# Full-depth current observation using ship-mounted and underwater-towed ADCPs off Sanriku Coast

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## 1. Introduction

Pacific coast in the northern part of Japan Honshu Island is a Ria coast with many deeply indented bays, called as ***Sanriku Coast*** (**Fig. 1**). ***Otsuchi Bay*** is one of these ones, which International Coastal Research Center (ICRC), AORI, faces.

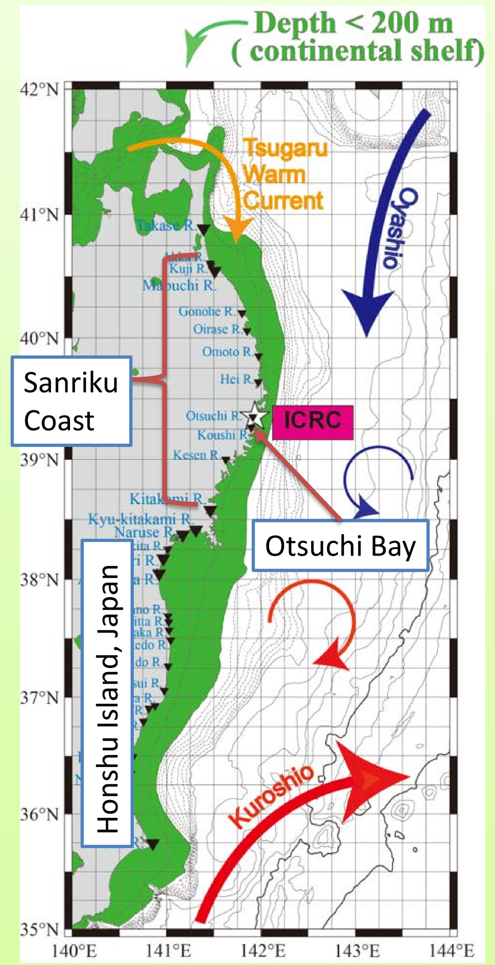


**Fig. 1** Pacific coast of Honshu Island.

In Otsuchi Bay, it has become known that ***baroclinic tidal circulation*** occurs; outflow in upper layer and inflow in lower layer are observed at flood tide (**Fig. 2**), and vice versa at ebb tide.

Tanaka et al (2017) indicate that spatially and temporally shorter scale or higher mode variability exists in the lowest layer.

However, shipboard ADCP observation is not sufficient for clarifying it (Fig. 3). We need ***full-depth current observation*** including the bottom layer flow.

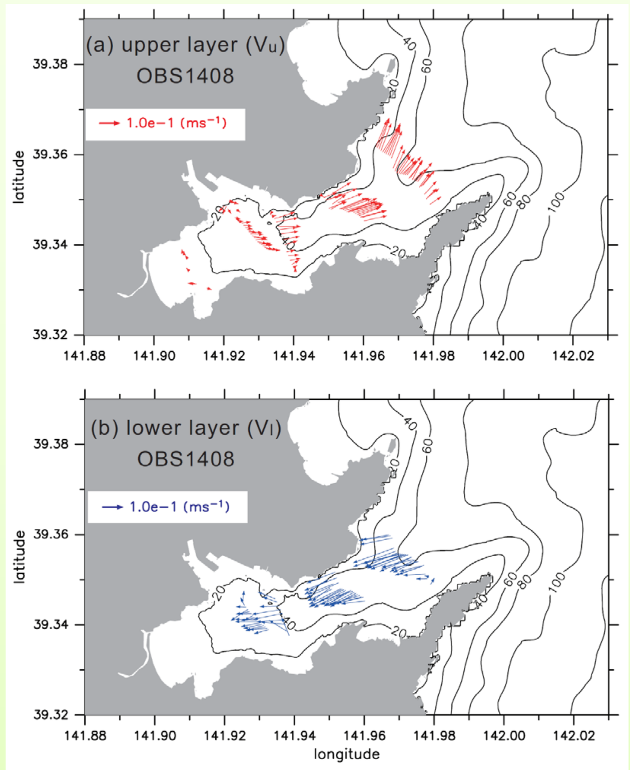


**Fig. 2** Flow patterns in upper and lower layers in Otsuchi Bay at flood tide in August 2014 (Tanaka et al., 2017)

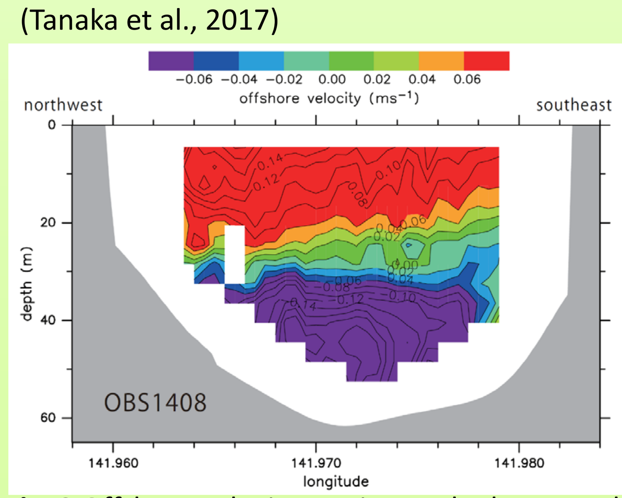


**Fig. 3** Offshore velocity section at the bay mouth in Fig.2 observation (Tanaka et al., 2017)

## 2. Observation methods

ADCPs generally have three or four transducers emitting sound beams which tilt at 10 – 25 degrees from vertical direction and have side lobes. We cannot measure currents precisely within the lowest 10% range from the seafloor to the instrument due to contamination by bottom reflection of the side lobes (**Fig. 4**).

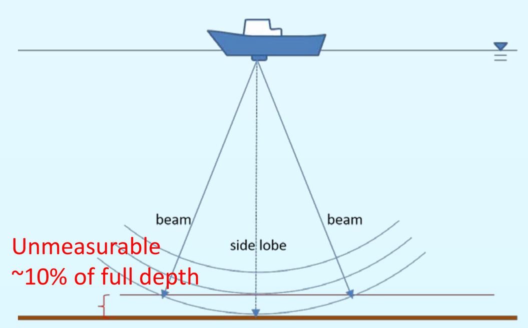


**Fig. 4** The bottom layer cannot be precisely measured due to contamination by side lobe refrection.

In order to measure the near-bottom current as possible, we need to make instruments closer to the bottom (**Fig. 5**). Therefore, we introduced an underwater-towed ADCP, ADP 500kHz equipped on ***V-fin***, manufactured by Xylem (**Photo 1**). ADP 500kHz has nominal ability to measure current profiles with minimum interval of 1 meter and maximum range of 120 meters.

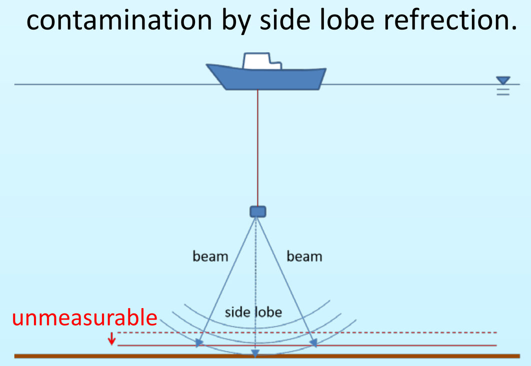


**Fig. 5** Closer to the bottom, unmeasurable length diminishes.

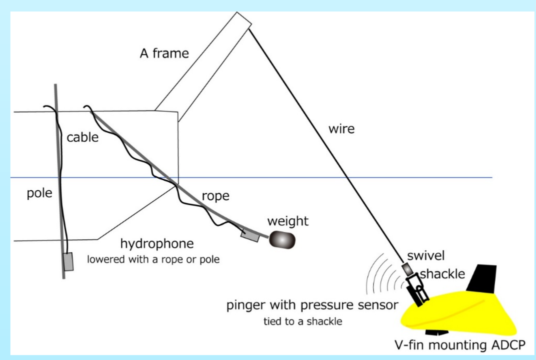


**Fig. 6** V-fin towed by wire from ship, and monitoring system of its depth with pinger and hydrophone.

To monitor the depth of V-fin towed by wire without electric cable (Fig. 6), we adopted bio-telemetry 69kHz pinger by Vemco (**Photo 2**).

Although pinger depth is quite noisy (**Fig. 6**), it is much better than not, and furtheremore, is easy to handle.

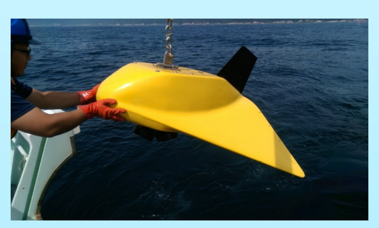

**Photo 1** V-fin mounting ADP 500kHz

**Photo 2** Vemco pressure sensor pinger

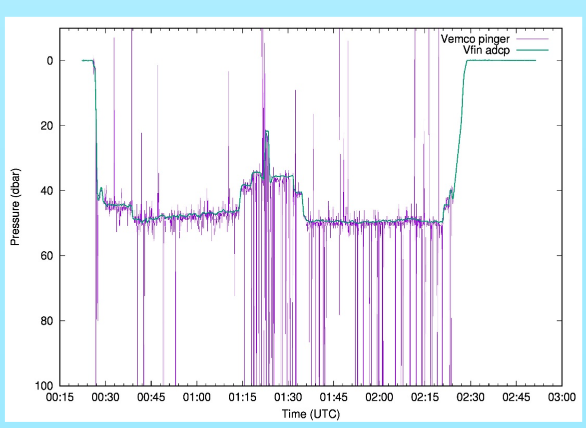

**Fig. 6** Monitored depth by pinger and recorded depth by V-fin ADP.

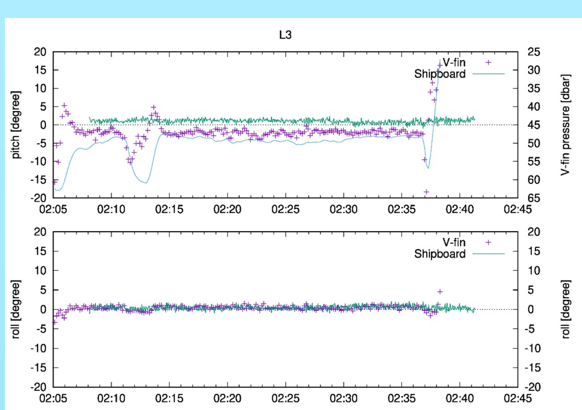


**Fig. 7** Atitude of V-fin compared with shipboard ADCP of R/V Yayoi.

V-fin keeps relatively stable attitude during tow except when its depth is changed (**Fig. 7**).

## 3. Observations off Otsuchi Bay, Sanriku Coast

We conducted V-fin observations with R/V Yayoi (a vessel of ICRC with 12 tonnage, **Photo 3**) off Otsuchi Bay in 2015, 2016, and 2018.

Photo 3 R/V Yayoi

Shipboard ADCP (RDI 300kHz Workhorse) was operated throughout every cruise, and hydrographic survey with CTD (RINKO-Profiler ASTD102, JFE Advantech) was also conducted with stopping the vessel between V-fin observations.

V-fin lines are shown in **Fig.7.**
**30 July 2015** : red line
mostly along 100-m isobath (*Section 4*)
**11 July 2016** : blue line
challenge to cross-isobath towing (*Section 6*)
**29 June 2018** : green line
mostly along 70-m isobath (*Section 5*)

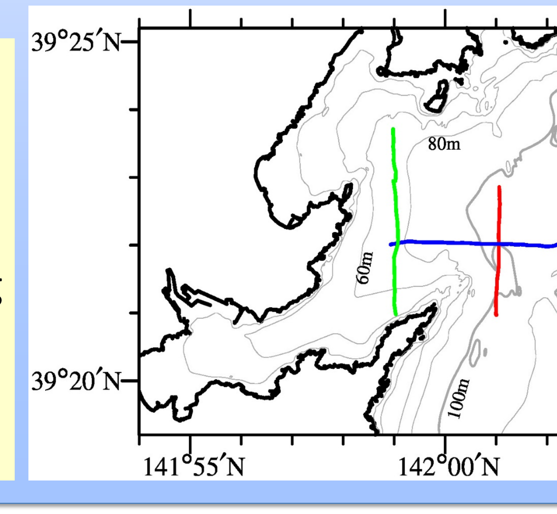


**Fig. 7** Observation lines (see left description).

## 4. Results from north-south observations along isobaths

We conducted four V-fin towings, L1 to L4, mostly along 100-m isobath on 30 July 2015 (red line in **Fig. 7**). These four towings were done from the beginning to the end of flow tide (**Fig. 8**).

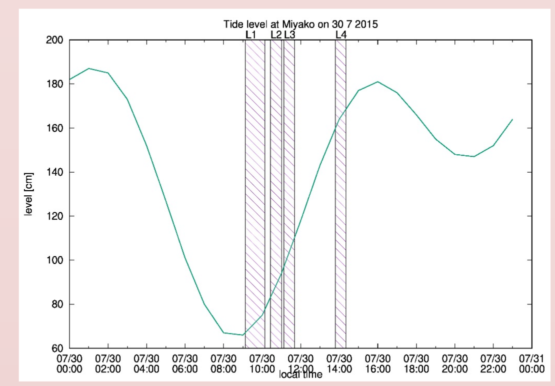


**Fig. 8** Observed tide levels at Miyako, about 30-km apart from Otsuchi Bay to the north. Our V-fin observation periods, L1 to L4, are hatched.

Westward velocity (negative u) is dominant in a layer from 30-m depth to 60-m depth especially during L2, L3, and L4 (rising tide is at peak), while eastward velocity (positive u) is dominant in the upper layer (**Fig. 9**). This is consistent with the conventional baroclinic tidal circulation.

On the other hand, u changes the sign by time and space in the lowest layer. It is seen commonly in the both ADCP results.

Shipboard u tends to have extreme values at the lowest depth due to low echo intensity while V-fin u is moderate throughout sections.

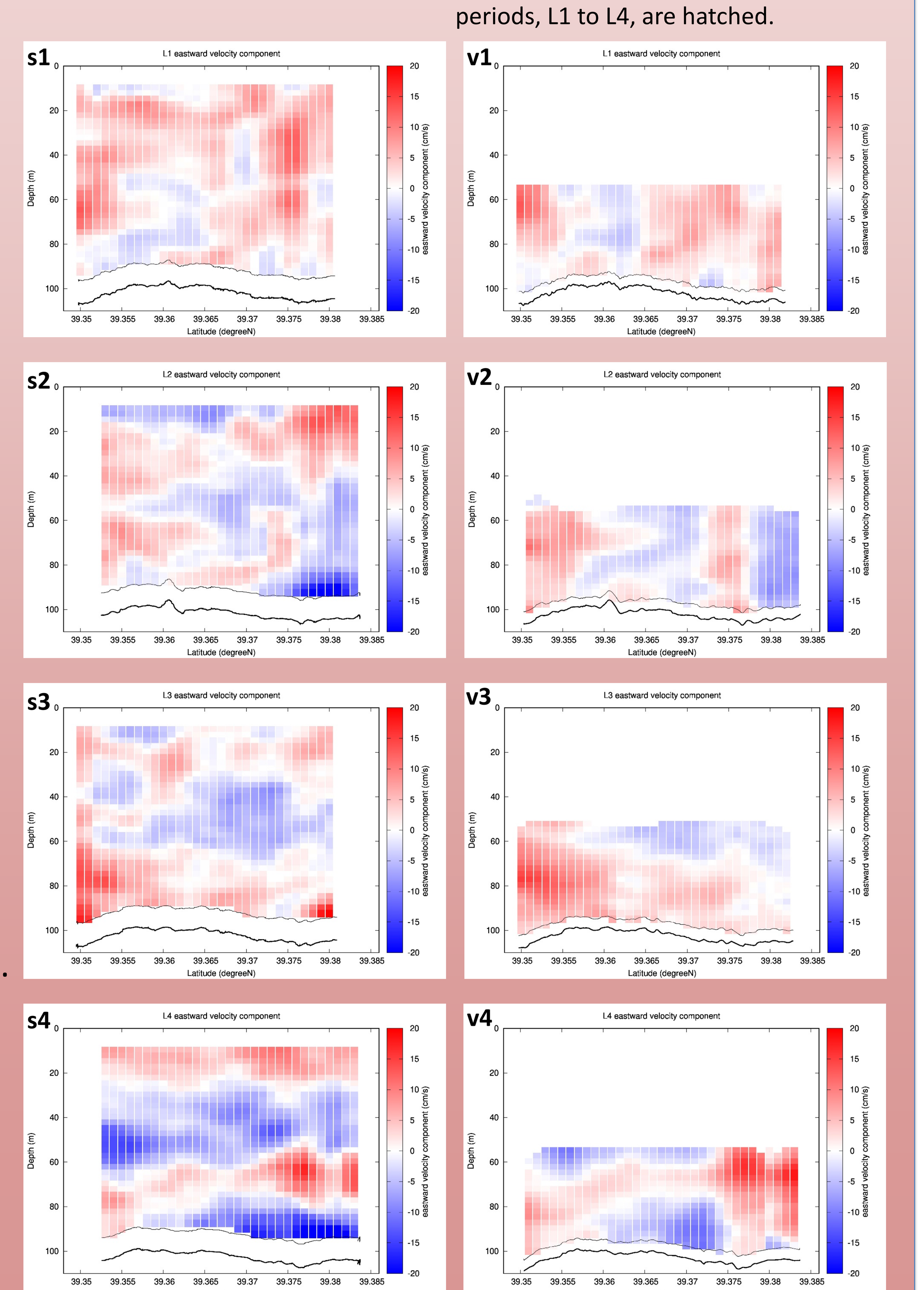


**Fig. 9** Vertical sectons of eastward velocity components (u) from shipboard ADCP and V-fin ADP. Panels **s1** to **s4** are of **shipboard** ADCP at L1 to L4, respectively. Panels **v1** to **v4** are of **V-fin** at L1 to L4, respectively.

## 5. Discrepancy between shipboard ADCP and V-fin measurements in 2018

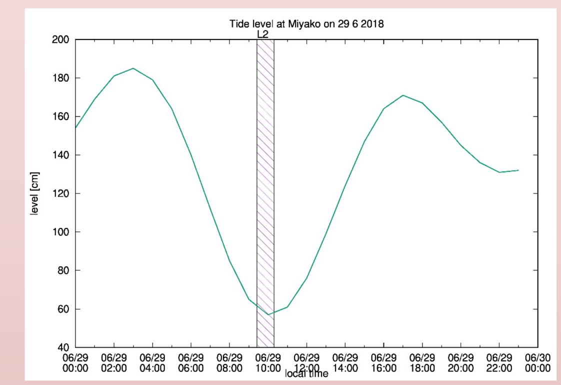

**Fig. 10** Observed tide levels at Miyako on the day of our V-fin towing L2 in 2018.

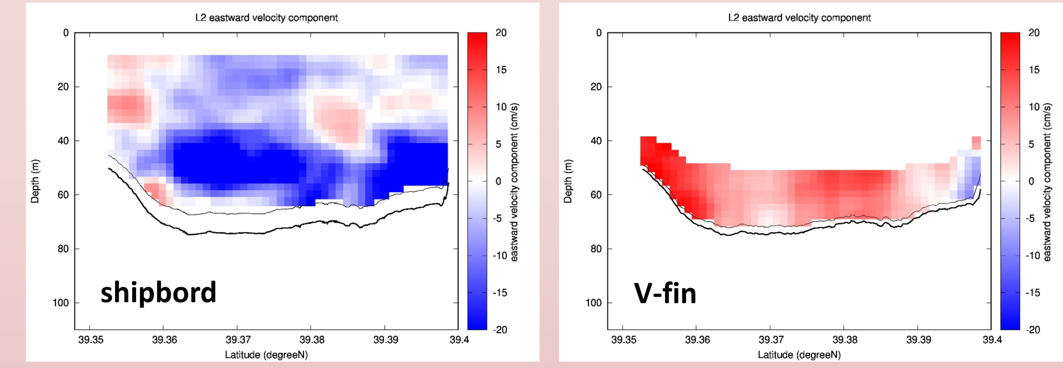


**Fig. 11** Eastward velocity components (u) from shipboard ADCP and V-fin ADP.

We observed L2 (green line in **Fig. 7**) at the end of ebb tide on 29 June 2018 (**Fig. 10**).

U by V-fin is almost positive, which is consistent with ebb tide, while u by ship is almost negative (**Fig. 11**).

This discrepancy in 2018 may happen by low echo intensity, which is supposed due to difference of dominant water mass (**Fig. 13**) with different sources (**Fig. 12**).

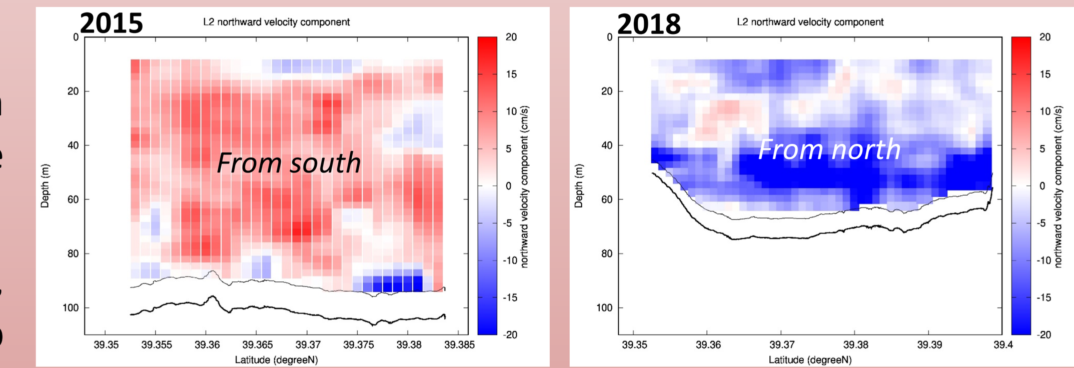


**Fig. 12** Northward velocity components (v) from shipboard ADCP in 2015 and 2018.

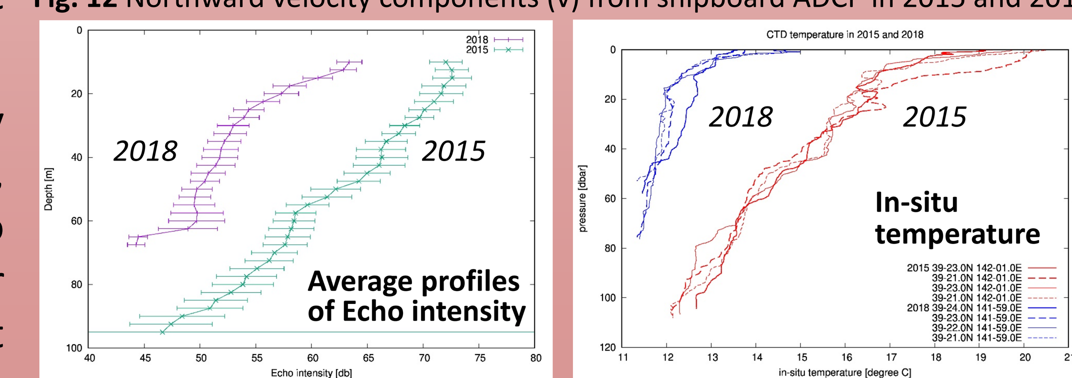


**Fig. 13** Echo intensity of shipboard ADCP and temperature by CTD in 2015 and 2018.

## 6. Challenge to east-west observation across isobaths

We challenged to cross-isobath V-fin towing, WE, toward offshore on 12 July 2016 (blue line in **Fig. 7**). Roll and pitch largely deviate at operating the winch in order to make V-fin descend so that it would keep 30 to 40-m height above the seafloor (**Fig. 14**). Otherwise, attitude of V-fin was relatively stable.

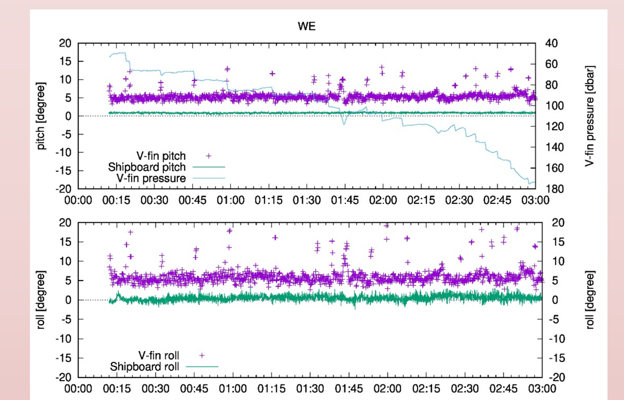


**Fig. 14** Atitude of V-fin compared with shipboard ADCP

At ebb tide (**Fig. 15**), ***offshore flow*** is dominant over the continental shelf bottom (**Fig. 16**).

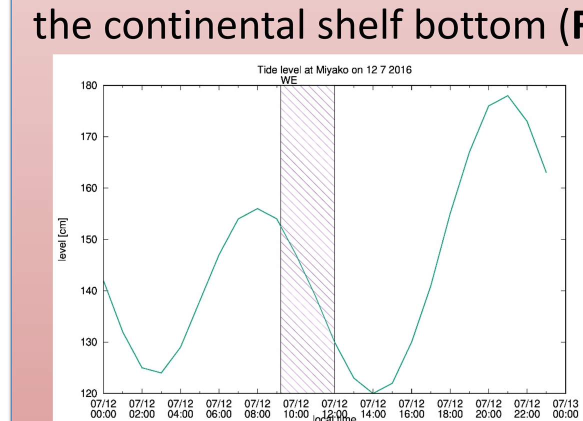

**Fig. 15** Observed tide levels at Miyako on the day of our V-fin towing WE in 2016.

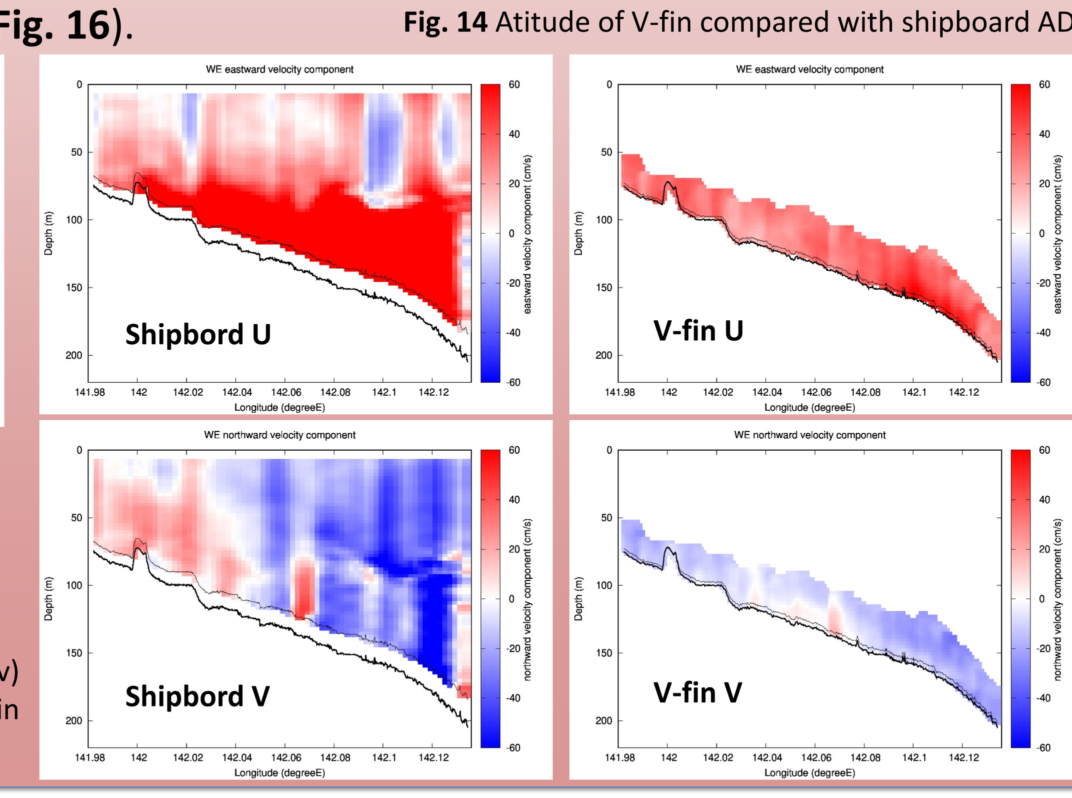


**Fig. 16** Velocity components (u, v) measured by shipboard ADCP and V-fin ADP.

## 7. Summary

We established the method for measuring full-depth current profiles using underwater towed ADCP, V-fin, as well as shipboard ADCP.

- V-fin is useful not only for measuring the near bottom flow that cannot be measured by shipboard ADCP due to its side lobe, but also for measuring current at depths where echo intensity is too low for shipboard ADCP measurement.
- It will clarify the higher mode variability below the baroclinic tidal circulation.

Issue: ADCP mounted on V-fin should have sufficient range, that is, longer range than 30m. If it has sufficient range, V-fin does not need frequent descents that reduce its altitude.