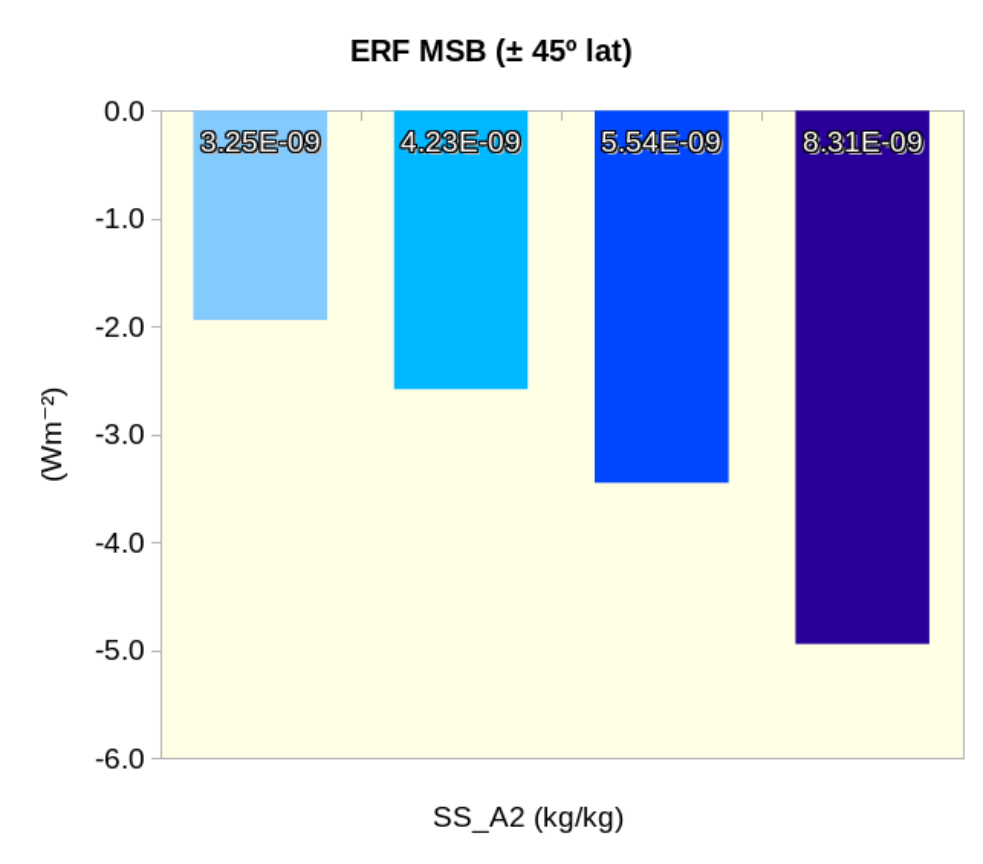
Marine Sky Brightening (MSB) EXPECT experiments

Helene Muri

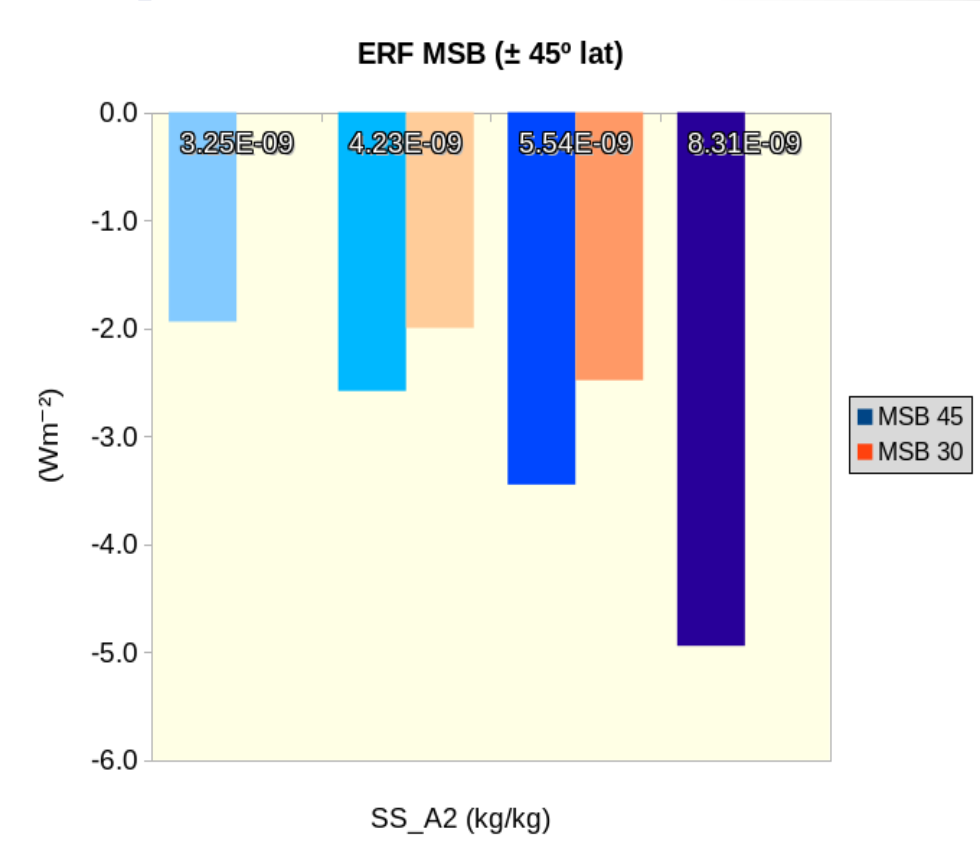
Marine Sky Brightening

- Following method of Alterskjær et al. (2013).
- Increasing emissions of accumulation mode sea salt aerosols.
  - Dry number modal radius 0.13 μm, geometric standard deviation 1.59, corresponding to dry effective radius 0.22 μm.
- Increasing emissions of *SS_A2* between 45°S and 45°N, to draw upon direct effect of aerosols.
- Increasing emission area from ±30° lat increases ERF by ~1/3.
- Starting in 2020, until year 2100.

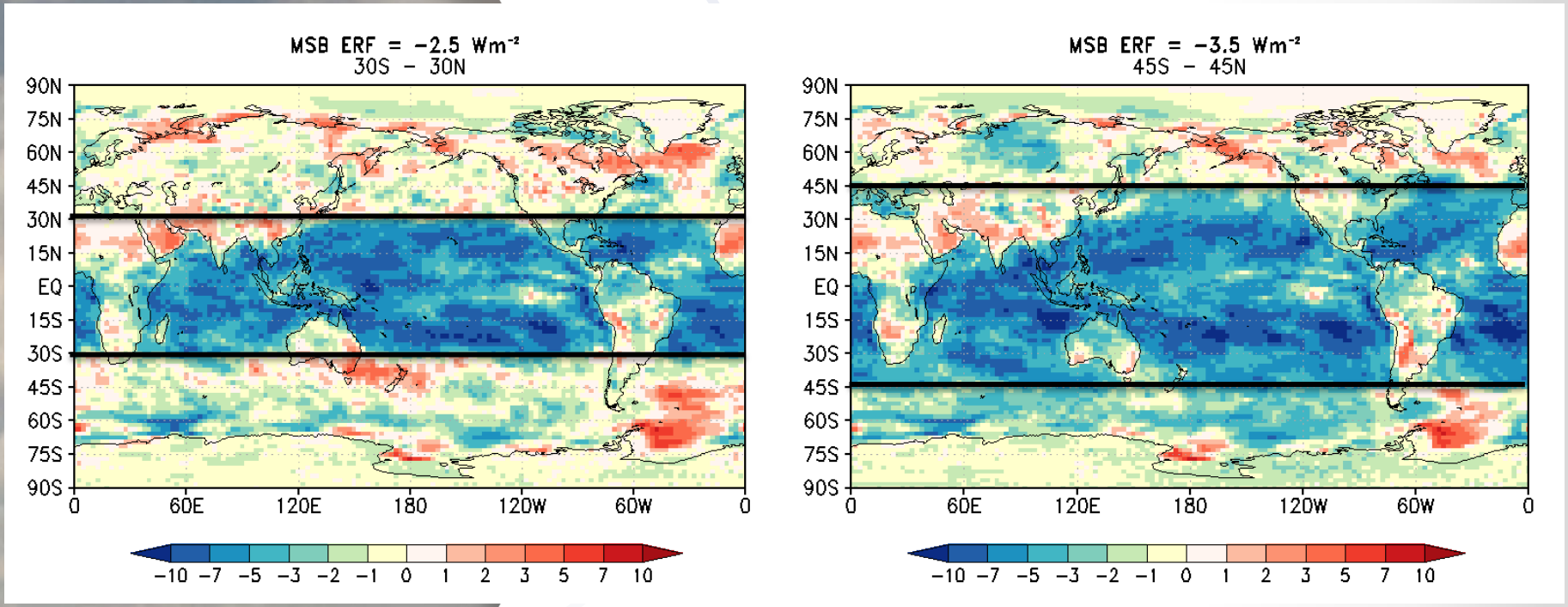
Effective radiative forcing estimates from fixed SST runs

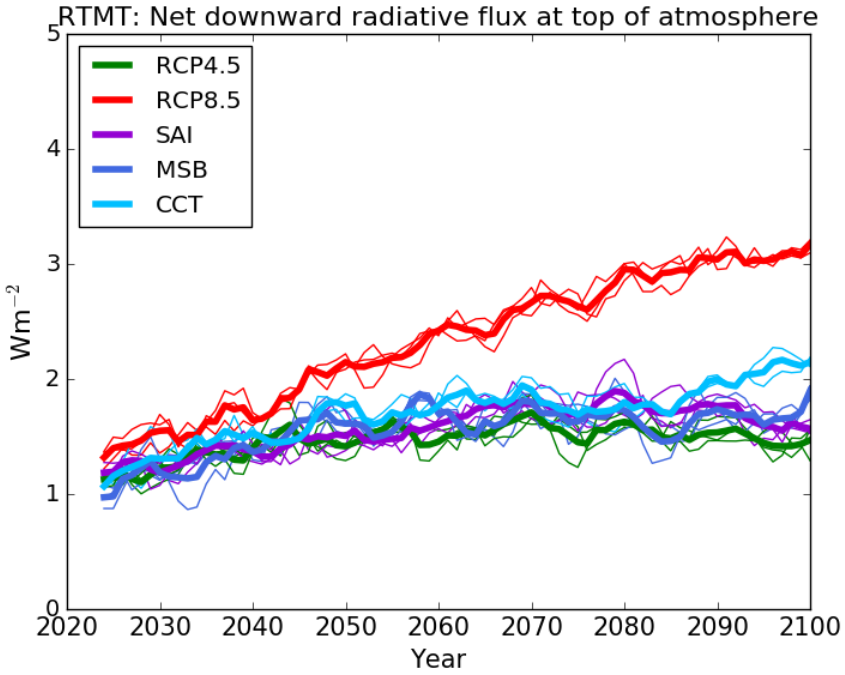


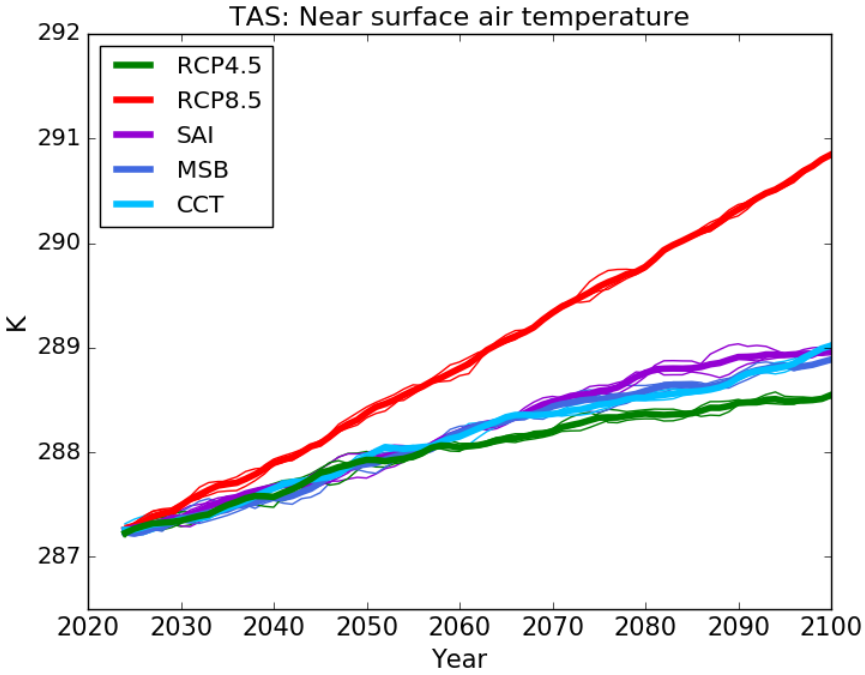
Effective radiative forcing estimates from fixed SST runs.

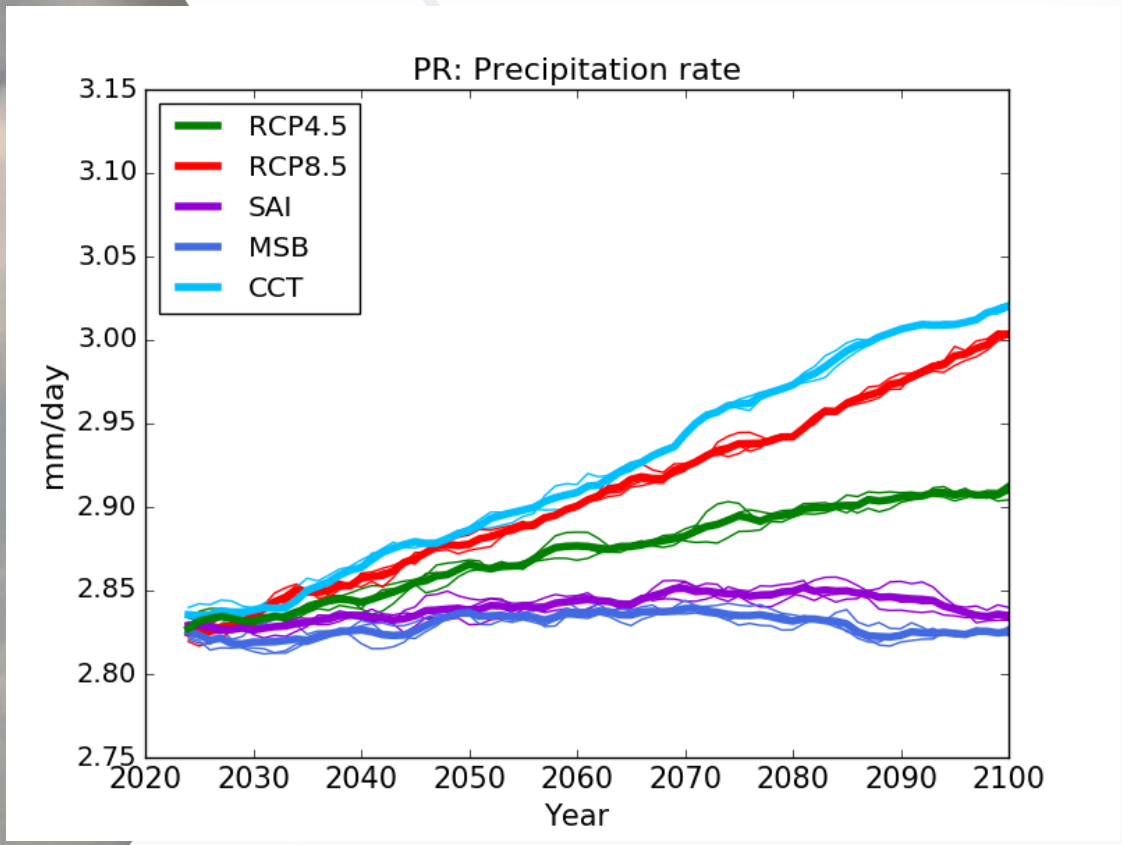


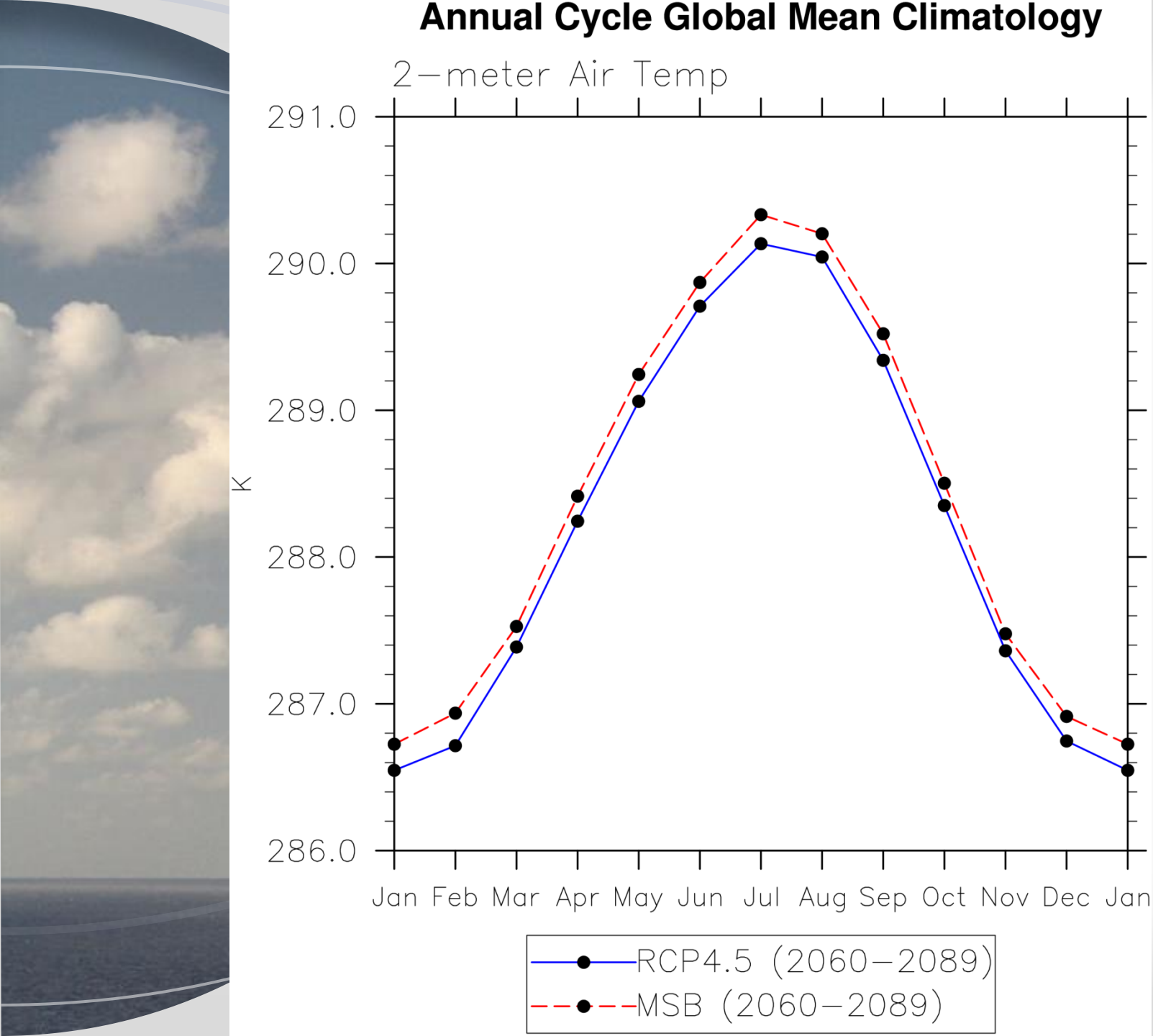
Change in net TOA fluxes (FSNT-FLNT) from fixed SST runs with same emission increases.



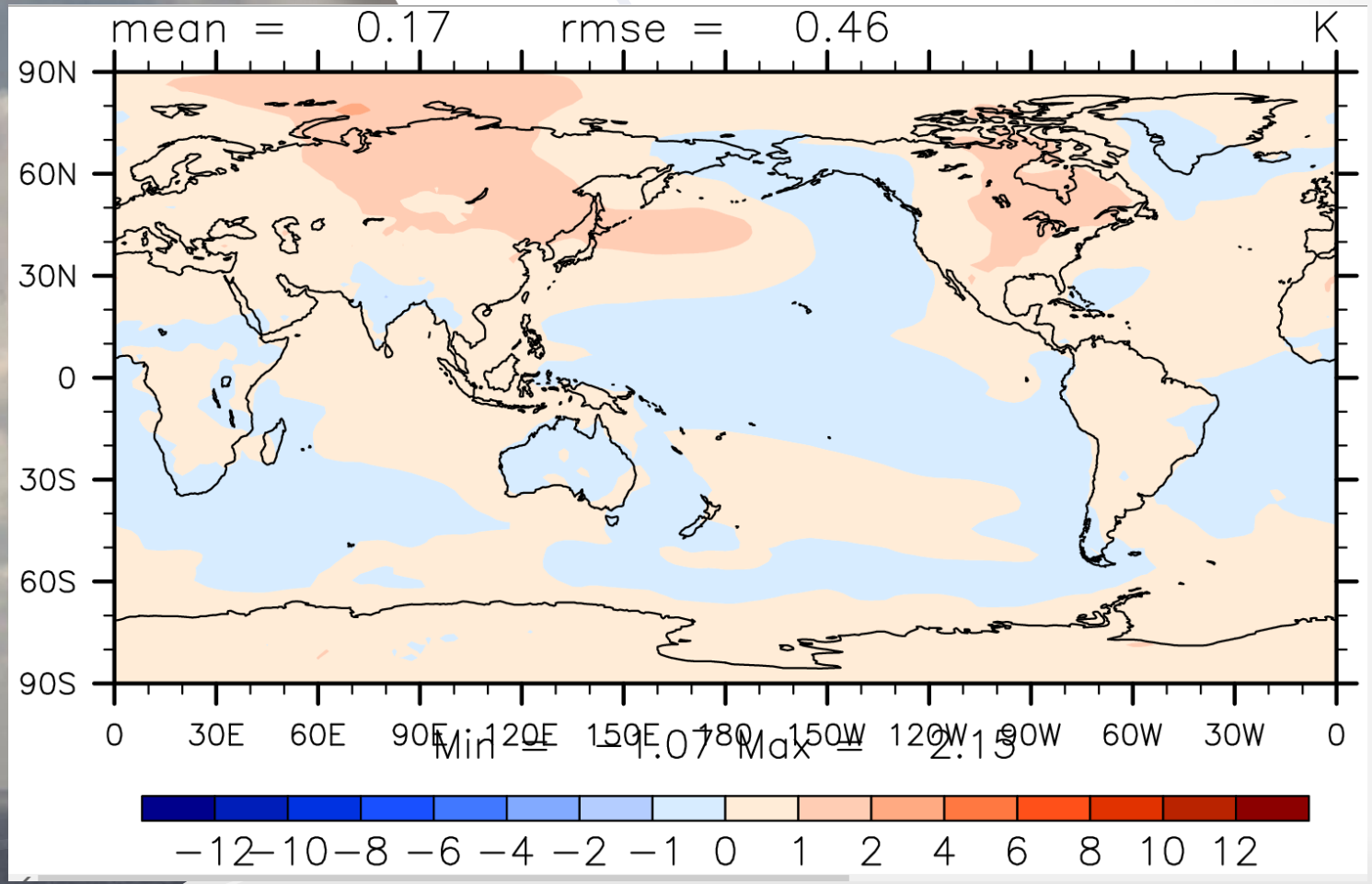

RTMT: Net downward radiative flux at top of atmosphere
RCP4.5
RCP8.5
SAI
MSB
CCT
Wm^{-2}
Year
0
1
2
3
4
5
2020
2030
2040
2050
2060
2070
2080
2090
2100


TAS: Near surface air temperature
RCP4.5
RCP8.5
SAI
MSB
CCT
K
Year
287
288
289
290
291
292
2020
2030
2040
2050
2060
2070
2080
2090
2100

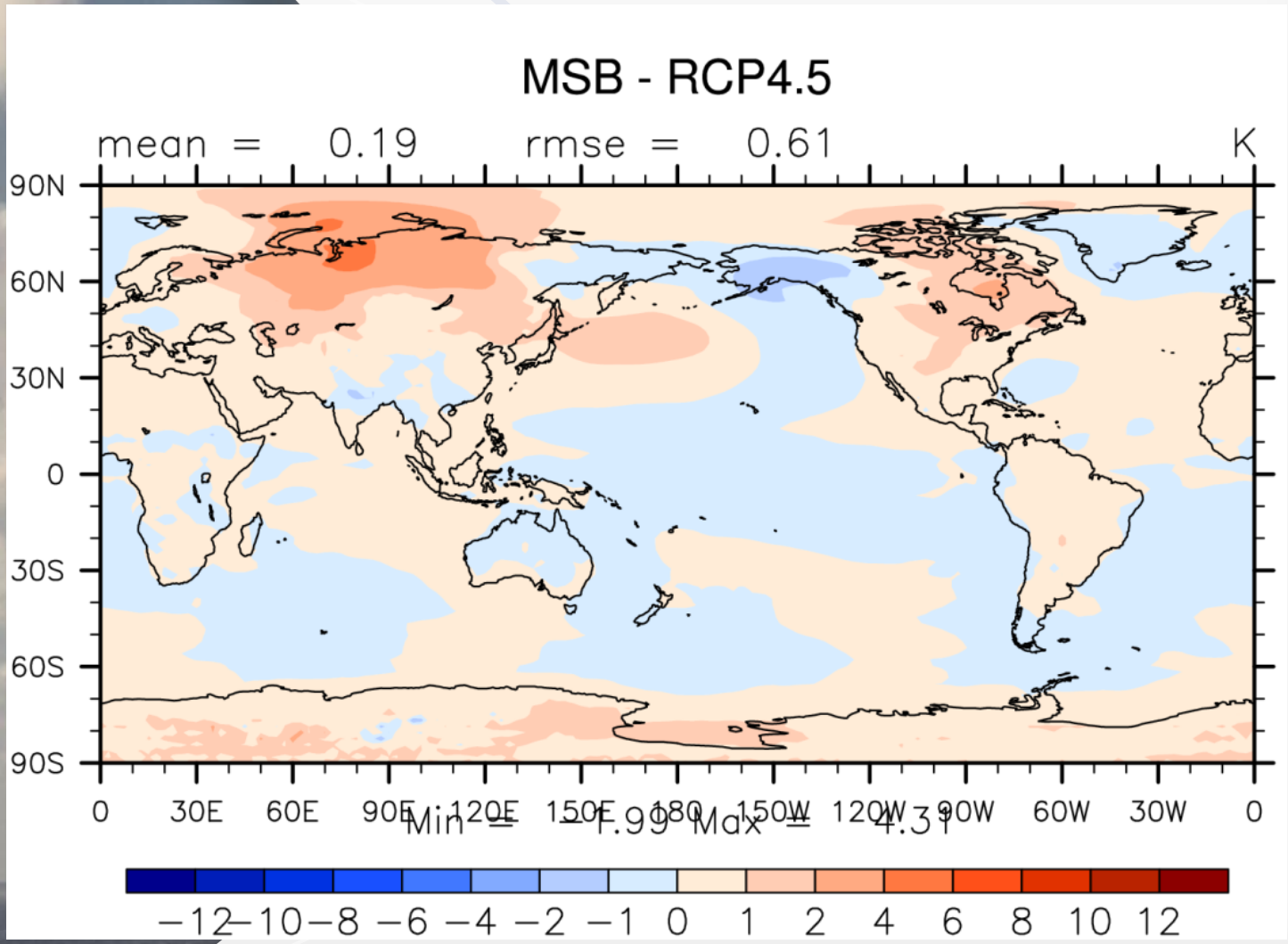

PR: Precipitation rate
RCP4.5
RCP8.5
SAI
MSB
CCT
mm/day
3.15
3.10
3.05
3.00
2.95
2.90
2.85
2.80
2.75
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year


Annual Cycle Global Mean Climatology
2−meter Air Temp
291.0
290.0
289.0
288.0
287.0
286.0
K
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
RCP4.5 (2060−2089)
MSB (2060−2089)

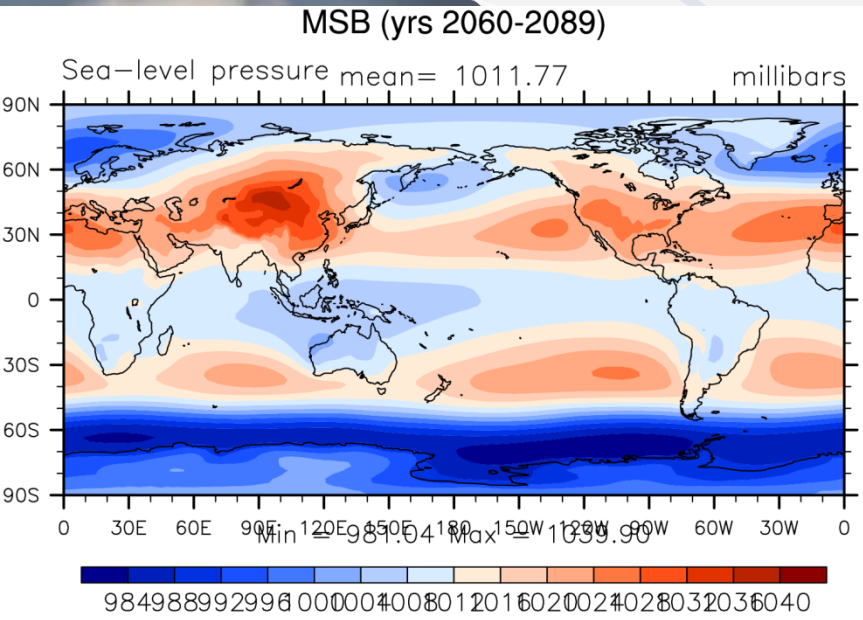
TAS, annual mean

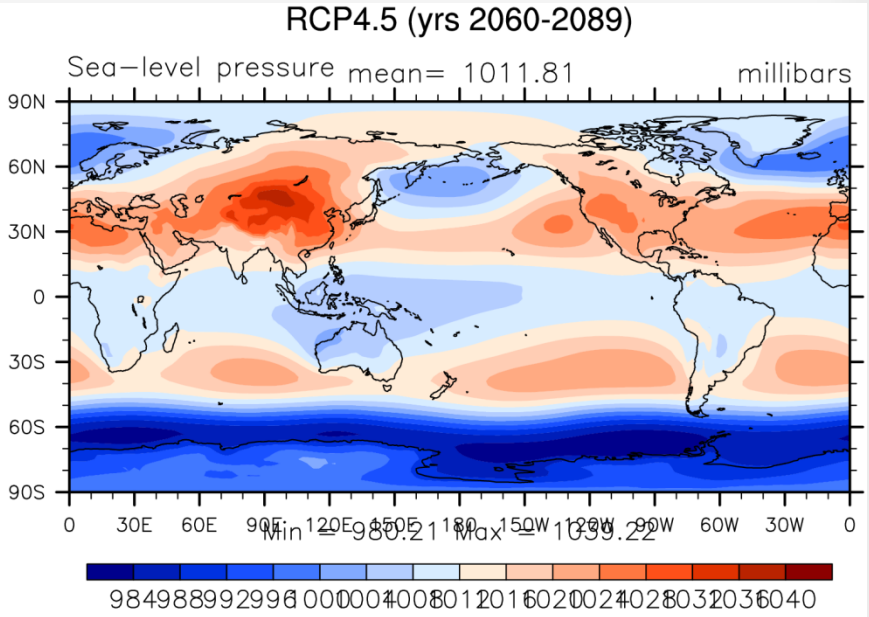


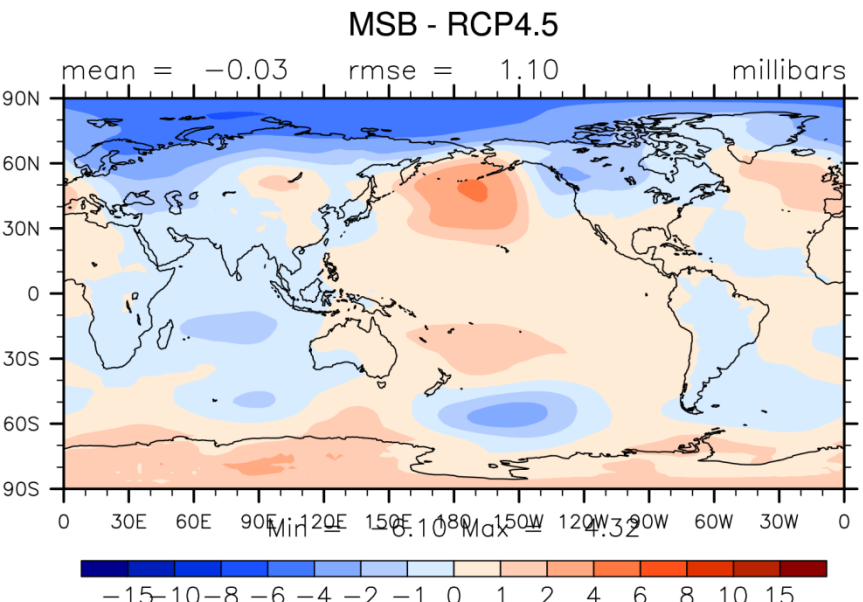
TAS, DJF

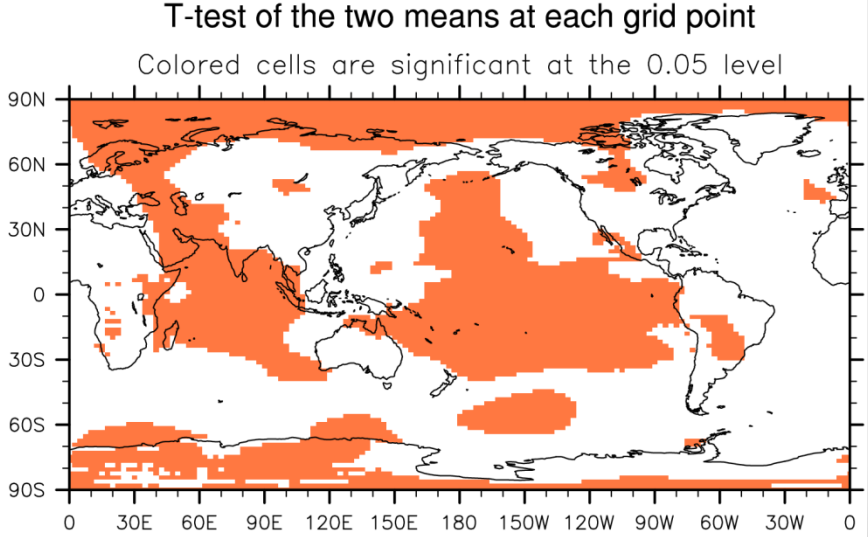

MSB - RCP4.5
mean = 0.19
rmse = 0.61
K
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
Min = -7.99 Max = 4.31
−12 −10 −8 −6 −4 −2 −1 0 1 2 4 6 8 10 12

DJF

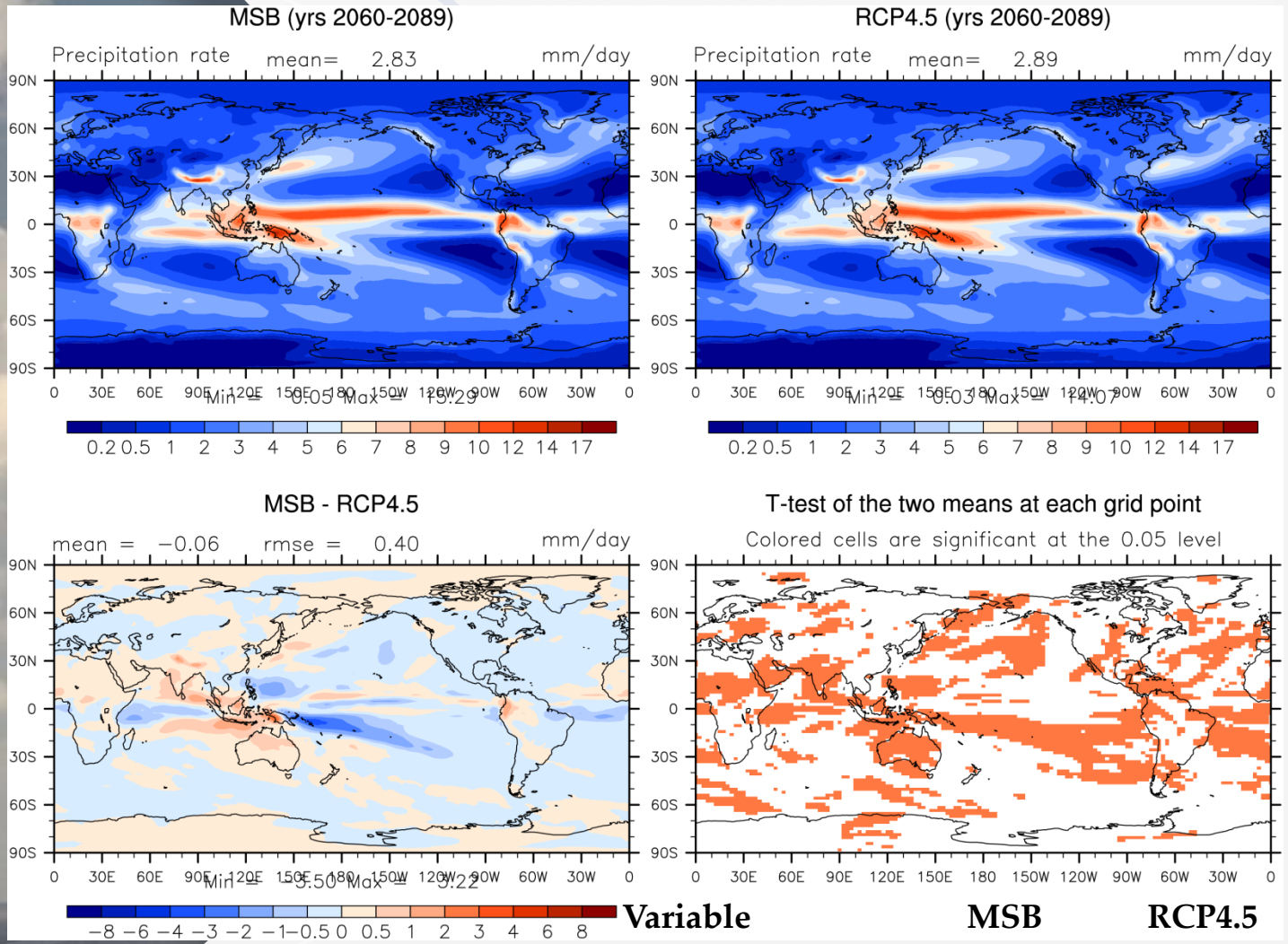

MSB (yrs 2060-2089)
Sea−level pressure mean= 1011.77 millibars
90N
60N
30N
0
30S
60S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
Min = 981.04 Max = 1039.90
984 988 992 996 1000 1004 1008 1012 1016 1020 1024 1028 1032 1036 1040


RCP4.5 (yrs 2060-2089)
Sea−level pressure mean= 1011.81 millibars
90N
60N
30N
0
30S
60S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
Min = 980.21 Max = 1039.22
984 988 992 996 1000 1004 1008 1012 1016 1020 1024 1028 1032 1036 1040


MSB - RCP4.5
mean = −0.03 rmse = 1.10 millibars
90N
60N
30N
0
30S
60S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
Min = −6.10 Max = 4.32
−15 −10 −8 −6 −4 −2 −1 0 1 2 4 6 8 10 15

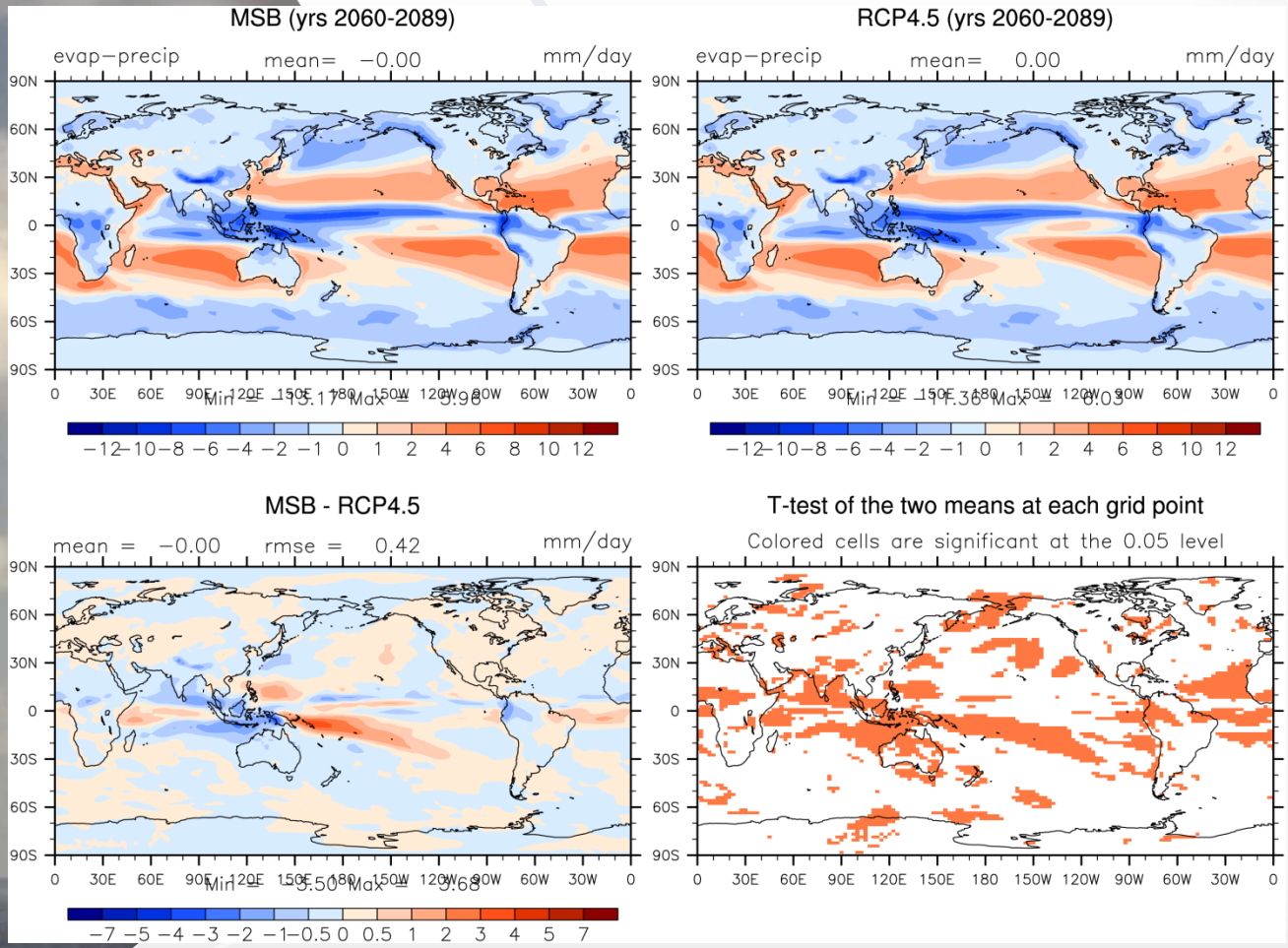

T-test of the two means at each grid point
Colored cells are significant at the 0.05 level
90N
60N
30N
0
30S
60S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0

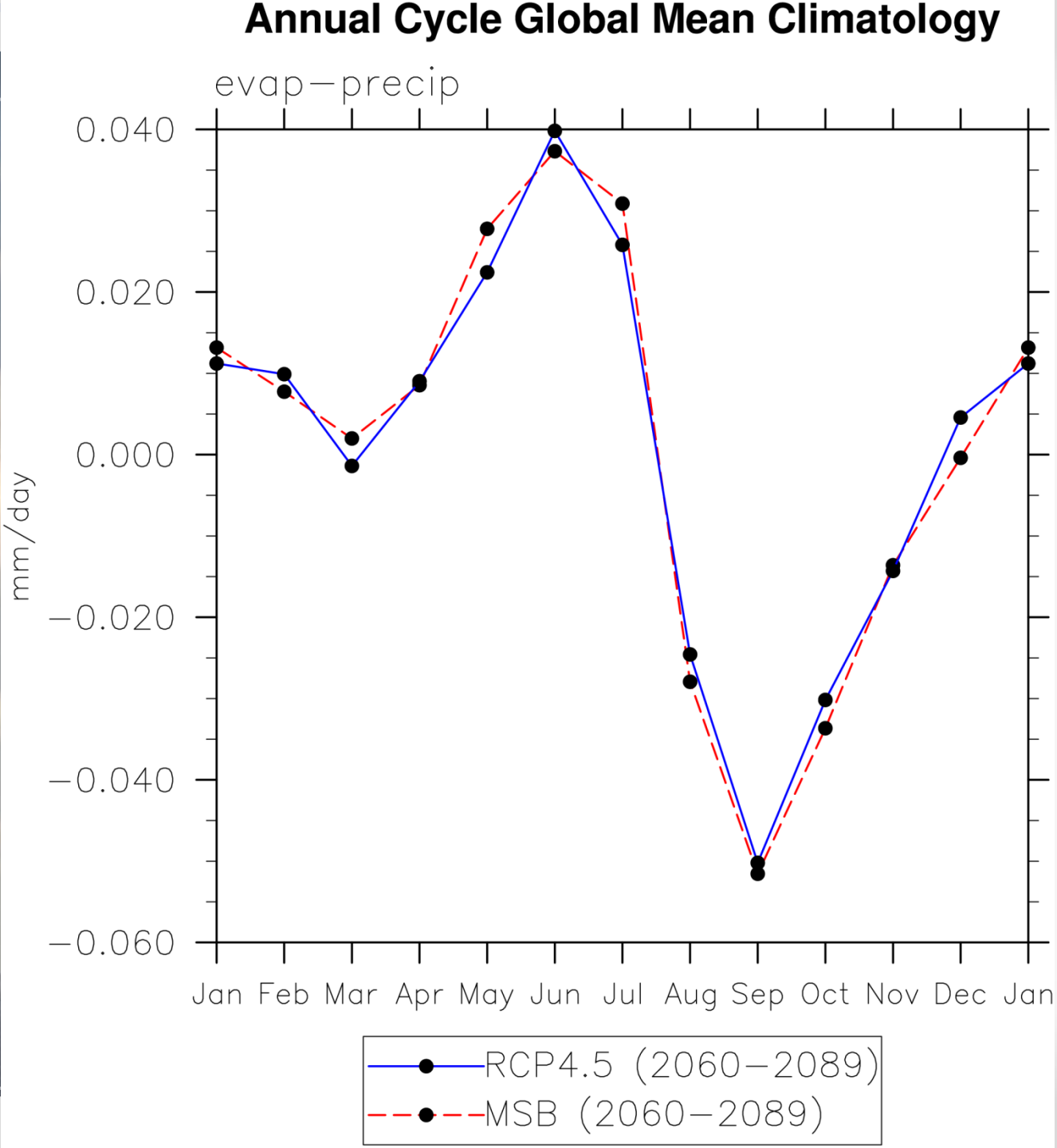
Precipitation rate (mm/day) annual mean

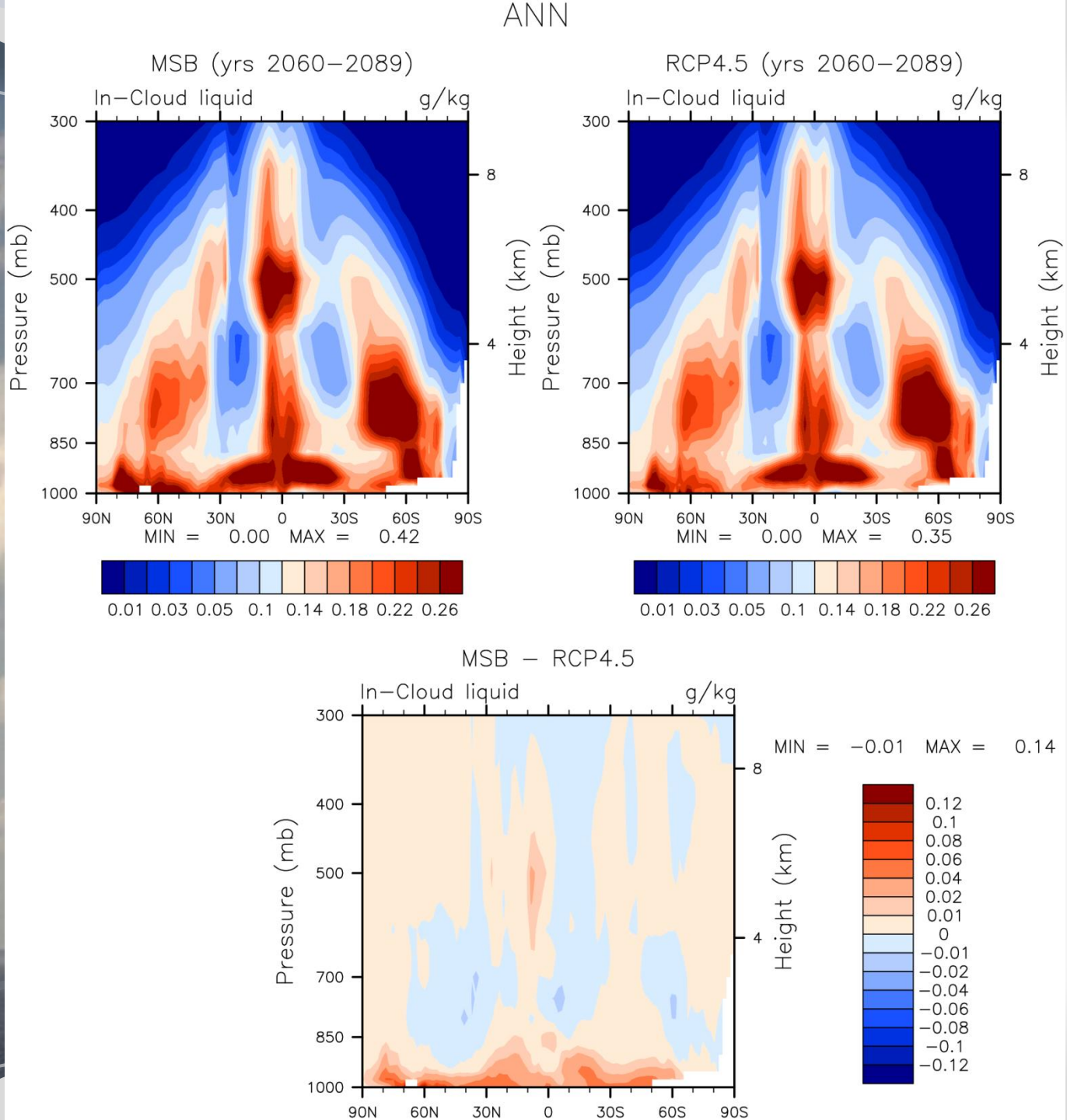


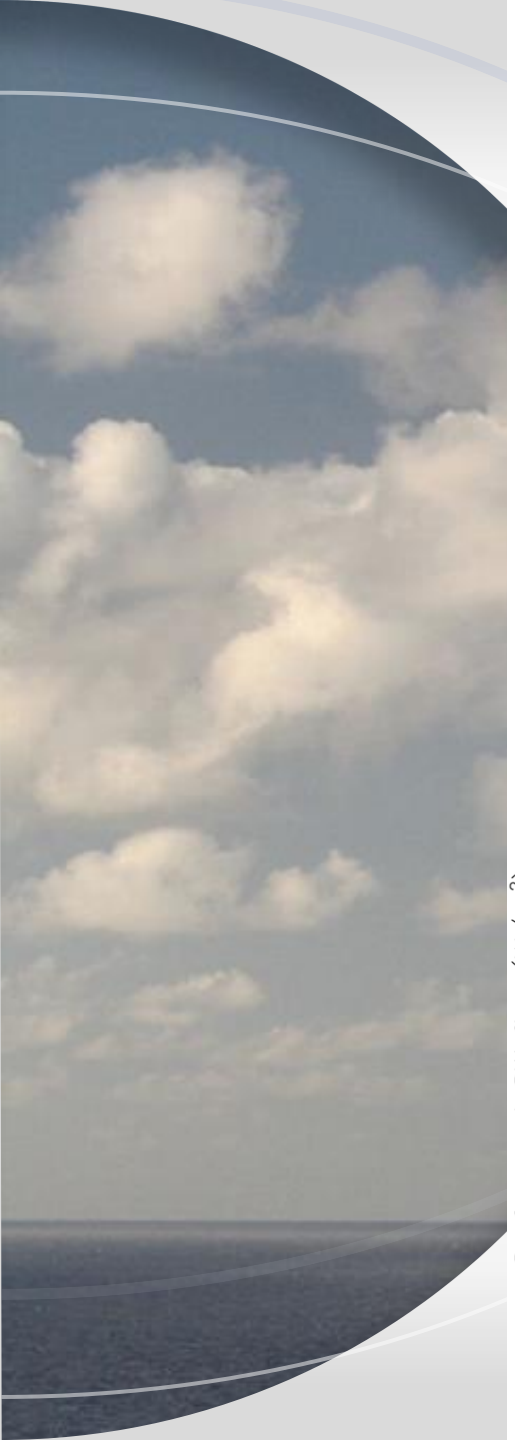
Variable	MSB	RCP4.5	MSB-RCP4.5
PRECT	2.833	2.892	-0.059
PRECT_LAND	2.419	2.369	0.051
PRECT_OCEAN	3.125	3.241	-0.116

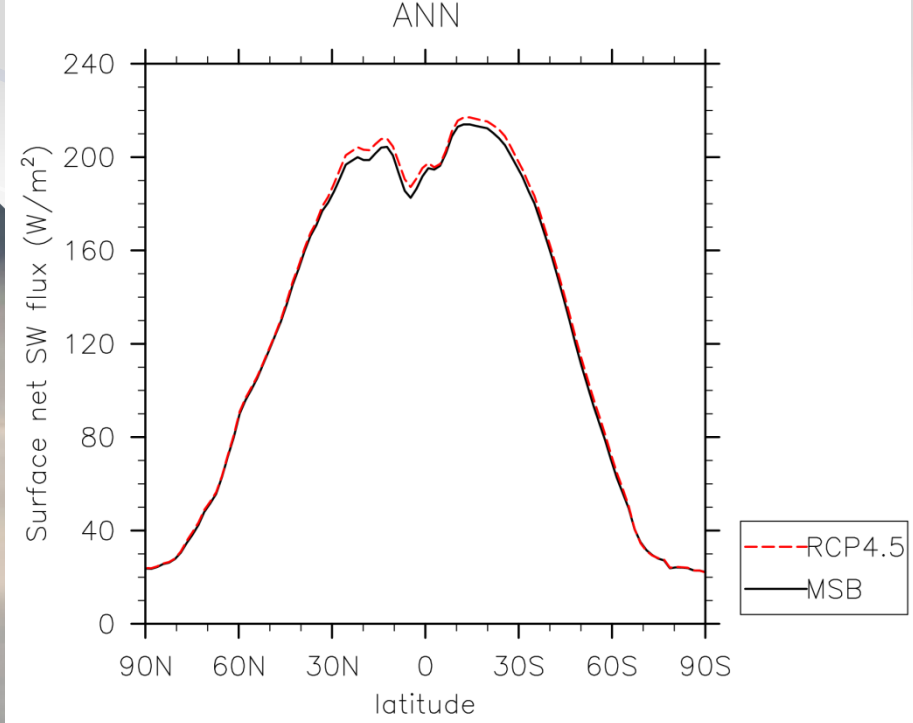
Evaporation – precipitation (mm/day)

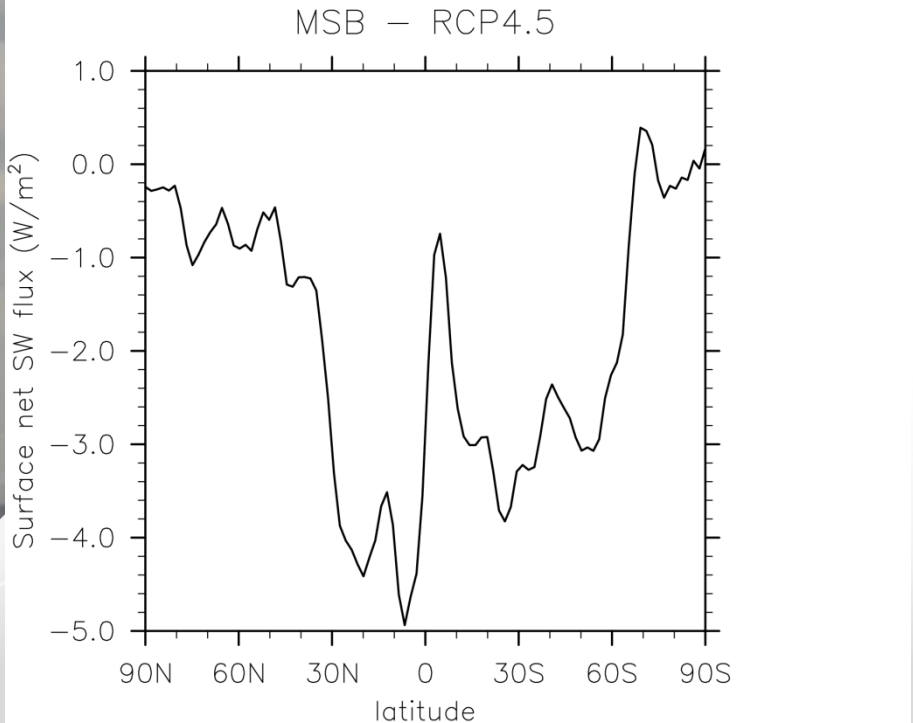


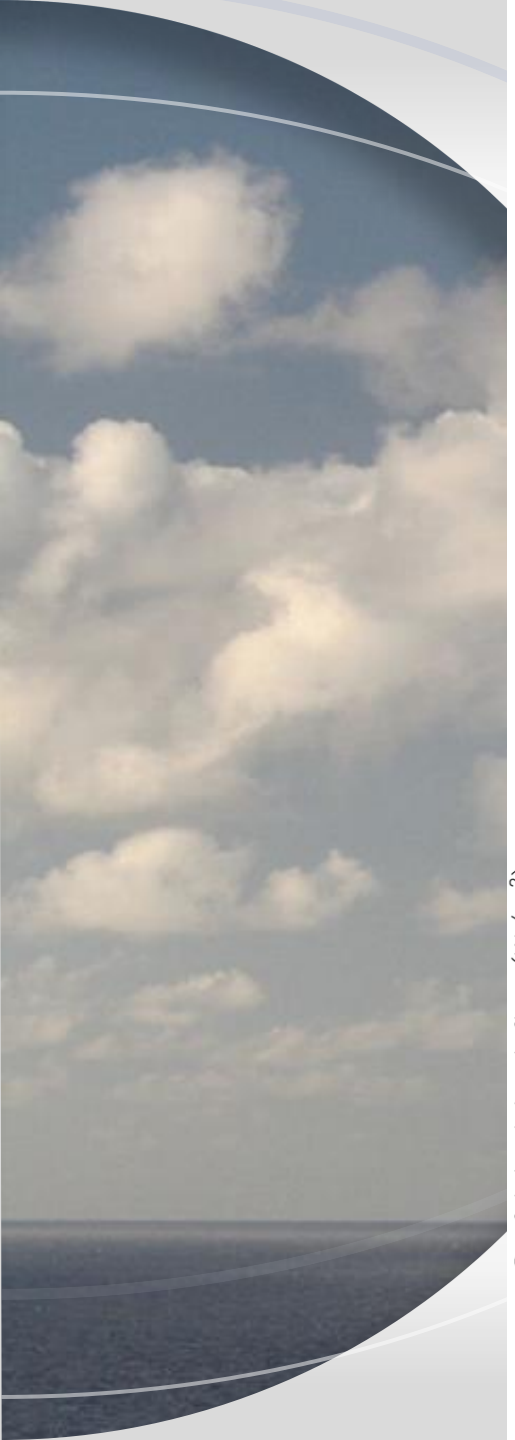

Annual Cycle Global Mean Climatology
evap−precip
0.040
0.020
0.000
−0.020
−0.040
−0.060
mm/day
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
RCP4.5 (2060−2089)
MSB (2060−2089)

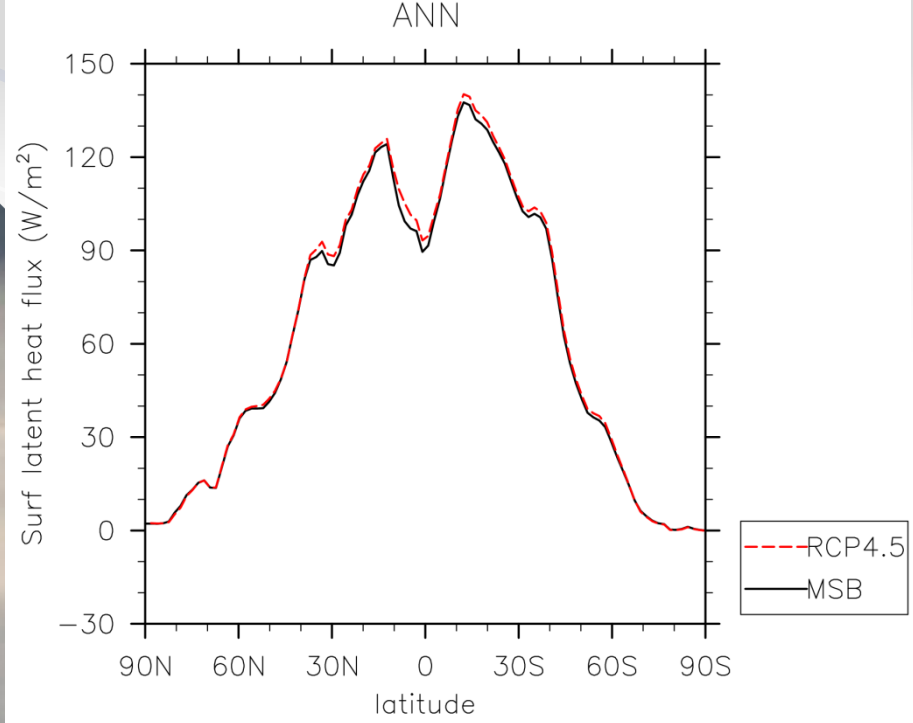

ANN
MSB (yrs 2060–2089)
ln–Cloud liquid
g/kg
Pressure (mb)
Height (km)
300
400
500
700
850
1000
8
4
90N
60N
30N
0
30S
60S
90S
MIN = 0.00 MAX = 0.42
0.01 0.03 0.05 0.1 0.14 0.18 0.22 0.26
RCP4.5 (yrs 2060–2089)
ln–Cloud liquid
g/kg
MIN = 0.00 MAX = 0.35
0.01 0.03 0.05 0.1 0.14 0.18 0.22 0.26
MSB – RCP4.5
ln–Cloud liquid
g/kg
MIN = −0.01 MAX = 0.14
0.12
0.1
0.08
0.06
0.04
0.02
0.01
0
−0.01
−0.02
−0.04
−0.06
−0.08
−0.1
−0.12

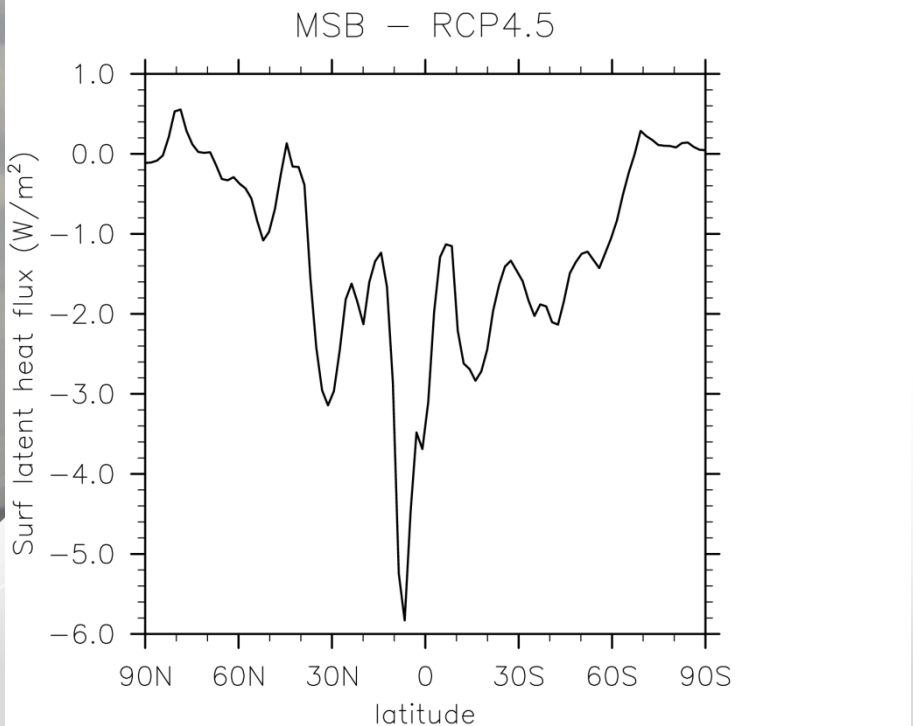


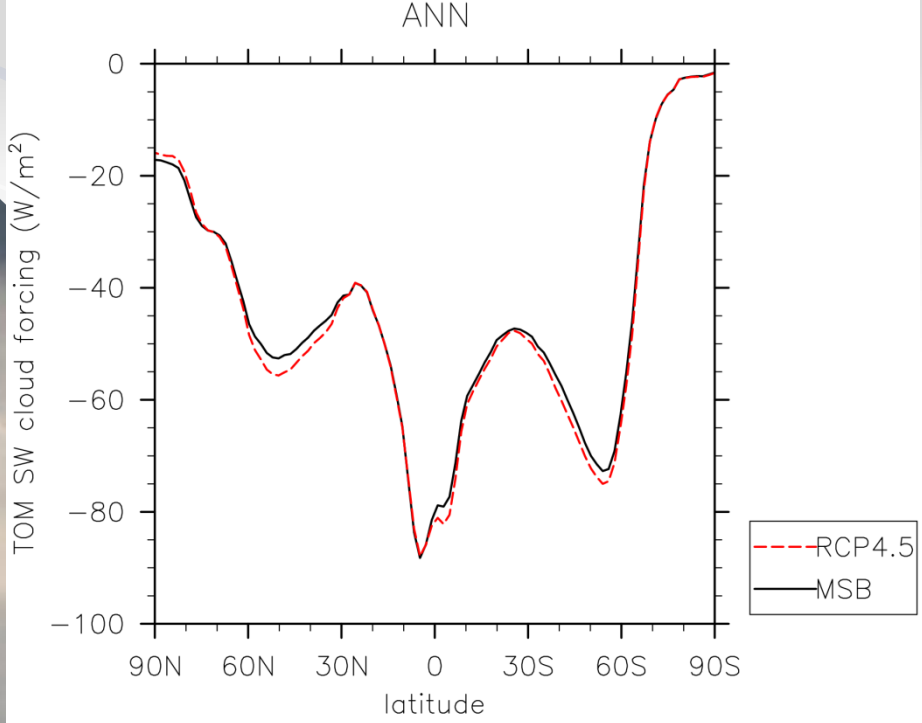

ANN
Surface net SW flux (W/m²)
240
200
160
120
80
40
0
90N
60N
30N
0
30S
60S
90S
latitude
RCP4.5
MSB

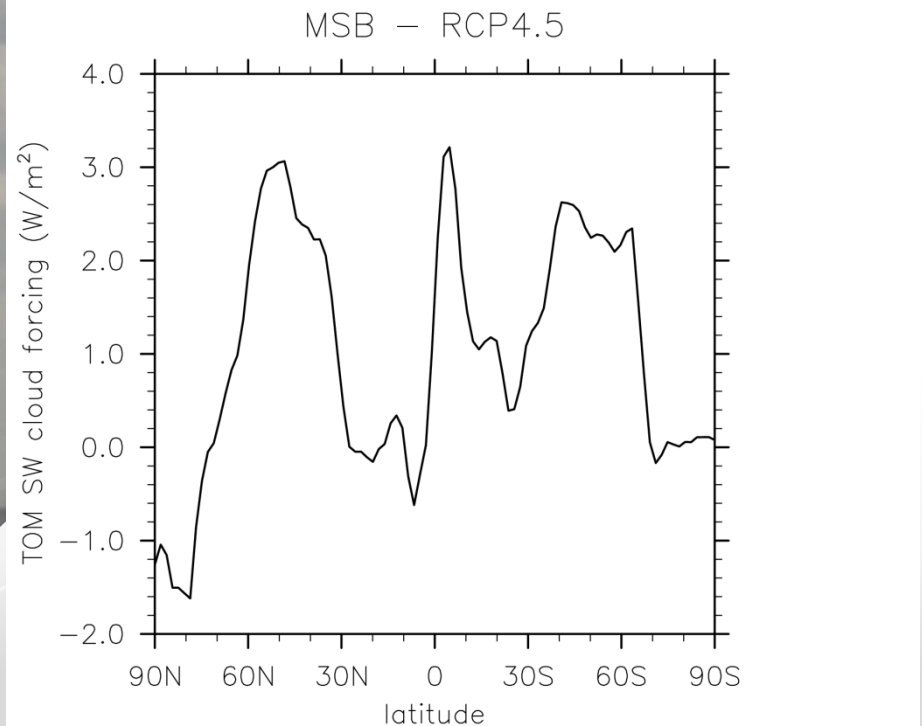

MSB – RCP4.5
Surface net SW flux (W/m²)
1.0
0.0
−1.0
−2.0
−3.0
−4.0
−5.0
90N
60N
30N
0
30S
60S
90S
latitude

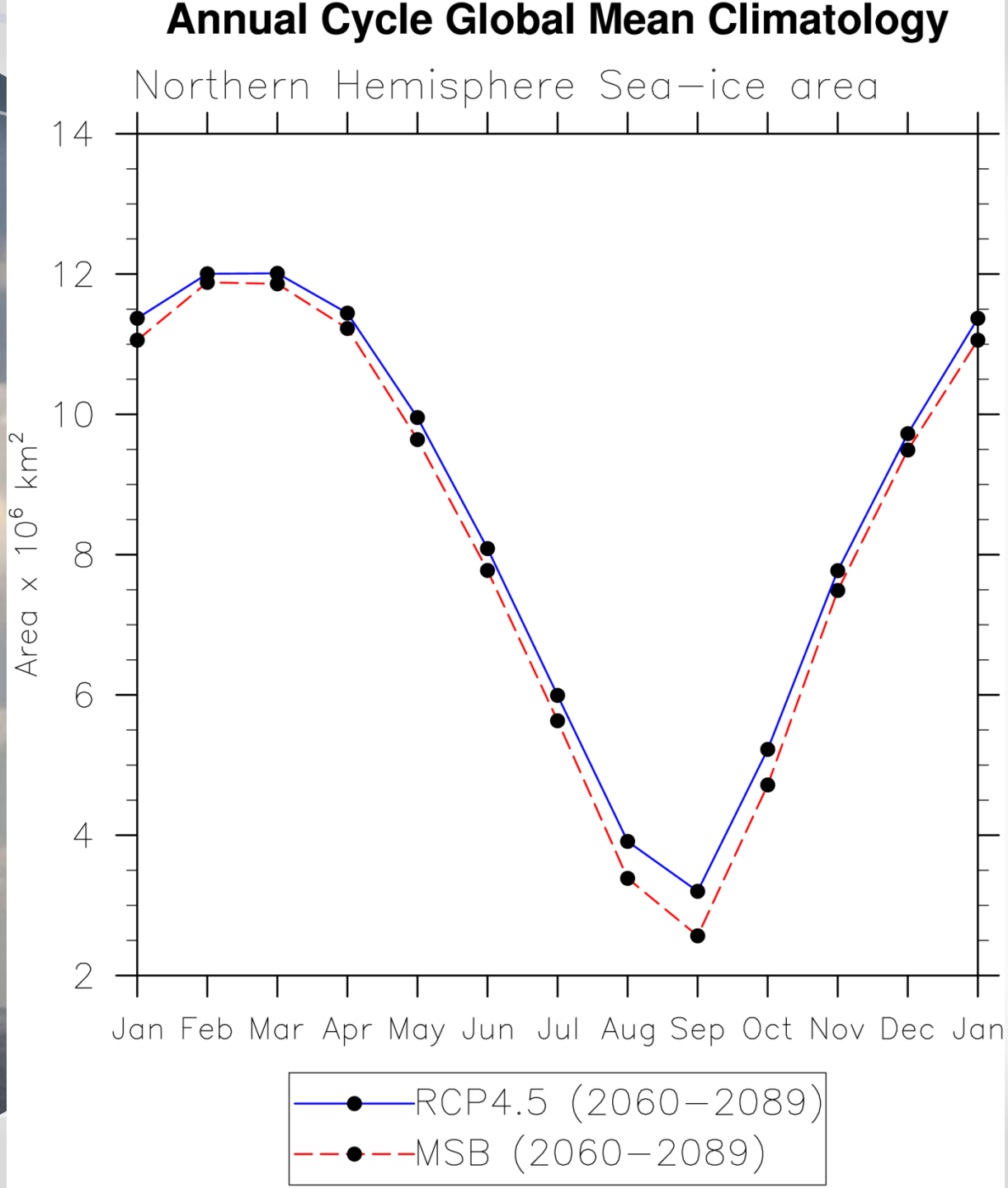


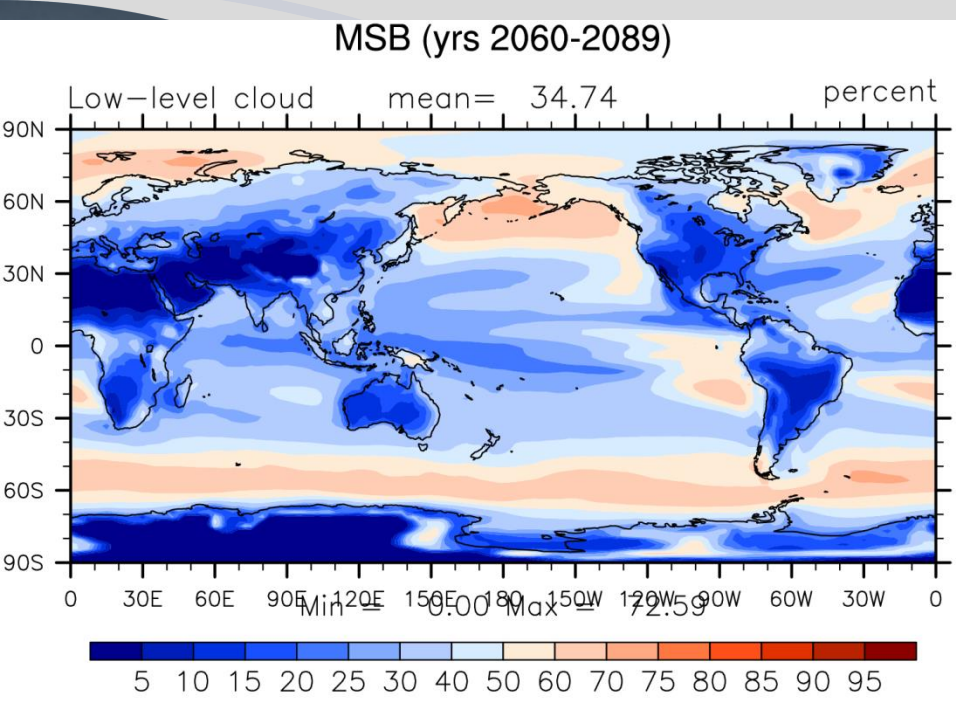

ANN
Surf latent heat flux (W/m^2)
150
120
90
60
30
0
−30
90N
60N
30N
0
30S
60S
90S
latitude
RCP4.5
MSB

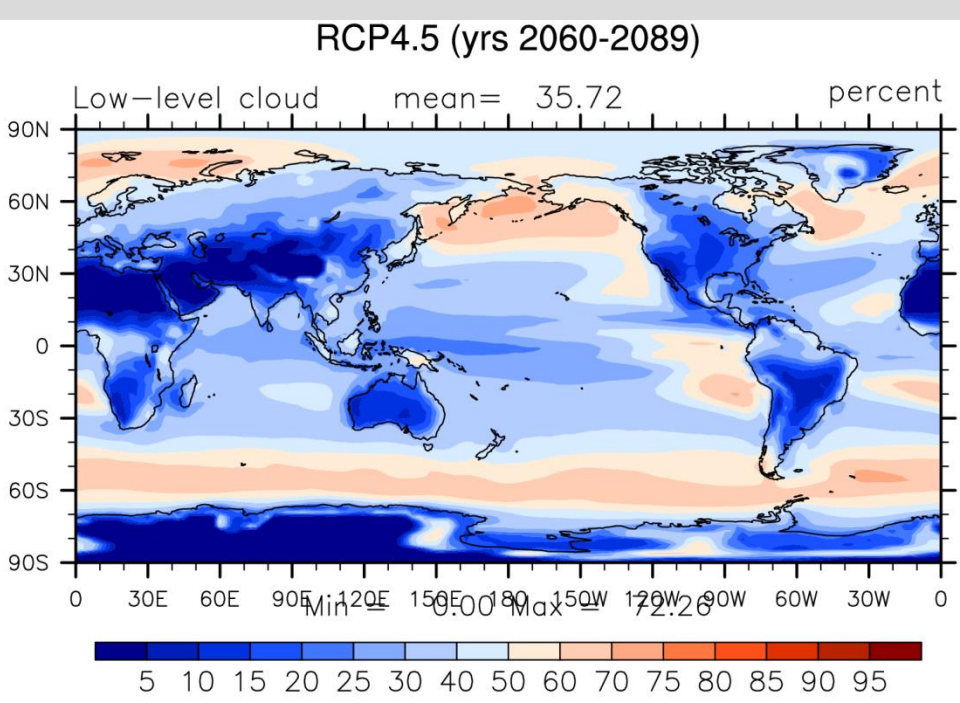

MSB − RCP4.5
Surf latent heat flux (W/m^2)
1.0
0.0
−1.0
−2.0
−3.0
−4.0
−5.0
−6.0
90N
60N
30N
0
30S
60S
90S
latitude

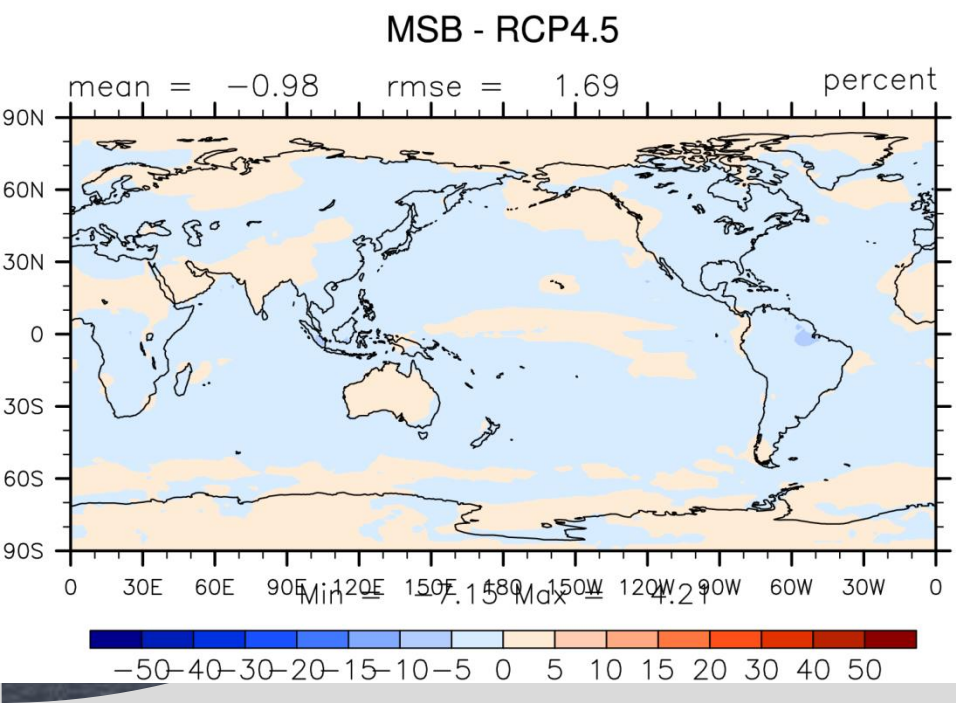

ANN
TOM SW cloud forcing (W/m²)
0
−20
−40
−60
−80
−100
90N
60N
30N
0
30S
60S
90S
latitude
RCP4.5
MSB

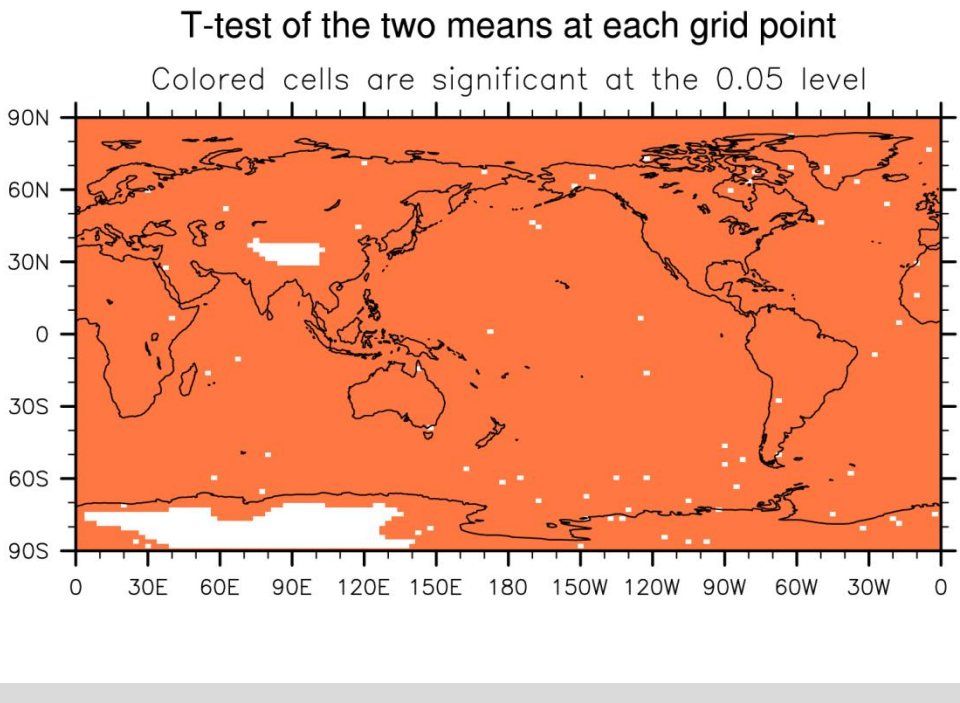

MSB − RCP4.5
TOM SW cloud forcing (W/m²)
4.0
3.0
2.0
1.0
0.0
−1.0
−2.0
90N
60N
30N
0
30S
60S
90S
latitude

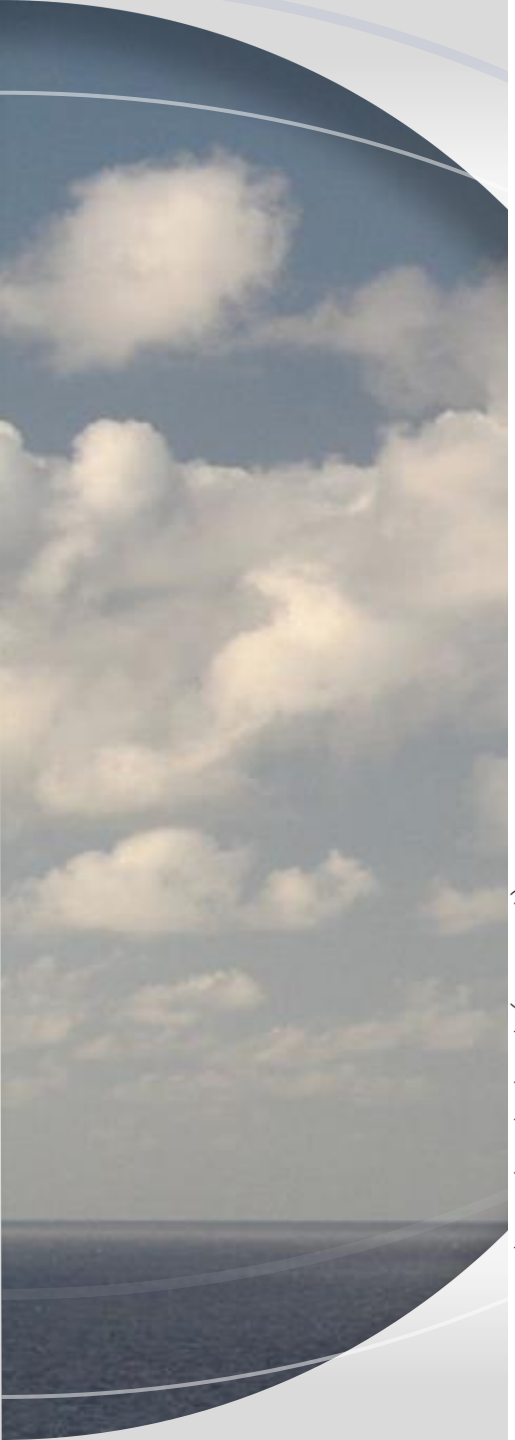

Annual Cycle Global Mean Climatology
Northern Hemisphere Sea–ice area
Area x 10^6 km^2
14
12
10
8
6
4
2
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
RCP4.5 (2060–2089)
MSB (2060–2089)

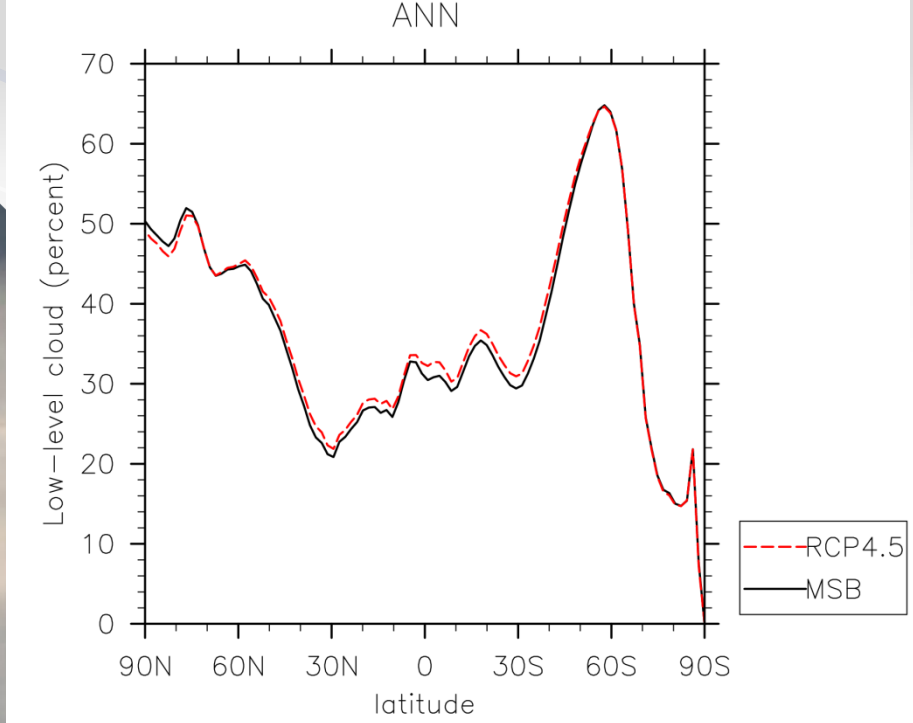

MSB (yrs 2060-2089)
Low−level cloud
mean= 34.74
percent
90N
60N
30N
0
30S
60S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
Min = 0.00 Max = 72.59
5 10 15 20 25 30 40 50 60 70 75 80 85 90 95

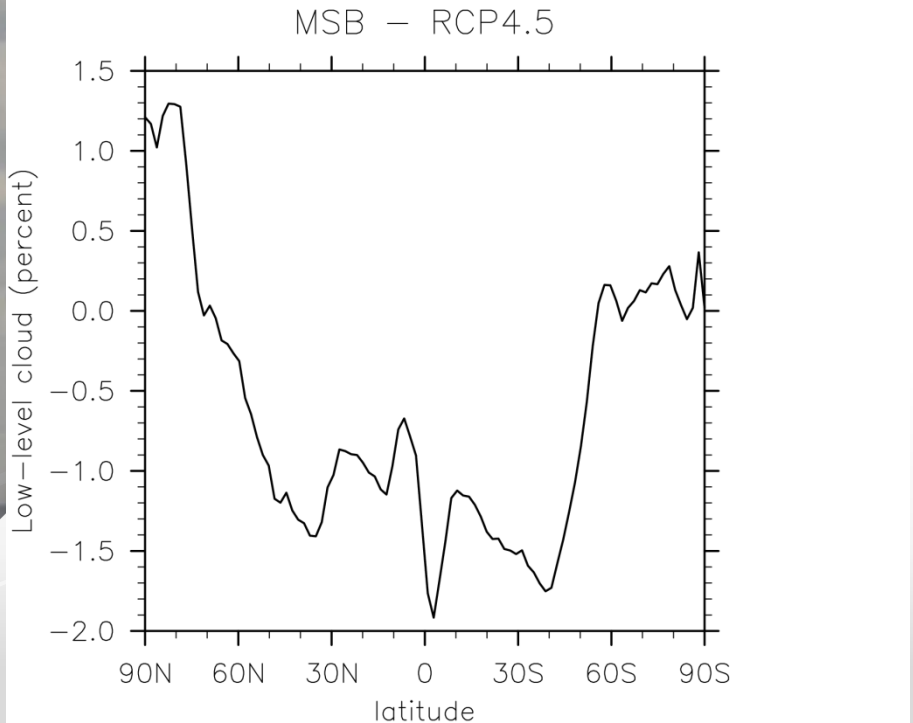

RCP4.5 (yrs 2060-2089)
Low−level cloud
mean= 35.72
percent
90N
60N
30N
0
30S
60S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
Min = 0.00 Max = 72.26
5 10 15 20 25 30 40 50 60 70 75 80 85 90 95


MSB - RCP4.5
mean = −0.98
rmse = 1.69
percent
90N
60N
30N
0
30S
60S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
Min = −7.15 Max = 4.21
−50 −40 −30 −20 −15 −10 −5 0 5 10 15 20 30 40 50

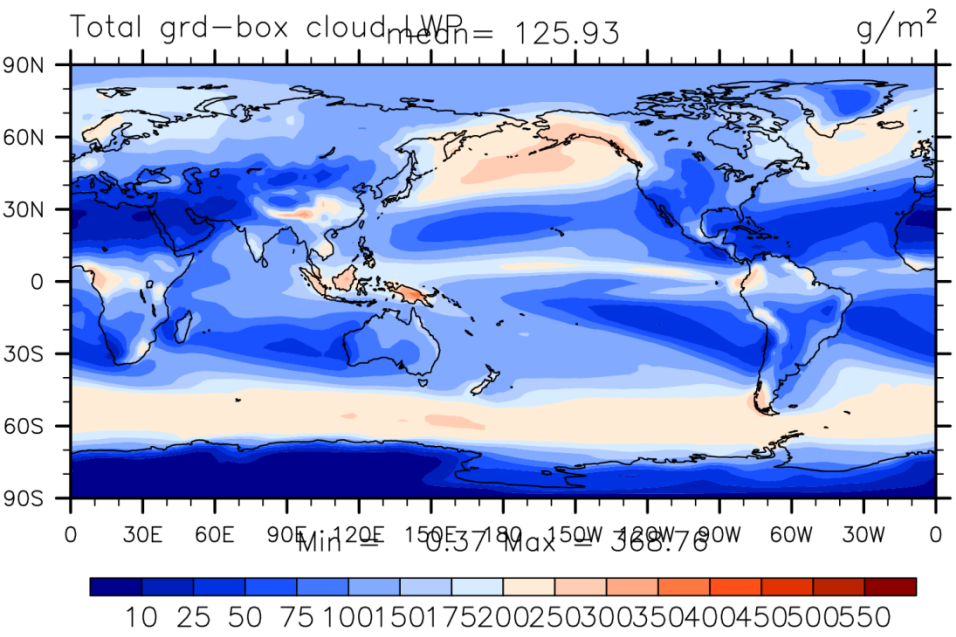

T-test of the two means at each grid point
Colored cells are significant at the 0.05 level
90N
60N
30N
0
30S
60S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0



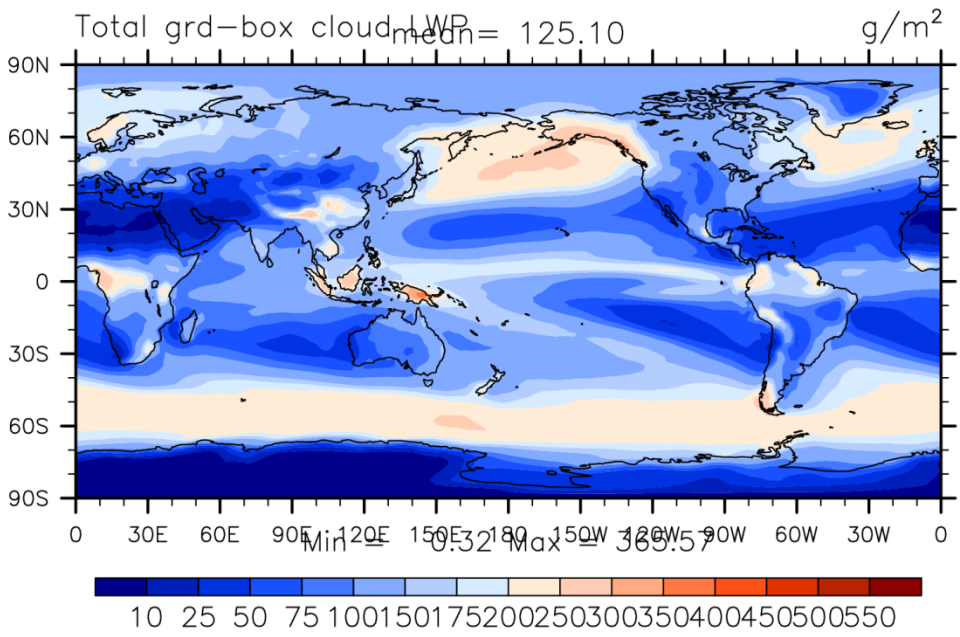

ANN
Low−level cloud (percent)
70
60
50
40
30
20
10
0
90N
60N
30N
0
30S
60S
90S
latitude
RCP4.5
MSB


MSB − RCP4.5
Low−level cloud (percent)
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
90N
60N
30N
0
30S
60S
90S
latitude

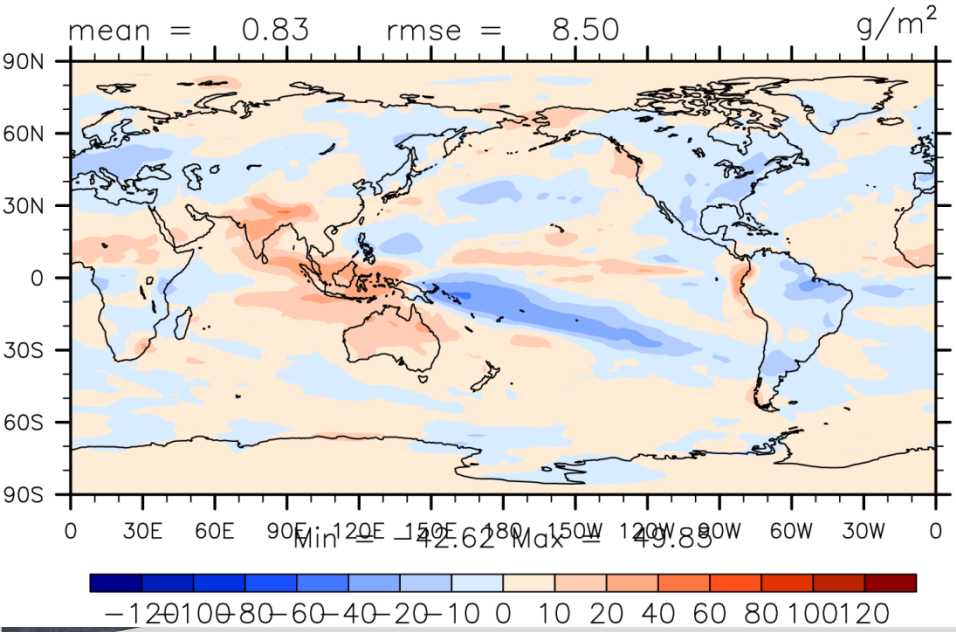
MSB (yrs 2060-2089)



RCP4.5 (yrs 2060-2089)



MSB - RCP4.5



T-test of the two means at each grid point