Dynamics and energetics of nonlinear internal wave around a double-canyon system

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1. Background

- The continental shelf-slope northeast of Taiwan is a hotspot of Internal Solitary Wave (ISW), which show complex spatial pattern (Hsu et al., 2000).
- Typical topographic features around this region include two adjacent canyon-the Mien-Hua canyon and the North Mien-Hua canyon, which are energetic sources of the internal tides.Besides that, northward internal tide originated from the I-Lan ridge can also contribute to the energy budget (Chang et al. 2019).
- The complex spatial pattern of ISW can be attributed to the multiple sources and the modulation of the Kuroshio.

Fig.1 Typical SAR image of ISW and statistical distribution of ISWs northeast of Taiwan (Hsu et al., 2000)
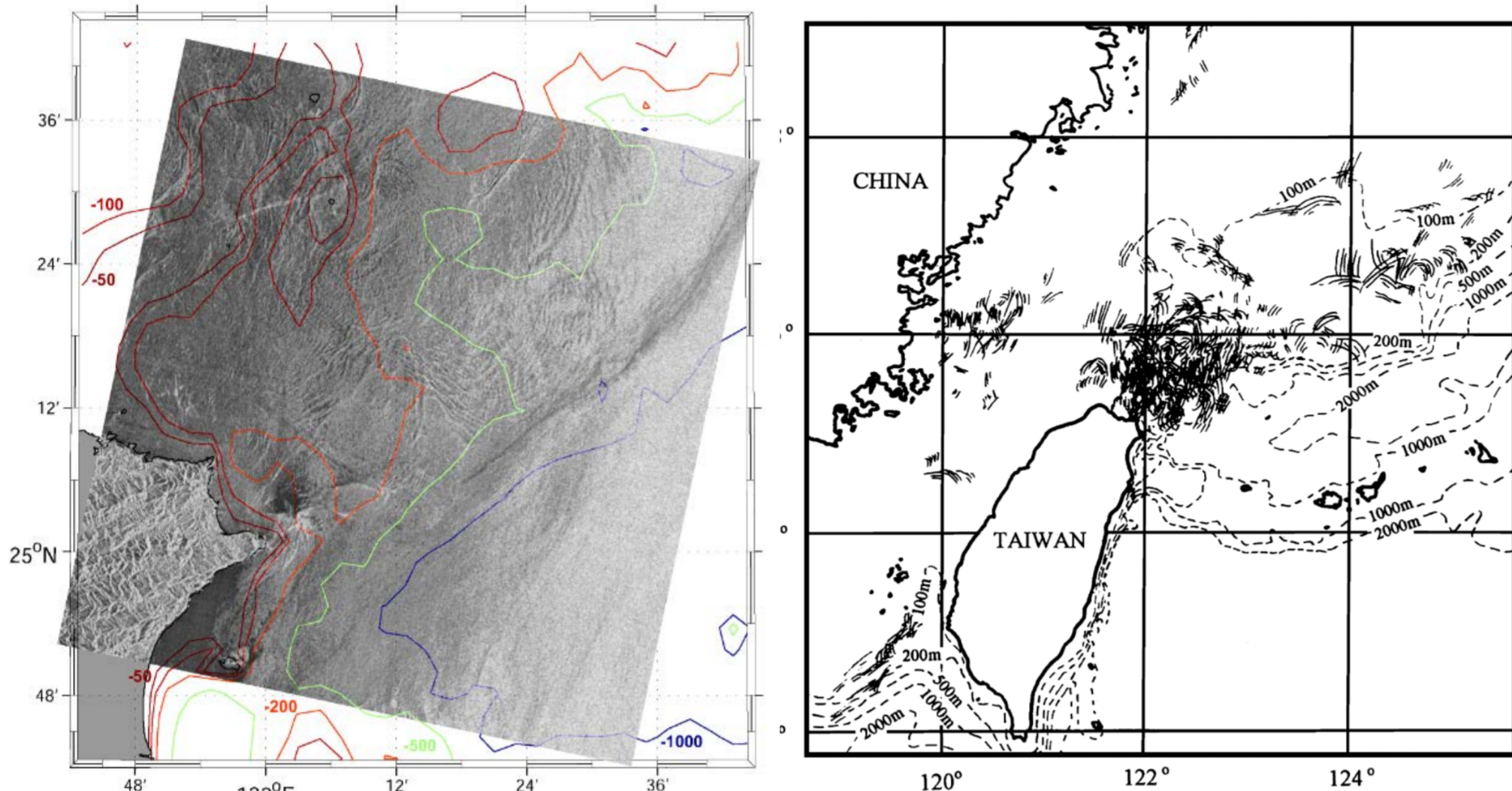
2. Model Configuration

- The MITgcm with nonhydrostatic approximation tuned on is used.
- The Richardson number dependent parameterization for turbulent closure of vertical viscosity and diffusivity was used, the horizontal viscosity and diffusivity were set to a constant $0.01 m^2/s$.
- The stretching grid was used with dlon, dlat ≈100m around focusing region, 70 layers in vertical, dz ≈6m in the upper 60m and increased to 180m in the deep ocean, dt=8s.
- Two model experiments were carried out, One with the horizontal averaged stratification and only tide was considered, the other one considered the influence of Kuroshio with realistic stratification.
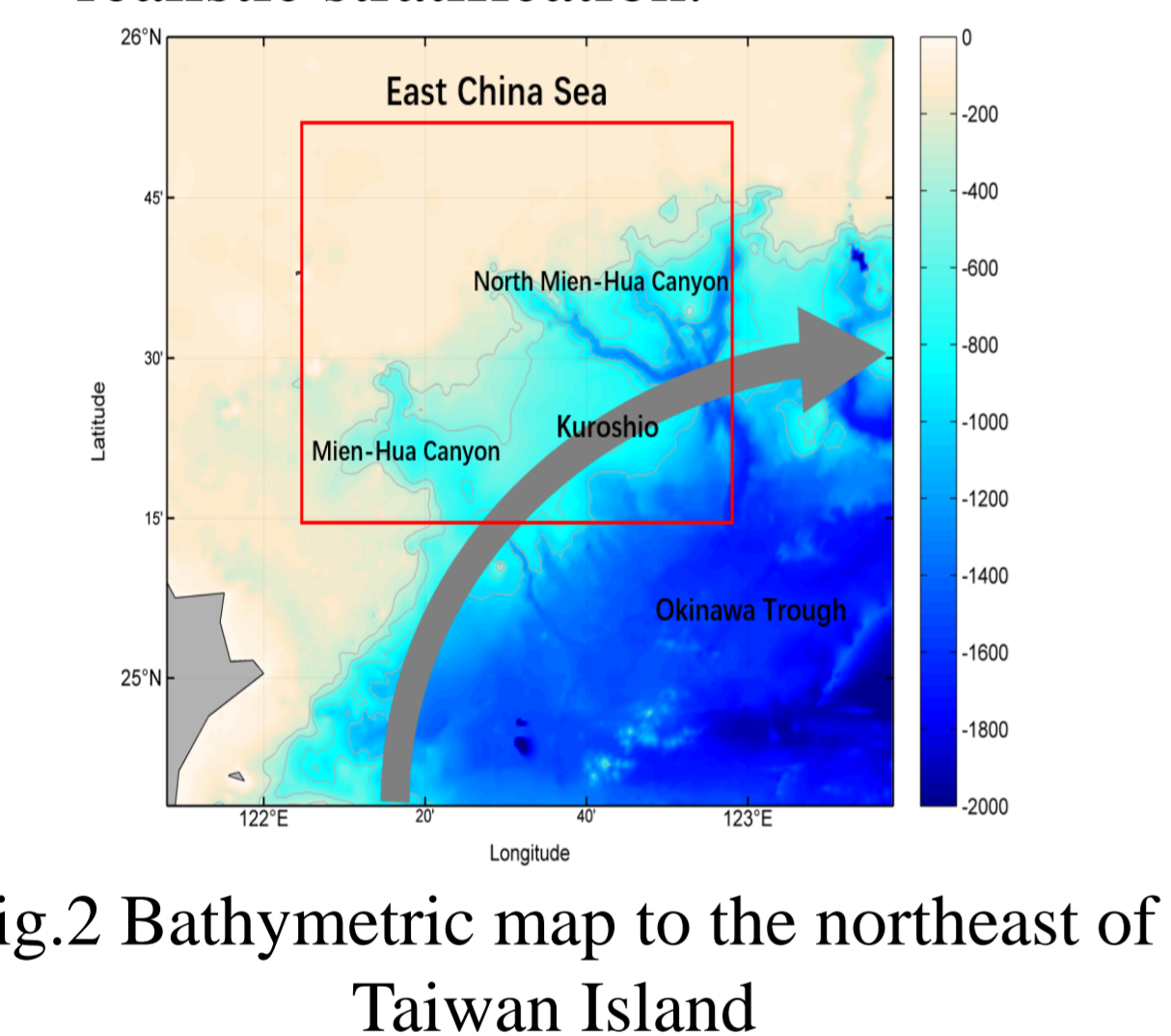

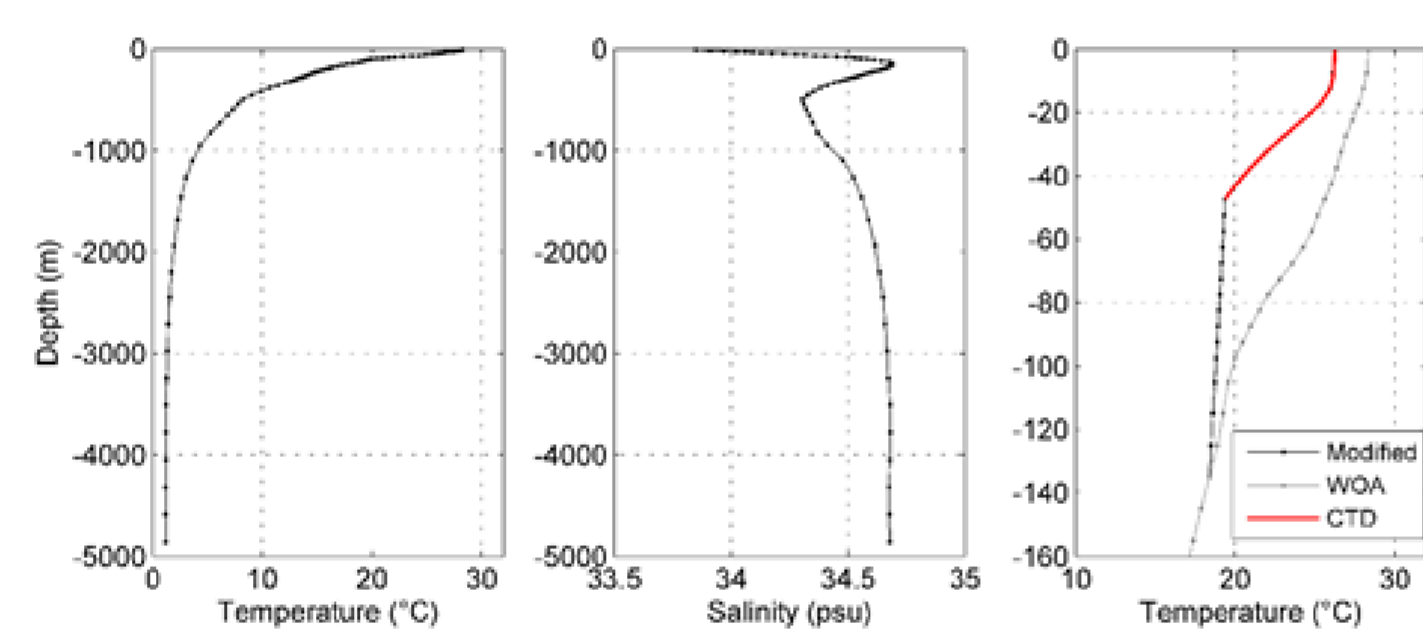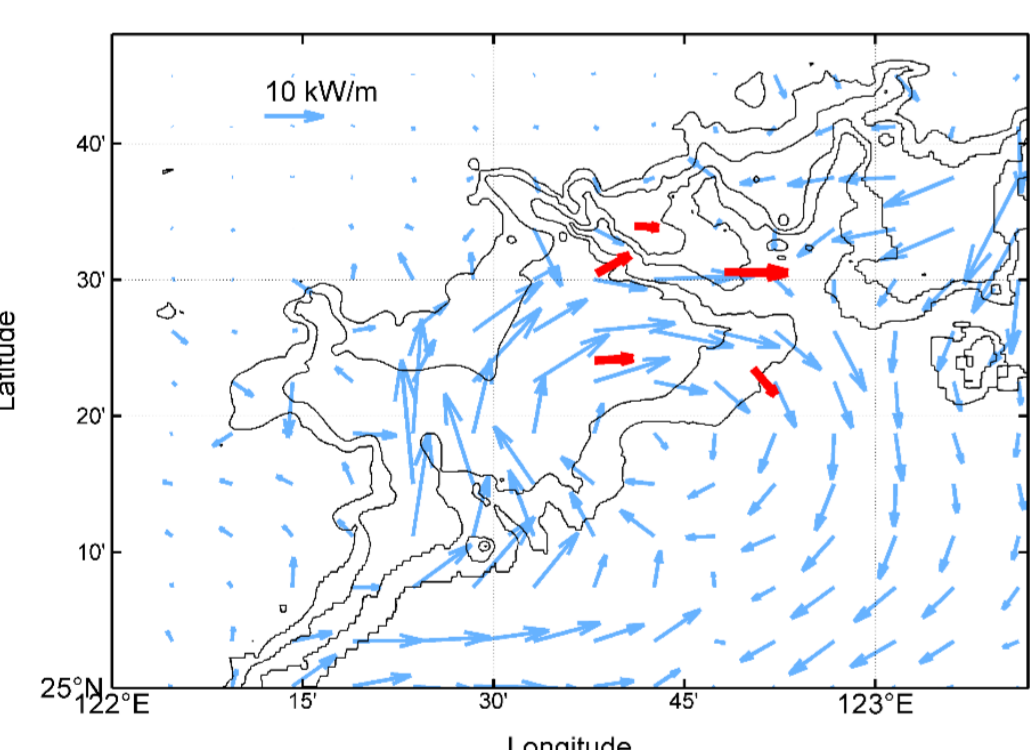Fig.2 Bathymetric map to the northeast of Taiwan Island

Fig.3 Typical stratification northeast Taiwan Island derived from WOA15, with modification of the upper layer based on in situ CTD data

3. Energy budget of Internal Tide-with Kuroshio

- Fig.4 Spatial distribution of the depth-integrated and period-averaged M2 baroclinic energy flux (Blue). The observed energy flux (red) derived from Lien et al. (2013).
- Anti-cyclonic structure was captured and consistent with obs and previous model result (Chang et al., 2019)
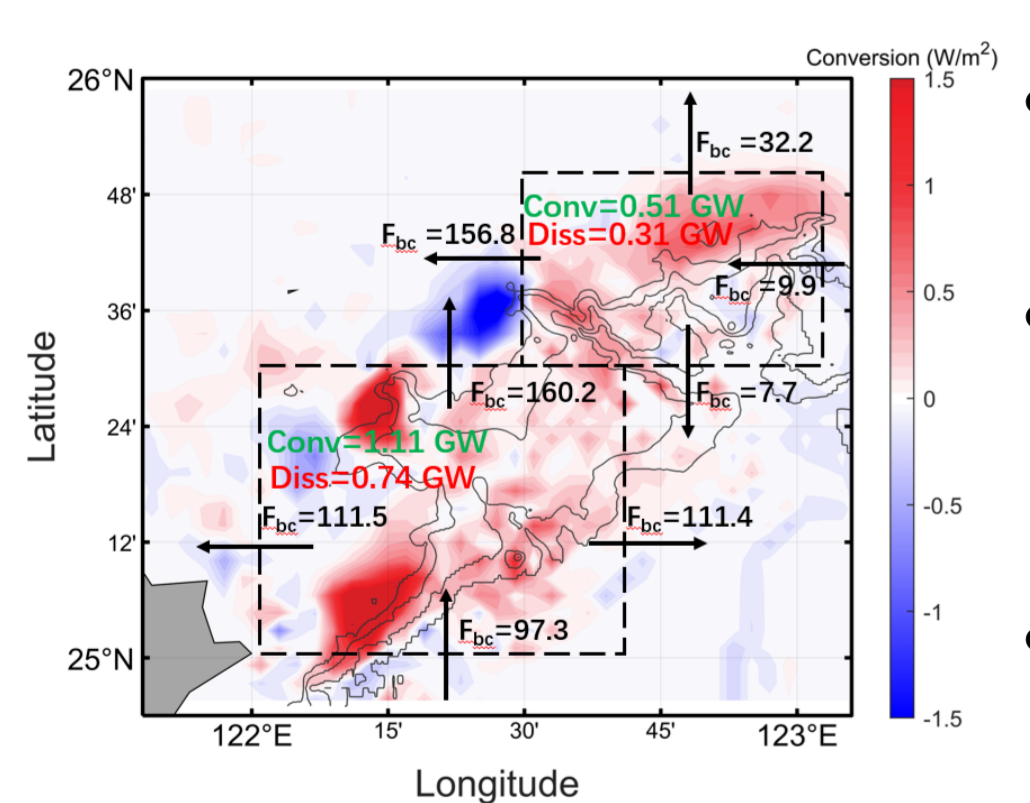
- Fig.5 Spatial distribution of the barotropic to baroclinic conversion rate and energy budget.
- Local generation and dissipation were dominant around the canyon compared with the energy from the south I-Lan ridge;
- Energy toward the shelf was stronger than that toward to the deep ocean.
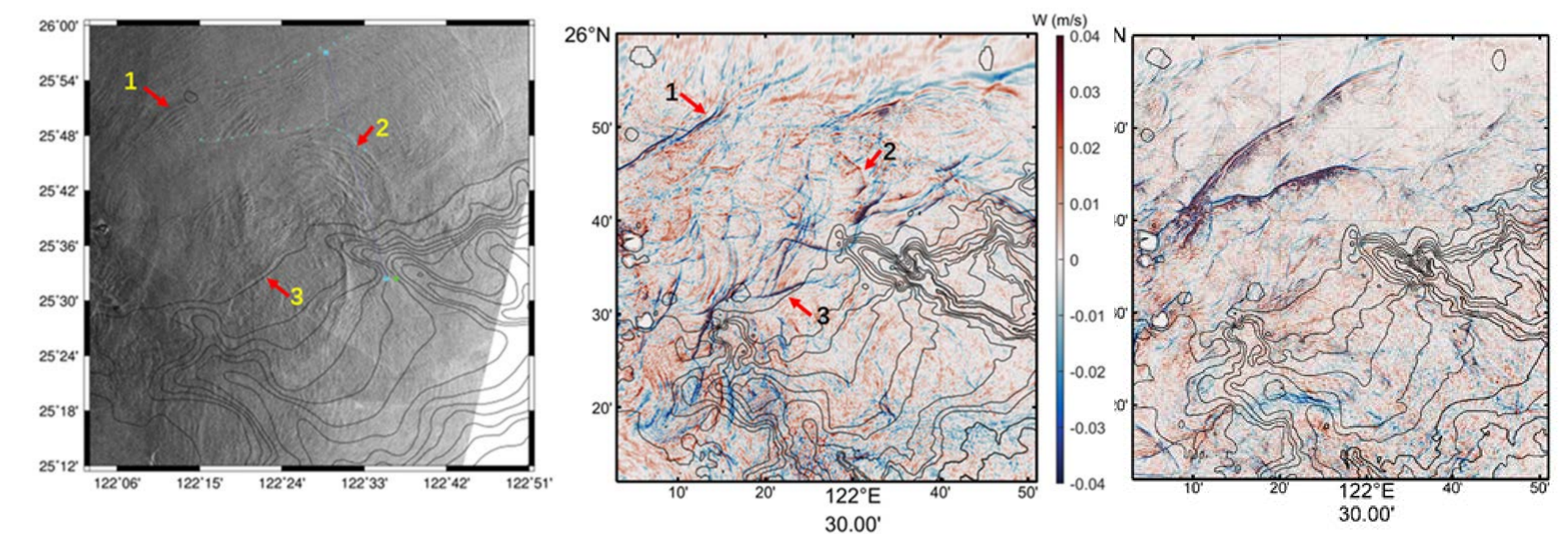
4. Spatial pattern of ISWs

Fig 6 Modal-data comparison of signatures induced by internal waves, (Left) SAR image collected on the continental slope region northeast of Taiwan from Duda et al.2013, (Mid) Modeled vertical velocity at 60m with tide and Kuroshio and (c) with tide only

- Numeber indicated typical ISW trains in the SAR image and clearly captured by the model with Kuroshio, while the model results from the tidal only experiment can only produce the shoreward ISW.
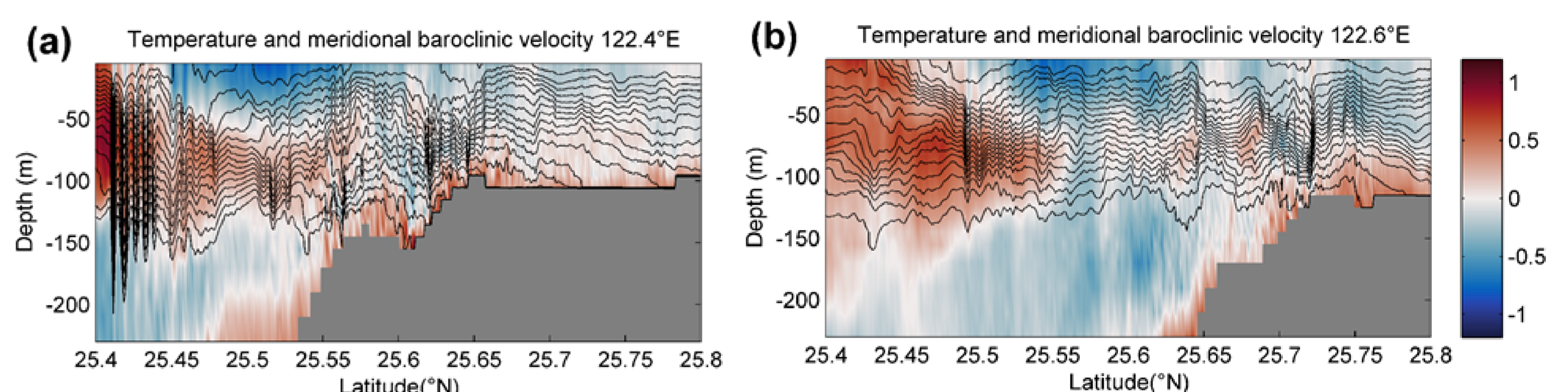

Fig.7 Meridional cross sections along 122.4° E (a) and 122.6° E (b) of differences in temperature (contours) and meridional baroclinic velocity at t=241 h. Contour interval for the temperature is 0.6^0C.

- Cross section of the ISW field (a) showed the shoreward ISW with large amplitude at the head of north canyon and revealed the multimodal structure at the shelf region with correspond to the strong mixing process around this region.
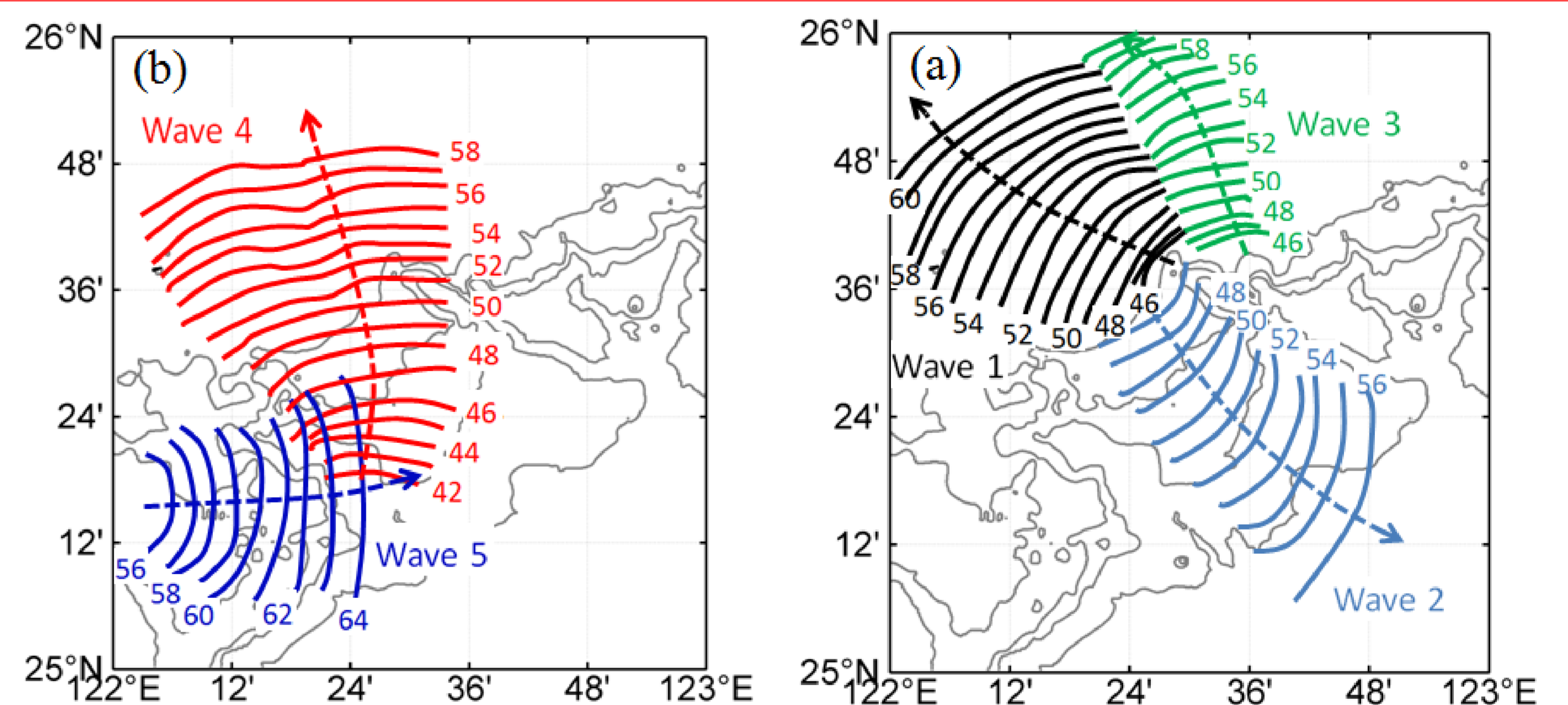

Fig.8 Evolution picture of thetypical wave systems generated in the area. The numbers on the wave fronts show the time (in h) after the beginning of the experiment. (c) The Froude number calculated for Waves.

- 5 typical ISW trains were identified from the model time series, it showed that the head of the north Mien-Hua canyon was more efficient on the generation of ISW, with two shoreward and one off-shore wave trains captured.
- The wave generated around the north flank of the Mien-Hua canyon was highly energetic and turn to the shoreward direction after the generation process due to the restriction of Kuroshio on the offshore.
- Analysis based on the Froude number (wave 1) showed that the generation mechanism of wave 1 is mixed-tidal-lee wave mechanism.

Reference

Chang, H., Xu, Z., Yin, B., Hou, Y., Liu, Y., Li, D., Wang, Y., Cao, S. and Liu, A. K., Generation and Propagation of M2 Internal Tides Modulated by the Kuroshio Northeast of Taiwan. Journal of Geophysical Research: Oceans. 2019, 124, 2728-2749.
Christopher R. Jackson.An Atlas ofInternal Solitary-like Wavesand their Properties, Second Edition, 2004, Global Ocean Associates, Jean Louise Way Alexandria, VA 22310
Duda, T. F., Newhall, A. E., Gawarkiewicz, G., Caruso, M. J., Graber, H. C., Yang, Y. J. and Jan, S., Significant internal waves and internal tides measured northeast of Taiwan. Journal of Marine Research. 2013, 71, 47-81.
Hsu, M.-K., Liu, A. K. and Liu, C., A study of internal waves in the China Seas and Yellow Sea using SAR. Continental Shelf Research. 2000, 20, 389-410.
Lien, R.-C., Sanford, T. B., Jan, S., Chang, M.-H. and Ma, B. B., Internal tides on the East China Sea Continental Slope. Journal of Marine Research. 2013, 71, 151-185.
Vlasenko, V., Stashchuk, N., Inall, M. E., Porter, M. and Aleynik, D., Focusing of baroclinic tidal energy in a canyon. Journal of Geophysical Research: Oceans. 2016, 121, 2824-2840.
warming of Arctic halocline by Atlantic heat fluxes over rough topography, Nature geoscience, 8:191-194, DOI: 10.1038/NGEO2350.

6. Conclusions

- The generation and evolution of nonlinear internal wave generation and evolution over a double-canyon region northeast of Taiwan Island was modeled based on 3D nonhydrostatic numerical model.
- The internal waves generated in the I-Lan Ridge are not likely to span large amplitude ISWs on the Mien-Hua Canyon area. Most of the energetic ISWs are generated by tide-topography interaction on the double-canyon region and the adjoint continental shelf slope area.
- The complex spatial pattern of ISW northeast of Taiwan was mainly modulated by the intrusion of the Kuroshio, with tide forcing only, the propagation of ISW was relatively unidirectional.
- Further refined grid resolution is necessary for accurately resolve the breaking details of ISW towards the shallow water.