Form 3

Annual Report

LaMer, Ehime University

Date (16 , 11 , 2017)

To Director of LaMer

Principle Investigator:

Affiliation Second Institute of Oceanography, SOA

Position Research Assistant

Name in print Ruixiang Zhao

e-mail zhaorx@sio.org.cn

Include the report on the result of the project/meeting in a separate sheet.

1. Project / Meeting title

Applications of pressure-recording inverted echo sounders

2. Members of project / meeting

Name	Affiliation	Position	Contribution part
PI			
Ruixiang Zhao	Second Institute of Oceanography, SOA	Research Assistant	Data processing; Paper writing
Members			
Xiao-Hua Zhu	Second Institute of Oceanography, SOA	Senior Research Scientist	Beneficial discussion
Xinyu Guo	Ehime University	Professor	Beneficial discussion

3. Contents (please write in separate sheet, A4-size, within 5 pages

Title

Applications of pressure-recording inverted echo sounders

Members' names and affiliations

Name	Institution and Department	Employment position	E-mail
Zhu Xiao-Hua	Second Institute of Oceanography, SOA	Senior Research Scientist	xhzhu@sio.org.cn
Xinyu Guo	Faculty member of LaMer	Professor	guoxinyu@sci.ehime-u.ac.jp

Aim

This project aims to carry out cooperative research with Prof. Guo Xinyu of Ehime University on the application of pressure-recording inverted echo sounders (PIESs) deployed in the South China Sea (SCS), Kuroshio and other regions.

Procedure

The principal investigator (PI) has first made an oral presentation "Observations from pressure-recording inverted echo sounders in the South China Sea" and showed the recent studies of PI including: 1. The variability of 22-year-long volume transport of the South China Sea western boundary current based on PIES and satellite altimeter measurements. 2. The impact of monsoon winds and mesoscale eddies on thermohaline structures and circulation patterns in the northern South China Sea. 3. Weakest winter South China Sea western boundary current caused by 2015/2016 El Niño event.

The PI will carry out further research with Prof. Guo Xinyu on the following subjects: 1. The variability of internal tide observed by PIESs in the SCS and Kuroshio. 2. The near-5-day nonisostatic response to atmospheric pressure from globally

distributed PIESs. 3. The response of Kuroshio to ENSO from PIES observations. A thorough discussion on the simulation of PIES observations or some numerical experiments will be carried out if enough time is available.

Results

Our joint research of this year (2016) is focused on the study of internal tides in the South China Sea from the PIES observations. During October 2012 to July 2014, 5 pressure-recording inverted echo sounders (PIESs) were deployed in the northern South China Sea. The PIESs mainly measure vertical acoustic travel time (τ), i.e., the time for sound pulses transmitted from the seafloor to the sea surface and back, and measure the near-bottom pressure (Pbot), all with a time interval of 1 hour. The Pbot is appropriate to capture the tides of the barotropic components, and the measured τ is good at detecting signals of the internal tides, for it is sensitive to the variation of the thermocline depths (Watts and Rossby, 1977; Park and Watts, 2006).

Though the wavelet analysis (Fig.2) of the band-pass filtered τ (with cutoff periods of 0.2 days and 2 days), the following conclusions are drawn: 1. The internal tide is more energetic in shallower waters near the continental slope, indicating the effects of topography. 2. The diurnal internal tide is stronger than the semidiurnal internal tides. 3. The internal tides are strongly impacted by the barotropic tides. 4. Both the semidiurnal and the diurnal internal tide show significant variability which may be strongly related to the occupation of mesoscale eddies. However, their behaviors to eddies are quite different (Fig.3): the semidiurnal tide strengthened (weakened) when cyclonic (anticyclonic) eddies were present, while the diurnal tides were extensively weakened with the arrival of cyclonic eddies. The reason why semidiurnal and diurnal internal

tides responded differently to meso-scale eddies are still under investigation, but we guess that variation of internal tides may be due to the fact that mesoscale eddies can cause changes of water properties, which may alter the path of the internal tides propagation (Park and Watts, 2006).

References:

1. Watts, D.R., and H. T. Rossby (1977), Measuring Dynamic Heights with Inverted Echo Sounders: results from MODE, *Journal of Physical Oceanography*, 7(3): 345- 358.
2. Park, J.-H., and D. R. Watts (2006), Internal Tides in the Southwestern Japan/East Sea, *Journal of Physical Oceanography*, 36(1): 22- 34.

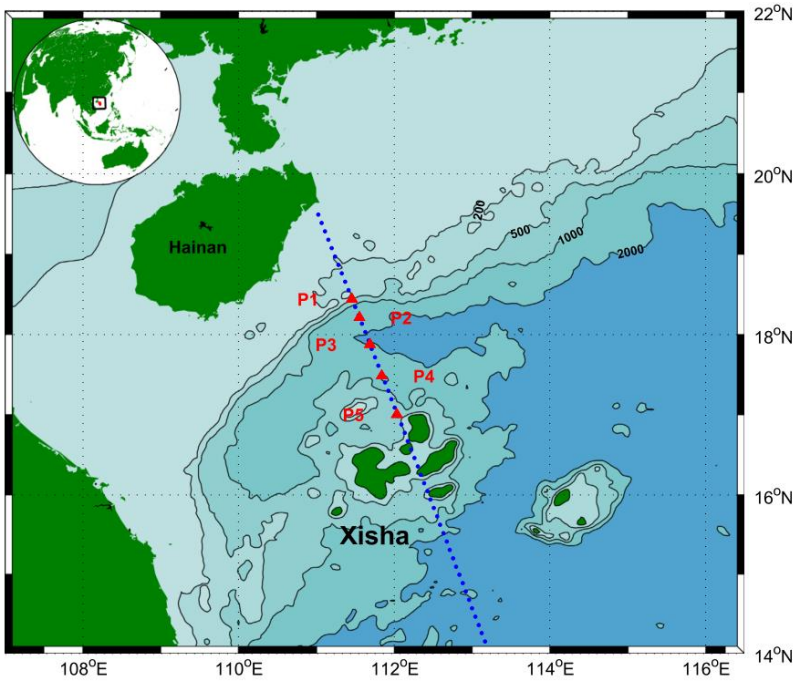

Figure 1. Location map of the PIES stations. Red triangles indicate the individual PIES instruments and blue dots indicate the TOPEX/POSEIDON and Jason-1/2 satellite altimeter track (track 114). Bathymetry is contoured in meters.

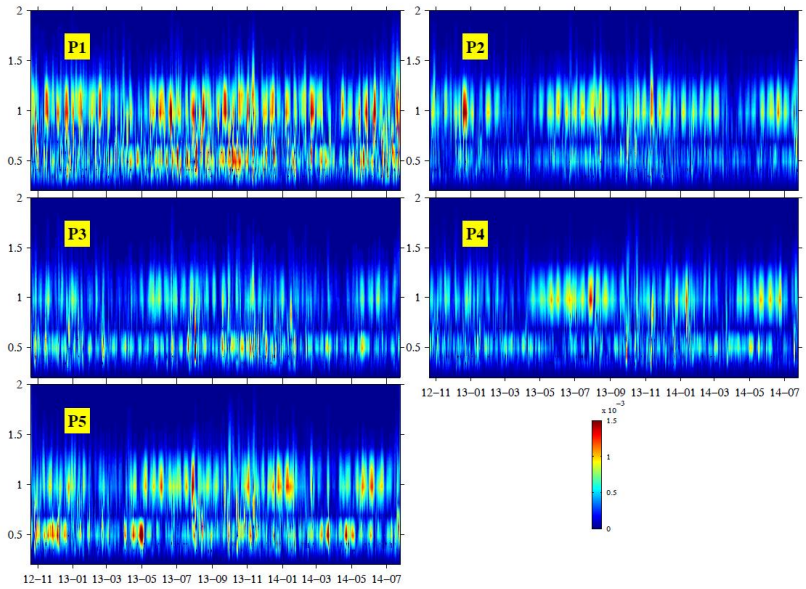

Figure 2. Wavelet analysis results of vertical acoustic travel time (τ) detected by 5 pressure-recording inverted echo sounders (PIESs) at the semidiurnal and diurnal bands.

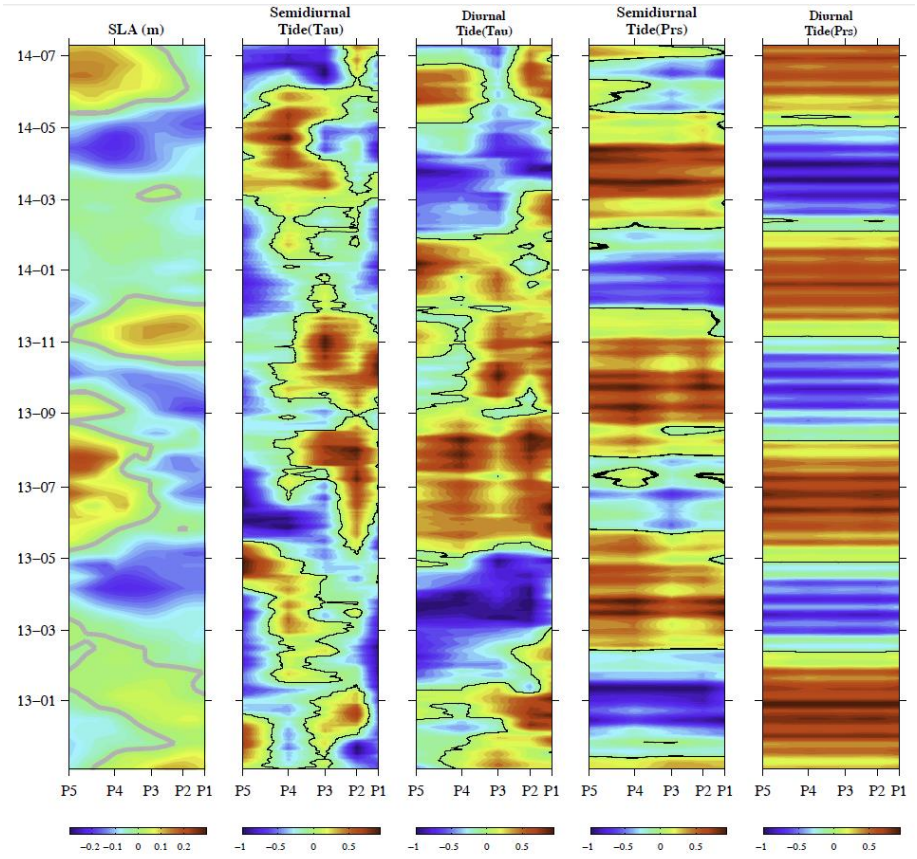

Figure 3. The Hovmöller diagram of the normalized (a) sea level anomaly (b)

semidiurnal internal tide signals (c) diurnal internal tide signals (d) semidiurnal barotropic tide signals (e) diurnal barotropic tide signals.

Publication/conference presentation

Publications:

1. Zhu, X.-H., R. Zhao, X. Guo, Y. Long, Y.-L. Ma ,and X. Fan (2015), A long-term volume transport time series estimated by combining in situ observation and satellite altimeter data in the northern South China Sea, Journal of Oceanography, 71(3), doi:10.1007/s10872-015-0305-5.

2. Zhao, R., X.-H. Zhu, and X. Guo (2016), The impact of monsoon winds and mesoscale eddies on thermohaline structures and circulation patterns in the northern South China Sea, Continental Shelf Research, doi: 10.1016/j.csr.2016.06.009.

Oral presentation:

Title: Applications of inverted echo sounder in the South China Sea.

Lecturer: Ruixiang Zhao.

Time: September 7, 2016.

Location: Ehime University.

Perspectives in future

We expect great progresses on the applications of PIES and our understanding of the circulation in the South China Sea, Kuroshio and other regions. We wish to publish our joint research on famous journals if possible.