The CHIME coupled climate model and other HYCOM activities at NOCS

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HYCOM in Southampton

CHIME (Megann, New, Blaker & Sinha)

- The CHIME project
- Model status and results
- Differences between HYCOM v0.9 and v2.1.34 implementations
- Conservation issues
- Summary
- Further work with CHIME

Near-global 3-degree resolution model (Zuo)

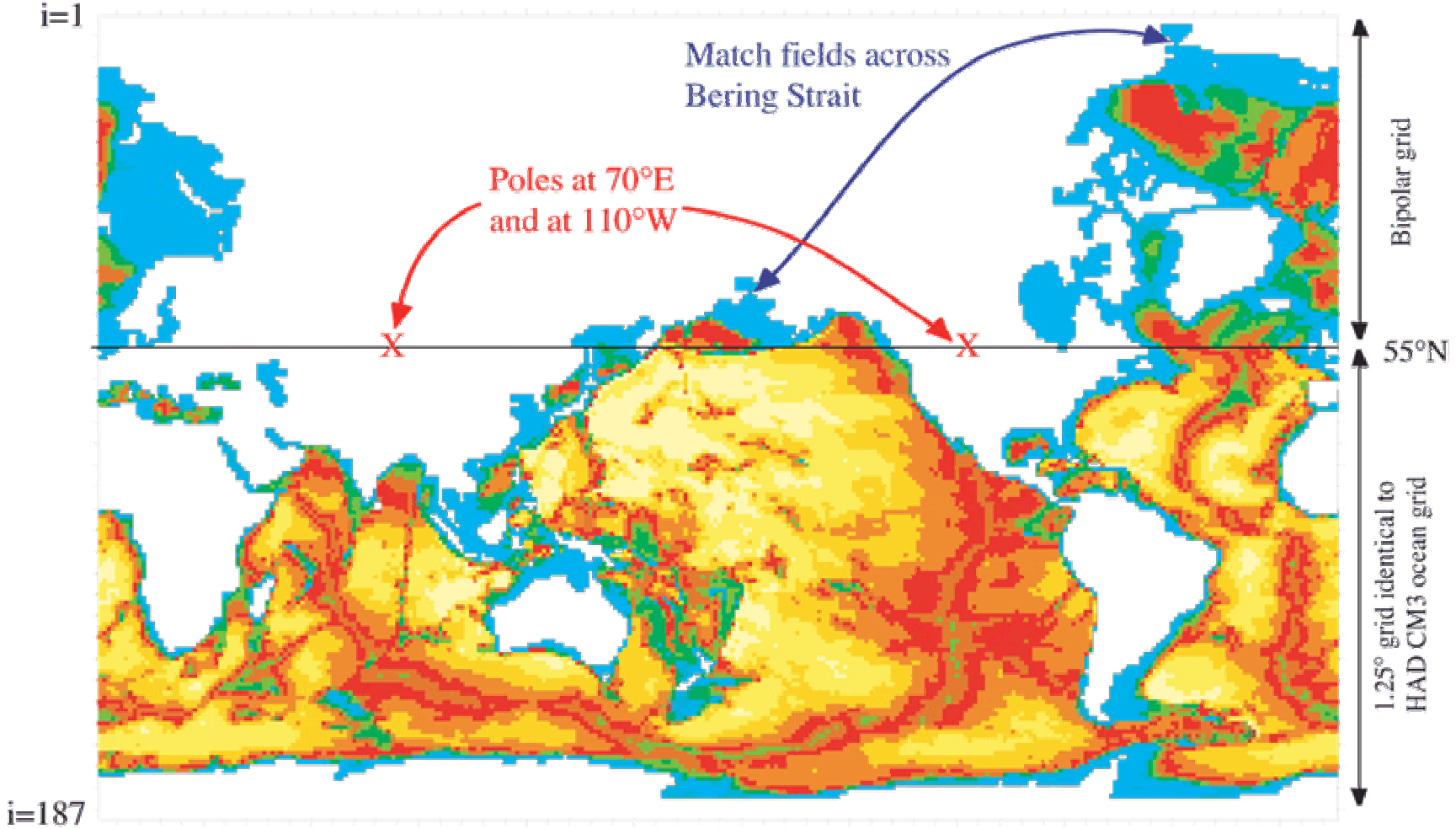
Irminger Basin model (Wilkinson)

The Coupled Hadley-Isopycnic Model Experiment (CHIME)

Ocean model

- Spherical 1.25° x 1.25° grid south of 55°N, with bipolar grid covering Arctic (poles at 110°W and 70°E).
- Bering Strait and Gibraltar Strait open.
- South of 55°N, mass points are coincident with those of HadCM3 ocean.
- HYCOM ocean.
- Advect and diffuse T and S on layers.
- KPP vertical mixing scheme.
- Uses 2000 dbar reference pressure for potential density (σ_2), and applies a correction for thermobaricity.

Chime ocean grid and bathymetry



CHIME components

Ice

- Semtner thermodynamics, plus drift with ocean surface current
- Same as in HadCM3, though on CHIME ocean C-grid.

Atmosphere

- HadAM3, identical to atmospheric component of HadCM3.
- 2.5° x 3.75° resolution, 19 vertical layers.

Coupling

- Connected to ocean through OASIS coupler: coupling once per day.
- Fluxes interpolated through Shan & Rainer's tiling scheme
- No flux adjustment necessary!

CHIME status

Original version of CHIME

- Used HYCOM version 0.9 (Rainer's "workbench" code)
- 30 metre surface layer
- Ran for 120 years

Current CHIME

- Grid, bathymetry and coupling as original
- Ocean model changed to HYCOM v2.1.34
- dp0 = 5, 7, 9, 12, 15, ,… metres
- Have added time-mean fields and NetCDF output to HYCOM
- Now running with pre-industrial CO_2 …
- … and has now completed more than 20 years.

Results from 120-year run with HYCOM v0.9

• CHIME heat transport in subtropical regions is larger than that in HadCM3. Kuroshio and NAC in CHIME are stronger and deeper than in HadCM3.

• CHIME shows surface warming in subtropical gyres which ventilates to 800m over decadal time scales. Kuroshio Extension is too far north.

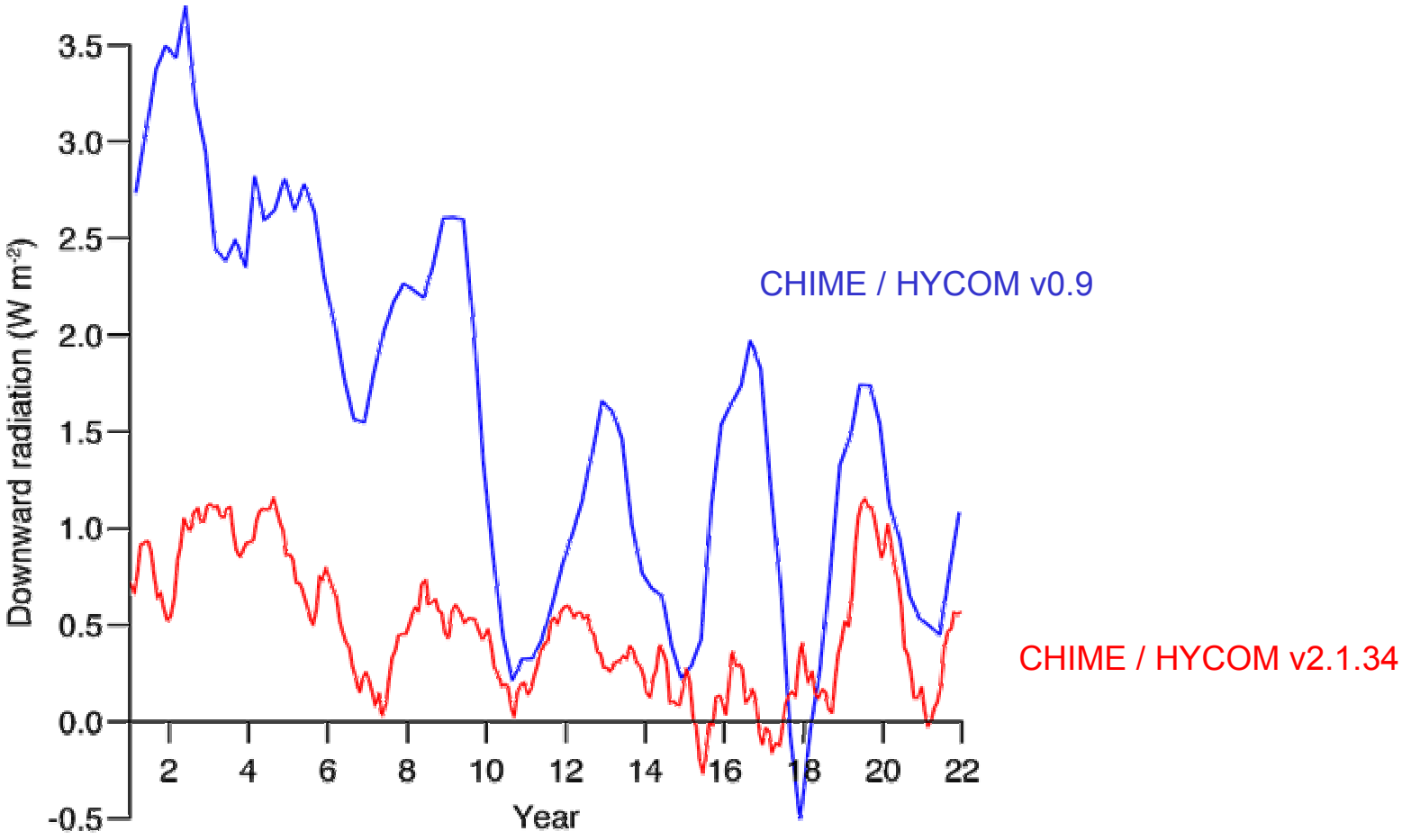
• Southward displacement of Kuroshio extension in HadCM3 is consistent with 3-4°C North Pacific cold bias.

• Subtropical gyres expand and warm in CHIME, but cool and contract in HadCM3.

• Accidental “hosing experiment” showed strong link between MOC in Atlantic at 30°N and temperatures over British Isles.

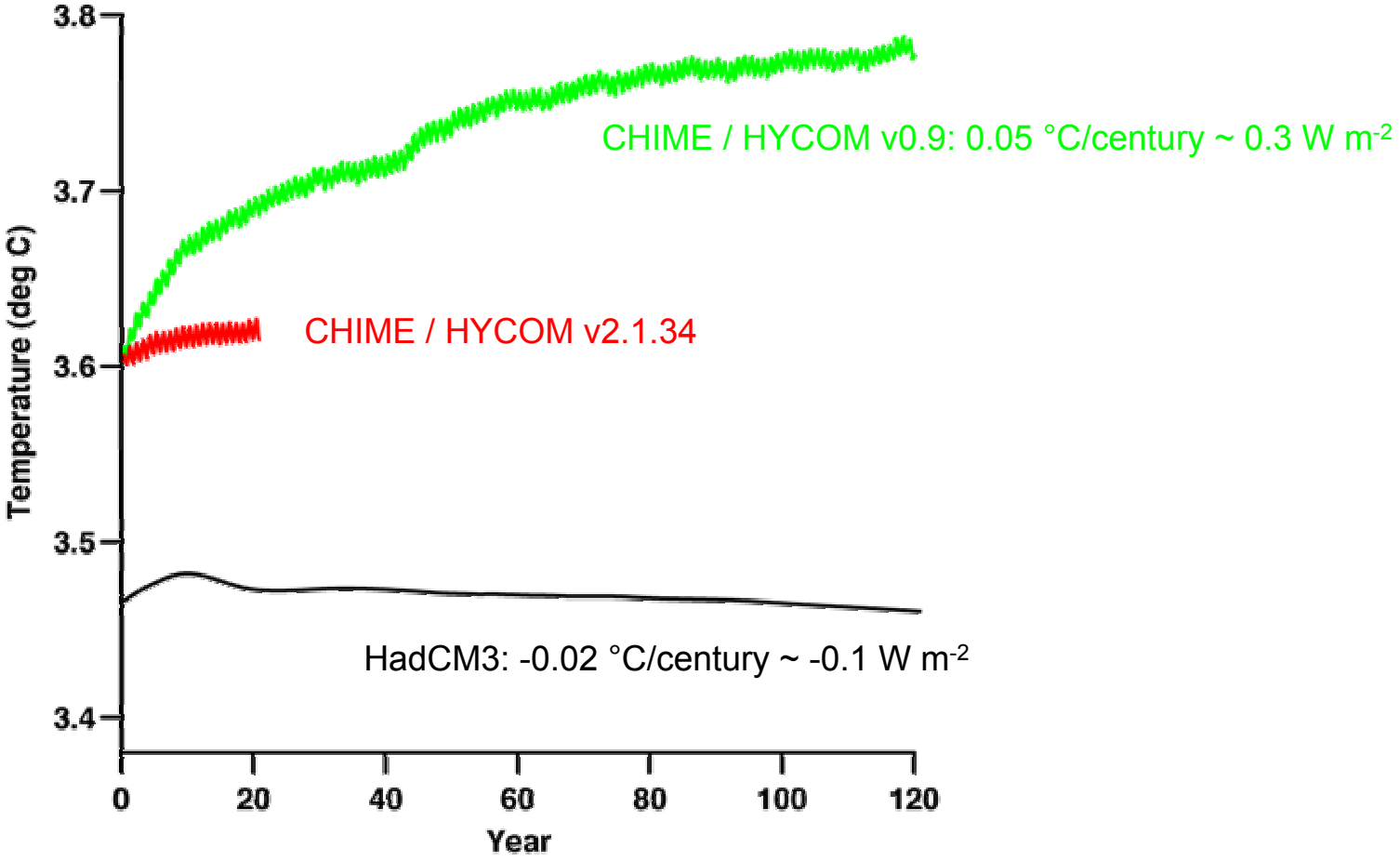
Top-of-Atmosphere (TOA) heat flux

The TOA flux in the new version of CHIME mostly stays below 0.5 W/m^{-2}.



Ocean mean temperature

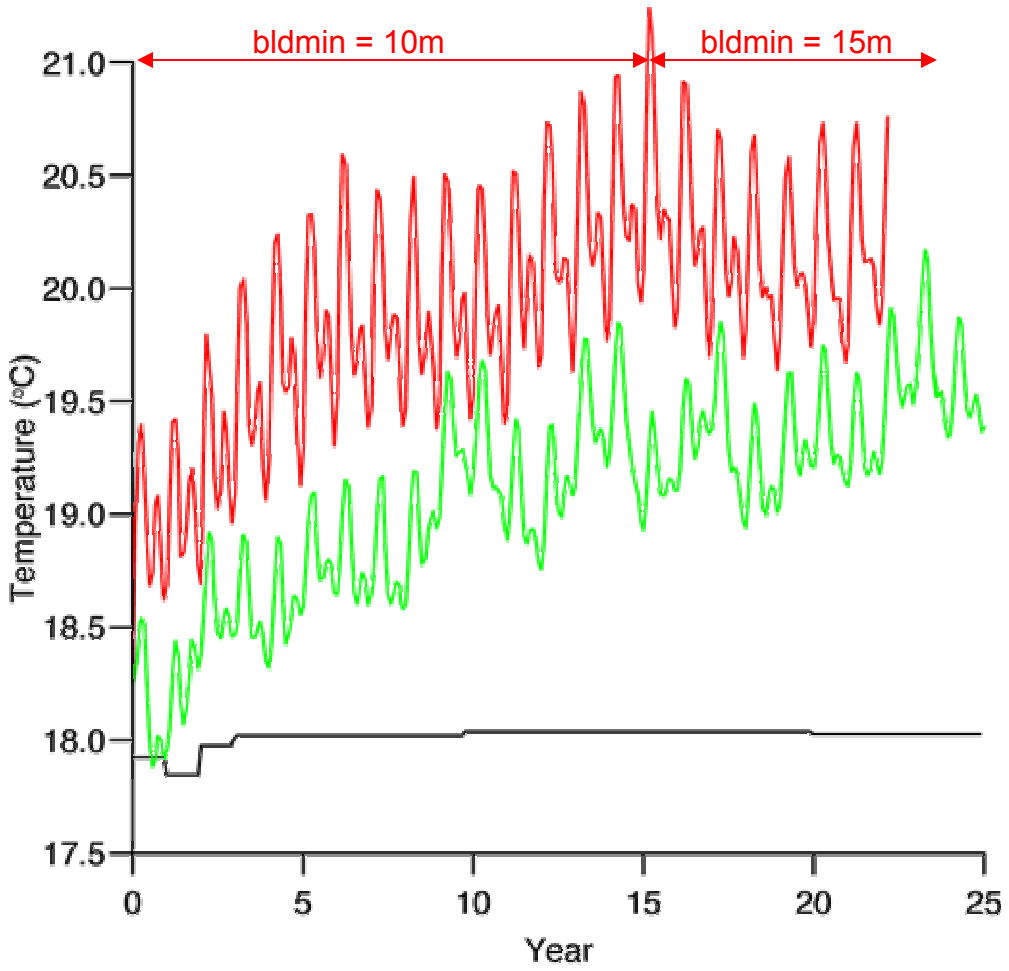
The mean ocean temperature in the new version of CHIME is acceptably stable, consistent with the low TOA residual.



Ocean surface temperature (1)

Mean SST error is higher than with HYCOM v0.9.

- Connection to minimum surface layer thickness? (dp0=30m in v0.9)



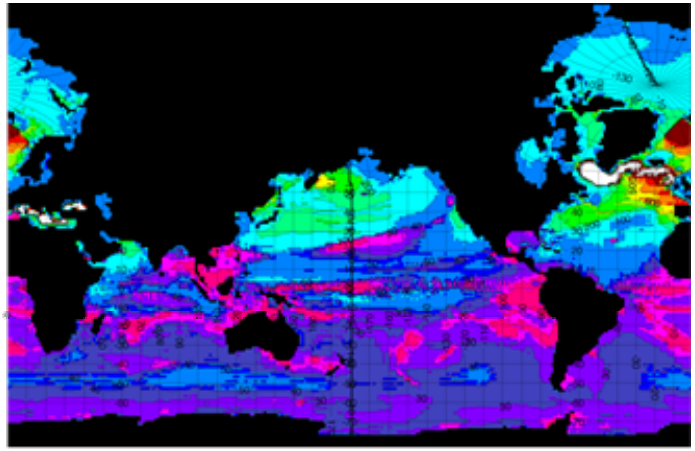
CHIME / HYCOM v2.1.34

CHIME / HYCOM v0.9
(dp0=30m)

HadCM3

Ocean surface temperature (2)

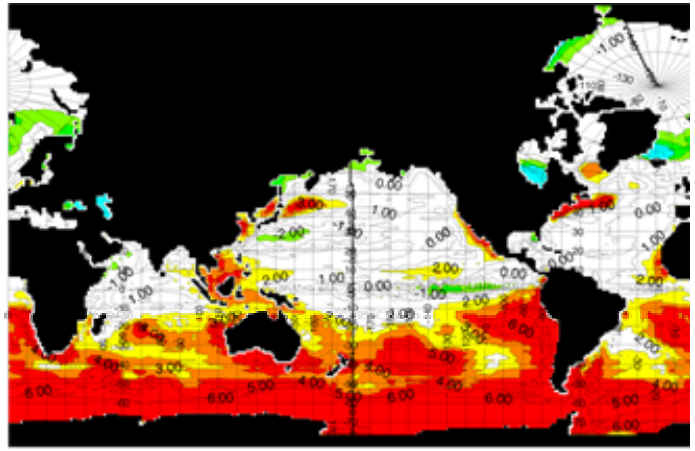
Known bias in KPP towards unrealistically shallow summer mixed layers -> warm surface errors.



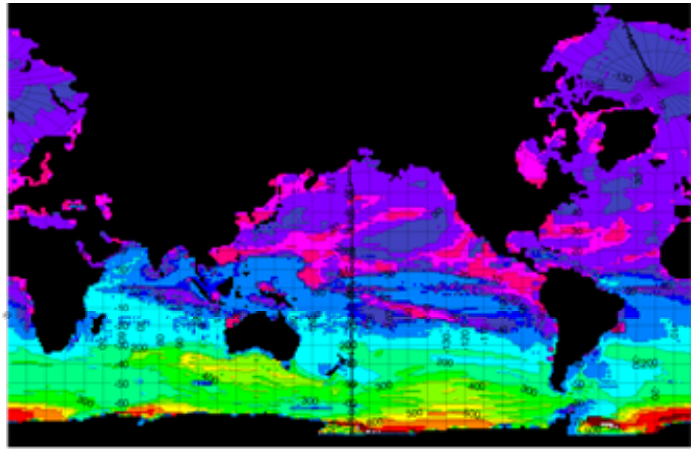
ML depth in year 19 of CHIME (HYCOM v2.1.34)
(pink areas shallower than 20m)

March

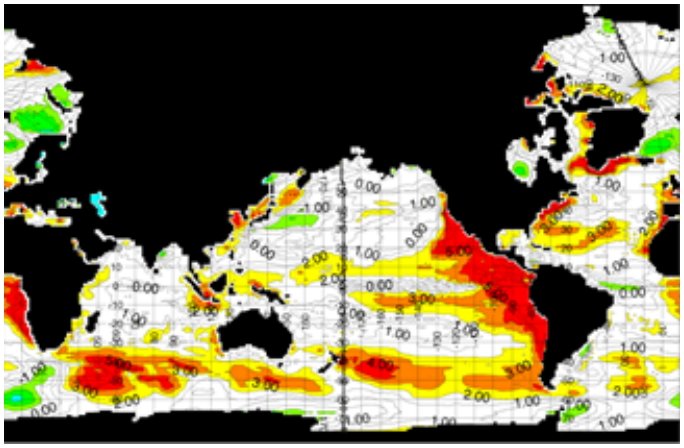
bldmin = 15m



SST errors in year 19 of CHIME (HYCOM v2.1.34)

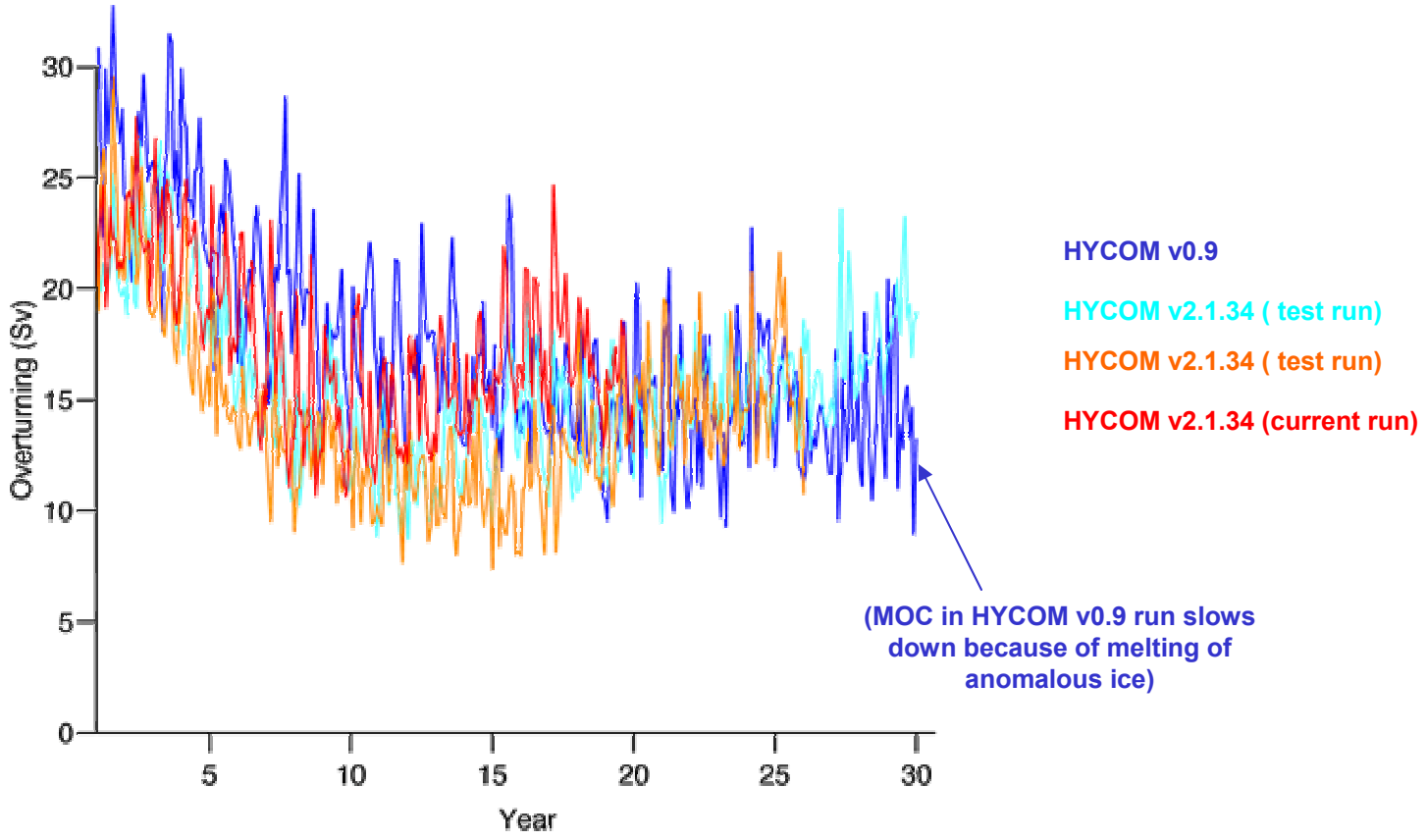


September



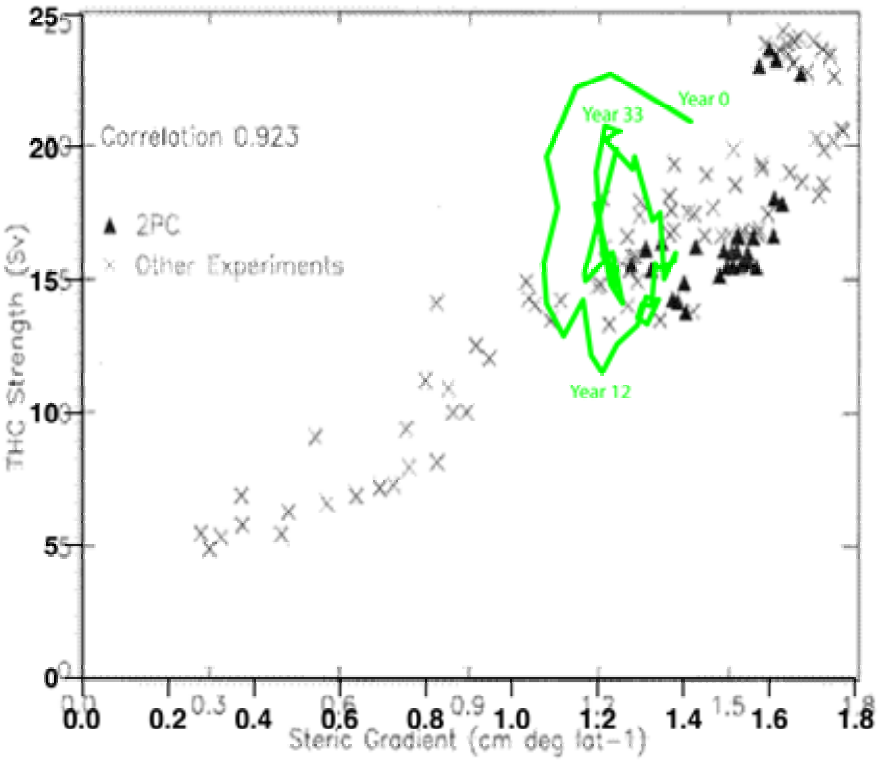
Atlantic overturning (1)

The maximum overturning at 30°N, after the first ten years, is in the range of 13-20 Sv in all the CHIME runs carried out so far.



Atlantic overturning (2)

Some kind of initial oscillation with time scale ~10 years between MOC at 30°N and north-south steric height gradient (cf. Thorpe et al., 2001)
- this will be an invaluable tool for GHG sensitivity runs of CHIME.



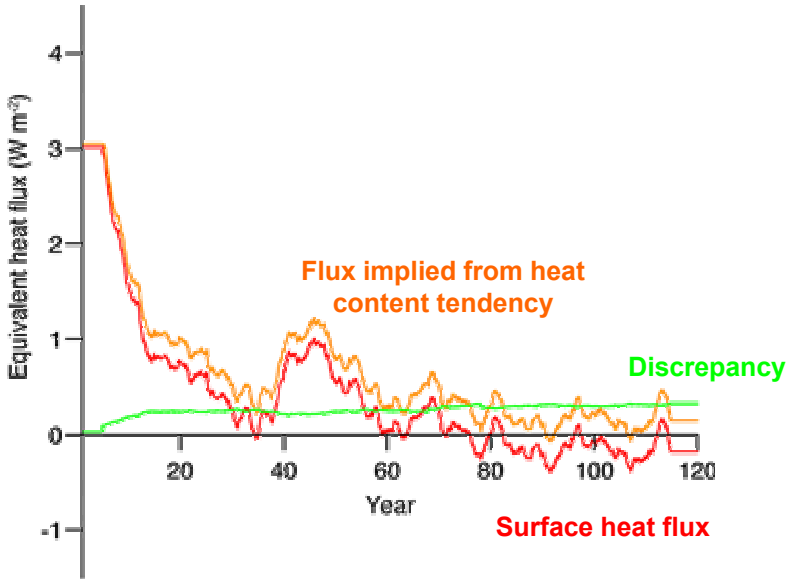
Annual mean maximum overturning at 30°N against annual mean steric height gradient from v2.1.34 run.

The CHIME sequence overlays Figure 3 from Thorpe et al., 2001.

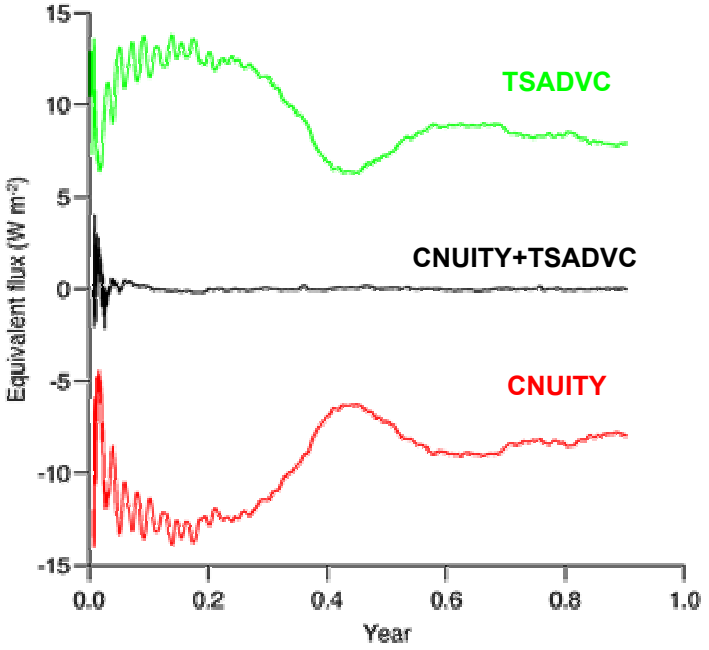
Conservation issues (1)

HYCOM is known to have issues with internal non-conservation of heat, due to time smoothing of layer thicknesses in CNUITY and TSADVC.

In the v0.9 version of CHIME, the non-conservation was equivalent to a surface warming of less than 0.25 W m^{-2}, and was judged not to be serious.



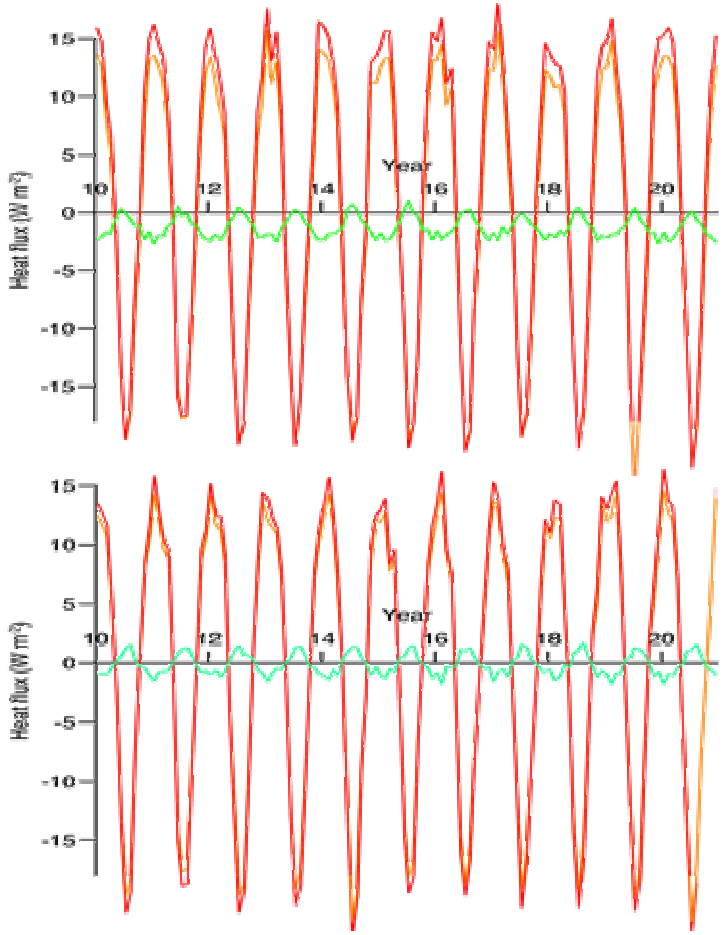
Global heat budget in HYCOM v0.9 CHIME



HYCOM internal heat generation

Conservation issues (2)

In the version of CHIME with HYCOM v1.2.34 the non-conservation was found to (surprisingly?) depend on viscosity and thickness diffusion parameters.



Surface heat flux

Flux implied from heat content tendency

Discrepancy

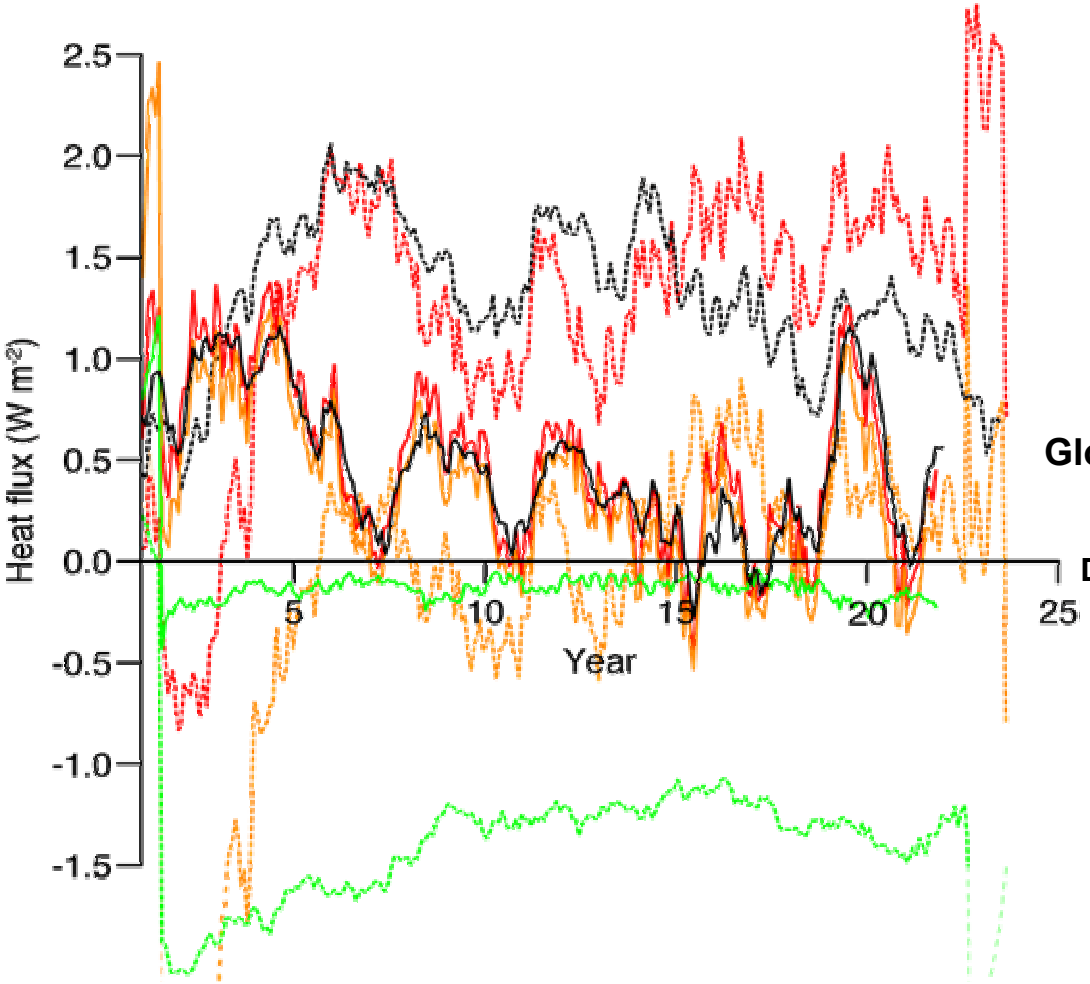
visco2 = 0.1
veldf2 = 0.01
thkdf2 = 0.003
Mean discrepancy ~ -1.3 W m^{-2}

Global heat budget in HYCOM v2.1.34

visco2 = 0.1
veldf2 = 0.02
thkdf2 = 0.02
Mean discrepancy ~ -0.2 W m^{-2}

Conservation issues (3)

With the higher viscosities, heat conservation is not a major issue (but should still be addressed in HYCOM!).



TOA flux residual

Surface heat flux

Flux implied from heat content tendency

Discrepancy

Global heat budget in HYCOM v2.1.34

12-month smoother applied
Dotted lines are from low-viscosity run

CHIME summary

The coupled climate model, CHIME, is now running reasonably satisfactorily with HYCOM v2.1.34 as its ocean component.

Outstanding issues:

- SST errors correlated to excessively shallow mixing in KPP

- Penetration of surface errors in Southern Ocean leads to deeper warming and reduction of ACC strength - not yet fully understood.

- Heat non-conservation: is this a significant issue?

- Freshwater balance still to be verified (salinity is rising)

Plans for CHIME

There is funding under the UK NERC Rapid Climate Change CMIP programme to carry out climate sensitivity experiments with CHIME.

We plan to complete out a 200 year control run and two standard CMIP2 experiments:

- CO_2 increasing 1% per year, for 140 years;

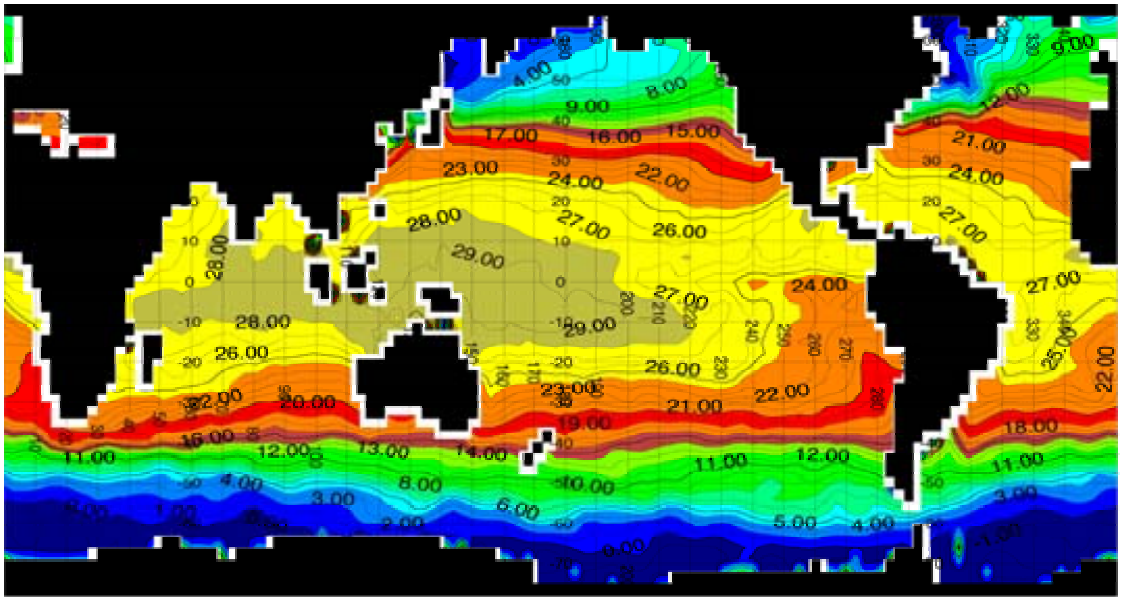
- Hosing experiment (0.1 Sv for 100 years, recovery for at least 40 years)

- and then other runs under NOC core programme: e.g.realistic CO_2 scenarios, and vertical coordinate structural sensitivity studies in coupled models.

Global mixing experiments (Hao Zuo, NOC)

• MICOM/HYCOM in global 3-degree domain: effect of diapycnal mixing parameterisations on global overturning circulation

• Model is now working, and is ready for experiments (though Hao is in Woods Hole for the summer!)



Global 3° model initial SST (Levitus 98)

Irminger Basin process studies (David Wilkinson, NOC)

- Run regional model of Irminger Basin and study behaviour of East Greenland Coastal Current under various surface forcing regimes

- Set up at 5km resolution
- 10 layers
- Now looking at effects of bathymetry and lateral boundary conditions in simple rectangular domain