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http://www.hyxb.org.cn
E-mail: hyxbe@263.net

News and Views

A new type of internal solitary waves with a re-appearance period of 23 h observed in the South China Sea

CHEN Liang[1, 2, 3], ZHENG Quanan[4], XIONG Xuejun[2, 3*], YUAN Yeli[1, 2, 3], XIE Huarong[2, 3]

[1] College of Oceanic and Atmospheric Sciences, Ocean University of China, Qingdao 266100, China

[2] The First Institute of Oceanography, State Oceanic Administration, Qingdao 266061, China

[3] Functional Laboratory for Regional Oceanography and Numerical Modeling, Pilot National Laboratory for Marine Science and Technology (Qingdao), Qingdao 266237, China

[4] Department of Atmospheric and Oceanic Science, University of Maryland, College Park, Maryland 20742, USA

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The South China Sea (SCS), in particular the northern SCS, is one of ocean areas where energetic internal solitary waves (ISWs) occur most frequently (Cai et al., 2012; Zheng, 2017). Based on the re-appearance period (RP) at an observation station, Ramp et al. (2004) divided the ISWs into two types: Type-a and Type-b. Type-a ISWs arrive regularly at the same time every day, i.e., the RP is about 24 h, and Type-b ISWs arrive about one hour late every day, i.e., the RP is about 25 h. The discovery of the Types-a and b ISWs has caused many oceanographers and scholars to study their characteristics and generation mechanisms. Ramp et al. (2010) found that the propagation speeds of both types of waves are (323±31) cm/s in the deep basin and (222±18) cm/s over the continental slope. Huang (2013) found that there are at least two cases of the ISWs in the SCS: the first case is that Type-a ISWs are strong, while Type-b ISWs are weak; the second case is that Type-a and Type-b are both strong. Huang et al. (2014) divided the 137 ISWs observed in the deep basin west of Luzon Strait into 81 Type-a and 56 Type-b ISWs, and found that during most of the experiments, Type-a ISWs induced a significantly larger horizontal velocity than Type-b ISWs. On the generation mechanism of the two types of waves, Ramp et al. (2004) revealed that tidal forcing at the Luzon Strait is the direct consequence: Type-a waves are generated on the strong side of the diurnal inequality, while Type-b waves are generated on the weaker beat. Zhao and Alford (2006) found that the two types of waves are both generated by the westward tidal current rather than lee-wave mechanism, the larger Type-a ISWs are generated by stronger tidal currents, while the smaller Type-b ISWs are generated by weaker tidal currents.

Recently, we discovered a new type of ISWs with a RP of about 23 h using mooring data observed in the west of Dongsha Islands in the SCS from 30 June 2016 to 21 July 2017. We define this newly discovered type of ISWs as Type-c ISWs, corresponding to the previously observed Types-a and b ISWs. The mooring location is on the northern shelf slope of the SCS with the depth of 397 m. The observation data include the current velocity, temperature and salinity. The current velocity was sampled via a 40-inch vitreous mounted, upward-looking 75 kHz acoustic Doppler current profiler (ADCP) at the depth of 380 m, 17 m above the bottom. It sampled 8-m bins every 3 min from 29 June 2016 to 13 June 2017 with a three month gap from 20 November 2016 to 20 February 2017 due to battery failure. Between the depths of 50 m and 380 m, a thermistor chain consisting of temperature loggers at every 10 m and conductivity-temperature-depth instruments at every 50 m was attached to the mooring to monitor the temperature and the salinity every 3 min.

Figure 1a shows that the ISWs observed from 2 to 4 September 2016 arrived regularly at the same time every day with the RP of about 24 h, implying that they are Type-a ISWs (Ramp et al., 2004). Figure 1b shows that the ISWs arrived about an hour late every day, i.e., the RP is about 25 h, and consist of a single soliton growing out of the center of the wave packet observed from 14 to 16 July 2017, which meet the definition of Type-b ISWs (Ramp et al., 2004). Besides the above two types of ISWs, Fig. 1c shows a new type of ISWs observed from 10 to 12 July 2017, which are characterized by early arriving for tens of minutes to an hour every day, i.e., the RP is about 23 h, and occurrences in the forms of single soliton and wave packets.

We define this type of early arriving ISWs as Type-c ISWs, which are distinct from previously observed Types-a and b ISWs. During the mooring observation period, the Type-c ISWs were repeatedly observed from 21 to 23 July and from 20 to 22 August 2016 (packets), as well as from 10 to 12 February 2017 (single soliton) (not shown here).

Figure 2 shows another case of Type-c ISWs with simultaneous current observations from 20 to 22 August 2016. From the temperature profiles shown in Fig. 2a, one can see that the ISWs arrived 50 min early every day, which is a typical feature of Type-c ISWs. The velocity profiles shown in Figs 2b and c show clear evidence for the existence of this new type of ISWs. The zonal velocity profiles show a two-layer structure characterized by a maximum westward velocity of 48.6 cm/s in the layer above 100 m and a

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*Corresponding author, E-mail: xiongxj@fio.org.cn

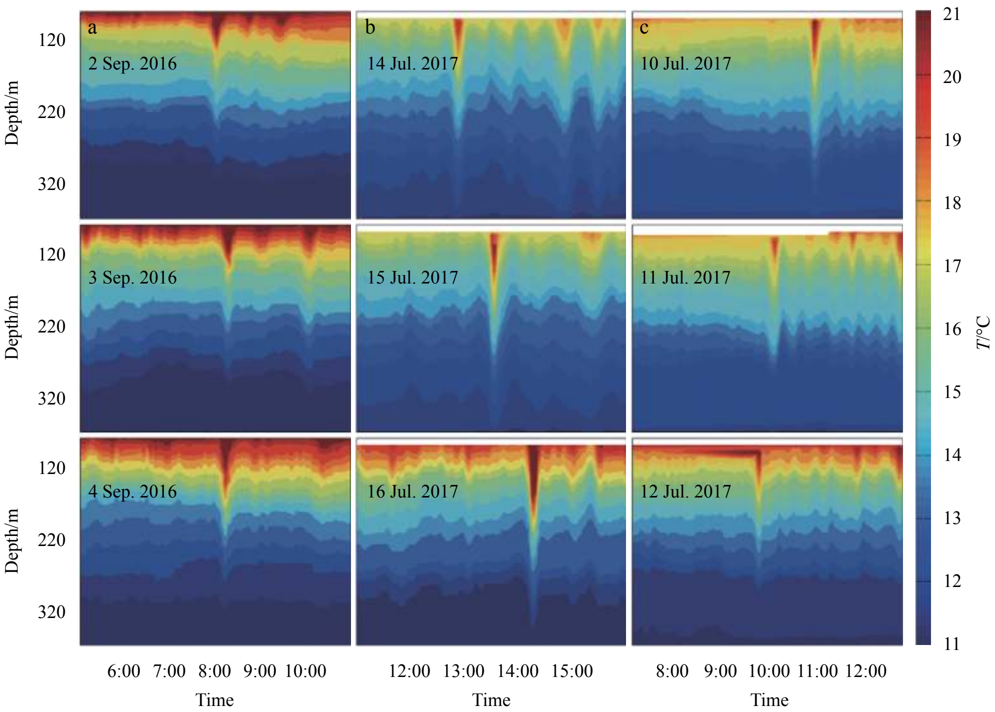

Fig. 1. Water temperature profiles of three types of ISWs signatures observed by thermistor chain attached to the mooring deployed in the west of Dongsha Islands in the SCS from 30 June 2016 to 21 July 2017. a. Type-a ISW signatures, b. Type-b ISW signatures, and c. newly observed Type-c ISWs.

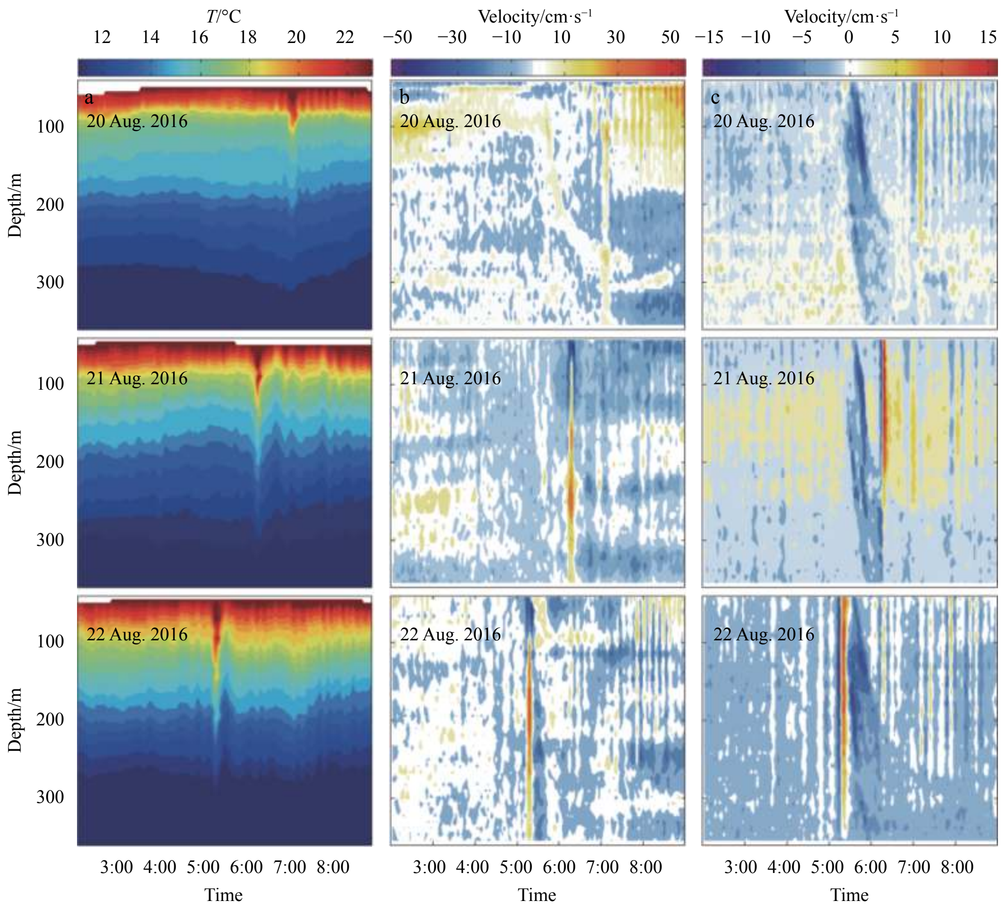

Fig. 2. Temperature and velocity signatures of type-c ISWs. a. Temperature profile, b and c. zonal and vertical velocity signatures, respectively.

maximum eastward velocity of 56.2 cm/s in the layer below 100 m. Vertically, strong downward currents with a peak of 15 cm/s were observed at the leading edge of the soliton, and the upward currents with the comparable velocity magnitudes were observed at its trailing edge. These ISW signatures also appeared 50 min early every day.

Table 1 lists the statistical features of three types of ISWs from our mooring observation data. One can see the following facts:

(1) Type-b ISWs occur the most frequently with 28 packets including 125 ISWs observed, corresponding to 5 and 19 of Type-a ISWs and 8 and 30 of Type-c ISWs.

(2) Type-b ISWs have the amplitudes larger than that of Type-a and Type-c ISWs, with a mean amplitude of (52.90±19.53) m, and a maximum amplitude of 106 m. The mean amplitudes of Type-a and Type-c ISWs are close to each other, but the deviation of Type-c ISWs is greater. The maximum amplitude of Type-c is as large as 79 m, 25% larger than that of Type-a. It is also worth noting that the mean amplitude of the Type-a ISWs is smaller than that of Type-b ISWs. This is different from the observations by Ramp et al. (2004, 2010).

(3) The mean periods of Type-a and Type-b ISWs are (24.20±0.14) and (25.08±0.49) h, respectively, which are close to the results of Zhao and Alford (2006), (24.3±0.7) and (25±0.5) h. The mean period of Type-c ISWs is (23.04±0.29) h, which is the reason for that the Type-c ISWs arrive about one hour early every day.

Table 1. Statistics of three types of ISWs

Types of ISWs	Number of packets	Number of ISWs	Re-appearance period/h	Mean amplitude/m	Maximum amplitude/m
Type-a	5	19	24.20±0.14	44.32±8.30	59
Type-b	28	125	25.08±0.49	52.90±19.53	106
Type-c	8	30	23.04±0.29	44.44±16.68	79

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