Modeling Tidal Mixing

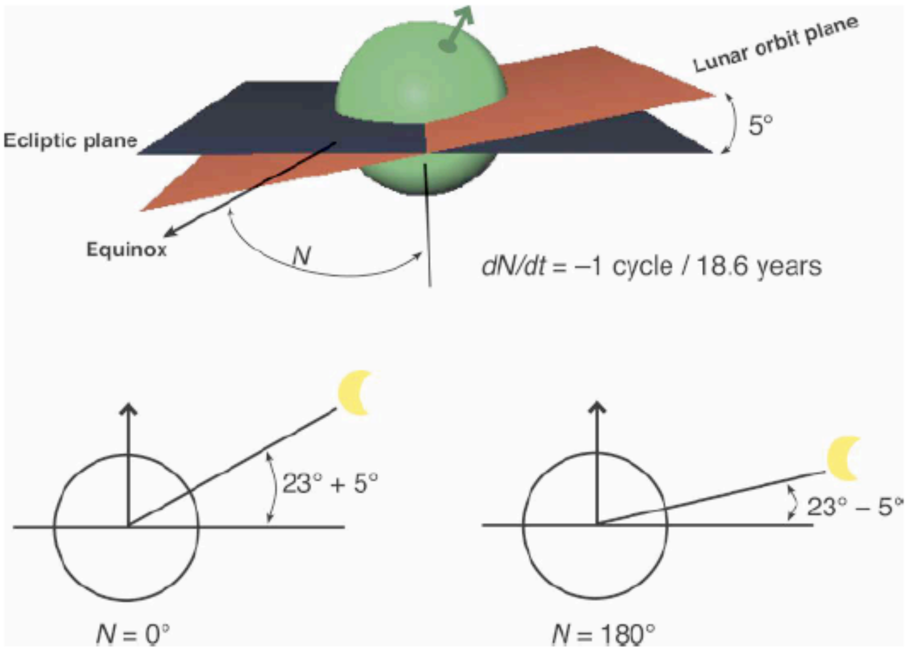
Past, Present, and Future

Andreas Schmittner, Gary Egbert
College of Earth, Ocean, and Atmospheric Sciences
Oregon State University
Mattias Green
Bangor University

Supported by the National Science Foundation's Physical Oceanography and Marine Geology and Geophysics Programs

Schmittner & Egbert (2014) An improved parameterization of tidal mixing for ocean models, Geophysical Model Development 7, 211-224.

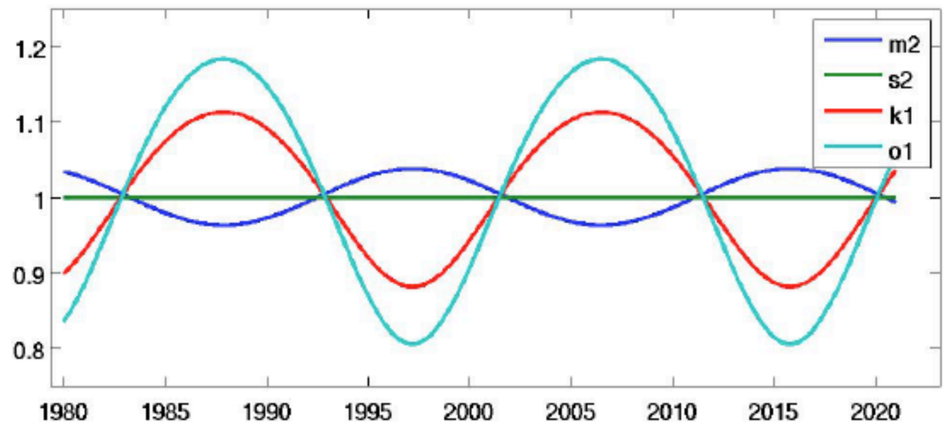
Future



Lunar Nodal Cycle
(LNC)
18.6 yr

Could this affect climate and improve predictability?

Upcoming talk by Yasuda et al.



Ray (2007) J. Clim.

Present

Pioneering Work on Parameterizing Tidal Mixing in Global Ocean / Climate Models

- St. Laurent, Simmons, and Jayne (2002) GRL
- Simmons, et al. (2004) OM

Tidal Mixing Scheme

[*Simmons et al.*, 2004]

Diffusivity

$$k_v = k_0 + \frac{\Gamma \varepsilon}{N^2}$$

Mixing Efficiency

$$\Gamma = 0.2$$

Turbulent Energy Dissipation

$$\varepsilon = \frac{qE(x,y)F(z)}{\rho}$$

Exponential Decay Above Sea Floor H

$$F(z,H) = \frac{e^{-(H-z)/\varsigma}}{\varsigma(1-e^{-H/\varsigma})} \qquad \varsigma = 500\ \mathrm{m}$$

$E(x,y)$ = Energy Flux out of Barotropic Tide

Innovations:

1. Four Tidal Constituents TC = (M2, S2, K1, O1) with time variations due to LNC $a_{TC}(t)$
2. Subgrid-scale Bathymetry (z') 3D

$$\varepsilon = \frac{1}{\rho}\sum_{z'=z}^{H}\sum_{TC} a_{TC}(t) q_{TC} E_{TC}(x,y,z') F(z,z')$$

Dissipation Efficiencies

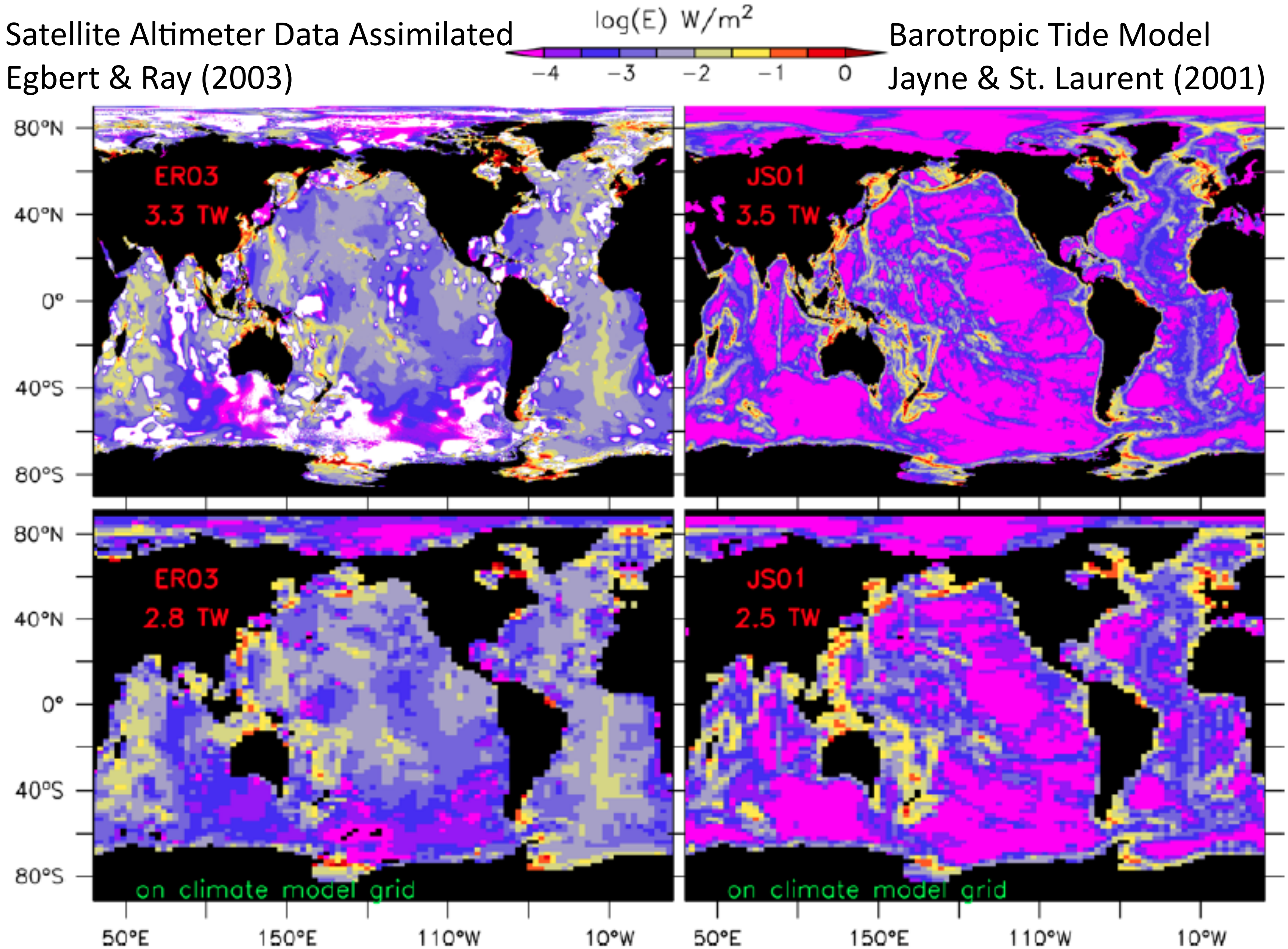
$(q_{M2} = q_{S2} = 0.33)$

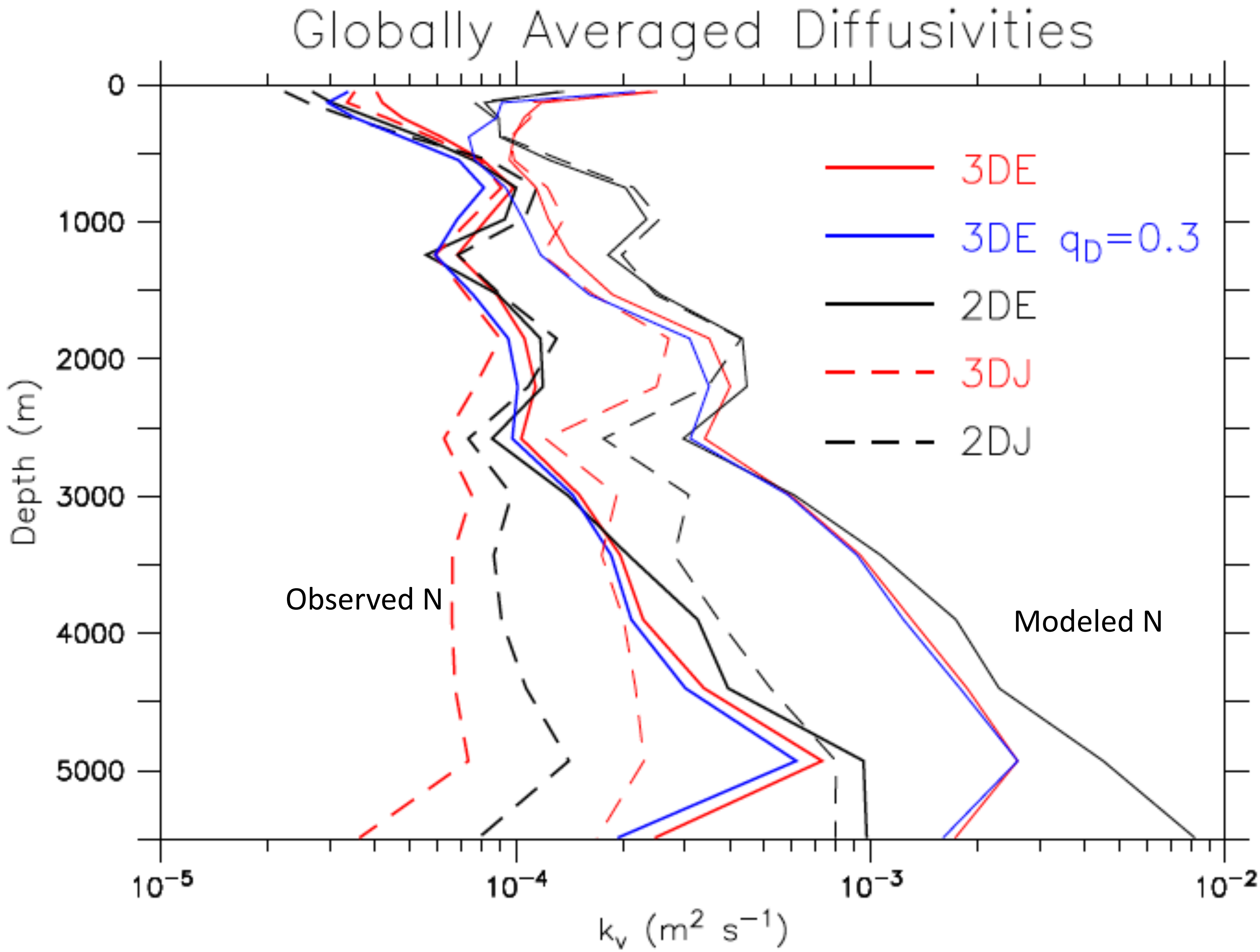
poleward of 30° $(q_{K1} = q_{O1} = 1)$

$$a_{M2} = (1 - 0.03\sin(2\pi t/18.6\mathrm{yr}))^2$$

$$a_{K1} = (1 + 0.11\sin(2\pi t/18.6\mathrm{yr}))^2 \qquad a_{O1} = (1 + 0.18\sin(2\pi t/18.6\mathrm{yr}))^2$$

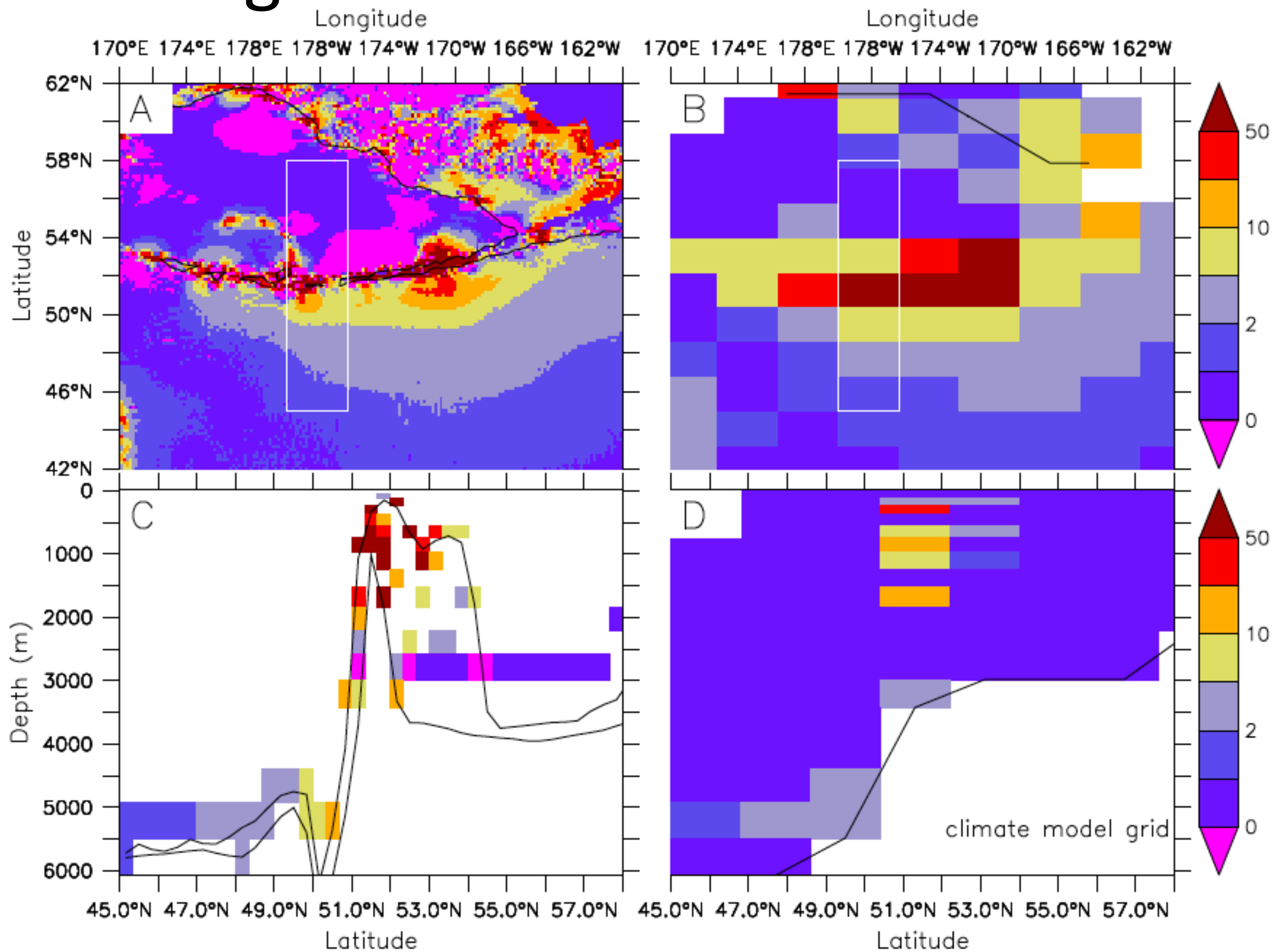
Dissipation Estimates



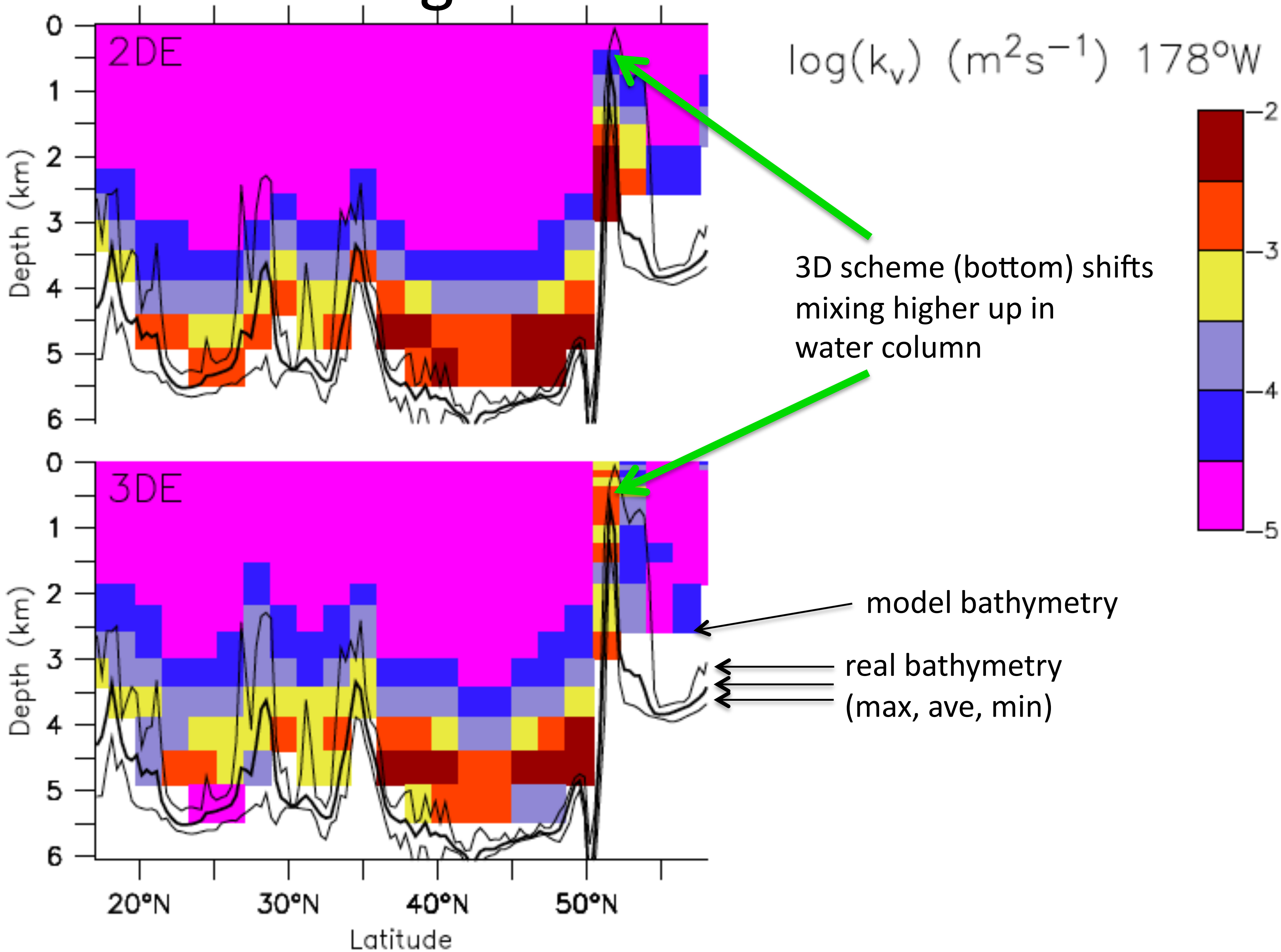


Globally Averaged Diffusivities
3DE
3DE q_D=0.3
2DE
3DJ
2DJ
Observed N
Modeled N
Depth (m)
0
1000
2000
3000
4000
5000
10^{-5}
10^{-4}
10^{-3}
10^{-2}
k_v (m^2 s^{-1})

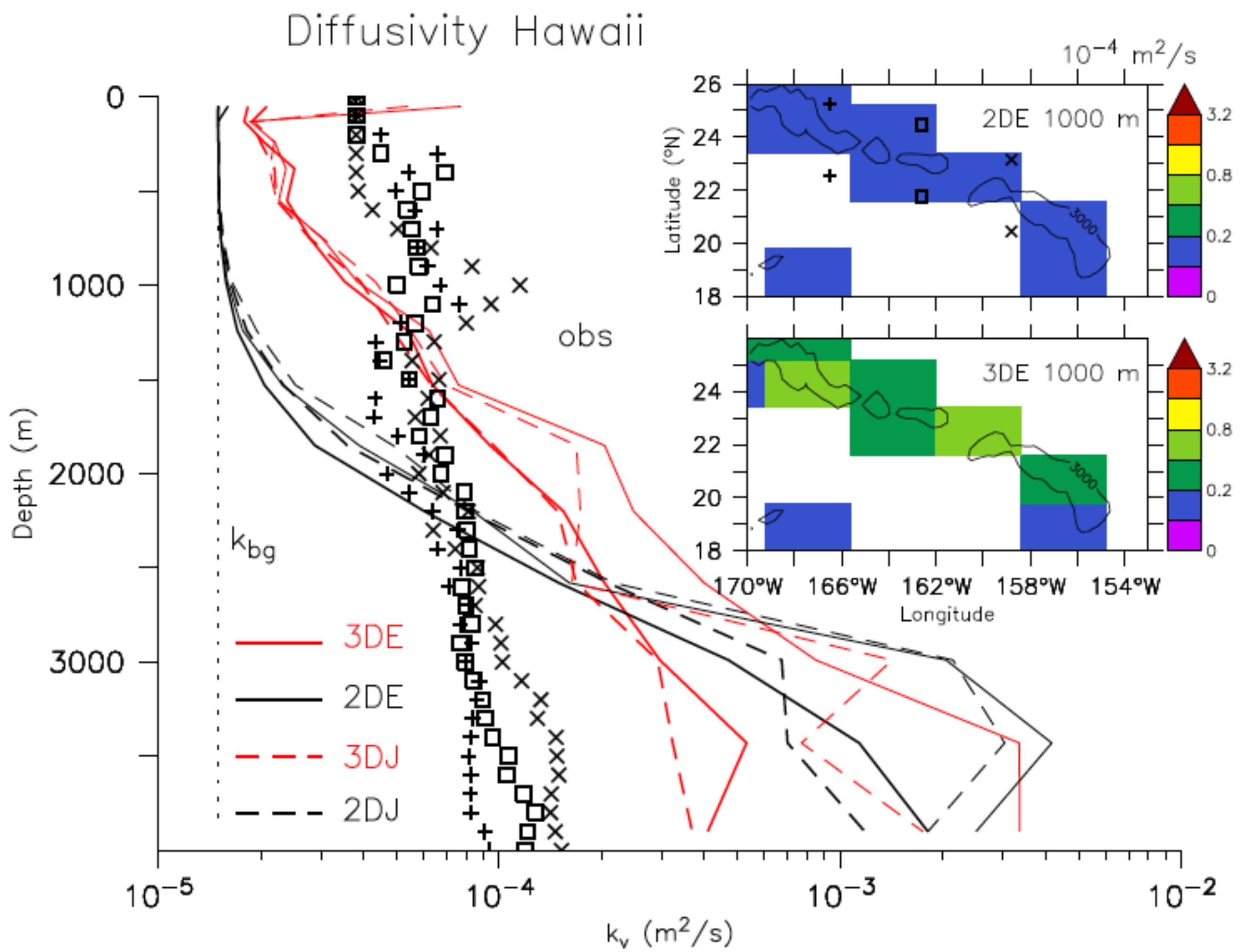
Subgrid-Scale Scheme Aleutians



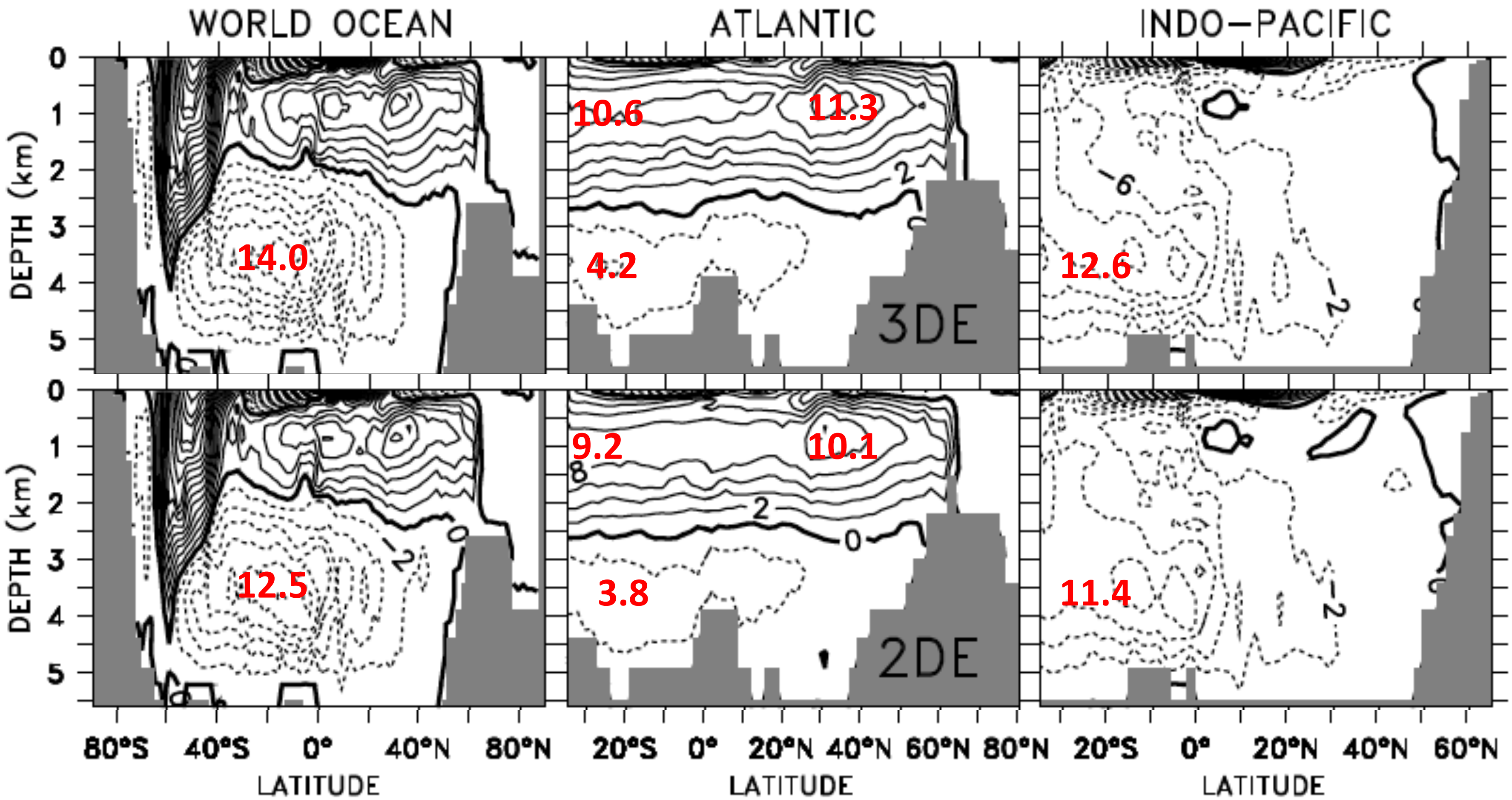
Subgrid-Scale Scheme



Comparison to Observations (HOME) Hawaii



Impact of Subgrid-Scale Scheme on Circulation

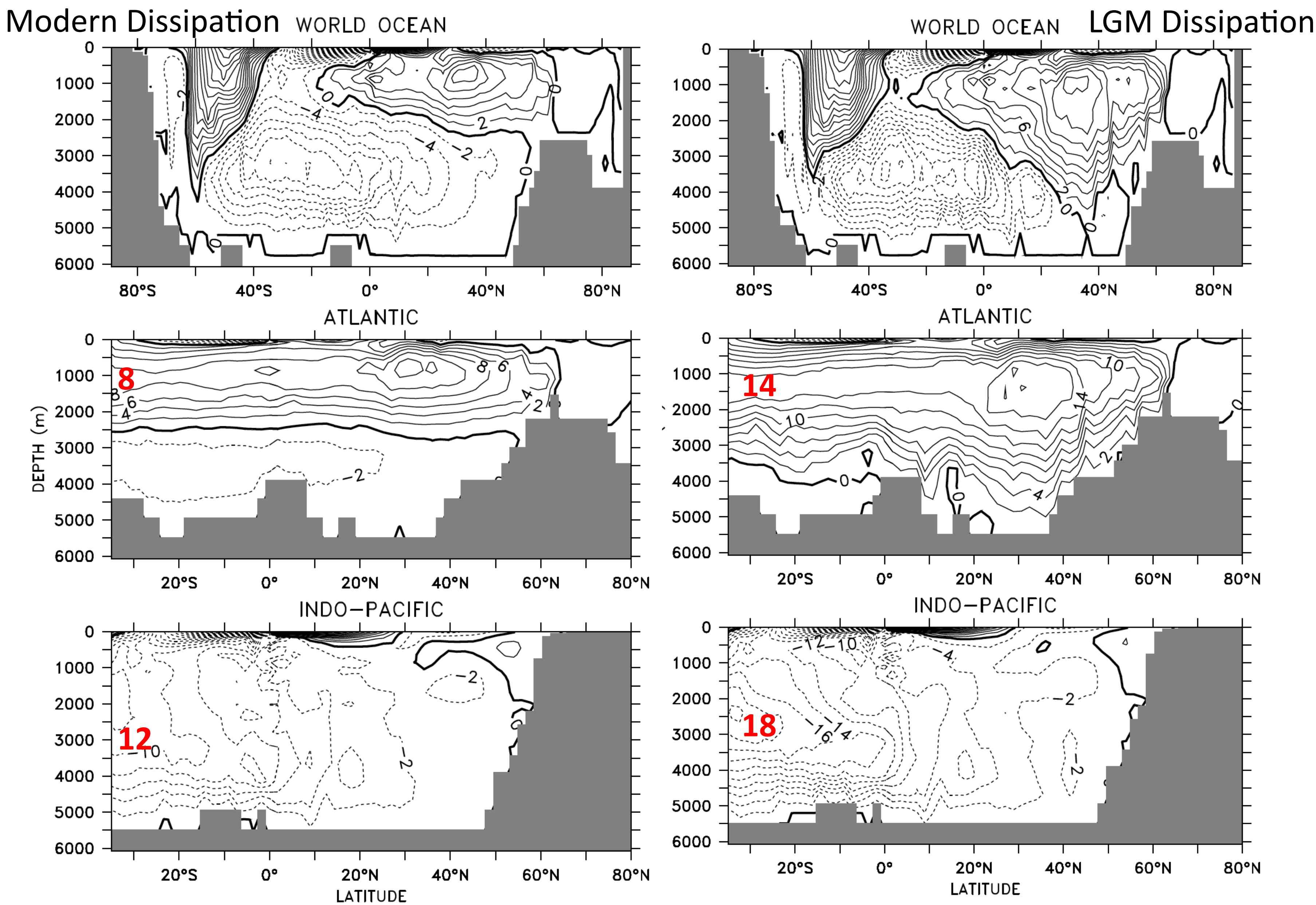


Meridonal Overturning Circulation stronger by 10-20%

Past

- Egbert et al. (2004, JGR) Increased tidal energy dissipation in deep ocean at Last Glacial Maximum (23-19 ka BP)
- Dissipation increased by 50% globally
- Triples in deep ocean
- See next talk (Wilmes and Green)
- What will be the impact on circulation?

Last Glacial Maximum (23-19 ka BP)



Conclusions

- Considering subgrid-scale bathymetry improves tidal mixing scheme for coarse resolution ocean models
- Shifts mixing to shallower depths
- Increases Meridional Overturning Circulation (10-20%)
- Separation of diurnal and semi-diurnal tides also improves results (e.g. Kuril Straits; not shown; see paper) and allows testing of LNC hypothesis
- Increased dissipation at LGM increases MOC by 50%
- Should to be considered in future simulations (e.g. PMIP)