Overview of Met Office Hadley Centre and collaborators activities

Malcolm Roberts

(with thanks to Dave Stevens, Len Shaffrey, Ian Stevens, Chris Jones, Bill Collins, Ian Totterdell, Spencer Liddicoat, Andrew Coward, Chris Harris and many others)

Model contributions to IPCC AR5

- HadGEM2-ES (Earth System)
  - Main modelling contribution to long-term climate change
  - Includes biogeochemistry in ocean+atmosphere, carbon cycle etc etc
  - Ocean based on HadGEM1, Bryan-Cox, 1°x1-1/3° with enhancement near equator, 40 z -levels
- In collaboration with NCAS-Climate (University of Reading, University of East Anglia)
  - HiGEM (Shaffrey et al, 2009)
  - Decadal prediction contribution (together with Hadley Centre's DePreSys system using HadCM3)
  - Ocean also based on HadGEM1, 1/3°x1/3°, 40 z-levels
  - Some small differences to ocean parameters but basically similar to HadGEM2-ES ocean

HiGEM

A national UK programme in ‘Grand Challenge’ high resolution modelling of the global environment between NERC and the Met Office Hadley Centre

higem.nerc.ac.uk

University of East Anglia

HiGEM ocean model 1 (HadGEM2)

- 1/3 degree global ocean with polar island (a pain!) (1x1-1/3 degree with polar island)
- 40 z-levels with analytic stretching for 2nd order accuracy (without analytic stretching)
- Implicit linear free surface using Chronopoulos-Gear Conjugate Gradient Solver
- Timestep 15 mins (Robert time filter 0.01) (1 hour)
- Fourier filtering north of 80^{o}N (76N)
- Implicit vertical momentum and tracer mixing (same)
- Explicit Coriolis terms (semi-implicit, 0.75)
- 4th order tracer advection - upwind at bottom (same)
- Rahmstorf full convection (same)
- McDougall equation of state (UNESCO)
- Mediterranean Strait parameterised (same)

HiGEM ocean model 2

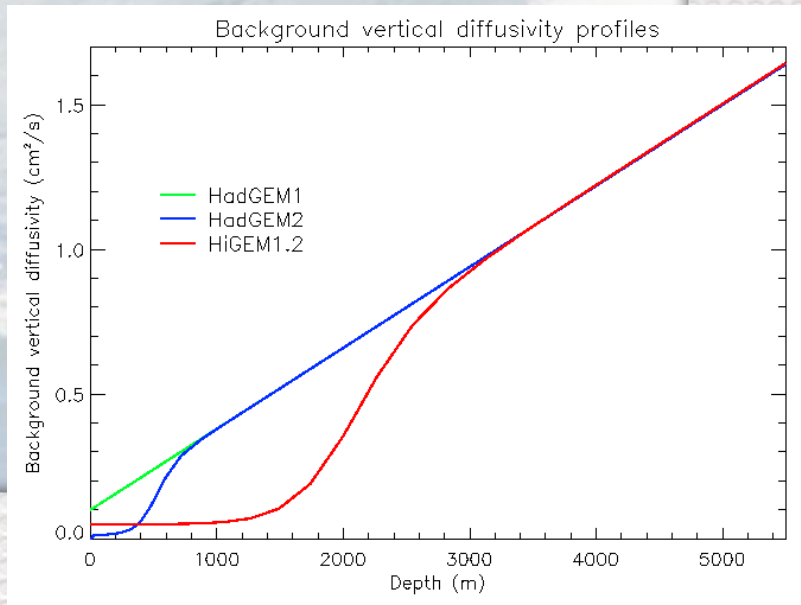
- Bathymetry based upon GEBCO 1/12^{o} dataset with hand carved straits and deep sills.
- Initial hydrography - September 1/4^{o} Levitus 2001 (1998)
- Quadratic bottom friction with drag coefficient 0.001 (same)
- No Bottom Boundary Layer or partial cells
- Horizontal momentum mixing
  - Laplacian: none (750-750 x cos ϕ m^2s^{-1})
  - biharmonic: $-4 \times 10^{11} \times \cos^3\phi - 5 \times 10^5\ m^4s^{-1}$ ($-1 \times 10^{13} \times \cos^3\phi - 5 \times 10^5\ m^4s^{-1}$)
- Isopycnal diffusion 500 m^2s^{-1} (max slope 1/100) (same)
- GM thickness diffusion 250 m^2s^{-1} (where used) (spatially-varying)
- Roberts and Marshall Biharmonic GM ($1 \times 10^{11} \times \cos^3\phi$) (1×10^{12})
- Biharmonic tracer mixing in top 2 levels (same)

HiGEM ocean model 3

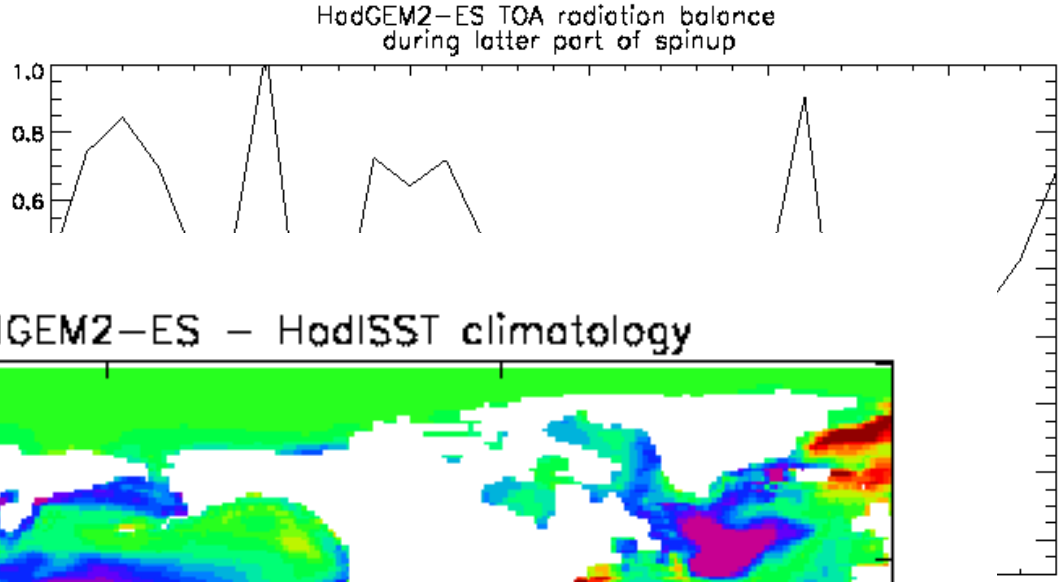
- Background vertical viscosity = 10^{-5} m^2s^{-1}
- Peters Richardson number based vertical viscosity (maximum 10^{-2} m^2s^{-1})
- Met Office quadratic reduced Large scheme (KPP) sets diffusivities and viscosities where Ri < 0.3 in addition a Kraus Turner model is used to calculate mixed layer depth (with wind mixing efficiency λ_m=0.7 (0.55)

  and decay scale δ=50m (100m))
- Background vertical diffusivity initially

  10^{-5}-$2.8\times10^{-8}\times z$ m^2s^{-1} but now modified



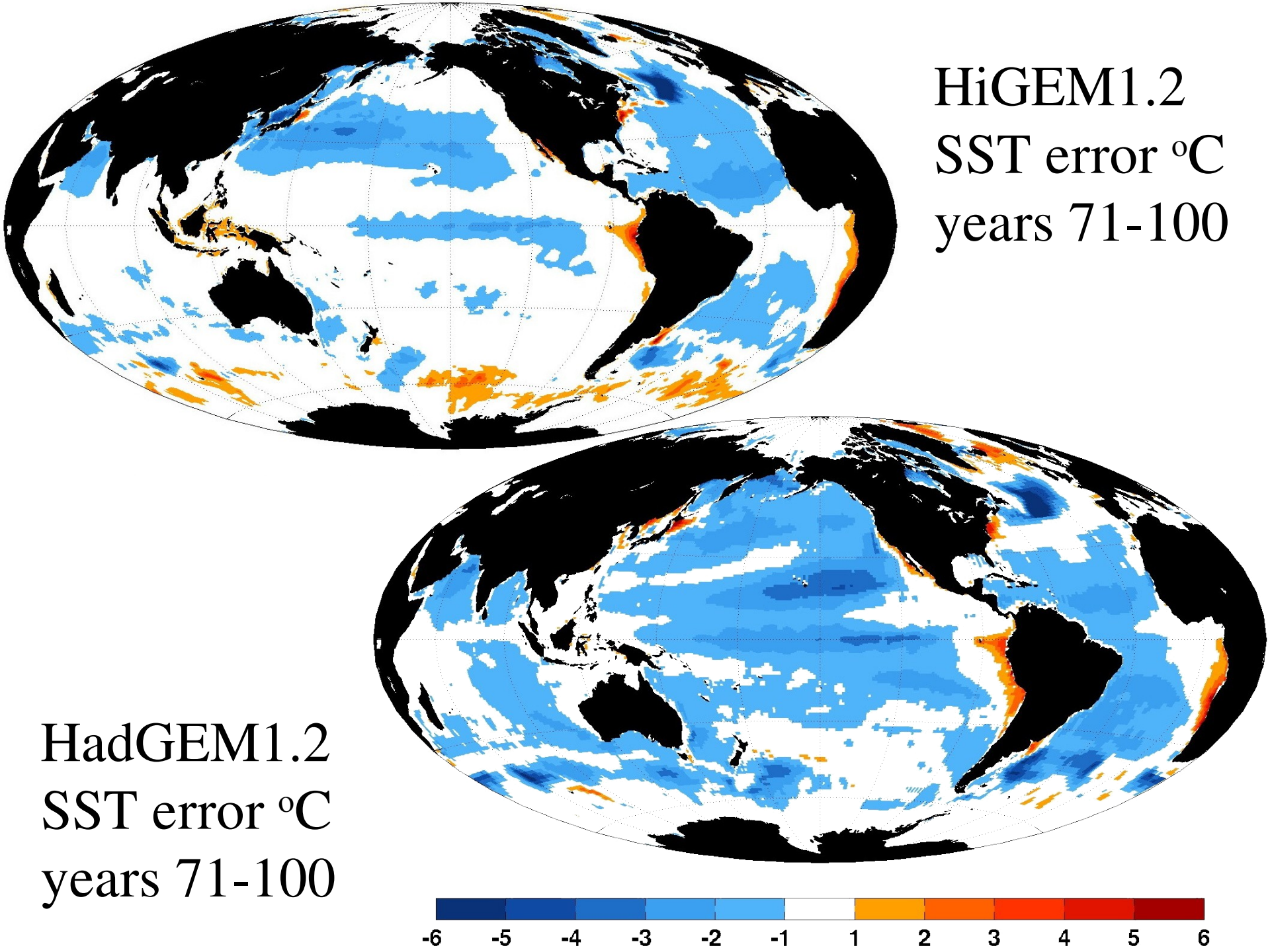
University of East Anglia

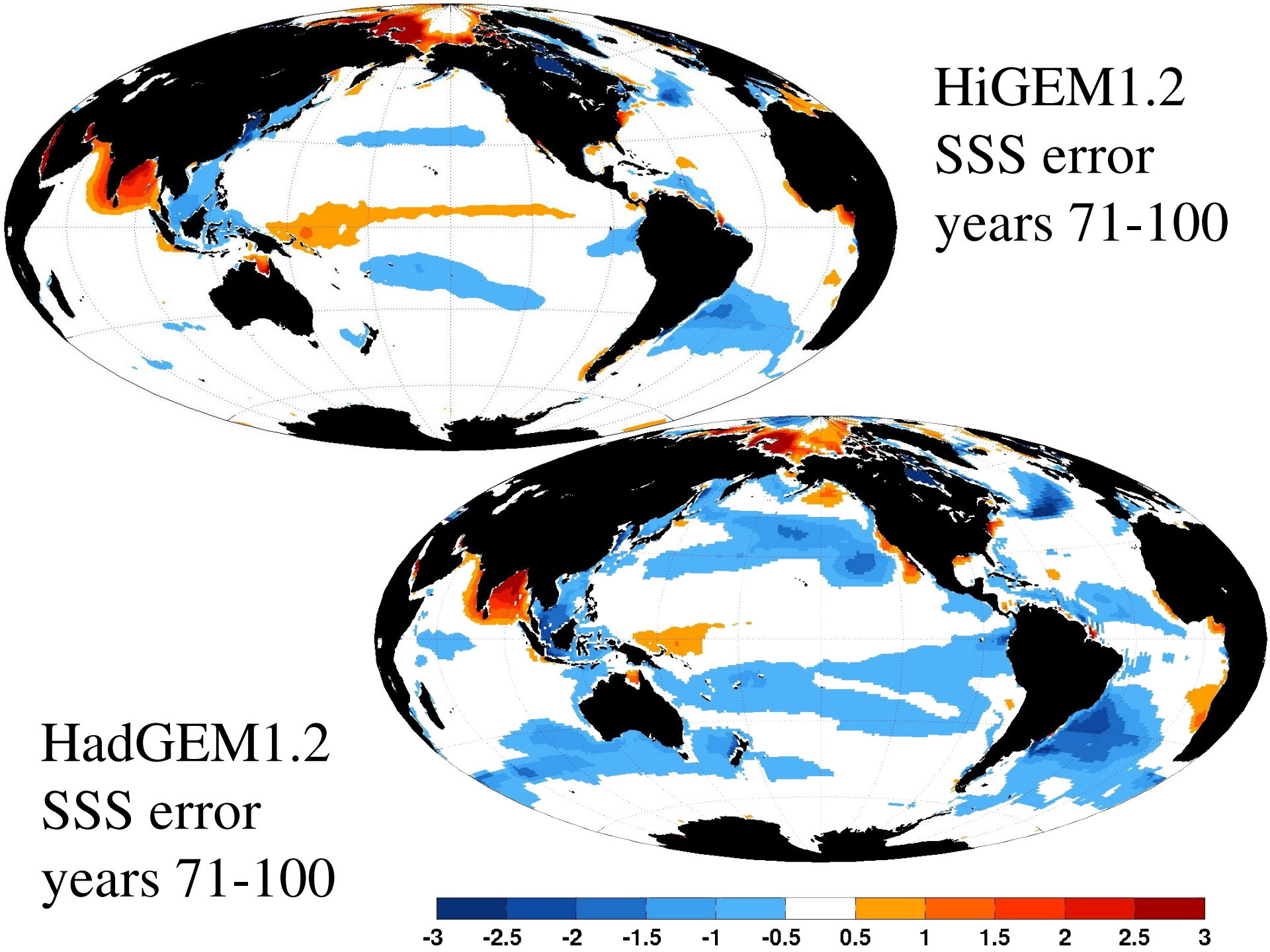


SST error: Decadal HadGEM2-ES – HadISST climatology

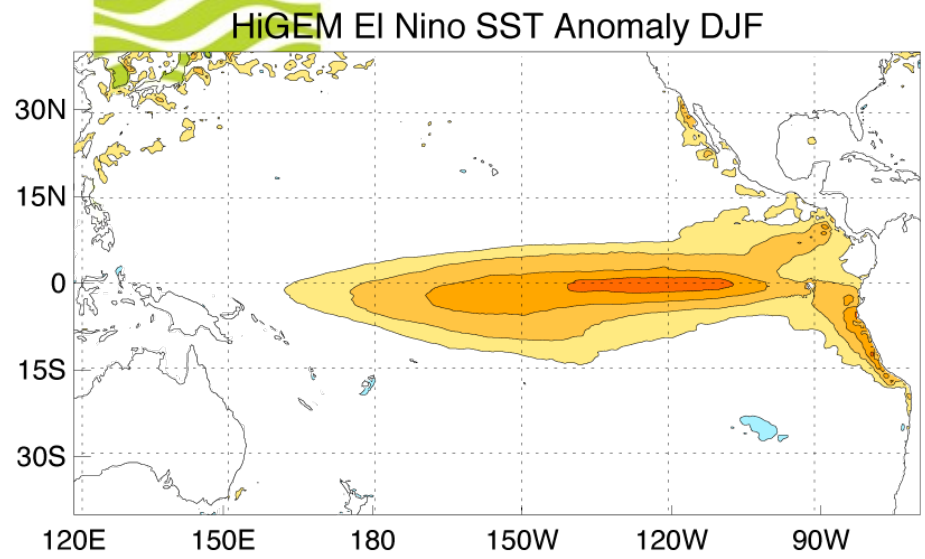
90N
45N
0
45S
90S
0
90E
180
90W

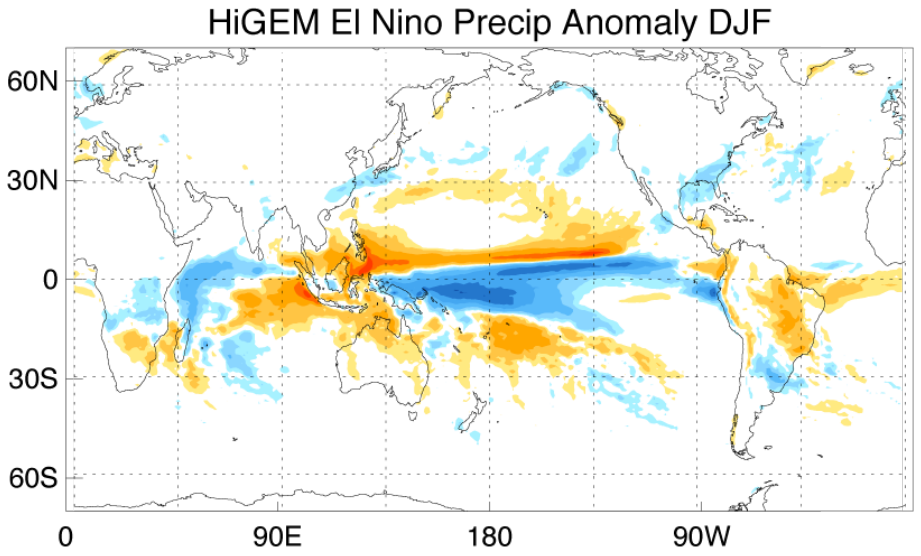
−2.7 −1.8 −0.9 0 0.9 1.8 2.7

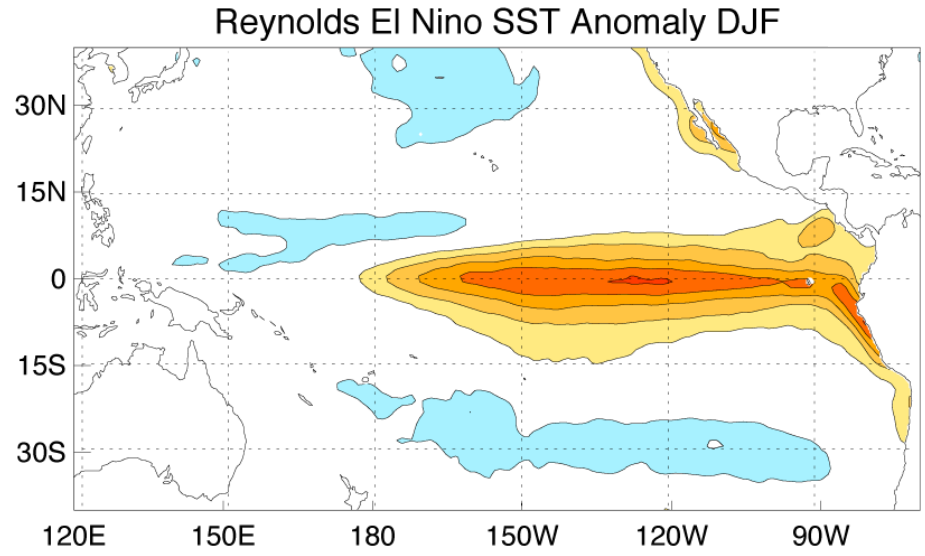

HiGEM1.2
SST error °C
years 71-100
HadGEM1.2
SST error °C
years 71-100
-6
-5
-4
-3
-2
-1
1
2
3
4
5
6

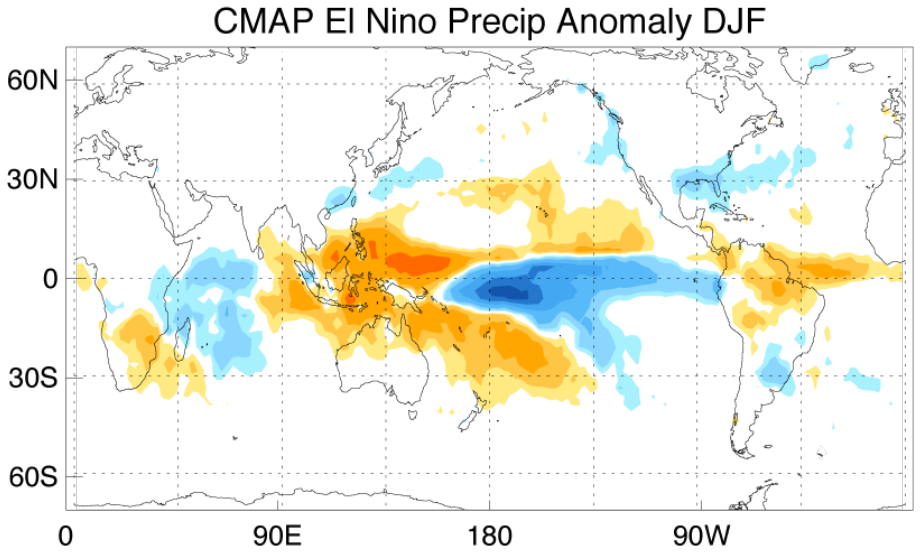

HiGEM1.2
SSS error
years 71-100
HadGEM1.2
SSS error
years 71-100
-3
-2.5
-2
-1.5
-1
-0.5
0.5
1
1.5
2
2.5
3

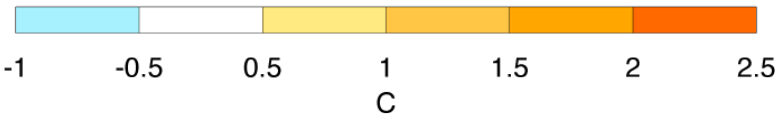
A composite ENSO

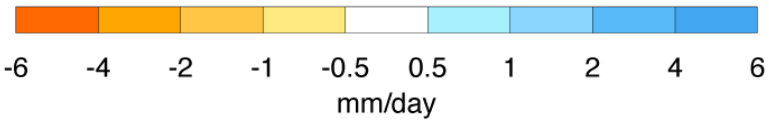








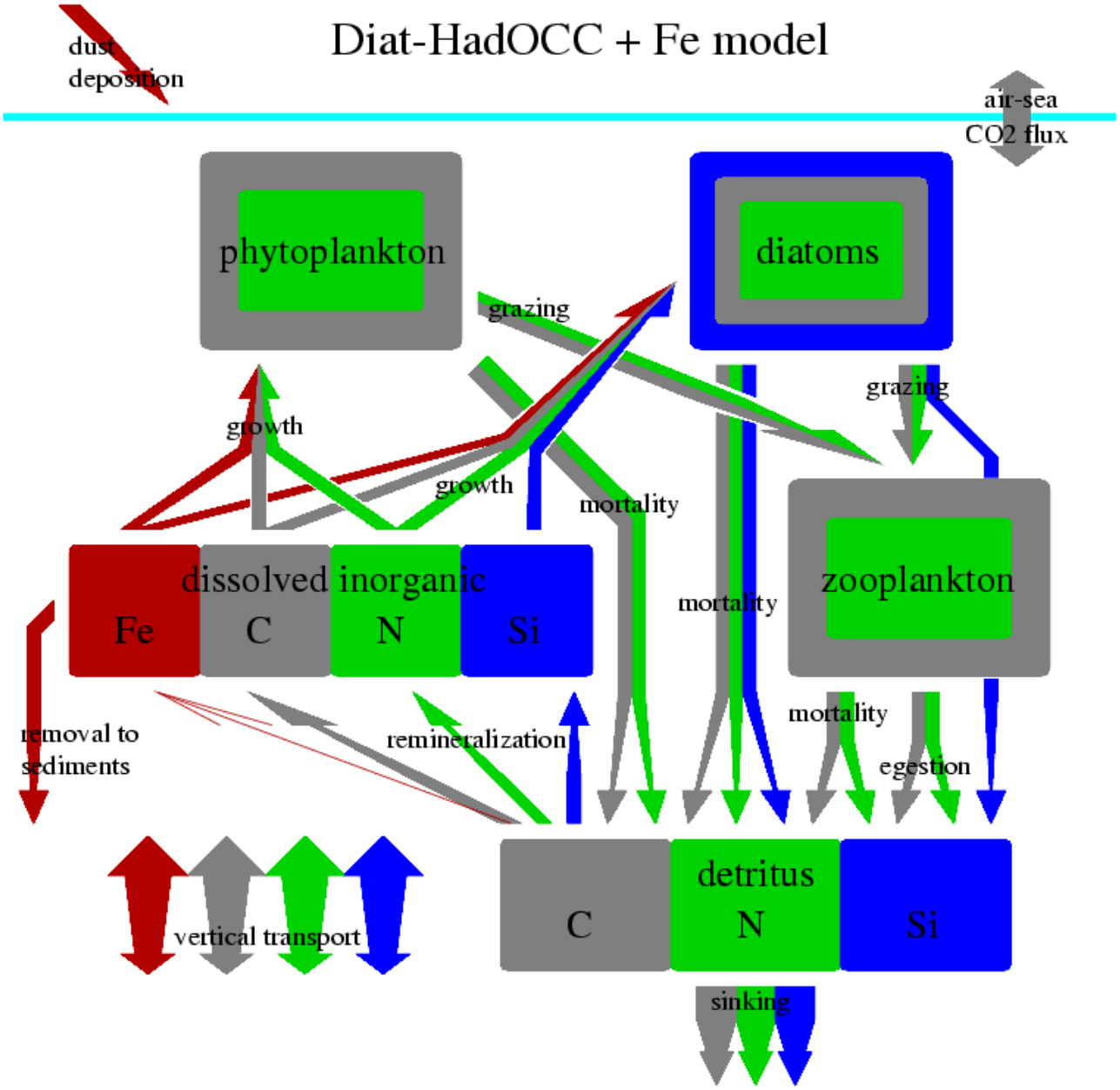




Ocean biogeochemistry model

Met Office

Diat-HadOCC + Fe model



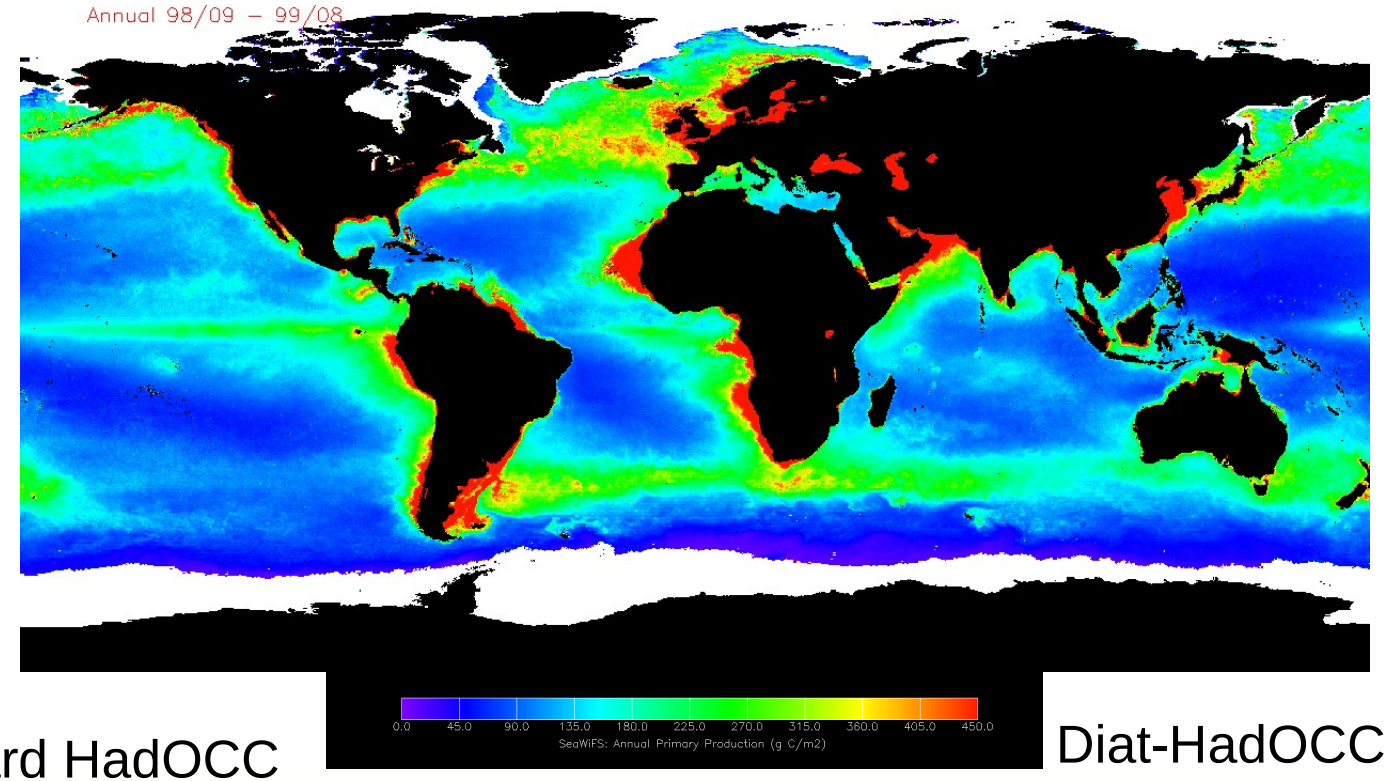
Courtesy Ian Totterdell

Met Office

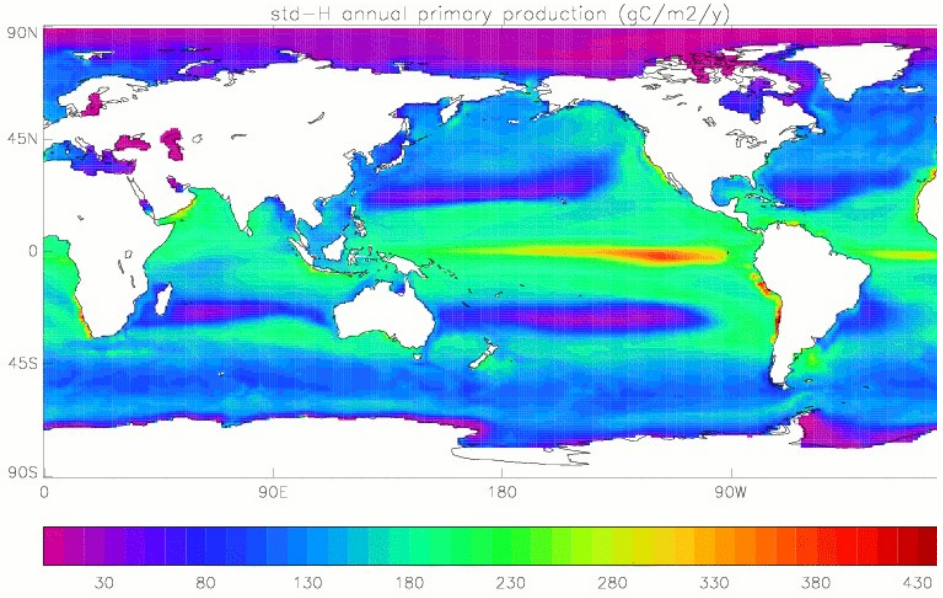
VGPM
(SeaWiFS)
Total: 50-60 GtC/y

Std-HadOCC
Total: 53 GtC/y

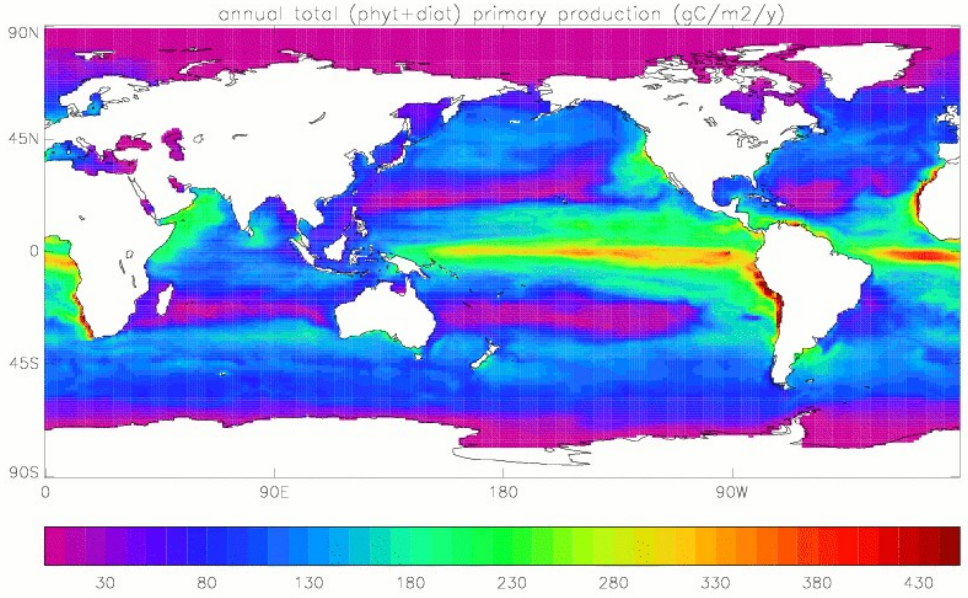
Diat-HadOCC
Total: 42.8 GtC/y



Standard HadOCC



Diat-HadOCC



Main issues for biology from ocean model

- Too much upwelling at equator
  - Too much biological production, and nutrient trapping
- North Atlantic loses nutrient too quickly in spring

Post-IPCC

- HadGEM3-AO

- A core coupled climate model able to be applied across a range of space and time scales, from seasonal and decadal forecasting to centennial climate predictions

- Consisting of
  - UM-Atmosphere (150km), NEMO ocean + CICE sea-ice models (on ORCA1 grid)
  - Coupled together using OASIS in a basic FLUME environment

- First application
  - Operational seasonal prediction model – April 2009

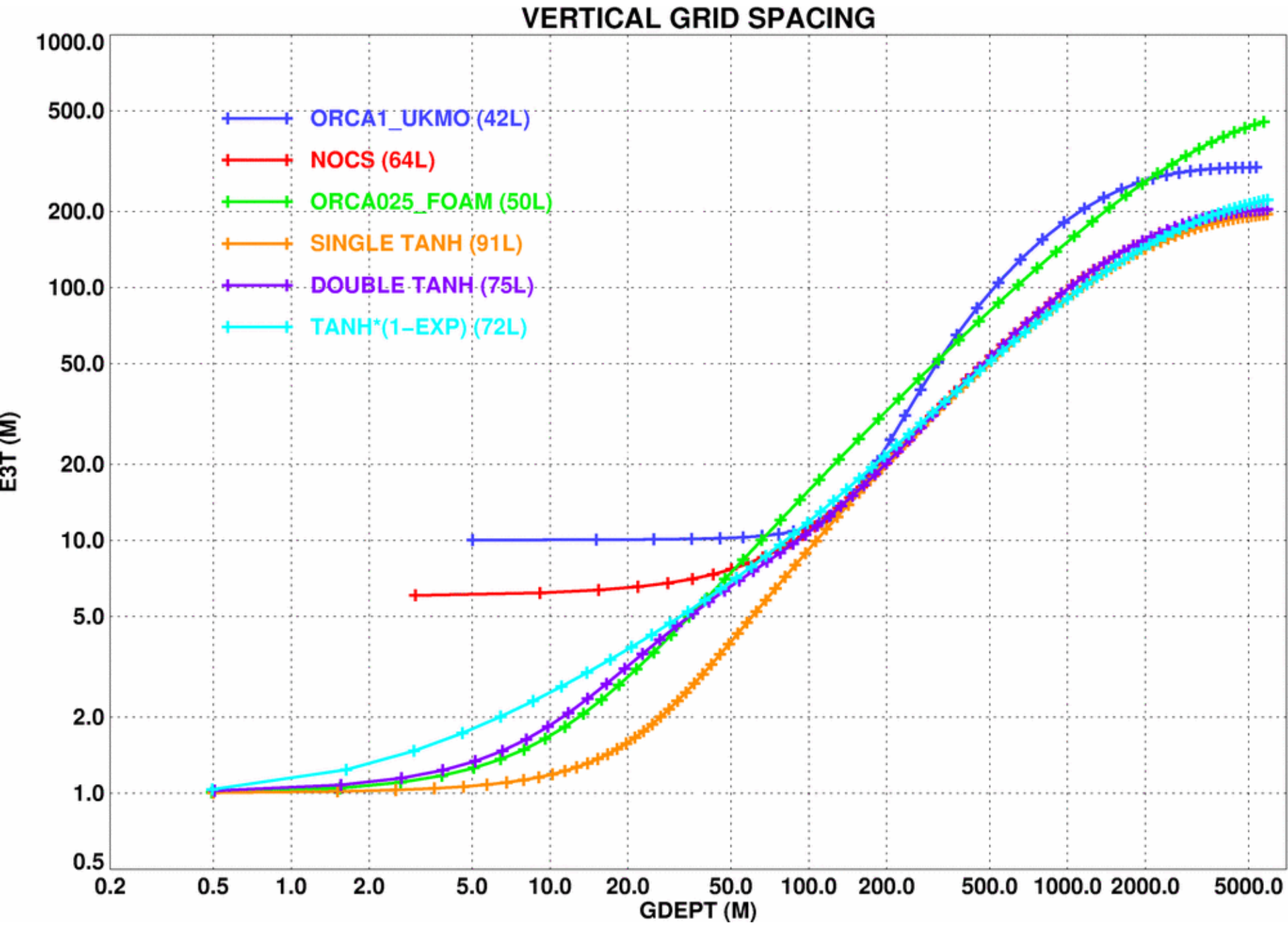
- For IPCC, will not be used before AR6

- Will eventually develop an Earth System version of this model

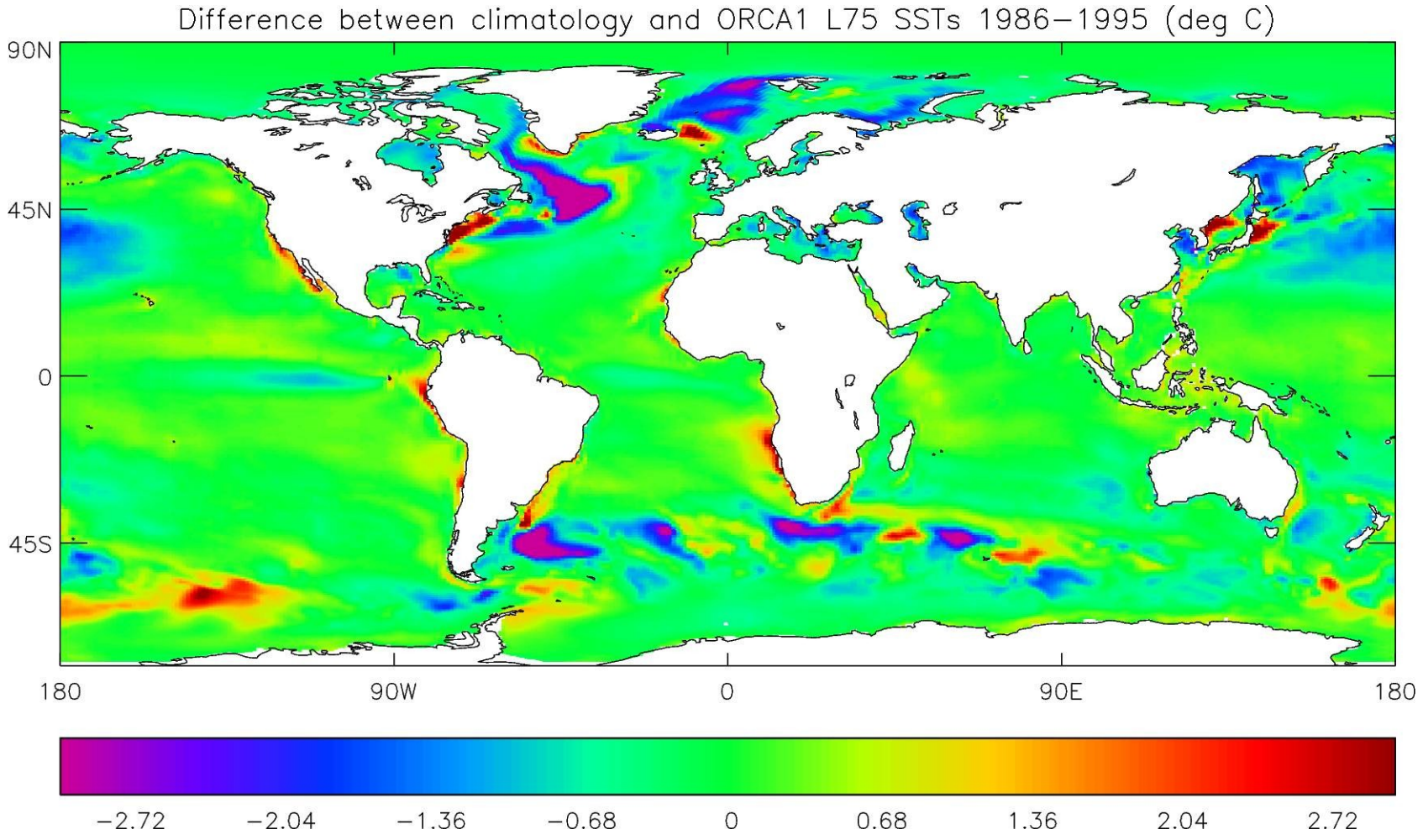
- Use it as the basis for a model hierarchy – to understand processes across a wide range of space and time scales
  - As part of the new Seamless Model Assessment (SMA) area (Keith Williams)

Post-IPCC

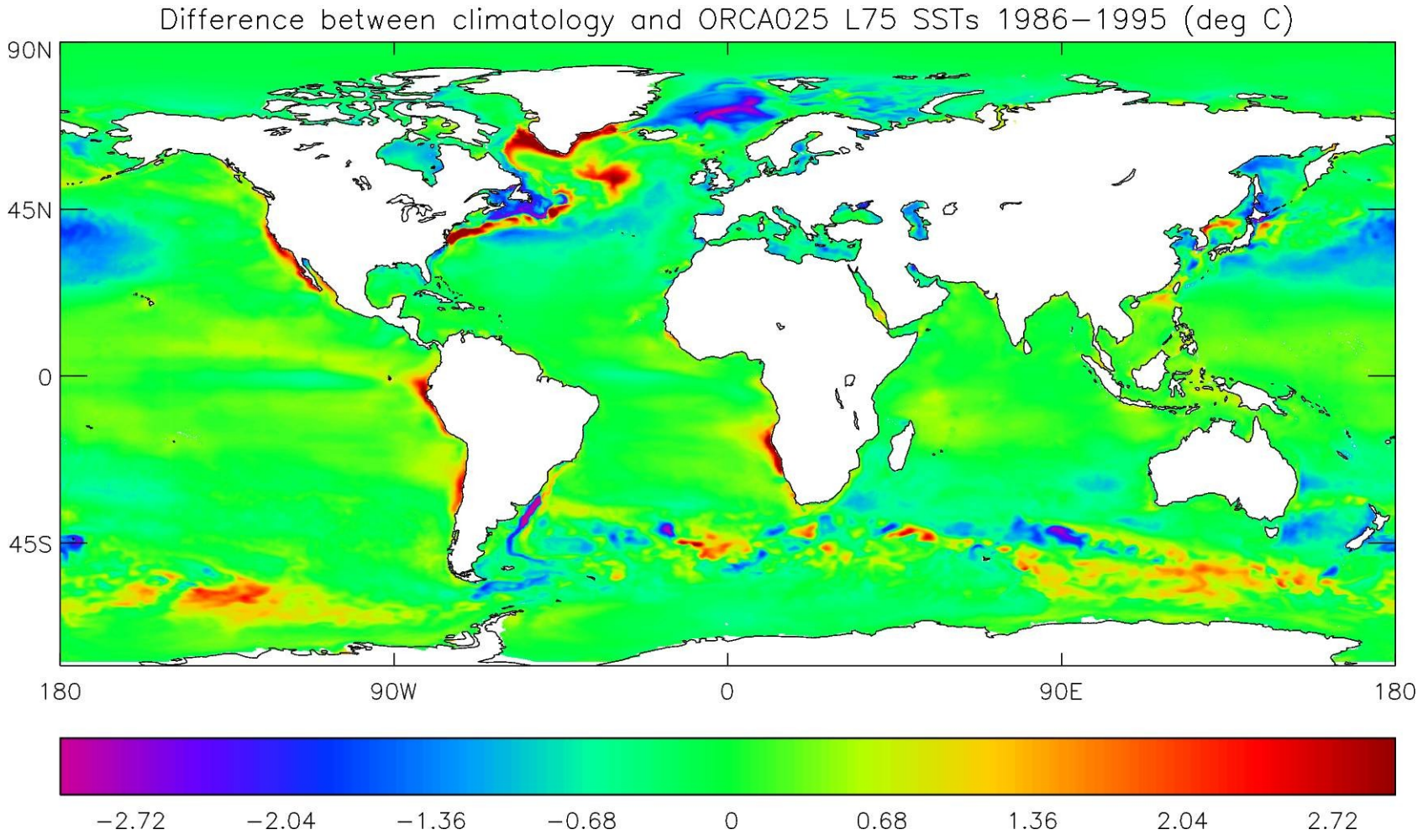
- HadGEM3-AO
  - Currently have resolutions ORCA1 and ORCA025
  - Coupled to 150km and 60km atmosphere models respectively
  - Agreed 75 z-level set with 1m thick top box and 3-hour coupling interval
  - Unifying UK model configurations used by NOCS (Southampton), ESSC (University of Reading), NCOF (Met Office) ocean forecasting model
  - Primary current use of model: seasonal forecasting system
  - Soon to use z* non-linear free surface
  - Also looking towards embedding sea-ice within ocean


VERTICAL GRID SPACING
ORCA1_UKMO (42L)
NOCS (64L)
ORCA025_FOAM (50L)
SINGLE TANH (91L)
DOUBLE TANH (75L)
TANH*(1-EXP) (72L)
E3T (M)
GDEPT (M)
1000.0
500.0
200.0
100.0
50.0
20.0
10.0
5.0
2.0
1.0
0.5
0.2
0.5
1.0
2.0
5.0
10.0
20.0
50.0
100.0
200.0
500.0
1000.0
2000.0
5000.0

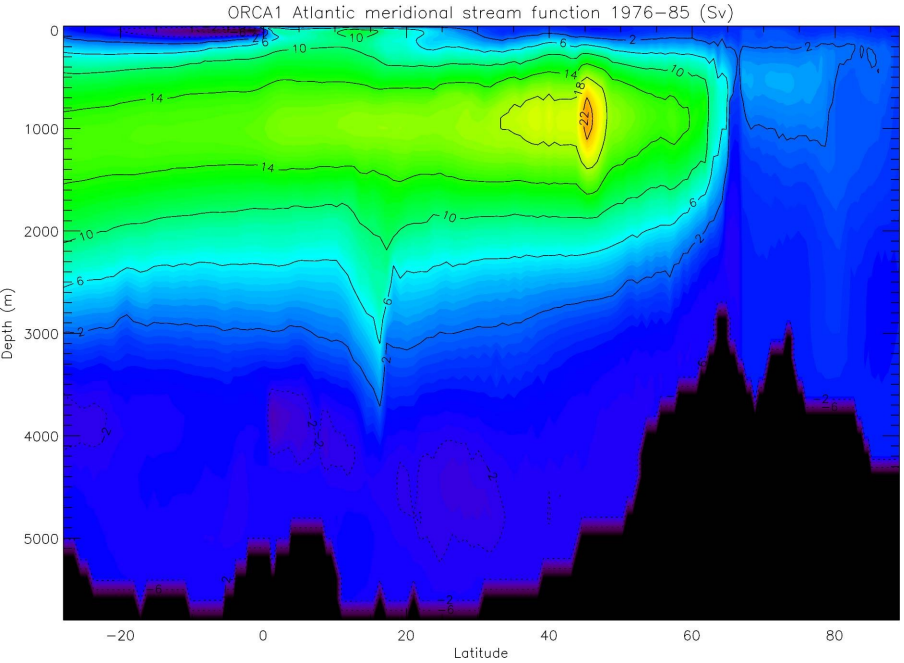
ORCA1 SST anomaly 1986-95, forced mode with DFS4.1 forcing

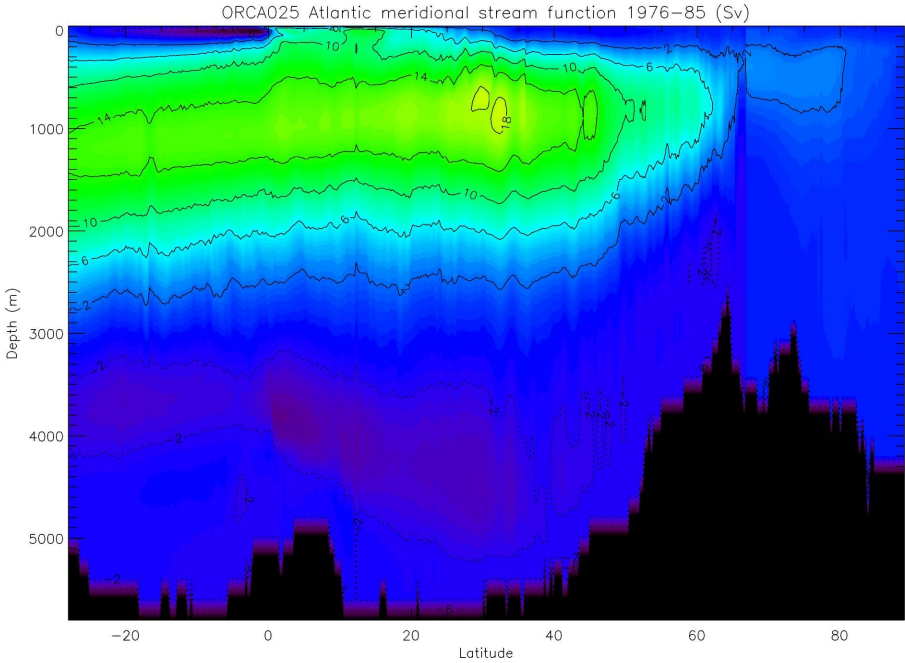


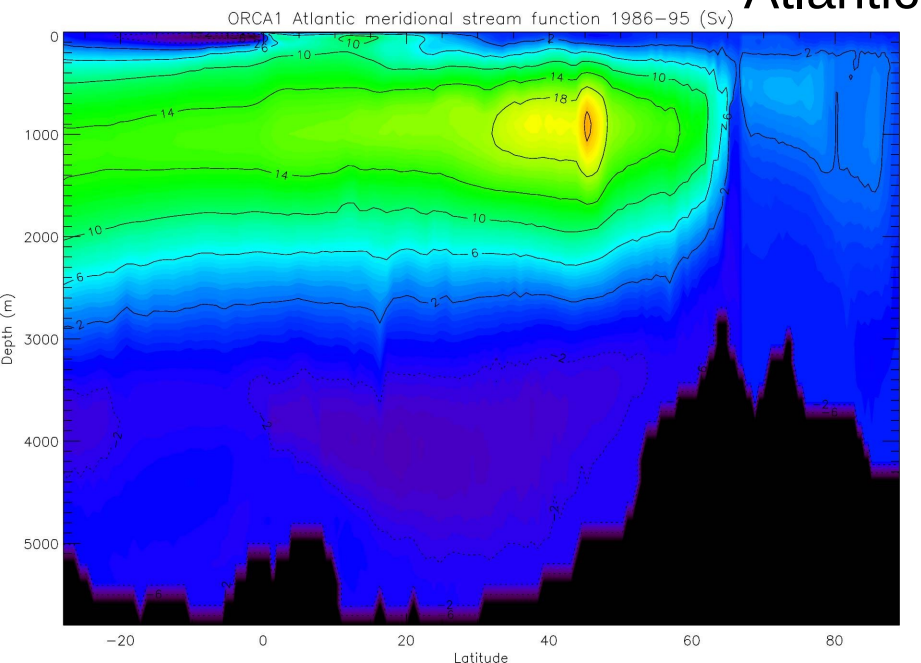
ORCA025 SST anomaly 1986-95, forced mode with DFS4.1 forcing

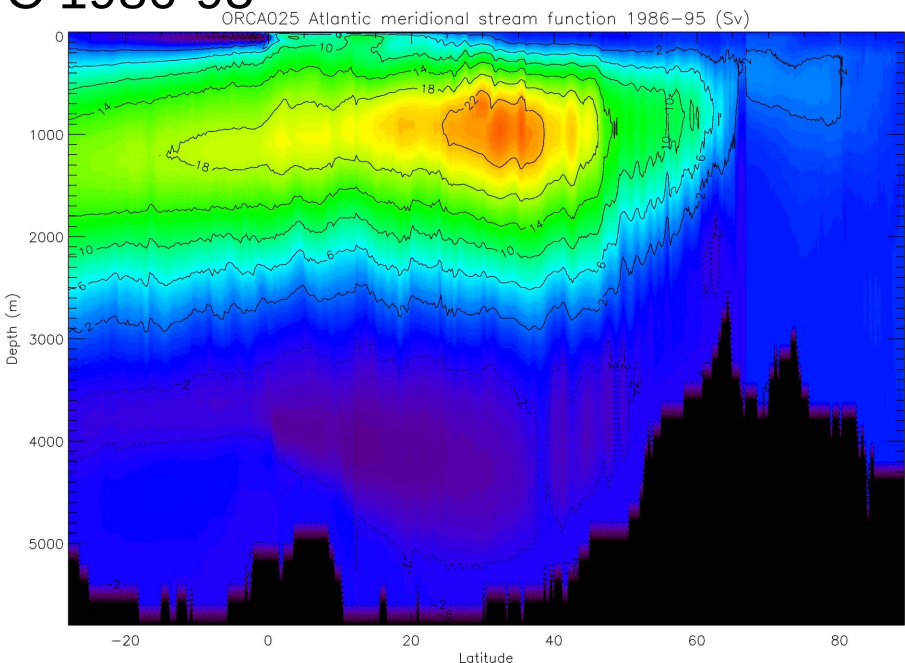


Atlantic MOC 1986-95









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Questions