Atlantic meridional overturning circulation in the global warming ($2xCO_2$) scenario using GISS/HYCOM coupled climate model

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Model components used at GISS:

- Atmospheric GCM, 4^0x5^0 spherical grid, 20 layers.
- HYCOM, 2^0 compound Mercator-tripole grid, refined near equator, 20 mostly isopycnic layers.
- Pre-industrial atmospheric conditions are used in the control run.
- In perturbation run, CO2 rises 1% annually and remains constant after doubling.

One Lesson learned from this IPCC:

- Errors in temperature at the surface have an immediate, devastating impact on climate; the effect of errors in the interior is indirect and much harder to assess.

Regional SST biases in GISS/HYCOM coupled model:

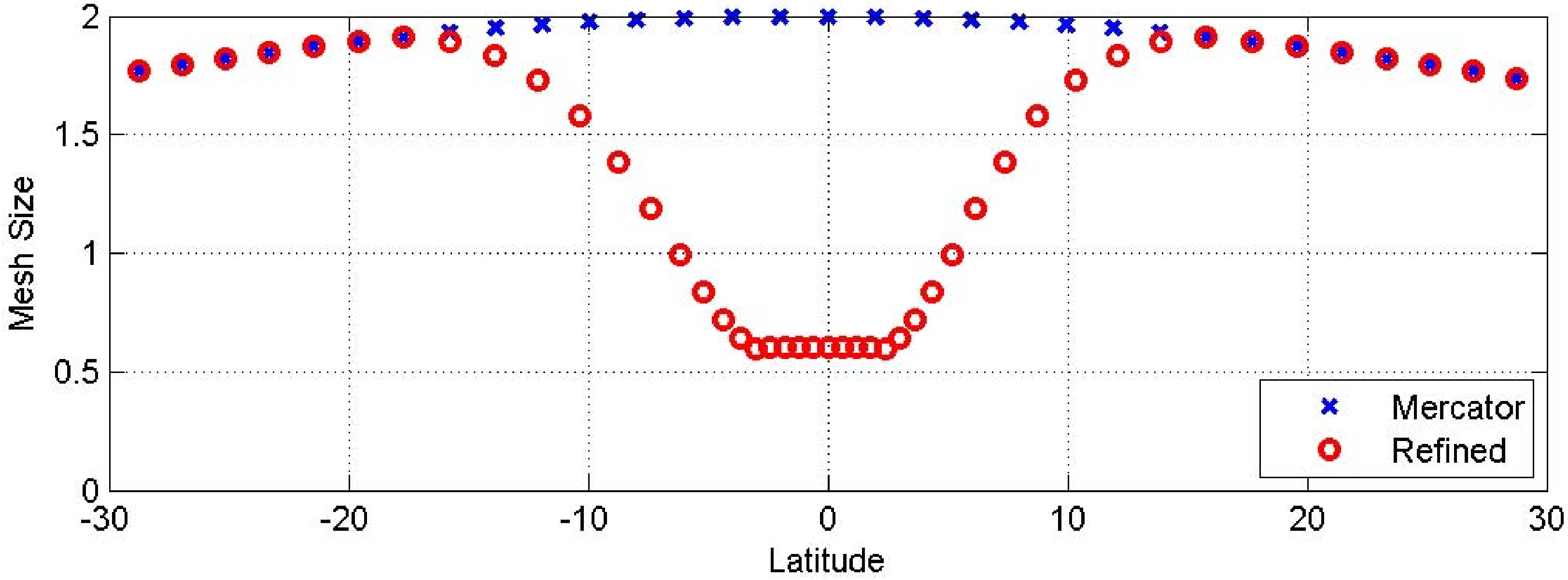
- Too warm in the Southern Ocean.
- Cold/warm biases in the both north Pacific and north Atlantic.
- SST errors along sea ice edge related to errors in sea ice extent

Recent changes in HYCOM architecture at GISS:

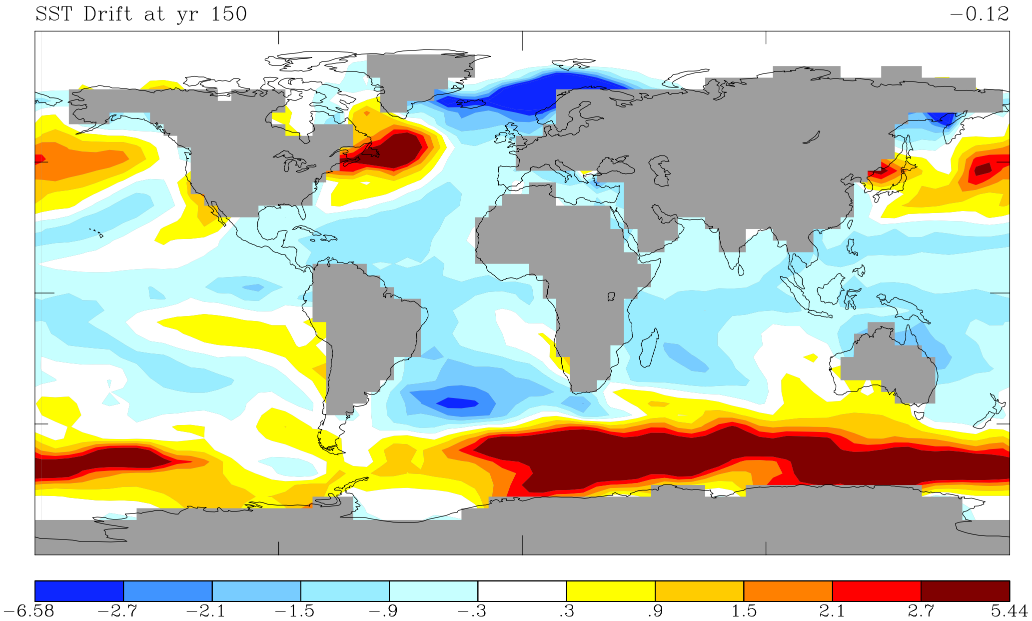
- More accurate state equation due to inclusion of thermobaricity.
- Improved formal conservation properties due to switch from density/spiciness advection to T/S advection.
- More accurate (=> less diffusive) vertical advection in z-coordinate subdomain.
- Multiple turbulent surface layer options.
- Tracer transport done intermittently on longer time steps (to speed up biogeochemical submodels)
- Bolus ("GM") fluxes now based on biharmonic interface smoothing.
- Combination of KPP vertical mixing scheme in the mixed layer and McDougall-Dewar scheme in the interior.

Choices of prescribed vertical mixing parameter:

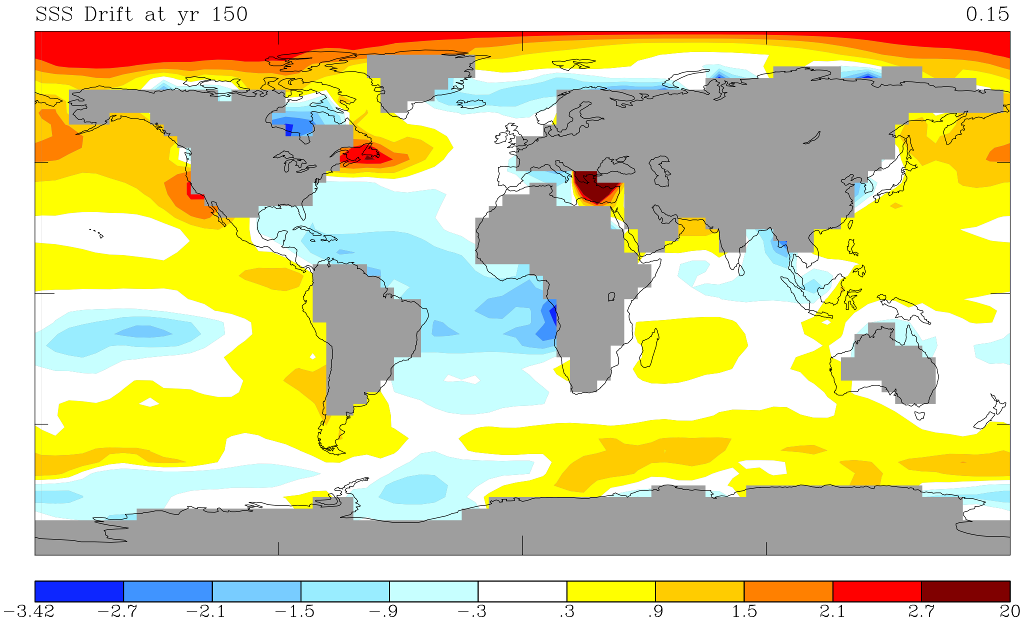
- 0.2/N (cm2/sec): leads to subsurface cooling in the tropics.
- 0.2 (cm2/sec): reduces ENSO variability.
- We are experimenting with using minimum of the two.



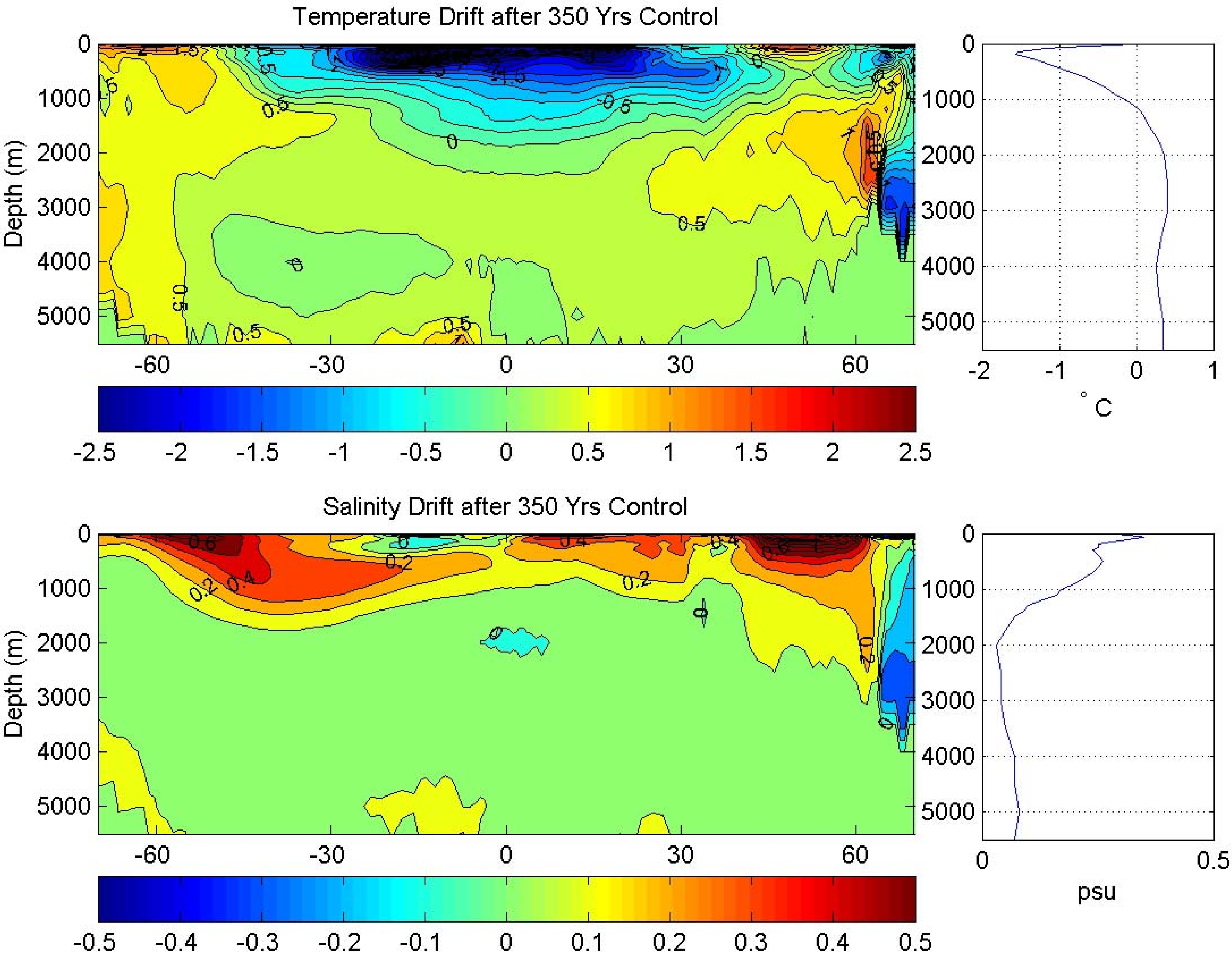
Mesh Size
Latitude
2
1.5
1
0.5
0
-30
-20
-10
0
10
20
30
Mercator
Refined

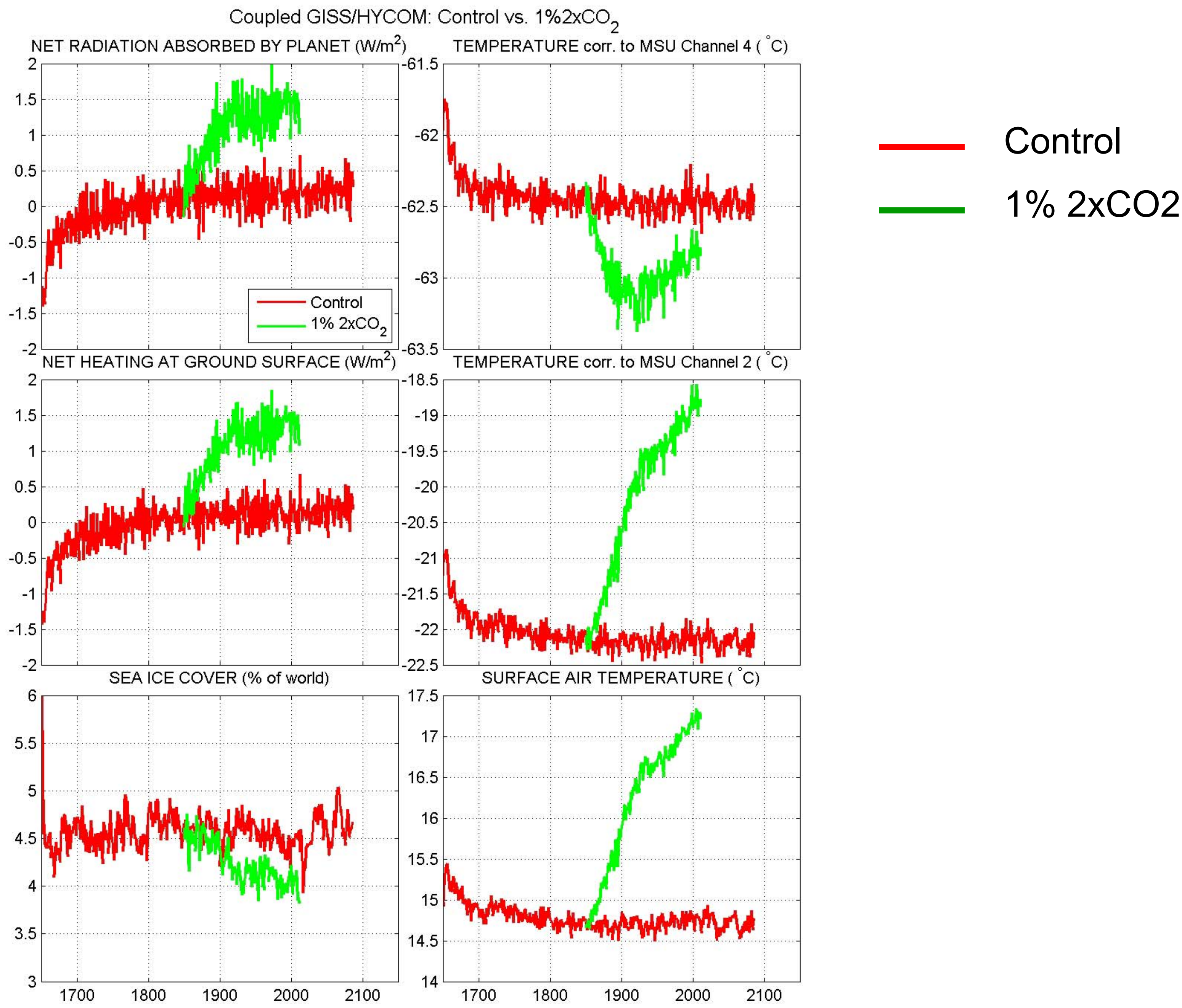


SST drift at yr 150



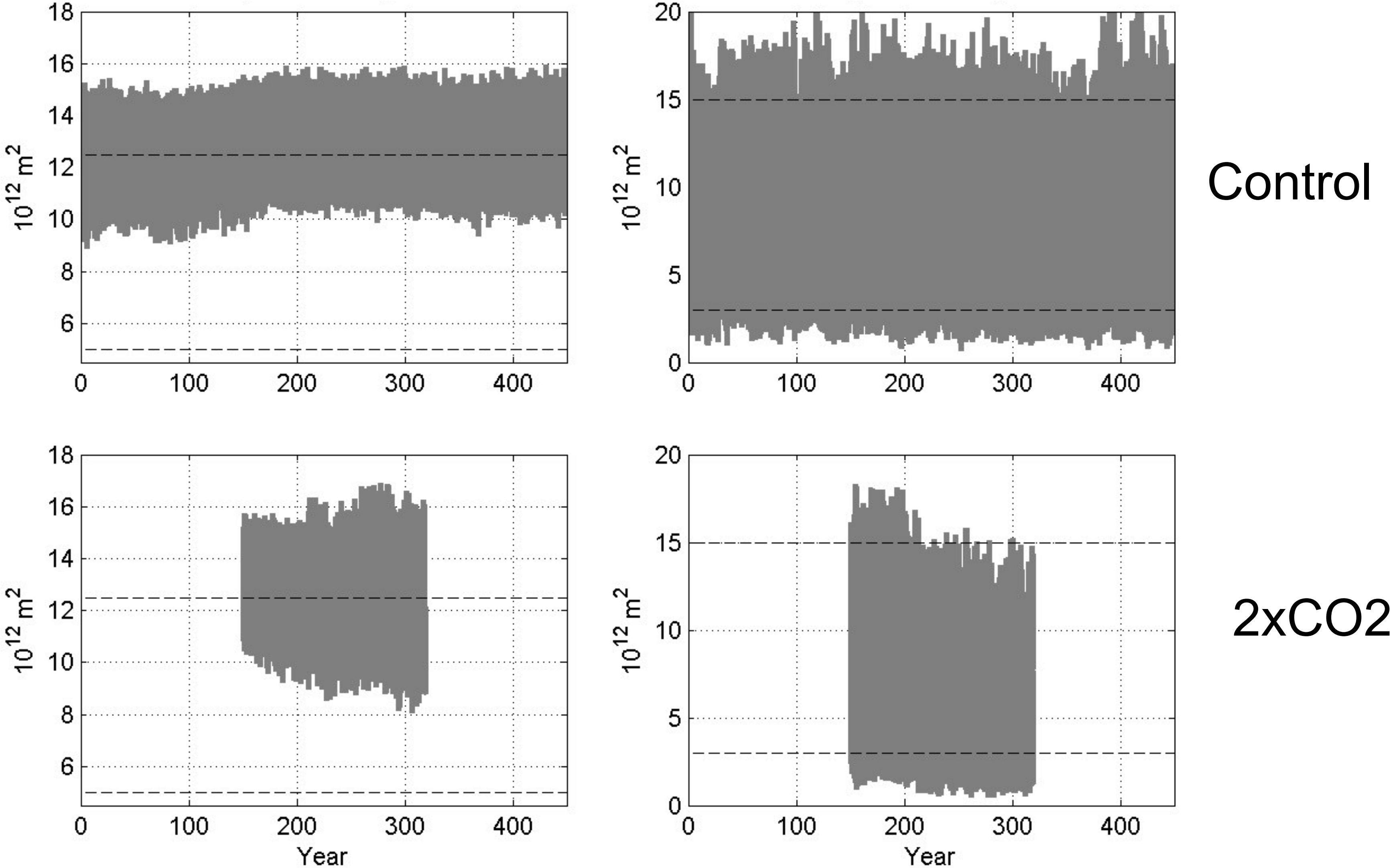
SSS drift at yr 150

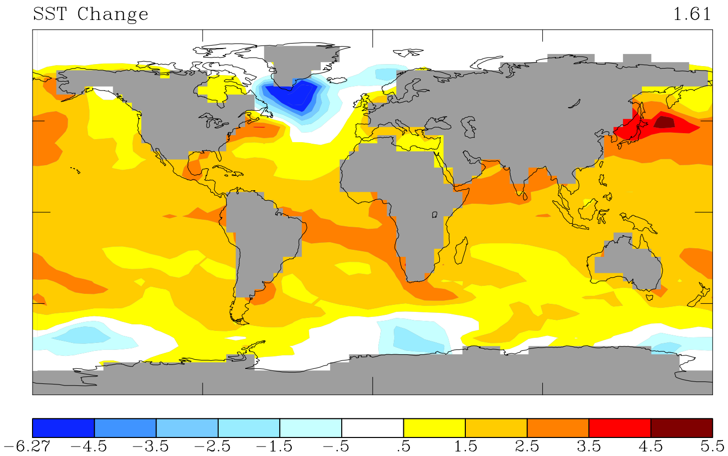

Temperature Drift after 350 Yrs Control
Depth (m)
°C
Salinity Drift after 350 Yrs Control
Depth (m)
psu



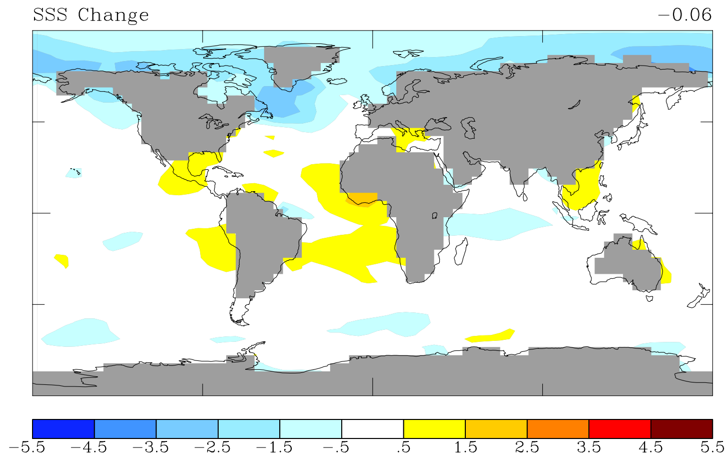
Coupled GISS/HYCOM: Control vs. 1%2xCO2
NET RADIATION ABSORBED BY PLANET (W/m2)
TEMPERATURE corr. to MSU Channel 4 (°C)
NET HEATING AT GROUND SURFACE (W/m2)
TEMPERATURE corr. to MSU Channel 2 (°C)
SEA ICE COVER (% of world)
SURFACE AIR TEMPERATURE (°C)
Control
1% 2xCO2
1700
1800
1900
2000
2100
Control
1% 2xCO2

Ice Coverage in NH | Ice Coverage in SH

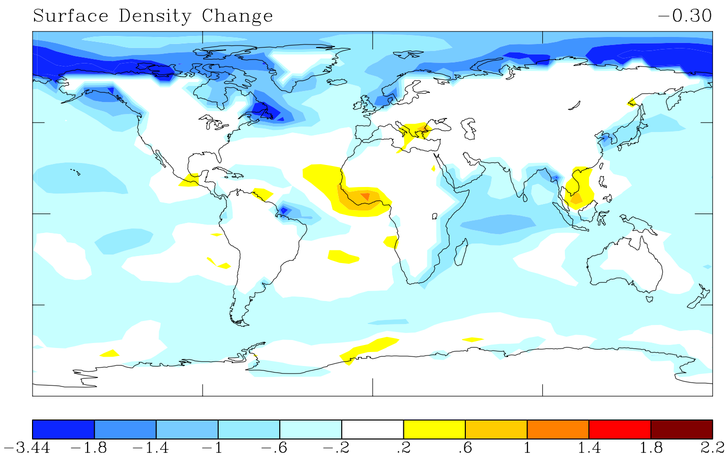




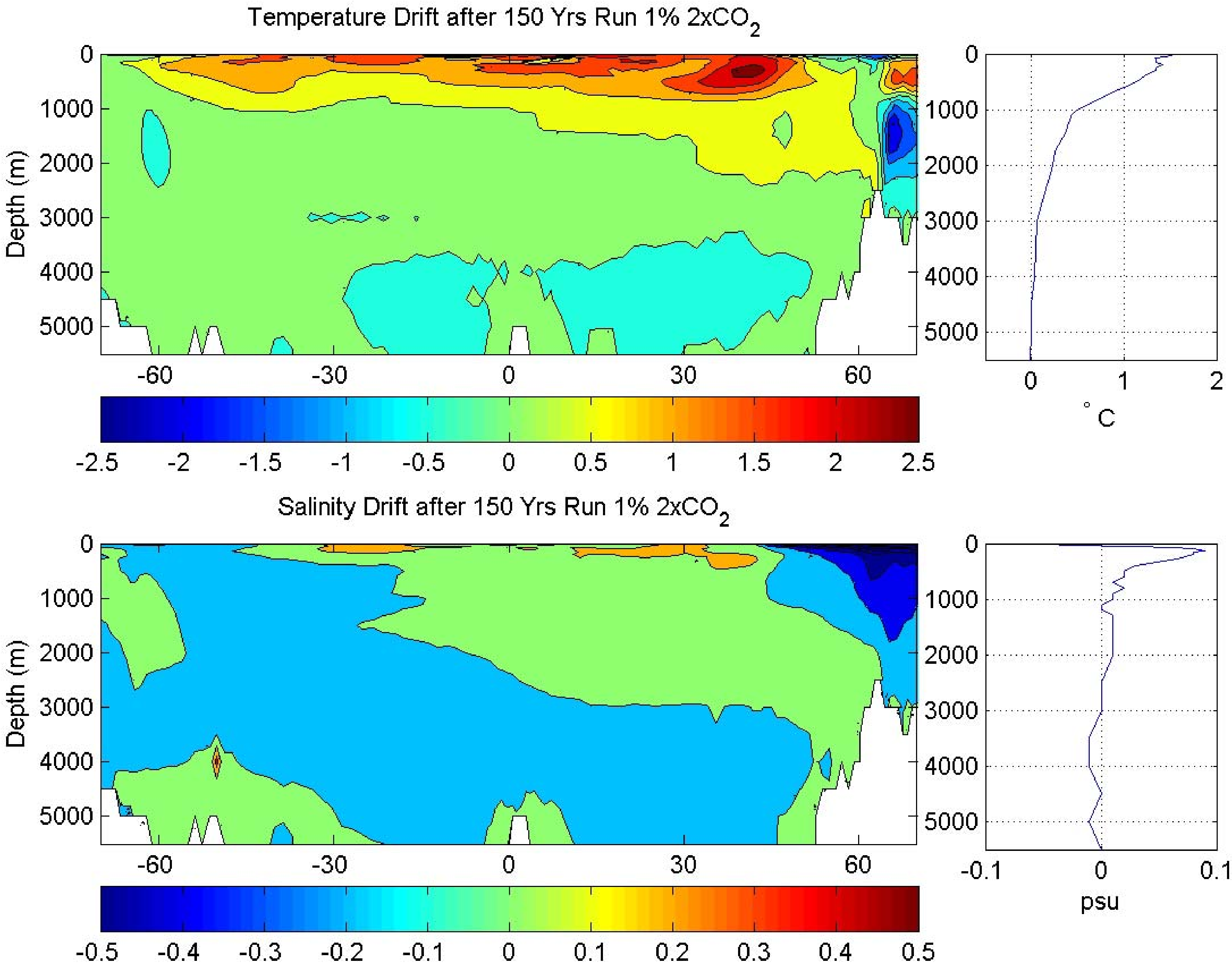
Sea surface temperature, CO2 minus CTL



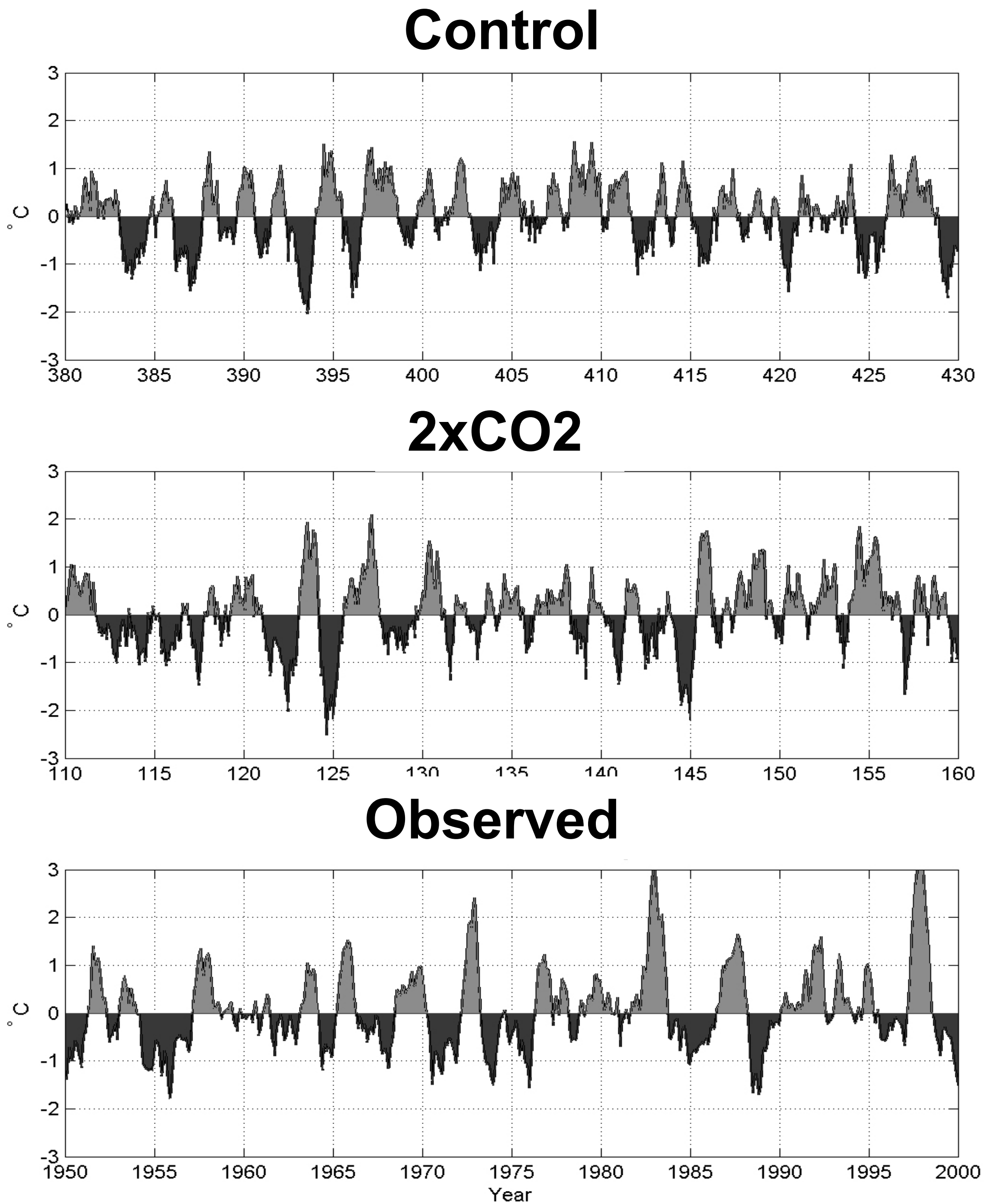
Sea surface salinity, CO2 minus CTL

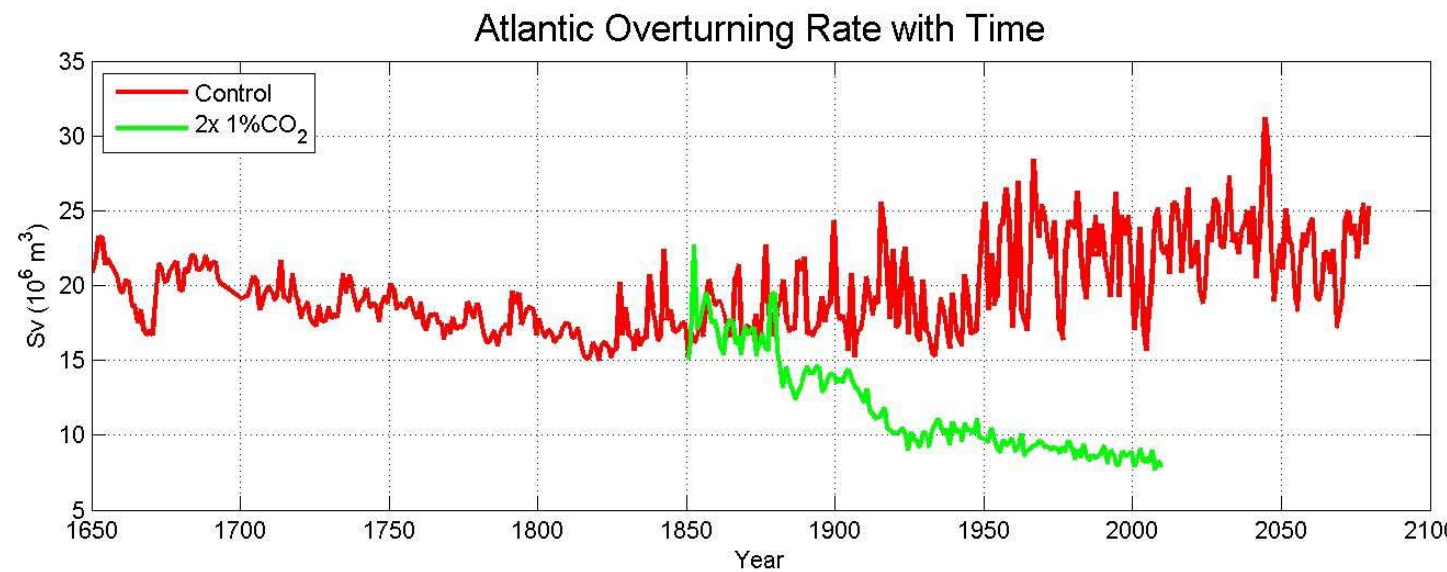


Surface density, CO2 minus CTL

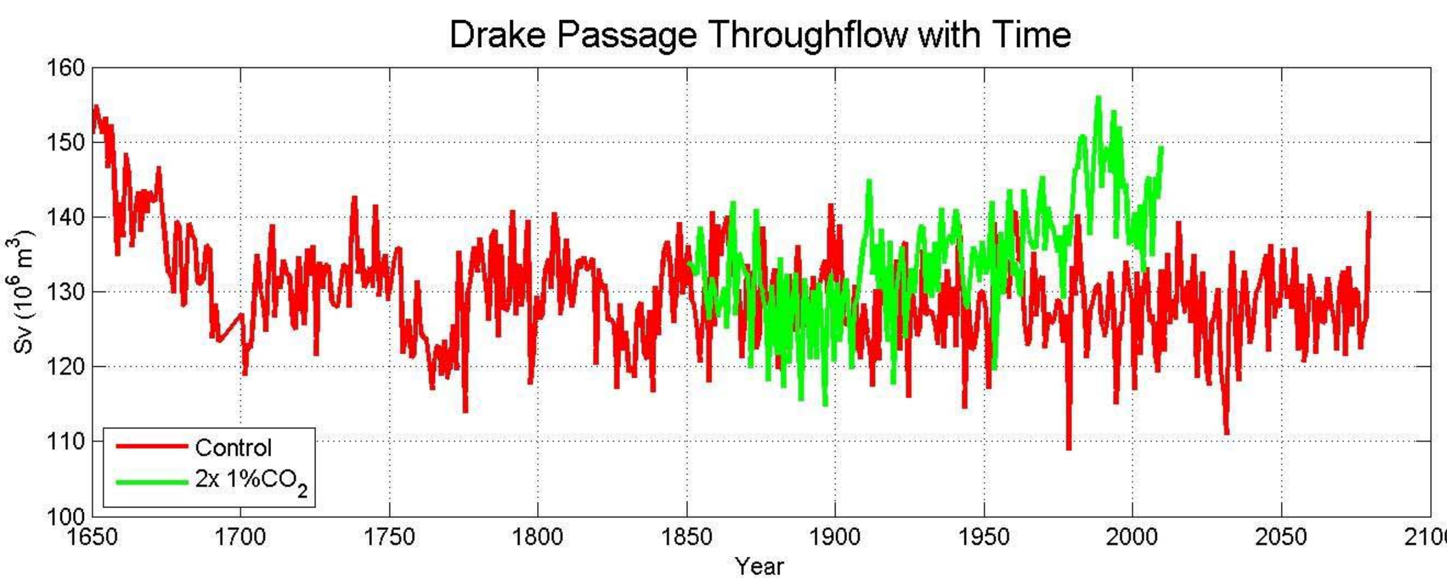

Temperature Drift after 150 Yrs Run 1% 2xCO2
Depth (m)
0
1000
2000
3000
4000
5000
-60
-30
0
30
60
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
0
1
2
°C
Salinity Drift after 150 Yrs Run 1% 2xCO2
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
-0.1
0
0.1
psu

Nino3 Index

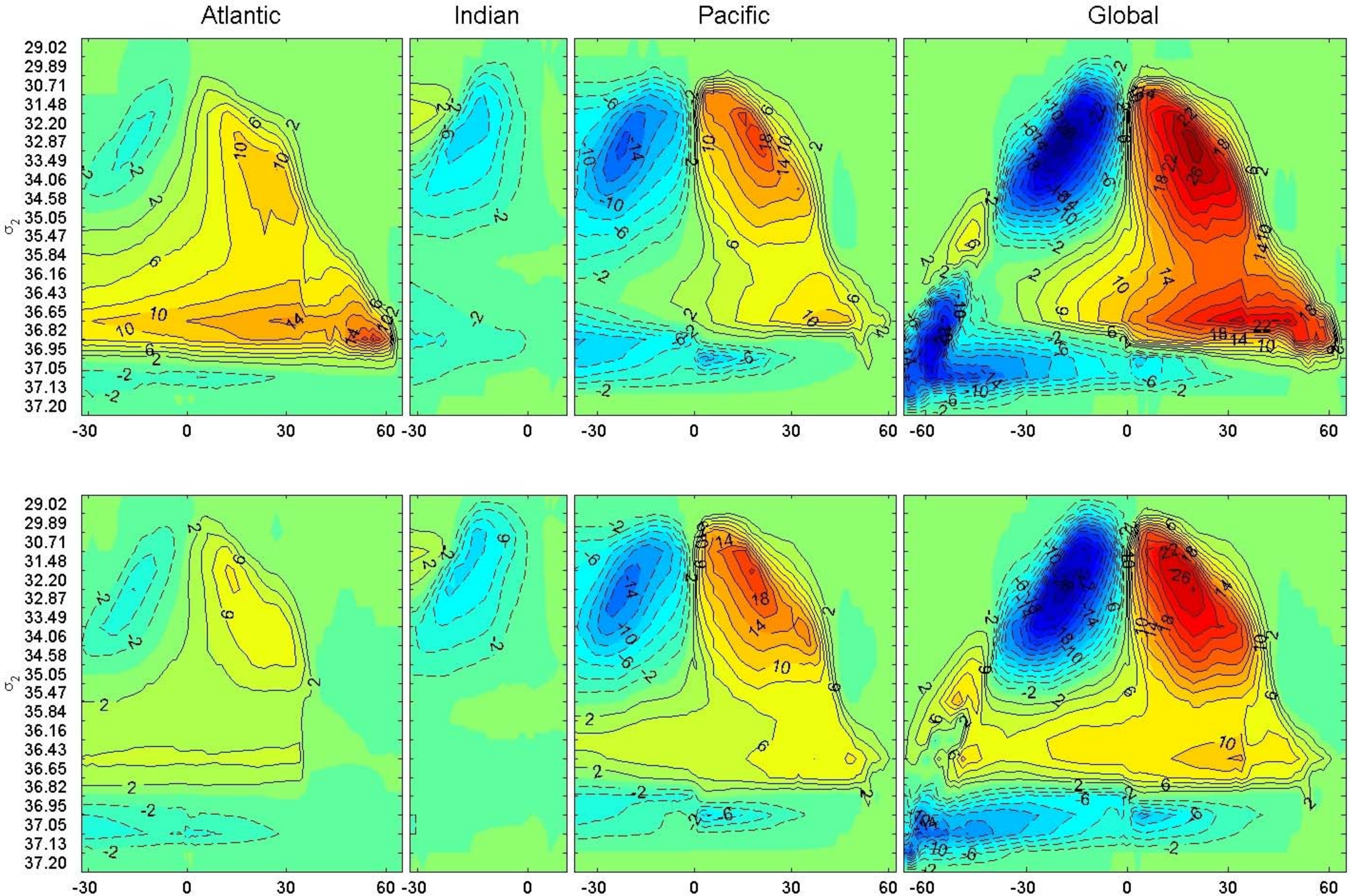

Control
2xCO2
Observed
3
2
1
0
-1
-2
-3
°C
380 385 390 395 400 405 410 415 420 425 430
110 115 120 125 130 135 140 145 150 155 160
1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000
Year



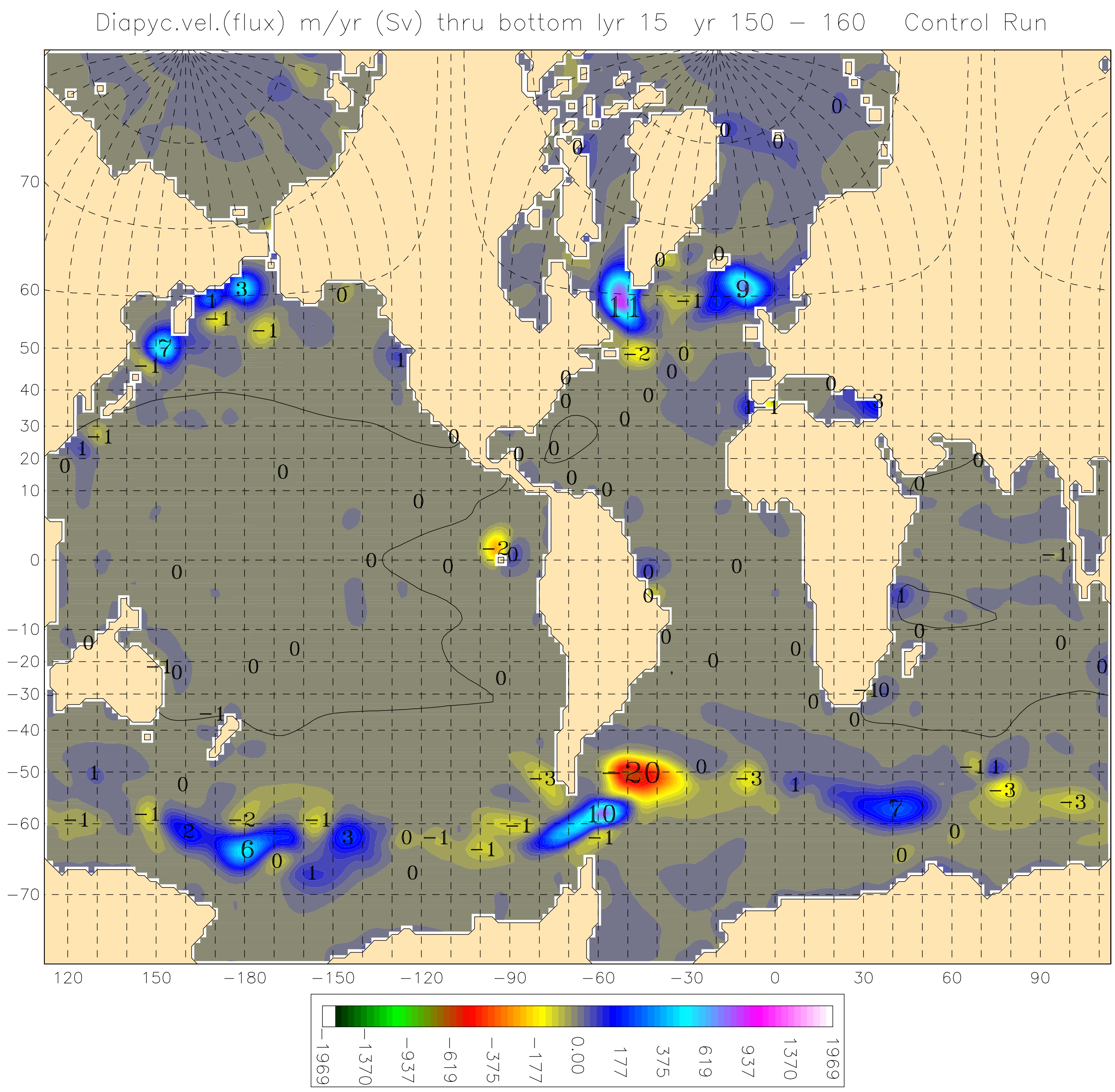
Atlantic Overturning Rate with Time
Control
2x 1%CO2
Sv (10^6 m^3)
35
30
25
20
15
10
5
1650
1700
1750
1800
1850
1900
1950
2000
2050
2100
Year



Drake Passage Throughflow with Time
Control
2x 1%CO2
Sv (10^6 m^3)
160
150
140
130
120
110
100
1650
1700
1750
1800
1850
1900
1950
2000
2050
2100
Year

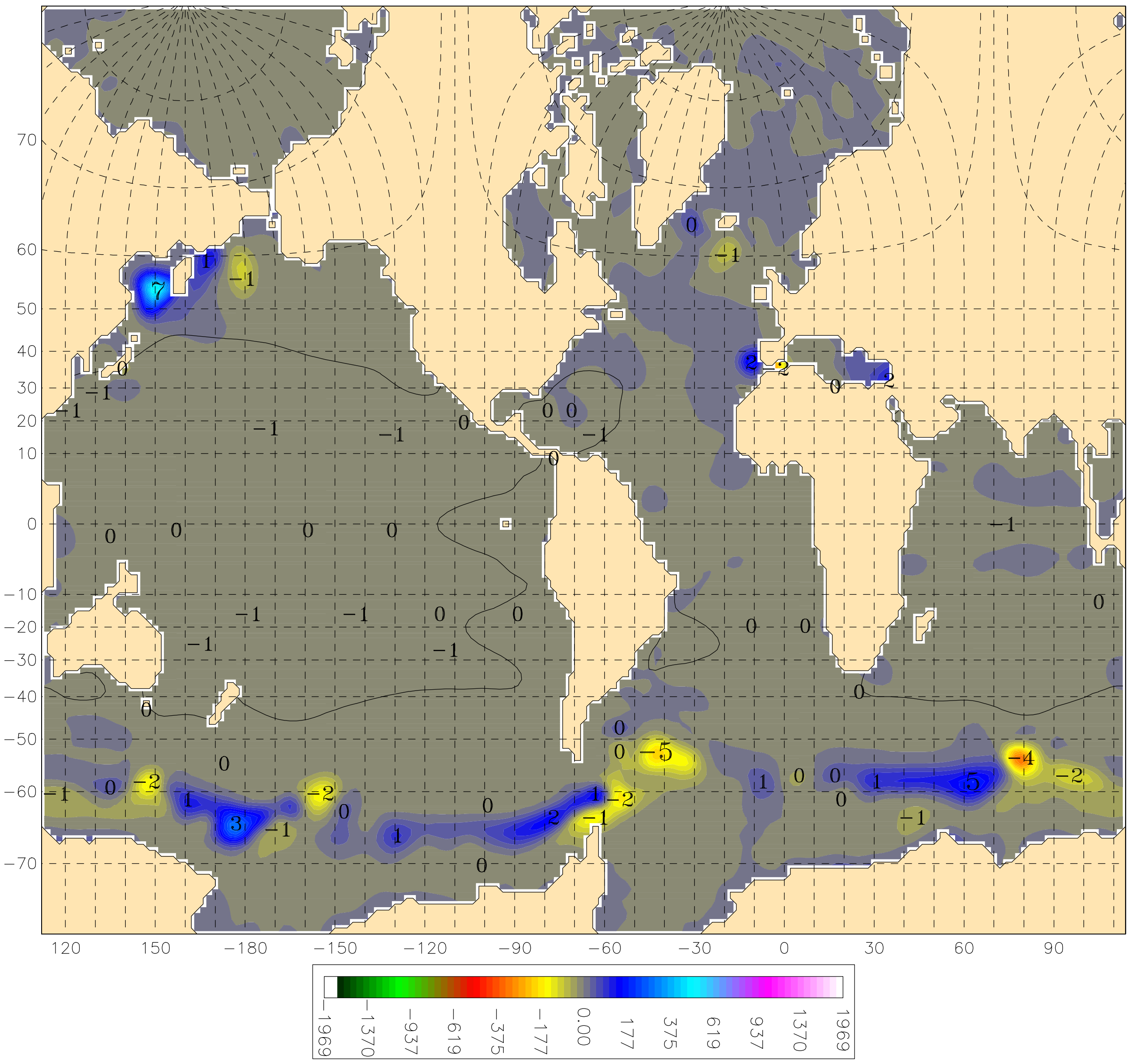


Atlantic
Indian
Pacific
Global
σ_2
29.02
29.89
30.71
31.48
32.20
32.87
33.49
34.06
34.58
35.05
35.47
35.84
36.16
36.43
36.65
36.82
36.95
37.05
37.13
37.20
-30
0
30
60
-60



Diapyc.vel.(flux) m/yr (Sv) thru bottom lyr 15 yr 150 – 160 Control Run
70
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
−60
−70
120
150
−180
−150
−120
−90
−60
−30
0
30
60
90
−1969
−1370
−937
−619
−375
−177
0.00
177
375
619
937
1370
1969

Diapyc.vel.(flux) m/yr (Sv) thru bottom lyr 15 yr 150 – 160   Control Run



Summary

- Regional temperature drift in the control run is still uncomfortably large.
- Northern North Atlantic is fresher and colder in the 2xCO_2 run, yielding a lighter surface density and reduced overturning.
- Deep convection is excessive in the north Pacific and north Atlantic, probably caused by the path shift of warm currents.
- Positive SST bias in the Southern Ocean is likely related to too weak Ekman suction.