# Effects of subgridscale parameterizations on ocean CFC distributions in CCSM

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(i) Background vertical diffusivity
with Markus Jochum, Keith Lindsay
******Preliminary Results******

(i) $N^2$, NSEF, and Submesoscale Parameterizations
with Gokhan Danabasoglu, Baylor Fox-Kemper

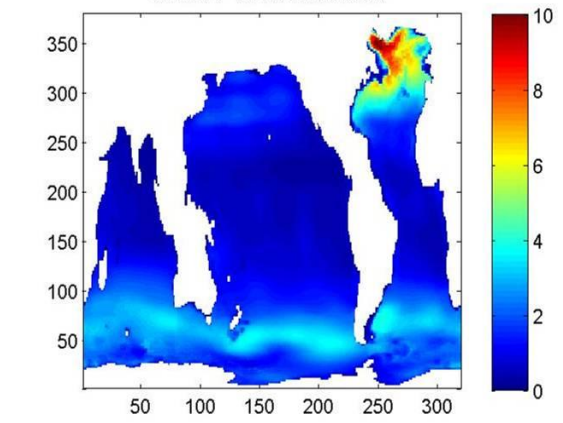
# Comparison of simulated CFC distributions with observations (GLODAP 1994)

All CCSM runs (coupled and forced, 3.0 physics, 3.5 physics, …) show very large biases in the high latitude oceans (model biases in representing deep and/or intermediate water formation).

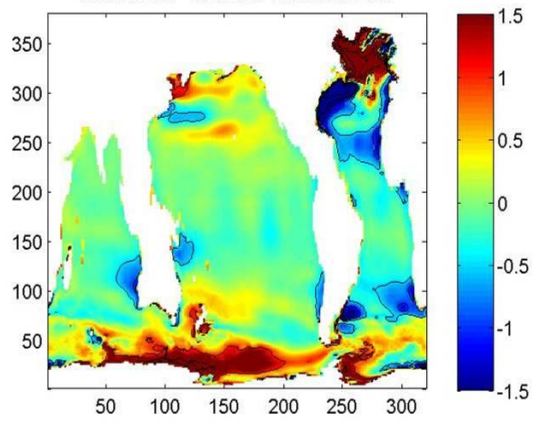
Note: in some coupled runs, this depletion of anthropogenic tracers in AAIW does not show up so clearly; but this is because the Southern Ocean winds are much stronger than observations suggest – i.e. the coupled runs are getting AAIW right for the wrong reasons

All runs look fairly good compared with observations in much of the low and mid-latitude ocean

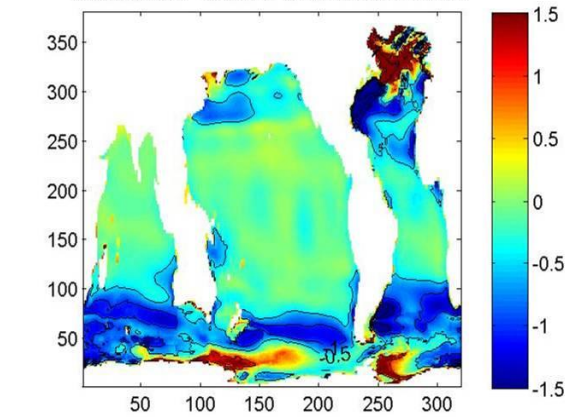
CFC11 column inv: obs



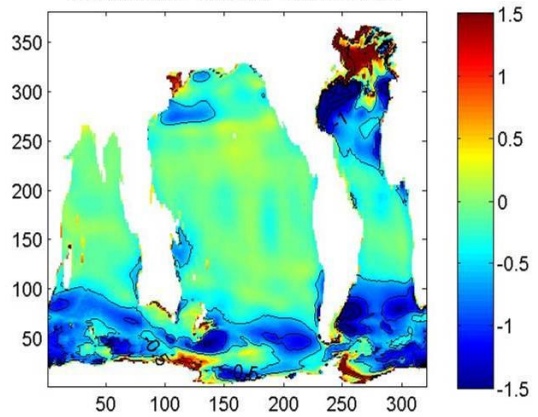

CCSM3.0 coupled run




CCSM3.0 forced ocn




CCSM3.5 forced ocn



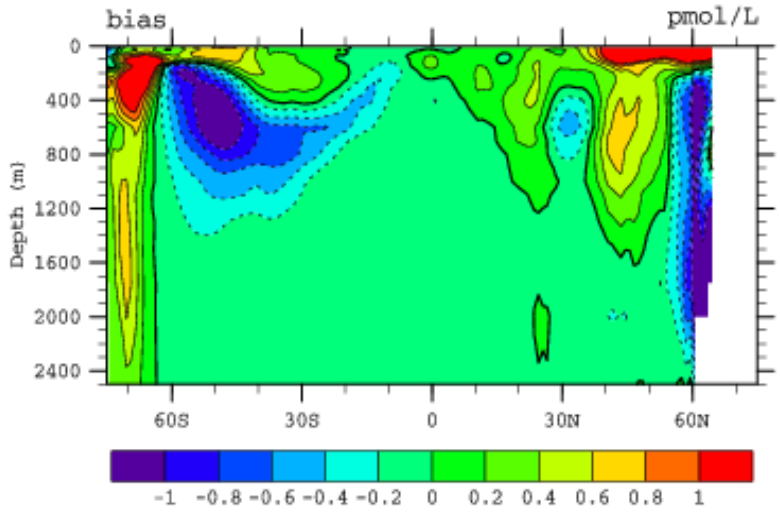
# Zonally averaged CFC11 and anthropogenic $CO_2$: model vs observations

- AAIW in forced ocean runs (and some coupled runs – those with more realistic winds!) appears to be too weak, leading to large depletion in AAIW CFC and anthropgenic $CO_2$

  [note – this does not show up so clearly in T,S]

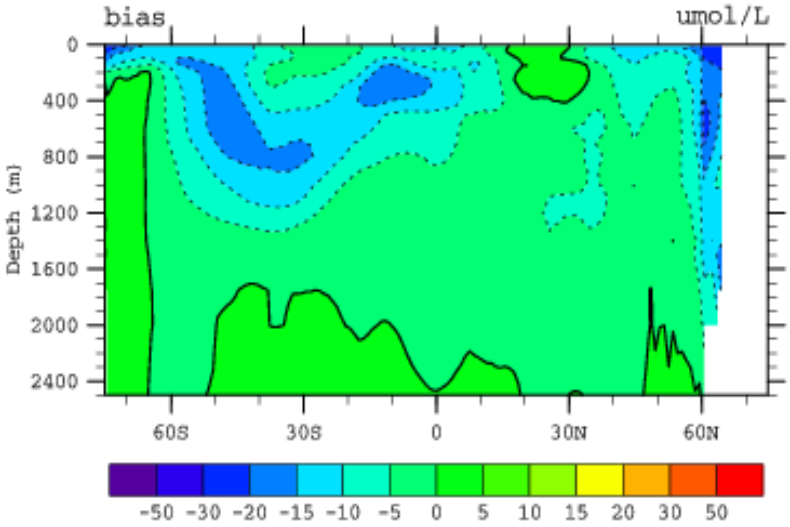
CFC11,

Model-obs




Anthrop $CO_2$,

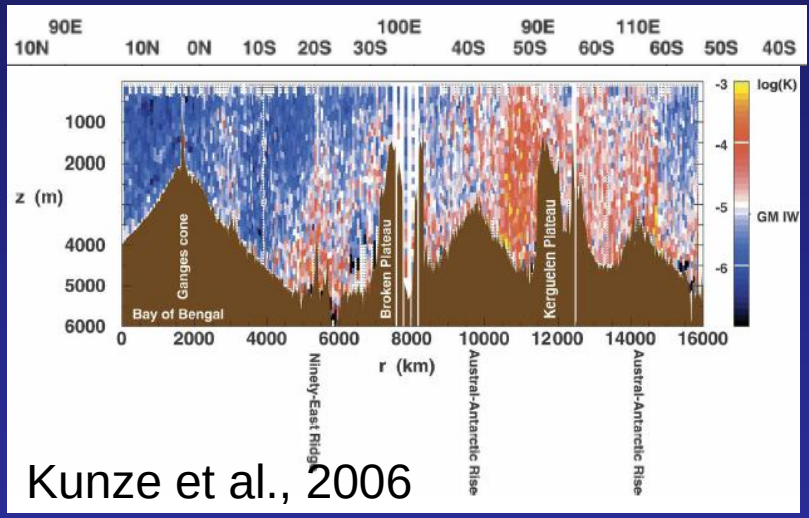
Model-obs



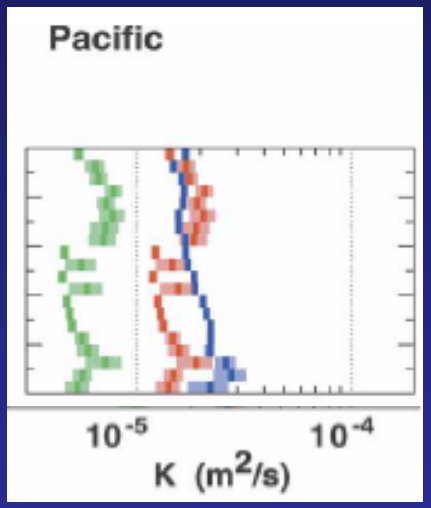
# Part I : Experiments changing background vertical diffusivity

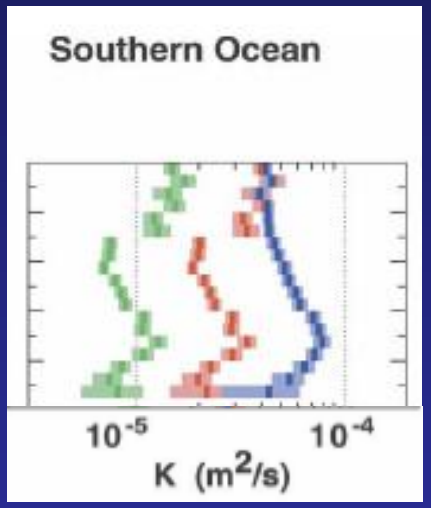
- There is some observational evidence suggesting that the vertical diffusivity is enhanced in the Southern Ocean.

Kunze et al., 2006: Inferred eddy diffusivity κ

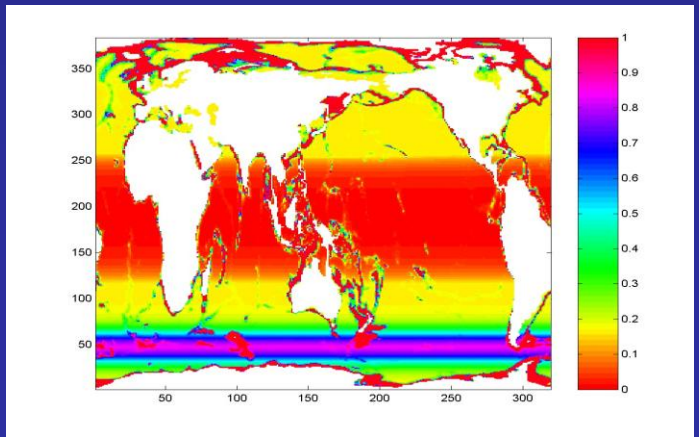


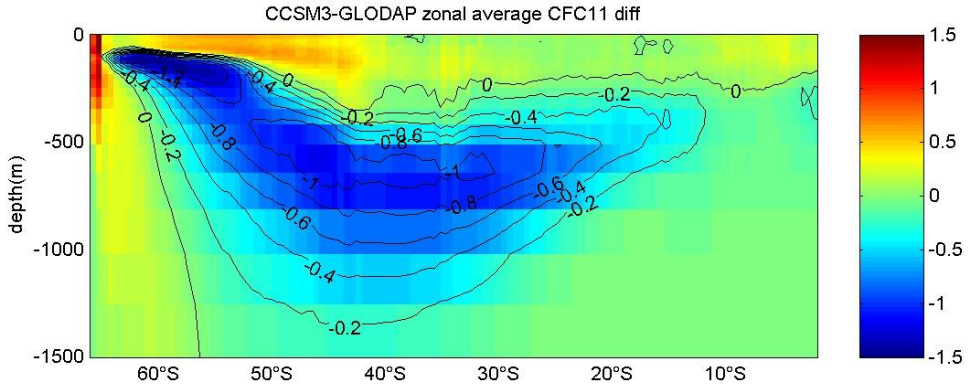

Kunze et al., 2006

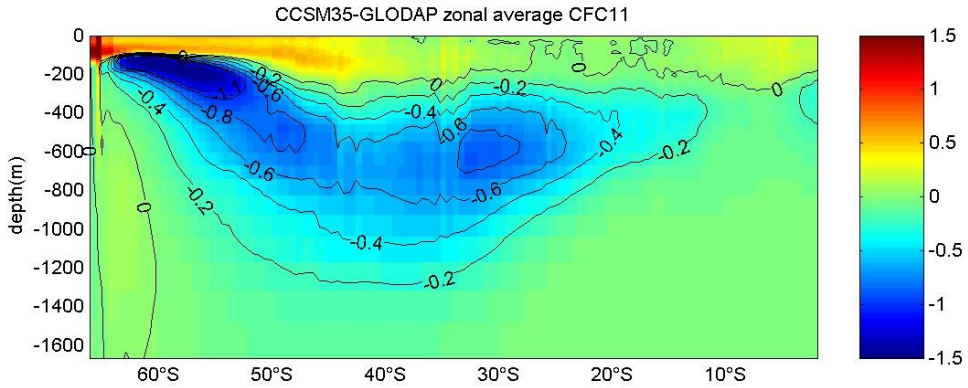


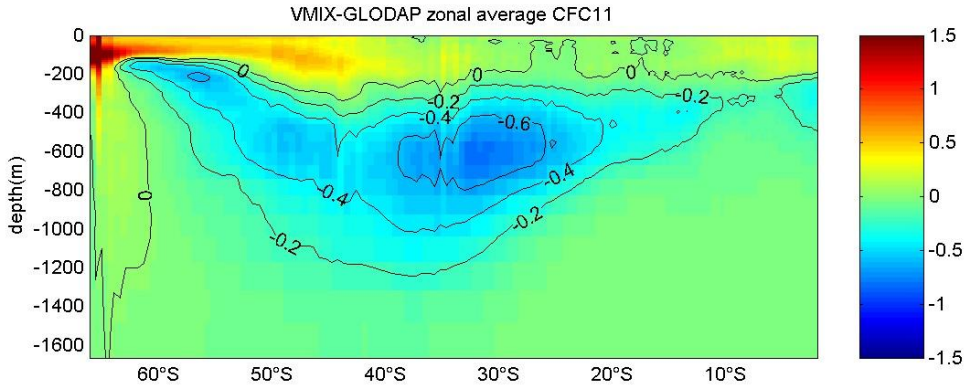




-> Sensitivity experiment using NY-forced CCSM3.5 ocean, varying the background vertical diffusivity in a band centered at 55°S.



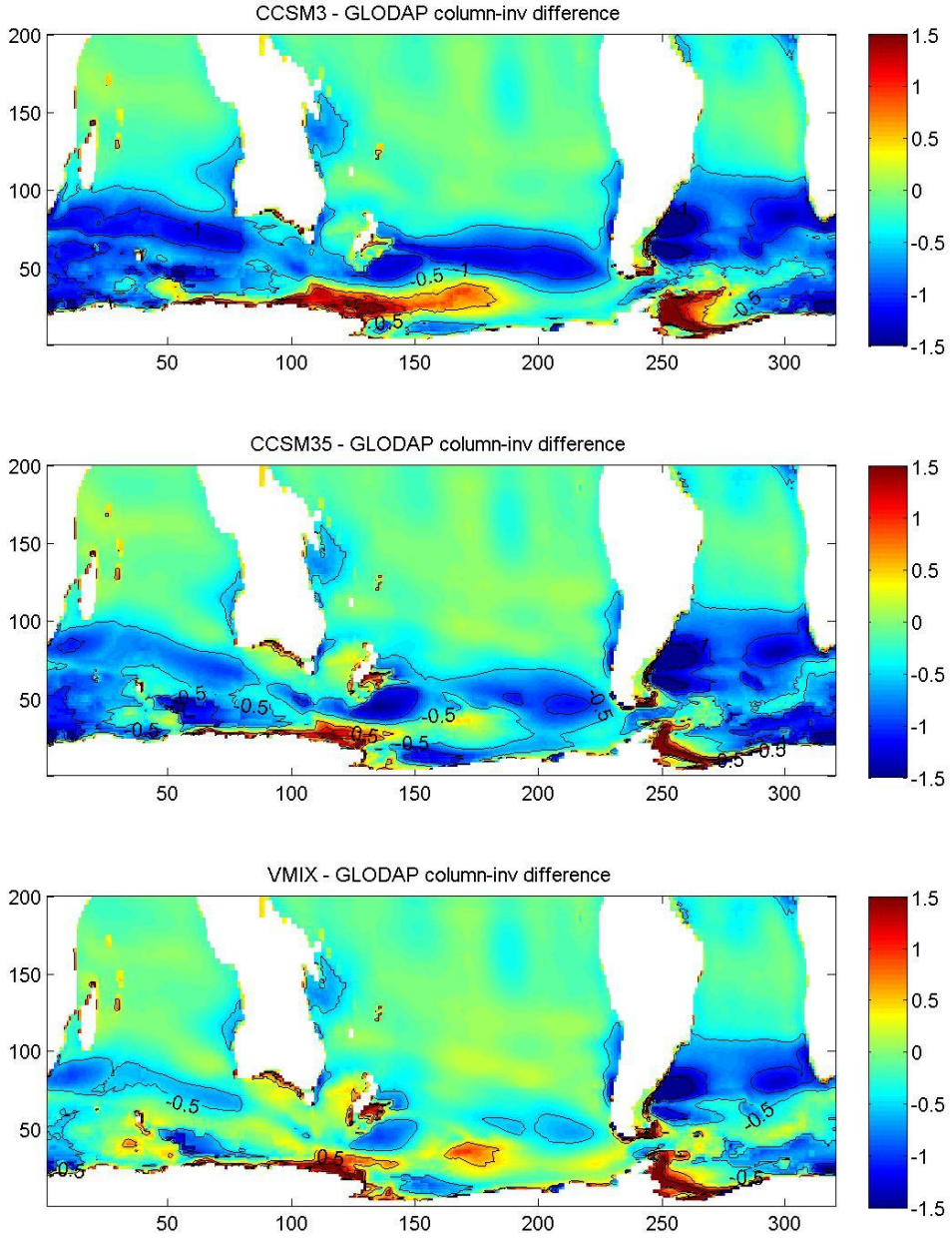



Pacific-Indian Zonal Mean CFC11, model minus observations.

Strong negative bias in AAIW in both CCSM3.5 and CCSM3.0. Bias reduced by about 50% in experiment with enhanced background diffusivity in Southern Ocean.




Model minus observations; model is annually average 1994 field, obs are GLODAP.

NOTE: The GLODAP dataset was obtained by taking all the CFC ocean data (spans mid-1980s to late 1990s), and objectively mapping to create a single dataset, which is taken to represent 1994 conditions (the mean year of the observations).

- Is there enough observational evidence to justify increasing the background vertical diffusivity in the Southern Ocean?

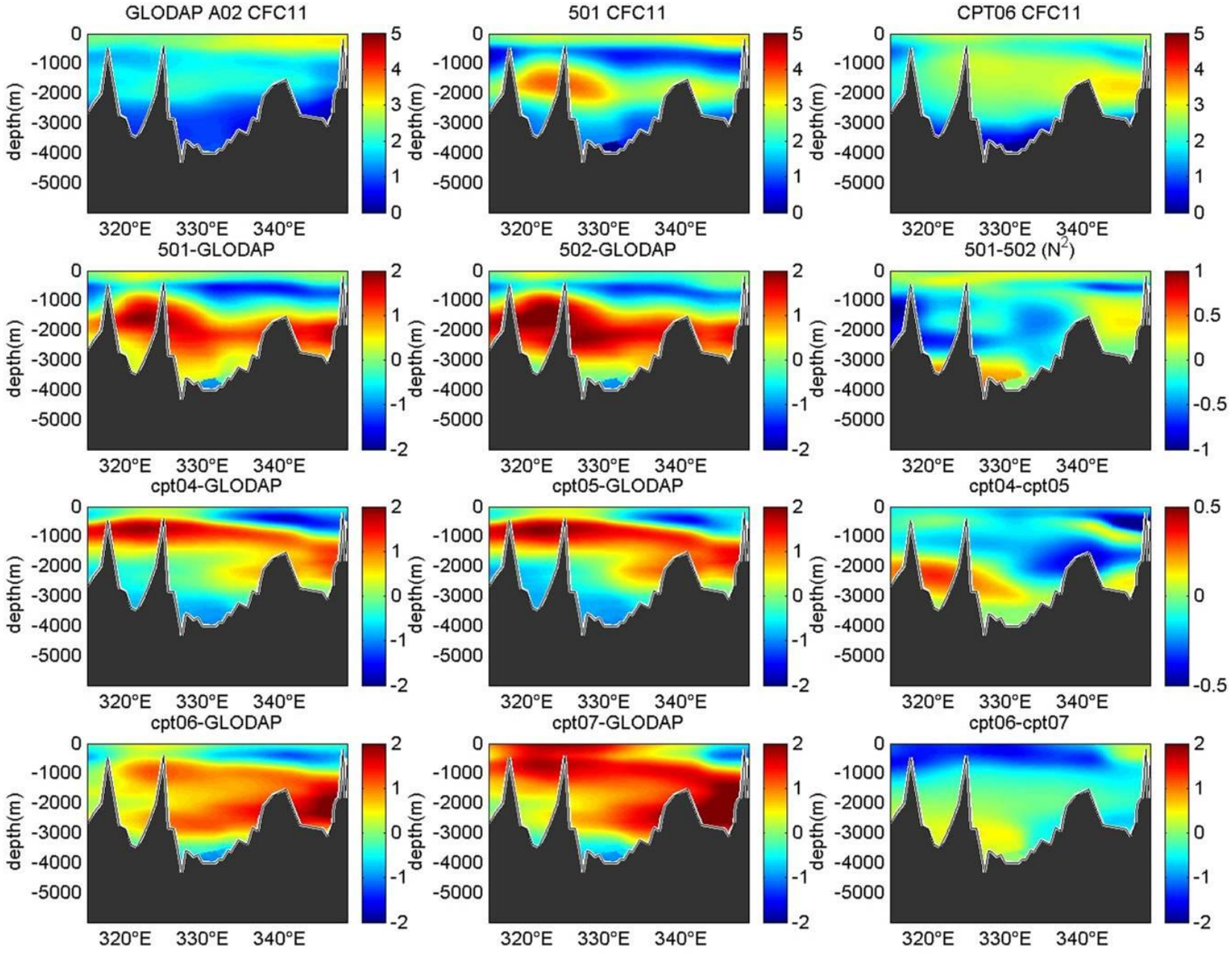
- If yes, then how should this be physically parameterized in the model? (some function of ACC strength and bottom topography? Tuned to match CFC distribution?)

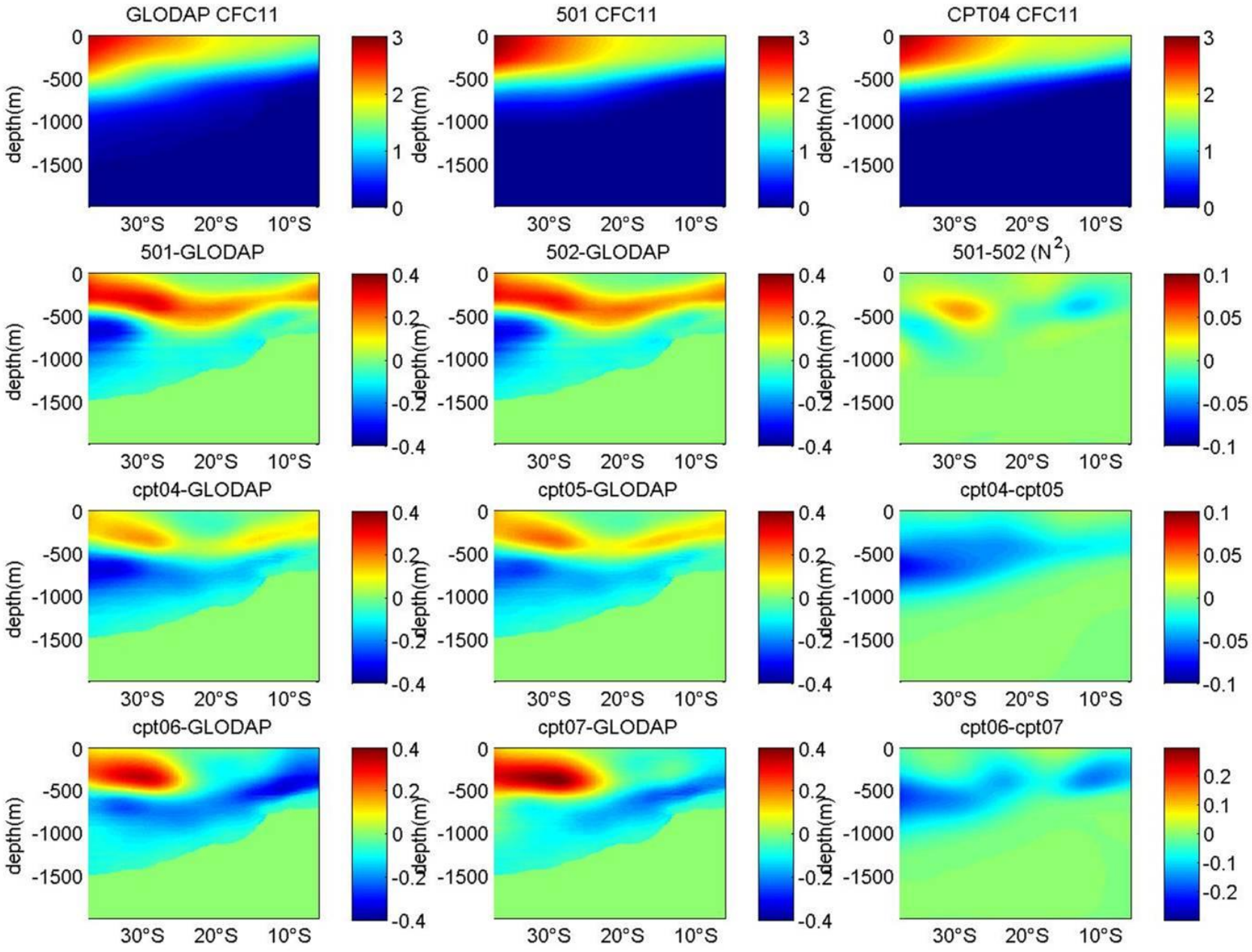
- Note – these results are very preliminary – from a single sensitivity study. Much room for further work, not only in the model, but also in the model-data comparison.

# Part II: What impact do the $N^2$, NSEF and submesoscale parameterizations have on oceanic CFC distributions?

- In regions where all models show a very poor agreement with observations (e.g. the North Atlantic), including these subgridscale parameterizations appears to have a positive impact on simulated CFC distributions. However, the biases remain large in such regions

- In regions where the model-observation differences are small, these parameterizations have a minimal effect.


GLODAP A02 CFC11
501 CFC11
CPT06 CFC11
501-GLODAP
502-GLODAP
501-502 (N2)
cpt04-GLODAP
cpt05-GLODAP
cpt04-cpt05
cpt06-GLODAP
cpt07-GLODAP
cpt06-cpt07
depth(m)
0
-1000
-2000
-3000
-4000
-5000
320°E
330°E
340°E
5
4
3
2
1
0
2
1
0
-1
-2
1
0.5
0
-0.5
-1


GLODAP CFC11
501 CFC11
CPT04 CFC11
501-GLODAP
502-GLODAP
501-502 (N2)
cpt04-GLODAP
cpt05-GLODAP
cpt04-cpt05
cpt06-GLODAP
cpt07-GLODAP
cpt06-cpt07
depth(m)
0
-500
-1000
-1500
30°S
20°S
10°S
3
2
1
0
0.4
0.2
-0.2
-0.4
0.1
0.05
-0.05
-0.1

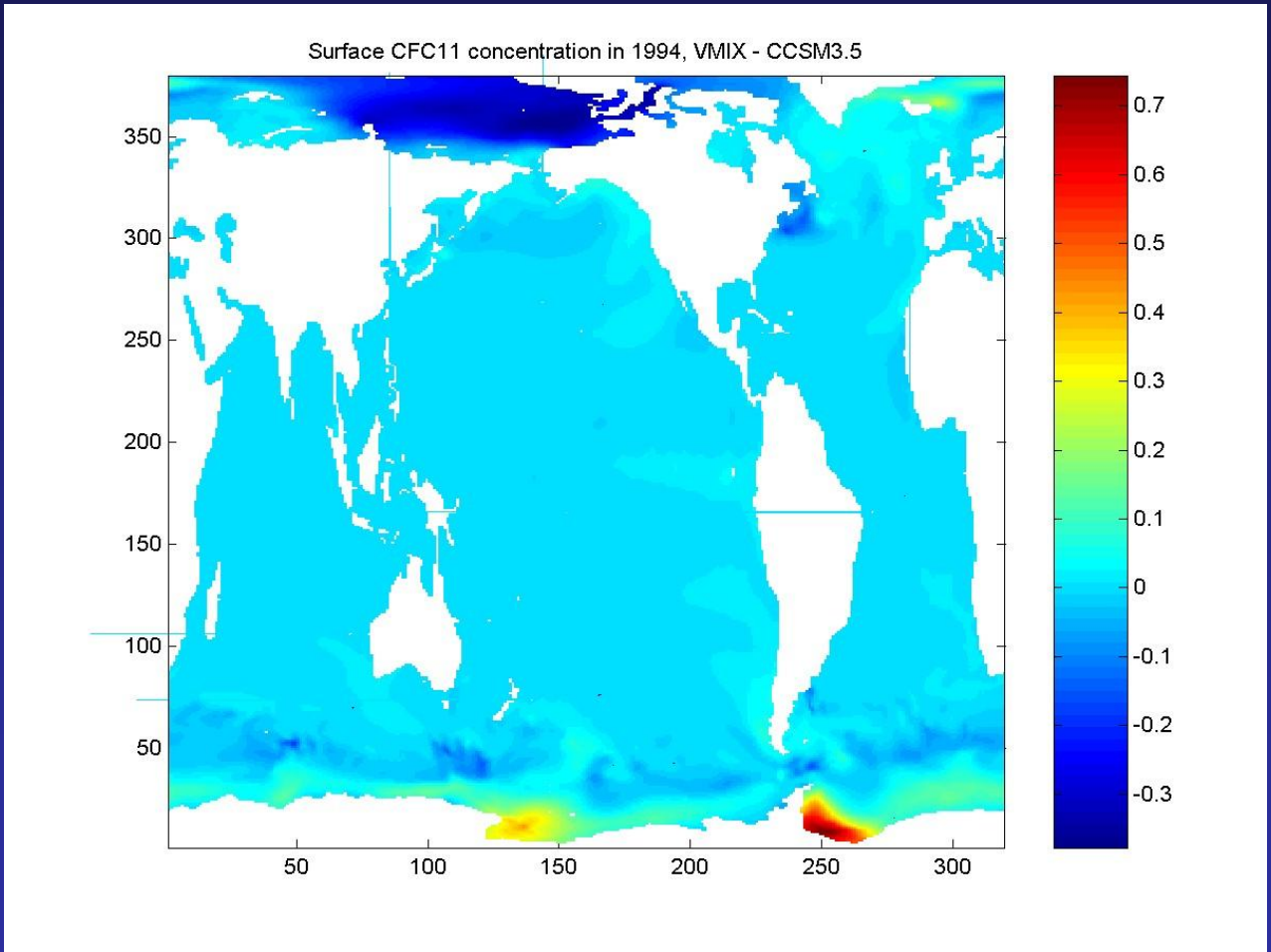
# Conclusions

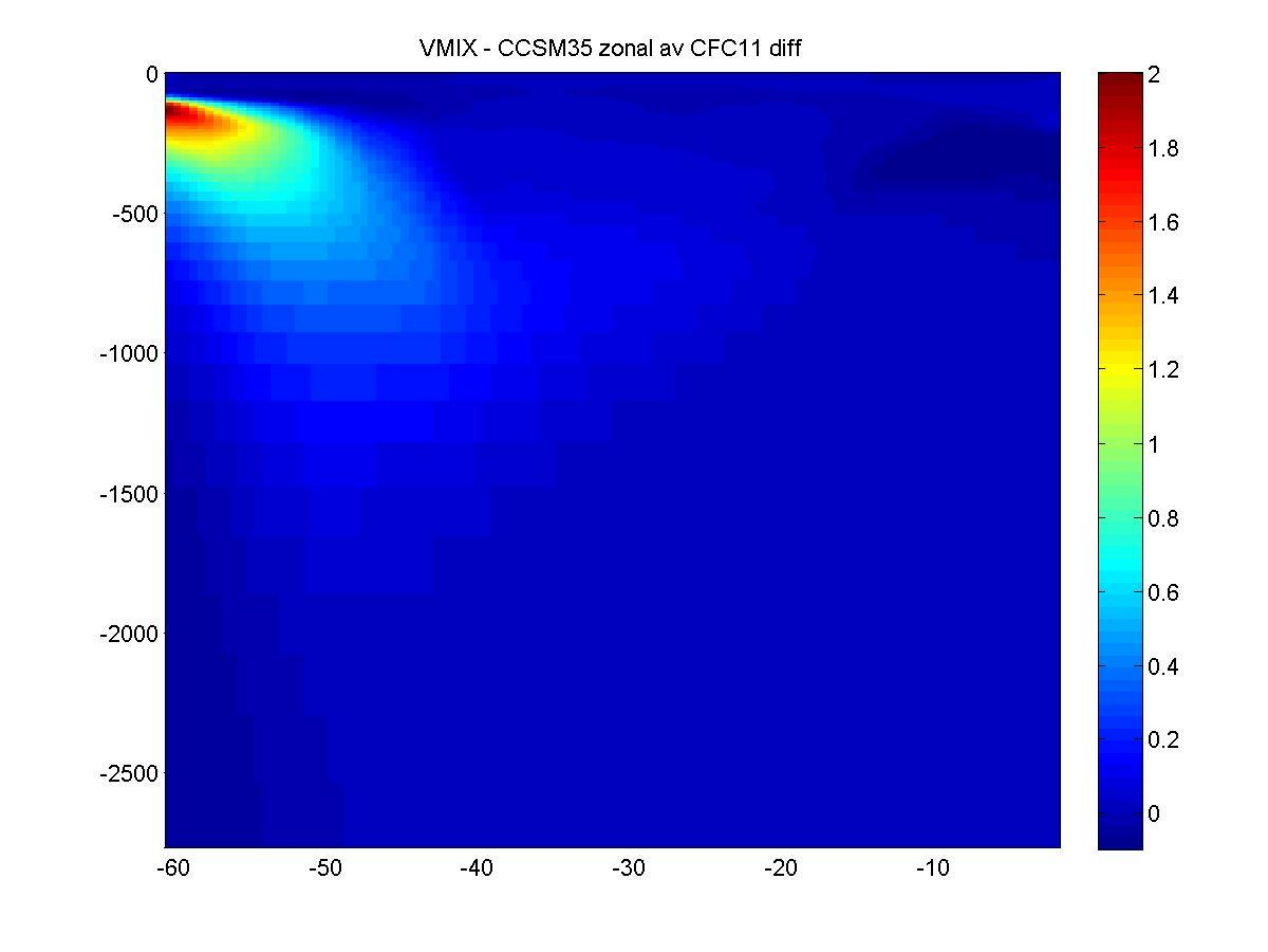
- Sensitivity experiment changing the background vertical diffusivity in a band centered on 55 S appears to help alleviate the large negative CFC bias seen in all forced CCSM3.0 and CCSM3.5 model runs.

- Next step – can enhanced vertical mixing in the Southern Ocean be justified? Does it depend on wind-stress? Bottom-topography and flow interaction?

- The CFC signature of recent eddy-mixing parameterizations (such as $N^2$, NSEF, submesoscale) is small throughout much of the ocean, and therefore use as a validation tool presents a challenge.

- Including such parameterizations appears to make a much larger difference in regions where there is a strong model CFC bias (such as the North Atlantic); however, in order to ‘fix’ these biases larger changes are needed (such as the overflow parameterization).


Surface CFC11 concentration in 1994, VMIX - CCSM3.5
350
300
250
200
150
100
50
50
100
150
200
250
300
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3


VMIX - CCSM35 zonal av CFC11 diff
0
-500
-1000
-1500
-2000
-2500
-60
-50
-40
-30
-20
-10
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0