

# **Nonlinear Internal Waves in the Northwestern Part of South China Sea**

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The nonlinear internal waves in the South China Sea (SCS) in deep basin, on shelf break, and in shallow coastal water have been observed by satellite remote sensing, shipboard instruments, and moorings for many years. Recently, internal waves on the shelf break in the northwestern part of SCS near Hainan observed by satellite and mooring have been studied. Elevation and depression waves have been observed at the same mooring location corresponding to different environmental (stratification) and tidal conditions. An internal wave distribution map has been compiled by delineated from many Synthetic Aperture Radar (SAR) images in the northwestern part of SCS. Based on these distribution maps, most of the internal waves in the northeastern part of the SCS were propagating westward. It suggests that these waves may originate from tide-topography interactions in the Luzon Strait. However, since all these waves on the shelf follow bathymetry closely, it is also likely generated along the shelf break from local tidal-topography interactions.

Besides on the shelf near Dongsha, there are also many oil drilling rigs around Hainan. Recently, internal solitary waves in this area have been studied by Li et al. (2008) using satellite images. Base on their map of the northern SCS and barotropic tidal forcing analysis, they suggest that these waves originate from tide-topography interactions in the Luzon Strait. However, some field observations were made in 2005 at Wenchang Station east of Hainan on the northwestern shelf of SCS as shown in Figure 1 for depression waves and elevation waves on August 22, 2005.

Both elevation and depression waves have been observed at the same mooring location with amplitudes of 10 m and 20 m, respectively, corresponding to different environmental (stratification) and tidal conditions. Similar depression and elevation wave amplitudes of 40 m and 25 m were also measured on September 9 and 10 respectively.

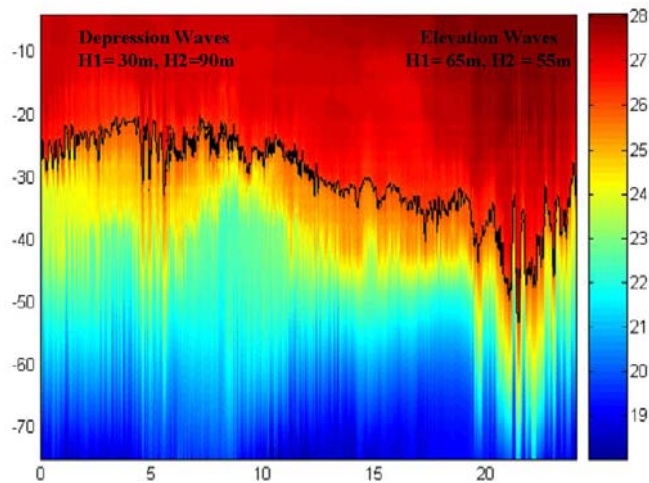


Figure 1. Time series of isotherm depths from temperature data with depression and elevation waves on August 22, 2005.

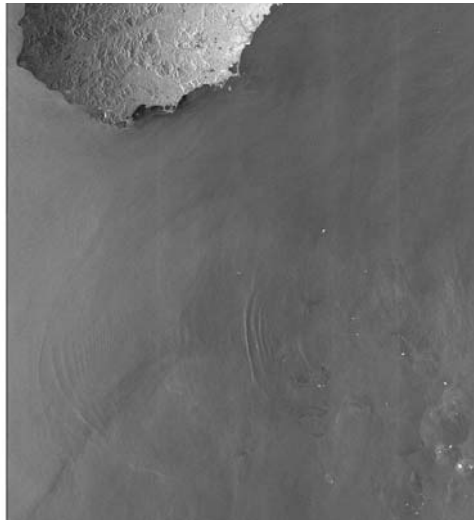


Figure 2. ENVISAT SAR image collected over south of Hainan on June 9, 2008 with large internal waves in the deep water.

Based on the measurements on the passing large depression hump of tidal bore in the mooring area, it suggested these internal waves on top of these tidal bore are most likely locally generated near the shelf break. Otherwise, the tidal bore and solitons/waves should be well-developed if they have propagated 880 km during 100 hours from the Luzon Strait across the SCS deep basin to the mooring area. Therefore it is plausible that these internal waves south/southeast of Hainan are probably generated locally from the shelf breaks as tidal current encounters the topographic feature or shelf break.

As an example, Figure 2 shows a SAR image collected over south of Hainan on

June 9, 2008 with large internal waves in the deep water. Based on the SAR images collected near the south of Hainan, a composite map of internal tides and waves delineated from SAR images is shown in Figure 3. Since all these waves on the shelf follow bathymetry closely, it is likely generated along the shelf break from local tidal-topography interactions.

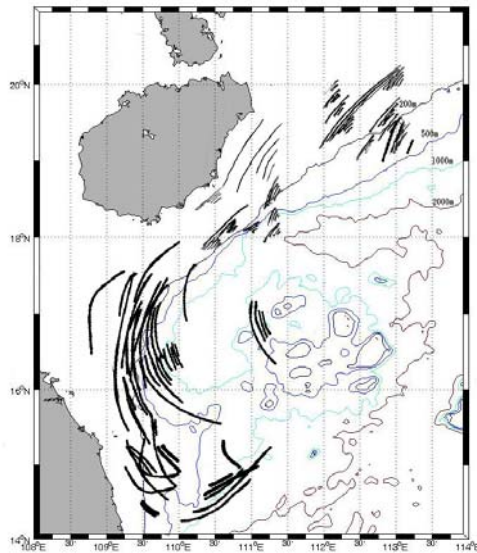


Figure 3. Bathymetry and internal wave distribution map in the south of Hainan.

Based on the observations from SAR and mooring data, the environmental condition and typical internal wave characteristics in the northeast part of SCS can be summarized as follows:

- 1) Water Depth from 1 km to 120 m on shelf in shallow water;
- 2) Internal Wave Direction from 15° on the shelf of China coast to southeastern and southern on the shelf of Vietnam;
- 3) Internal Wave Speed is averaged approximately 1.0 m/s;
- 4) Soliton/Wave Width is estimated around 1.2 km;
- 5) Number of waves in a packet ranges from 5 to 10;
- 6) Wave Amplitude is ranged from 50 m to 15 m.

Based on ADCP mooring data, a 0.4 m/s drift eastward in the upper mixed layer is accompanied by a westward drift of 0.4 m/s in the bottom layer for a mode-one wave. More in-situ measurements are required in conjunction with satellite observations to establish the statistics for wave characteristics in the northwest part of SCS. One of the major issues is the sources of generation; whether it is originated from the Luzon Strait or generated from local shelf break or topography. Recently, Chinese petroleum exploration has found oil wells in the deep ocean (1500 m)

southeast of Hainan. The impact of these internal waves in deep water on the Raiser Tower System (RTS) and Artificial Buoyancy Seabed (ABS) for deep ocean oil platform technology will be discussed.

### **Reference**

Li, X, Zhao, Z, and Pichel, WG (2008). “Internal Solitary Waves in the Northwestern South China Sea Inferred from Satellite Images”, *Geophy. Res. Let.*, Vol 35, L13605, doi:10.1029/2008GL034272.