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Paleoceanography and Paleoclimatology

AGU100 ADVANCING EARTH AND SPACE SCIENCE

RESEARCH ARTICLE
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Key Points:
- Modeled deep ocean tidal dissipation approximately doubled during the LGM, but the magnitude is dependent on LGM ice sheet extent
- Increase in LGM tidal mixing

Glacial Ice Sheet Extent Effects on Modeled Tidal Mixing and the Global Overturning Circulation

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Modeling Tidal Mixing in the Glacial Ocean

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CESM Ocean Modeling Group Meeting, April 15, 2020

Methods

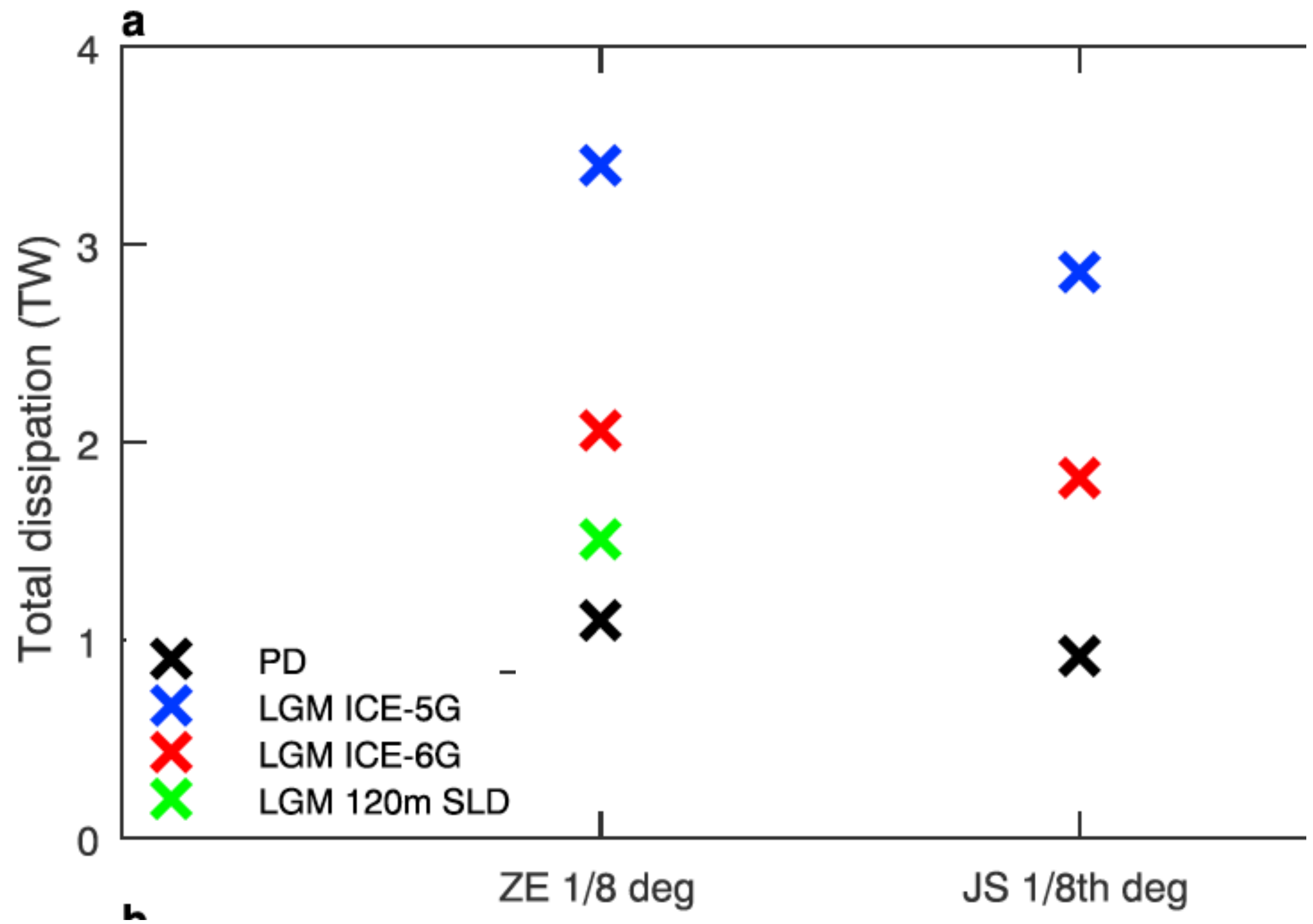
Tide Model Simulations

- OTIS (Oregon State Tidal Inversion Software)
- M2, S2, O1, K1
- Different resolutions (up to 1/12°)
- Different Internal Tide (IT) Drag Parameterizations
- Different LGM bathymetries (ICE5G, ICE6G)

Climate Model Simulations

- University of Victoria (UVic) model
- Tidal Mixing Parameterization (Jayne, St. Laurent, Simmons)
- Model of Ocean Biogeochemistry & Isotopes (MOBI) includes paleo tracers $\delta^{13}C$, and radiocarbon
- Vary Southern Ocean buoyancy fluxes

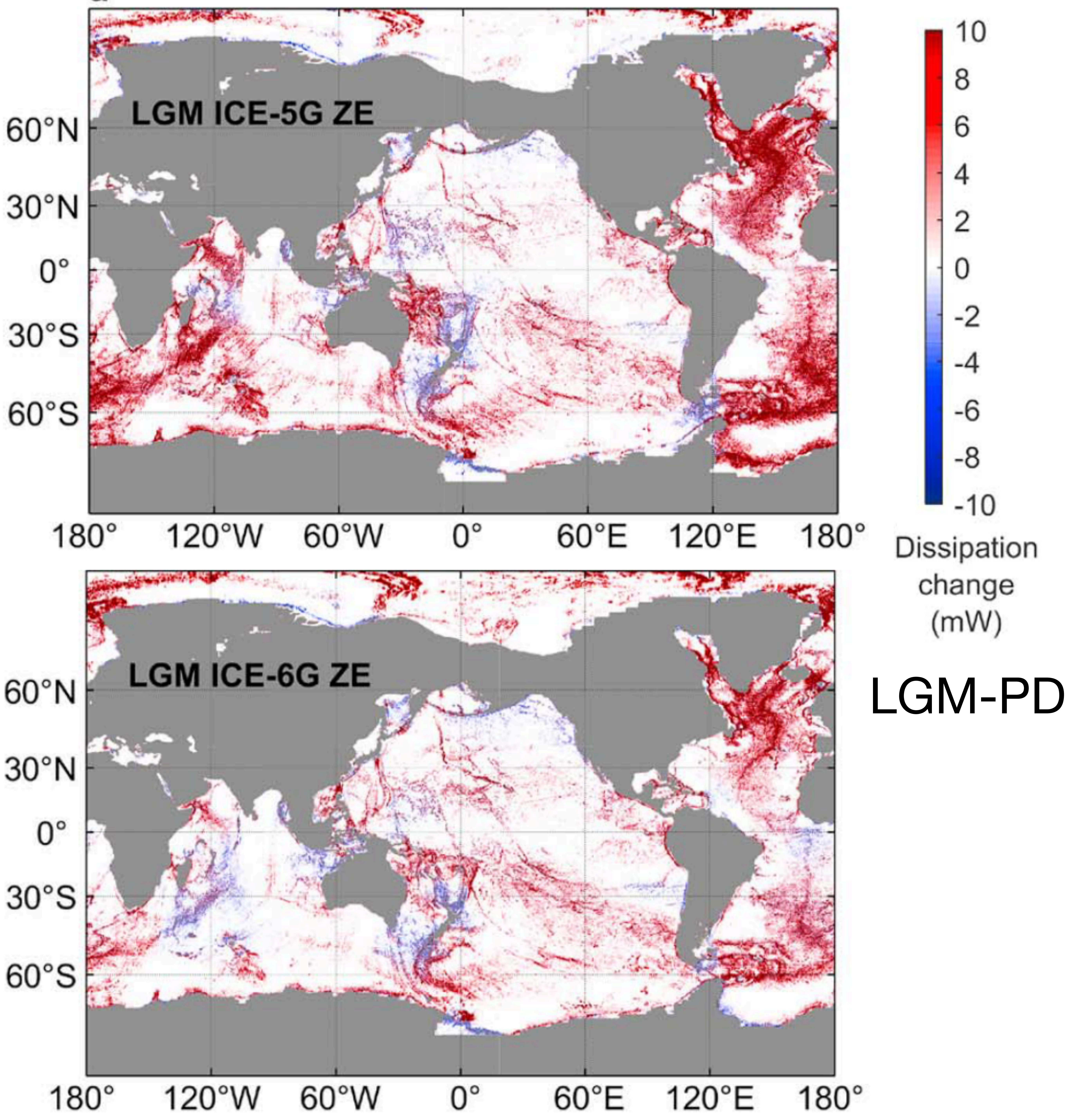
Tidal Dissipation



IT drag param.

Zaron & Egbert (2006)

Jayne & St. Laurent (2001)



LGM-PD

Wilmes et al., (2019)

Tidal Mixing Parameterization

Diapycnal Diffusivity: $$k_v = k_{\mathrm{bg}} + \frac{\Gamma \epsilon}{N^2},$$

$k_{\mathrm{bg}} = 0.3 \times 10^{-4}\ \mathrm{m^2/s}$

Considers only locally dissipated energy, which is only 1/3 of the total!

Subgrid-scale bathymetry:

$$\epsilon = \frac{1}{\rho} \sum_{z'>z}^{H} \sum^{\mathrm{TC}} q_{\mathrm{TC}} D_{\mathrm{IT,TC}}(x, y, z') F(z, z'),$$

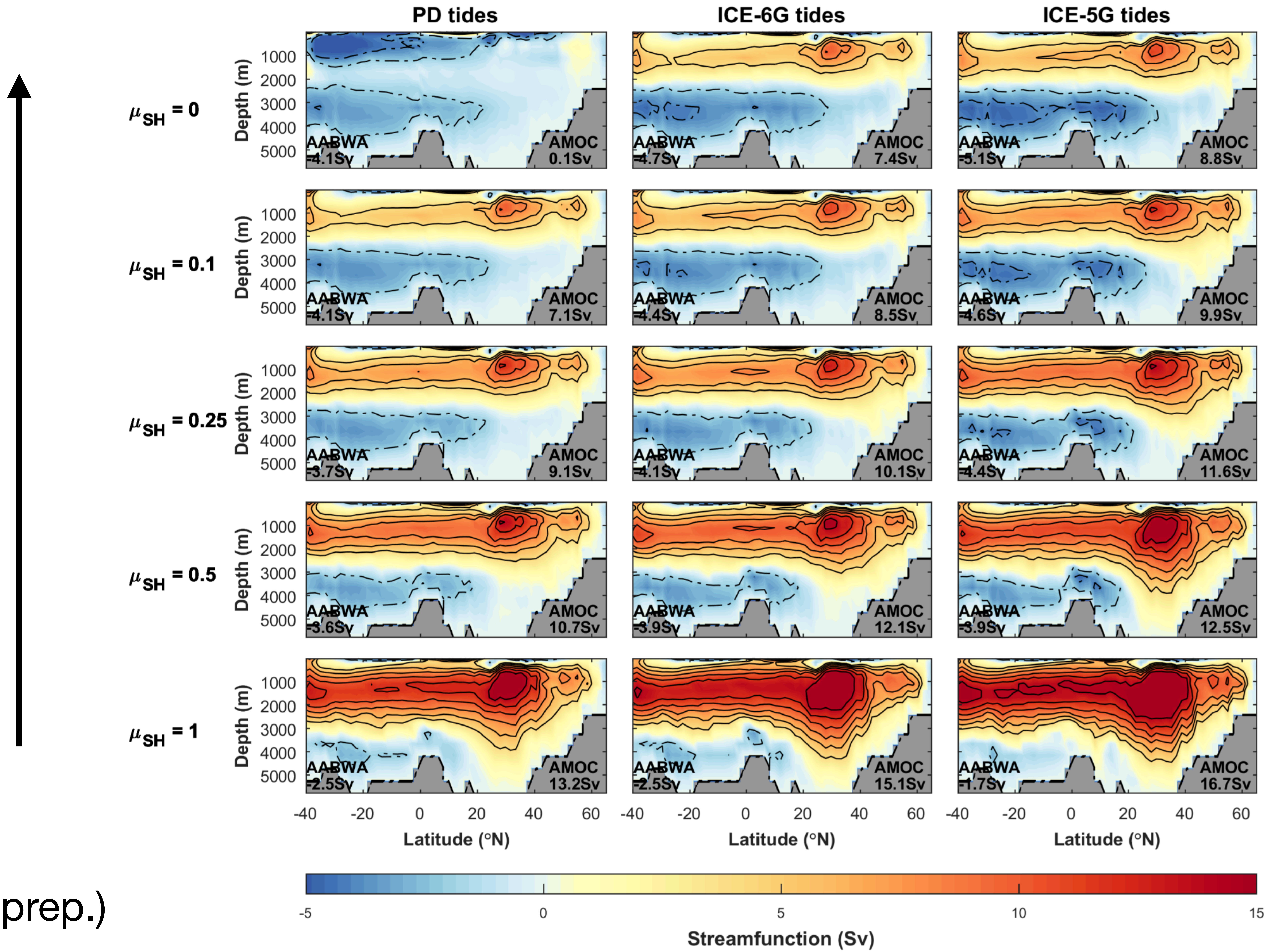
Dissipation Efficiency = Fraction of locally dissipated energy

$$q_{\mathrm{TC}} = \begin{cases} 1, \text{for} |y| > y_{c,\mathrm{TC}} \\ 0.33, \text{otherwise.} \end{cases}$$

Schmittner & Egbert (2014) Geosc. Mod. Devel.

Saltier AABW, shallower & weaker AMOC

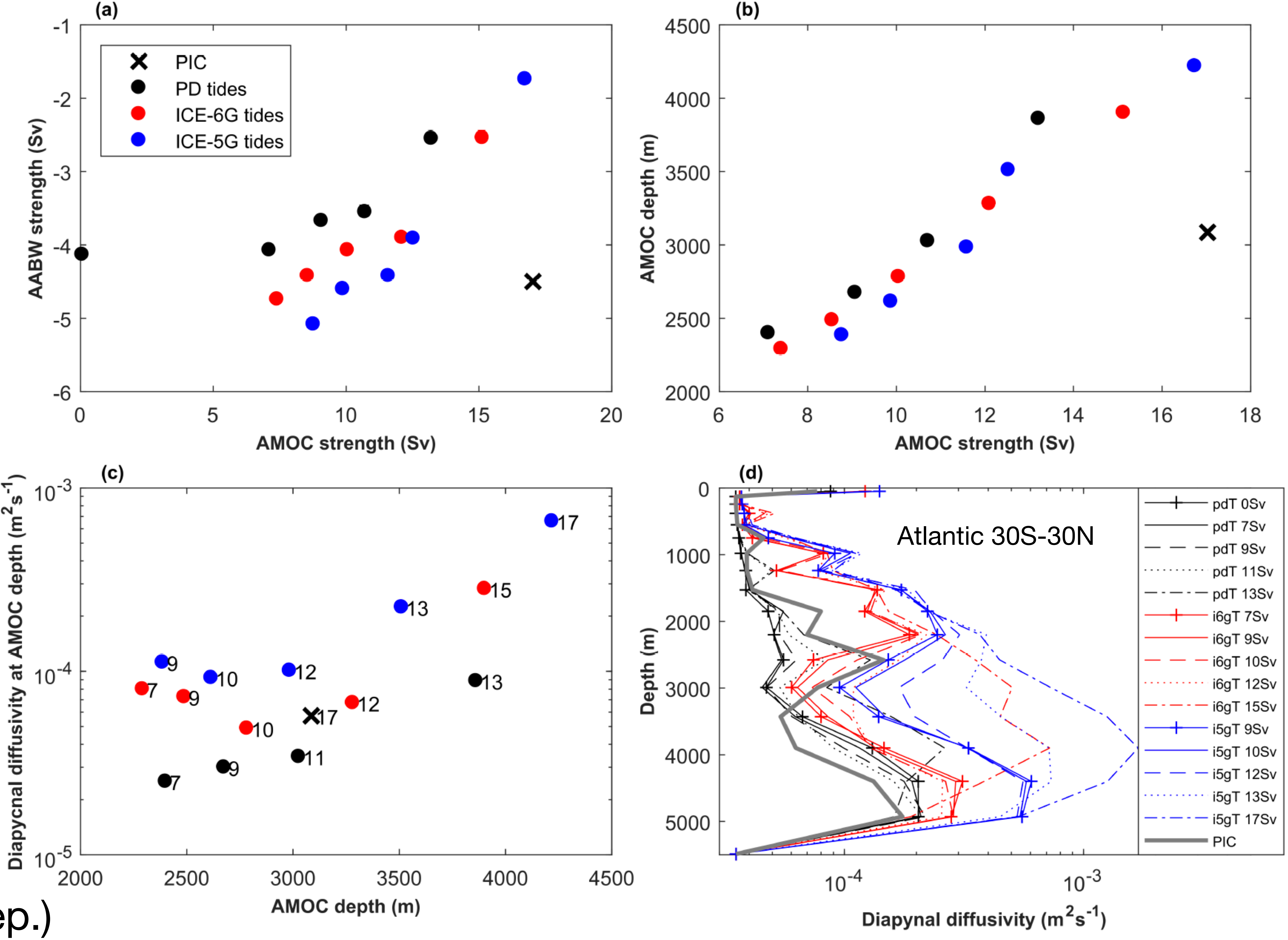
Reduced atmospheric meridional moisture flux in Southern Hemisphere



Wilmes et al., (in prep.)

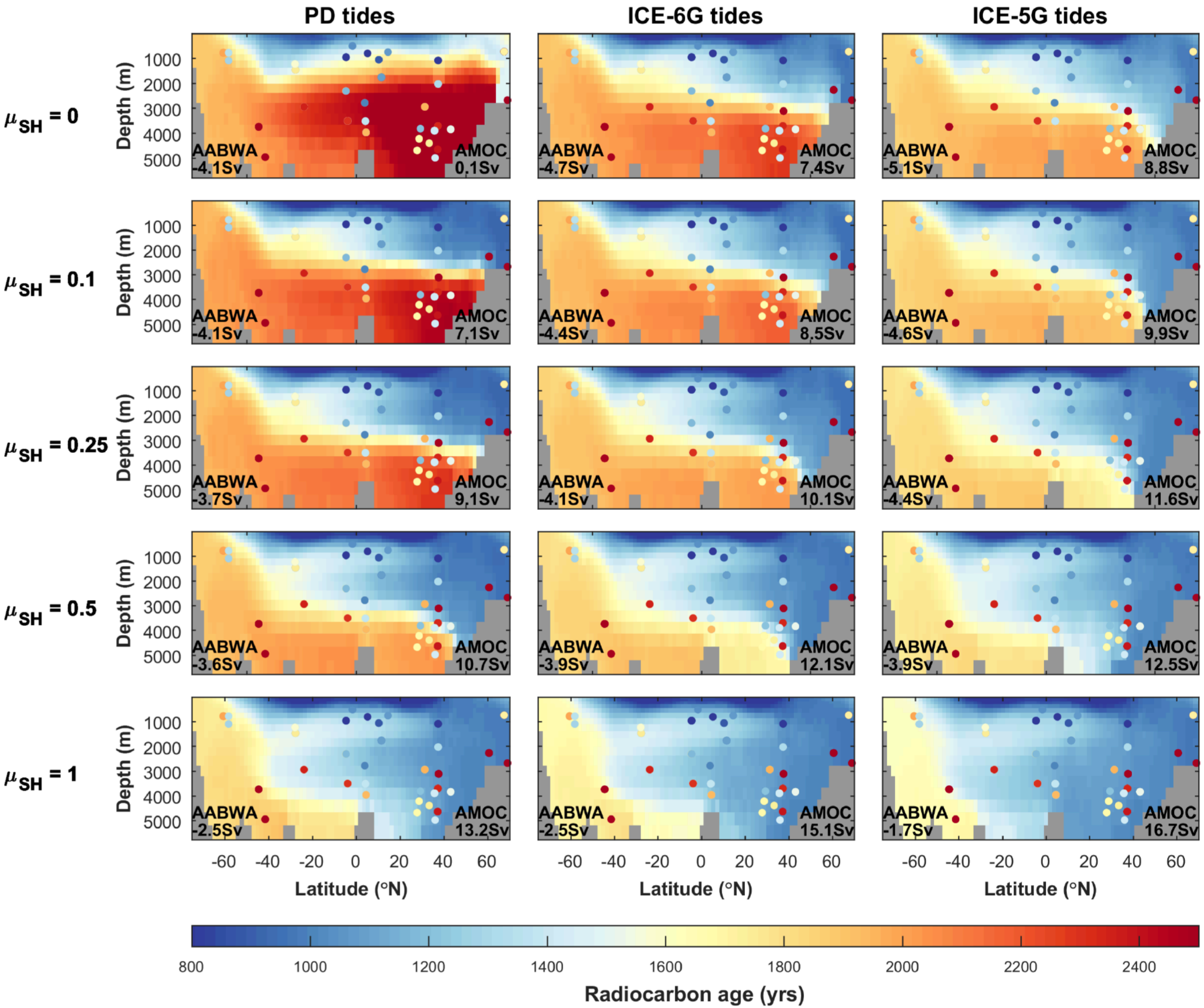
LGM tidal mixing

- Increases k_v
- Increases AMOC
- Increases AABW



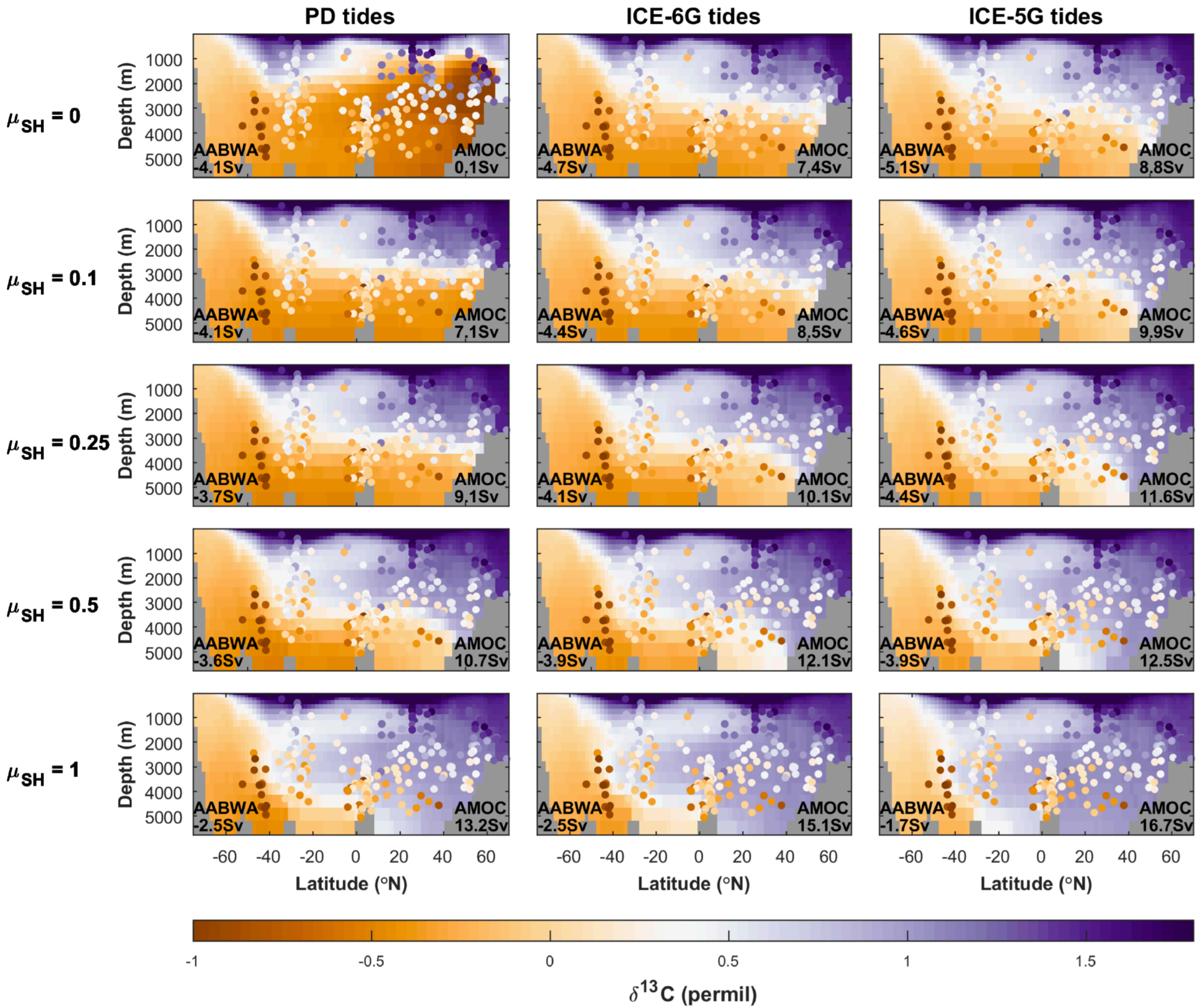
Wilmes et al., (in prep.)

Radiocarbon

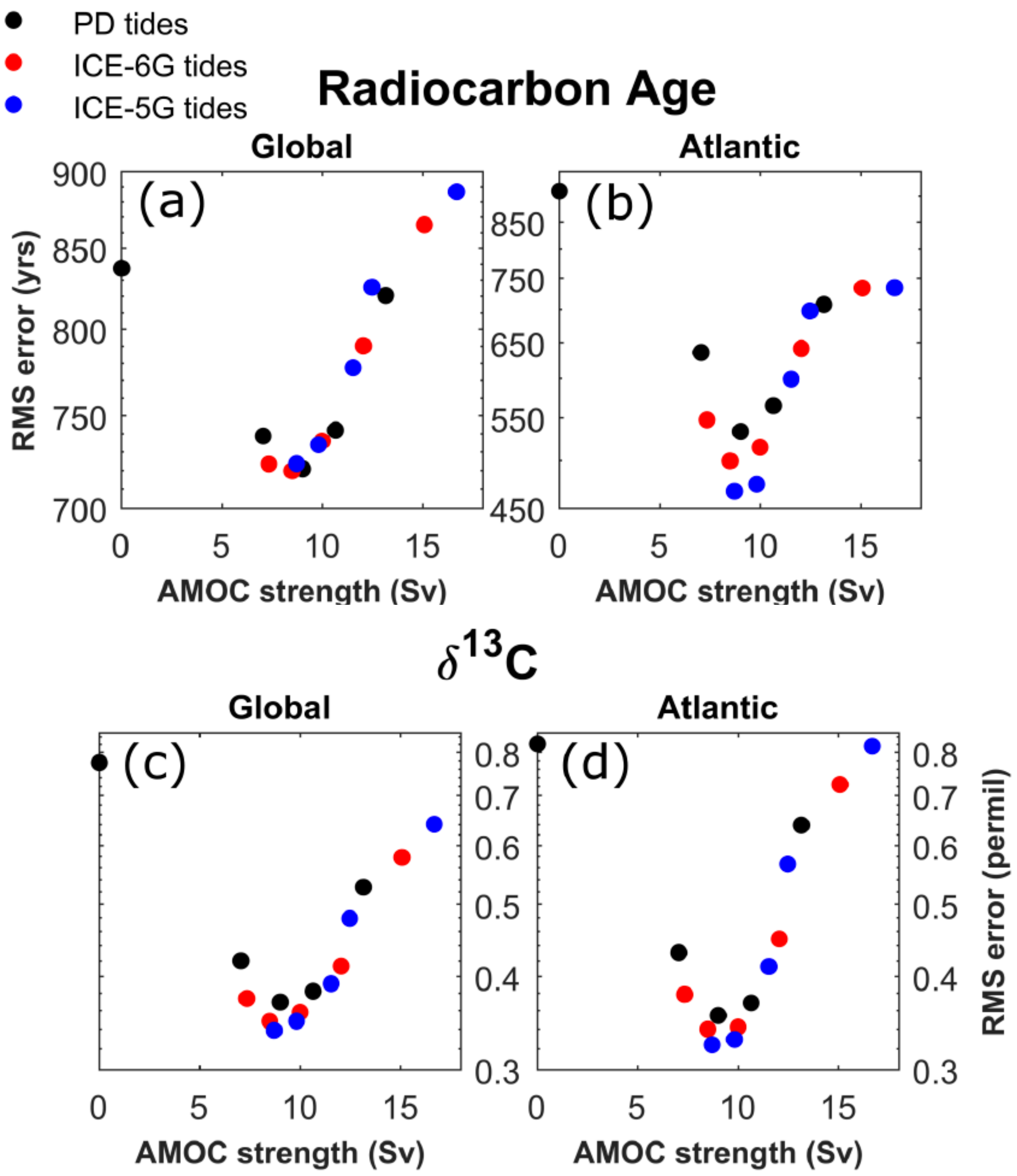


Wilmes et al., (in prep.)

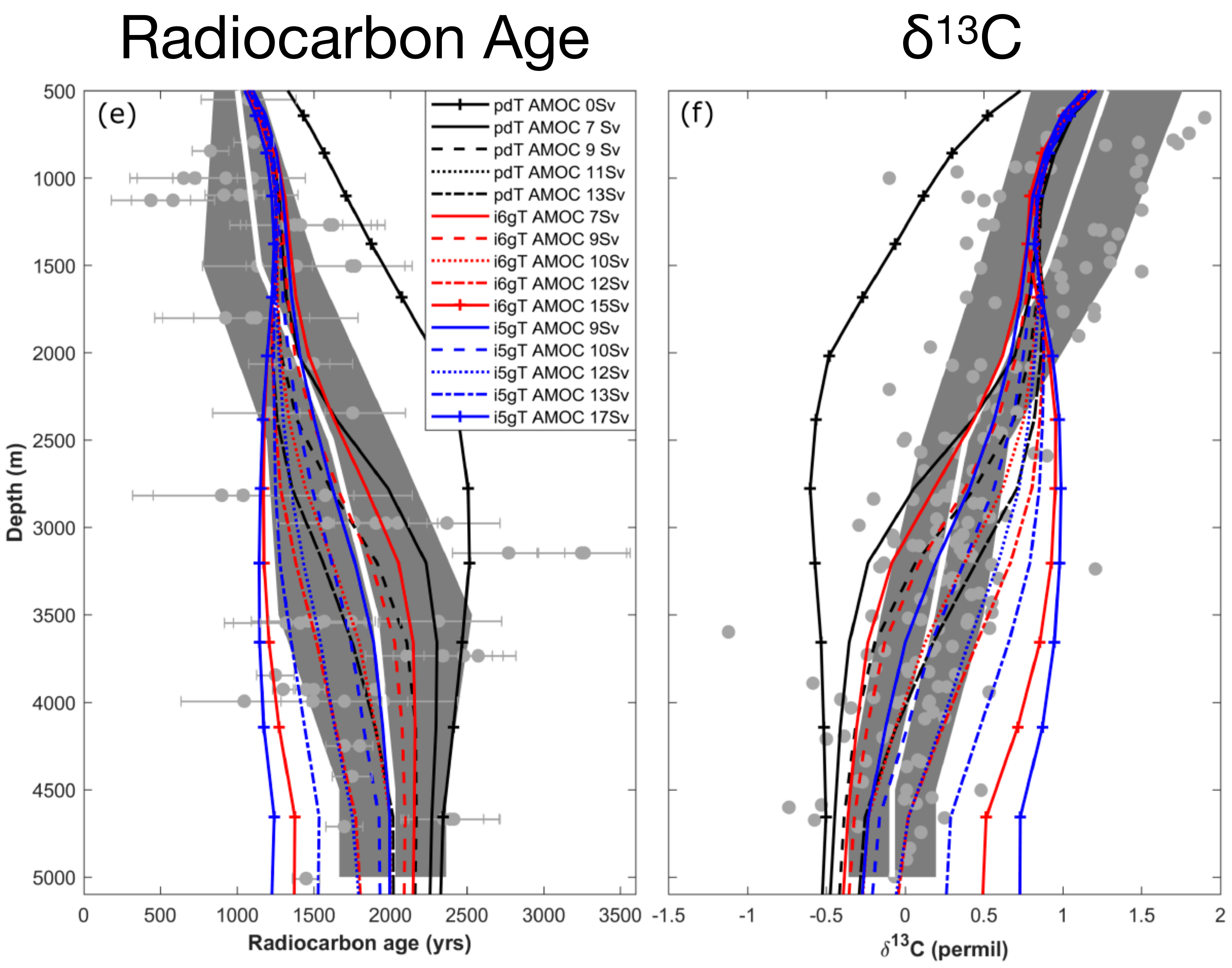
δ^{13}C



Wilmes et al., (in prep.)



Atlantic Profiles



Wilmes et al., (in prep.)

Conclusions

- Increased tidal mixing in LGM is robust result, but quantitatively depends on reconstructed bathymetry (basin geometry; land ice extent)
- Increased diffusivities increase AMOC & AABW flow rates
- MOC geometry (AMOC depth) strongly affects isotopes
- Effect of increased mixing is more subtle but improves model-data agreement
- All these results are conservative because they neglect changes in remotely dissipated energy
    - Would be good to include remotely dissipated energy in future simulations e.g. by using Eden & Olbers parameterization (who wants to collaborate on this?)