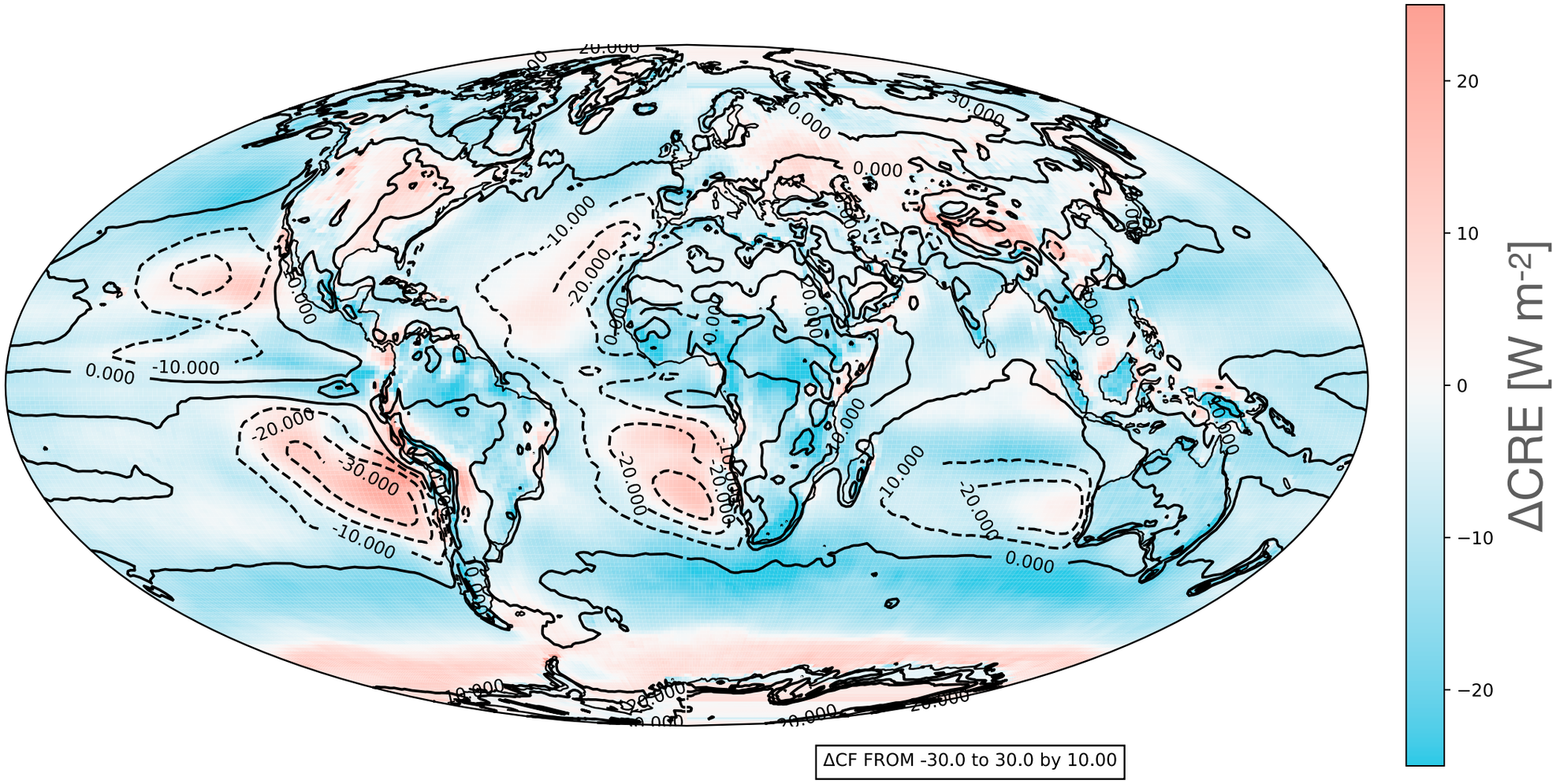
Almost all the pattern of clouds below10km is from subsidence

MISR Simulator — Tropical subsidence

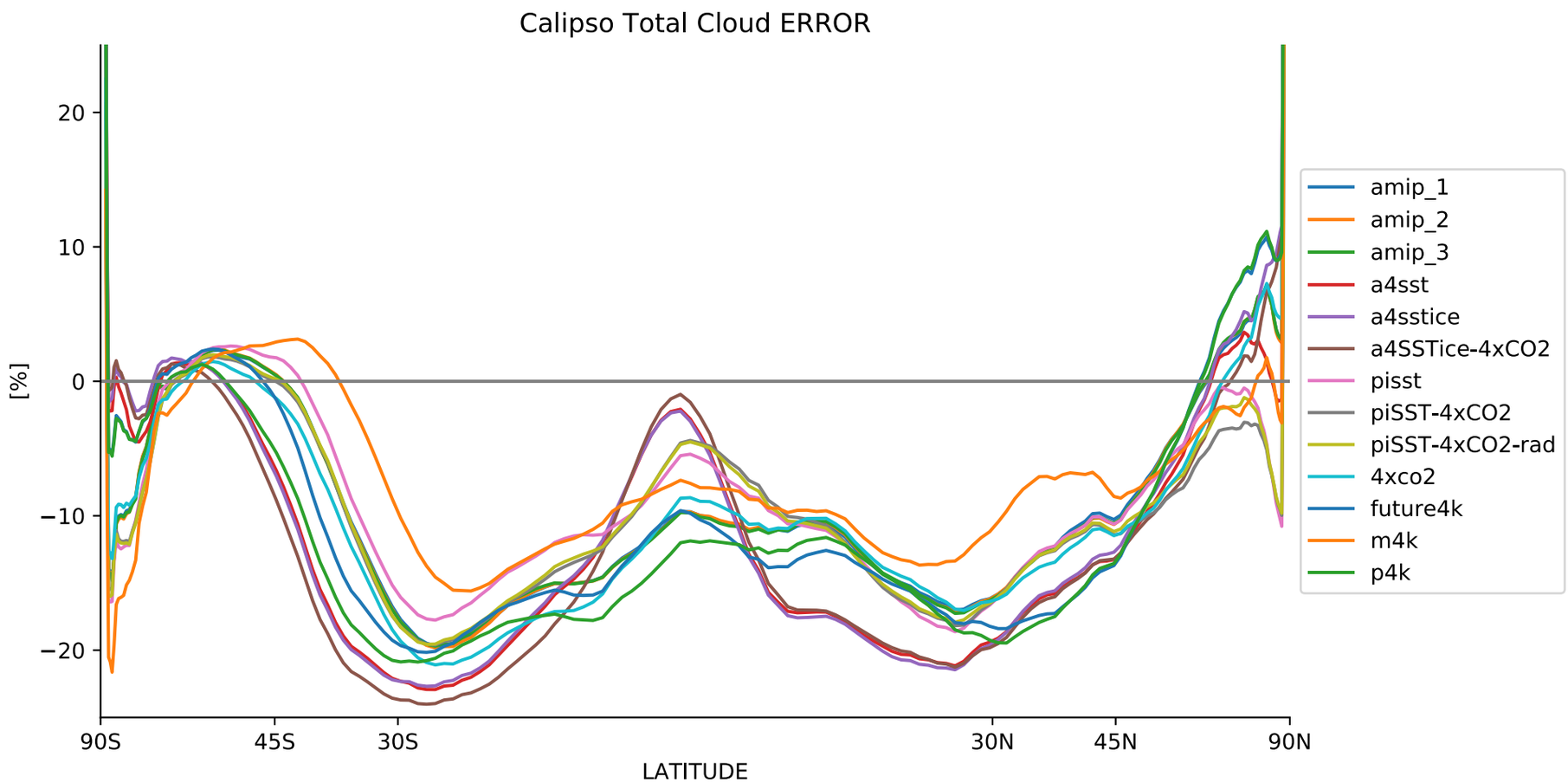


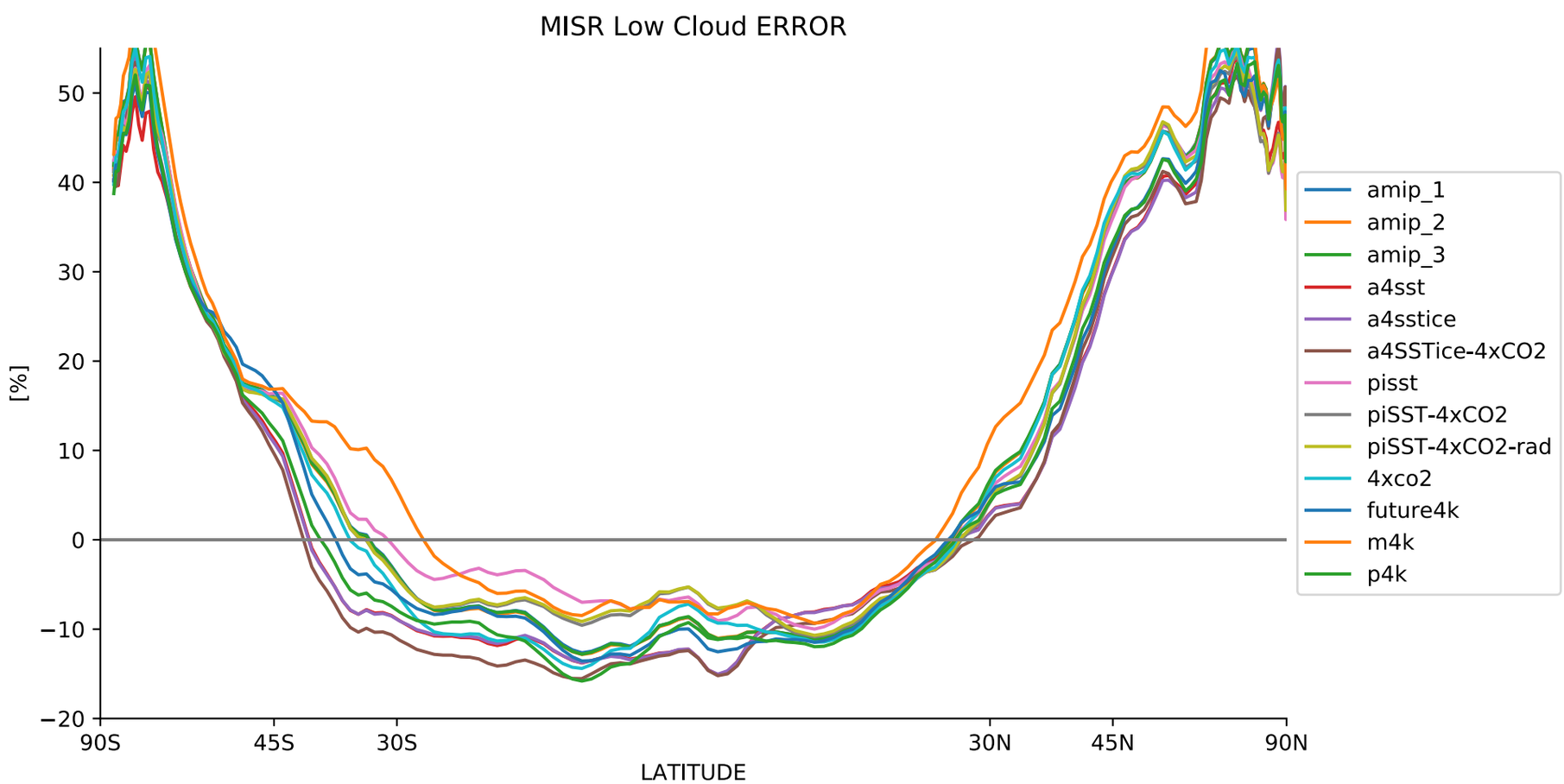

AMIP
[AMIP-p4k] - AMIP
Along 20°S
HEIGHT [m]
LONGITUDE
LONGITUDE
[%]
[%]
5000
4000
3000
2000
1000
0
200
220
240
260
280
300
64
56
48
40
32
24
16
8
0
18
12
6
0
−6
−12
−18
−24
−30
−36

Does CESM2 have a too-few-too-bright problem?



*FWIW, CRE bias looks much better vs CERES EBAF v2.8


Calipso Total Cloud ERROR
[%]
20
10
0
−10
−20
90S
45S
30S
30N
45N
90N
LATITUDE
amip_1
amip_2
amip_3
a4sst
a4sstice
a4SSTice-4xCO2
pisst
piSST-4xCO2
piSST-4xCO2-rad
4xco2
future4k
m4k
p4k


MISR Low Cloud ERROR
[%]
50
40
30
20
10
0
−10
−20
90S
45S
30S
30N
45N
90N
LATITUDE
amip_1
amip_2
amip_3
a4sst
a4sstice
a4SSTice-4xCO2
pisst
piSST-4xCO2
piSST-4xCO2-rad
4xco2
future4k
m4k
p4k

CESM2 ECS > 5K

Strong cloud response, focused on subtropical stratocumulus

Patterned warming (amip-future4K) experiment shows different, weaker cloud response

CO_2 direct response has strong cloud-top response

CESM2 has too little cloud cover over subtropical oceans

Experiment name	Status
amip	complete
amip-p4K	complete
amip-4xCO2	complete
amip-future4K	complete
aqua-control	complete
aqua-p4K	complete
aqua-4xCO2	complete
amip-m4K	complete
amip-lwoff	
amip-p4K-lwoff	
aqua-control-lwoff	
aqua-p4K-lwoff	
abrupt-solp4p	
abrupt-solm4p	
abrupt-2xCO2	
abrupt-0p5xCO2	
amip-piForcing	**running (year 33/145)**
piSST	complete
piSST-pxK	
piSST-4xCO2-rad	complete
piSST-4xCO2	complete
a4SST	complete
a4SSTice	complete
a4SSTice-4xCO2	complete
amip-a4SST-4xCO2	