Numerical mixing in idealized simulations of submesoscale baroclinic instabilities over a shelf

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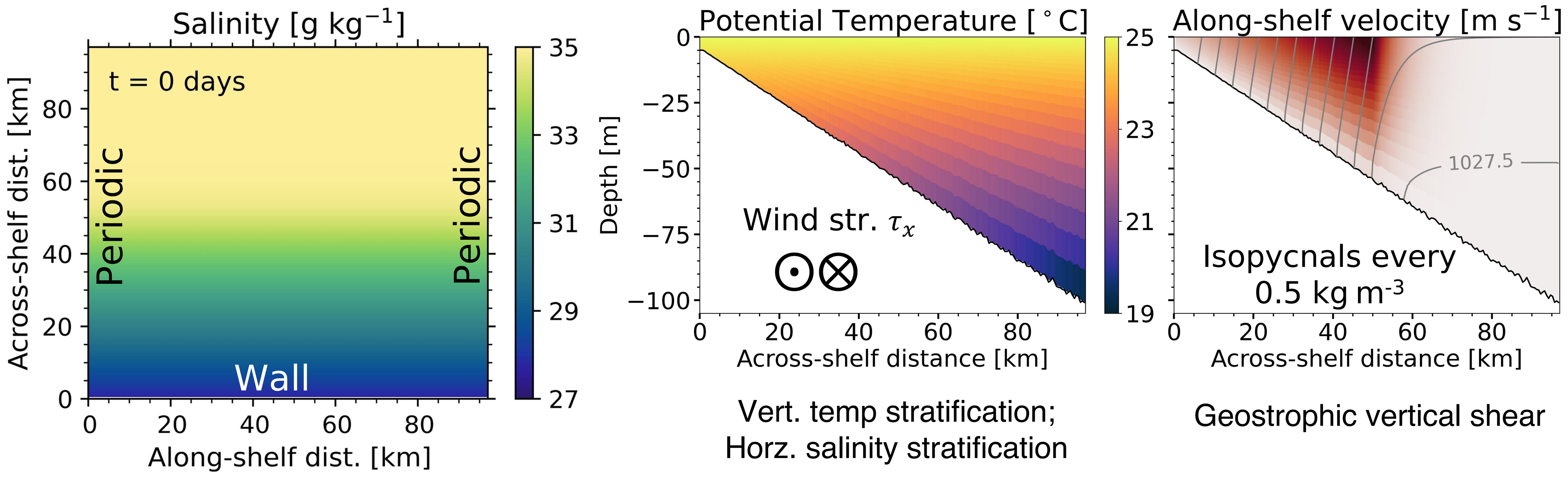
I. Numerical mixing is generated by advection discretization



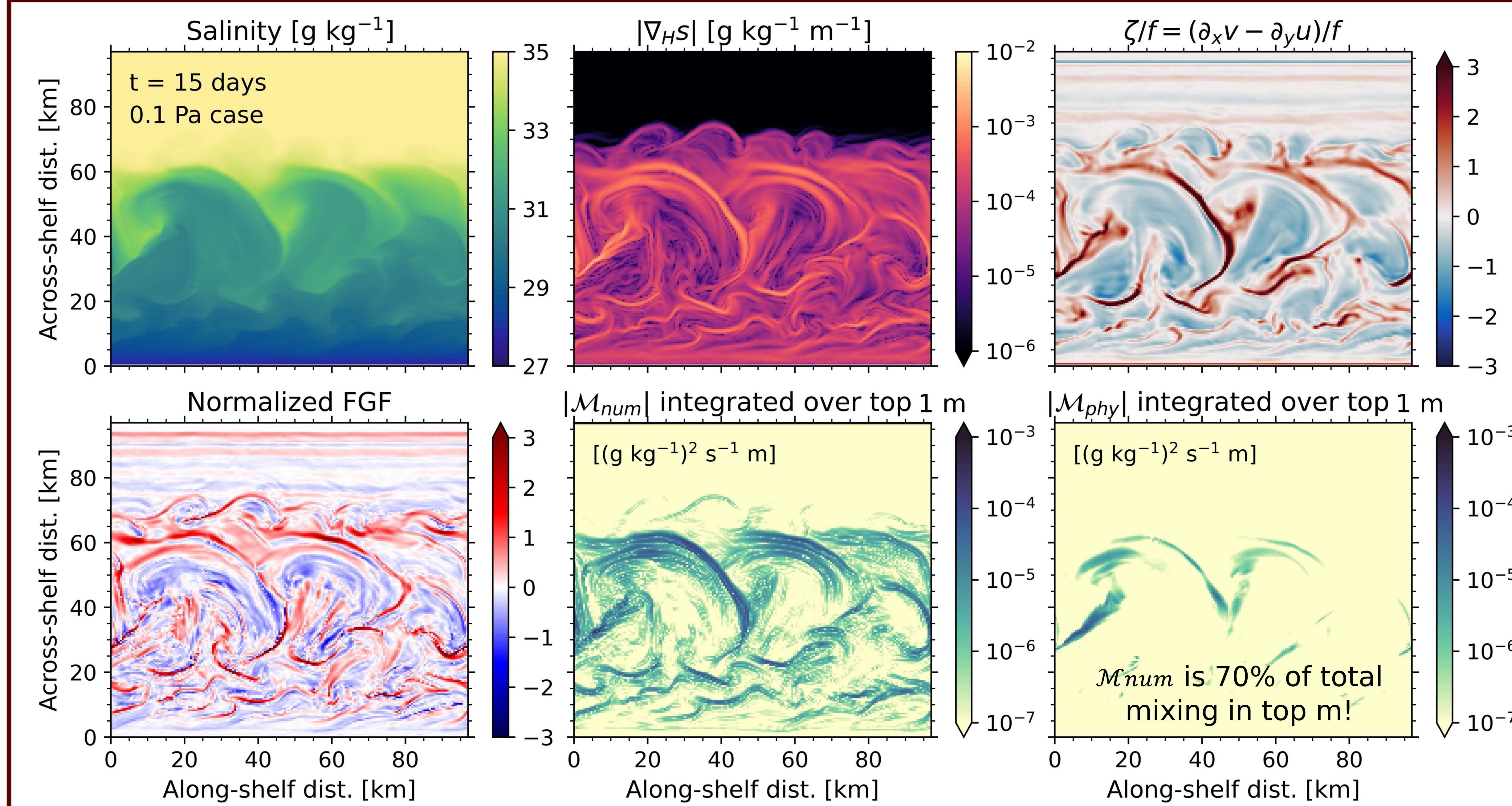
Vert. temp stratification; Horz. salinity stratification

Geostrophic vertical shear

- $\mathcal{M}_{num} = (A\{s^2\} - A\{s\}^2)/\Delta t$ (Burchard & Rennau, 2008), $\mathcal{M}_{phy} = 2K_v(\partial_z s)^2$ (Osborn & Cox, 1972)
- Idealized ROMS model based on Hetland (2017); 500 m horizontal resolution; 30 vertical layers
- $z = 5 - 105$ with 1% noise; $f = 43°N$; $\kappa - \epsilon$ turbulence closure; MPDATA for tracer advection; 20 day simulation; oscillatory winds of varying amplitude starting on day 5

How does numerical mixing impact larger scale flow and salinity field?

II. Numerical mixing is enhanced at fronts



$$FGF = \frac{1}{2f}\left(\frac{\partial s}{\partial x_j}\right)^{-2}\frac{D}{Dt}\left(\frac{\partial s}{\partial x_j}\right)^2 \longrightarrow FGF > 0 \text{ frontogenesis, } FGF < 0 \text{ frontolysis.}$$

Hetland and Qu (in-prep).

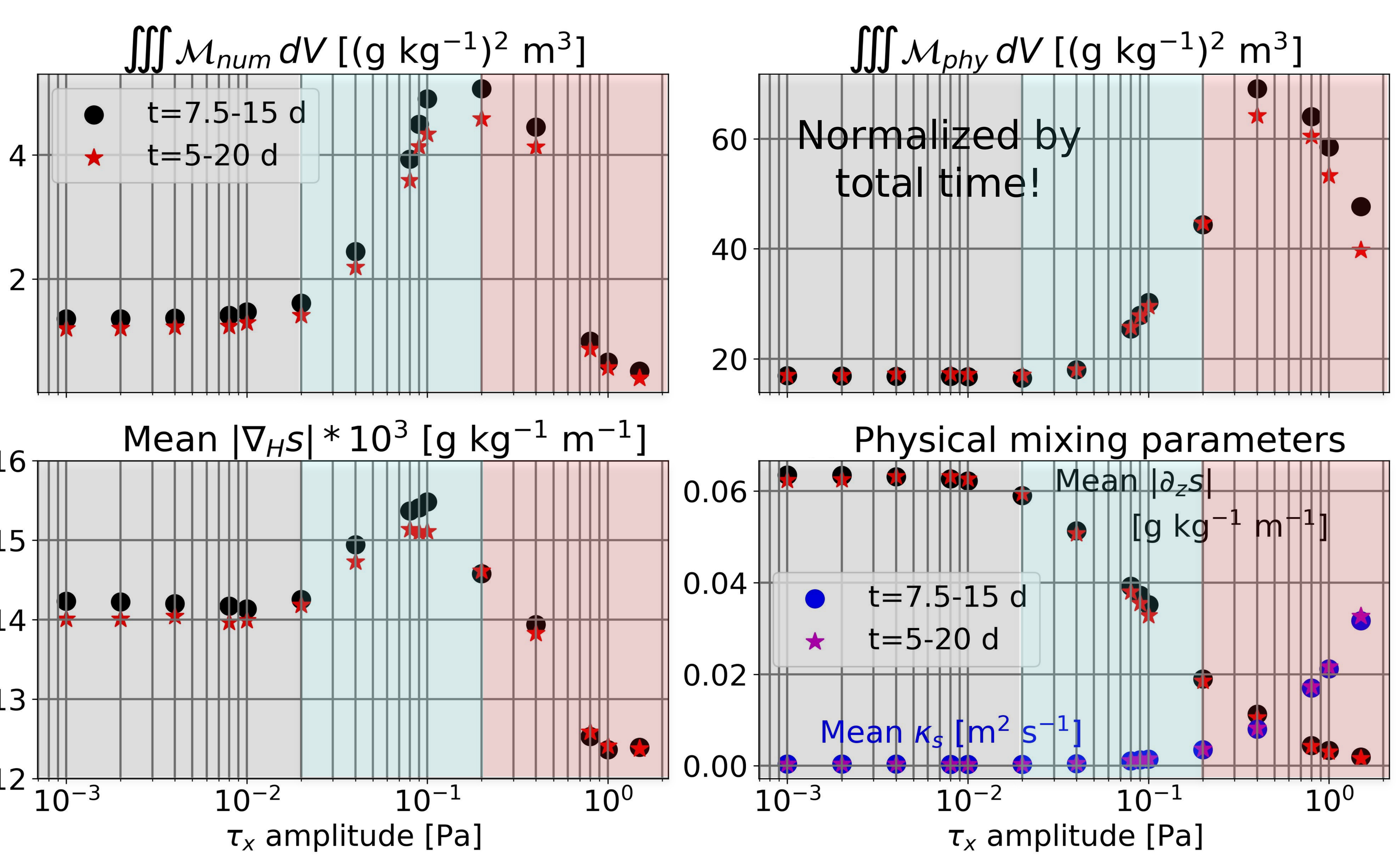
III. Oscillatory wind experiments help build intuition

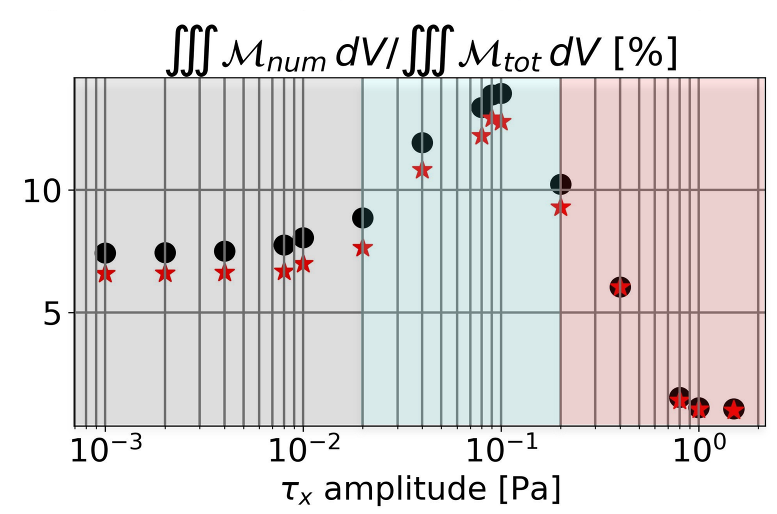
$$u = \bar{u} + u', \quad \bar{u} = \frac{1}{L}\int_0^L u \, dx$$

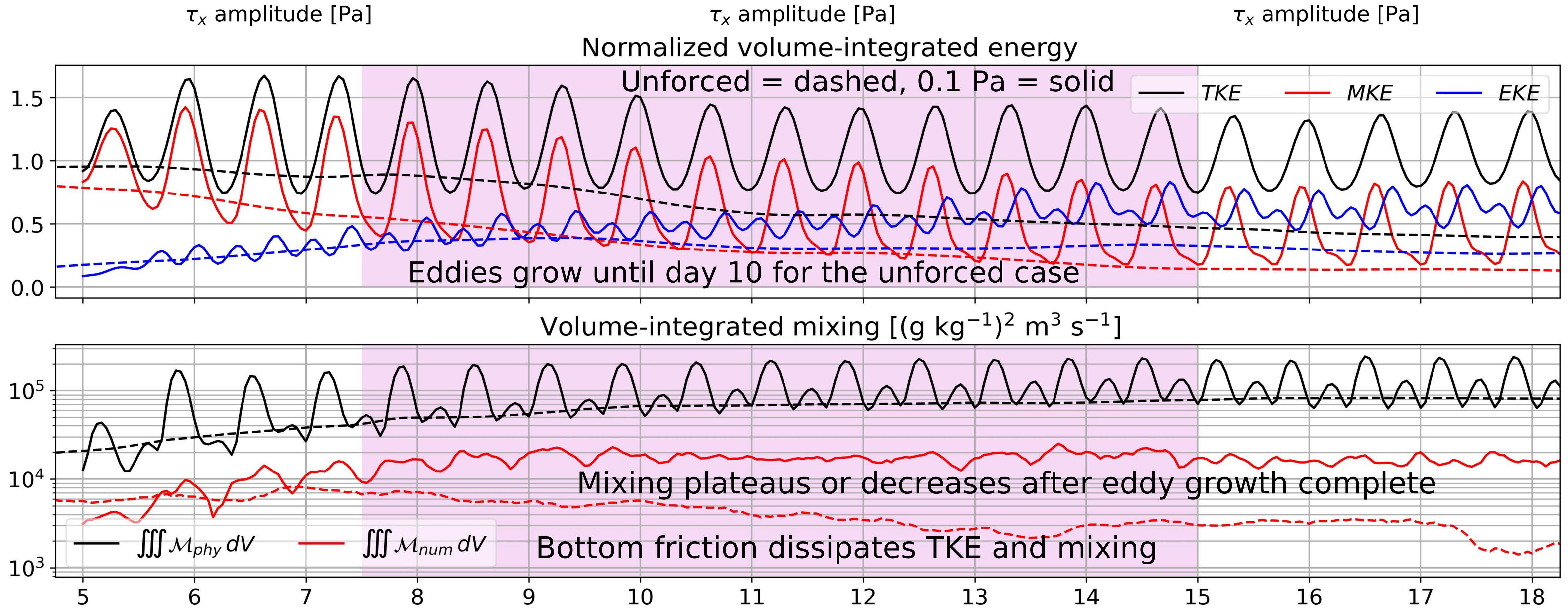
$$TKE = 0.5(u^2 + v^2)$$

$$MKE = 0.5(\bar{u}^2)$$

$$EKE = 0.5(u'^2 + v'^2)$$





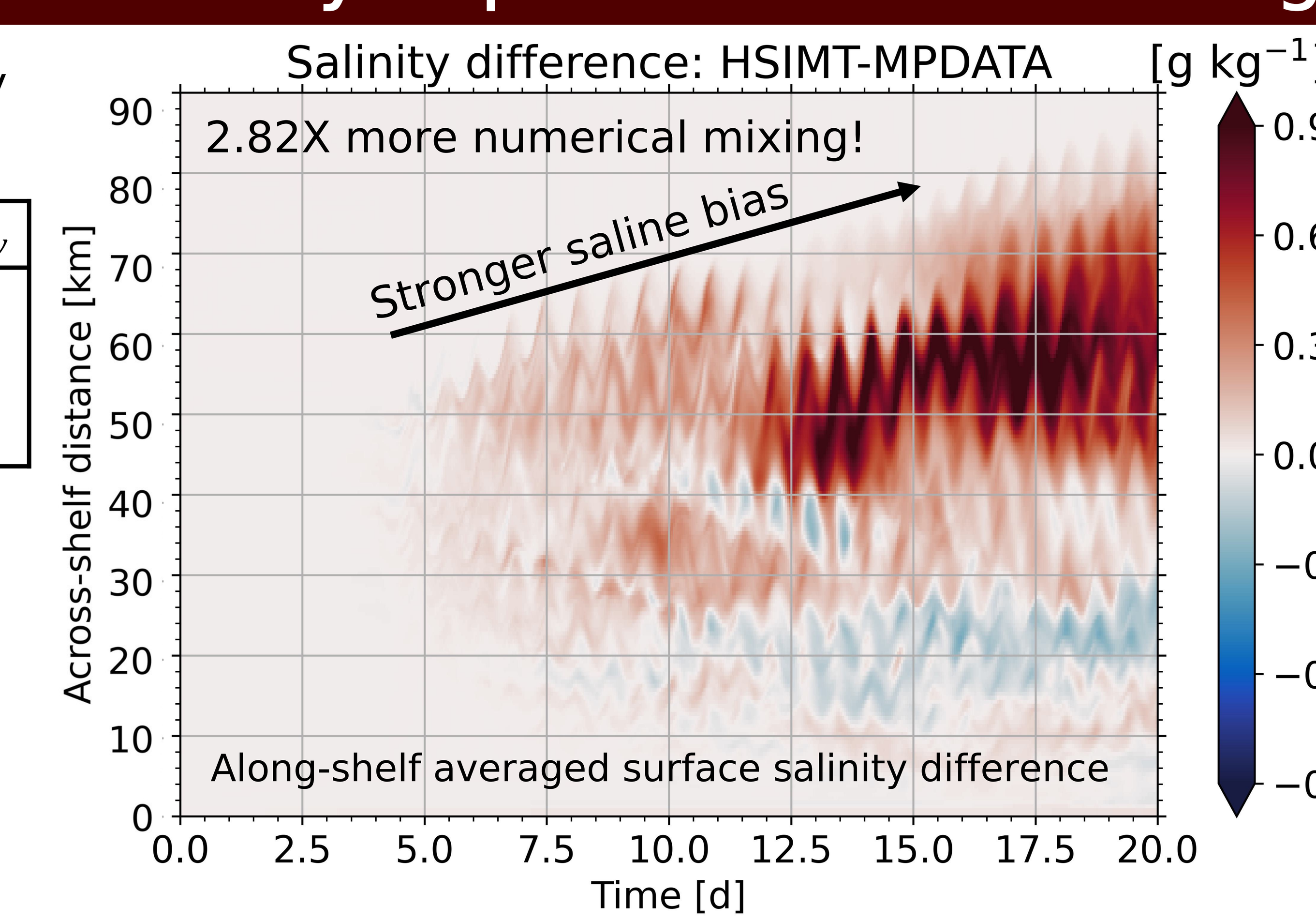


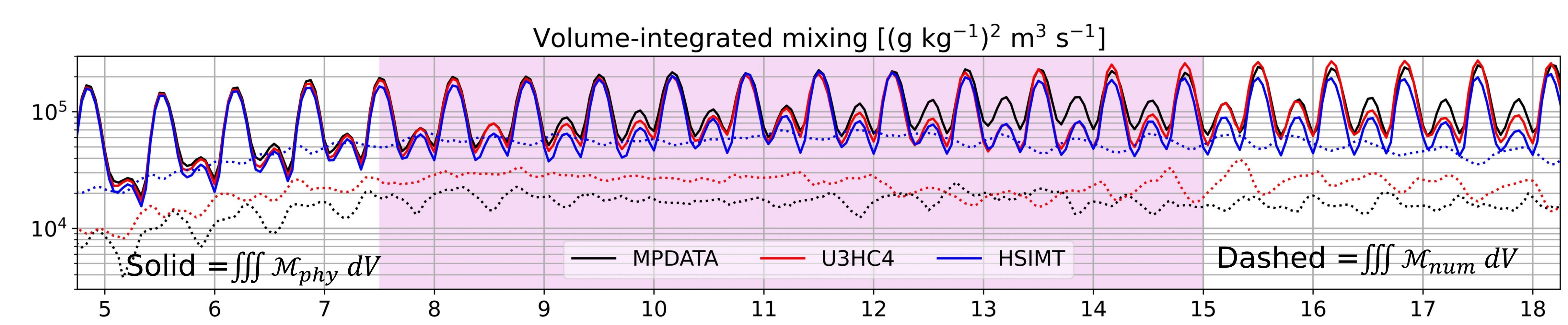
IV. Advection schemes substantially impact numerical mixing

Mixing statistics integrated inshore of initially stratified region

Scheme	$\mathcal{M}_{phy}/\mathcal{M}_{tot}$	$\mathcal{M}_{phy}/\mathcal{M}_{tot}$	$\mathcal{M}_{num}/\mathcal{M}_{phy}$
MPDATA	0.14	0.86	0.16
U3HC4	0.21	0.79	0.26
HSIMT	0.39	0.61	0.65

- MPDATA has most physical mixing, least numerical and total mixing. Most qualitative structure @ fronts!
- HSIMT has the least physical mixing, most numerical and total mixing
- U3HC4 in between other schemes





HSIMT has ~10% saline bias relative to MPDATA, partially due to the excessive numerical mixing

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