Near-Surface Parameterizations

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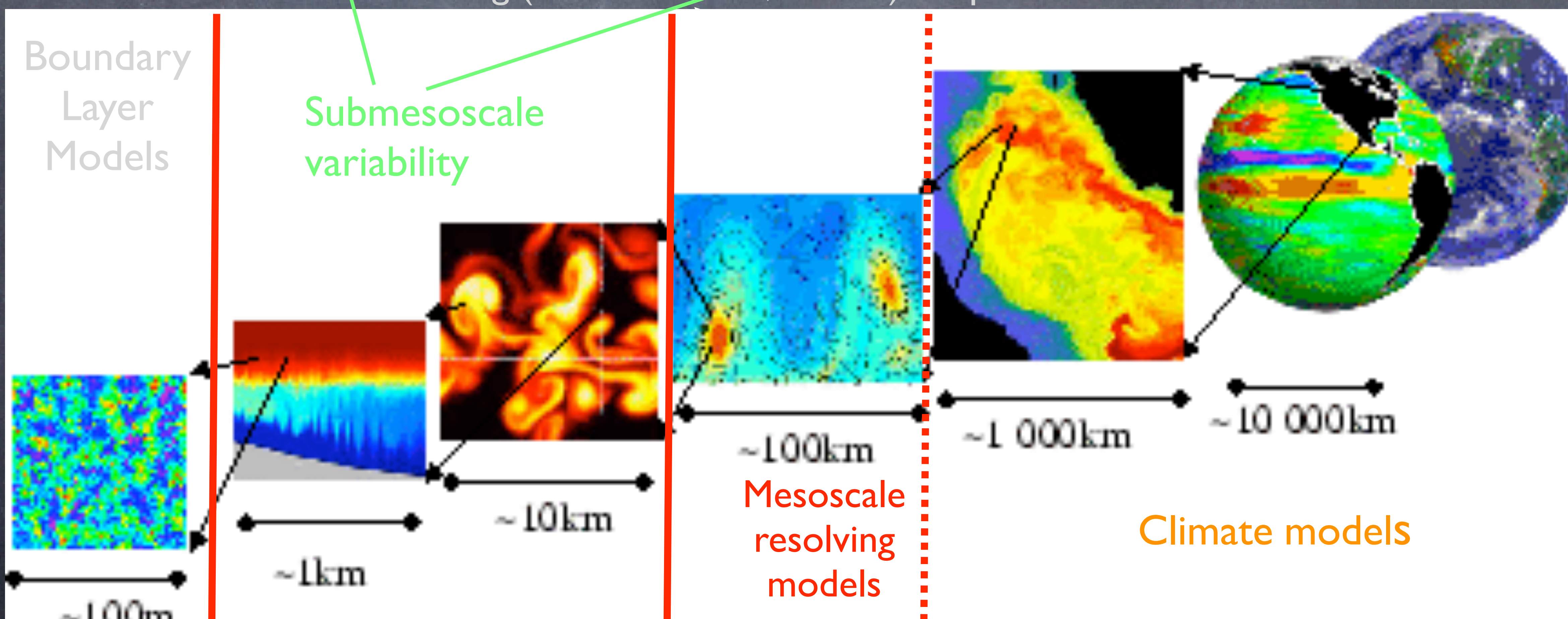
Collaborations with: R. Ferrari, G. Boccaletti, G. Danabasoglu, S. Peacock, W. Large, GFDL...

Upper Ocean in Climate Models

- Large-scale ocean circulation (100 - 10,000 km, yrs->centuries) => resolved
- Mesoscale variability (10 - 100 km, mo -> yrs) => resolved or parameterized
- Submesoscale variability (100 m - 10 km, d -> mo) => ignored until recently
- Internal waves & Langmuir circulations (10-100m, hr -> day) => crudely param.
- Turbulent mixing (10 cm - 100 m, s -> hr) => parameterized



Surface Wave Effects?

Coupling?

The Character of the Submesoscale

(Capet et al., 2008)

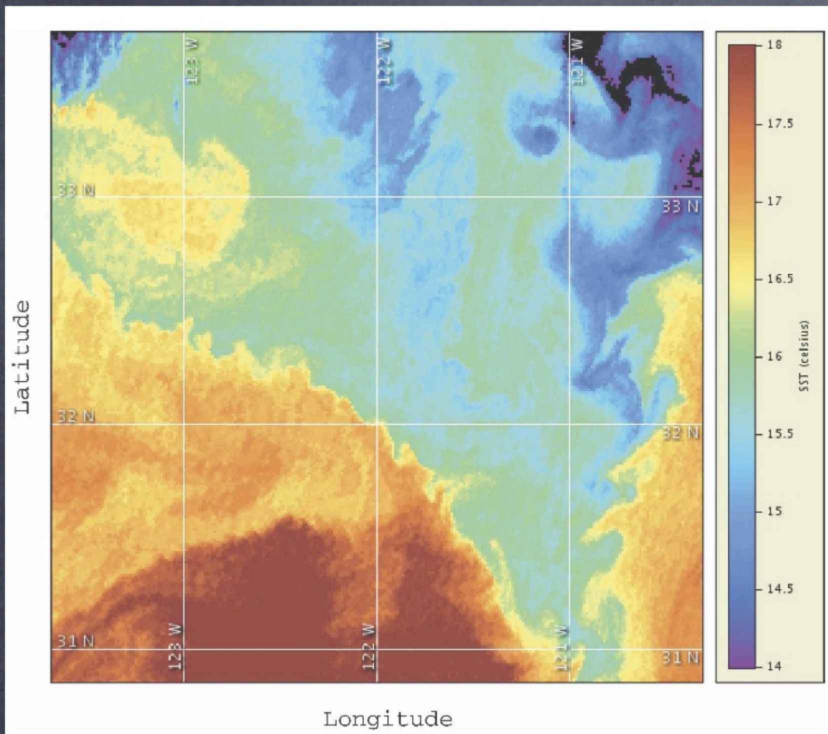
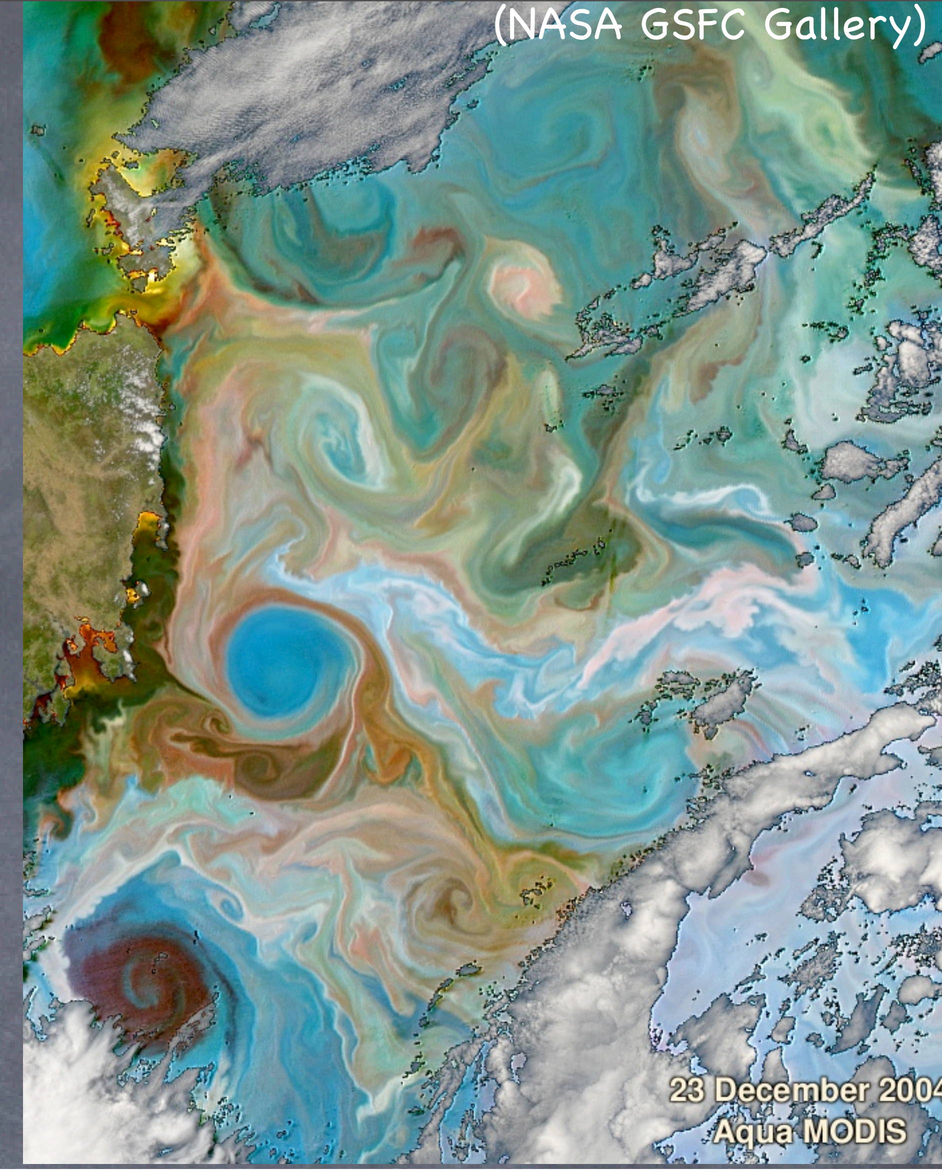


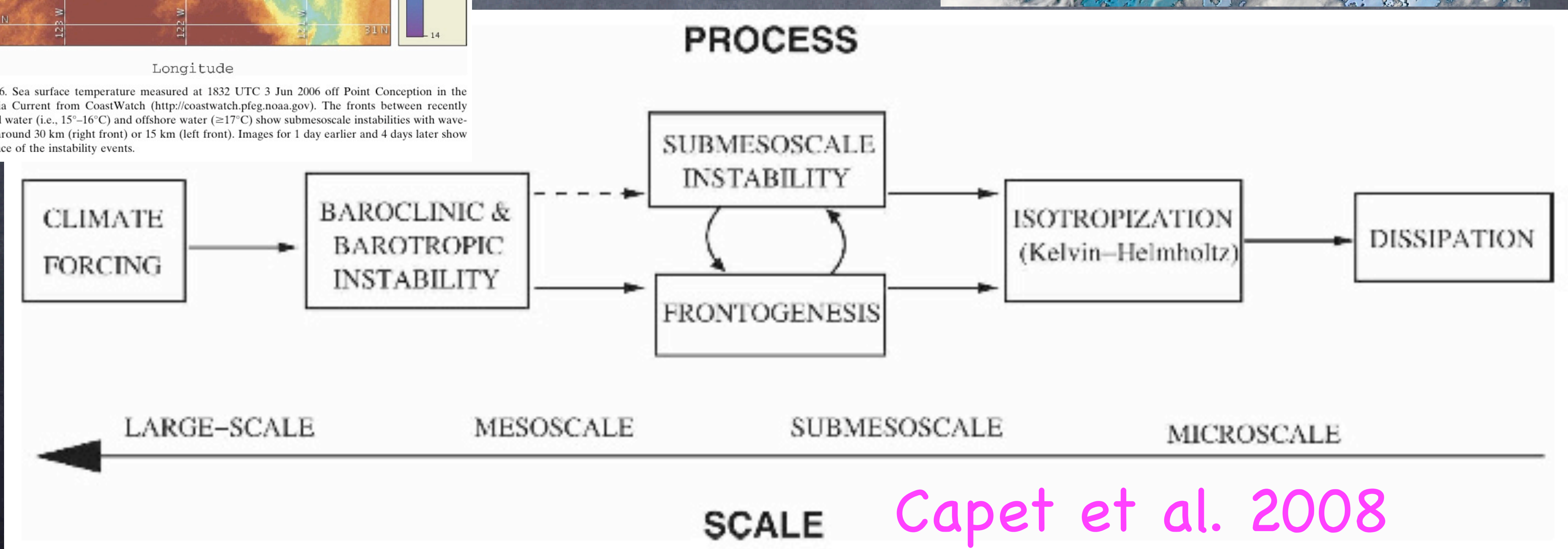
FIG. 16. Sea surface temperature measured at 1832 UTC 3 Jun 2006 off Point Conception in the California Current from CoastWatch (http://coastwatch.pfeg.noaa.gov). The fronts between recently upwelled water (i.e., 15°–16°C) and offshore water (≥17°C) show submesoscale instabilities with wavelengths around 30 km (right front) or 15 km (left front). Images for 1 day earlier and 4 days later show persistence of the instability events.

- Fronts
- Eddies
- Ro=O(1)
- Ri=O(1)

100 km

(NASA GSFC Gallery)





Capet et al. 2008

A Global Parameterization of Mixed Layer Eddy Restratification

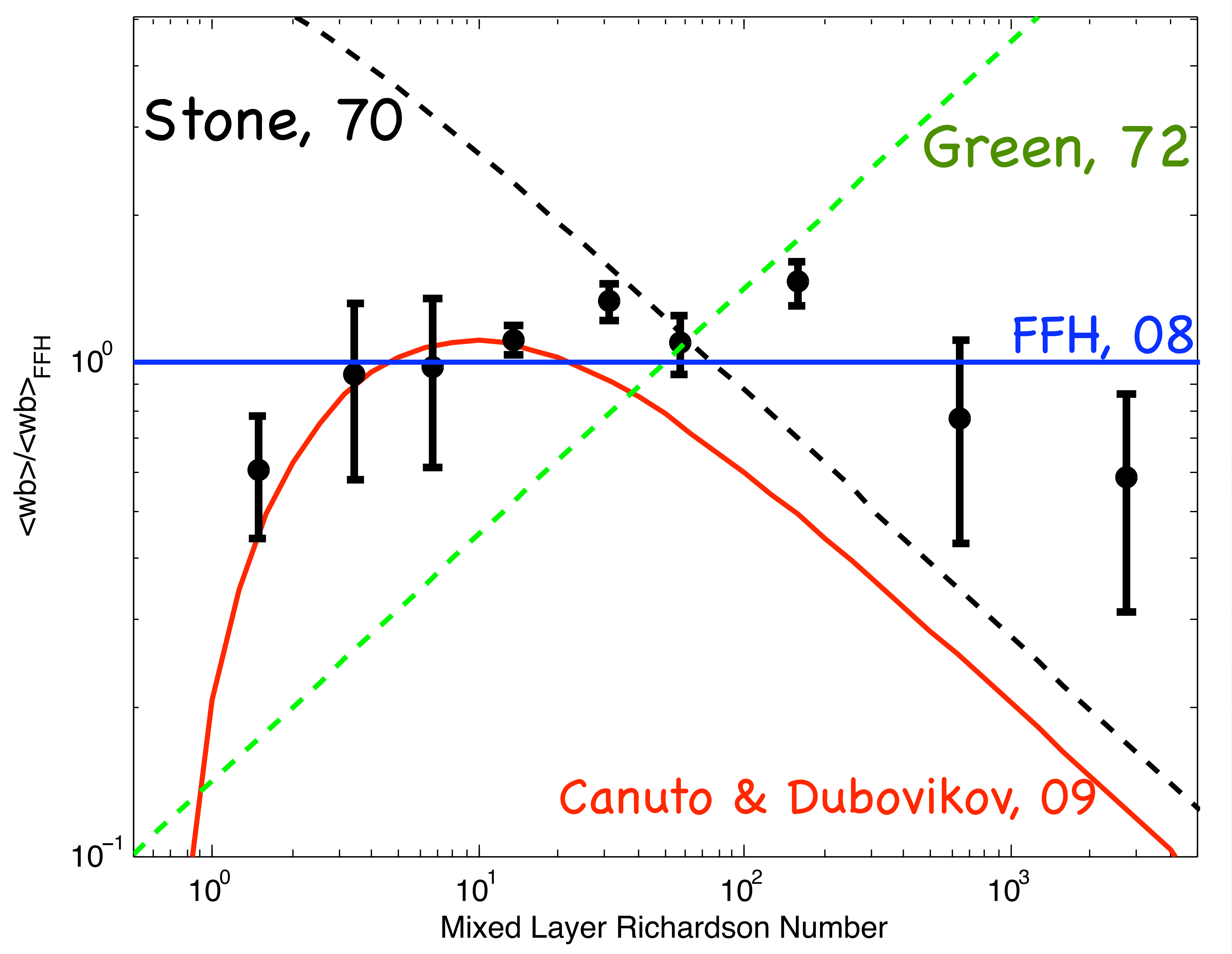
$$\mathbf{\Psi} = \left[\frac{\Delta x}{L_f}\right] \frac{C_e H^2 \mu(z)}{\sqrt{f^2 + \tau^{-2}}} \nabla \bar{b} \times \hat{\mathbf{z}}$$

$$\mu(z) = \left[1 - \left(\frac{2z}{H} + 1\right)^2\right] \left[1 + \frac{5}{21}\left(\frac{2z}{H} + 1\right)^2\right]$$

Which parameterizes eddy-induced velocity and buoyancy fluxes

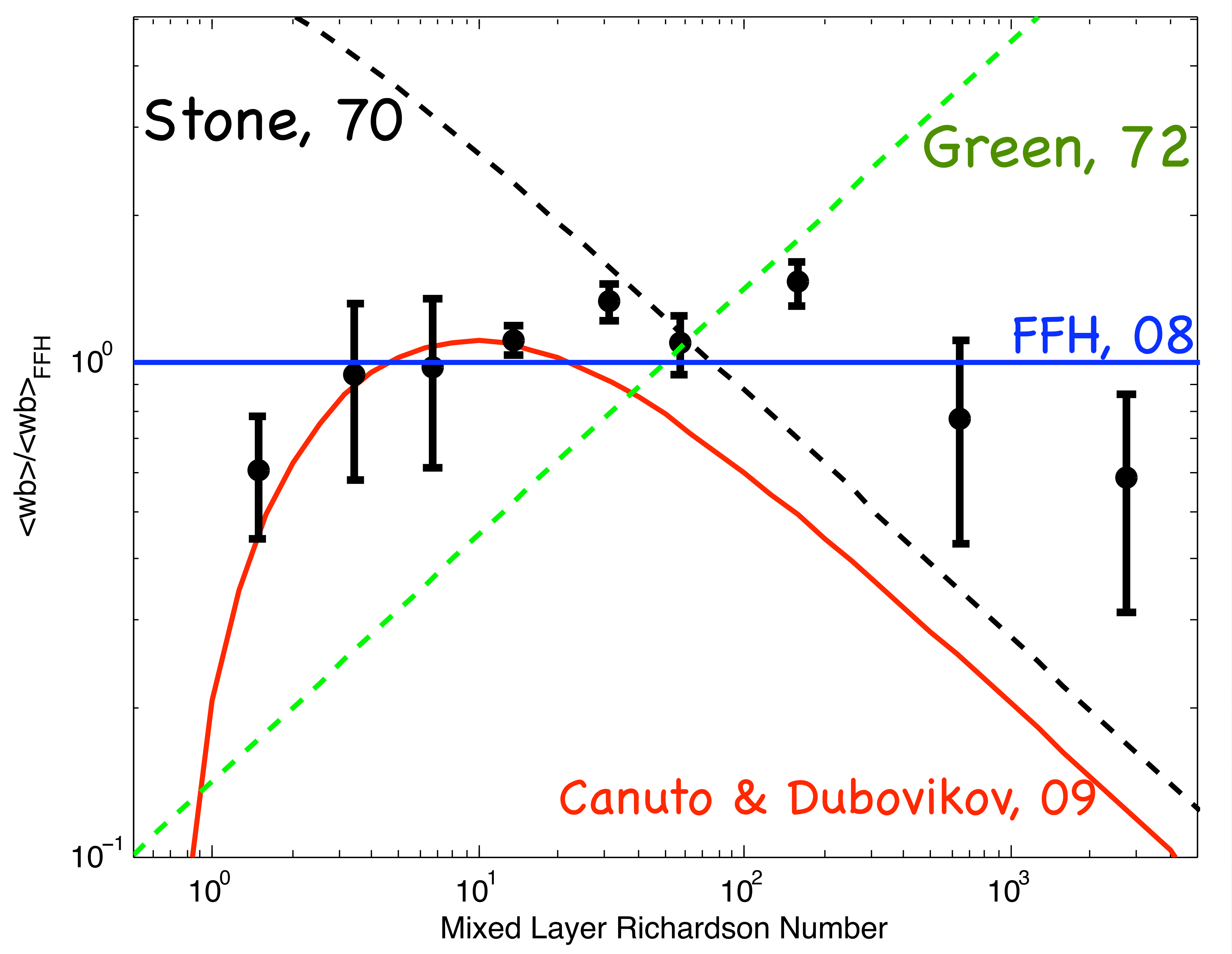
$$\mathbf{v}^{\dagger} = \nabla \times \mathbf{\Psi} \qquad \overline{\mathbf{v}'b'} \approx \mathbf{\Psi} \times \nabla \bar{b}$$

Better than the Competition:



Extends over Ri more mesoscale (9000) than submesoscale (1)

Better than the Competition:



Green equals Visbeck (97) Held & Larichev (95)

Extends over Ri more mesoscale (9000) than submesoscale (1)

And Agrees with Deep Convection Studies: Jones & Marshall (93,97), Haine & Marshall (98)

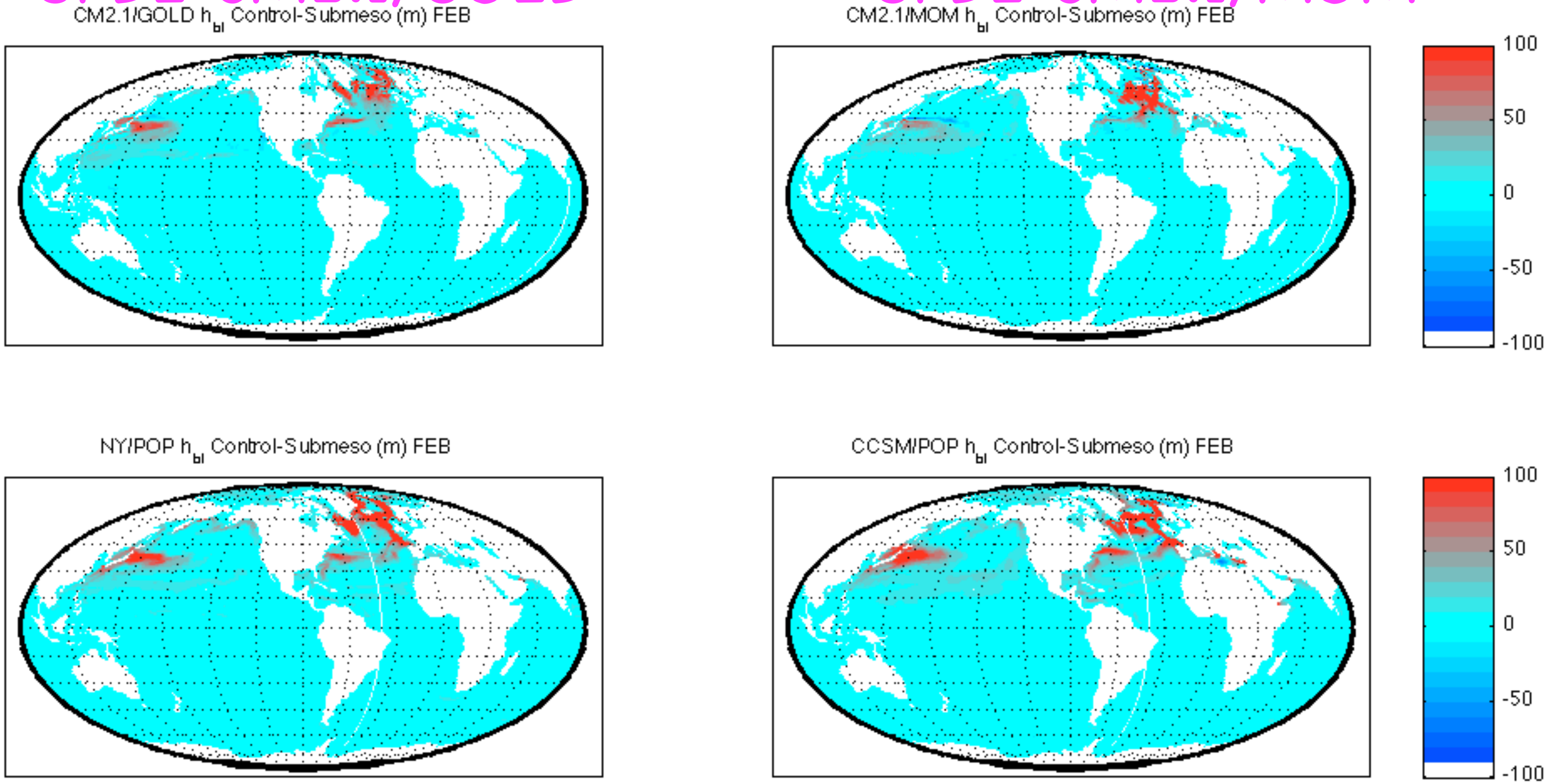
Improves Restratification after Deep Convection

Note: param. reproduces Haine&Marshall (98) and Jones&Marshall (93,97)

& generally shallower boundary layers

GFDL CM2.1/GOLD

GFDL CM2.1/MOM



NCAR Normal Year/POP

NCAR CCSM/POP

MLE-Control:Climatologies at end of > 100yr simulation

Improves Restratification after Deep Convection

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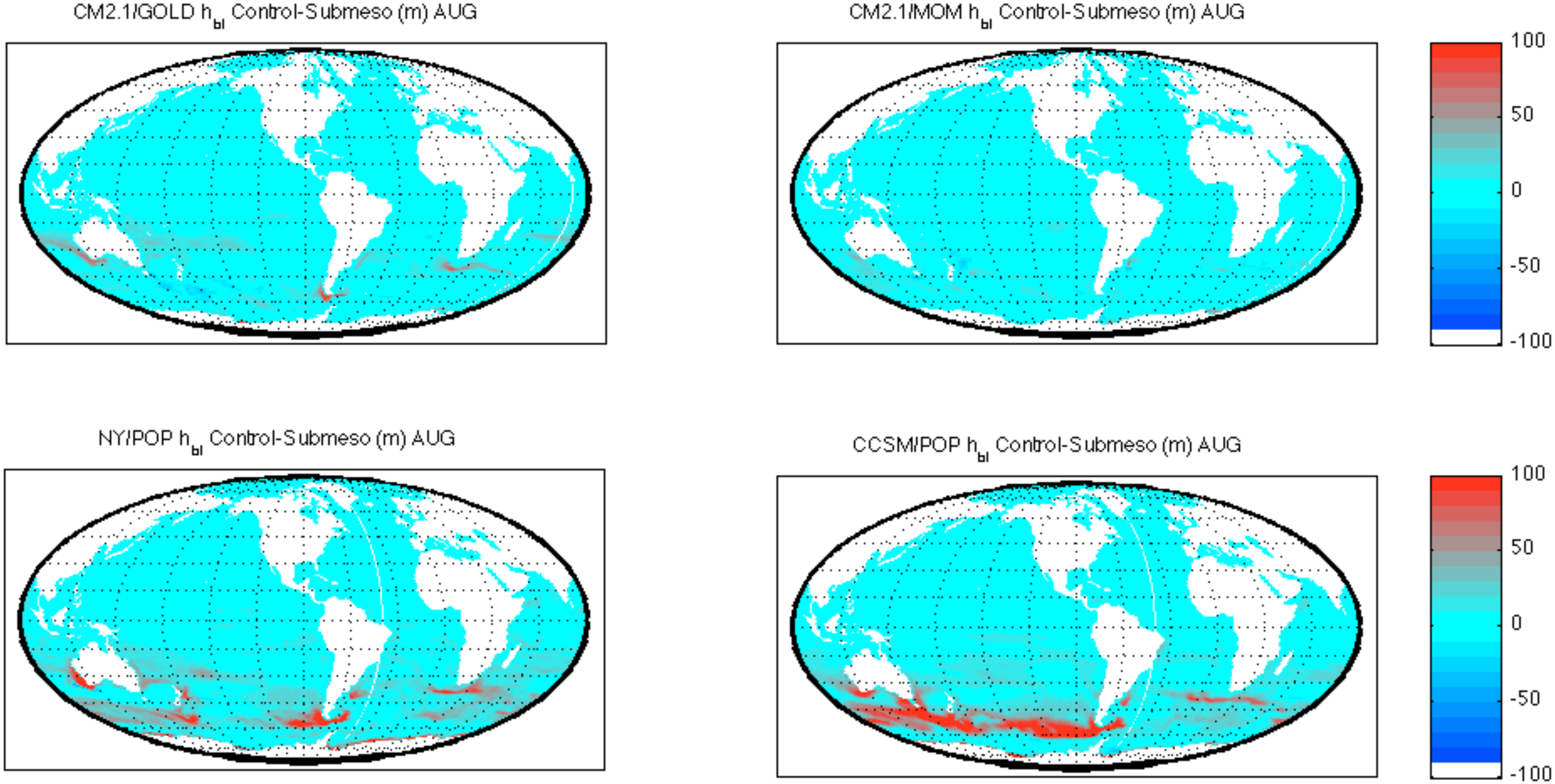
GFDL CM2.1/GOLD

GFDL CM2.1/MOM



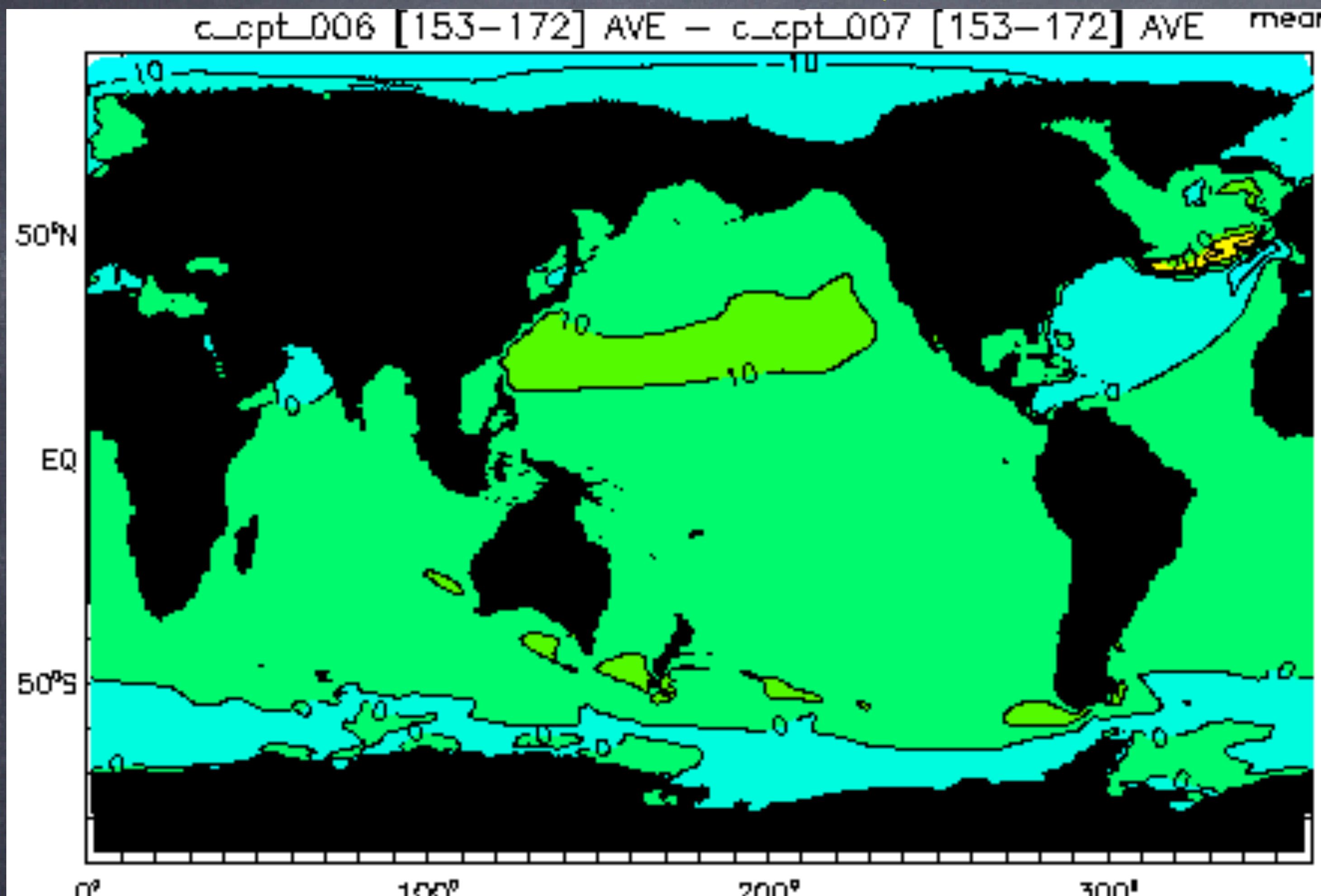
NCAR Normal Year/POP

NCAR CCSM/POP

MLE-Control:Climatologies at end of > 100yr simulation

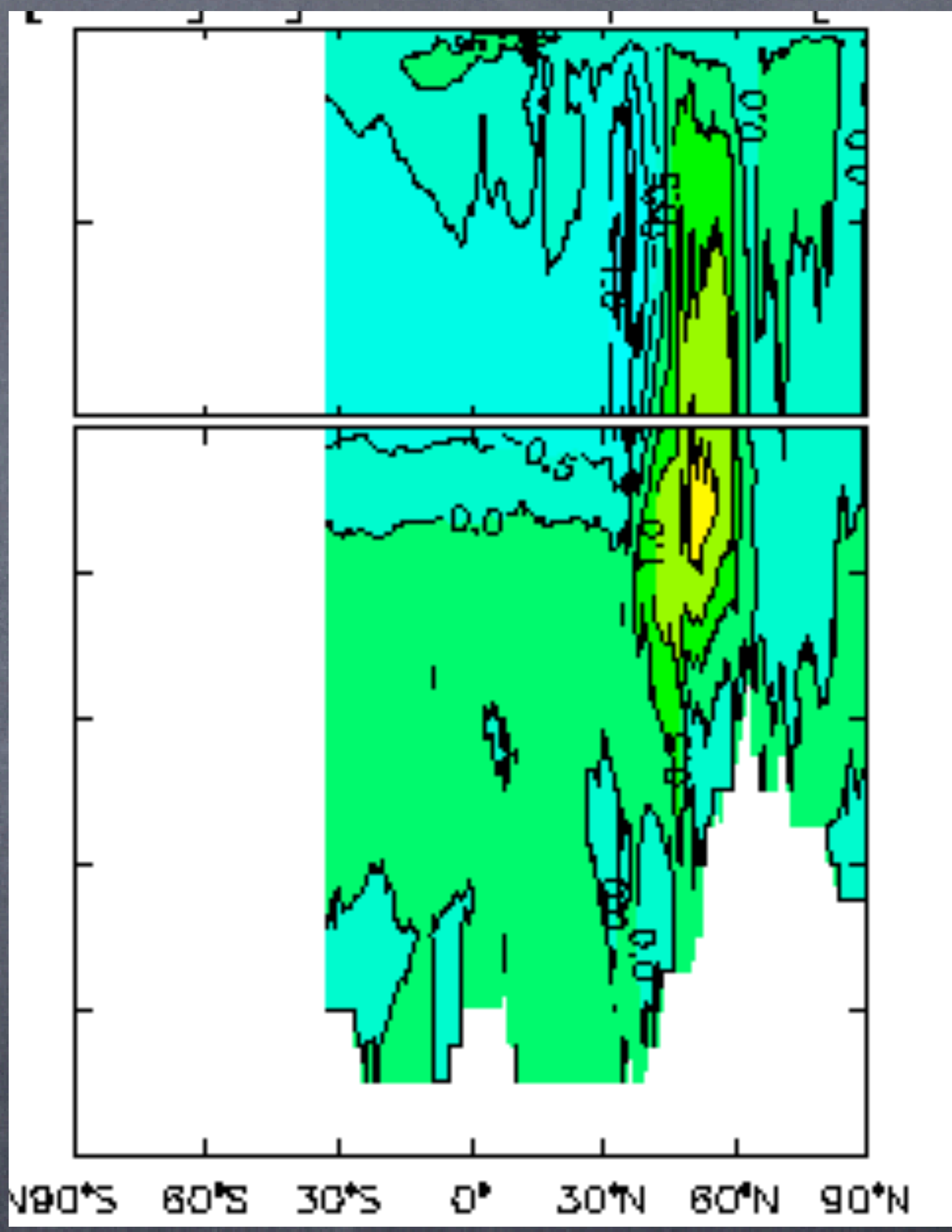
Changes other variables we care about... CCSM

Avg. Ideal Age 4 yrs older at 500m with MLE (up to 30%)



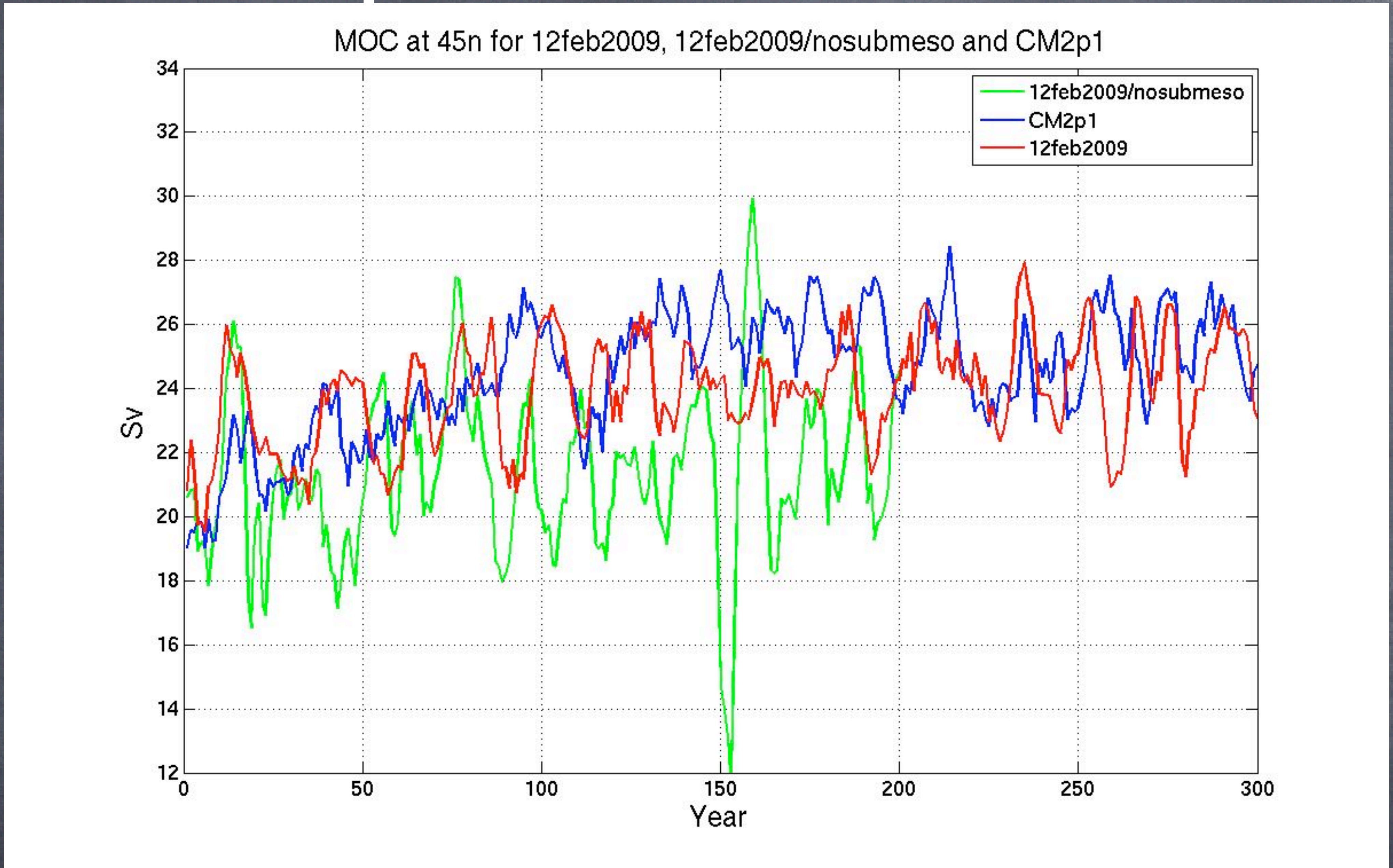
(as big as coarse vs 10km, Frank)

MOC 10% greater with MLE



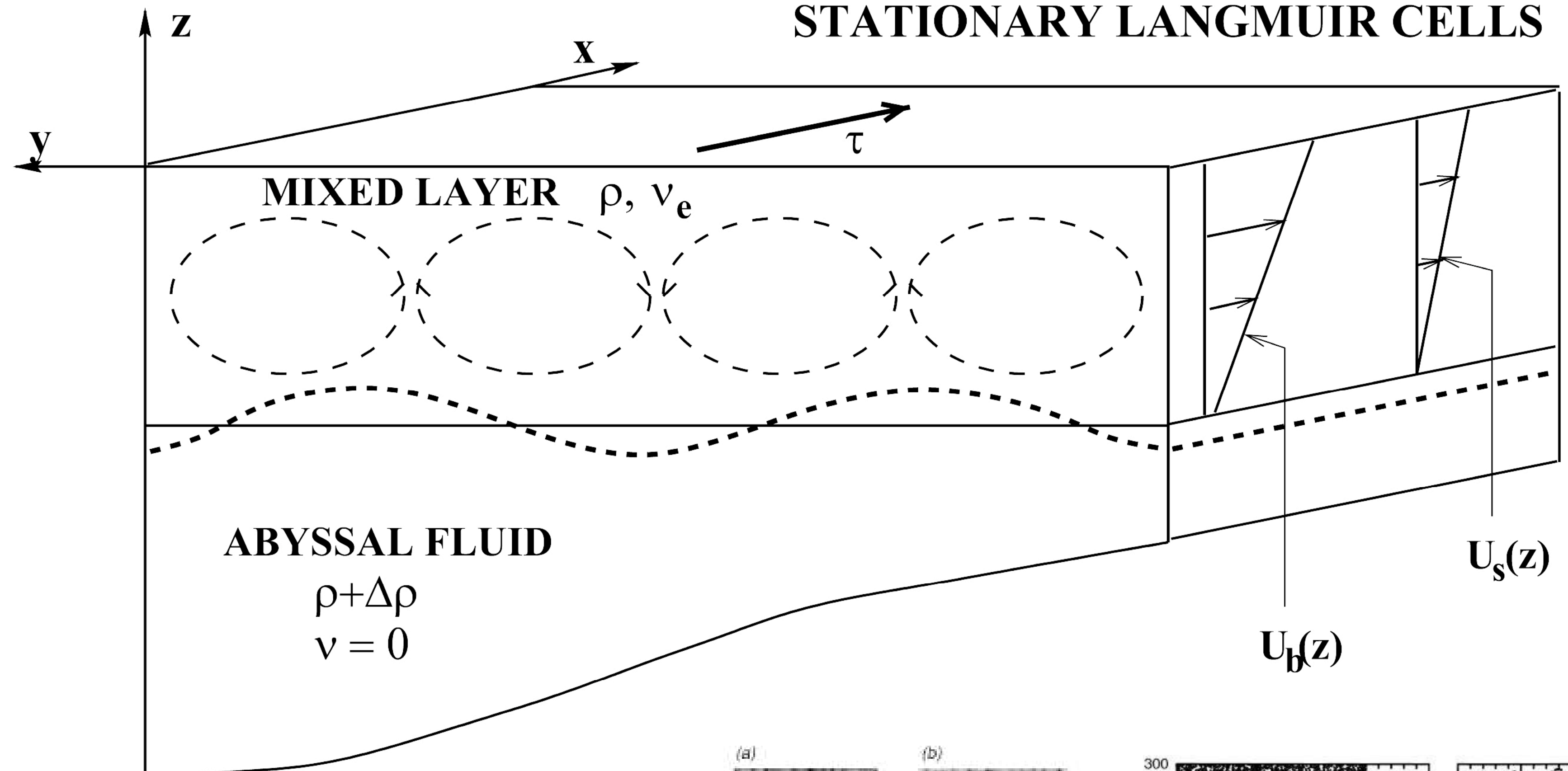
MLE-Control:Climatologies at end of > 100yr simulation

Coupled MOM Shows



Submeso increases MOC stability

Langmuir Parameterization



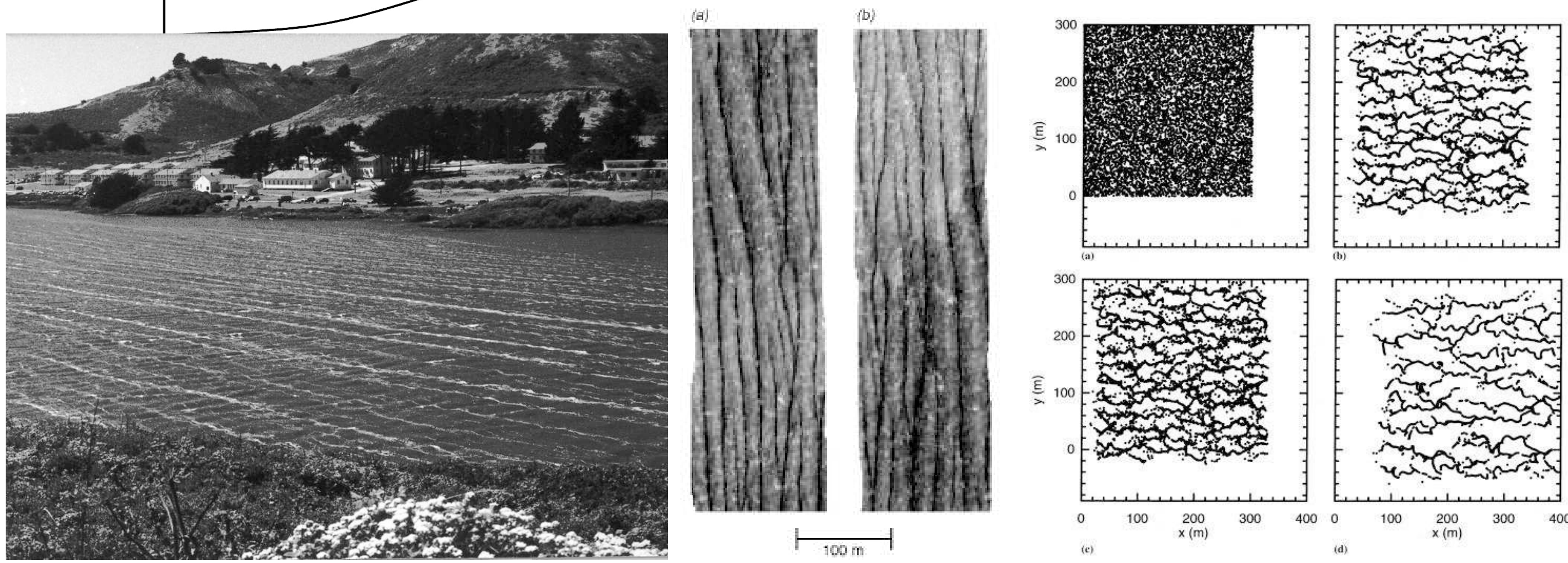


FIGURE 1: Images of Langmuir circulation windrows: (a) a photograph of Rodeo Lagoon in CA (from Szeri, 1996), (b) an infrared image of the surface of Tampa Bay (courtesy of G. Marmorino, NRL, D.C.), and (c) the evolution of surface tracers in a LES of Langmuir turbulence (McWilliams et al., 1997). Reproduced from Chini et al. (2008).

A Simple Scaling for Langmuir Depth/Entrainment:

(Li & Garrett, 1997)

related to CAM u* by WW3 Climatology

CAM

$$Fr = \frac{\omega}{NH} \approx 0.6 \qquad \omega \approx \frac{V}{1.5} \approx \frac{\sqrt{u^* u_s}}{1.5}$$

The Algorithm

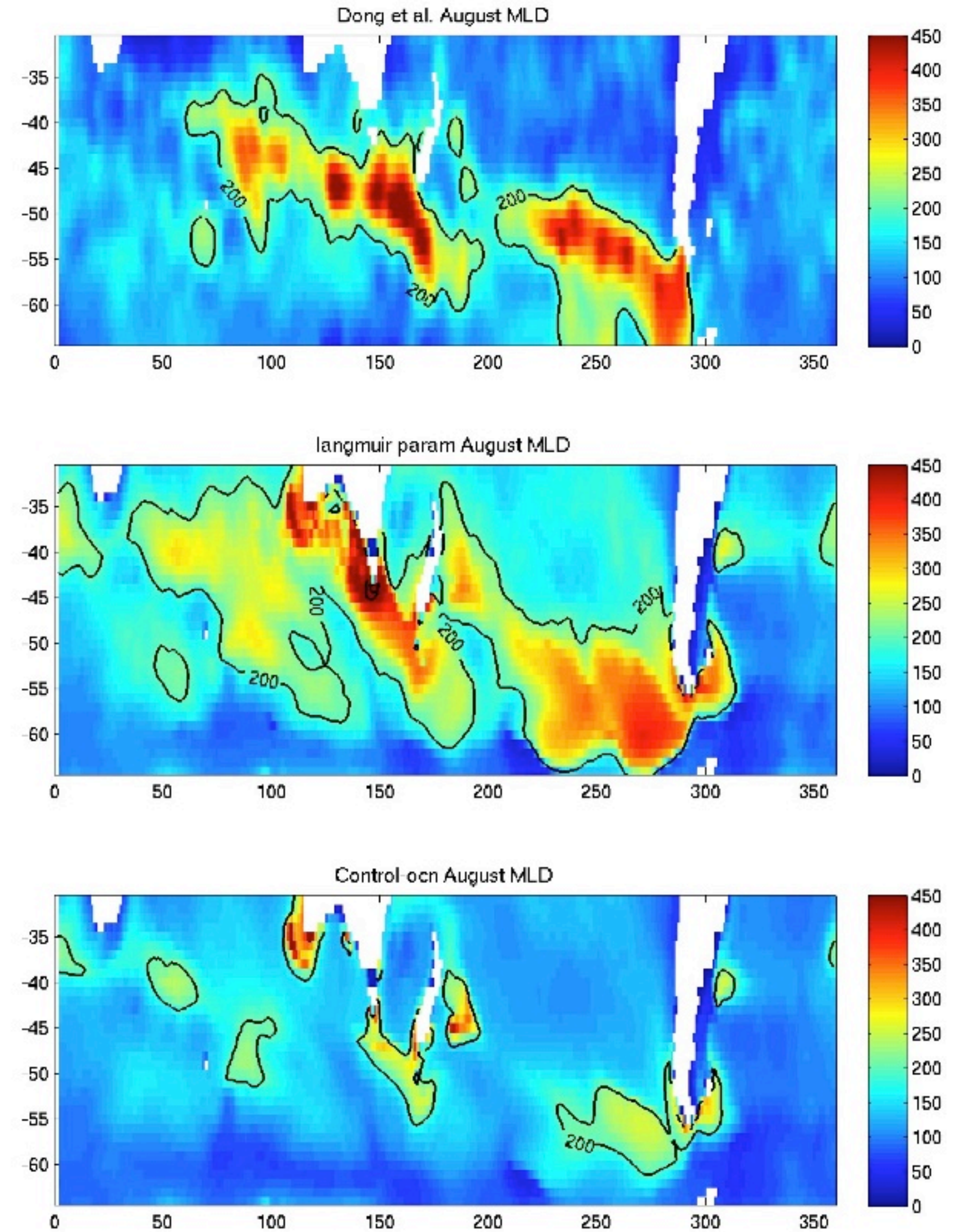
- Use Fr to determine H
- If H is deeper than KPP Boundary Layer depth, use H

Large came up with clever choices for N, H that lead to a robust implementation in KPP

With these choices, H and BLD converge over time.

CCSM3.5 Impact: MLD

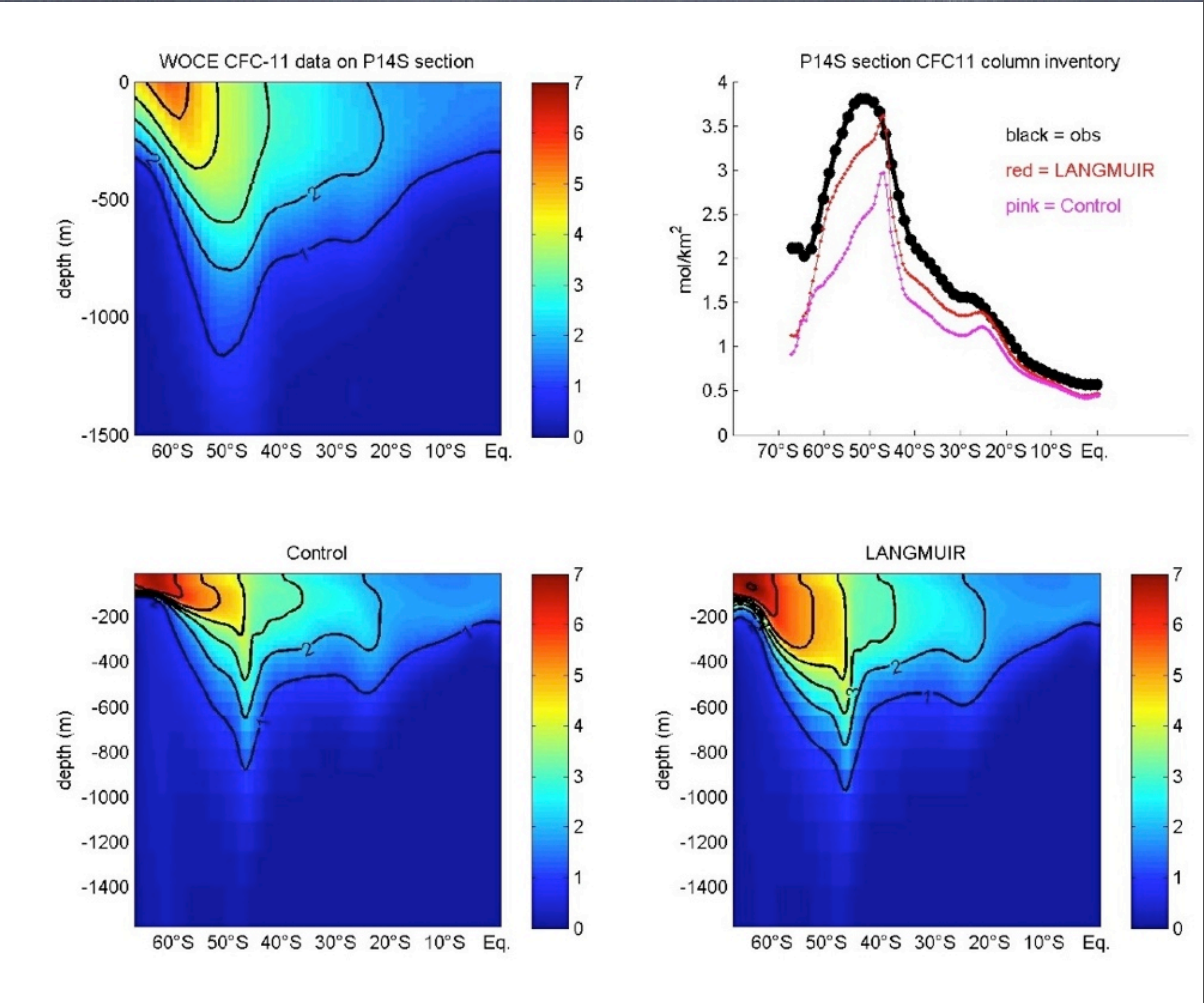
- With reasonable parameters, can produce deeper mixed layers
- This often reduces bias in some regions, e.g., ACC



August mixed layer depths.

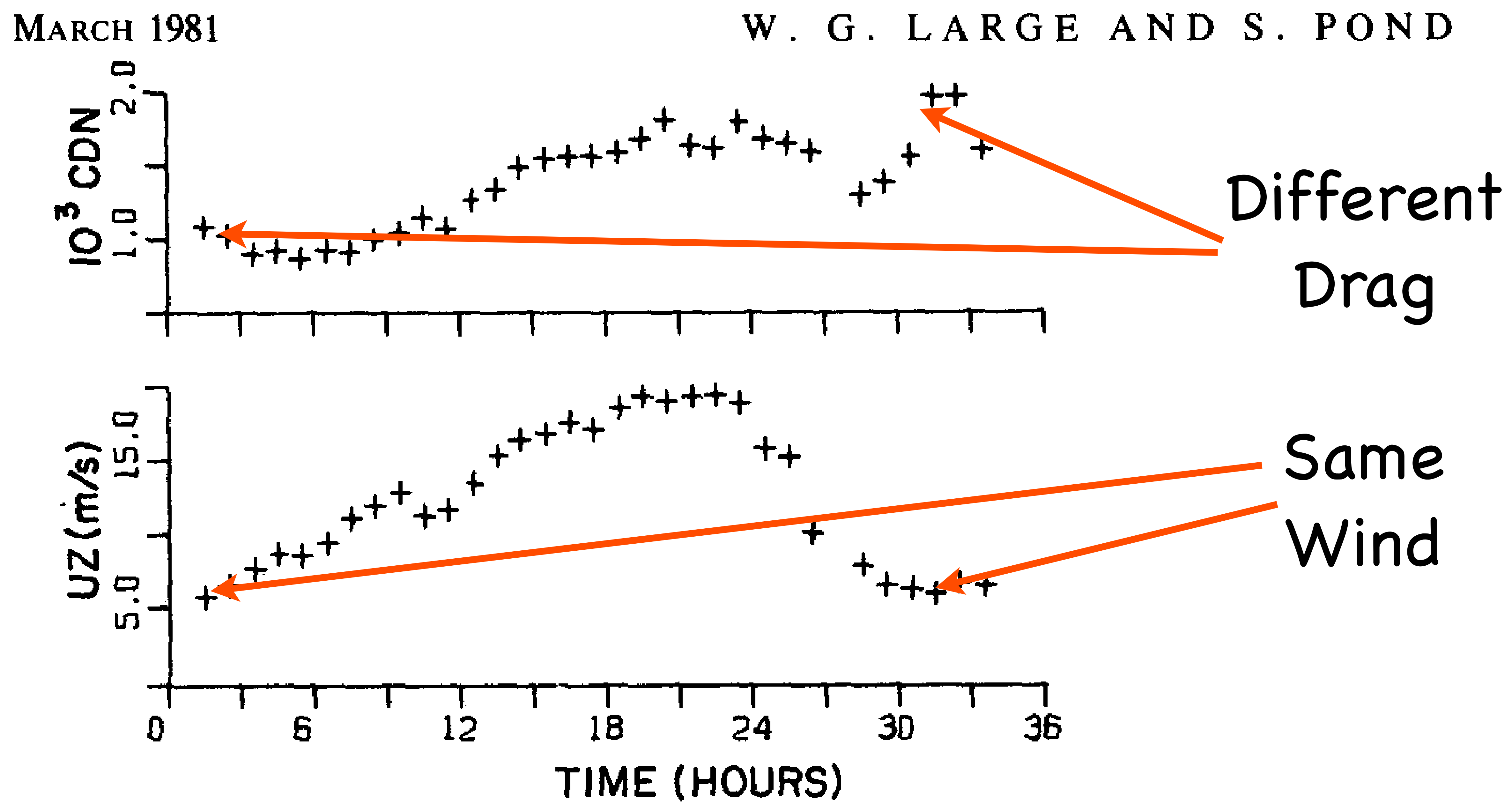
CCSM3.5 Impact: CFCs

- With reasonable parameters, can affect CFCs
- This reduces bias in some regions, e.g., ACC versus WOCE
- Potentially Large impact, change as large as bias



CFC in CCSM & P14S WOCE observations.

Other Effects of Wind+Waves != Wind



Conclusions

- Submeso generally accepted. Reduces bias, improves MOC stability, reduces spurious deep convection
- Langmuir turbulence important in mixed layer mixing and deepening, may reduce SO bias
- Langmuir scaling requires wind & waves: coupling prognostic wave model in planning phase, some discrepancies with satellite obs.
- Once we've got the wave model, it will be useful for other things!

Publications

Submeso

- Boccaletti, Ferrari, Fox-Kemper: 2007, JPO
- Fox-Kemper, Ferrari, Hallberg: 2008, JPO
- Fox-Kemper, Ferrari: 2008, JPO
- Fox-Kemper, Danabasoglu, Ferrari, Hallberg: 2008 CLIVAR Exchanges
- Fox-Kemper, Danabasoglu, Ferrari, Griffies, Hallberg, Samuels, Peacock: In prep for OMod

Langmuir

- Webb et al.: In prep for JGR

MLE Param. is now in testing in:

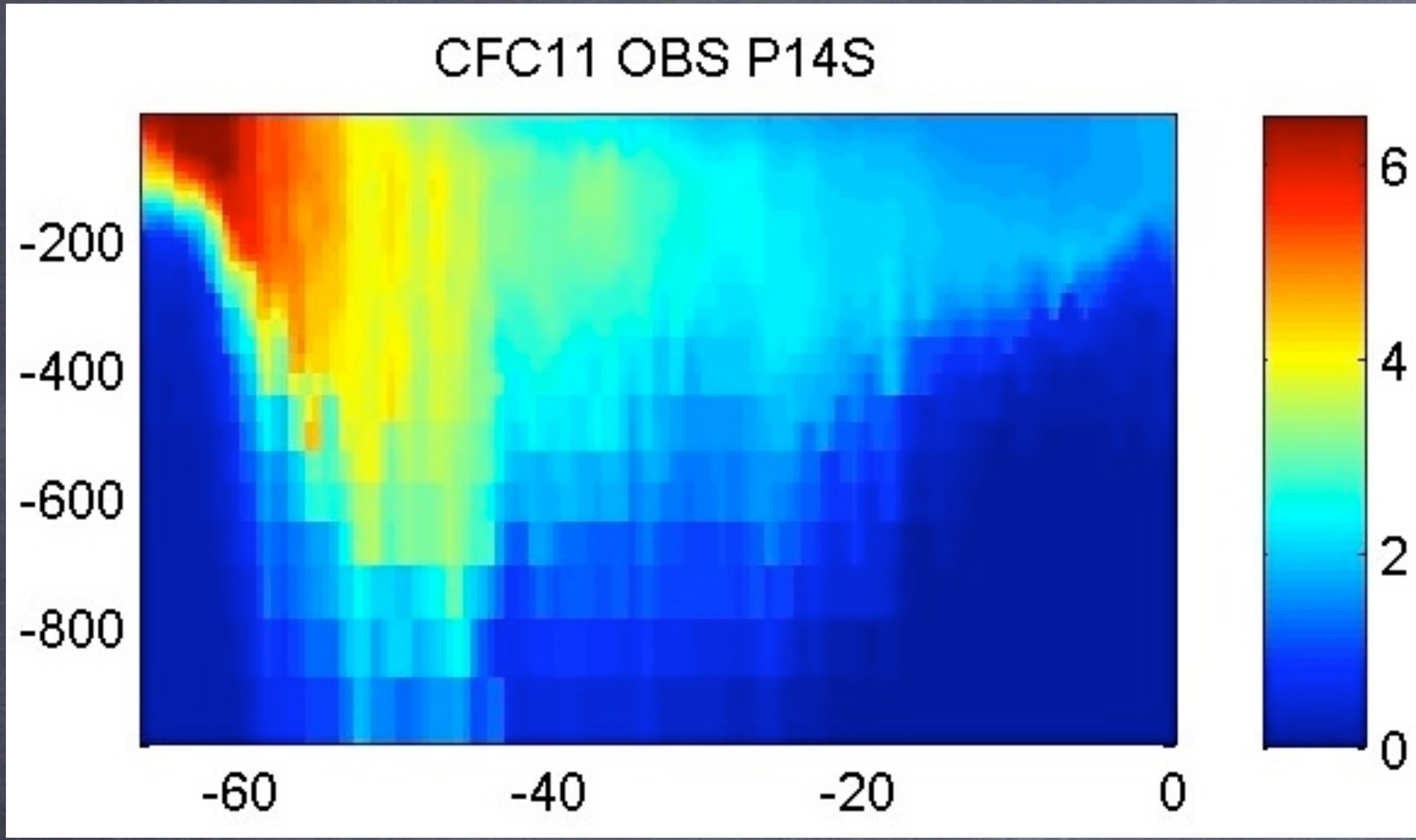
Models

- CCSM/POP
- CM/MOM
- CM/GOLD
- MITgcm
- NEMO
- Norway
- ECMWF?

Results

- Reduced ML Depth
- Reduced MLD Bias
- Modest CFC changes, some bias reduction
- Reasonable changes to circulation
- Stable, Minimal Cost

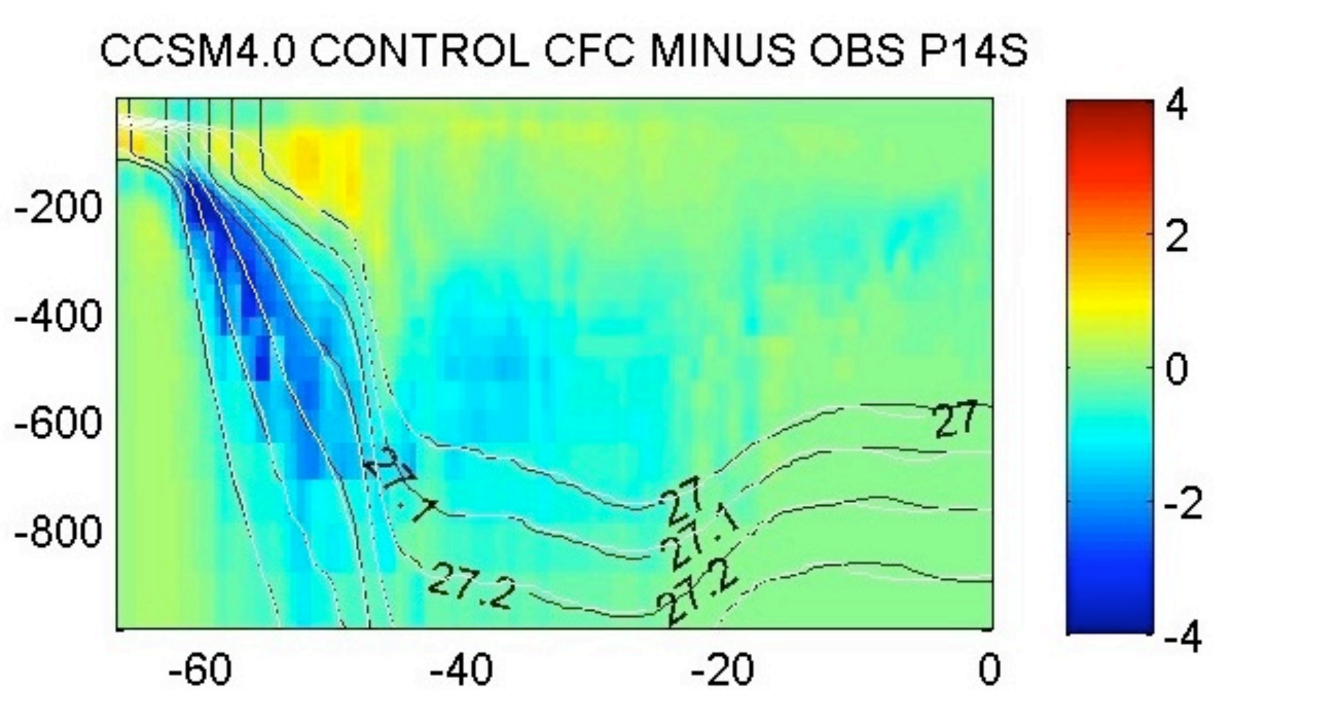
Nuance--CCSM3.5 and CCSM4.0

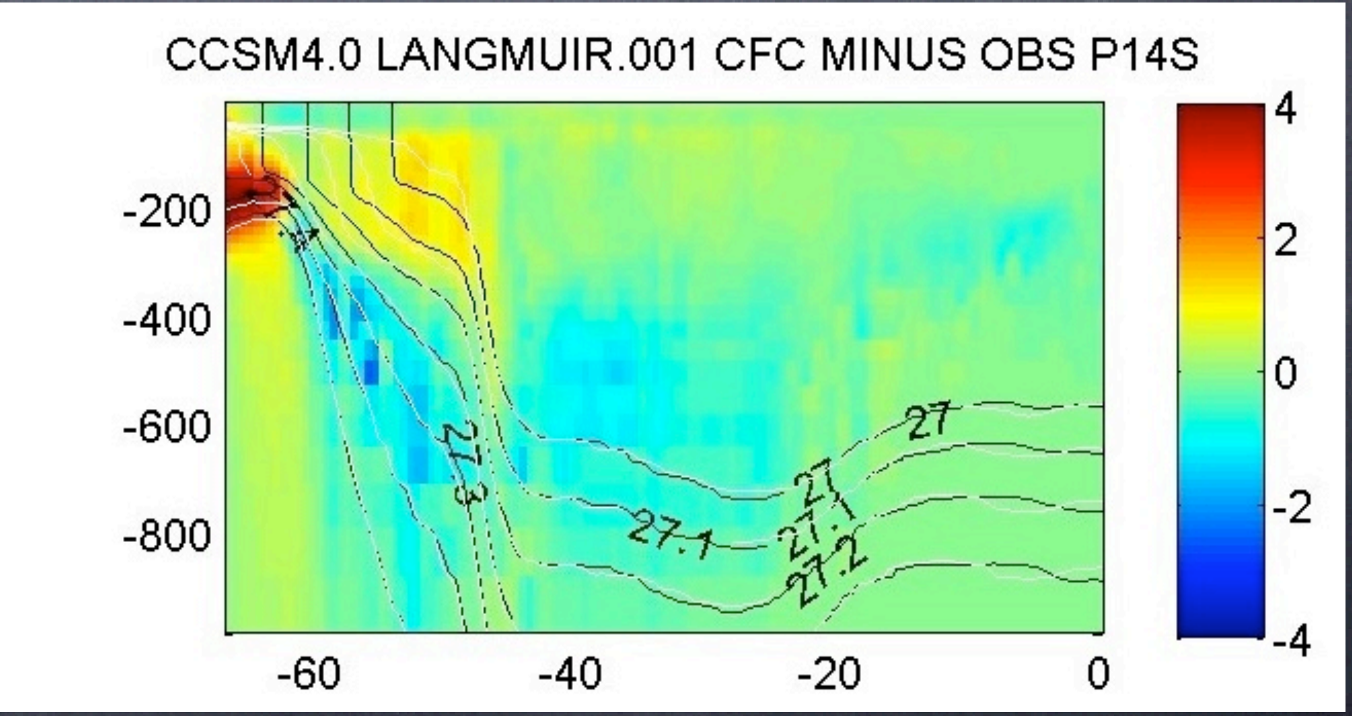


CCSM4.0 did not have the same initial improvement!

S & T particularly bad

Interactions with submeso?





Nuance--CCSM3.5 and CCSM4.0