Signature55 Usage Reports

1. Background

Long-range current profilers are deployed across the globe to measure currents in the open ocean. The hunt for energy in ever-deeper water has generated an interest in understanding and predicting the forces that are acting on marine structures (Hu, Wu et al. 2015, Qiu, Chen et al. 2015). Especially the study of the strong currents like Kuroshio and Mindanao Current in the Western Pacific.

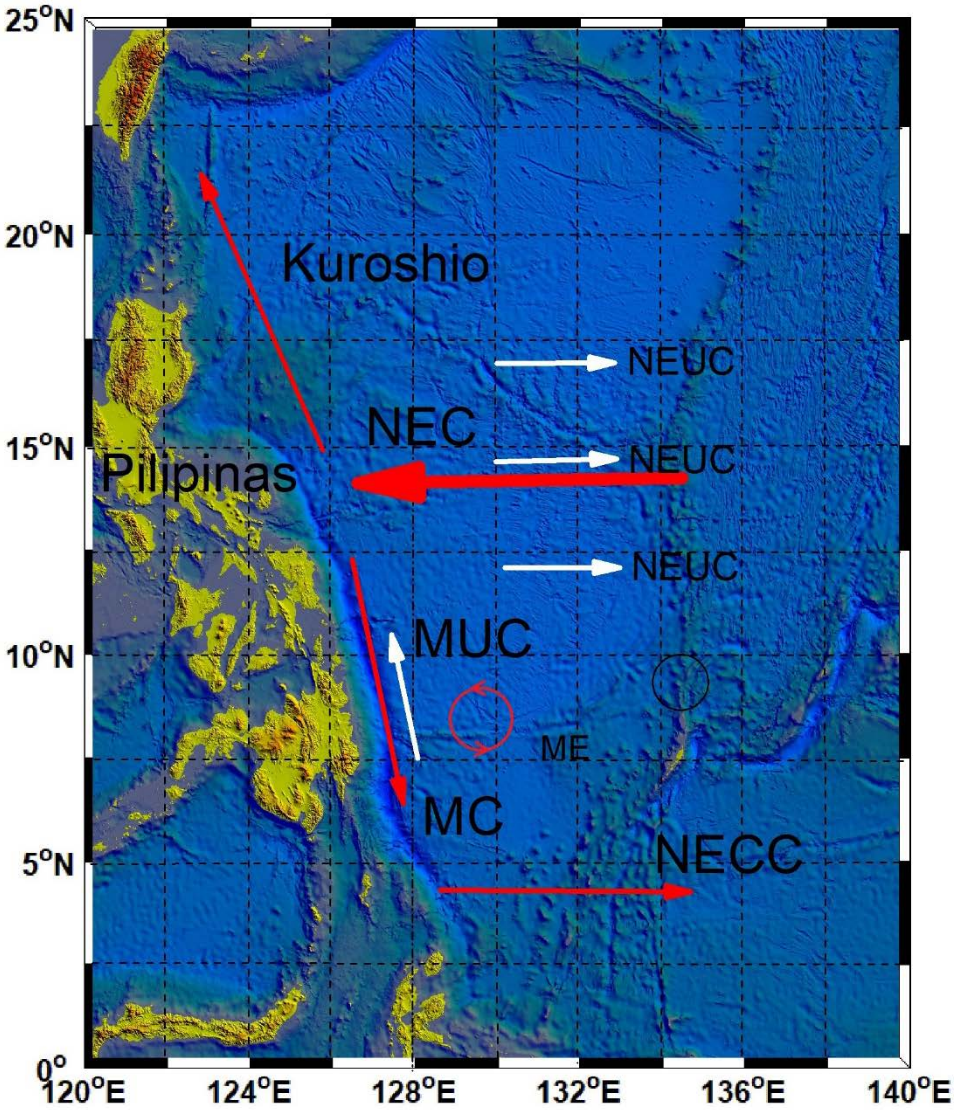


Figure 1. Map of the western Pacific, including major currents and features above (red) and below

(blue) the thermocline. The North Equatorial Current (NEC) is a broad westward flow that hits the Philippine coast in the Bifurcation Region. From the Bifurcation Region, the Mindanao Current (MC) heads southward. The Kuroshio is difficult to identify close to the Bifurcation Region, but it strengthens as it proceeds northward. The Mindanao Eddy（MC） is a semi-permanent cyclonic feature off the coast of Mindanao, Philippines. Subthermocline boundary currents include the Mindanao Undercurrent (MUC) heading northward. These boundary currents feed the eastward North Equatorial Undercurrent (NEUC) jets below the NEC. The testing area is just near East of the Philippines in Western Pacific (Black circle).

Researchers at The Institute of Oceanology in Qingdao, China, now use Nortek's Signature55 to study the circular current structure of the westward currents of the Western Pacific. The low-latitude north-western Pacific is a key region for global climate, owing to its residence in the western Pacific warm pool and important role in meridional redistribution of heat, moisture, and mass (Yaremchuk and Qu 2004, Chen, Qiu et al. 2015). The upper ocean circulation system (Figure 1) composed by the east-west North Equatorial Current (NEC), the northward flowing Kuroshio Current (KC), and the southward flowing Mindanao Current (MC), has been paid much attention over the past three decades (Toole, Millard et al. 1990, Masumoto and Yamagata 1991). On the one hand, the water masses transported by MC feed the tropical circulation cells, influencing the evolution of El Niño–Southern Oscillation (ENSO) and regulating the regional/global climate. On the other hand, the Kuroshio, originating to the east of the Philippines due to the bifurcation of NEC, carries warm water to downstream regions of colder air temperature, supplying heat, and moisture to the atmosphere along its paths (Zhang, Hu et al. 2014, Andres, Mensah et al. 2017, Duan, Chen et al. 2017).

Compared to this upper-ocean circulation pattern, flow features in the intermediate depth below the thermocline (i.e., 500–2000m) in the northwestern Pacific Ocean remain observationally fragmentary and theoretically speculative. A schematic for the subthermocline circulation adopted commonly by past investigators is that of the white arrows in Figure 1.

Undercurrents in the region are less well observed and understood theoretically than the currents that extend to the surface (Zhang, Hu et al. 2014). Only have Shipboard 38 KHz ADCP can reach undercurrents about 1000m, but usually the data at this depth is poor quality. Recently, underwater gliders were used extensively to measure the major currents in the region, but the time scale is too short for global climate studies (Rudnick, Centurioni et al. 2013, Qiu, Chen et al. 2015, Schönau, Rudnick et al. 2015).

2. Deployment

Scientists at The Institute of Oceanology in Qingdao retrieved the current profiler in June 2017, after a deployment of approximately 500 days, beyond their planned retrieved time. The deployment been done with the Signature55 in a subsurface buoy on a mooring line at 800m and the instrument is operated in a stand-alone measurement mode (Figure 2). The testing area is just near East of the Philippines in Western Pacific, north of Palau (Figure 1). The sampling interval were set to 1h and the 75 kHz data used 10m cells, while the 55 kHz used 20m cells. The Nortek subsurface buoy is purpose built for the Signature55. The elliptical shape minimizes the drag and an integrated frame holds the instrument in place. Easy access to the battery compartment is available from the end opposite the transducers, so downloading of data or battery change is simplified and does not require the instrument to be dismounted (Lohrmann and Nylund 2013). The Signature55 hold a good attitude in strong current during delivery, owe mainly to subsurface buoy.

Figure 2. Signature55 mounted on a buoy.

3. Result and Discussions

Within a period of nearly 500 days, Signature55 retrieved broadband and narrowband sets of data, respectively. The effective depth of the narrowband data is close to 1600m, distance from the instrument 800m (Figure 3), the effective depth of the broadband data reaches 1200m, distance from the instrument 400m (Figure 4). This is in the range of other current profilers operating at higher frequencies. The range of a current profiler is primarily determined by the acoustic frequency, but a host of instrument and environmental parameters strongly influence how far the instrument can accurately measure velocity. The echo intensity, the correlation and the horizontal flow rate obtained in the narrowband mode (broadband) are show in Figure 3 (Figure 4). QA/QC been conducted on individual data ("single pings") to remove interference (Lohrmann and Nylund 2013). The amplitude of the echo is obviously stratified, and the correlation of the quality control parameters reaches more than 80% above 1400m. The horizontal velocity profile has four current core during the whole observation period, the strongest speed reaches 0.35m/s, and the velocity has a significant daily cycle. The overall current data quality is very good; get a complete more than one year of data. Since the location of the long-term flow field data is still blank, there is only part of the shipborne ADCP data and glider profile data, so the nearly 500 days Signature55 data has important research significance for the region's current circulation system.

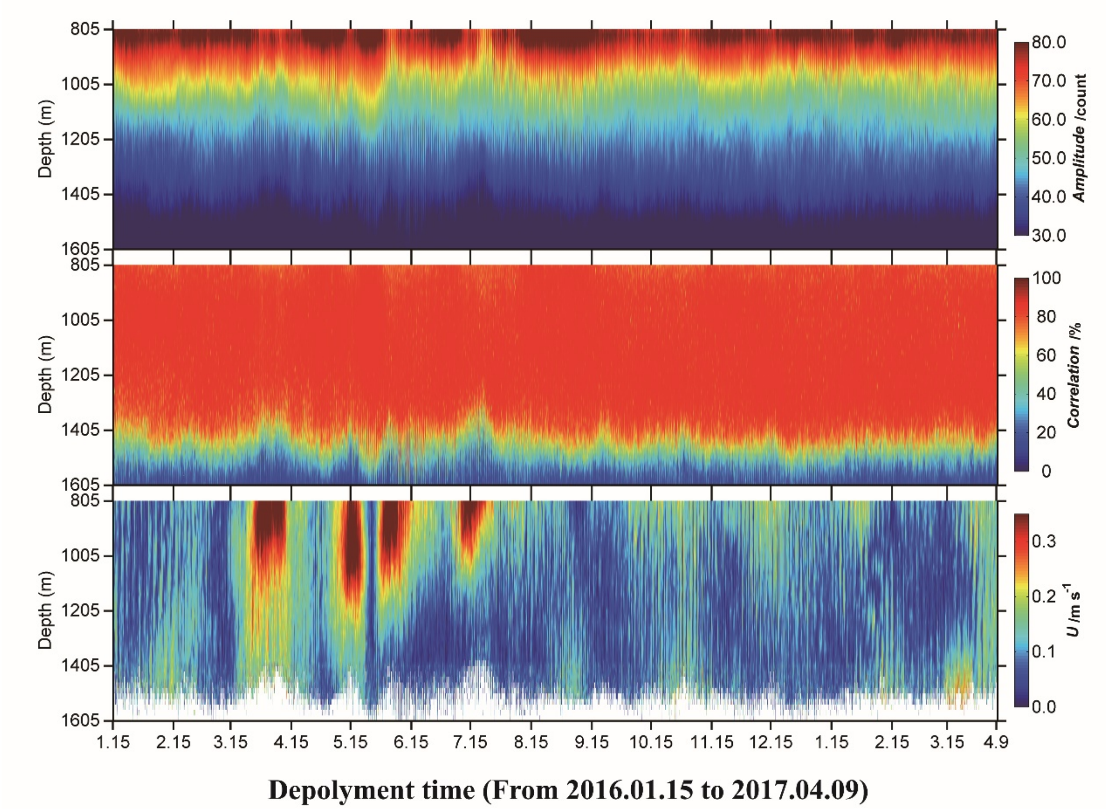


Figure 3. Time series of hourly amplitude, correlation and horizontal velocity measured by the mooring Signature55 in 55 kHz during 2016.01.15 to 2017.04.09

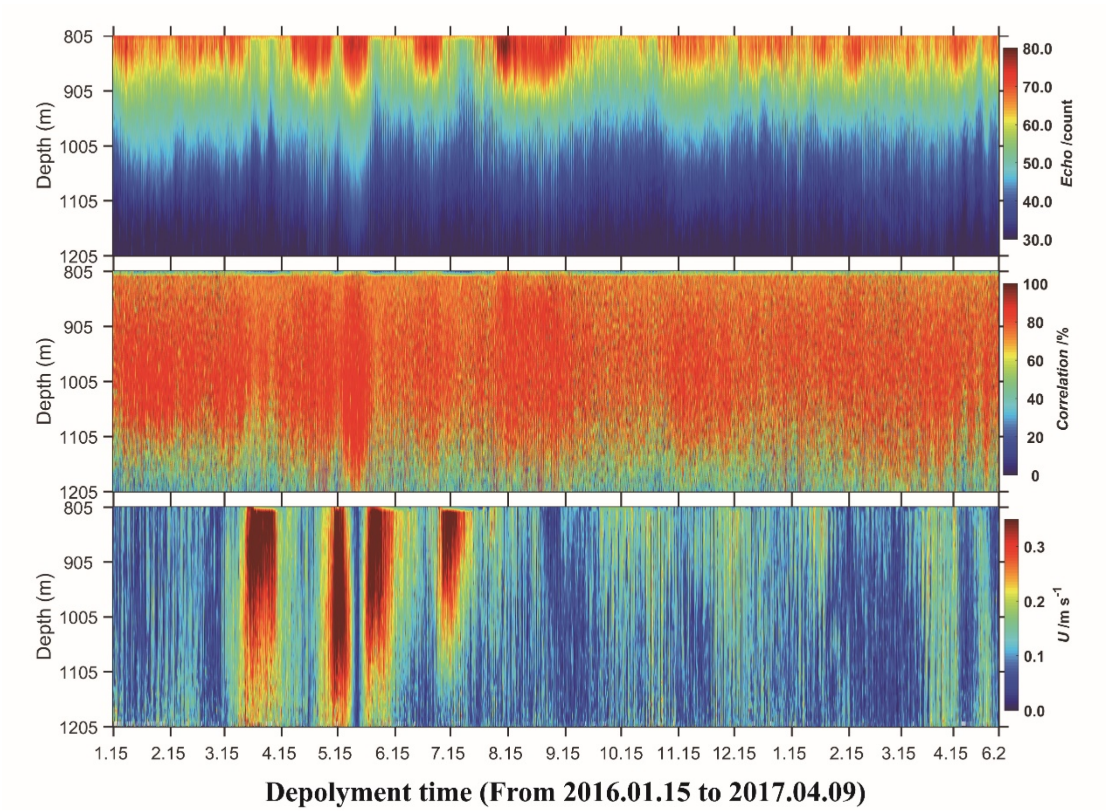


Figure 4. Time series of hourly amplitude, correlation and horizontal velocity measured by the mooring Signature55 in 75 kHz during 2016.01.15 to 2017.04.09

Figure 5 shows the time series of hourly eastward (u) velocity, northward (v) velocity and horizontal velocity during the observation, and it can been see that the velocity east and north components have significant seasonal variations. In order to highlight this cyclical change, select the depth of 805m, 1205m, 1405m, 1385m daily meridional velocity vector of time series drawn in Figure 6. The color and arrow direction represents the current direction, the length of the arrow represents the velocity speed, and it can clearly see the direction of current changes. Between spring and summer (March to August), the current has several direction change in high speed, especially between in the 805m to 1205m is the more obvious. In the autumn and winter, the direction change in low speed.

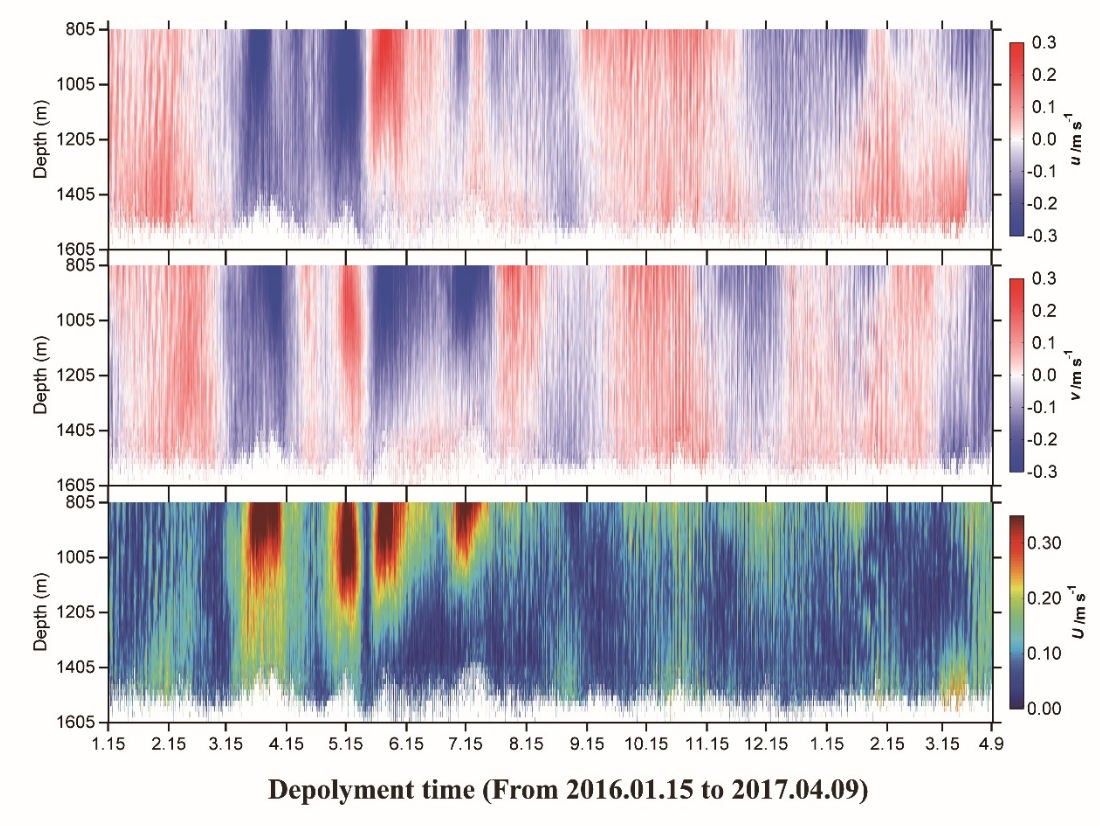


Figure 5. Time series of hourly eastward (u) velocity, northward (v) velocity and horizontal velocity measured by the mooring Signature55 in 55 kHz during 2016.01.15 to 2017.04.09.

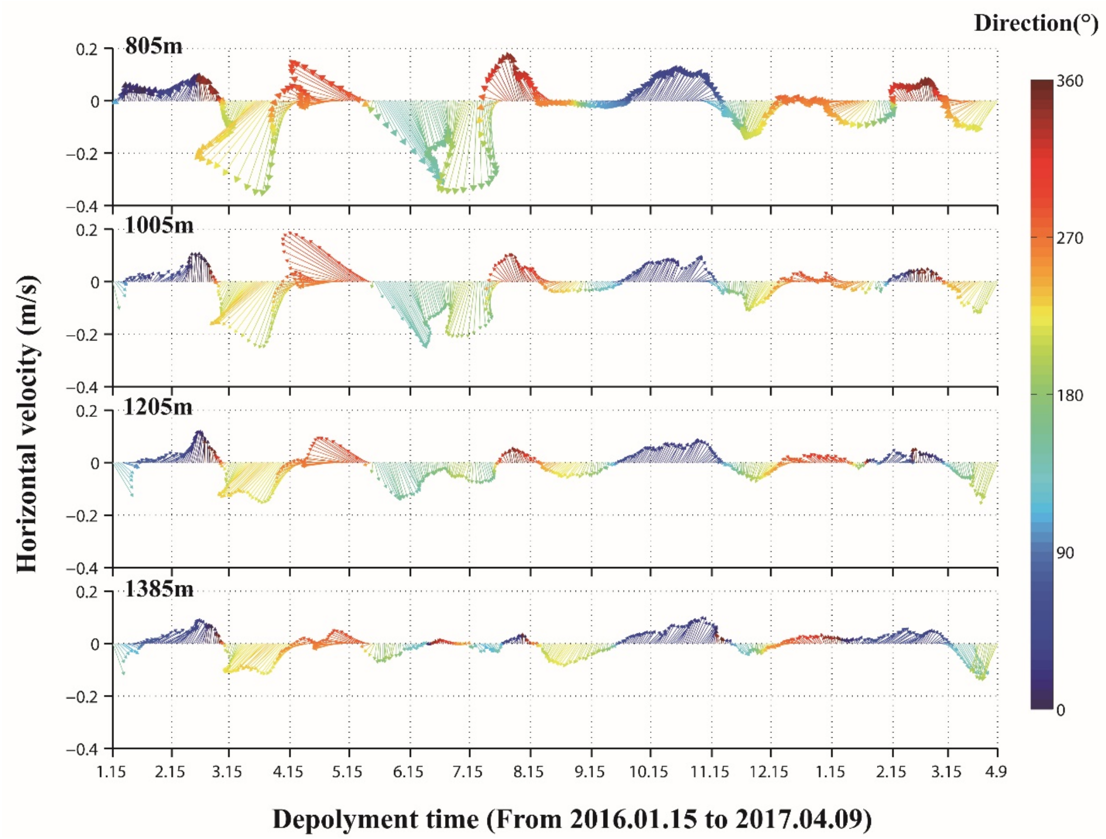


Figure 6. Daily meridional velocity vector between 805m and 1385 m during 2016.01.15 to 2017.04.09 from the mooring Signature55 in 55 kHz. The color and arrow direction represents the current direction; the length of the arrow represents the velocity speed.

The results show that the region has current core below 800m whether in meridional or zonal, and there is seasonal variation. Figure 7 - 9 show the study of glider and model in this region, respectively. These observations are consistent with the existing results, seasonal analyses show that the magnitude of this forcing varied such that the highest values occurred in spring and summer while the lowest occurred in fall and winter similar to the eddy kinetic energy (EKE) variability to the east. In addition, the observed results show that the velocity direction is mainly in the north-south direction (Figure 6), this is a new discovery that has not observed in the past. The intraseasonal variability may be caused by subthermocline eddies, which are nearly invisible at the sea surface. In addition, the intraseasonal activity appears to vary in different years, energetic in 2016 spring and summer (Figure 4) with large fluctuations and weak in 2017 spring (Figure 4). The reason for this distinct and abrupt interannual change will be explored in further studies. By the way, explain the difference between the time series shown in Figure 3 and Figure 4, when the narrowband mode is stop in

April 2017, the broadband mode is still working until June 2017 at double the time interval.

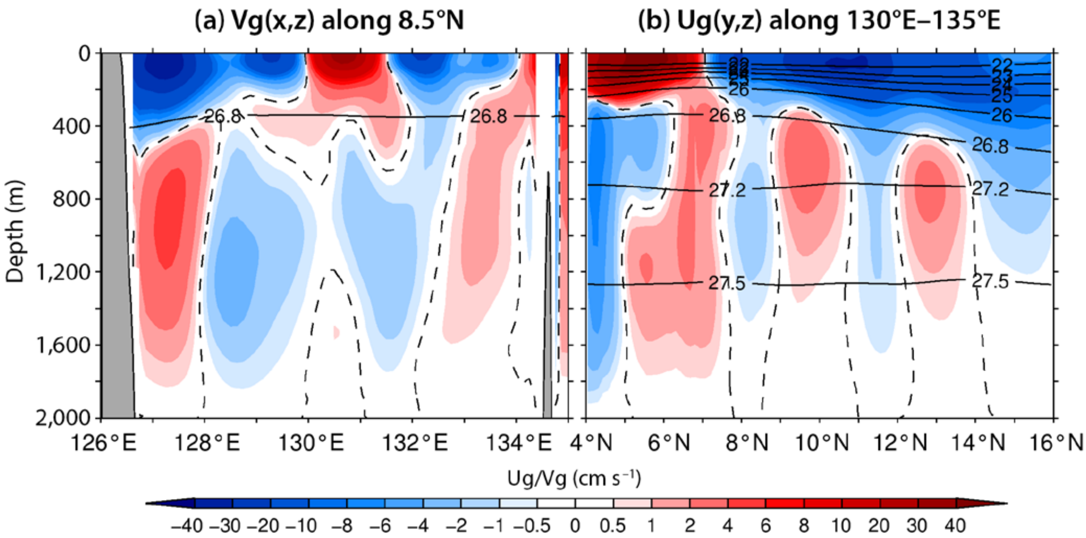
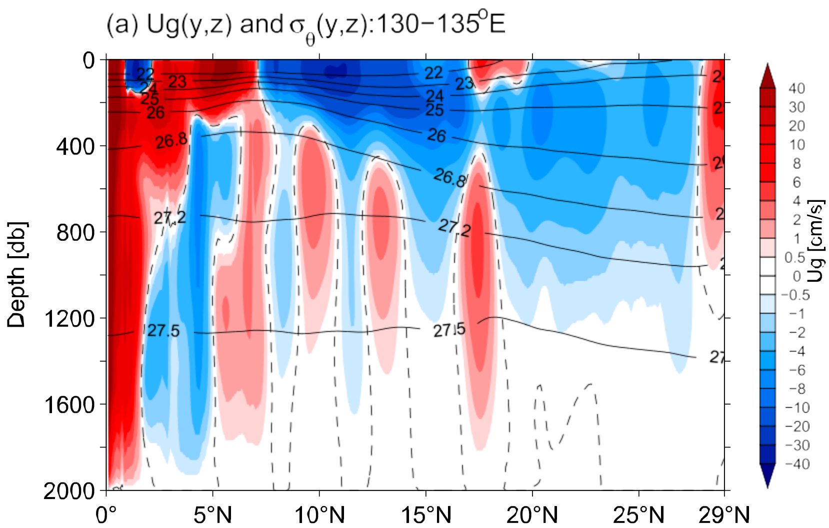


Figure 7. Float observations of (a) longitude-depth section of meridional geostrophic velocity along 8.5 °N, and (b) latitude-depth section of density (solid contours) and zonal geostrophic velocity (color shading) along 130 °E–135 °E. This figure was acquired from the paper of Schönau M C (2015).



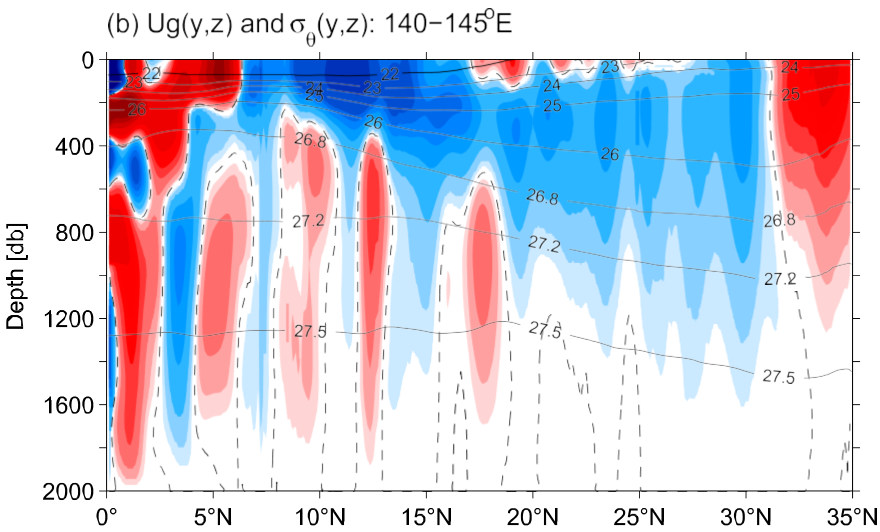


Figure 8. Latitude–depth section of density (solid contours) and zonal geostrophic velocity (color shading) along (a) 130 °–135 °E and (b) 140 °–145 °E. The geostrophic velocity is referenced to 2000 m, and dashed lines denote the zero velocity contours. This figure was acquired from the paper of Qiu B (2015).

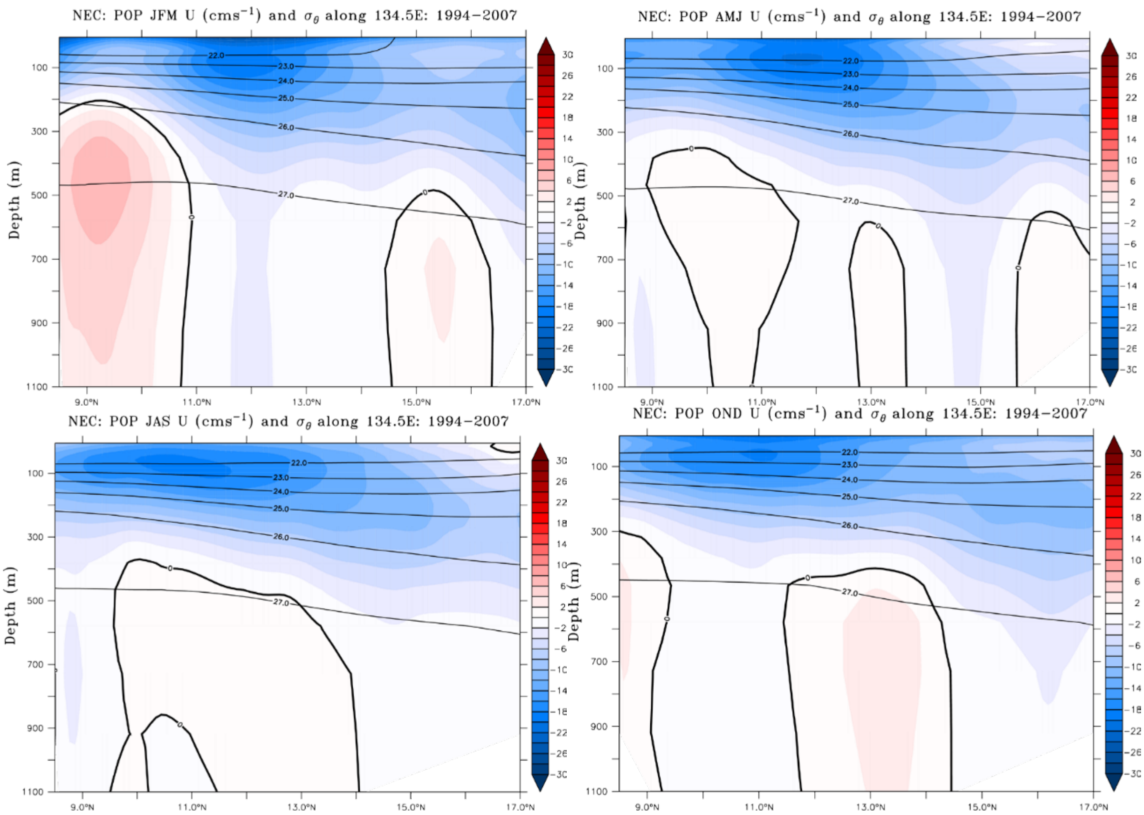


Figure 9. Meridional sections of zonal velocity (cms-1) from global ocean general circulation model along 134.5° E between 8.5° and 17°N for winter (Jan-Feb-Mar; upper left), spring (Apr-May-Jun; upper right), summer (July-Aug- Sep; lower left) and fall (Oct-Nov-Dec; lower right). Seasons were constructed from monthly global ocean general circulation model climatologies for 1994-2007. This figure was acquired from the paper of Rudnick D L (2013).

4. Summary

Based the more than one year of field-testing, we are more confident about the Signature55. A unique feature of the Signature55 ADCP is its ability to collect high-resolution and long-range data concurrently at the same time. Low power consumption makes it easier to observe than the same frequency instrument. The Signature75 store every current profile as it is being collected, before it is averaged to form an ensemble current profile, this allows the data to have a lower noise level. A new long-range acoustic current profiler, the Nortek Signature55 AD2CP, is a 55/75 kHz dual frequency long-range current profiler that uses broadband processing and modern electronics to give the most flexible current profiler available, and it is success fully used to measure currents in the open ocean.

Acknowledgements

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Reference

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Appendix

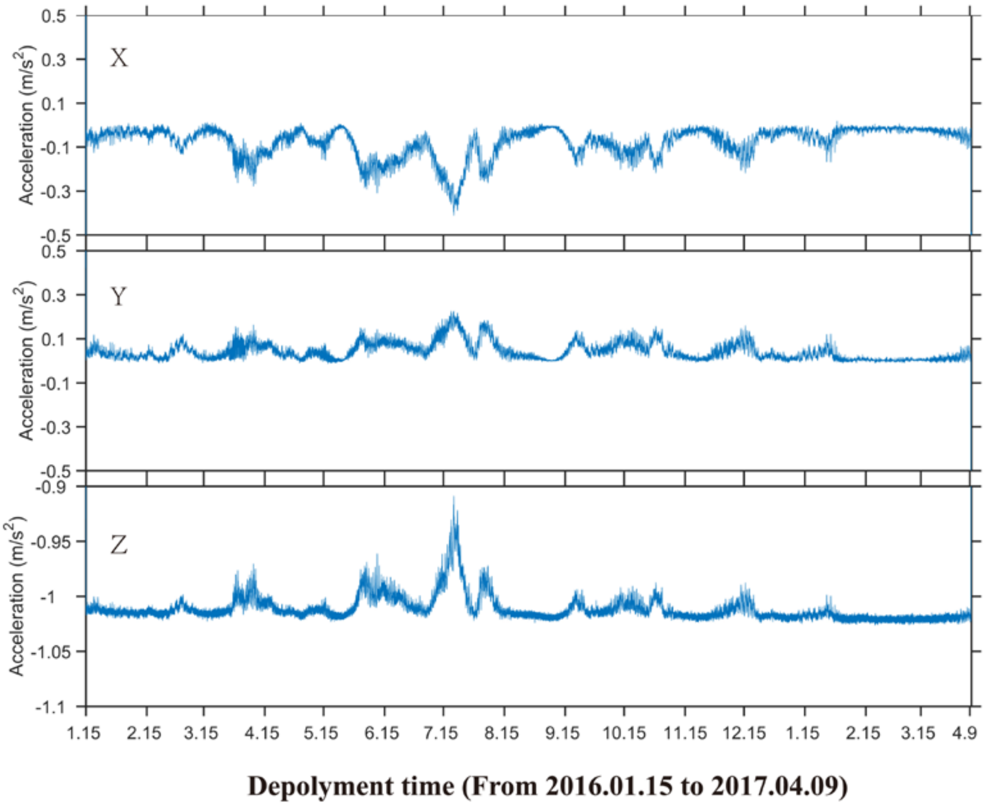

Figure 10. Time series of hourly acceleration by the mooring Signature55 during 2016.01.15 to 2017.04.09.

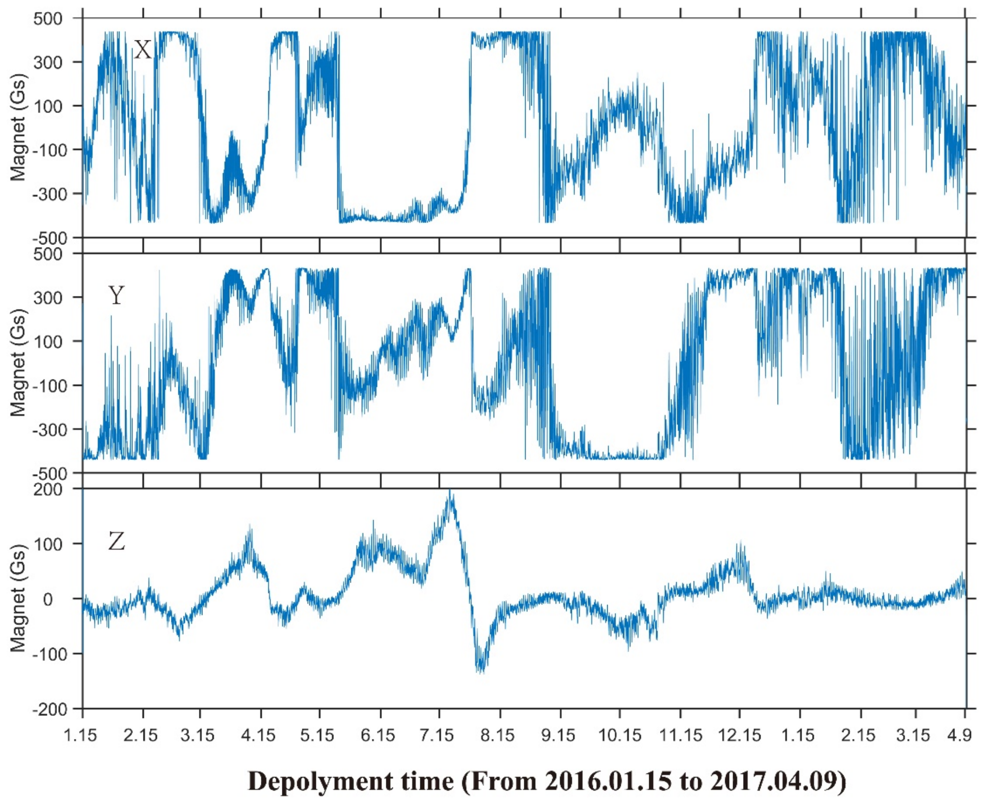

Figure 11. Time series of hourly magnet by the mooring Signature55 during 2016.01.15 to 2017.04.09.

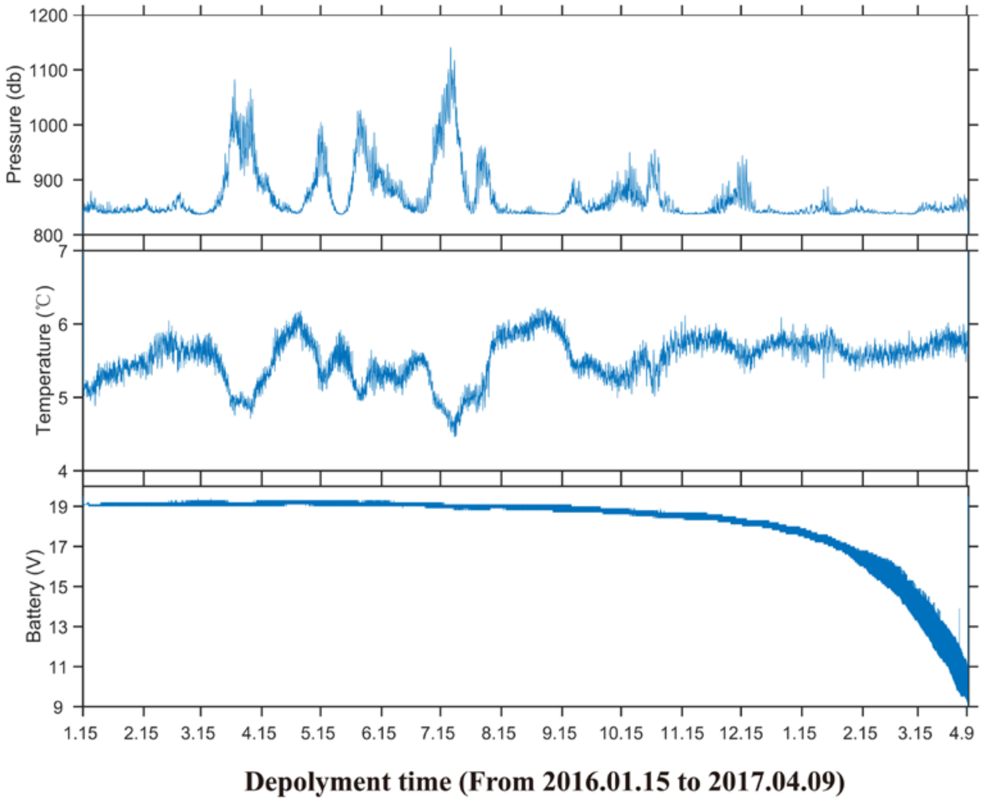

Figure 12. Time series of hourly pressure temperature and battery by the mooring Signature55 during 2016.01.15 to 2017.04.09.