REVISITING TIDAL MIXING PARAMETERIZATIONS IN POP2

(work in progress)

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As part of our CPT on Internal Wave Mixing activities:

- Incorporating new developments in tidal mixing parameterizations,
- Assessing their impacts on ocean and climate model solutions.

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Existing Formulation in POP2
[based on Jayne & St. Laurent (2001, GRL); St. Laurent et al. (2002, GRL); Simmons et al. (2004, Ocean Modelling)]

Vertical diffusivity due to background and tidal mixing:

$$k_v = k_{\mathrm{bg}} + \frac{\Gamma \varepsilon}{N^2}$$

where *N*: buoyancy frequency,

Γ (=0.2): canonical mixing efficiency of turbulence.

$$\varepsilon = \frac{q E(x, y) F(z, H)}{\rho}$$

where q (=1/3): local dissipation efficiency,

ρ: density,

E: energy flux out of the barotropic tide,

F: vertical distribution (decay) function

$$F(z, H) = \frac{e^{-(H-z)/\zeta}}{\zeta(1 - e^{-H/\zeta})}$$

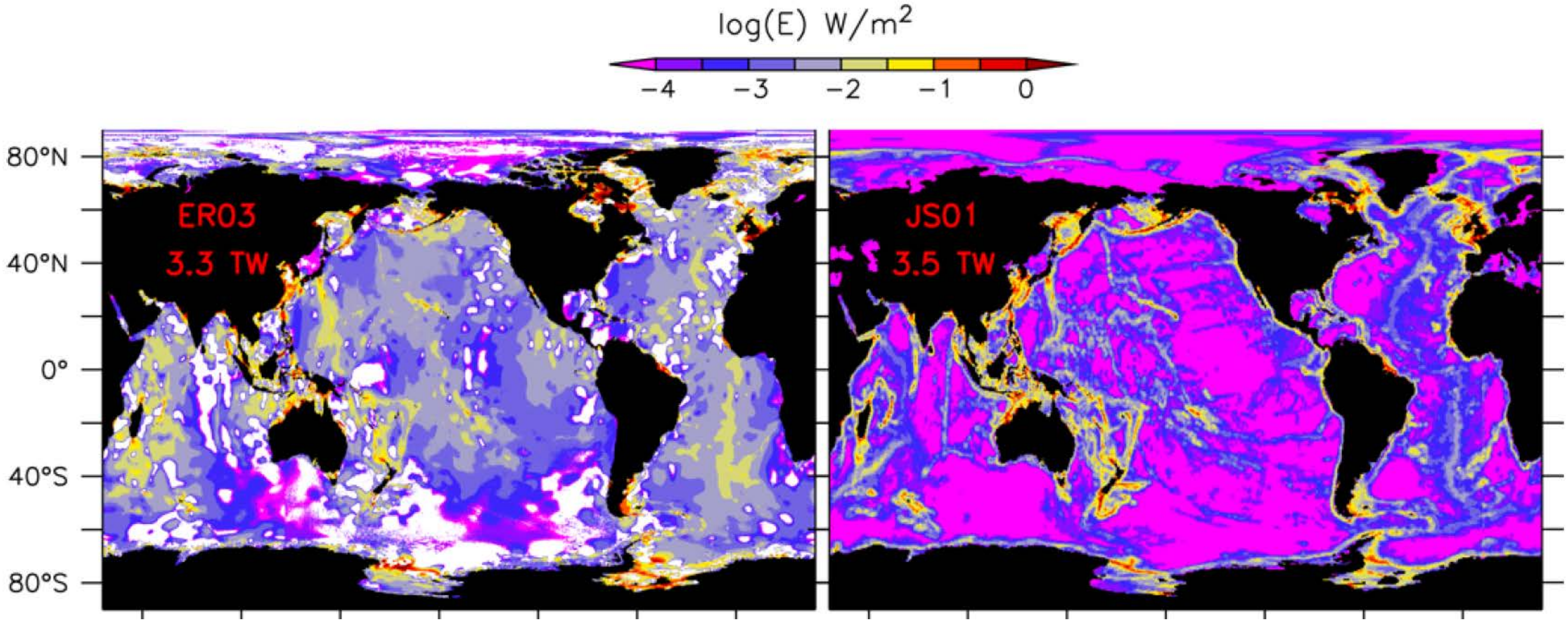
with ζ = 500 m

Modifications

We consider three modifications based on Schmittner & Egbert (2014, GMD). They are …

- A new energy flux field from the barotropic tide from Egbert & Ray (2003, GRL),
- Consideration of subgrid-scale bathymetry in the energy flux field,
- Separation of semi-diurnal and diurnal tides with different local dissipation efficiency.

Total Energy Flux from the Barotropic Tide



Estimated from assimilation of satellite altimetry data into a hydrodynamic model; 4 tidal constituents

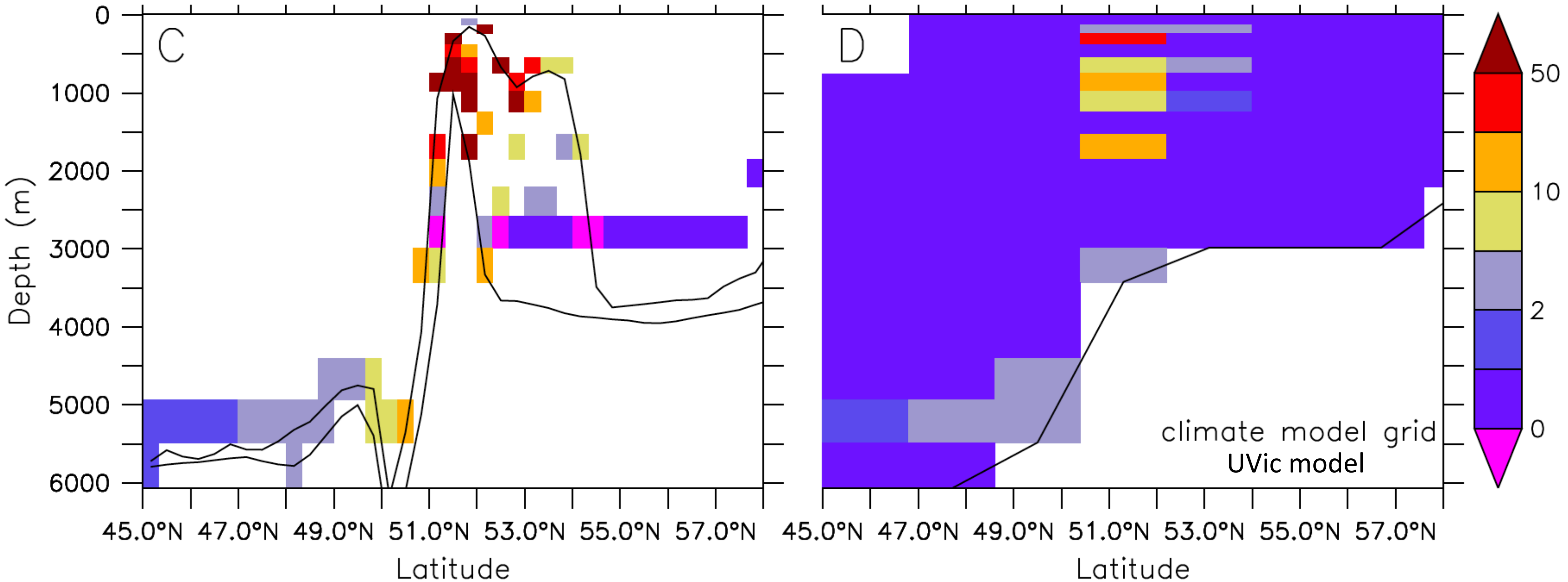
Estimated using a barotropic tide model with parameterized internal wave drag; 8 tidal constituents

JS01: Jayne & St. Laurent (2001, GRL)
ER03: Egbert & Ray (2003, GRL)

Schmittner & Egbert (2014, GMD)

Subgrid-Scale Bathymetry
An example using the Aleutian Islands chain

Energy flux from the K1 barotropic tide (10^{-3} W m^{-2})



Schmittner & Egbert (2014, GMD)

Tidal Constituents (TCs)

Four TCs:

- Semi-diurnal lunar and solar tides, M2 and S2, respectively, with $q = 1/3$,
- Diurnal tides K1 and O1 with $q = 1$ polewards of 30^{o} latitude

$$\varepsilon = \frac{1}{\rho} \sum_{z' > z}^{H} \sum_{\mathrm{TC}} q_{\mathrm{TC}} E_{\mathrm{TC}}(x, y, z') F(z, z')$$

Regularization of Tidal Diffusivities

$$k_v = k_{\mathrm{bg}} + \frac{\Gamma \varepsilon}{N^2}$$

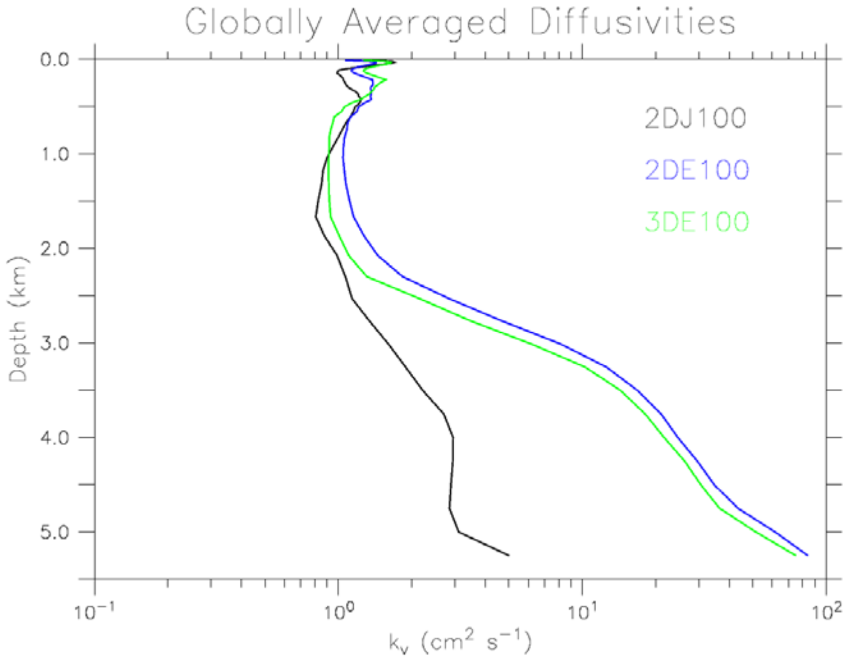
- Limit minimum value of N^2, e.g., 10^{-8} s^{-2}
- Limit k_v using $k_v = \min(k_v, k_{max})$, e.g., $k_{max} = 100$ cm^2 s^{-1}
- Limit both

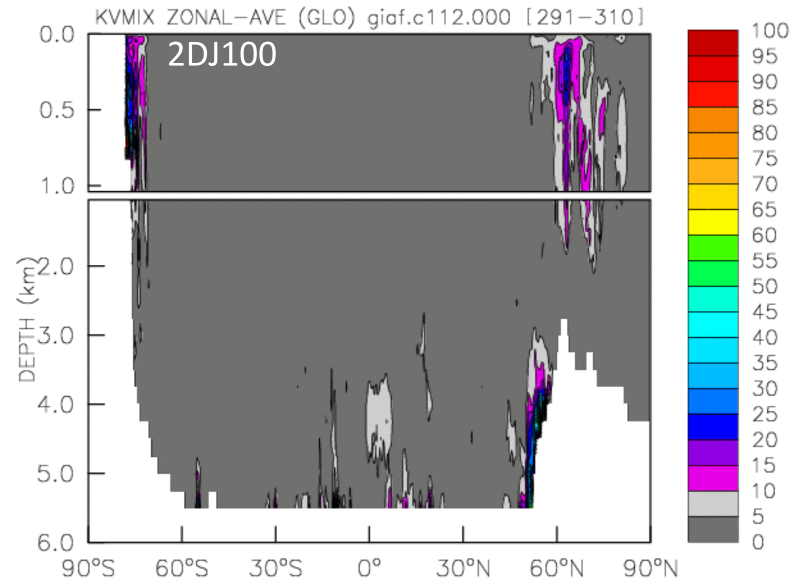
Model Simulations

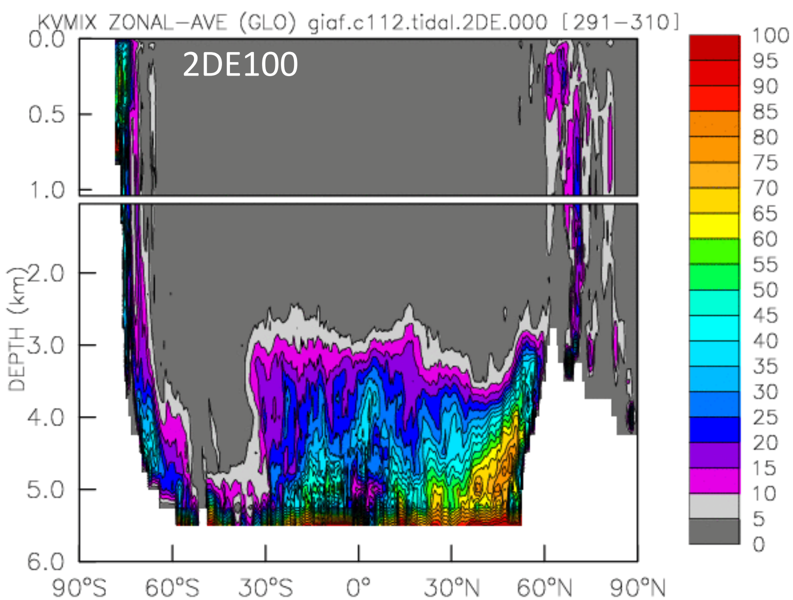
- Ocean – sea-ice coupled simulations (G compset) forced with the Coordinated Ocean – ice Reference Experiments inter-annually varying atmospheric data sets (aka, CORE-II simulations);
- 310-year experiments corresponding to five repeat cycles of the 1948-2009 forcing period;
- Time series and 1990-2009 mean fields.

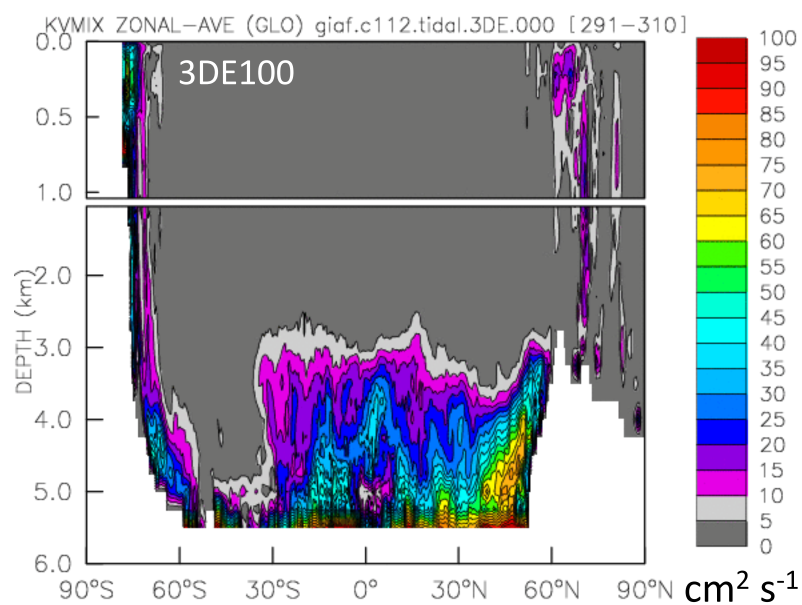
Case name	2D vs. 3D	Energy Field	limit on k_v ($cm^2\ s^{-1}$)
2DJ100	2D	JS01	100
2DE100	2D	ER03	100
3DE100	3D	ER03	100

Tidal + Background Vertical Diffusivity

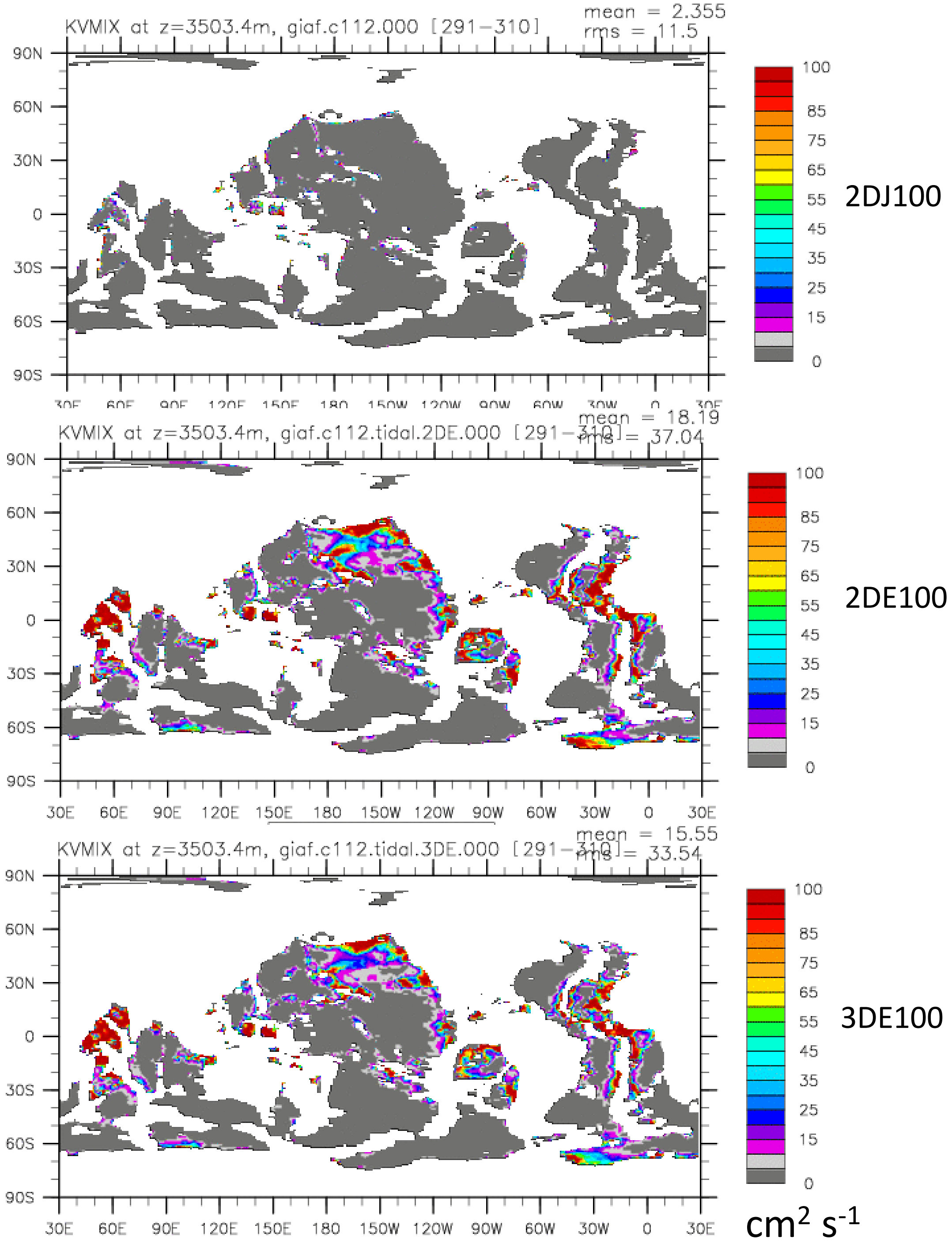




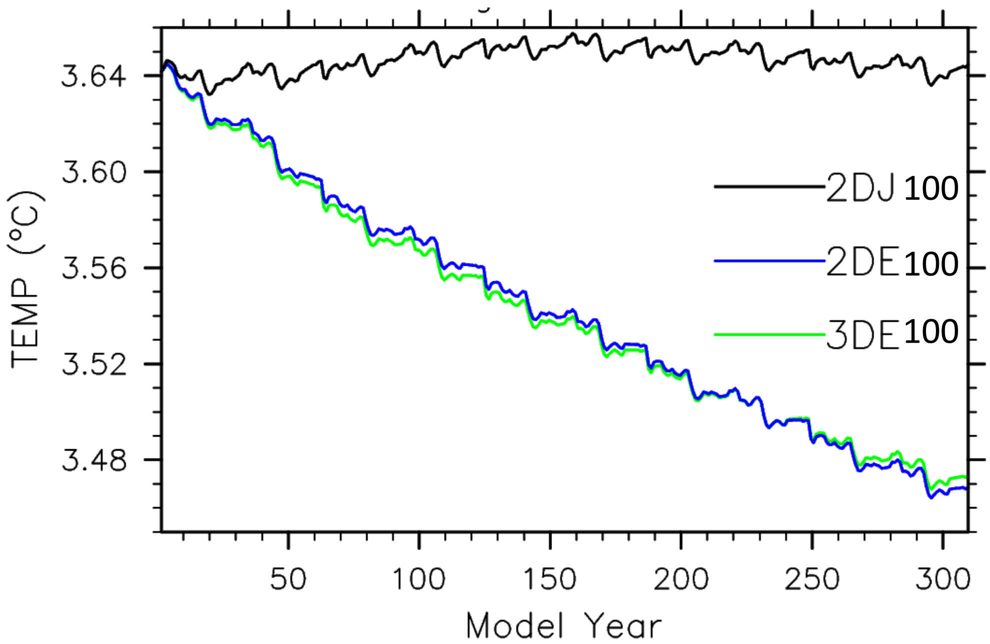




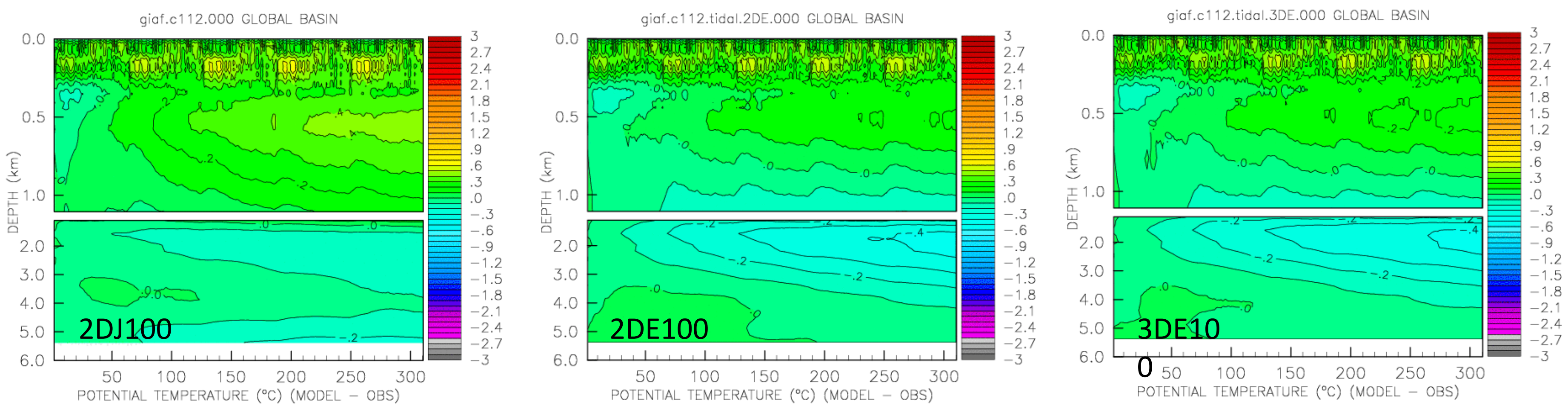
k_v at 3500 m depth



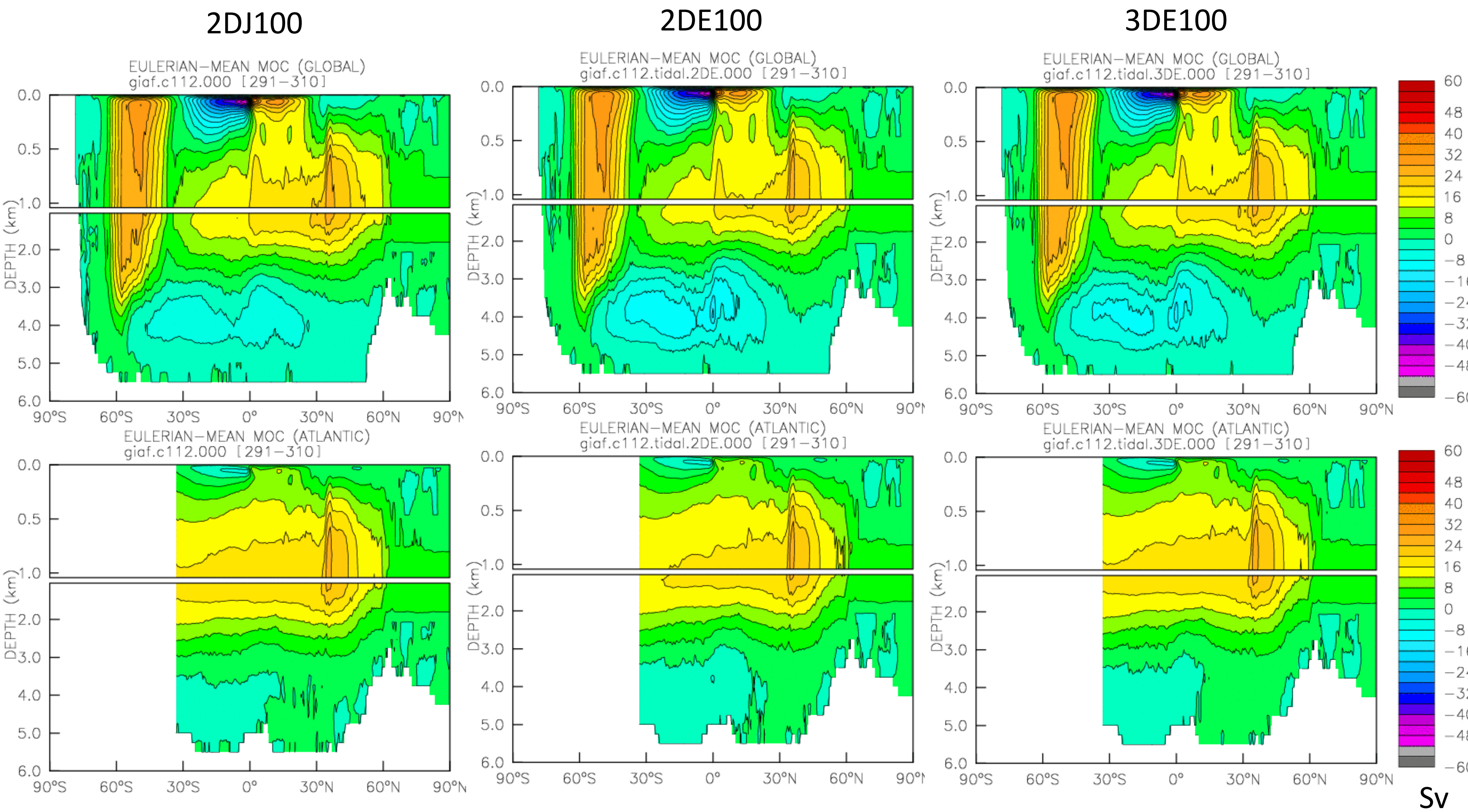
Global-mean Potential Temperature



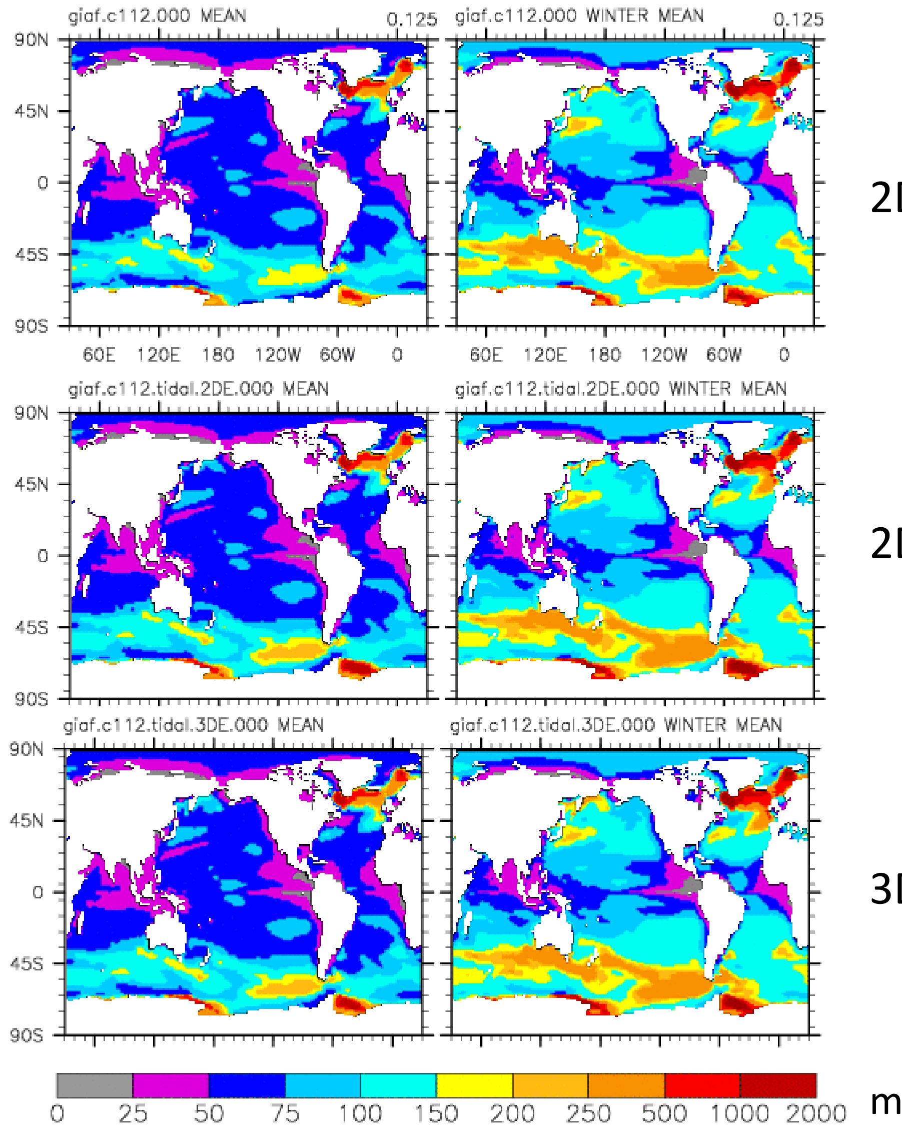
Horizonal-Mean Potential Temperature Model – Observation Differences (Global)



Global and Atlantic Meridional Overturning Streamfunction



Mixed Layer depth

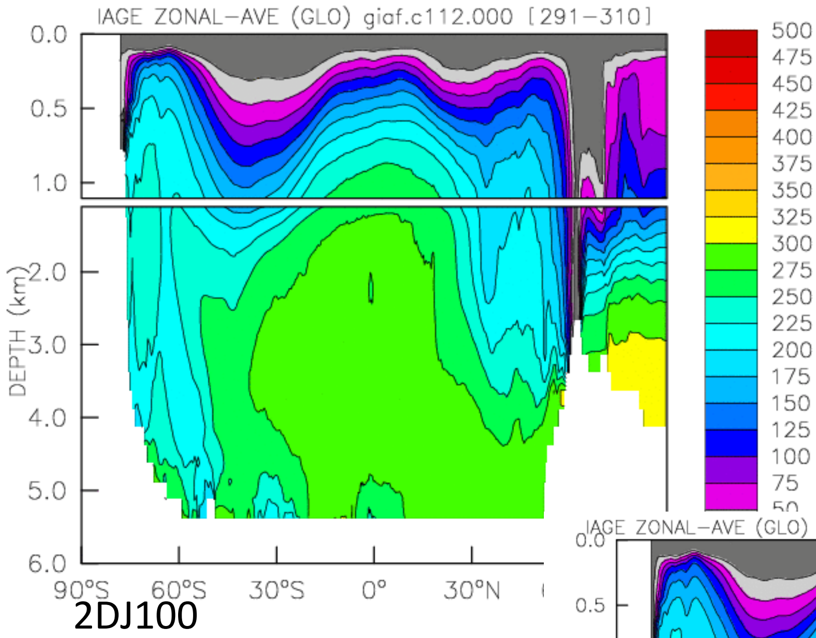


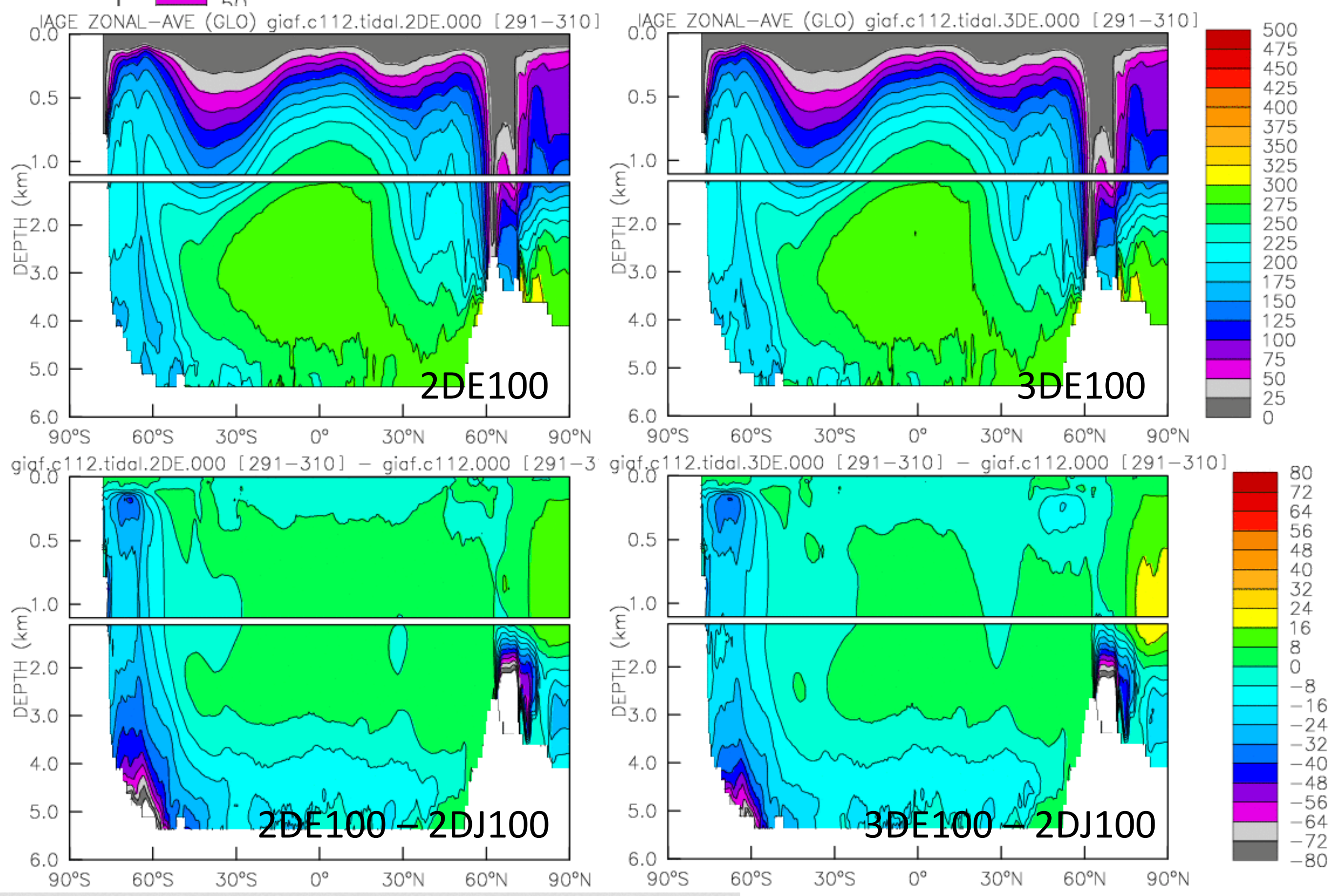
2DJ100

2DE100

3DE100

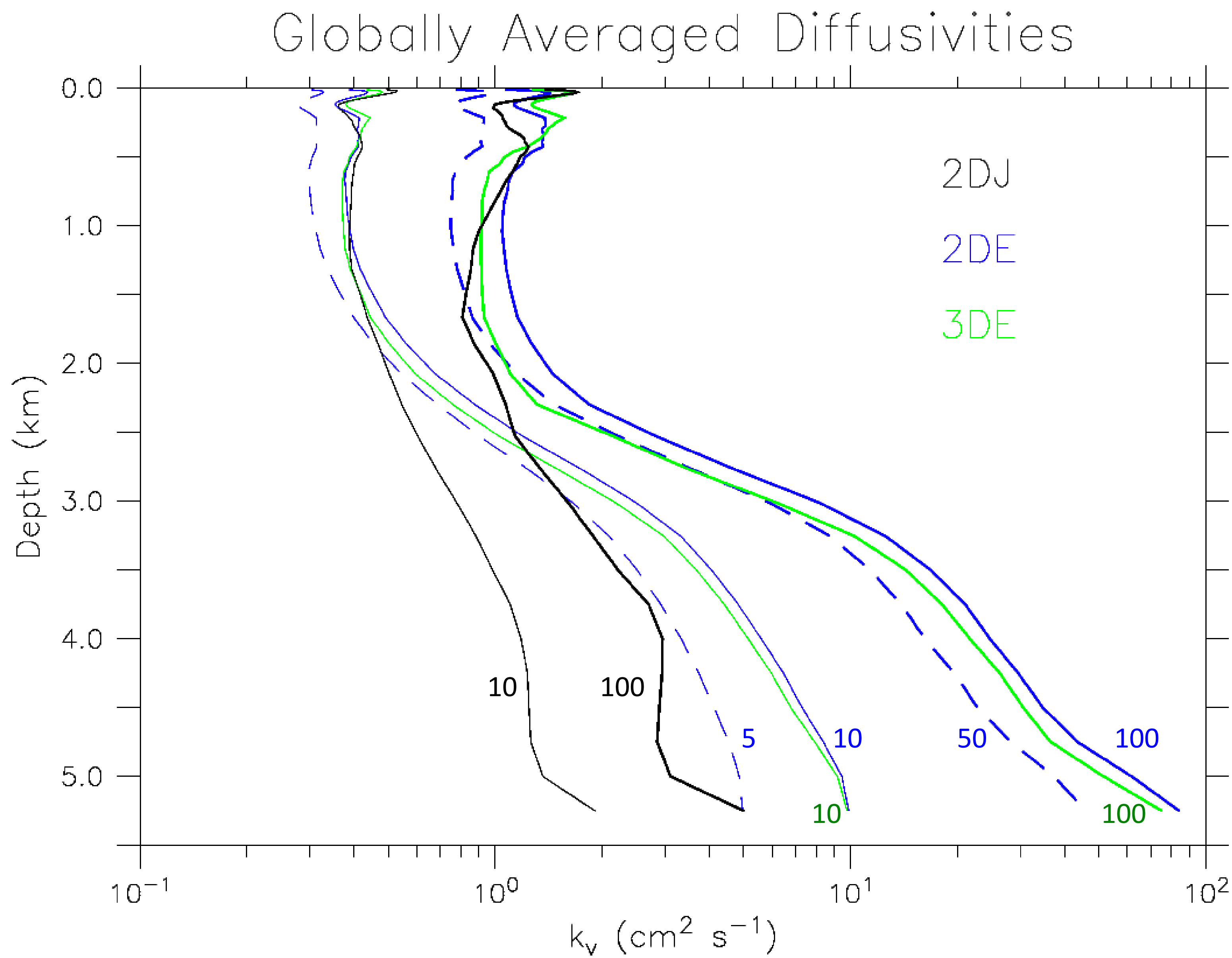
Zonal-Mean Ideal Age (yr)





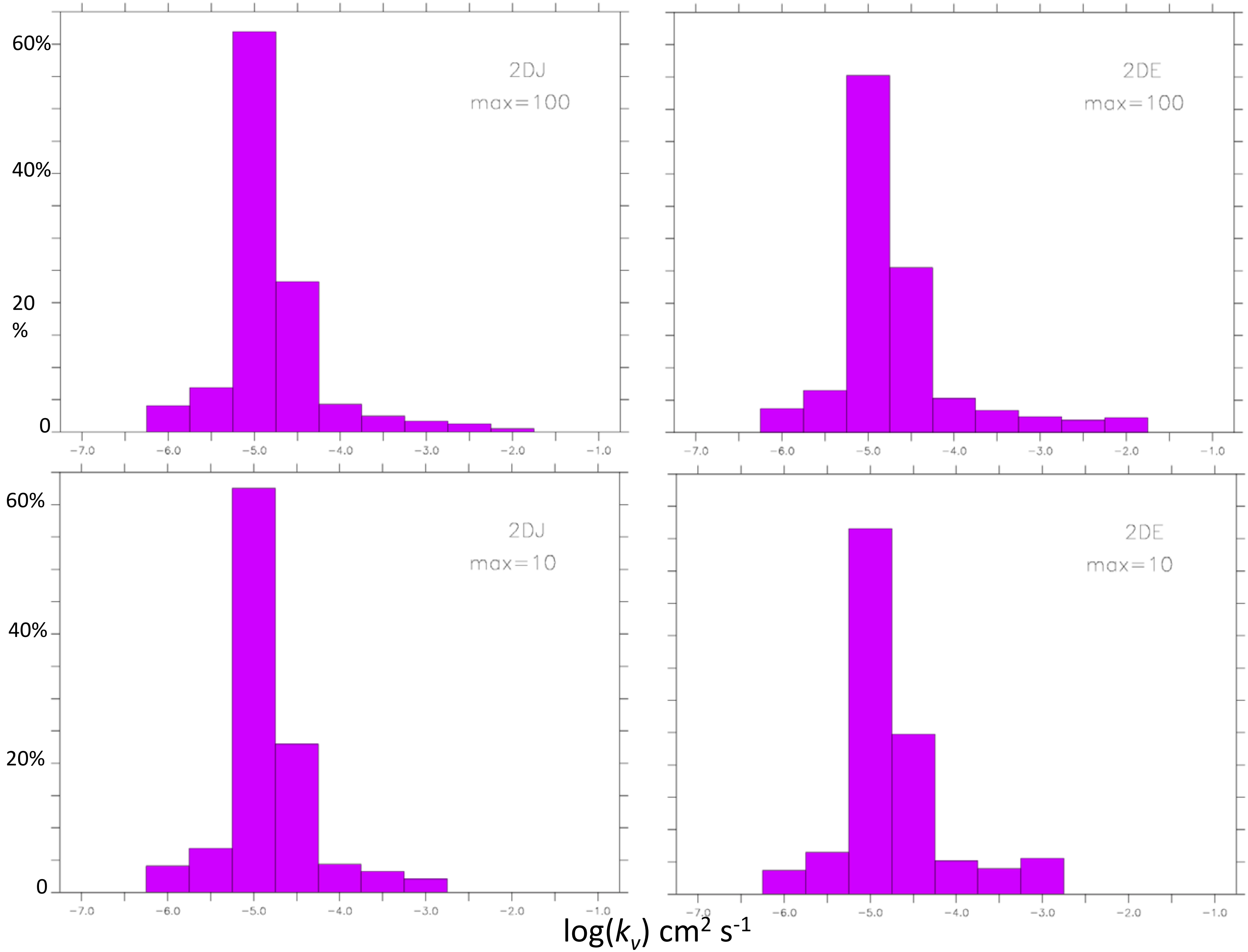
Sensitivity Experiments

Case name	2D vs. 3D	Energy Field	limit on k_v ($cm^2\ s^{-1}$)
2DJ100	2D	JS01	100
2DE100	2D	ER03	100
3DE100	3D	ER03	100
2DJ10	2D	JS01	10
2DE50	2D	ER03	50
2DE10	2D	ER03	10
2DE5	2D	ER03	5
3DE10	3D	ER03	10

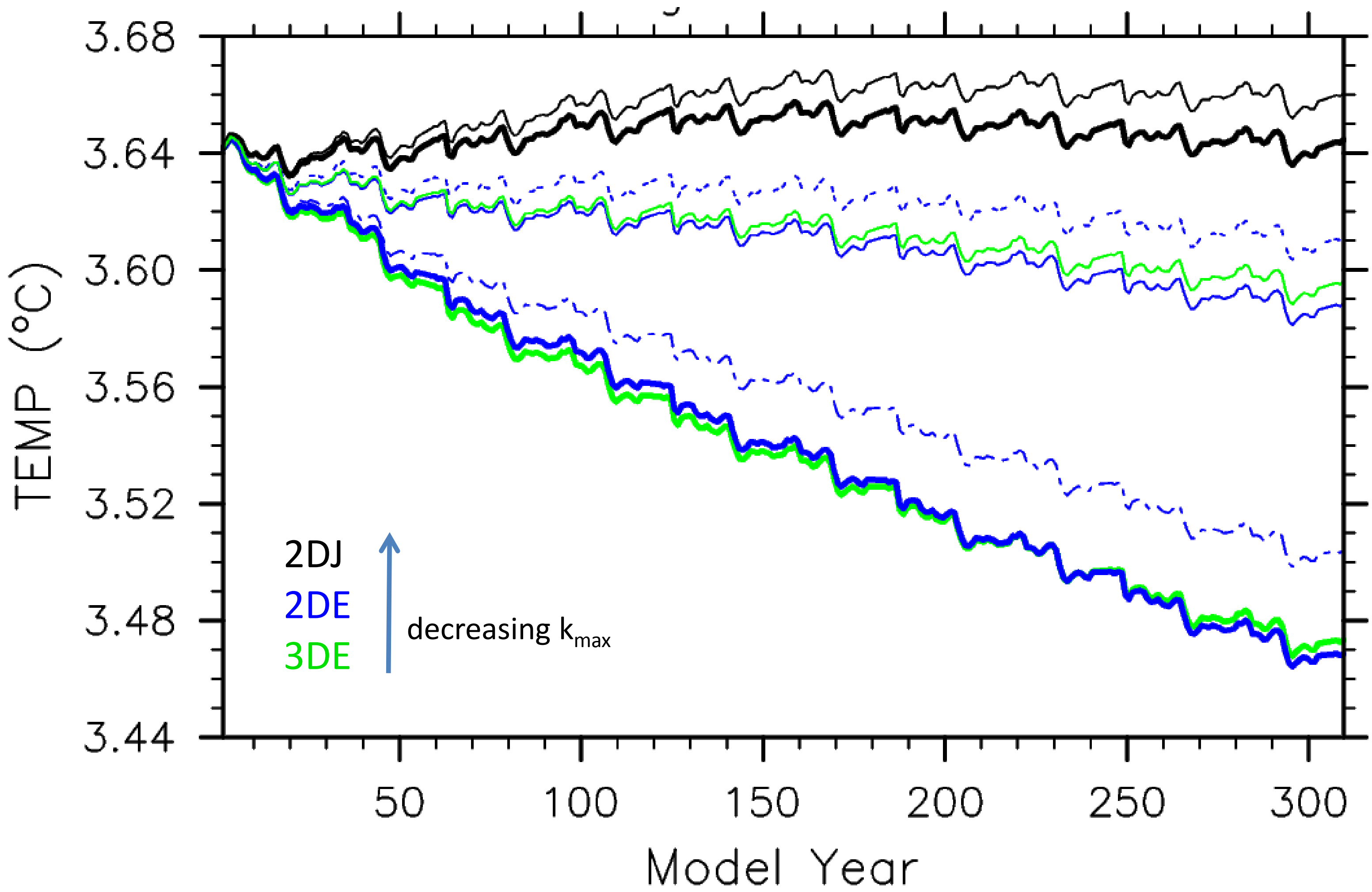


Globally Averaged Diffusivities
2DJ
2DE
3DE
Depth (km)
0.0
1.0
2.0
3.0
4.0
5.0
10
100
5
10
50
100
10
100
10^{-1}
10^{0}
10^{1}
10^{2}
k_v (cm^2 s^{-1})

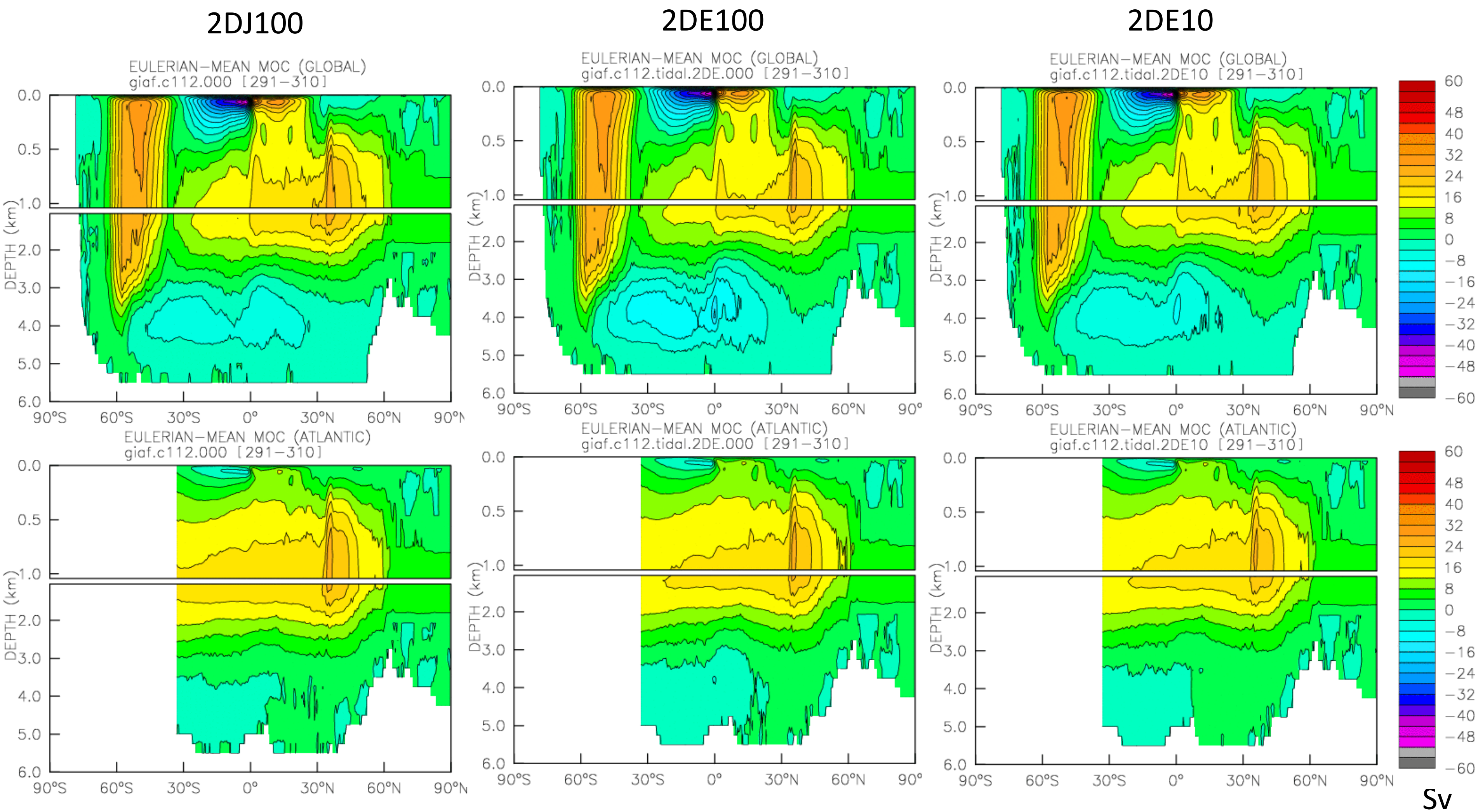
Distribution of k_v (as % of grid points)



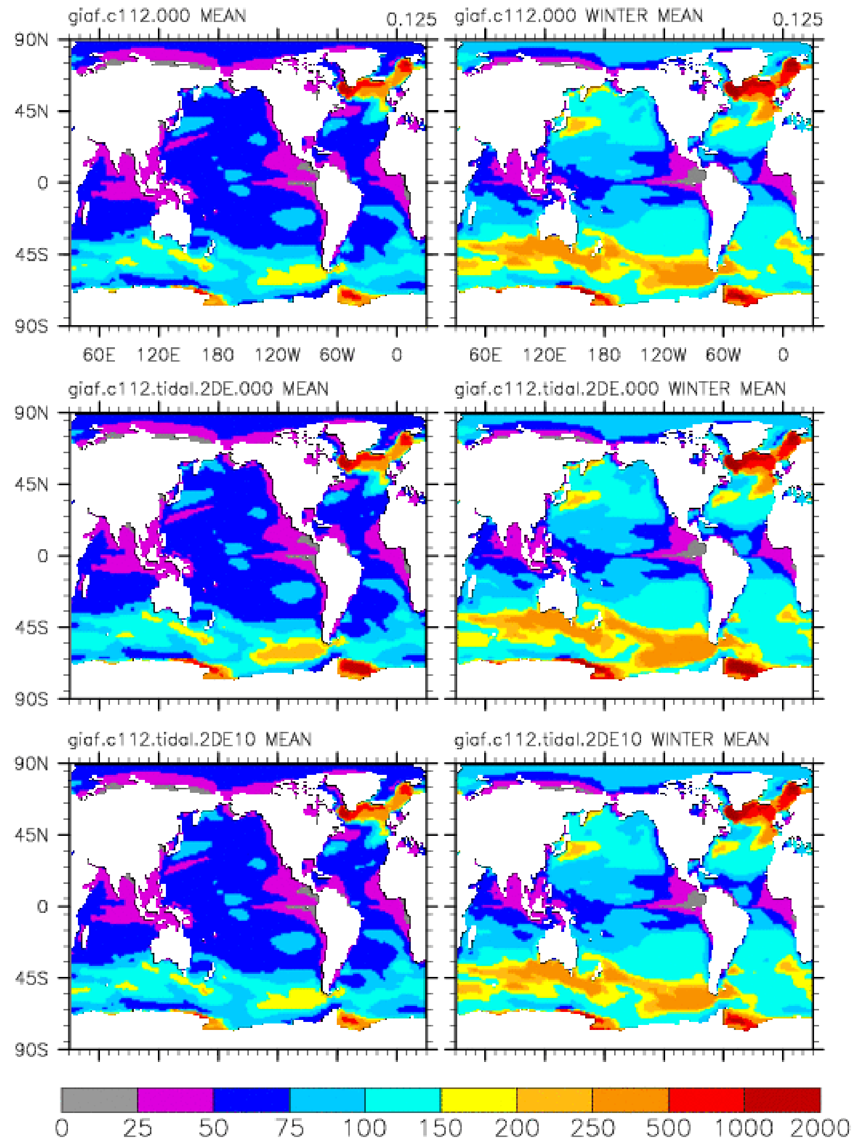
Global-mean Potential Temperature



Global and Atlantic Meridional Overturning Streamfunction



Mixed Layer depth



2DJ100

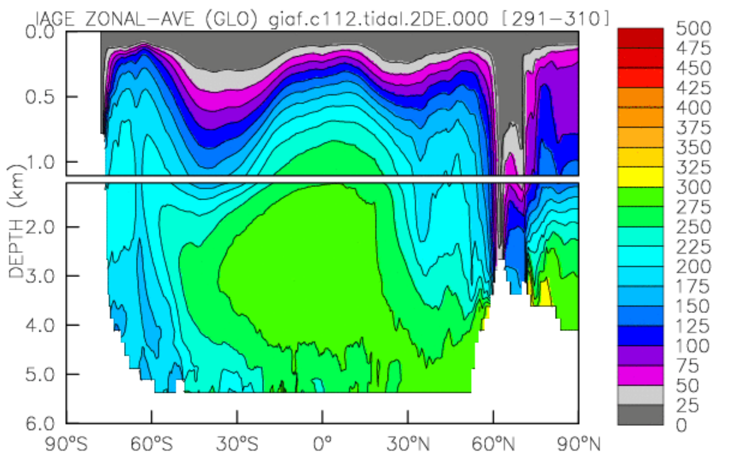
2DE100

2DE10

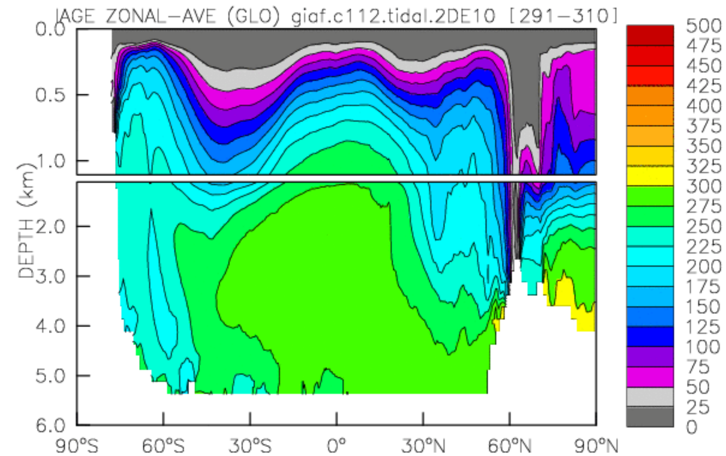
m

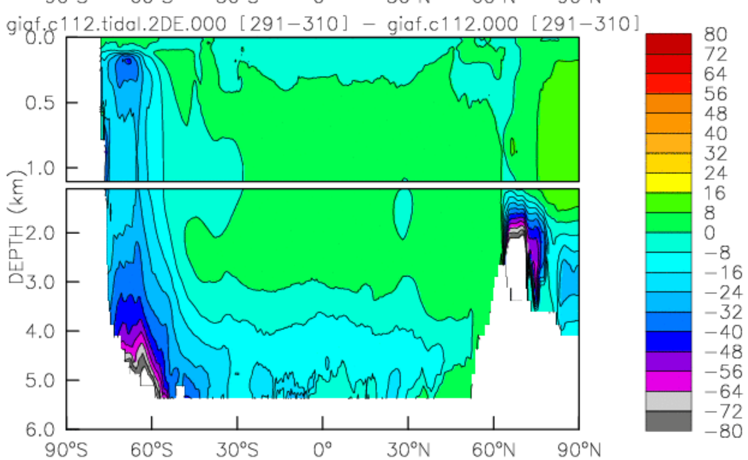
Zonal-Mean Ideal Age (yr)

2DE100

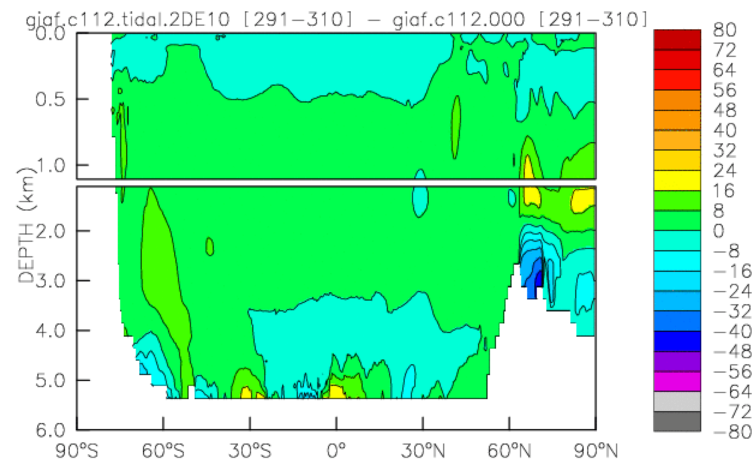


2DE10





2DE100 – 2DJ100



2DE10 – 2DJ100

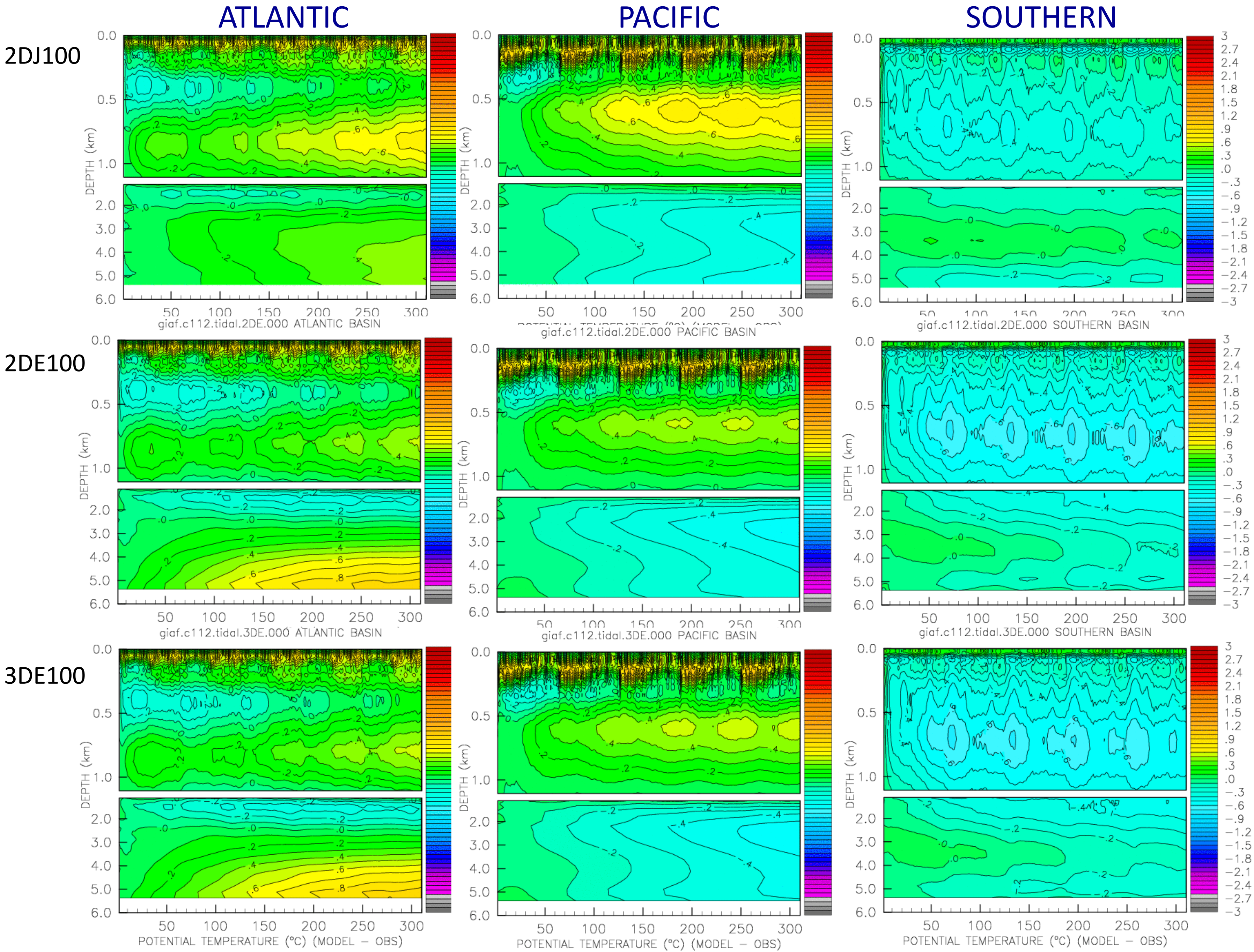
Summary

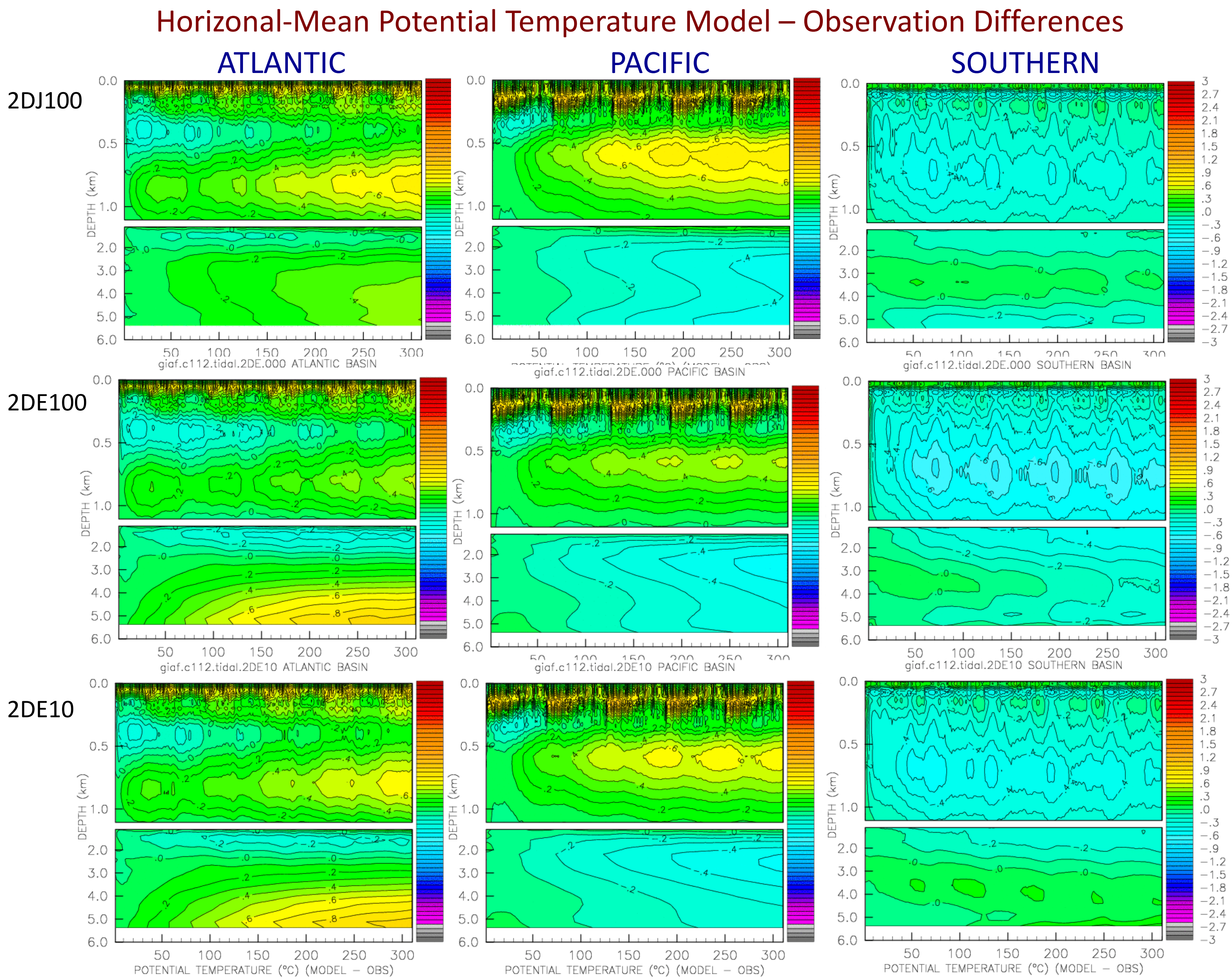
- Work in progress ….
- Very uncomfortable sensitivities to regularization
- More detailed assessment to come

Other related work:

- Infrastructure to use time varying tidal forcing, e.g., Lunar Nodal Cycle of 18.6 years
- Alternative tidal dissipation energy fields, e.g., Green & Nycander (2013), Arbic et al. (2015+)
- Alternative vertical decay function, i.e., Polzin (2009) via Melet et al. (2013)

Horizonal-Mean Potential Temperature Model – Observation Differences





Horizontal-Mean Potential Temperature Model – Observation Differences
ATLANTIC
PACIFIC
SOUTHERN
2DJ100
2DE100
2DE10
DEPTH (km)
giaf.c112.tidal.2DE.000 ATLANTIC BASIN
giaf.c112.tidal.2DE.000 PACIFIC BASIN
giaf.c112.tidal.2DE.000 SOUTHERN BASIN
giaf.c112.tidal.2DE10 ATLANTIC BASIN
giaf.c112.tidal.2DE10 PACIFIC BASIN
giaf.c112.tidal.2DE10 SOUTHERN BASIN
POTENTIAL TEMPERATURE (°C) (MODEL – OBS)

Horizontal-Mean Potential Temperature Model – Observation Differences (Global)