Comparison of CFC-11 distribution in CCSM, x1-ocean, x3-ocean and 0.4-deg ocean models

Models

- CCSM 3.0
- x1 ocean with normal-year forcing (x1-NY)
- x1 ocean with inter-annually varying forcing (x1-IA)

identical grid

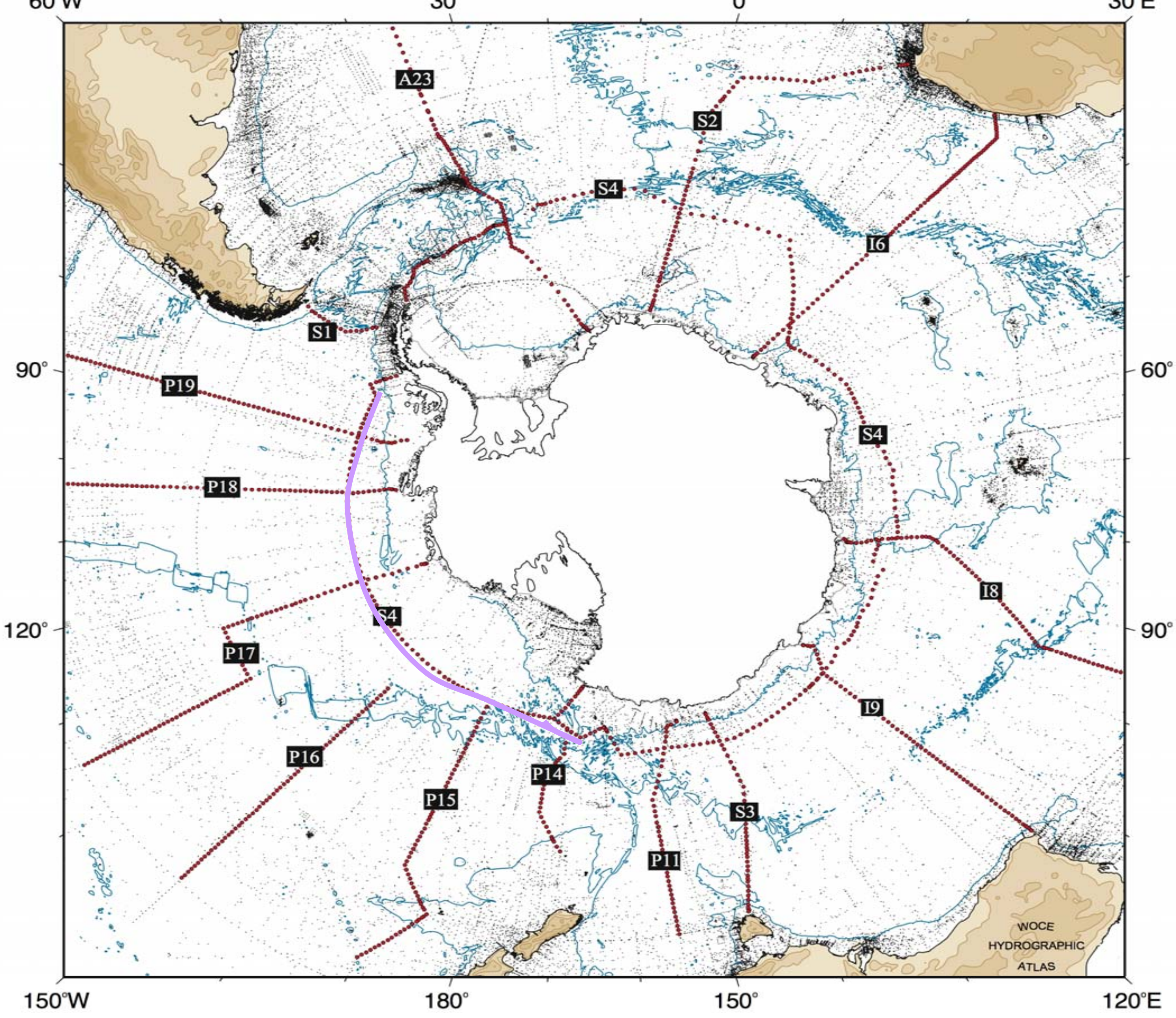
- x3 ocean
- 0.4-degree ocean

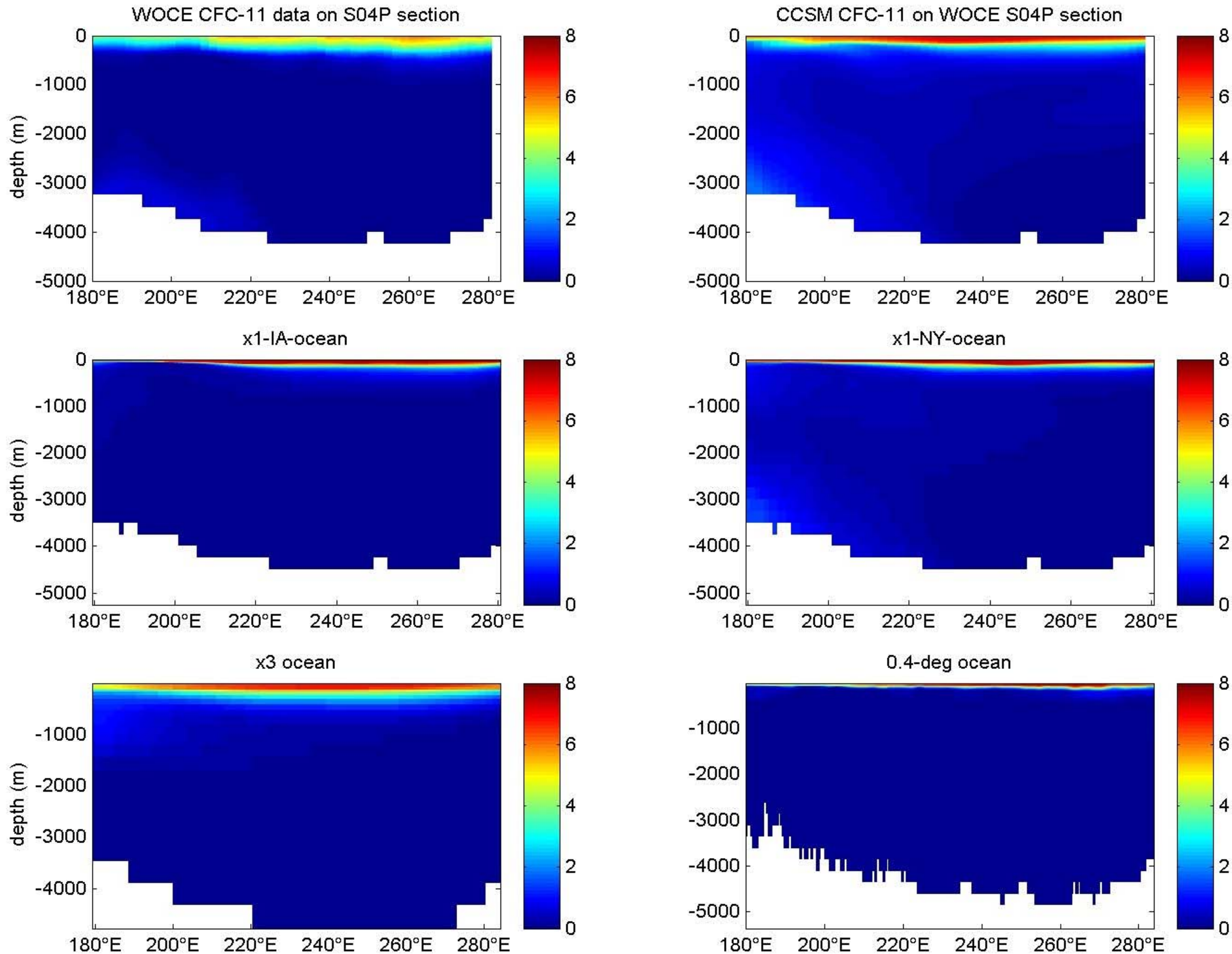
identical forcing

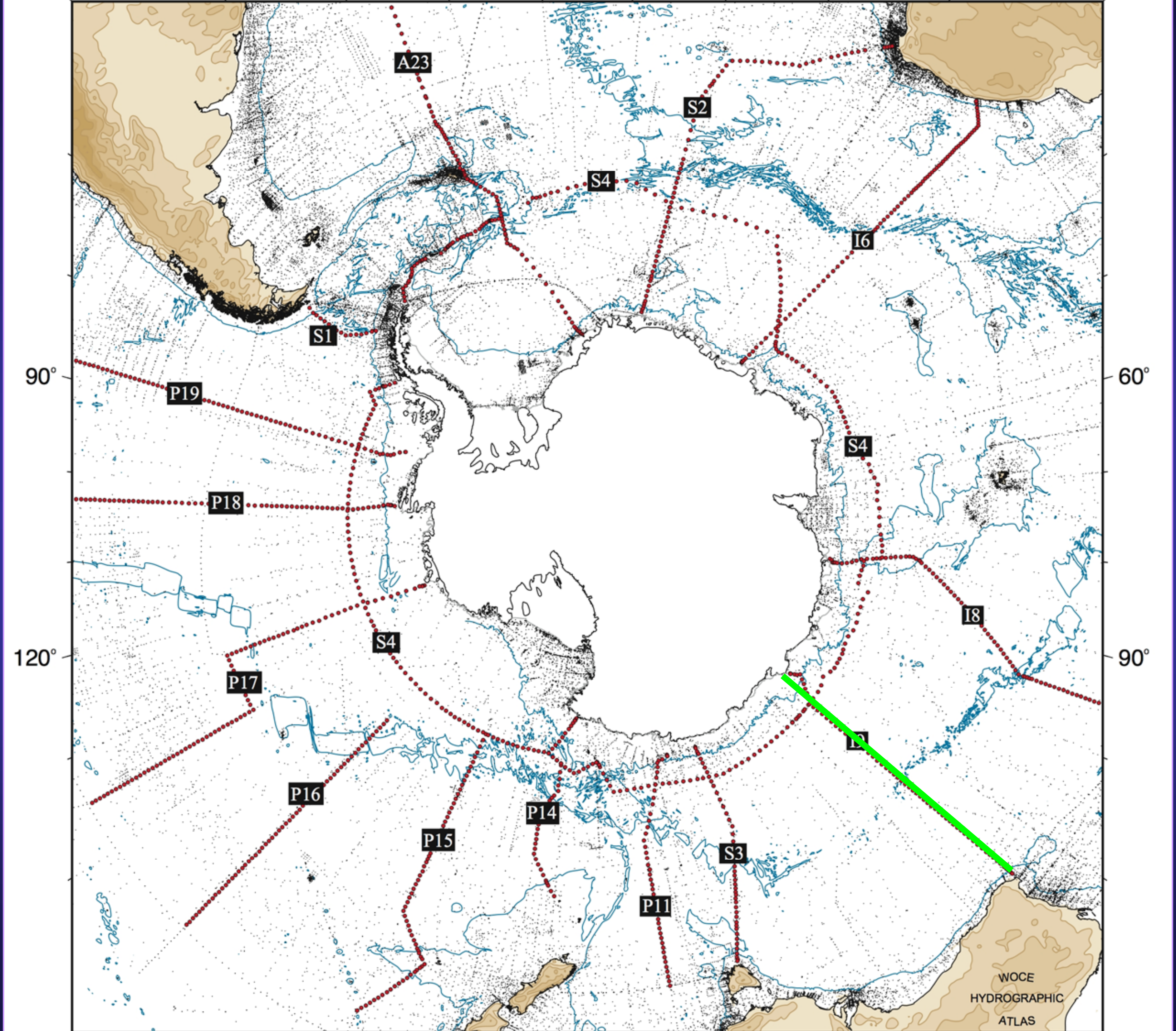
One fully coupled model;
Two ocean models with same grid, different forcing;
Two ocean models with same forcing, different grids

QUESTIONS:

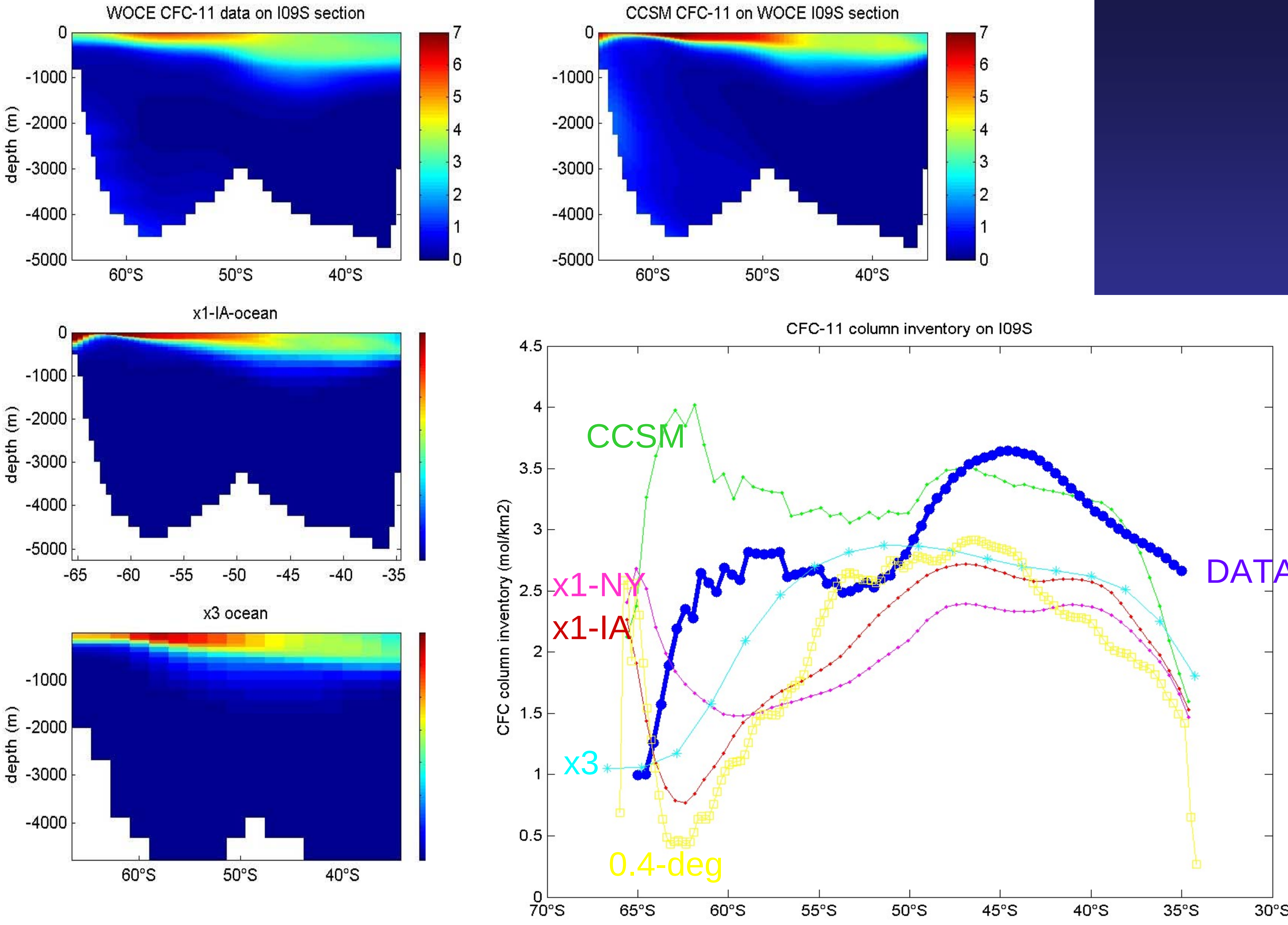
- How different are the CFC distributions in each model?
- Is any one model noticeably ‘better’ than the others?
- How important is forcing versus grid size?


60°W
30°
0°
30°E
A23
S2
S4
I6
S1
90°
60°
P19
S4
P18
I8
S4
120°
90°
P17
I9
P16
P14
P15
S3
P11
WOCE
HYDROGRAPHIC
ATLAS
150°W
180°
150°
120°E

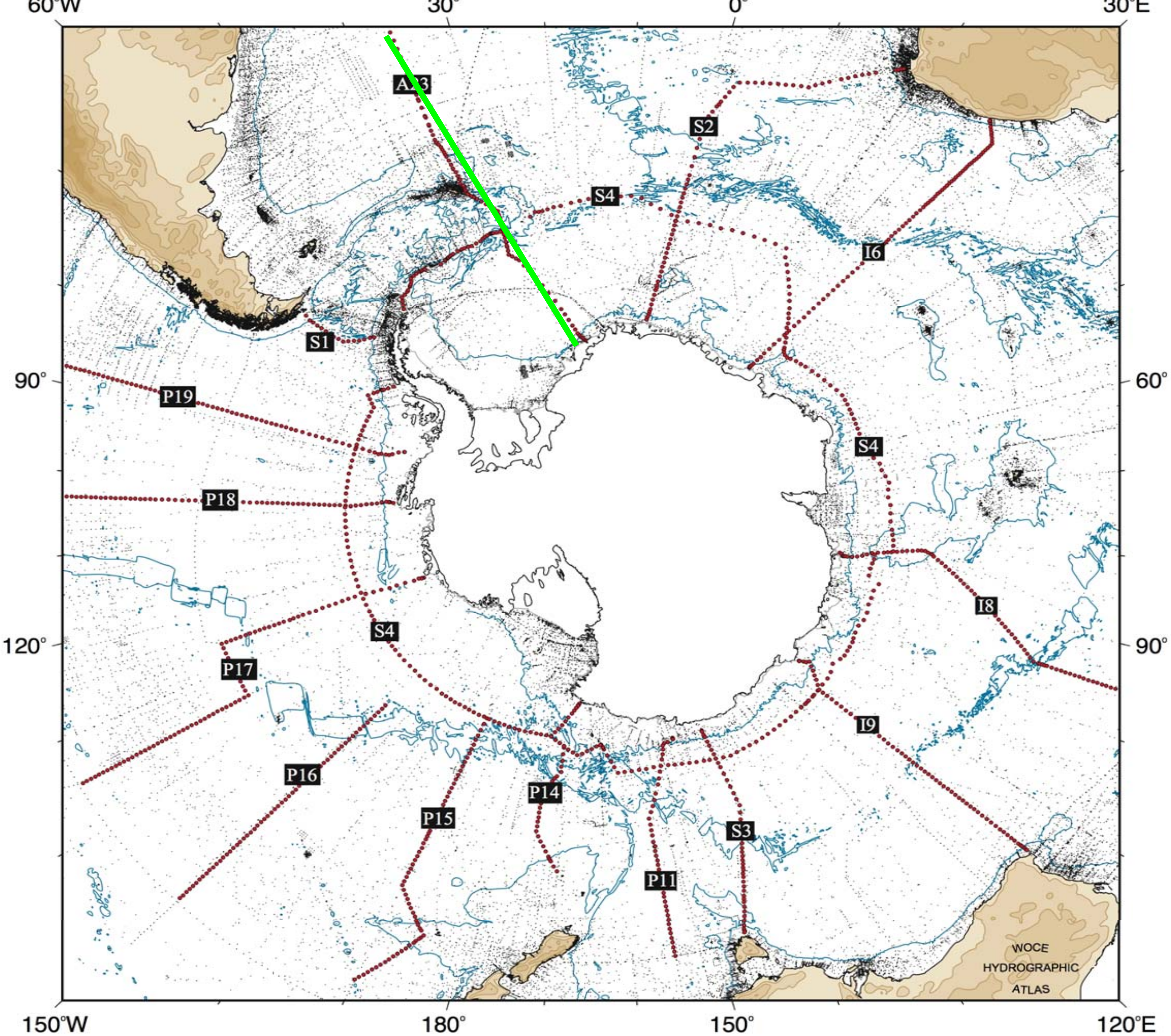

WOCE CFC-11 data on S04P section
CCSM CFC-11 on WOCE S04P section
x1-IA-ocean
x1-NY-ocean
x3 ocean
0.4-deg ocean
depth (m)
0
-1000
-2000
-3000
-4000
-5000
180°E
200°E
220°E
240°E
260°E
280°E
0
2
4
6
8



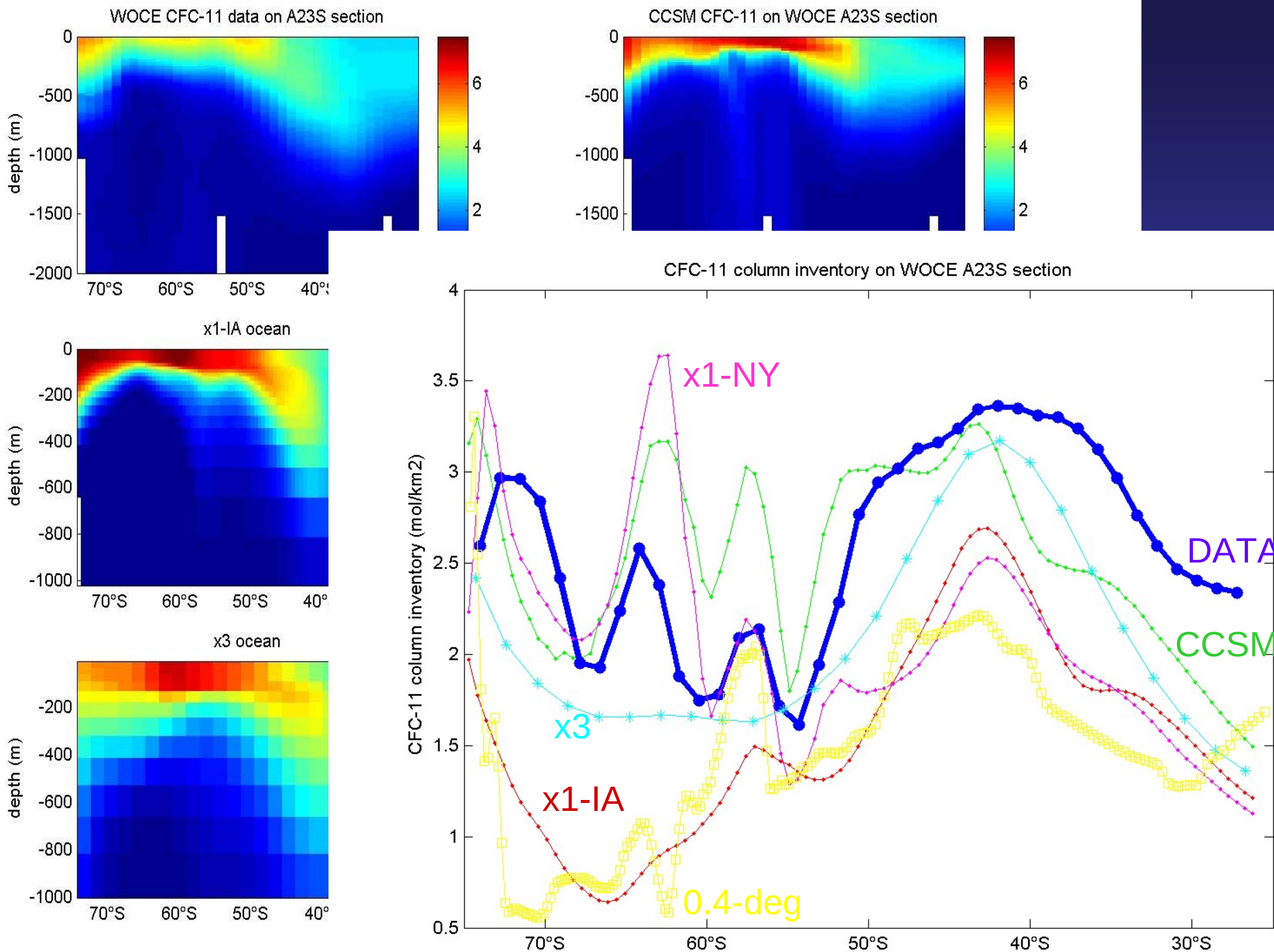
A23
S2
S4
I6
S1
90°
60°
P19
S4
P18
I8
S4
120°
90°
P17
I9
P16
P14
P15
S3
P11
WOCE
HYDROGRAPHIC
ATLAS



WOCE CFC-11 data on I09S section
CCSM CFC-11 on WOCE I09S section
x1-IA-ocean
x3 ocean
depth (m)
0
-1000
-2000
-3000
-4000
-5000
60°S
50°S
40°S
-65
-60
-55
-50
-45
-40
-35
0
1
2
3
4
5
6
7
CFC-11 column inventory on I09S
CFC column inventory (mol/km2)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
70°S
65°S
60°S
55°S
50°S
45°S
40°S
35°S
30°S
CCSM
x1-NY
x1-IA
x3
0.4-deg
DATA



60°W
30°
0°
30°E
90°
60°
120°
90°
150°W
180°
150°
120°E
A23
S2
S4
I6
S1
P19
S4
P18
S4
I8
P17
I9
P16
P14
P15
S3
P11
WOCE
HYDROGRAPHIC
ATLAS


WOCE CFC-11 data on A23S section
CCSM CFC-11 on WOCE A23S section
x1-IA ocean
x3 ocean
depth (m)
CFC-11 column inventory on WOCE A23S section
CFC-11 column inventory (mol/km2)
70°S
60°S
50°S
40°S
30°S
x1-NY
DATA
CCSM
x3
x1-IA
0.4-deg

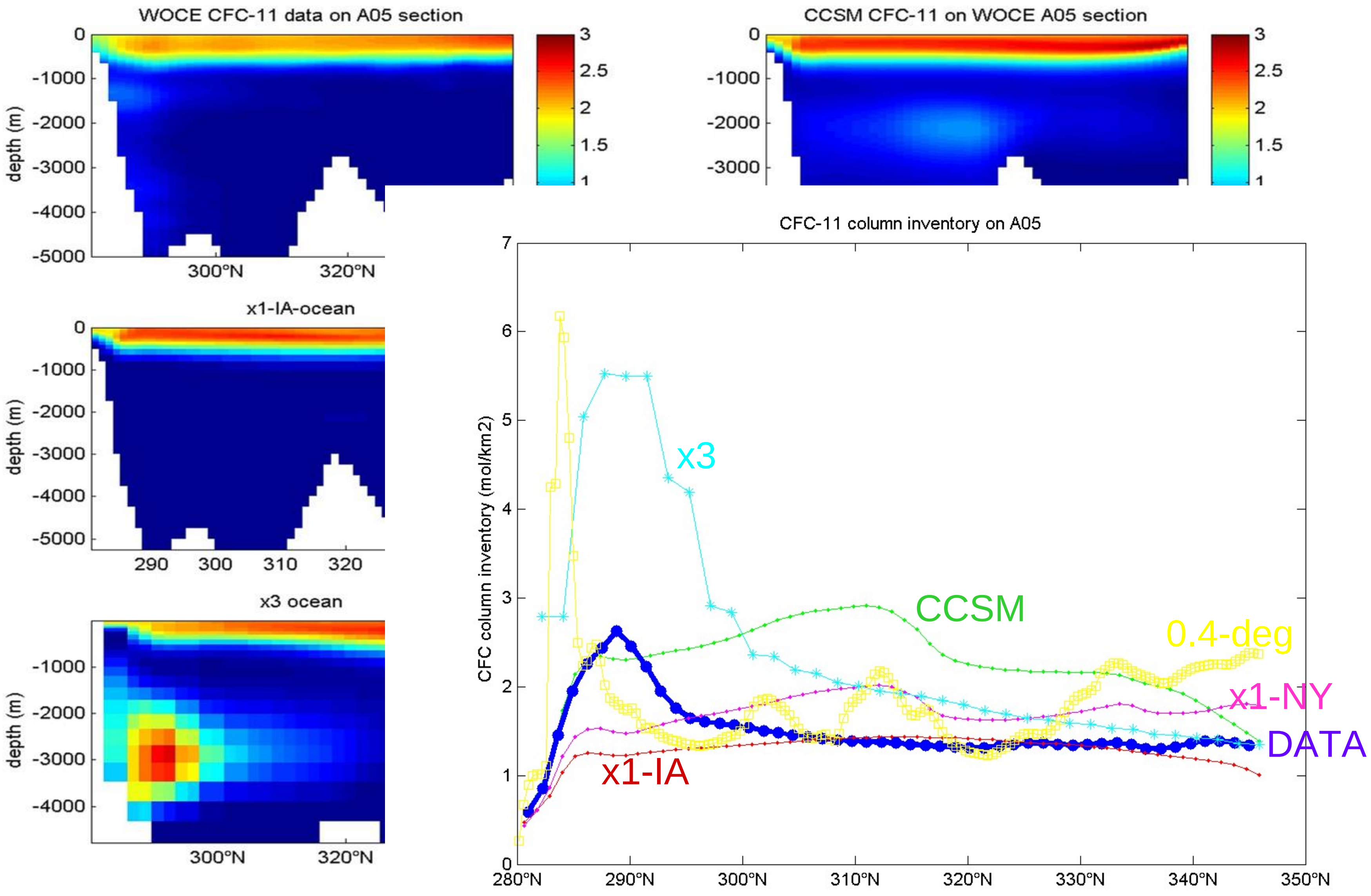
IN GENERAL:

- All models get deep convection wrong in the Southern Ocean: CCSM and x1-NY convect too strongly compared with observations in the Southern Ocean; x3, x1-IA and 0.4-deg models do not convect enough

- All models are too cold relative to observations in the surface Southern Ocean, and so model surface-ocean CFC concentrations are too high (strong temp-dependent solubility)

- In terms of column inventories, the x3 is probably the model that compares best with observations (!) – beware of the danger of just comparing global/column inventories

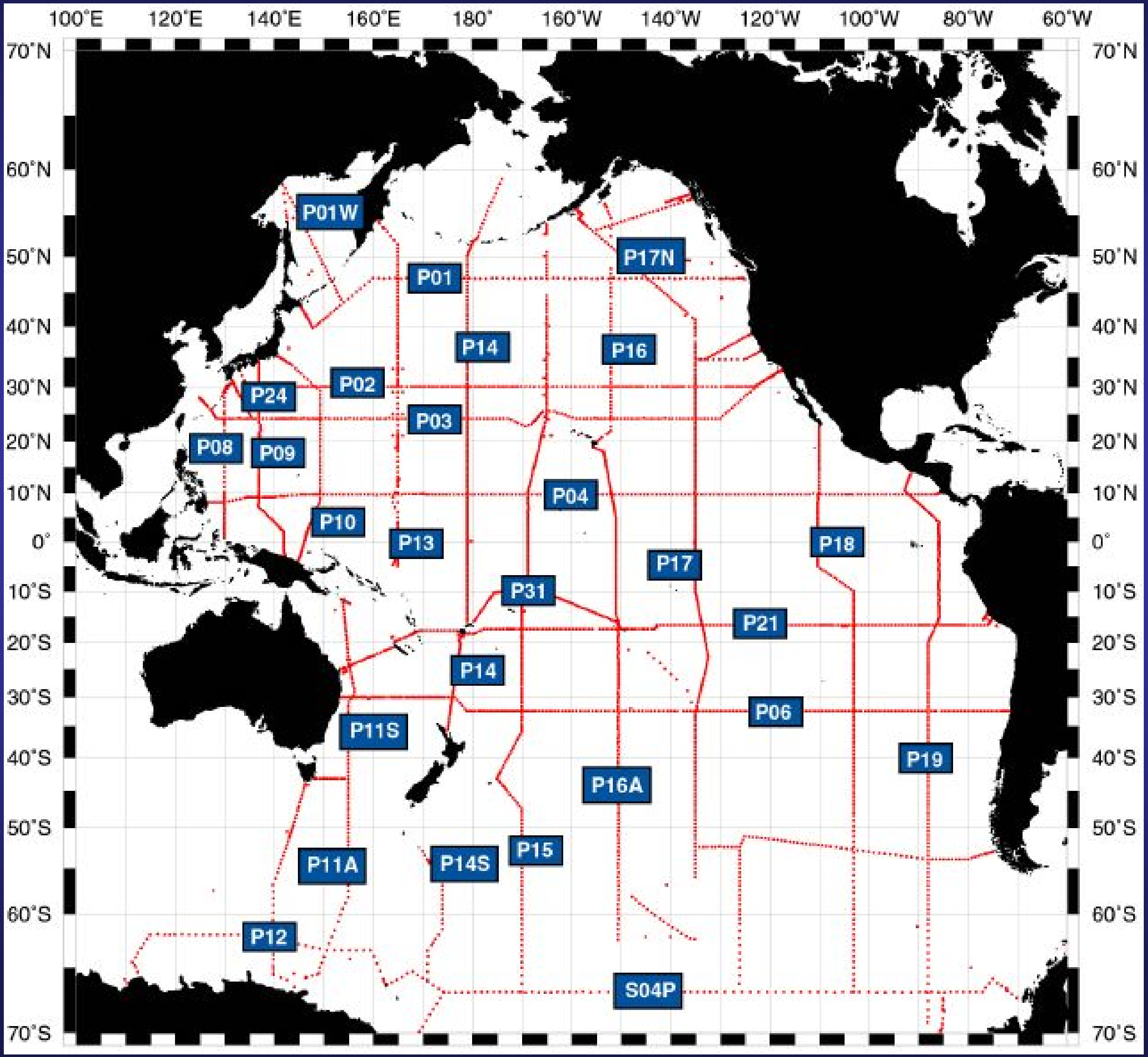
North Atlantic: a very different picture: WOCE A05 section (Atlantic, 24N)

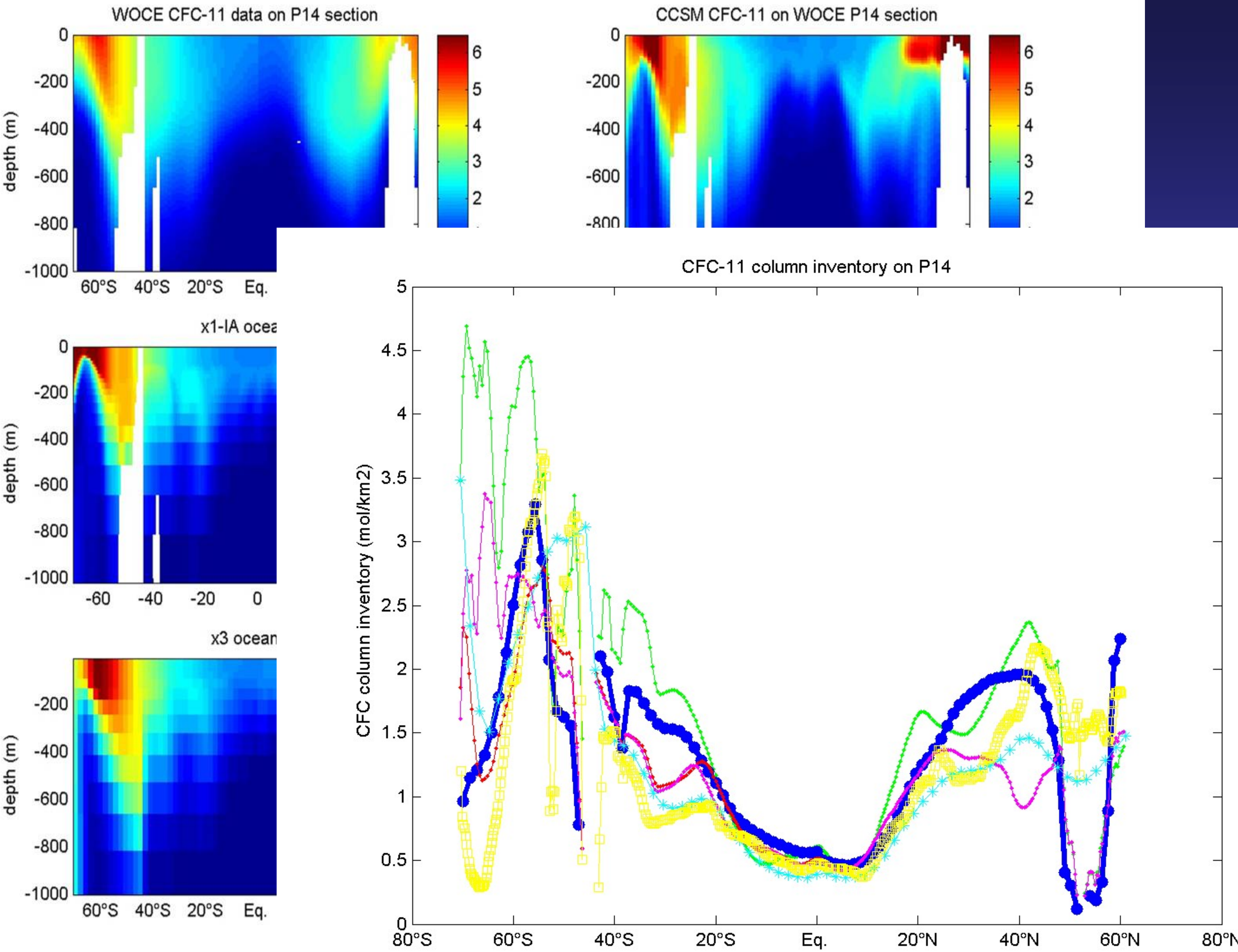


- x3 and 0.4-deg models are transporting too much CFC into DWBC (even though MOC looks fine) – this is due to too high CFC concentrations in deep convective regions in high-latitude North Atlantic

- CCSM and x1-NY have correct CFC concentration in NADW, but 1) maxima is not on western boundary, and 2) there is one core centered at around 2000m (as opposed to two distinct cores in the observations)

Upper Ocean thermocline ventilation – Pacific P14 line





WOCE CFC-11 data on P14 section
CCSM CFC-11 on WOCE P14 section
x1-IA ocea
x3 ocean
depth (m)
0
-200
-400
-600
-800
-1000
60°S
40°S
20°S
Eq.
-60
-40
-20
0
2
3
4
5
6
CFC-11 column inventory on P14
CFC column inventory (mol/km2)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
80°S
60°S
40°S
20°S
Eq.
20°N
40°N
60°N
80°N

Conclusions

- Thermocline CFC ventilation looks pretty good in all models compared with observations (as with high latitudes, slightly too much CFC in upper ocean due to temperature bias – models slightly colder than obs)

- Deep convection not great in any of the models – either to much, too little, or the wrong CFC properties being transmitted to depth

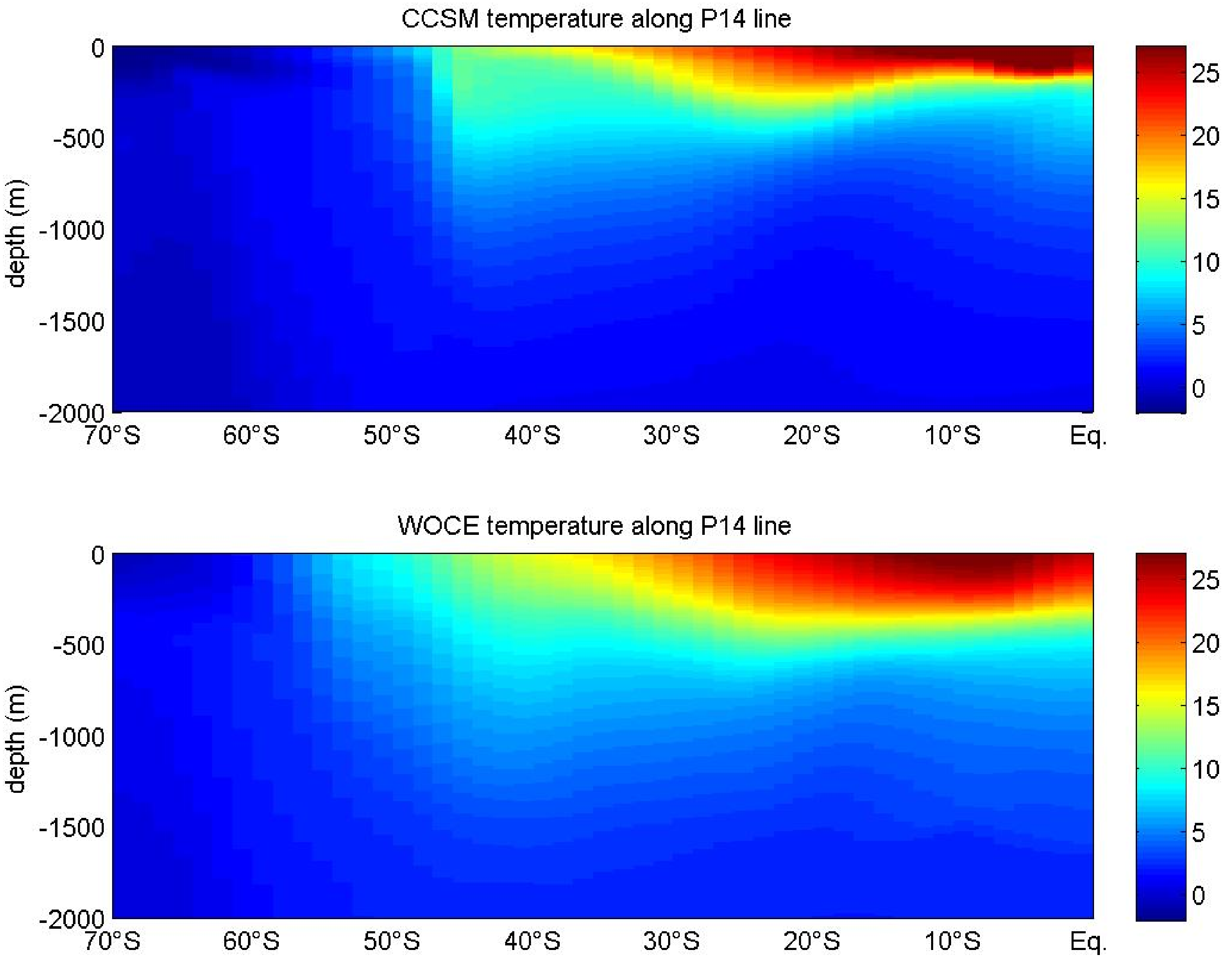
- Global/Column inventories can be misleading due to compensating biases (e.g. too much CFC in model upper ocean; too little in deep ocean)

- Higher resolution ocean is not necessarily better!

(e.g. 0.4-deg ocean generally performs worse than x3 in CFC comparisons; both models have identical forcing)

- Both forcing (same grid, different forcing) and grid (same forcing, different grid) make a huge difference to the results

- CCSM ventilates a little too much in the Southern Ocean; in the North Atlantic, the CFC maxima does not hug the western boundary; no ULSW in CCSM; thermocline ventilation in general good compared with observations.



CCSM temperature along P14 line
depth (m)
0
-500
-1000
-1500
-2000
70°S
60°S
50°S
40°S
30°S
20°S
10°S
Eq.
25
20
15
10
5
0
WOCE temperature along P14 line
depth (m)
0
-500
-1000
-1500
-2000
70°S
60°S
50°S
40°S
30°S
20°S
10°S
Eq.
25
20
15
10
5
0

Global 0.4°
900x600x40 grid points

Global 3°
100x116x25 grid points

similarities

World Ocean Atlas (+Polar Hydrography) PT, S initial conditions
World Ocean Atlas, GLODAP, constant value initial conditions
Daily NCAR/NCEP, monthly ISCCP, Xie-Arkin/MSU precip, runoff
278 ppm atmospheric CO_2
Mahowald dust deposition; Bottom iron flux (depth<1000m)
30 day restoring of SST, SSS under "ice"; 1 year for open ocean SSS
3rd order upwind advection (not positive definite)
KPP mixed layer; Variable thickness surface layer; UNESCO EOS

differences

Global 0.4°	Global 3°
North grid pole displaced into Hudson Bay	North grid pole displaced into Greenlan
Smith-Sandwell, IBCAO,BEDMAP bathymetry	ETOPO5 bathymetry
Biharmonic horizontal tracer diffusion	GM eddy diffusion and transport
Biharmonic horizontal momentum diffusion	Anisotropic laplacian viscosity
30 minute timestep	1 hour timestep