The fate and impact of internal waves induced by strong shear current over a marginal ridge

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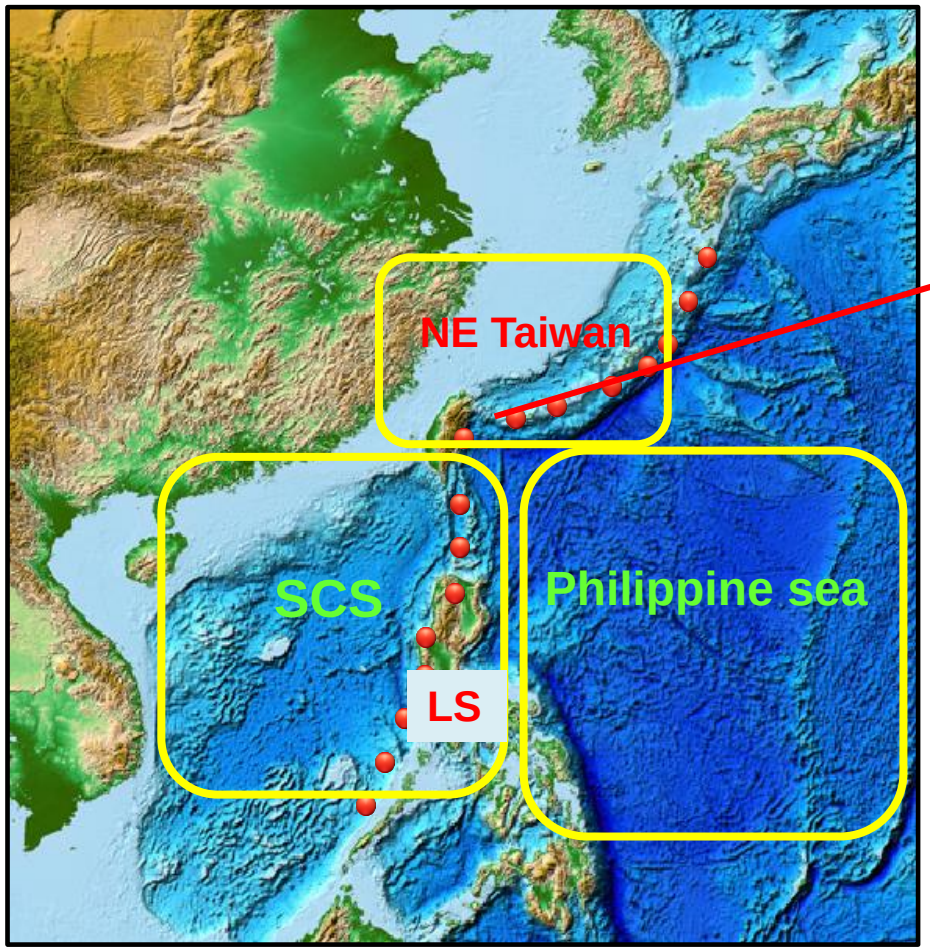
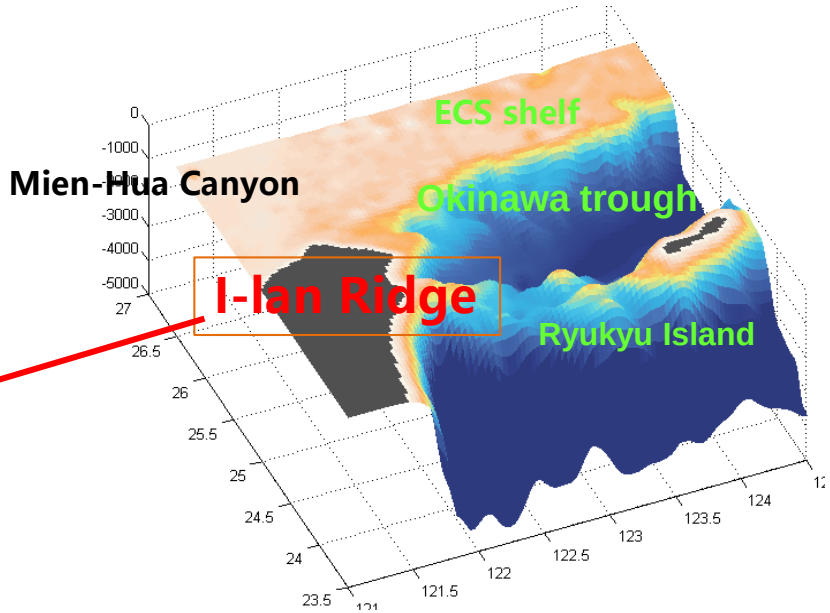
Strong shear current, complex and steep bathymetric make internal waves prevail in Northeast Taiwan





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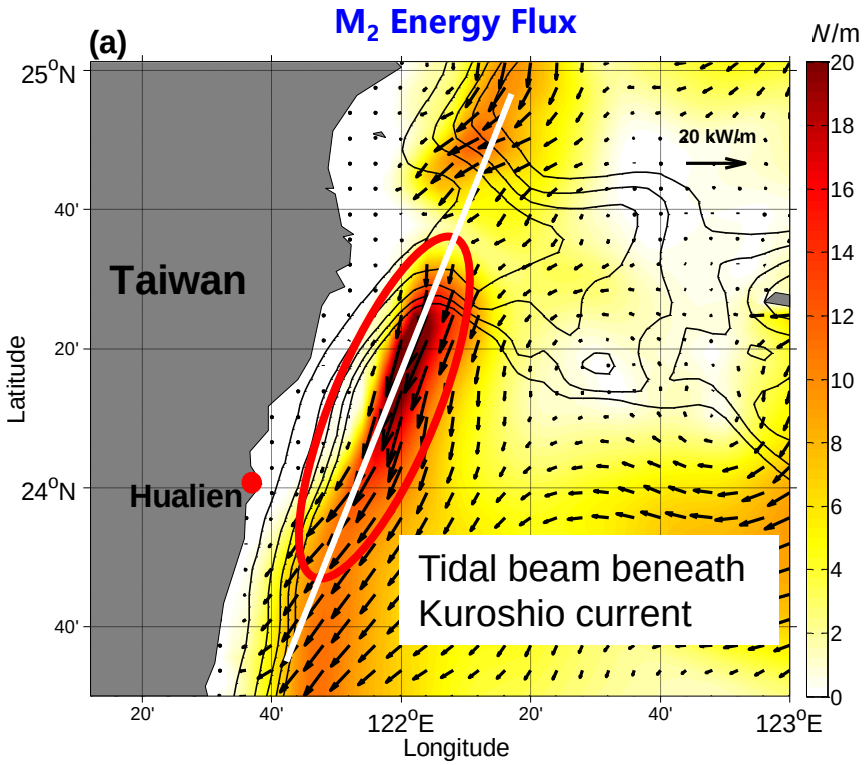
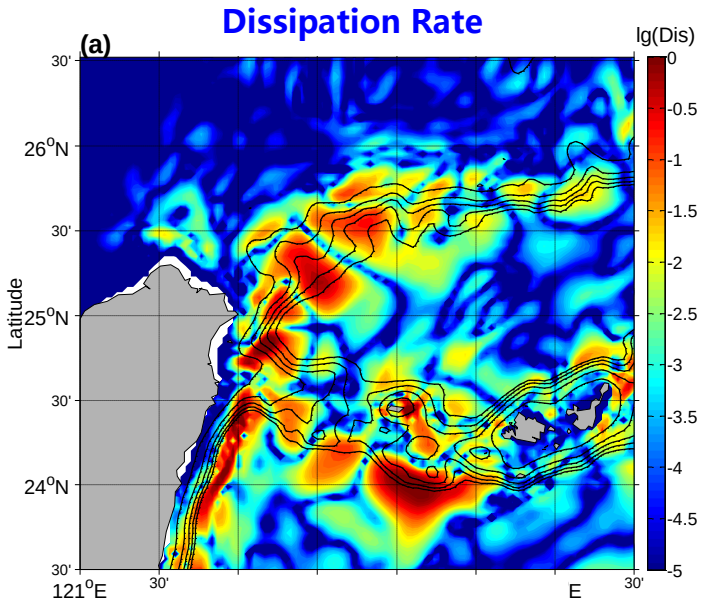
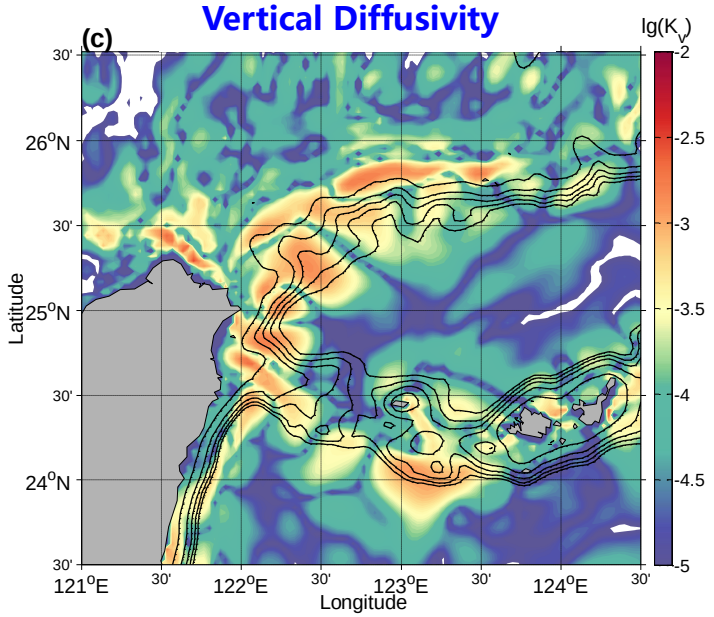
I-Lan ridge has been proved a strong source site of internal tides







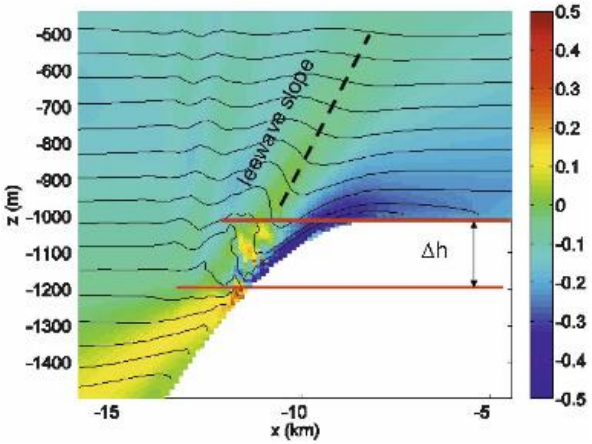
- Strong M2 internal tides are generated at the I-Lan Ridge, propagating against the Kuroshio
- The M2 internal tide energy dissipates primarily near the source
- Various geometry and background currents enhance dissipation, induce strong, inhomogeneous vertical mixing

(Chang et al., 2018)

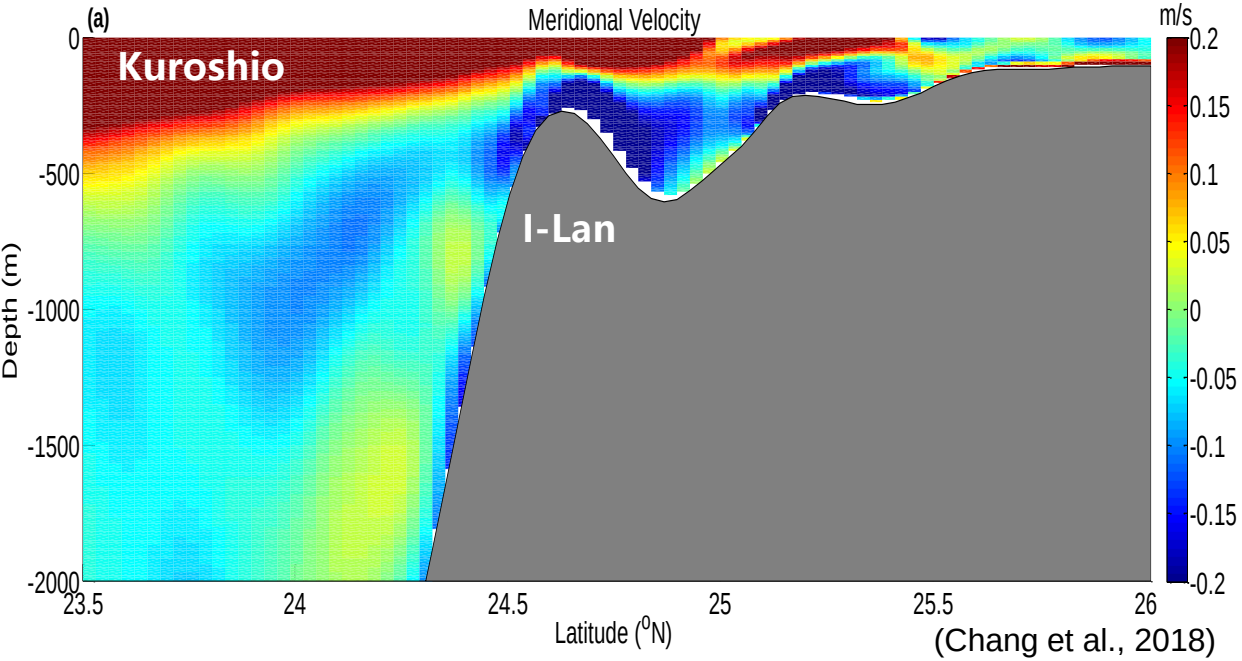
What about the highly nonlinear internal waves in I-Lan ridge?

What we know for mechanism

- ✓ Highly nonlinear internal waves can be triggered over steep topography by stratified flow
- ✓ Highly turbulent nature due to the convective and shear instability



(Legg & Klymak, 2008)

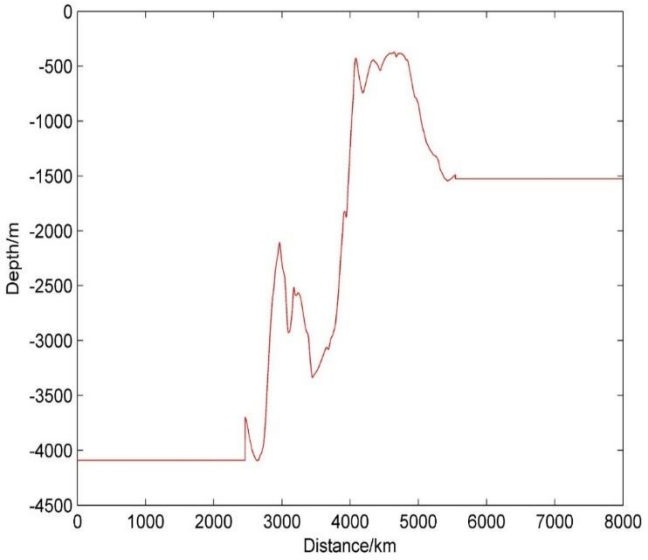


(Chang et al., 2018)

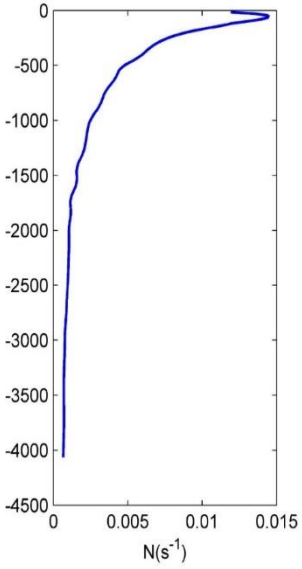
What we know for I-lan ridge

- ➢ Strong stratified flow (Kuroshio) over steep topography (I-lan ridge)
- ➢ Asymmetric depth
- ➢ Seasonal variation of flow strength and stratification

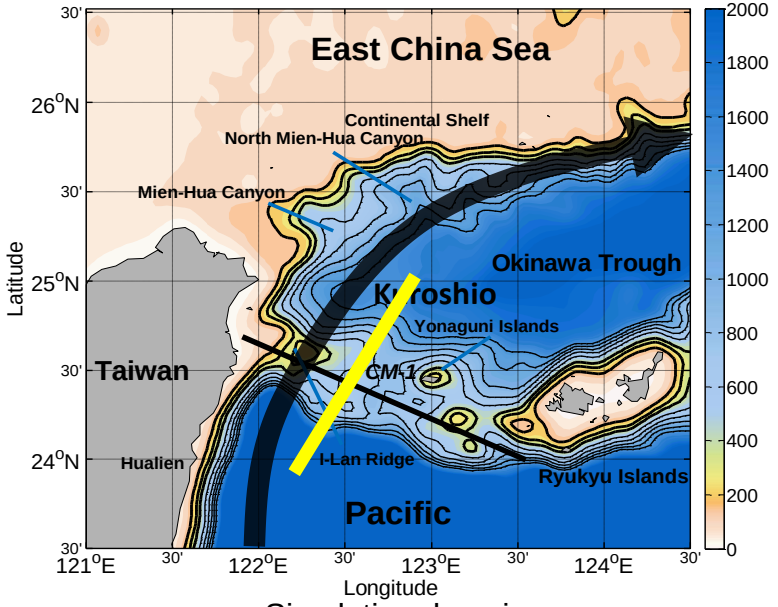
Numerical simulation settings



Cross section topography



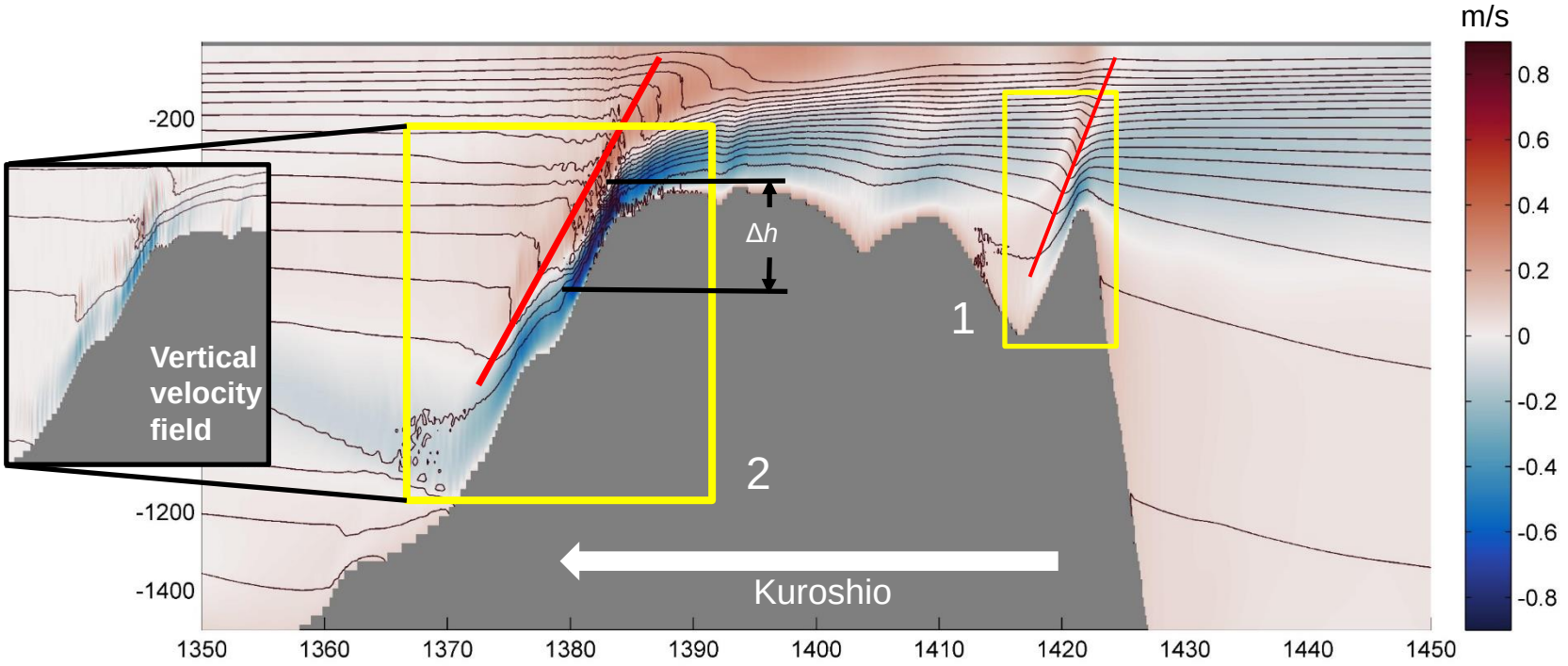
stratification



Simulation domain

Domain	Cross-section of I-lan ridge
Tidal forcing	Barotropic wave in amplitude of 0.01
Horizontal resolution	40m (8000 grid)
Vertical resolution	15m (near surface)– 23m (deep ocean) (200 layers)
Bathymetry	GEBCO 1/60
Current	Seasonal averaged kuroshio
Time step	1s

Results – experiment only consider the Kuroshio

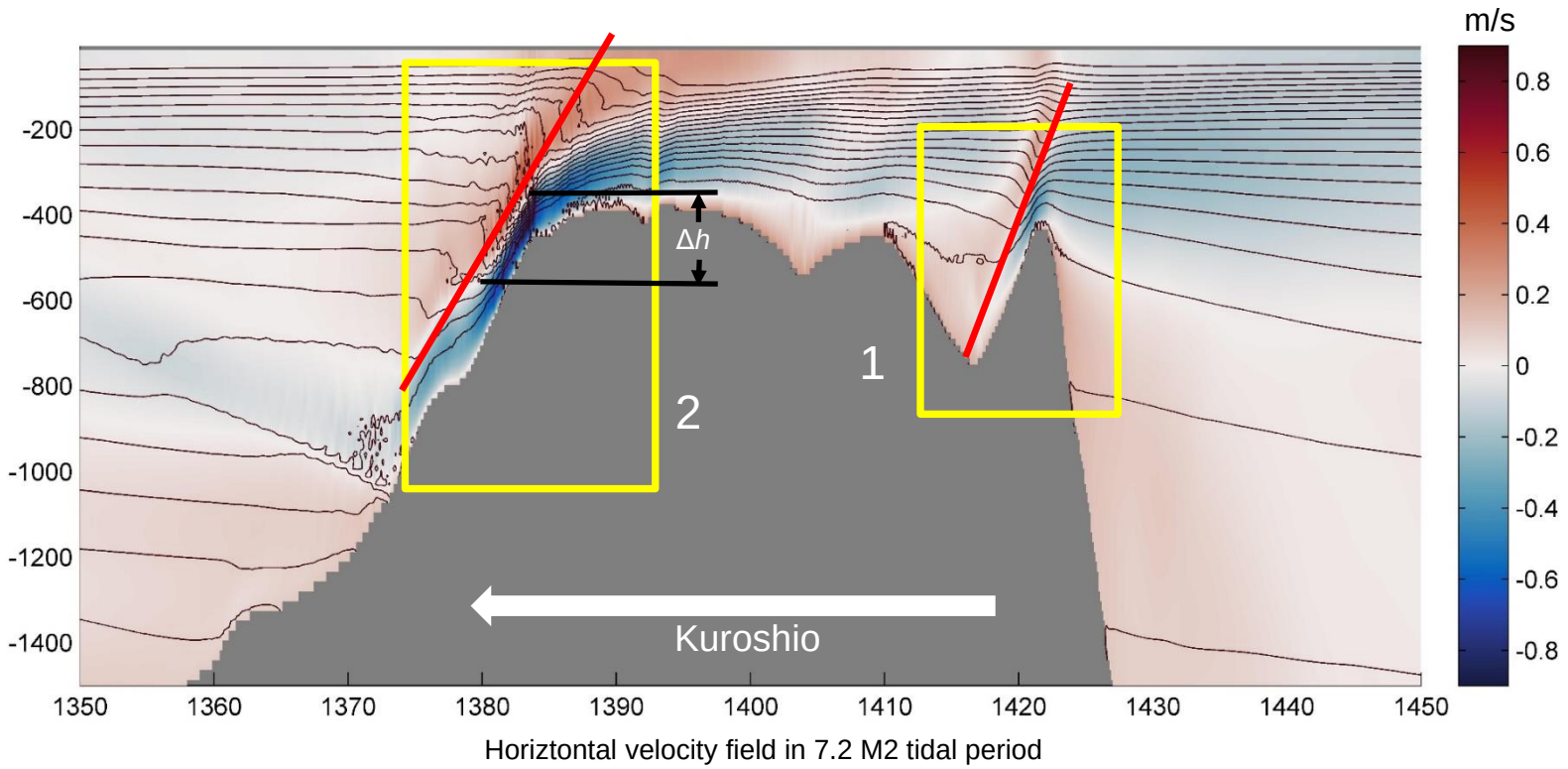


Horizontal velocity field in 8.8 M2 tidal period

Lee wave – like nonlinear process can be identified in first and second ridge

- At first ridge, the nonlinear process induced the steepen of density field, a structure similar to the lee wave slope can be observed as well.
- At second ridge, the steepen of density was strengthened, and a maximum downward isopycnals displacement formed. The vertical extension of this displacement defined by maximum horizontal velocity was ~250m, similar results was obtained by Legg & Klymak (2008)

Results – experiment consider the Kuroshio and tidal current

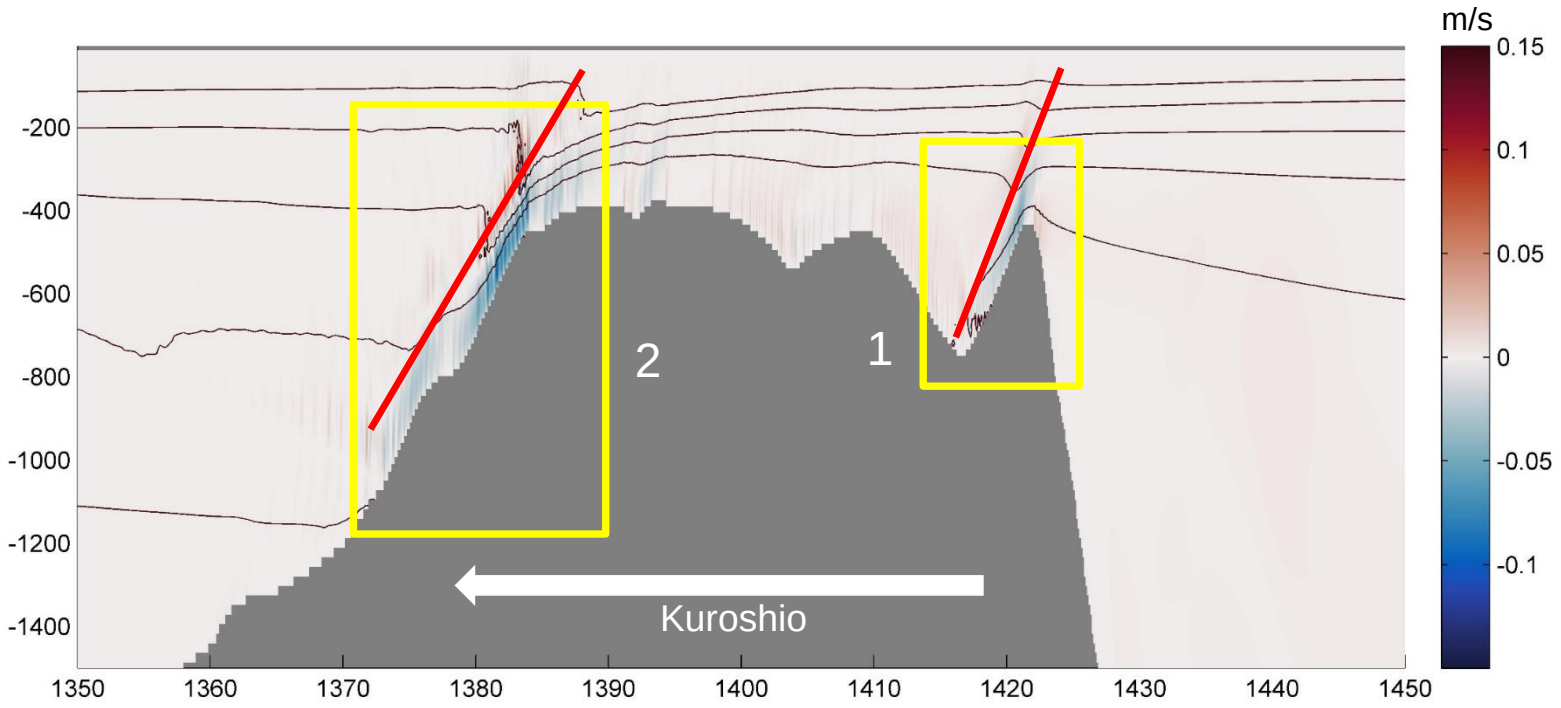


Horiztontal velocity field in 7.2 M2 tidal period

Consider the effect of both Kuroshio current and tidal current, the tidal flux was set to 40 (0.01*4000)

- With a relatively weak tidal flux, the horizontal velocity was increased, but no obvious strengthen was founded.
- The counter-current beneath Kuroshio was strengthened, it was verified by previous study (Chang et al., 2018)
- The extension of maximum vertical displacement decreased to ~200 m

Results – experiment consider the Kuroshio and tidal current



Vertical velocity field in 7.2 M2 tidal period

Compare with the case only consider the Kuroshio

- The vertical extension of maximum downward displacement was decreased
- The strength of vertical velocity of off slope flow was decreased as well
- The nonlinear process was modulated by the tidal flow, a combination effect should be taken into account

Staged progress

I. The generation of nonlinear process over I-lan ridge induced by the Kuroshio and tidal current was numerically simulated.

II. A lee wave slope like structure was founded in the downstream side of the ridge, causing an off slope flow down the ridge

III. The vertical extension of maximum isopycnals displacement caused by the nonlinear process can reach ~250m, similar to the results obtained by Legg & Klymak (2008)

IV. With the tidal current, the counter current beneath the Kuroshio was strengthened but the vertical velocity of off slope flow was decreased, demonstrating that the tidal current could modulate the generation of nonlinear process

Next step

I. The seasonal variation of Kuroshio current should be investigated, including the variation of the strength of current and the difference of stratification

II. The variation of vorticity induced by the stratified flow should be also investigated

III. Further analysis of nonlinear process is required, the dynamics need to be revealed and the turbulence should be quantitatively estimated

Thanks for your attention!