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**ADCP AND CTD OBSERVATIONS FROM VANCOUVER
HARBOUR, WINTER 2015/2016**

by

**Y. Wu, A. van der Baaren, X. Wang, C. Lunn¹, C. Hannah¹, D. Spear¹, and B. de
Lange Boom¹**

**Ocean and Ecosystem Sciences Division
Maritimes Region
Fisheries and Oceans Canada**

**Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia
Canada, B2Y 4A2**

¹ Institute of Ocean Sciences, Sidney, BC, V8L 4B2

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ABSTRACT

Y. Wu, A. van der Baaren, X. Wang, C. Lunn, C. Hannah, D. Spear, and B. de Lange Boom. 2017. ADCP and CTD Observations from Vancouver Harbour, Winter 2015/2016. *Can. Data Rep. Hydrogr. Ocean Sci.* 203: viii + 324 p.

This data report presents ocean current and water property data collected from November 2015 to May 2016 in Vancouver Harbour, British Columbia, Canada. The data were measured with three Acoustic Doppler Current Profilers (ADCPs), a vessel-mounted ADCP, and a hand-held conductivity-temperature-depth (CTD) profiler.

RÉSUMÉ

Y. Wu, A. van der Baaren, X. Wang, C. Lunn, C. Hannah, D. Spear, and B. de Lange Boom. 2017. Observations par profileur de courant à effet Doppler (ADCP) et profileur conductivité, température, profondeur (CTP) dans le port de Vancouver, hiver 2015-2016. *Can. Data Rep. Hydrogr. Ocean Sci.* 203: viii + 324 p.

Résumé : Ce rapport de données présente les données sur les courants océaniques et les propriétés de l'eau recueillies de novembre 2015 à mai 2016 au port de Vancouver, en Colombie-Britannique, au Canada. Les données ont été mesurées à l'aide de trois profileurs de courant à effet Doppler (ADCP), d'un ADCP amarré au navire et d'un profileur conductivité, température, profondeur (CTP) portatif.

1 INTRODUCTION

Burrard Inlet is a low-sided fjord located on the lower southwest coast of mainland British Columbia where the city of Vancouver is located. The sheltered waters of the inlet provide the perfect location for Vancouver Harbour, Canada's largest port. The harbour consists of an outer harbour that extends from the Strait of Georgia to the First Narrows; an inner harbour that extends from the First Narrows to the Second Narrows; and a central harbour that extends from the Second Narrows inland towards Port Moody.



Figure 1 Map of Vancouver Harbour/Burrard Inlet ("Map of Burrard Inlet", 2017, *Wikipedia, The Free Encyclopedia*)

Burrard Inlet itself is about 25 km long from west to east. Indian Arm is a steep-sided fjord near the eastern end of Burrard Inlet that extends northward opposite Burnaby. The inner and central harbours of Burrard Inlet have a shallow long sill that controls the physical oceanography within Indian Arm. The sill area is 15 m to 25 m deep and 15 km long. The entire length of the Burrard Inlet/Indian Arm system is 50 km. (Fisheries and Oceans Canada, 2009)

The Port of Vancouver is the largest port in Canada and the third largest in the Americas with 138 million metric revenue tons per year. ("Vancouver Fraser Port Authority", 2017, *Wikipedia, The Free Encyclopedia*) The high shipping volumes

means that there is the potential for accidental discharges of hydrocarbons and ballast water contaminants into the ecosystem. Work on building computer models for electronic navigation applications (delivering water levels and currents to the bridges of ships) began as part of the Government of Canada's The World Class Prevention, Preparedness and Response for Oil Spills from Ships Initiative.

To build a description of mean and seasonal flow and to validate ocean circulation models, Acoustic Doppler Current Profilers (ADCPs) and Conductivity-Temperature-Depth (CTD) sensors were deployed to collect water velocity data and water property data. This data report describes ocean currents measurements at three locations in Burrard Inlet from November 2015 through May 2016, vessel-mounted ADCP measurements from a survey in January 2016, and CTD measurements during the same January survey.

2 INSTRUMENTATION

2.1 MOORED ADCPS

Three ADCPs were moored in the outer harbour, in the central harbour near the Second Narrows, and in the inner harbour near the mouth of Indian Arm at Roche Point (Figure 2). These shallow moorings were deployed on November 8, 2015 and recovered on May 30 and May 31, 2016.

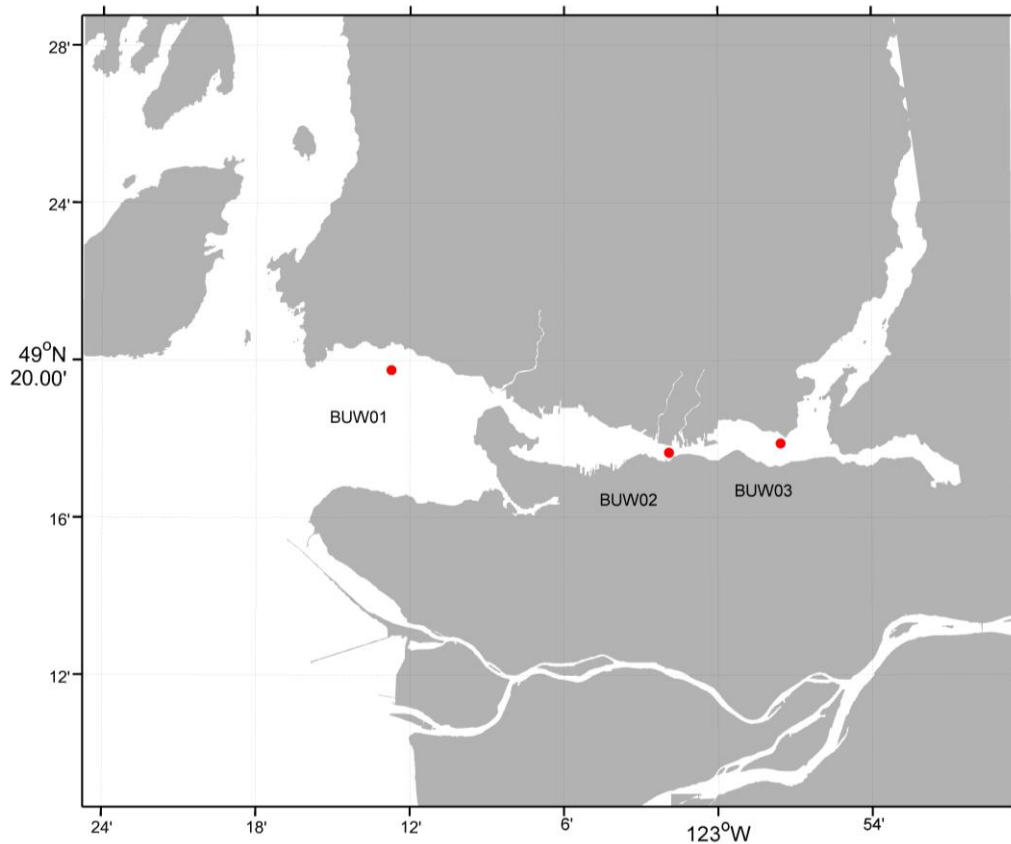


Figure 2 Map showing ADCP mooring locations

The ADCPs, manufactured by Teledyne RD Instruments, were 300 kHz Workhorse and 600 kHz Workhorse Sentinel models (WH300 and WH600) (<http://www.teledynemarine.com/workhorse-sentinel-adcp?ProductLineID=12>). The WH300s (actual 307.2 kHz) were at BUW01 and BUW02, and the WH600 (actual 614.4 kHz) was at BUW03 in the Central Harbour. Mooring log sheets and diagrams are in Appendix 1.

Table 1 Table of ADCP mooring details

Station	Serial #	Depth (m)	Deploy Time (UTC)	Recovery Time (UTC)	Bottom Depth (m)
BUW01	20471	35	08/11/2015 1850	31/05/2016 0007	39
BUW02	20473	42	08/11/2015 1541	30/05/2016 2258	45
BUW03	22075	31	08/11/2015 1615	30/05/2016 2034	35

2.2 VANCOUVER HARBOUR VESSEL-MOUNTED ADCP

For the Vancouver Harbour “underway” survey, an ADCP mounted on a vertical pole secured to a small towed boat measured ocean currents for three days along ten transects. The mounted ADCP configuration was the Sontek RiverSurveyor M9 with Serial Number M905082. Specifications for the instrument are found on the company web page (<http://www.sontek.com/productsdetail.php?RiverSurveyor-S5-and-M9-14>).

From 26 to 29 January 2016, five transects at First Narrows (Figure 3) and five transects at Second Narrows (Figure 4) measured currents during all stages of the tide.

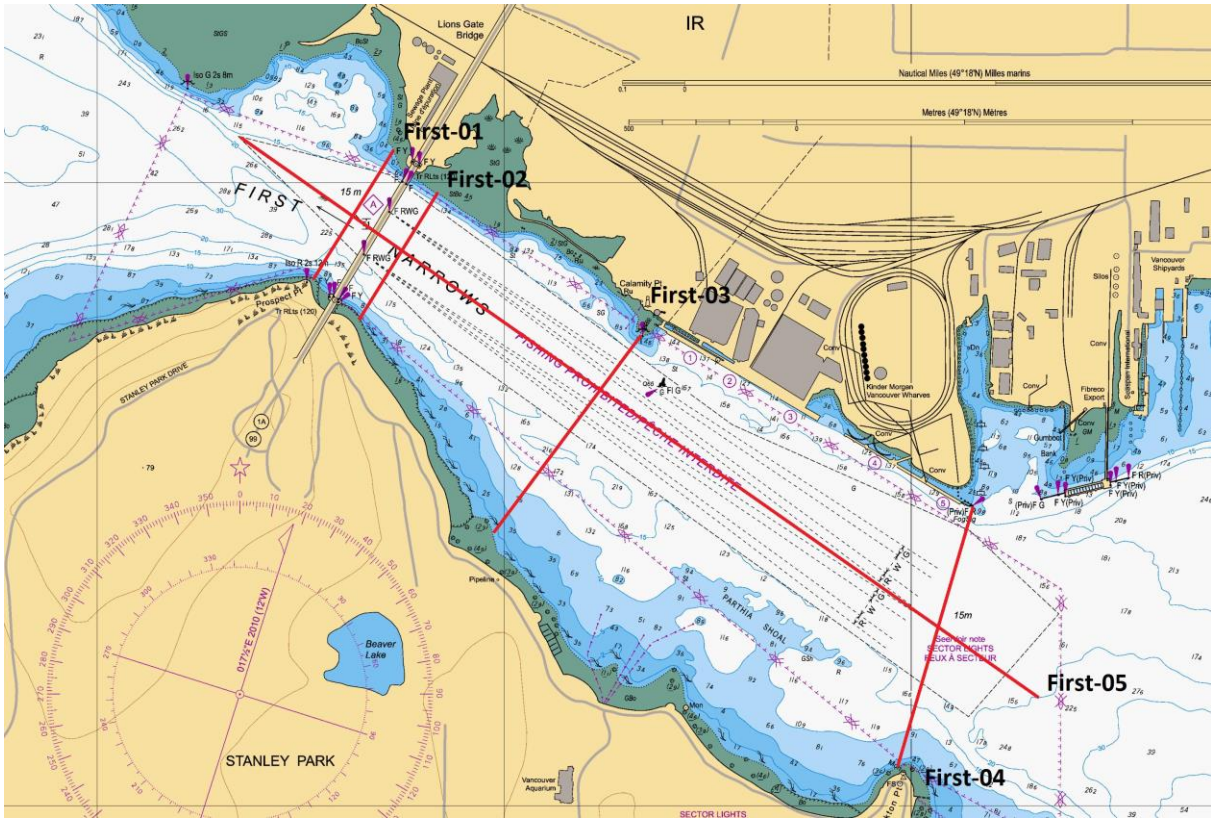


Figure 3 Map of First Narrows showing the 5 transects sampled by the RiverSurveyor

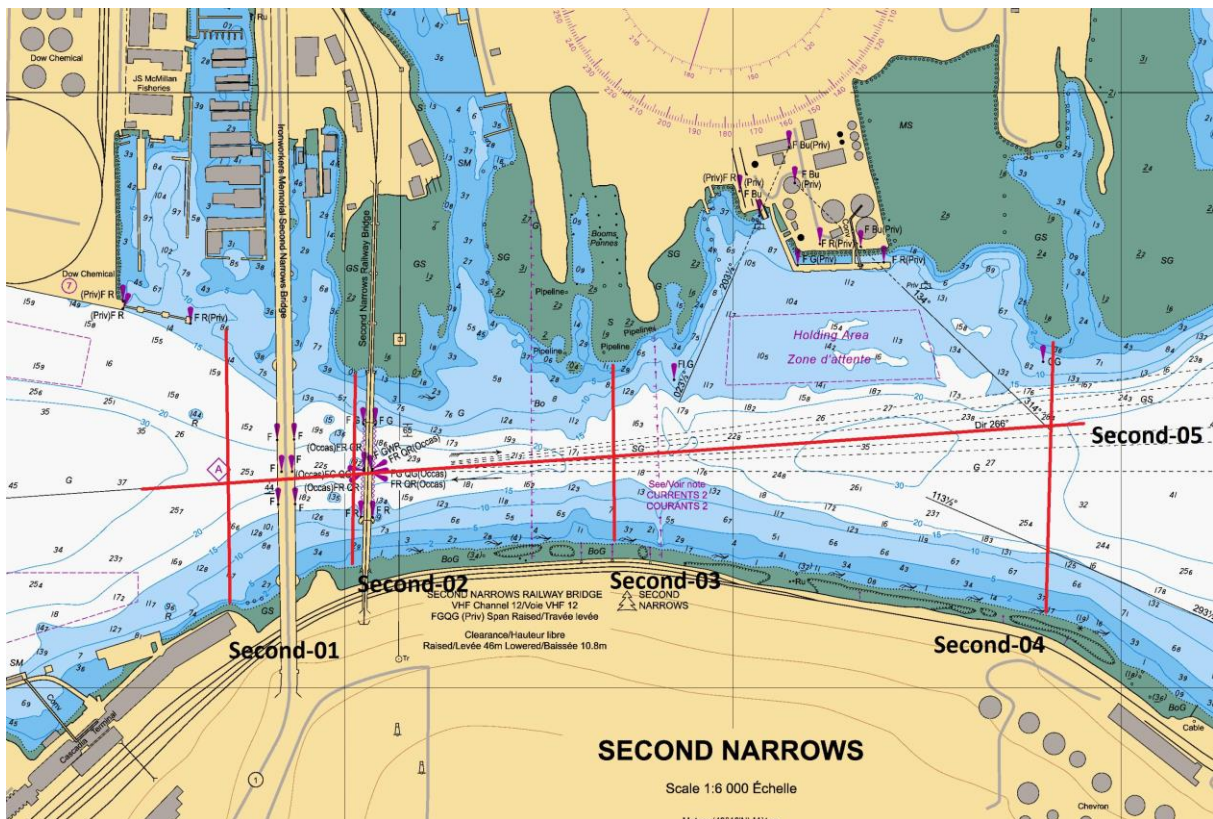


Figure 4 Map of Second Narrows showing the 5 transects sampled by the RiverSurveyor

We ran the transect lines forwards and backwards with forward lines going from Left Bank to Right Bank. Lines that ran parallel to the channel (First-05/Second-05) began up-inlet and went down-inlet.

2.3 CTD

A Sontek Castaway Conductivity Temperature Depth (CTD) profiler measured temperature, salinity, and speed of sound at stations next to each ADCP transect line in January 2016. Nine CTD stations were at First Narrows, and four stations were at Second Narrows.

The instrument is a handheld profiler and is designed to vertically sample up to 100 m. (Sontek, 2016) Specifications for the instrument are on the company's web page (<http://www.sontek.com/productsdetail.php?CastAway-CTD-11>). The CTD speed of sound data were used to correct ADCP measurements, and the temperature and salinity data will be used for numerical modelling.

Table 2 lists the CTD cast times and locations, and the map in Figure 5 shows the locations of the casts.

Table 2. CTD cast locations and dates (adapted from 2016 Field Report)

Cast #	Location	Latitude	Longitude	Date (UTC)	Time (UTC)
1	First Narrows	49.30433	-123.117	2016-01-25	22:03
2	First Narrows	49.30943	-123.132	2016-01-25	23:46
3	First Narrows	49.31301	-123.135	2016-01-26	16:49
4	First Narrows	49.31649	-123.142	2016-01-26	20:30
5	First Narrows	49.31447	-123.137	2016-01-27	01:00
6	Second Narrows	48.29439	-123.026	2016-01-27	17:15
7	Second Narrows	48.29525	-123.03	2016-01-27	20:44
8	Second Narrows	48.29489	-123.02	2016-01-27	22:31
9	Second Narrows	48.29475	-123.03	2016-01-28	01:14
10	First Narrows	49.31641	-123.141	2016-01-28	16:28
11	First Narrows	49.31657	-123.144	2016-01-28	21:19
12	First Narrows	49.31147	-123.146	2016-01-29	01:16
13	First Narrows	49.31584	-123.141	2016-01-29	16:23

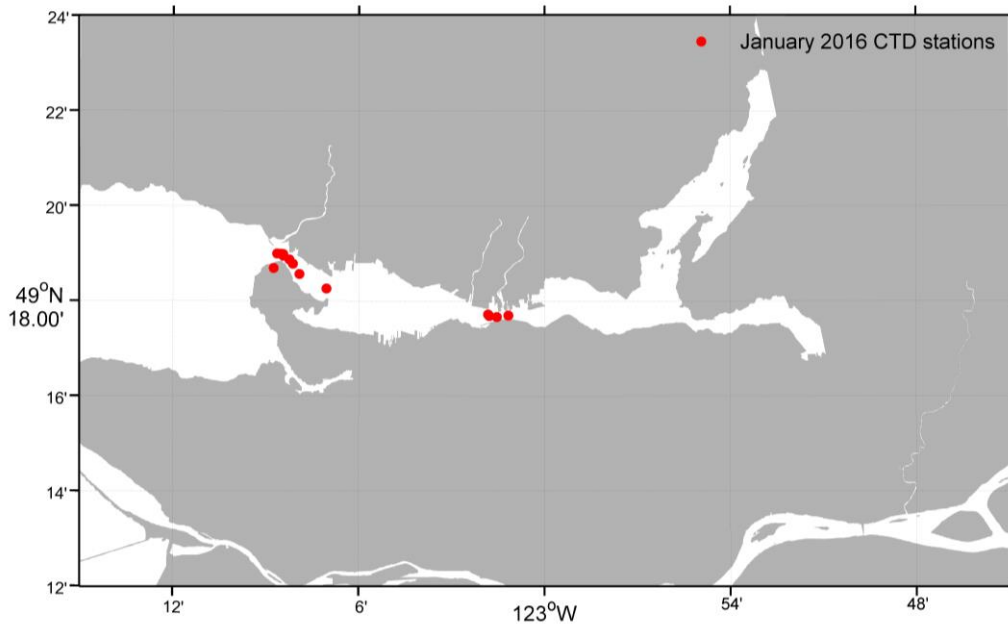


Figure 5 Map showing where the CTD casts occurred in January 2016

3 DATA PROCESSING AND DATA

Initial data processing occurred at the Institute of Ocean Sciences. C. Lunn, of the Canadian Hydrographic Service, transferred the data to the Bedford Institute of Oceanography. X. Wang, Y. Wu, and C. Lunn performed the quality control and Y. Wu plotted the ADCP data using Matlab®.

The horizontal velocity components, u and v , point east-west and north-south with respect to magnetic north. The raw velocity vector data were rotated with magnetic declinations for the stations as follows:

- BUW01=16.5769°
- BUW02=16.5358°
- BUW03=16.5239°

For the vessel-mounted ADCP data (“underway” data), the data were averaged into 20-m bins horizontally and 1-m bins vertically. The means and standard deviations for East and North directions were computed and combined. These ADCP data were initially processed at the Institute of Ocean Sciences by C. Lunn. Y. Wu used Matlab® for post-processing and creating the figures for this report.

This report presents the mooring data time series and the results of the tidal analyses in Section 3.1. Tidal analysis of the velocity components showed which tidal constituents dominated at which depths and at which time during sampling. An introduction to the vessel-mounted ADCP data is in Section 3.2 while the vertical profiles of the vessel-mounted ADCP data are in Appendices 2 and 3. CTD data vertical profiles are presented in Section 3.3.

3.1 MOORING DATA

3.1.1 Time Series

The following figures are vertical profiles of time series of the mooring data in this order: BUW01 (Figure 6), BUW02 (Figure 7), and BUW03 (Figure 8). The figures show the velocity components, u , v , and w (horizontal and vertical) measured by the ADCPs at the three locations over seven months. The units for the horizontal components are ms^{-1} , and the unit for the vertical speed, w , is mms^{-1} .

The time series reveal a strong two-layer flow in the outer harbour for most of the sampling season with periodic upward flow from the bottom to middle layer. To a lesser extent, the central harbour had a two-layer east-west flow, but there were periods when the circulation in the central harbour and in the inner harbour was barotropic.

3.1.1.1 Mooring BUW01

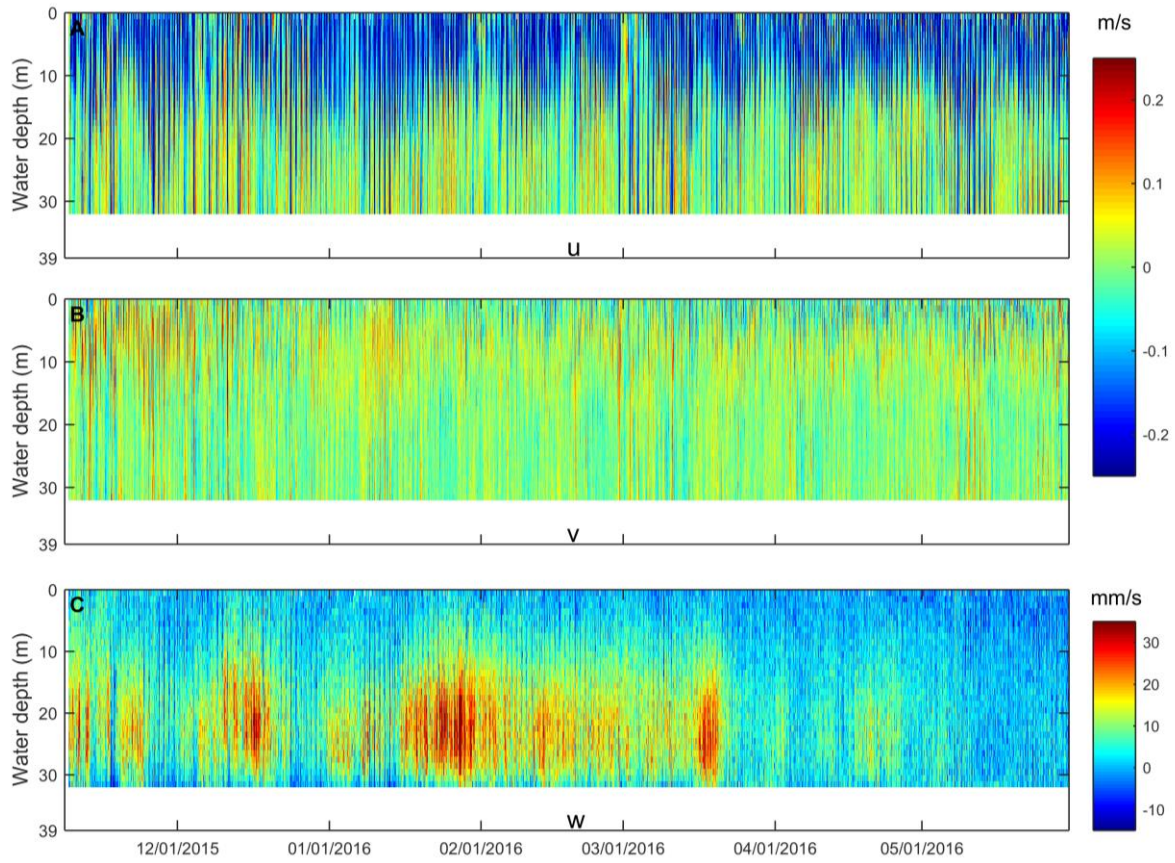


Figure 6 Time series of A) u , B) v , and C) w water velocity components measured at mooring BUW01 in outer Vancouver Harbour

3.1.1.2 Mooring BUW02

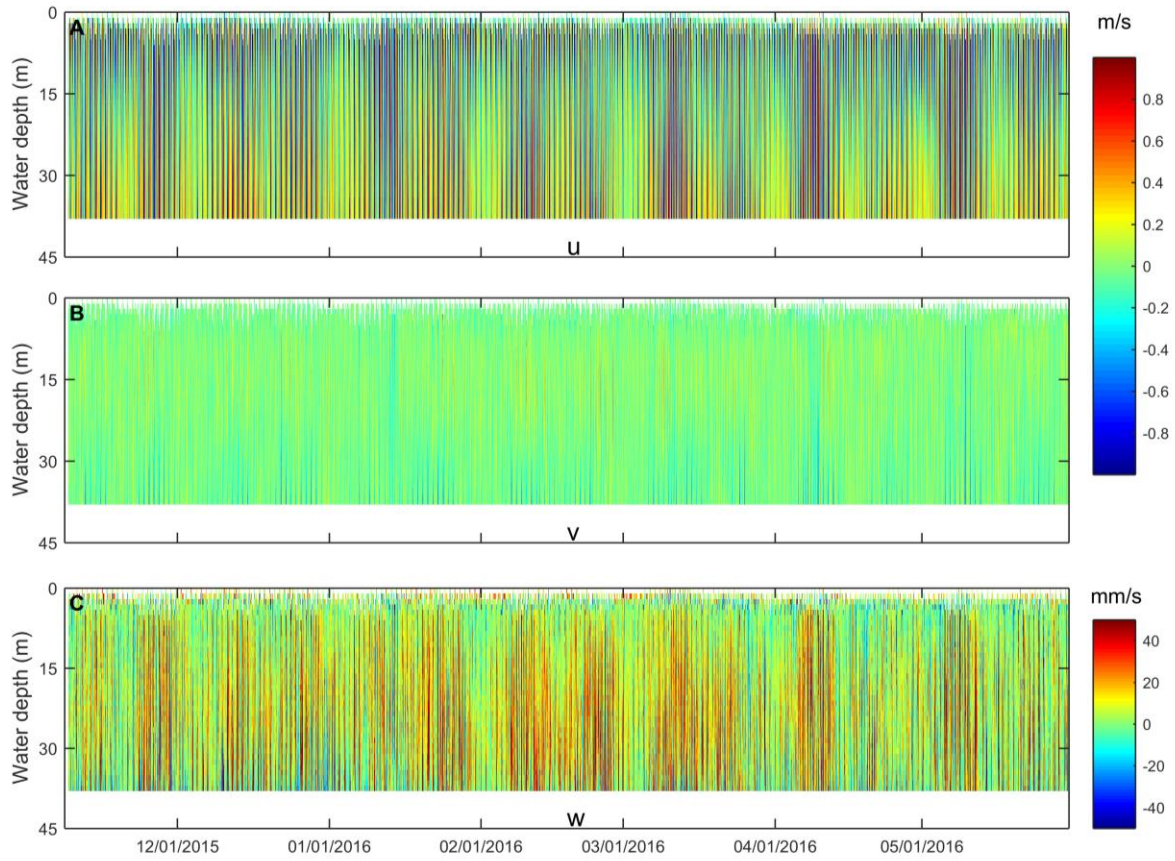


Figure 7 Time series of A) u , B) v , and C) w water velocity components measured at mooring BUW02 in inner Vancouver Harbour

3.1.1.3 Mooring BUW03

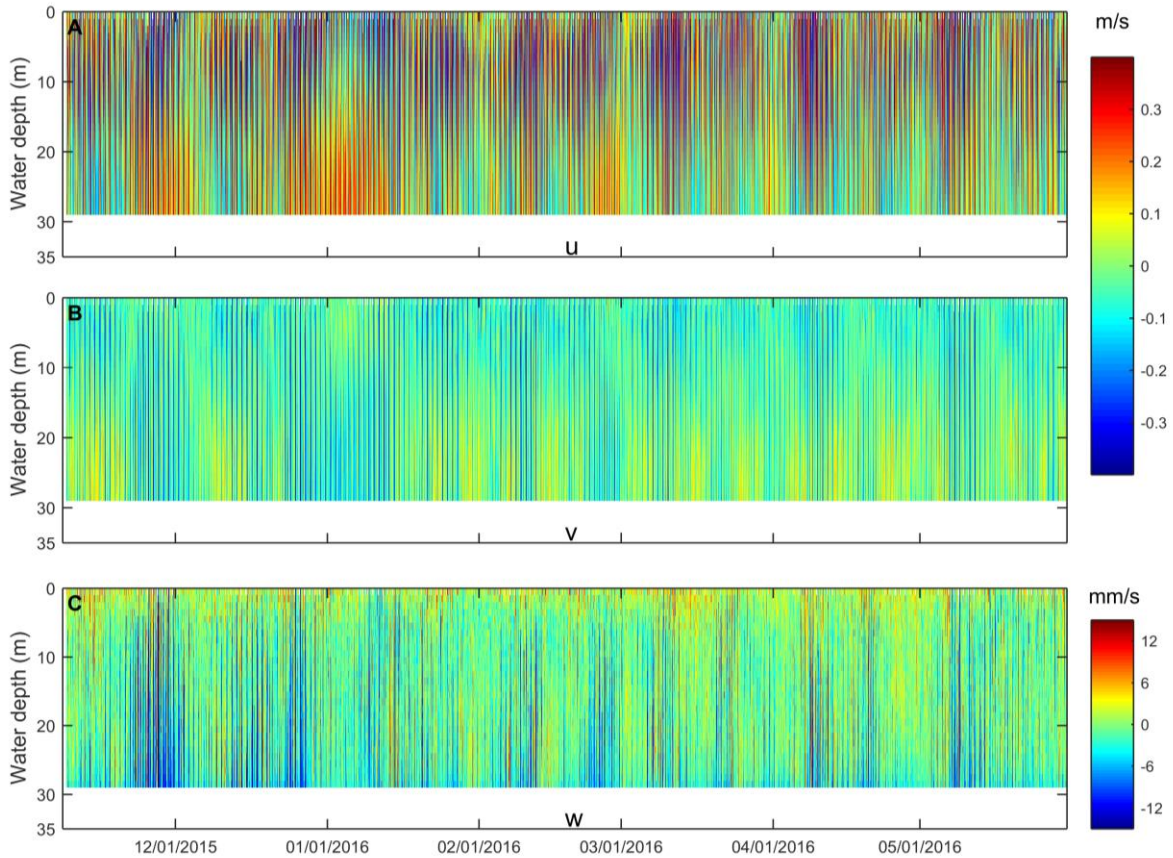


Figure 8 Time series of A) u , B) v , and C) w water velocity components measured at mooring BUW03 in central Vancouver Harbour

3.1.2 Tidal Analysis

The horizontal velocity components from the three moorings were decomposed into the top 13 tide constituents and the residuals. The following six figures are the time series for the K1 and M2 tides at the mooring locations (Figure 9 to Figure 14) for the averaged depth intervals: surface, mid-depth, and bottom. For each of the depth intervals, we used the top ten bins for the surface data, the last four bins for the bottom data, and mid-depth data were the data between the top and bottom bins. The figures display the semi-major and semi-minor axes of the tidal ellipses, the inclination, and the phase. Figure 15 to Figure 17 show the time series of the tidal residual of the horizontal velocity components, u and v , measured at each mooring.

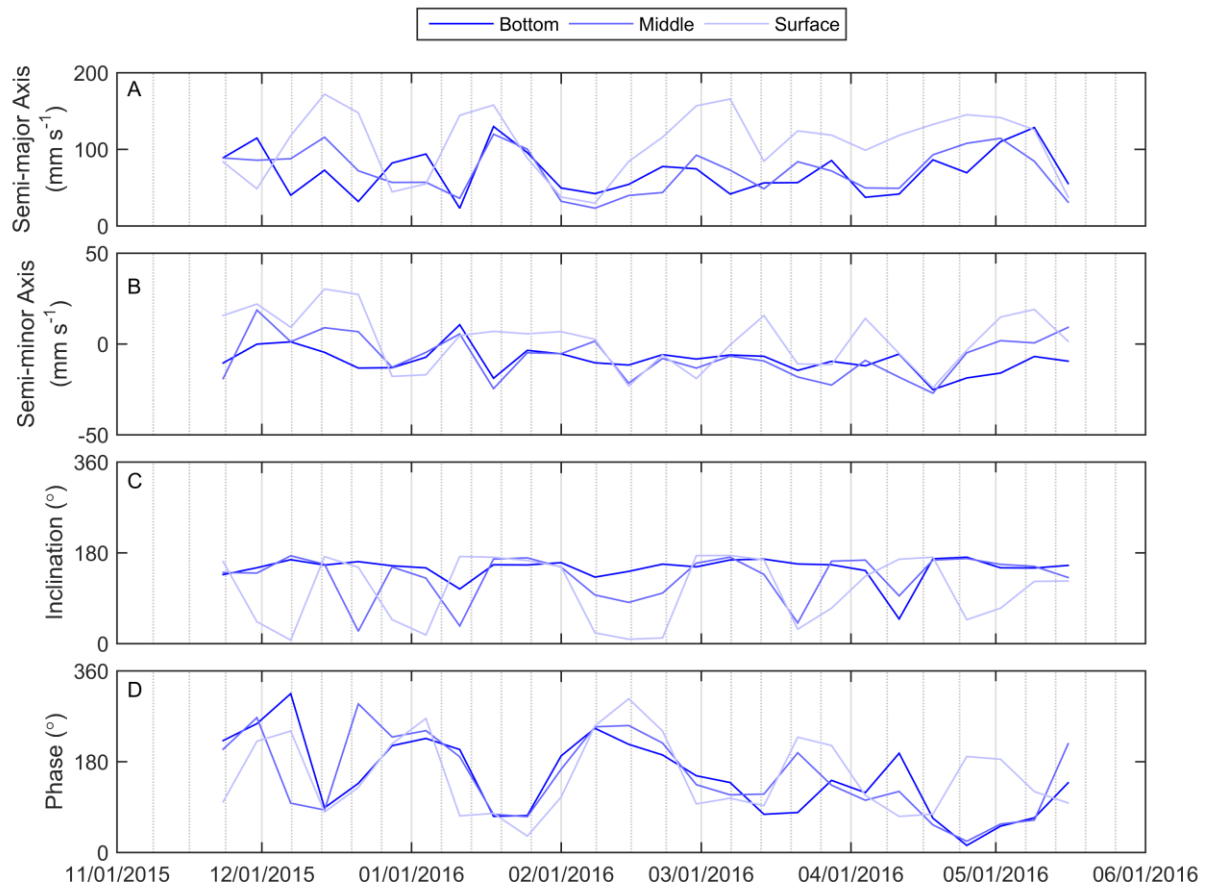


Figure 9 Time series of the K₁ tide at mooring BUW01 (outer harbour). The figure shows A) the semi-major and B) the semi-minor axes of the tidal ellipse in mms^{-1} , C) the inclination, and the D) phase.

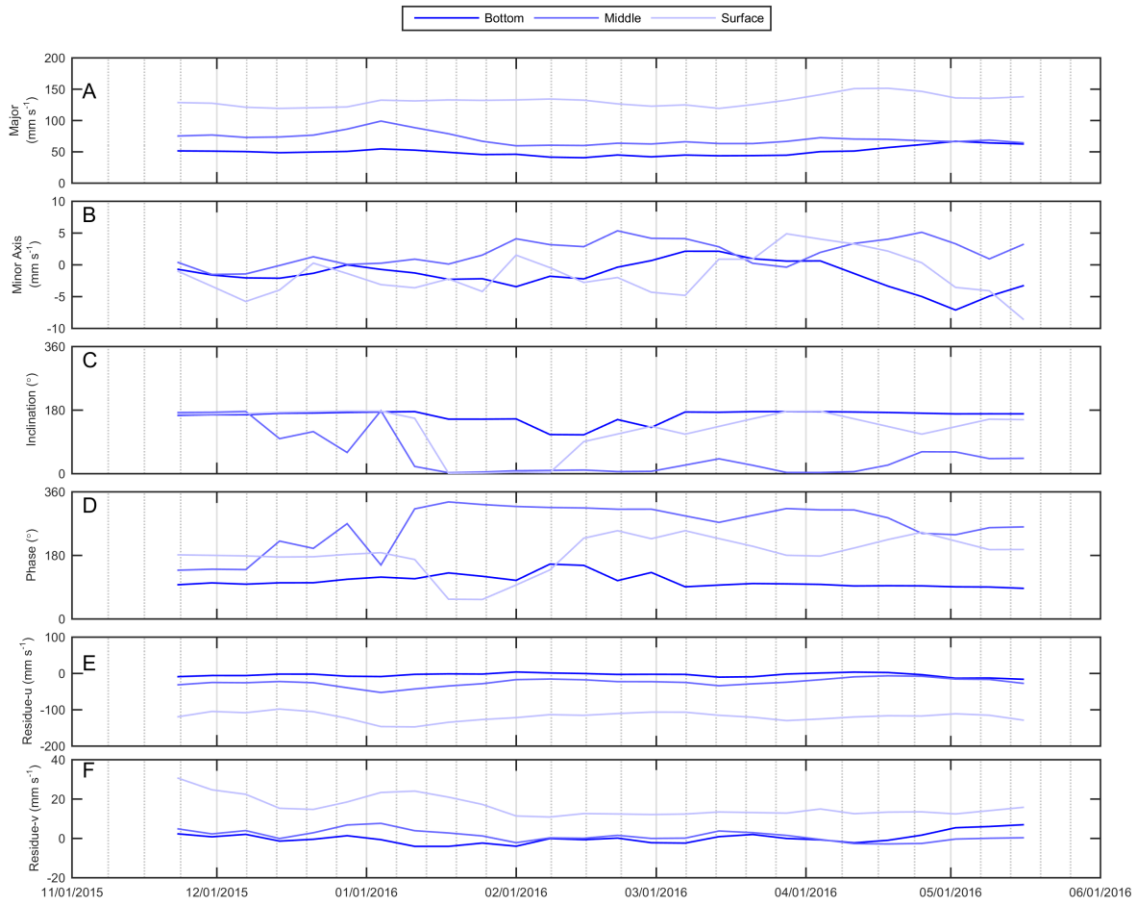


Figure 10 Time series of the M_2 tide at mooring BUW01 (outer harbour). The figure shows A) the semi-major and B) the semi-minor axes of the tidal ellipse in mms^{-1} , C) the inclination, and the D) phase.

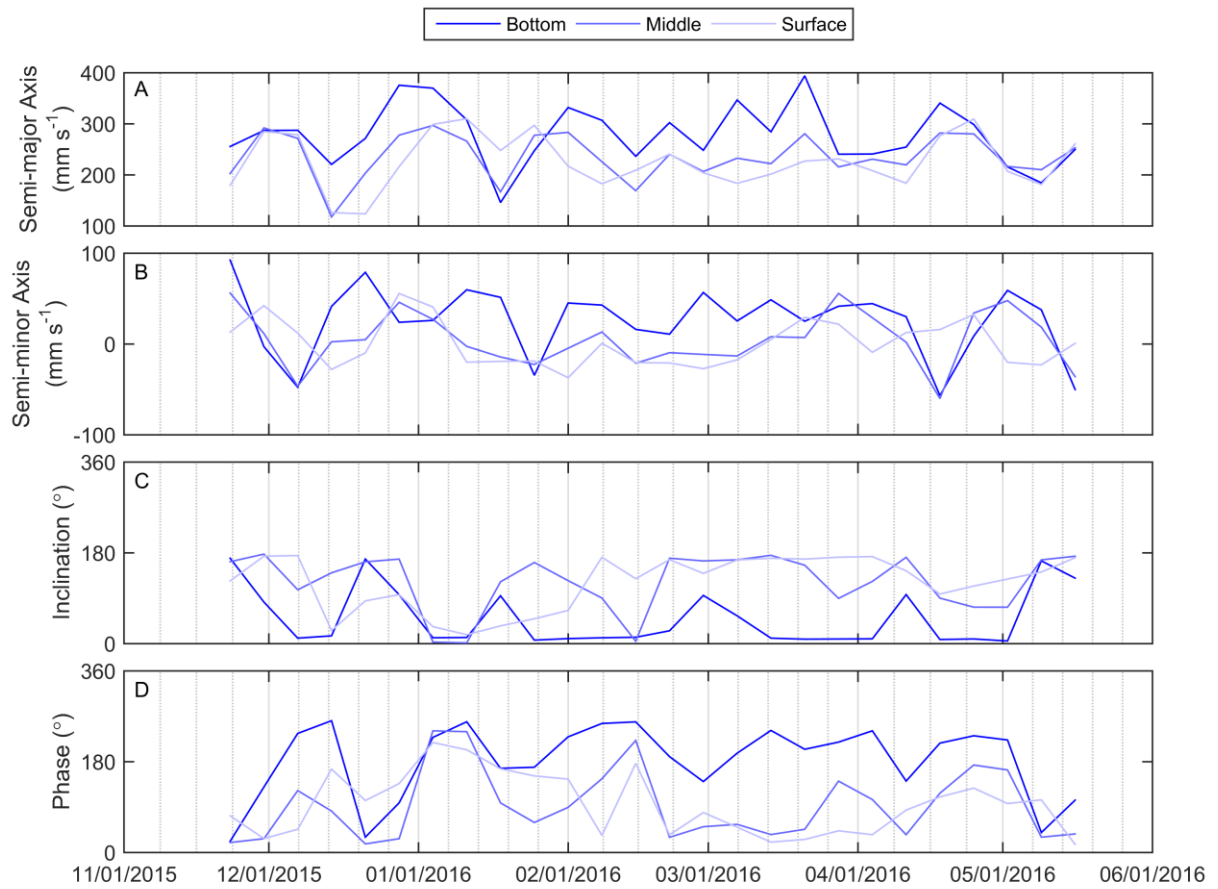


Figure 11 Time series of the K₁ tide at mooring BUW02 (inner harbour). The figure shows A) the semi-major and B) the semi-minor axes of the tidal ellipse in mms^{-1} , C) the inclination, and the D) phase.

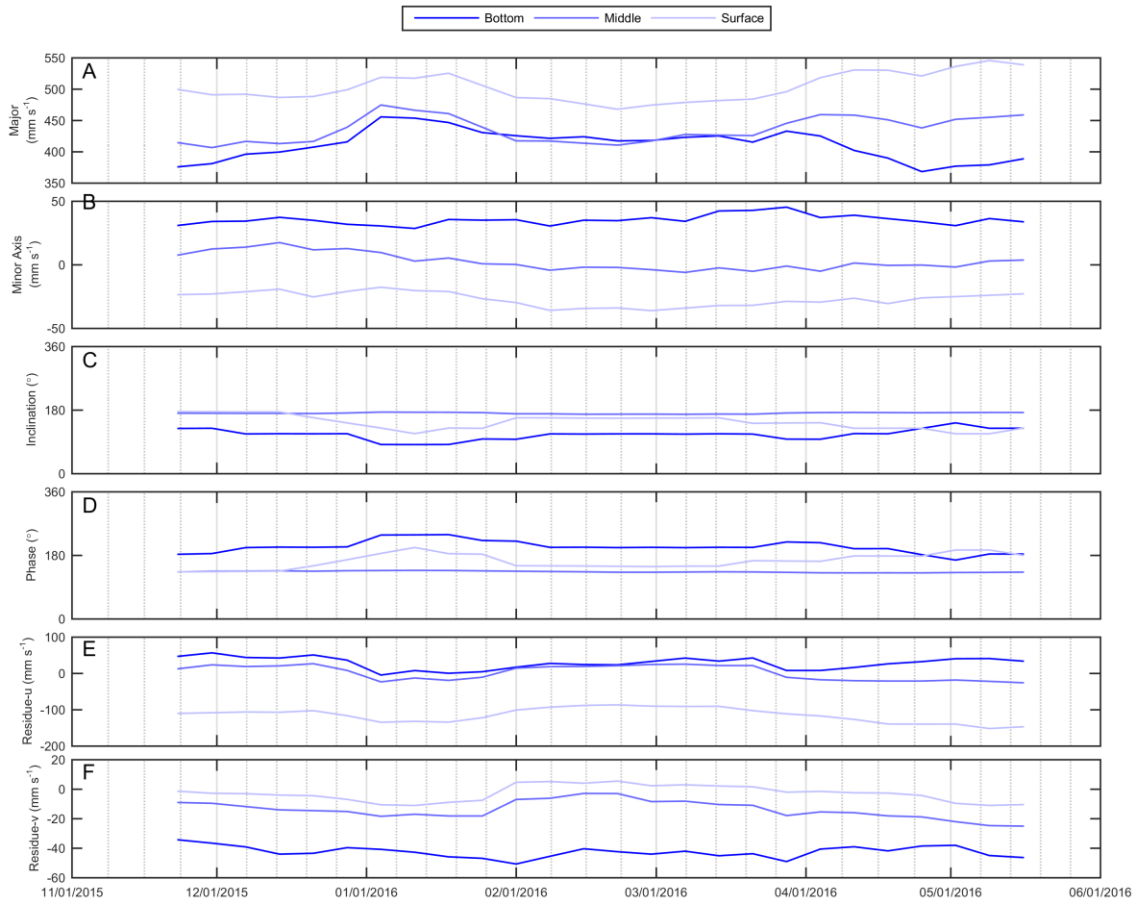


Figure 12 Time series of the M_2 tide at mooring BUW02 (inner harbour). The figure shows A) the semi-major and B) the semi-minor axes of the tidal ellipse in mms^{-1} , C) the inclination, and the D) phase.

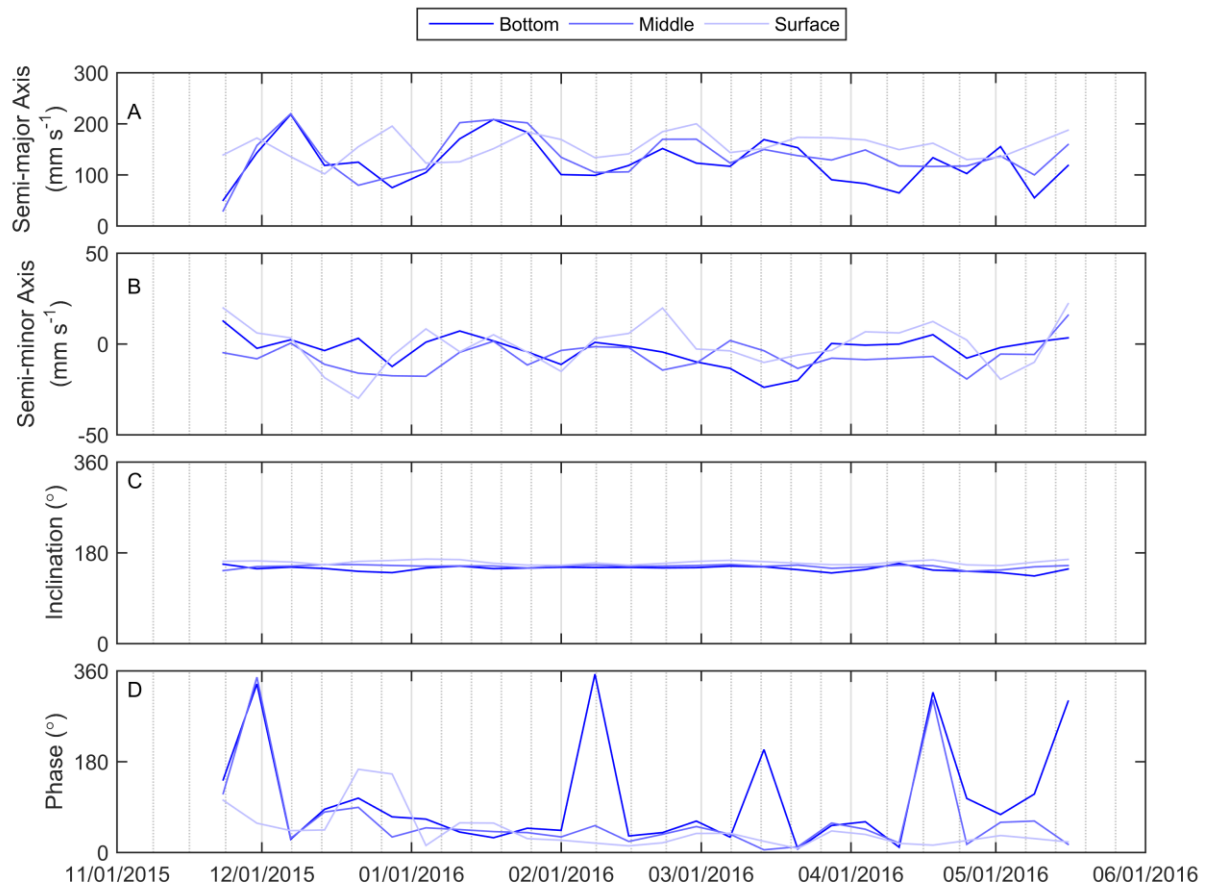


Figure 13 Time series of the K_1 tide at mooring BUW03 (central harbour). The figure shows A) the semi-major and B) the semi-minor axes of the tidal ellipse in mms^{-1} , C) the inclination, and the D) phase.

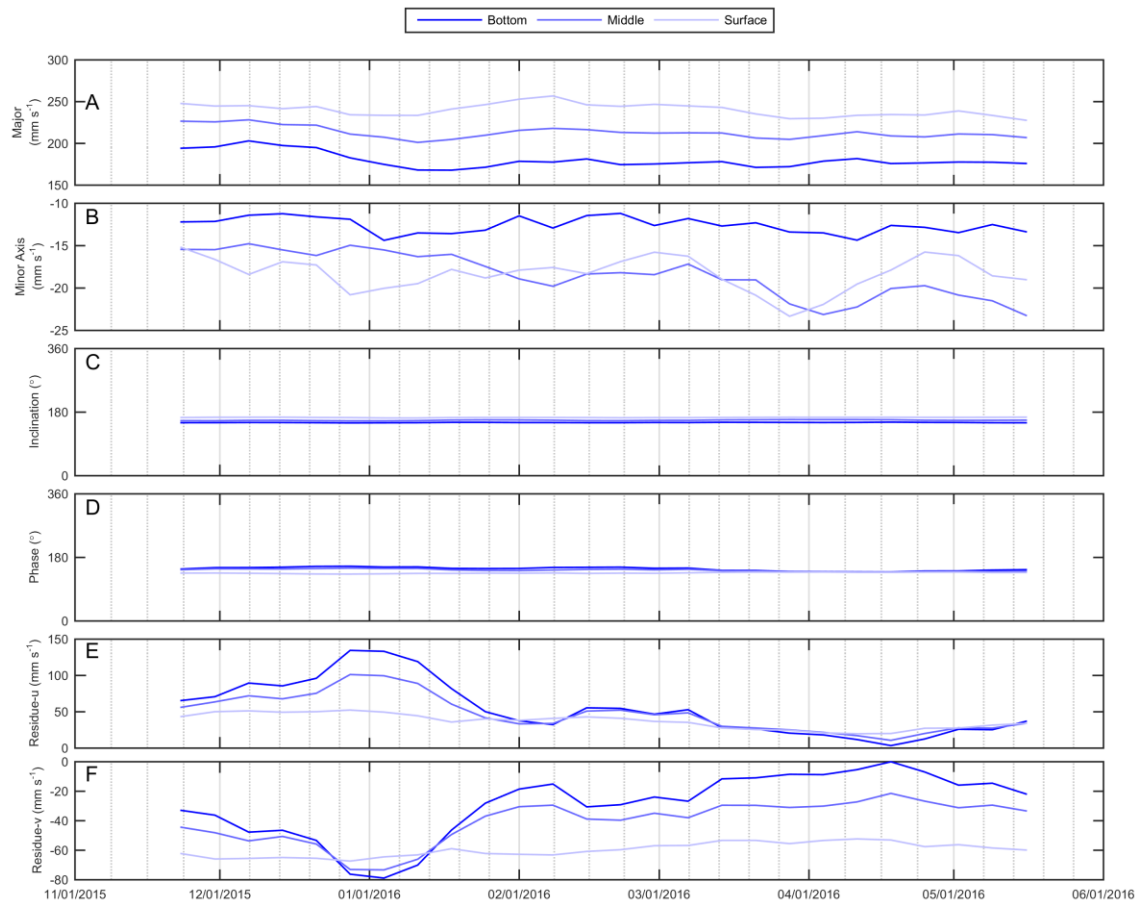


Figure 14 Time series of the M_2 tide at mooring BUW03 (central harbour). The figure shows A) the semi-major and B) the semi-minor axes of the tidal ellipse in mms^{-1} , C) the inclination, and the D) phase.

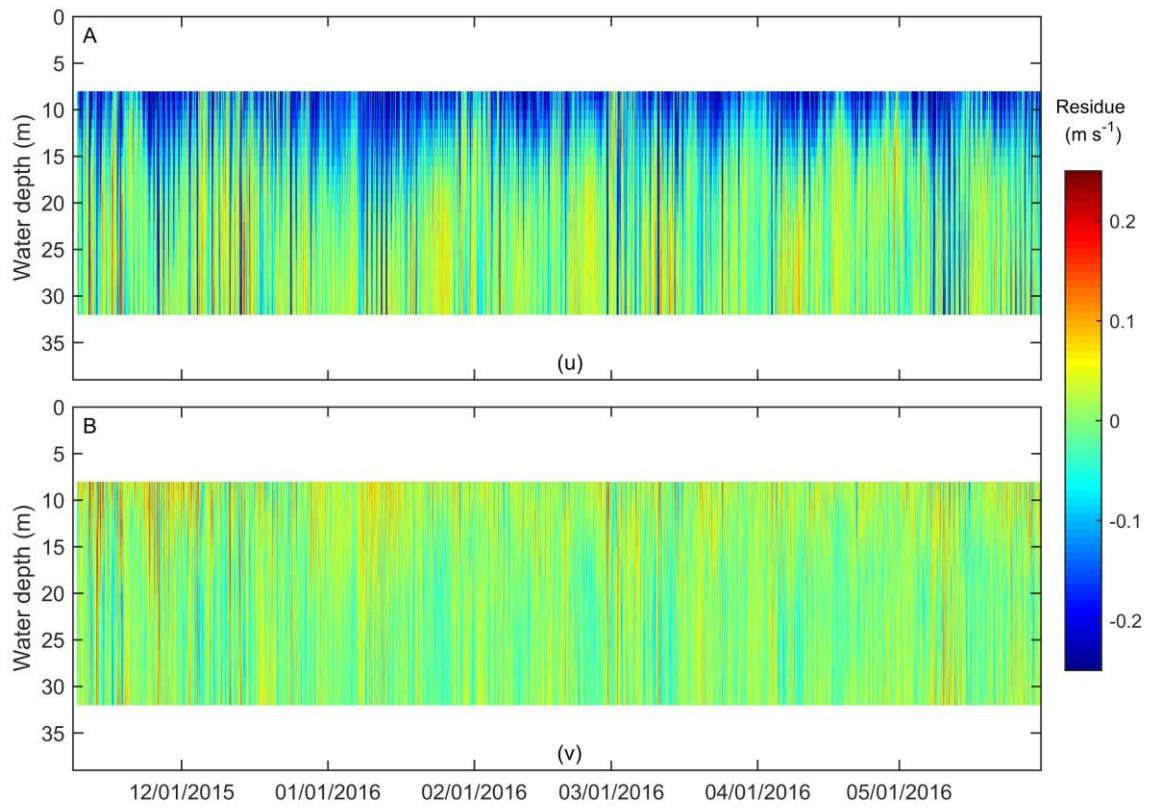


Figure 15 Time series of the tidal residual for A) u and B) v horizontal velocity components measured at mooring BUW01 (outer harbour). Units are ms^{-1} .

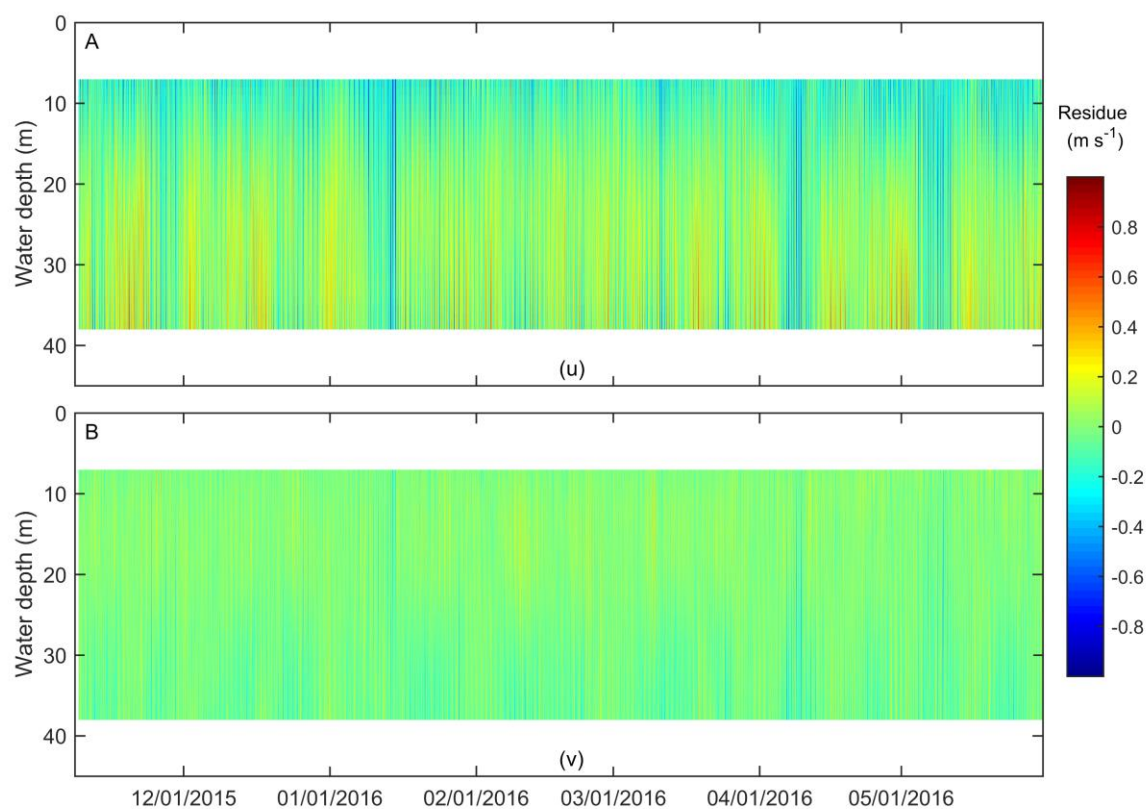


Figure 16 Time series of the tidal residual for A) u and B) v horizontal velocity components measured at mooring BUW02 (inner harbour). Units are ms^{-1} .

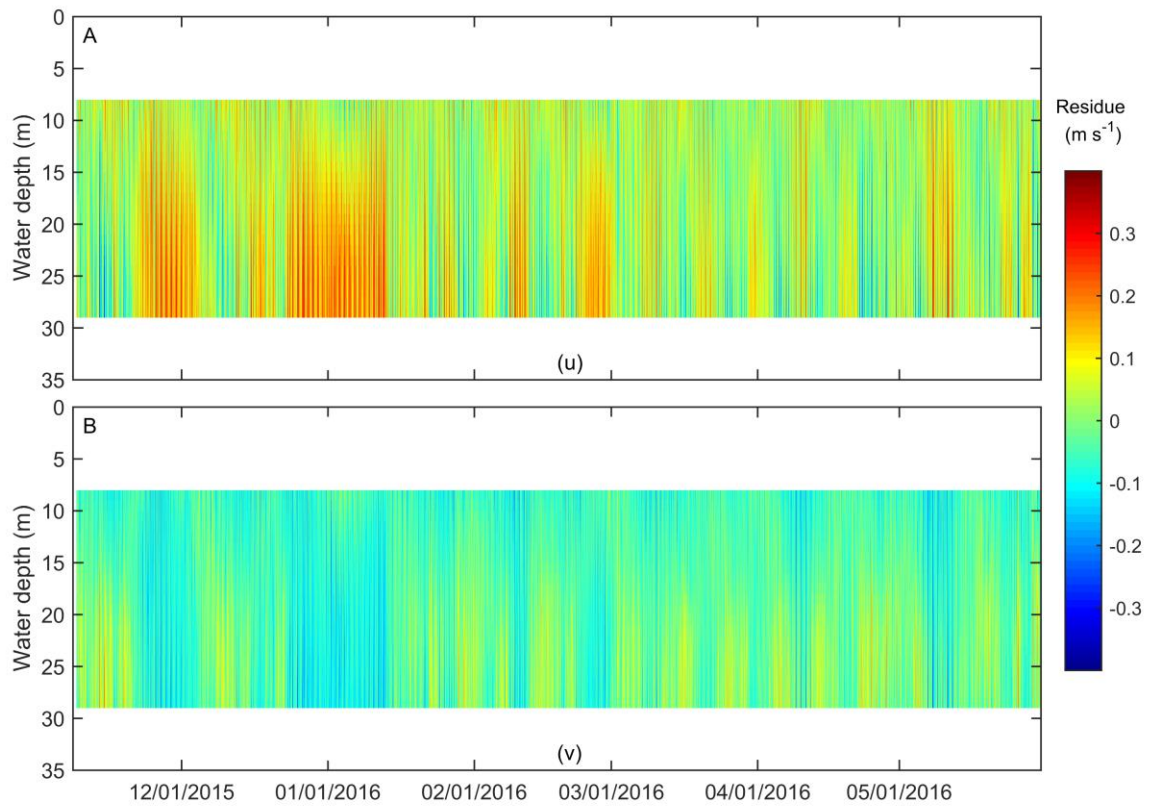


Figure 17 Time series of the tidal residual for A) u and B) v horizontal velocity components measured at mooring BUW03 (central harbour). Units are ms^{-1} .

3.2 VESSEL-MOUNTED ADCP DATA

Figures of the vessel-mounted ADCP data are too numerous to display in the main report so they are presented in Appendix 2 and Appendix 3. The statistics of the ADCP survey are in Table 3. The start and end times of each transect and their directions are in Table 4.

Table 3. Statistics of ADCP survey transects (adapted from 2016 Field Report)

Location	Line	~ Length (m)	# Runs
First Narrows	1	387	54
	2	393	56
	3	628	8
	4	741	2
	5 (Full)	2839	2
	5 (Partial)	550/1320	7
Second Narrows	1	448	15
	2	267	26
	3	223	14
	4	344	2
	5	1450	2

Table 4 Start and end times of each transect line for First Narrows and Second Narrows vessel-mounted ADCP surveys

First Narrows			
Line	Start	End	Direction
1	26 Jan 2016 17:07	29 Jan 2016 16:40	Cross-channel
2	26 Jan 2016 17:20	29 Jan 2016 00:46	Cross-channel
3	27 Jan 2016 18:23	28 Jan 2016 00:43	Cross-channel
4	25 Jan 2016 23:18	25 Jan 2016 23:28	Cross-channel
5	25 Jan 2016 22:51	26 Jan 2016 19:56	Along-channel
Second Narrows			
Line	Start	End	Direction
1	26 Jan 2016 17:57	28 Jan 2016 01:02	Cross-channel
2	27 Jan 2016 18:12	28 Jan 2016 00:54	Cross-channel
3	27 Jan 2016 18:23	28 Jan 2016 00:43	Cross-channel
4	25 Jan 2016 23:18	25 Jan 2016 23:28	Cross-channel
5	27 Jan 2016 17:23	27 Jan 2016 17:43	Along-channel

3.3 CTD VERTICAL PROFILES

This section presents the vertical profiles of of the January CTD data: temperature, salinity, and density. The figures also show the time during the tidal cycle when the profiles were measured and the locations of the casts.

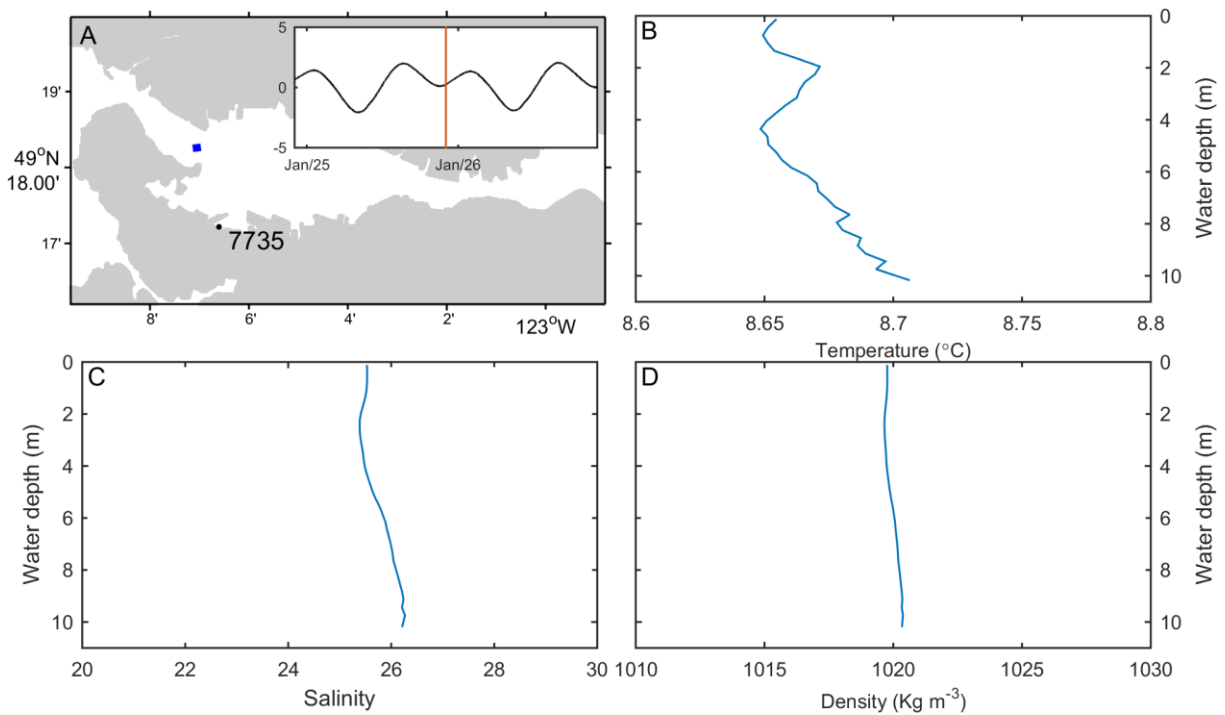


Figure 18 Temperature, salinity, and density data from January 25 @22:03

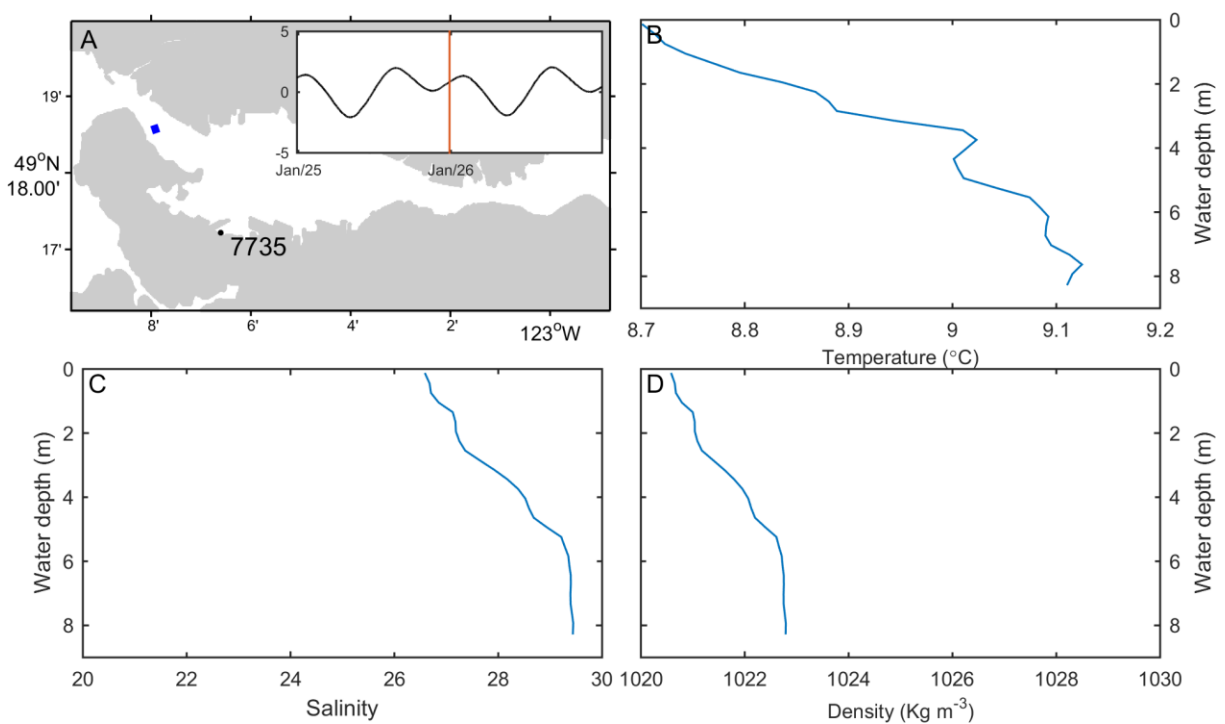


Figure 19 Temperature, salinity, and density data from January 25 @23:46

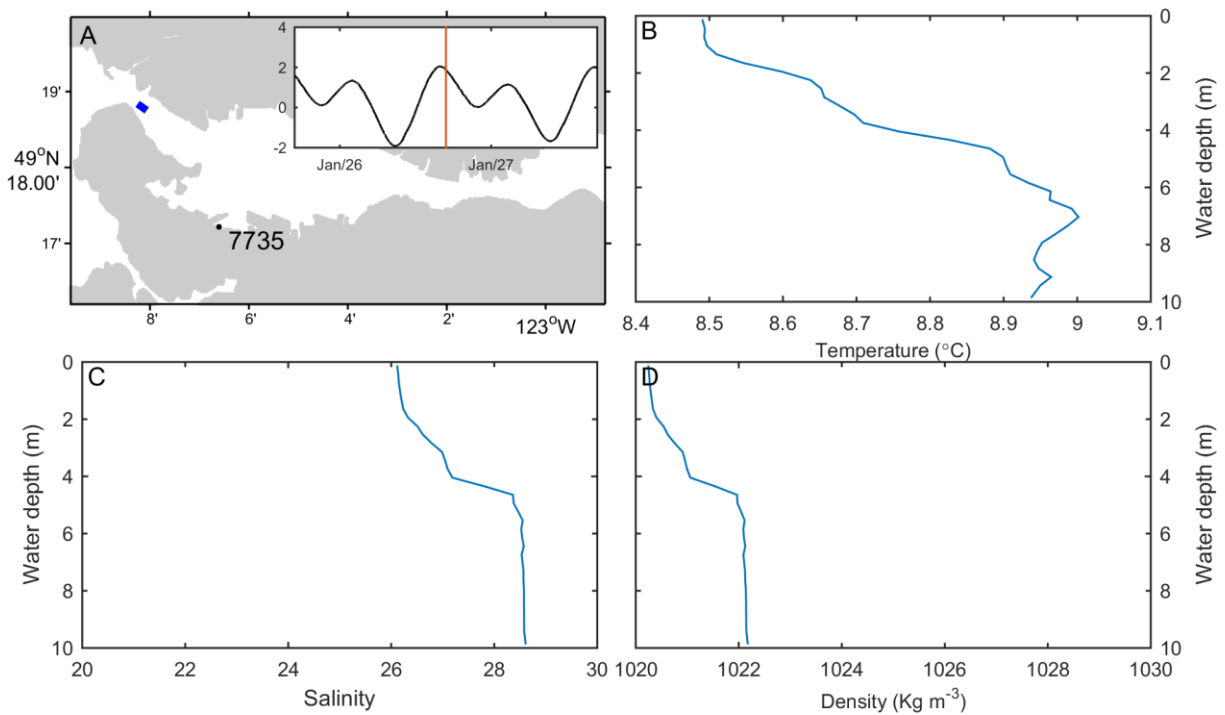


Figure 20 Temperature, salinity, and density data from January 26 @16:49

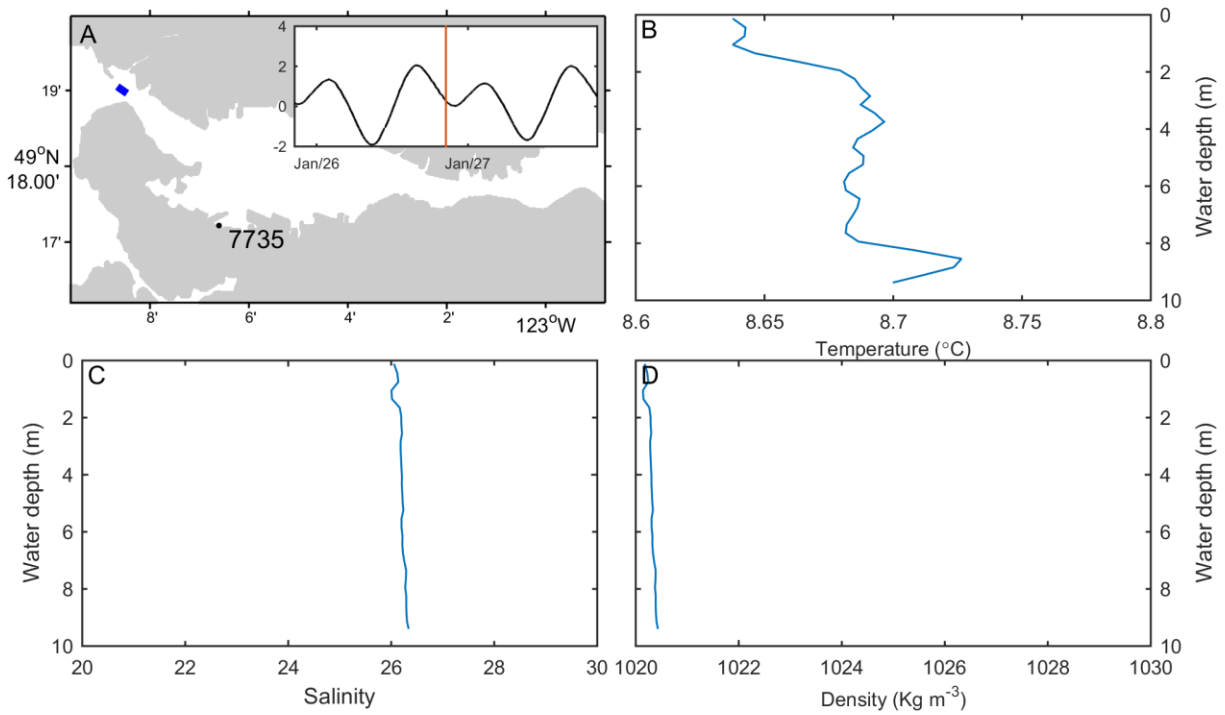


Figure 21 Temperature, salinity, and density data from January 26 @20:30

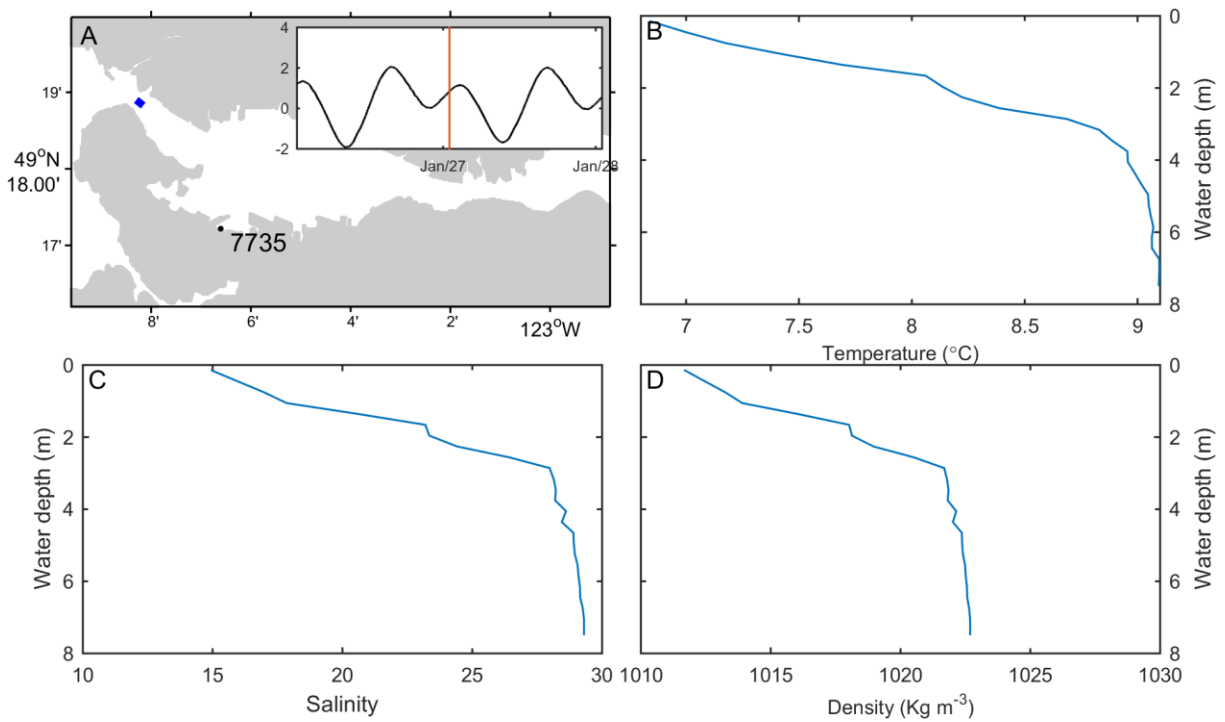


Figure 22 Temperature, salinity, and density data from January 27 @01:00

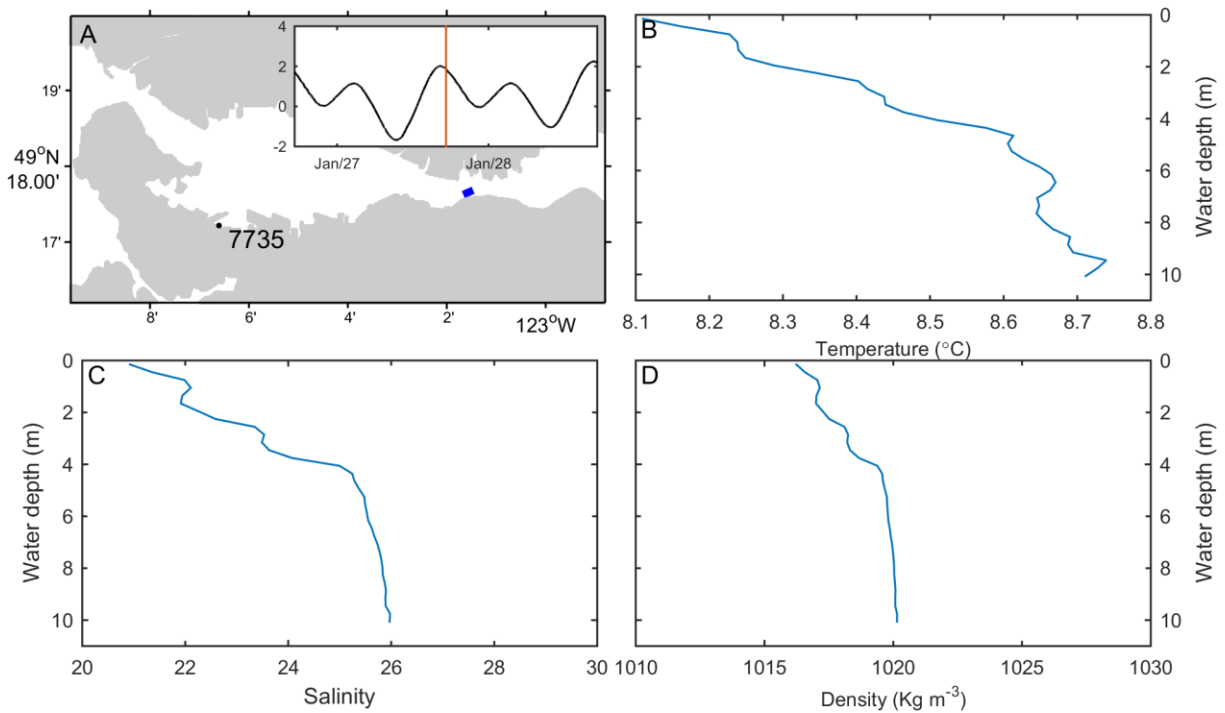


Figure 23 Temperature, salinity, and density data from January 27 @15:56

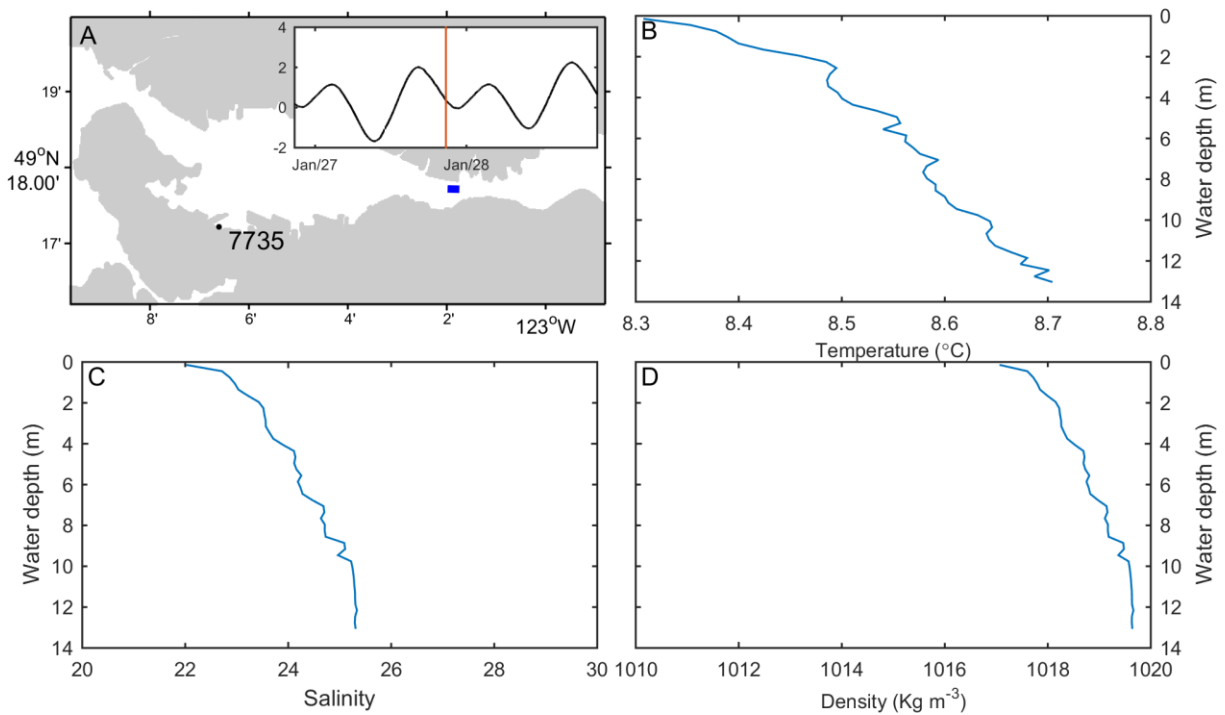


Figure 24 Temperature, salinity, and density data from January 27 @20:44

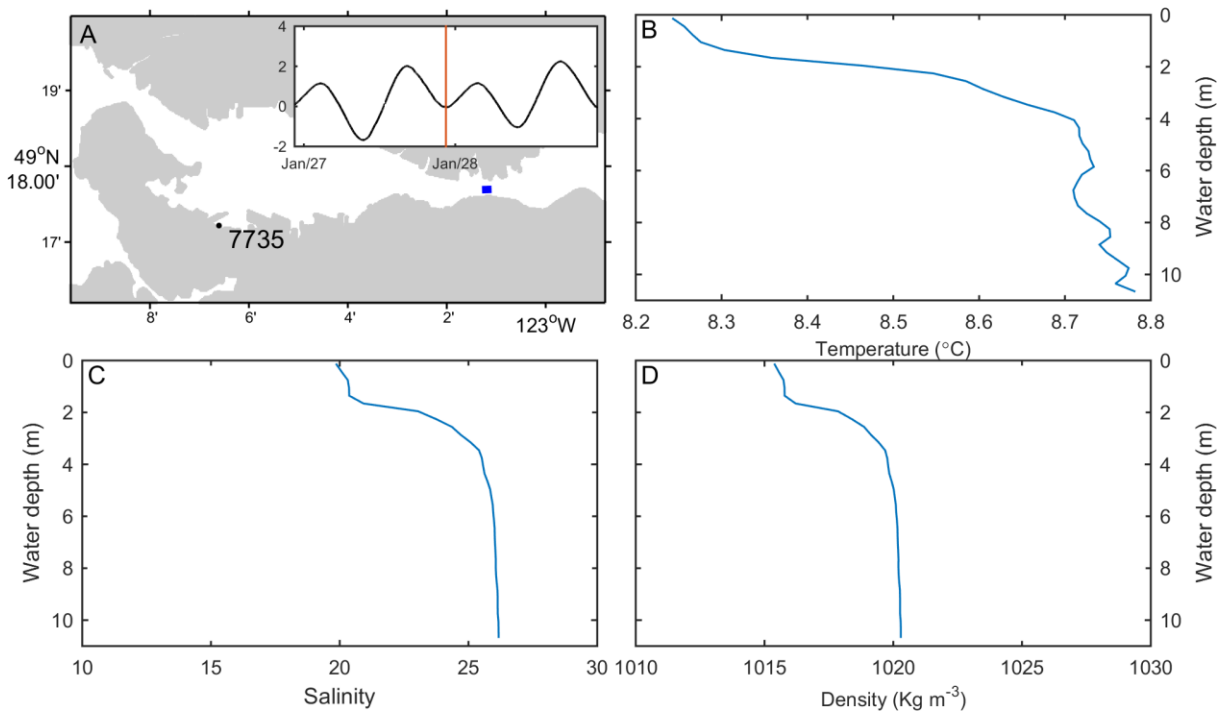


Figure 25 Temperature, salinity, and density data from January 27 @22:31

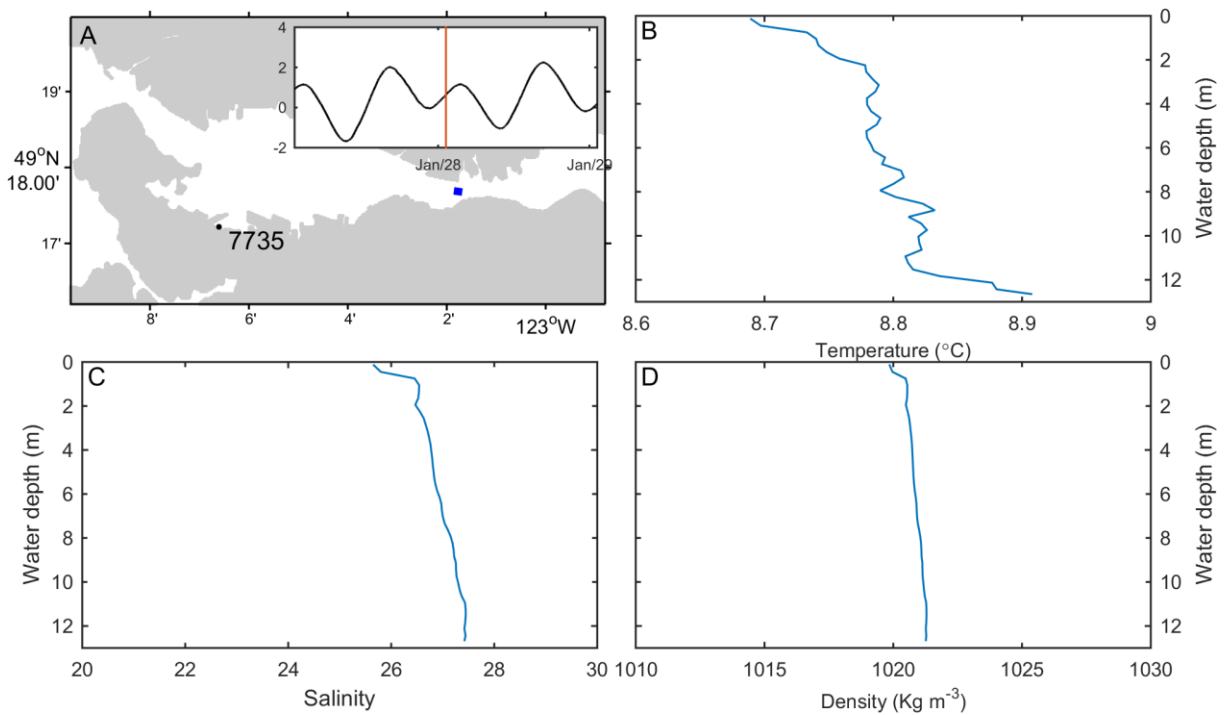


Figure 26 Temperature, salinity, and density data from January 28 @14:38

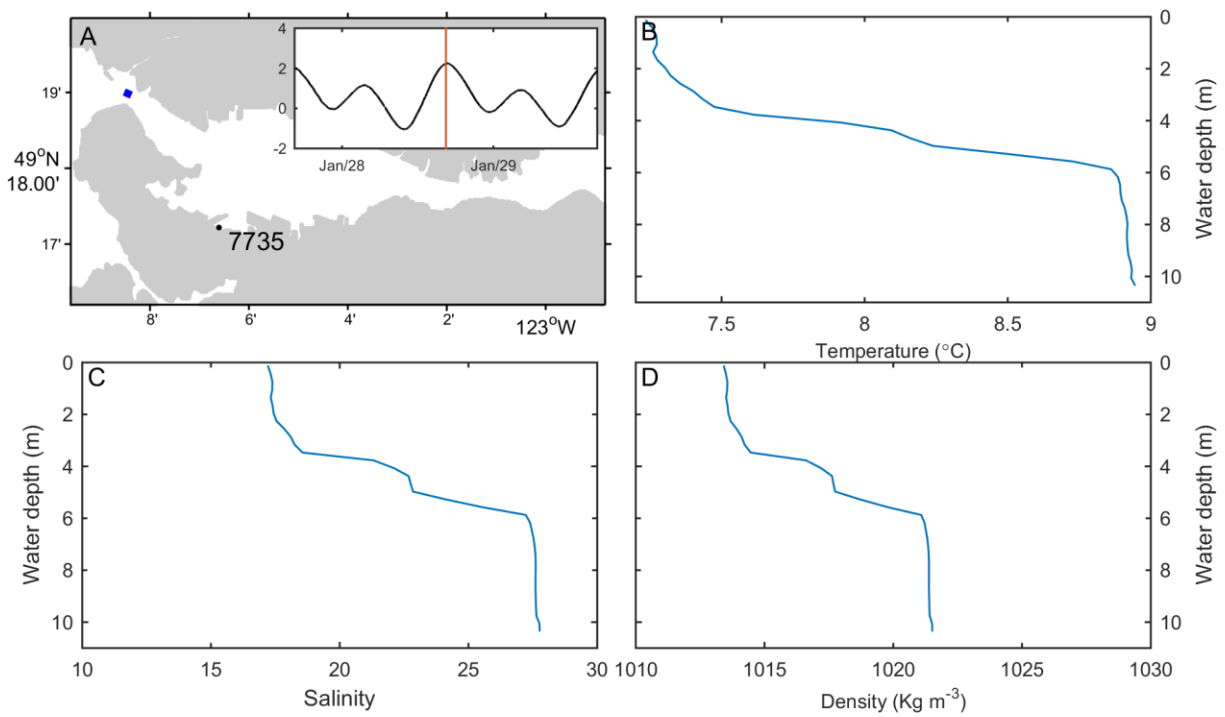


Figure 27 Temperature, salinity, and density data from January 28 @28:35

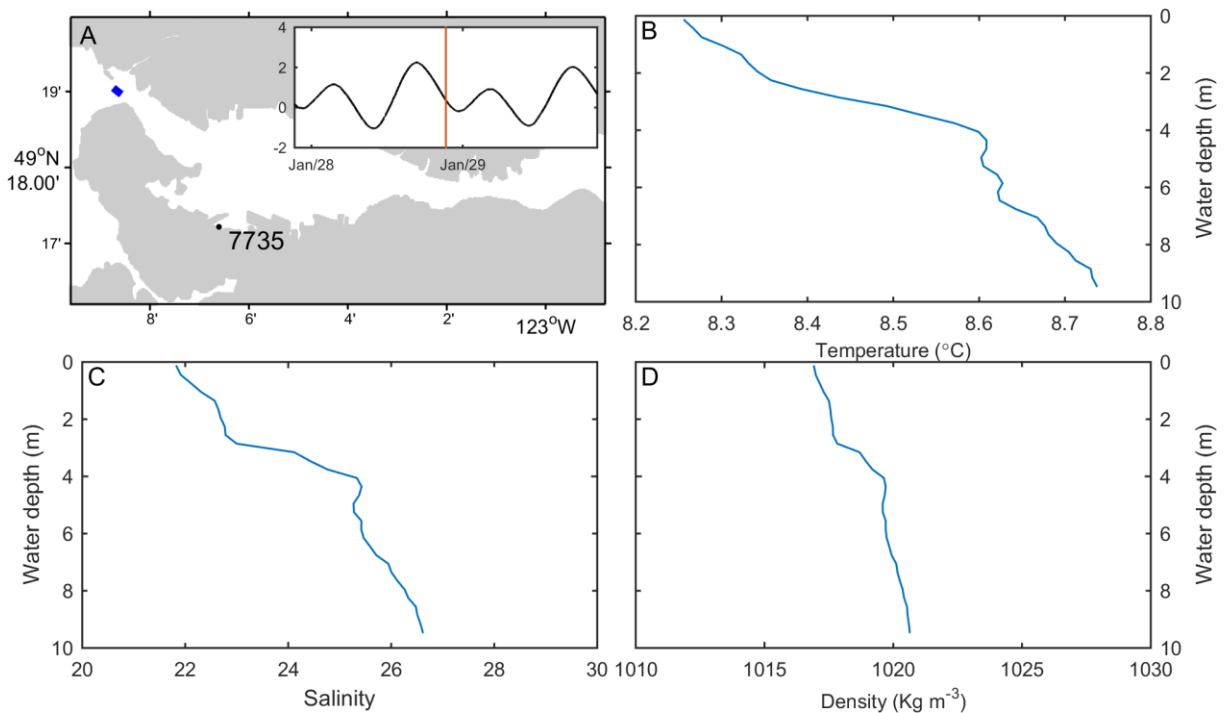


Figure 28 Temperature, salinity, and density data from January 28 @19:04

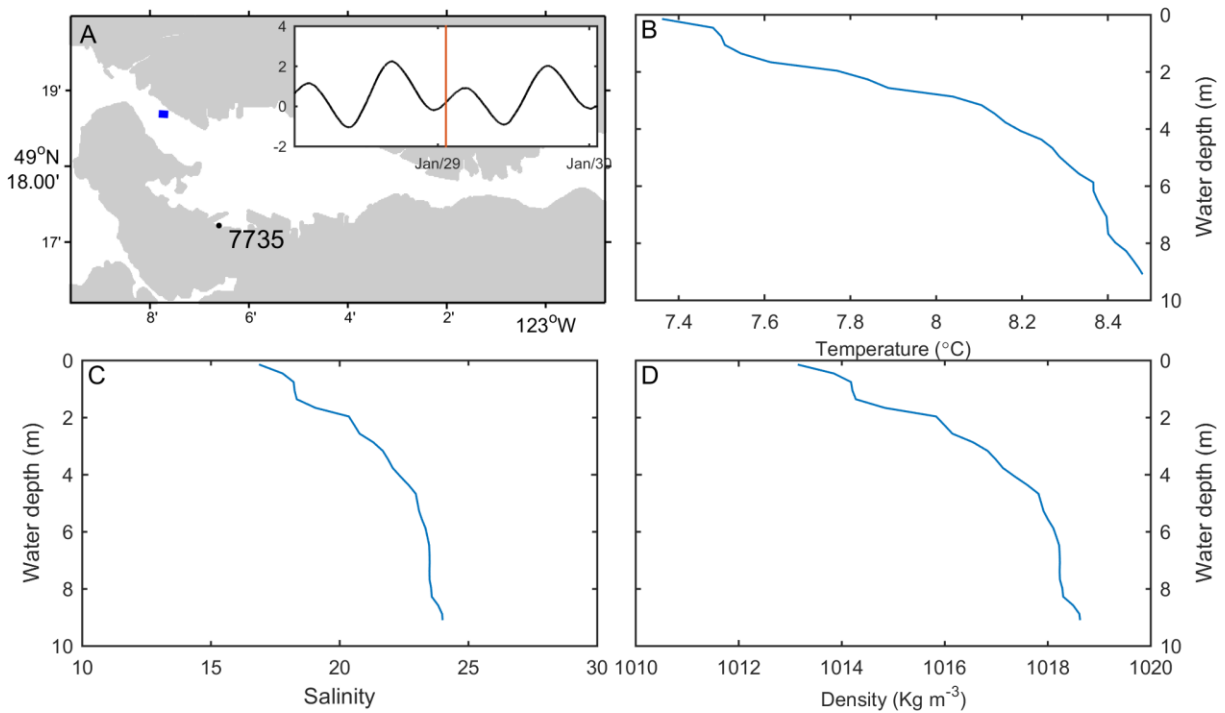


Figure 29 Temperature, salinity, and density data from January 29 @16:30

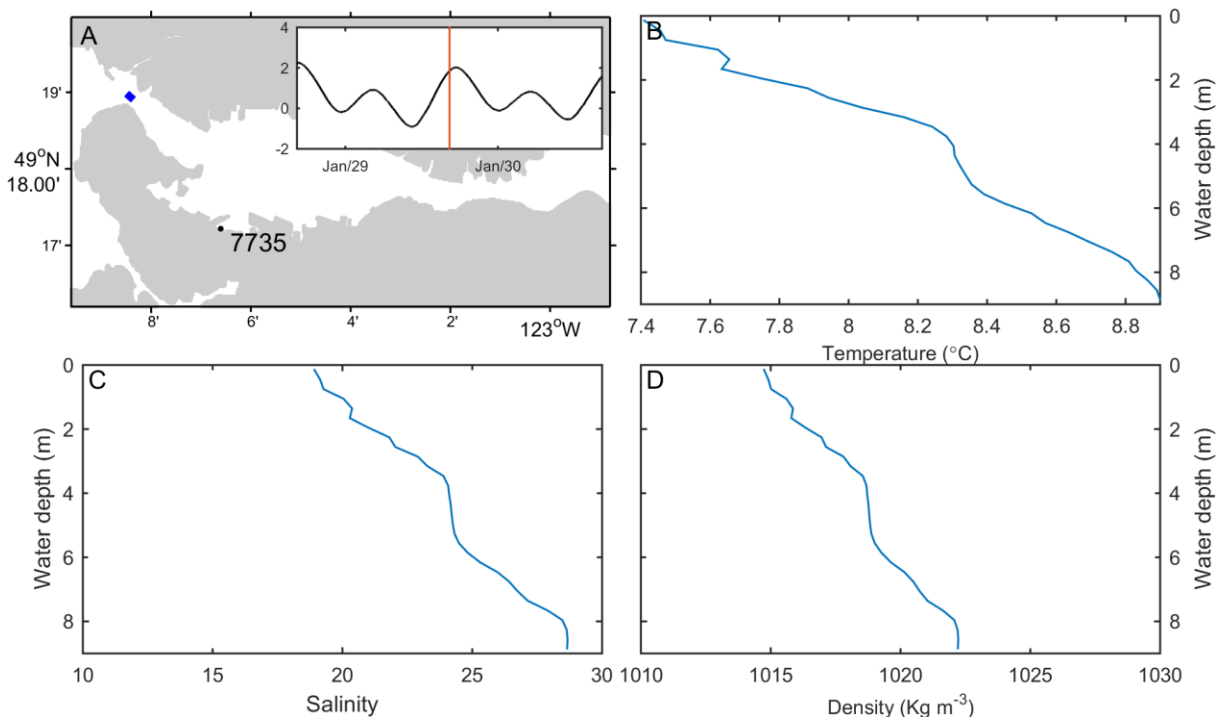


Figure 30 Temperature, salinity, and density data from January 29 @16:23

4 REFERENCES

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5 ACKNOWLEDGEMENTS

The authors gratefully acknowledge the data collection team from the Institute of Ocean Sciences. The team included Ron Woolley from the Canadian Hydrographic Service.

6 APPENDIX 1: MOORING CONFIGURATIONS

This appendix contains the mooring log sheets for the three ADCP moorings: BUW01-A, BUW02-A, and BUW03-A.

6.1 MOORING BUW01-A

Mooring Deployment Record

Project Name: <u>Vancouver Harbour</u>	
Project Area: <u>Vancouver Harbour</u>	
Mooring Name: <u>BUW01-A</u>	Station Name: <u>BUW01</u>
Latitude: <u>49° 19' 50"</u>	Longitude: <u>123° 12' 30"</u>
Depth: <u>39</u>	Tide:
Date: <u>Nov 8, 2015</u>	Time: <u>1850 (1050 PST)</u>
Time Zone:	
Remarks:	

Recovery

Date: <u>May 31, 2016</u>	Time: <u>0007 UTC</u>
Remarks:	

Instruments

Type	Serial #	Depth	Time In	Time Out	Notes
WH 300	20471	35			

Releases

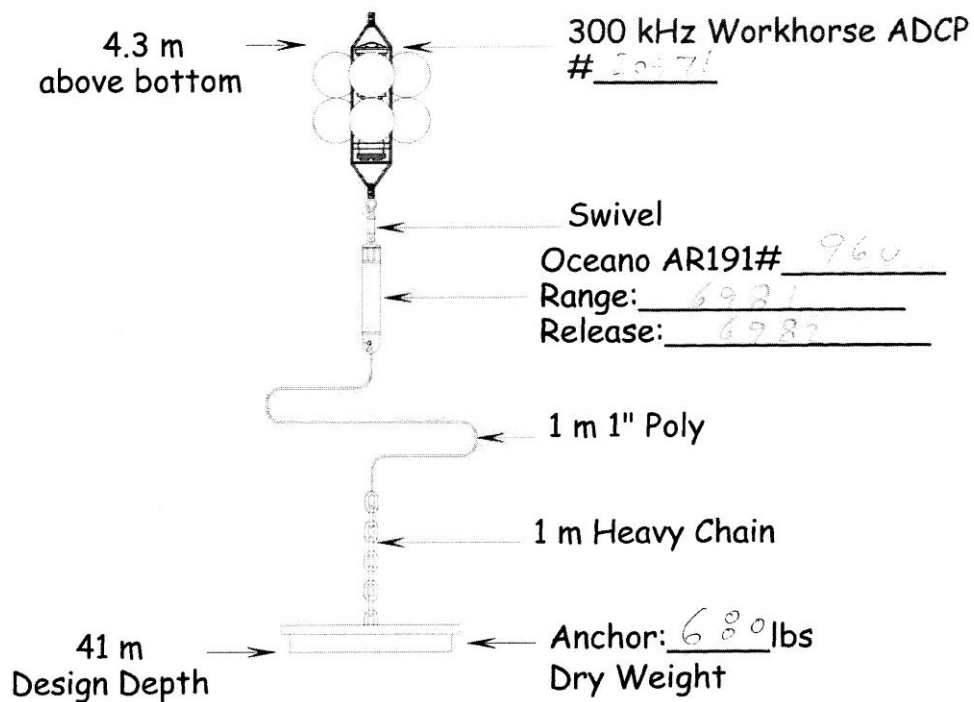
Release	Serial #	Enable	Release	Other
AR 191	960	6981	6982	

Pingers

Pinger	Serial #	Voltage	Frequency
OML			

Flotation

Type	Serial #	Size	Colour	Type	Serial #	Size	Colour
Viny x8			Orange				



BUW01-A	
Latitude:	<u>49 19.75</u>
Longitude	<u>123 12.73</u>
Time: <u>1050</u>	Date: <u>8 Nov 2015</u>
Depth: <u>39</u>	

6.2 MOORING BUW02-A

Mooring Deployment Record

Project Name: Vancouver Harbour	
Project Area: Vancouver Harbour	
Mooring Name: BCW02-A	Station Name: 1.906' W
Latitude: 49° 17.651' N	Longitude: 123° 2' 406' W
Depth: 45	Tide:
Date: 08 Nov 2015	Time: 1541
Time Zone: UTC	
Remarks:	

Recovery

Date: May 30, 2016	Time: 2258 UTC
Remarks: Mooring location was in correct on the deployment sheet, out by 1° S longitude (Should be 49° 17' 45" N 123° 19' 06" W)	
Instruments	

Instruments

[illegible]

Releases

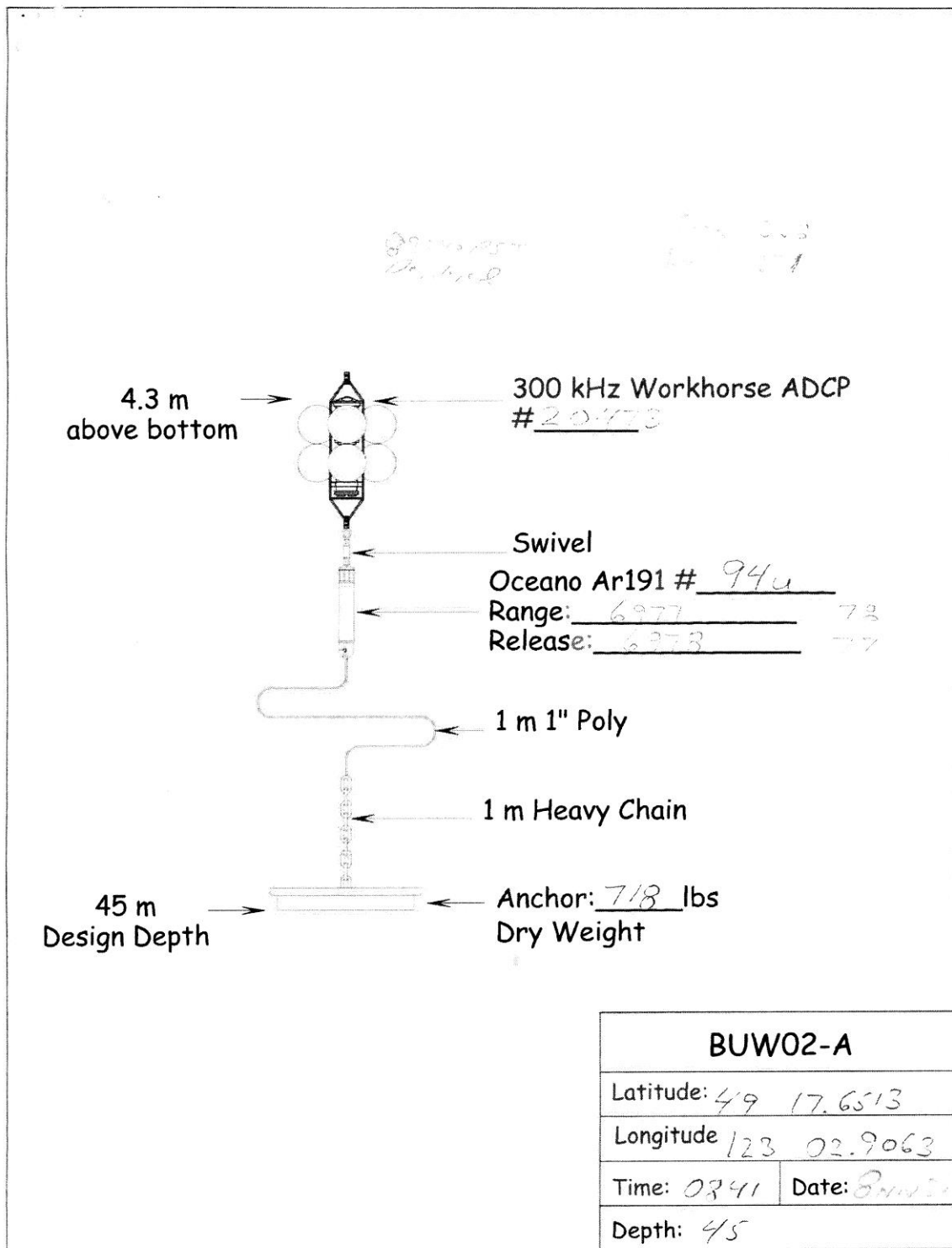
Release	Serial #	Enable	Release	Other
AR191	944	6977	6978	

Pingers

Pinger	Serial #	Voltage	Frequency
OML Station Finder			

Flotation

Type	Serial #	Size	Colour	Type	Serial #	Size	Colour



6.3 MOORING BUW03-A

Mooring Deployment Record

Project Name:	
Project Area: Vancouver Harbour	
Mooring Name: BUW03-A	Station Name:
Latitude: 49 17.885	Longitude: 122 57.556
Depth: 35	Tide:
Date: 08 Nov 2015	Time: 1615
Time Zone: UTC	
Remarks:	

Recovery

Date: May 30, 2016	Time: 2034 UTC
Remarks:	

Instruments

[illegible]

Releases

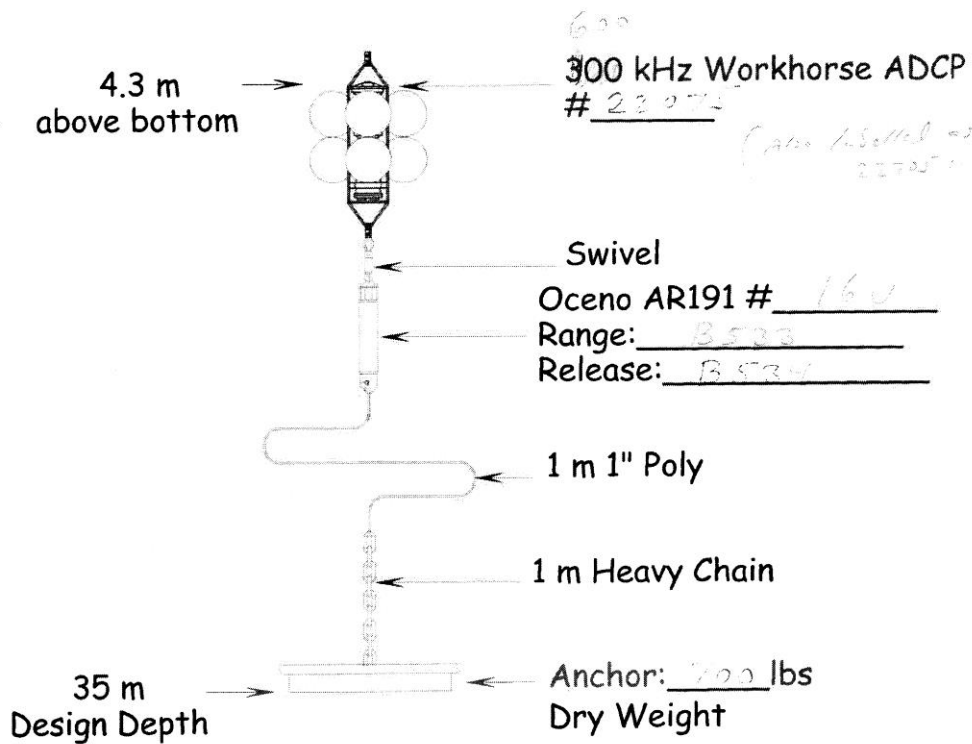
Release	Serial #	Enable	Release	Other
AR191	16u	B533	B534	

Pingers

Pinger	Serial #	Voltage	Frequency
QML Steinhilber			

Flotation

Type	Serial #	Size	Colour	Type	Serial #	Size	Colour
8 orange vines on SS Fram							

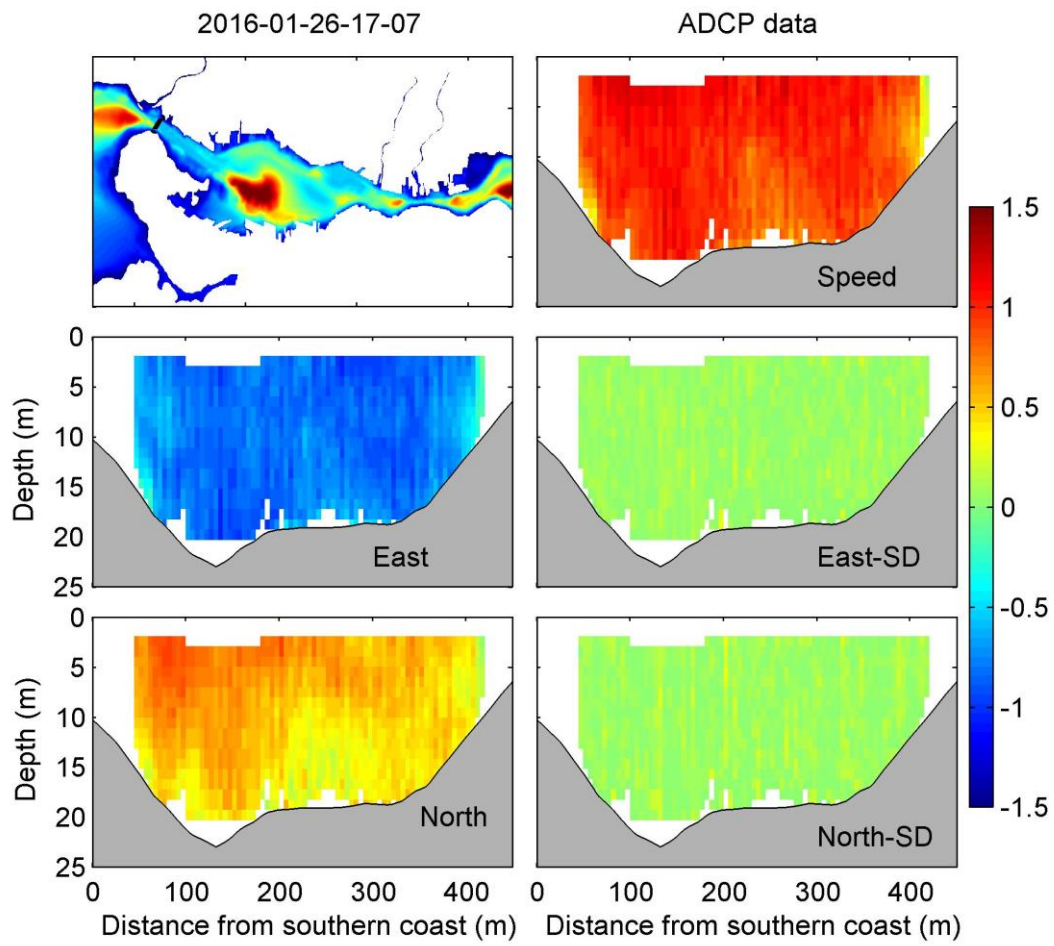


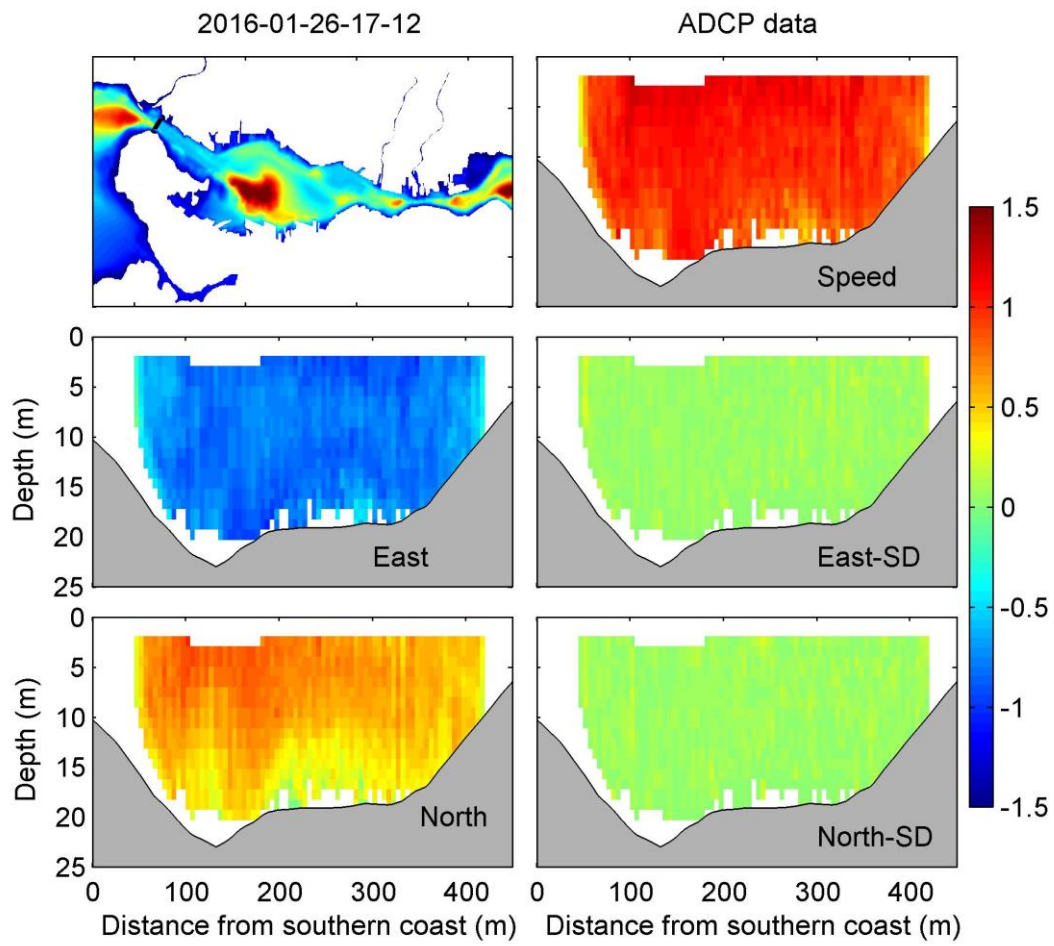
BUW03-A	
Latitude: <u>49 17.8852</u>	
Longitude <u>122 57.5558</u>	
Time: <u>0915</u>	Date: <u>8 Nov 2015</u>
Depth: <u>35</u>	

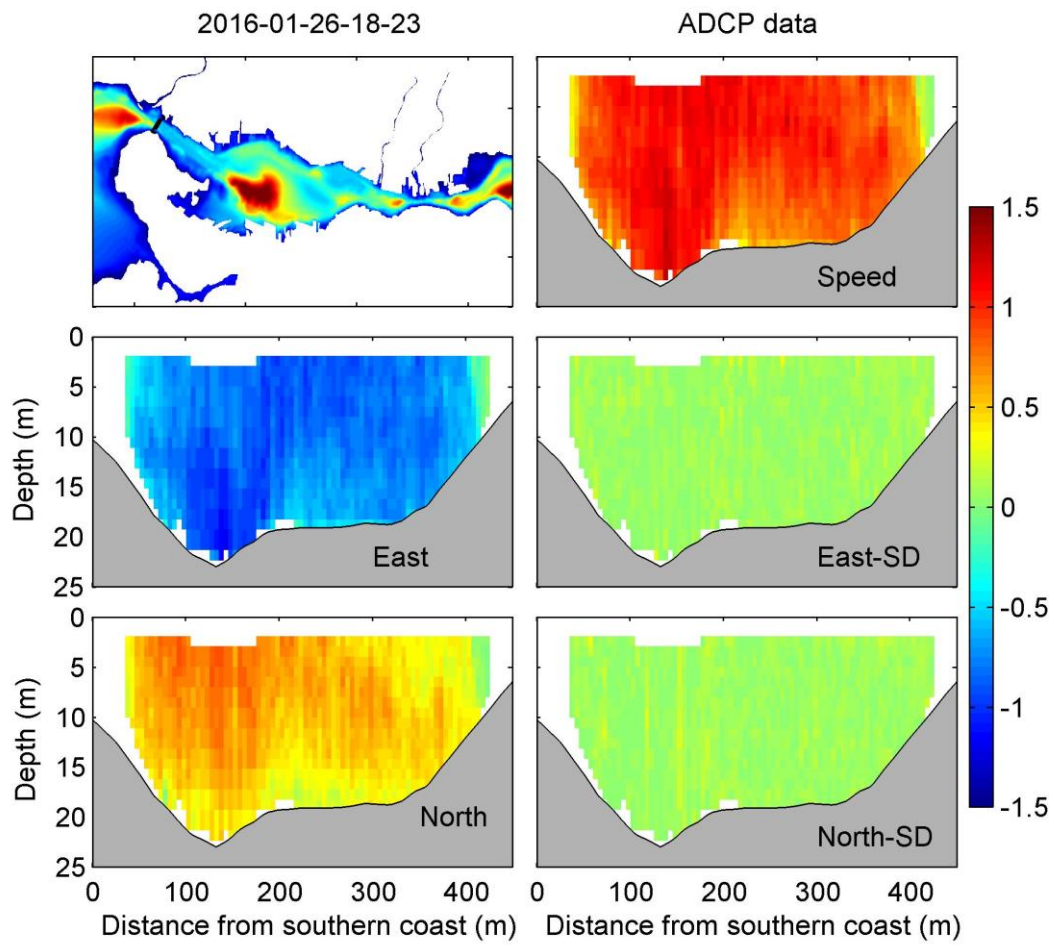
7 APPENDIX 2: VESSEL-MOUNTED ADCP AT FIRST NARROWS

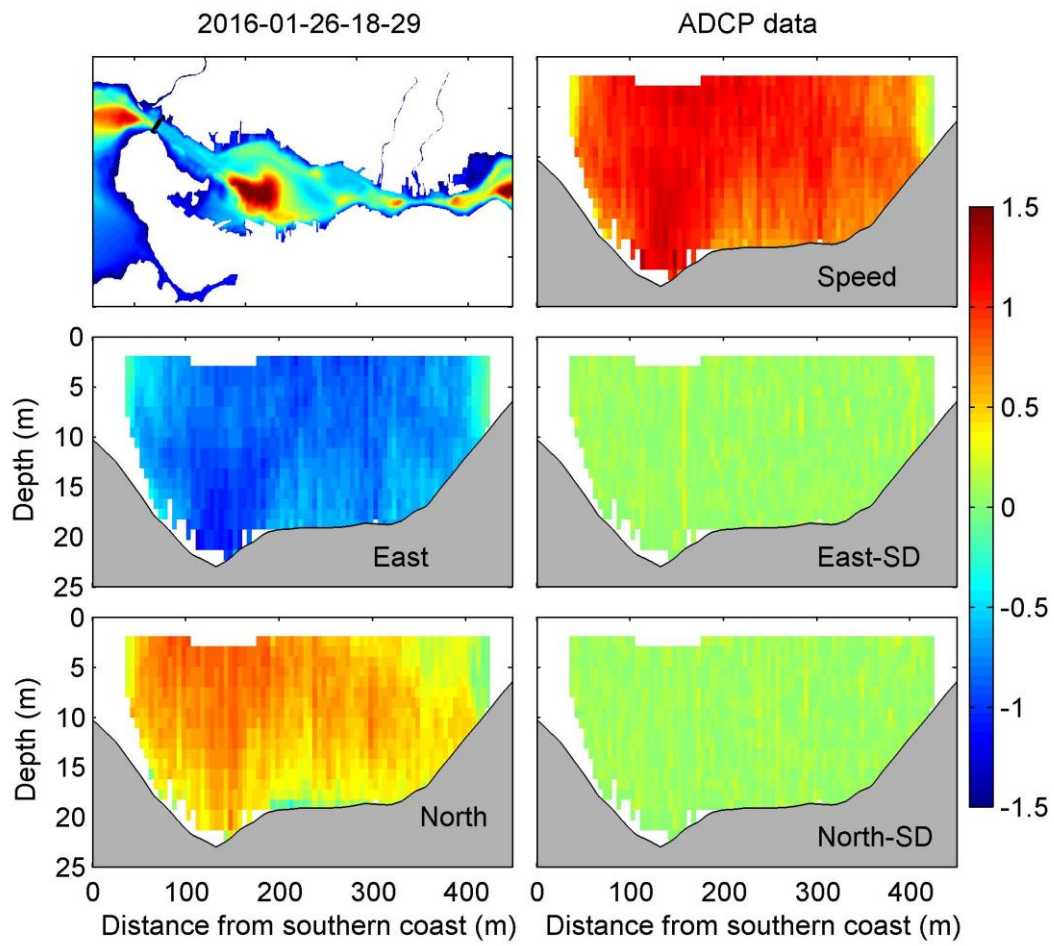
7.1 LINE 1 VELOCITY DATA AND STANDARD DEVIATION

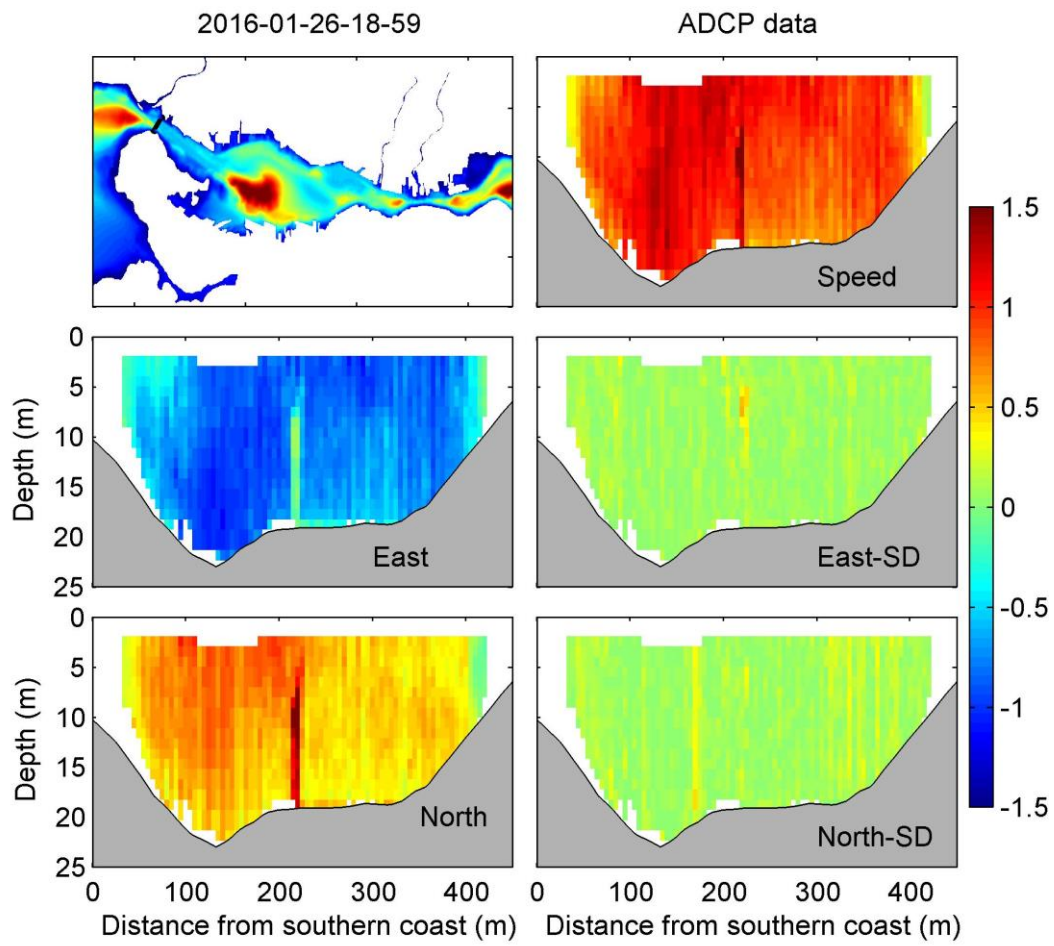
The following figures show vertical profiles of the east and north (u and v) horizontal velocity components for Line 1 measured in First Narrows. The units are in ms^{-1} . The figures include a map of the bathymetry that shows the position of the transect and the vertical profile of the velocity magnitude in the top row. The vertical profiles of the east and north horizontal velocity components with their standard deviations (SD) are in the second and third rows. The time of the sample is stated on the figures.

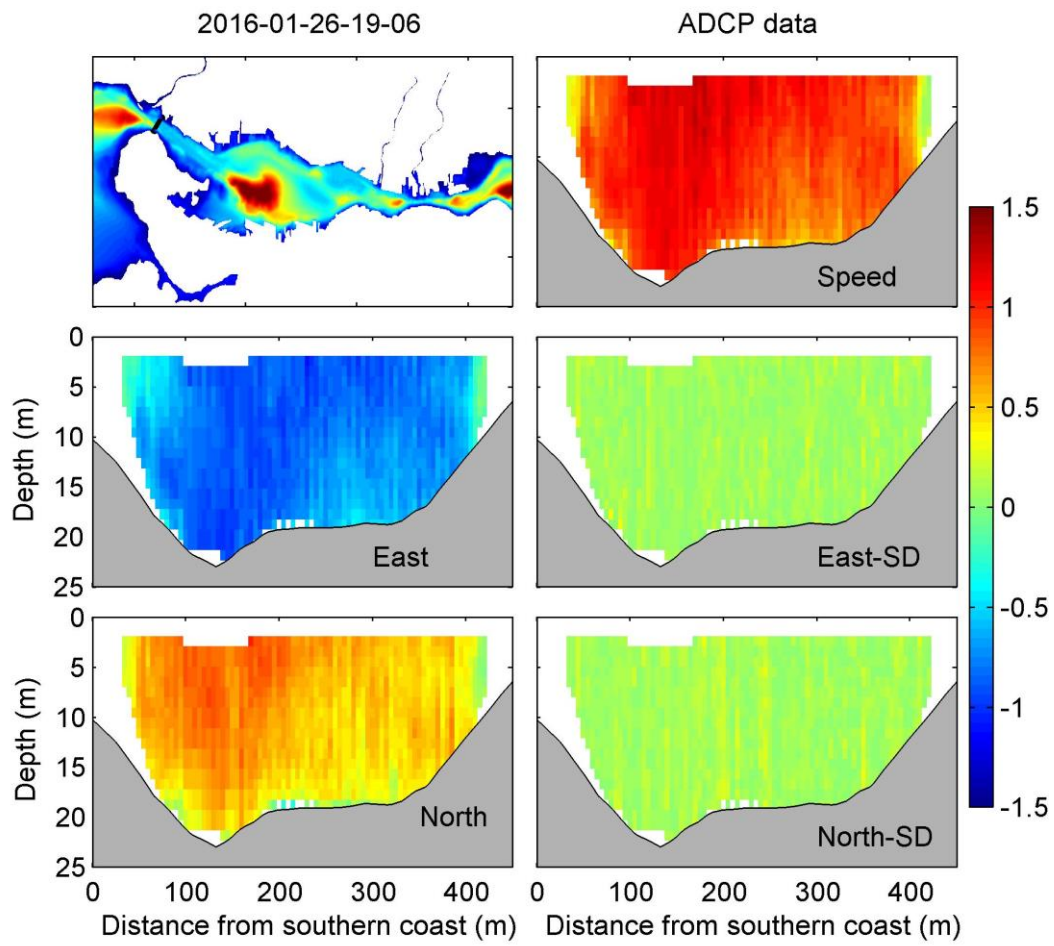


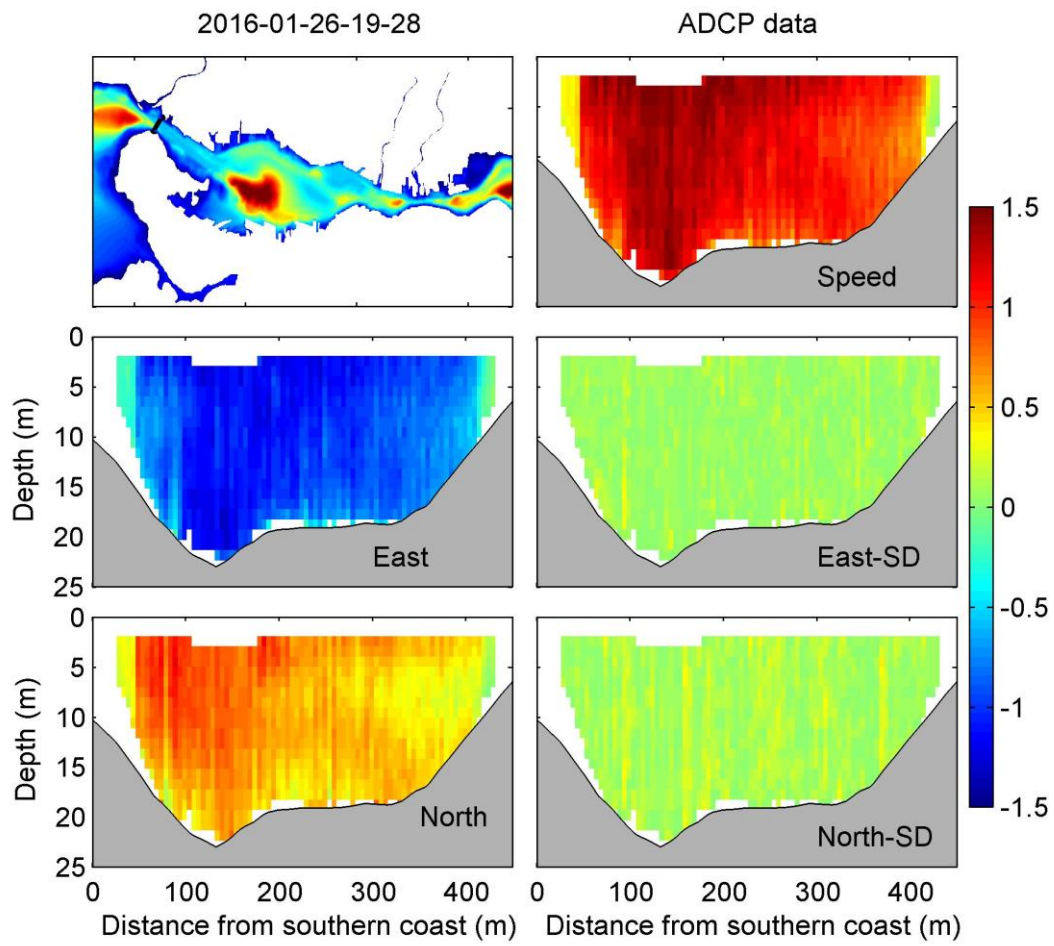


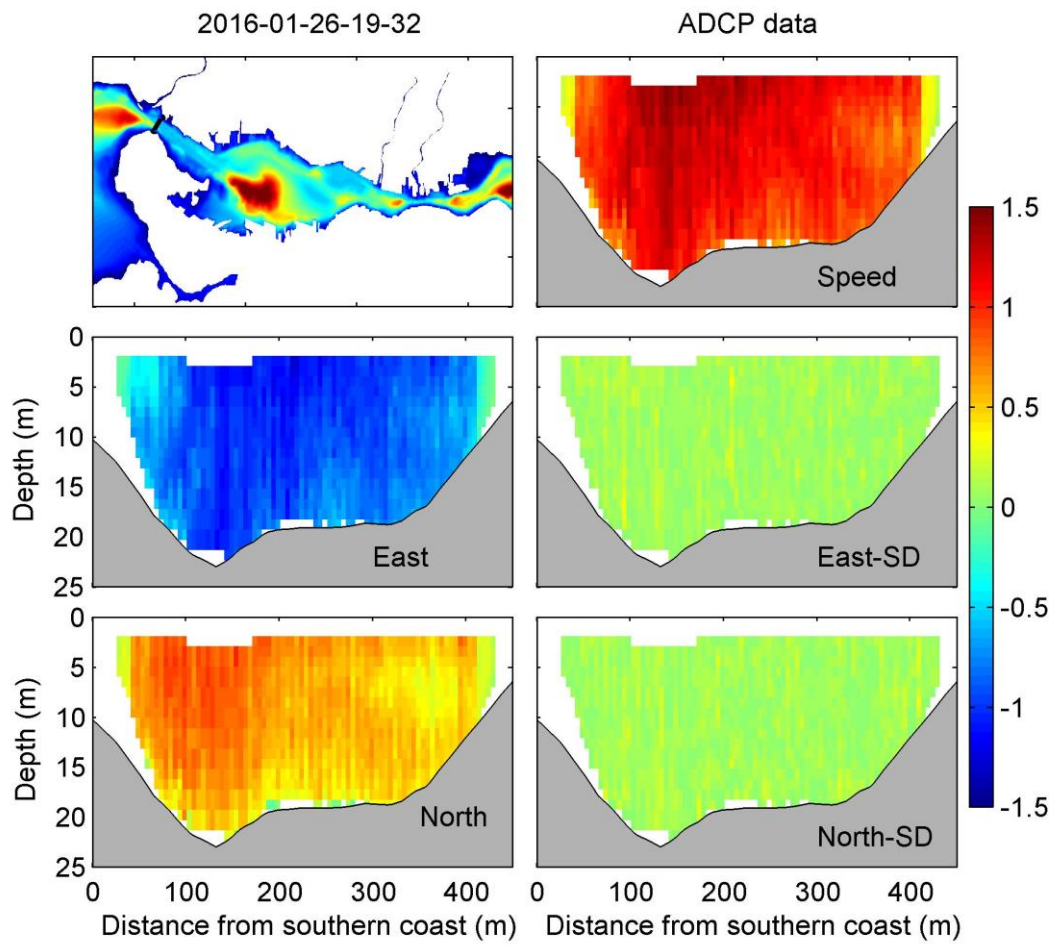


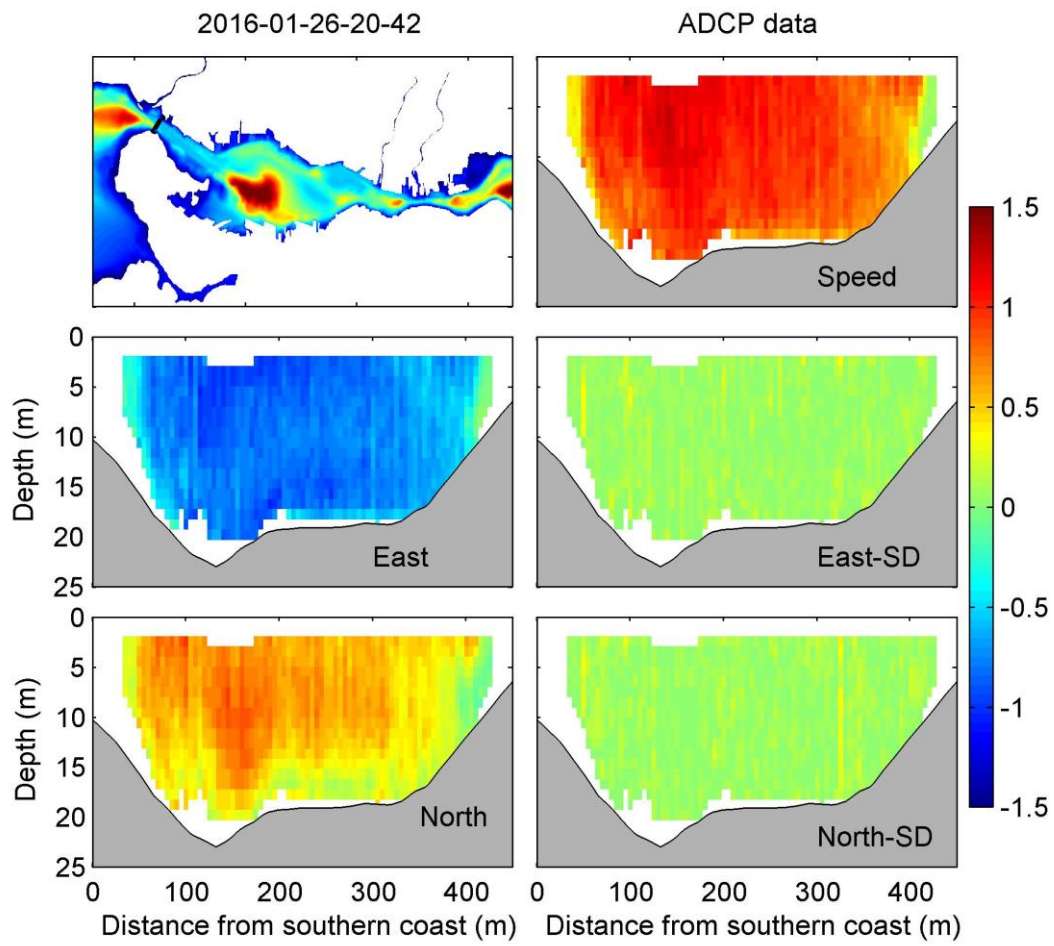


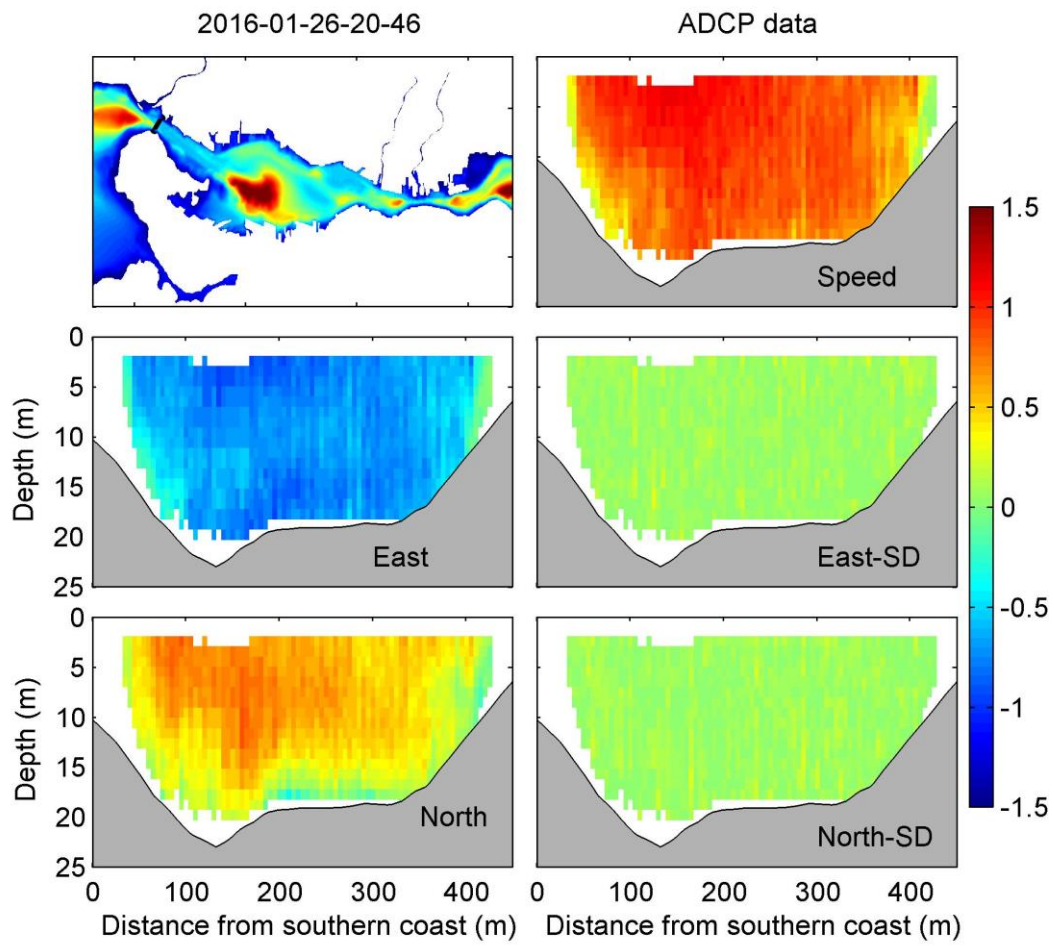


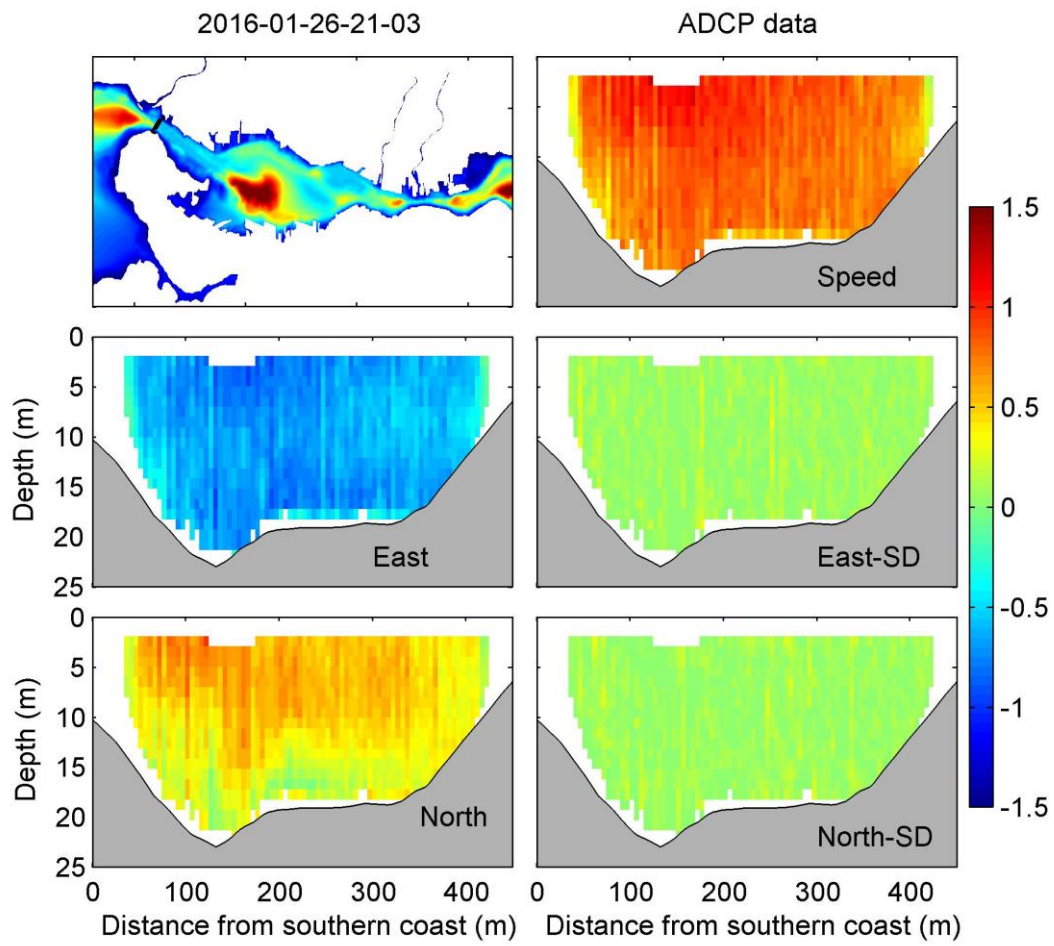


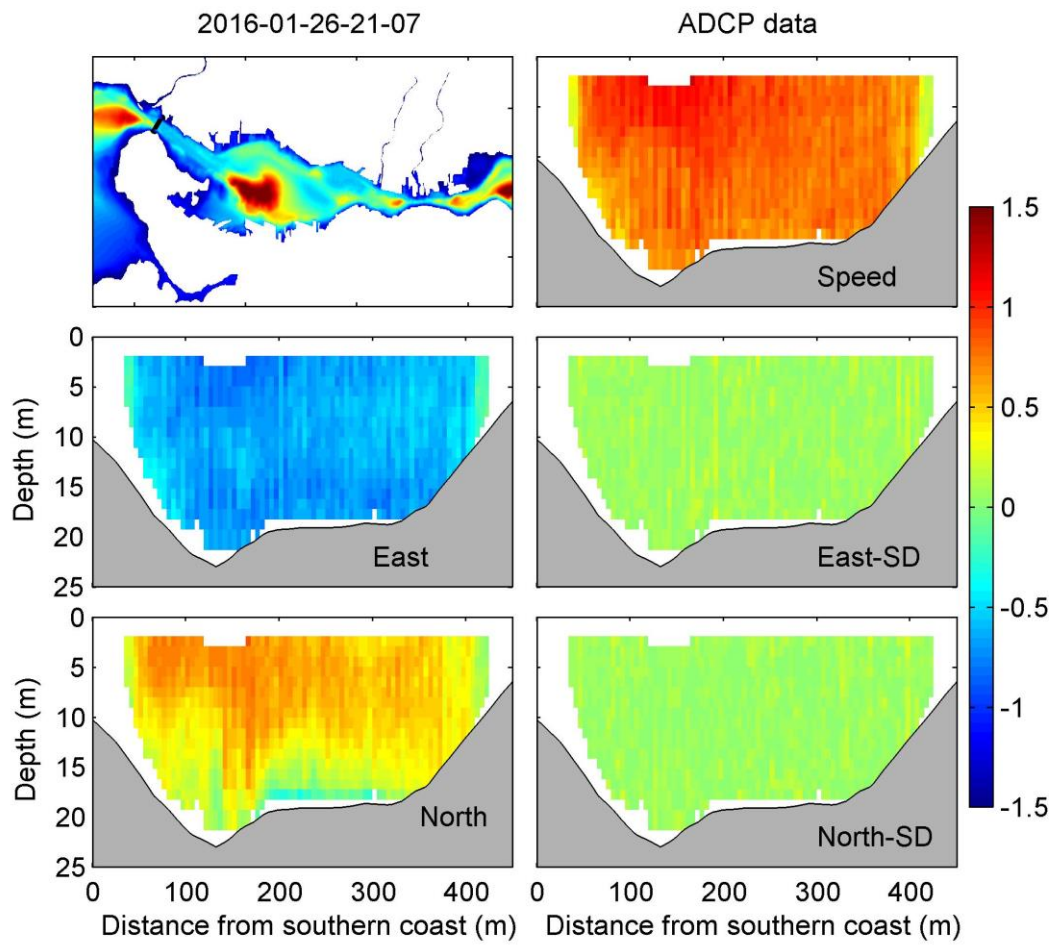


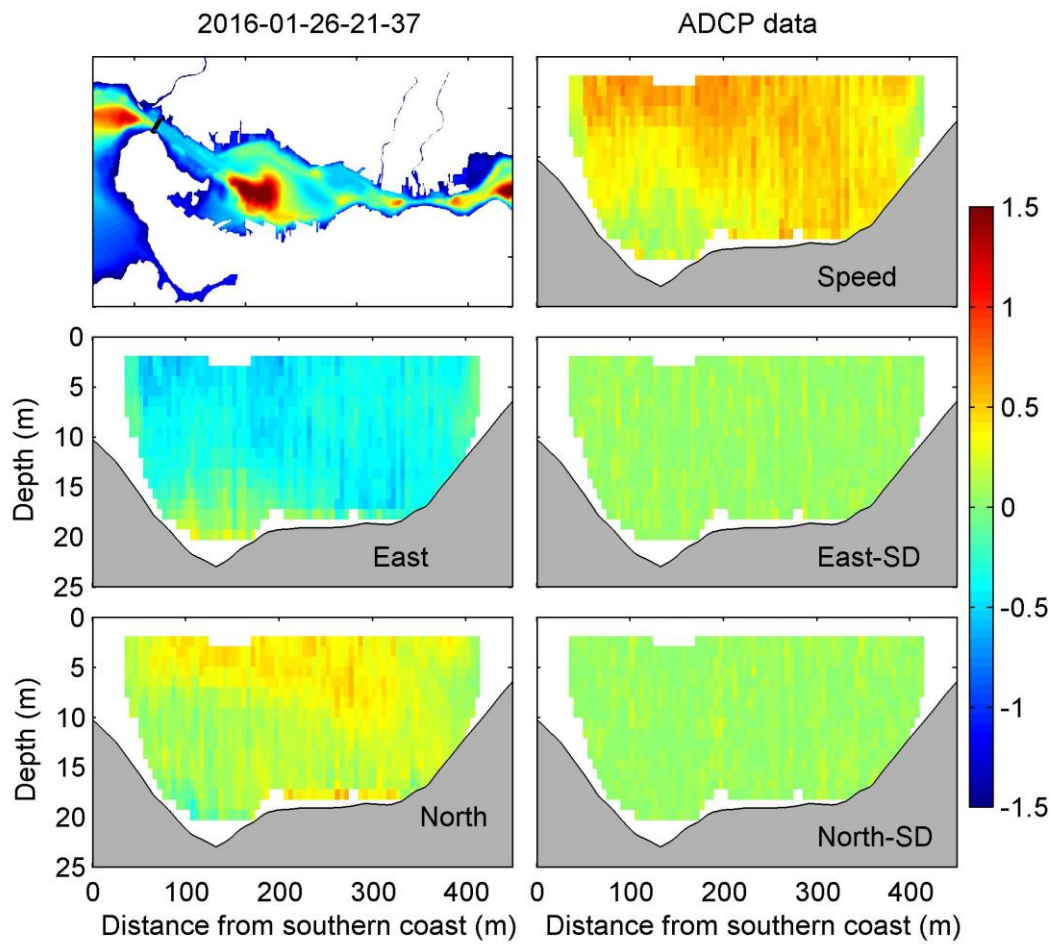


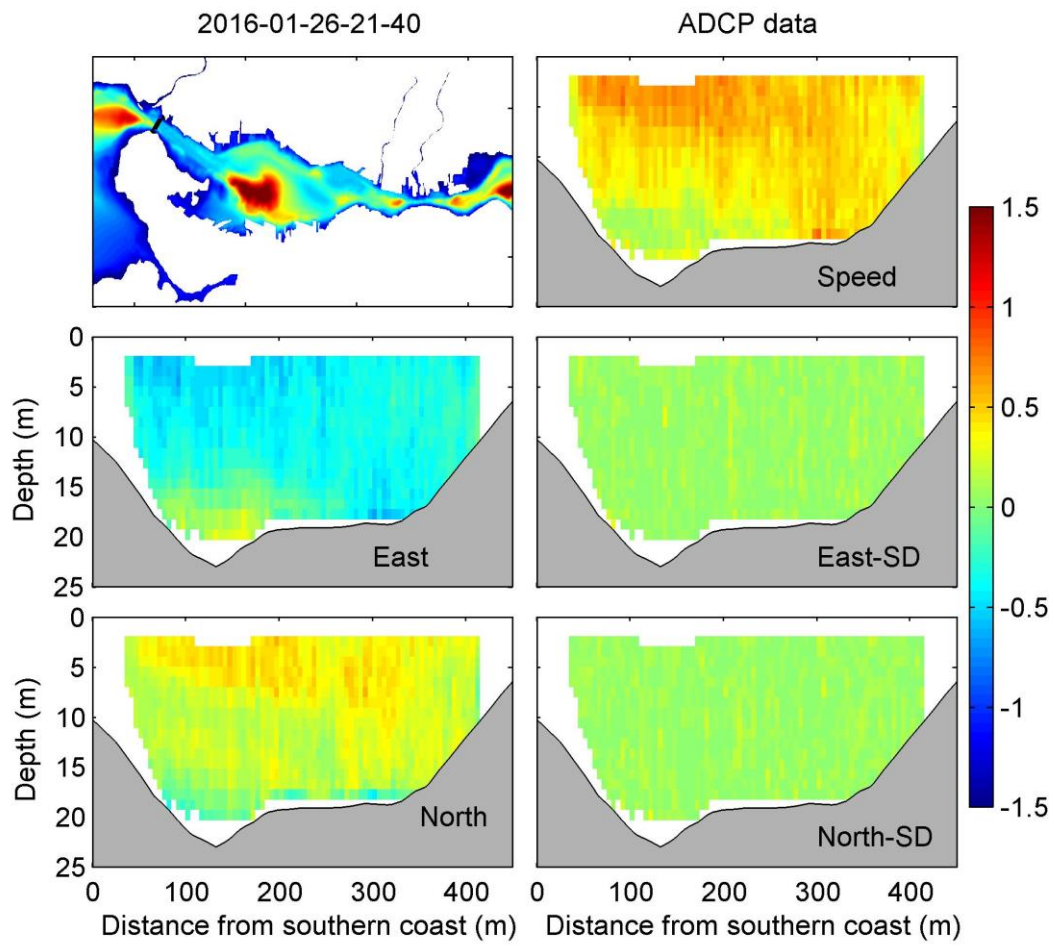


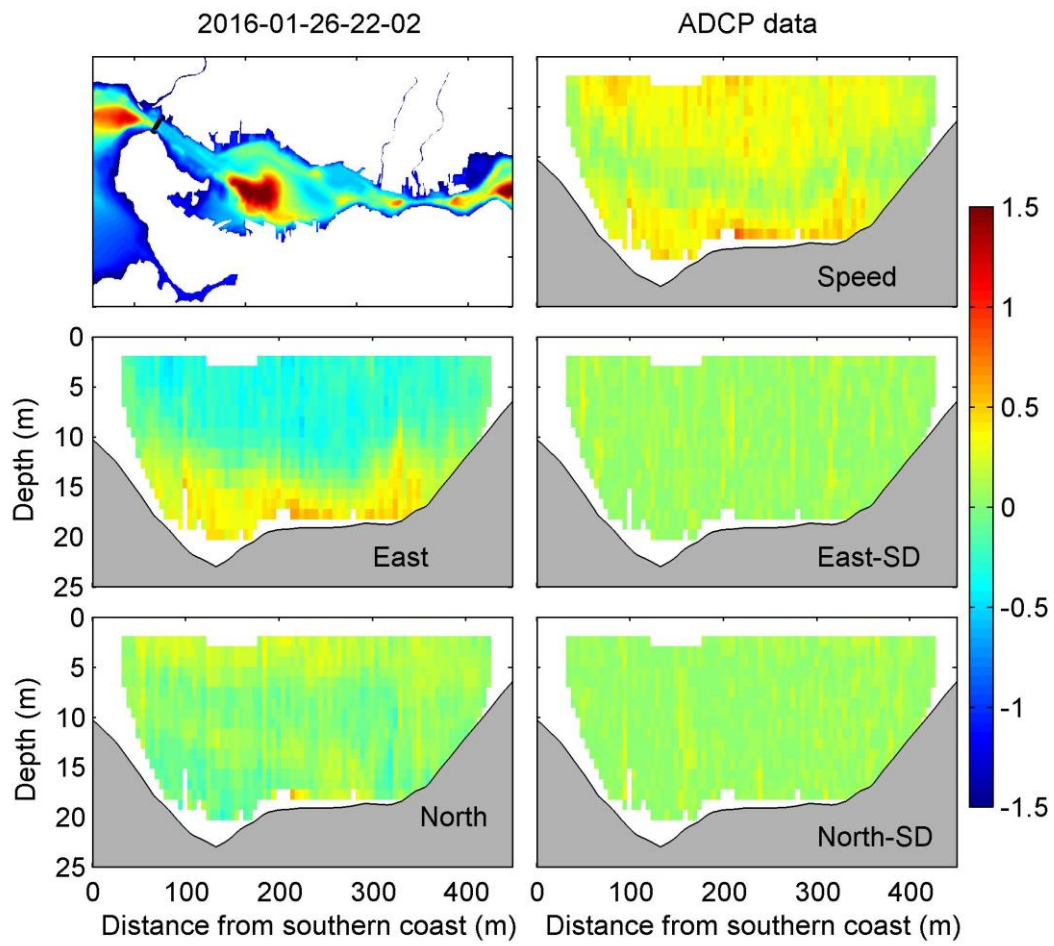


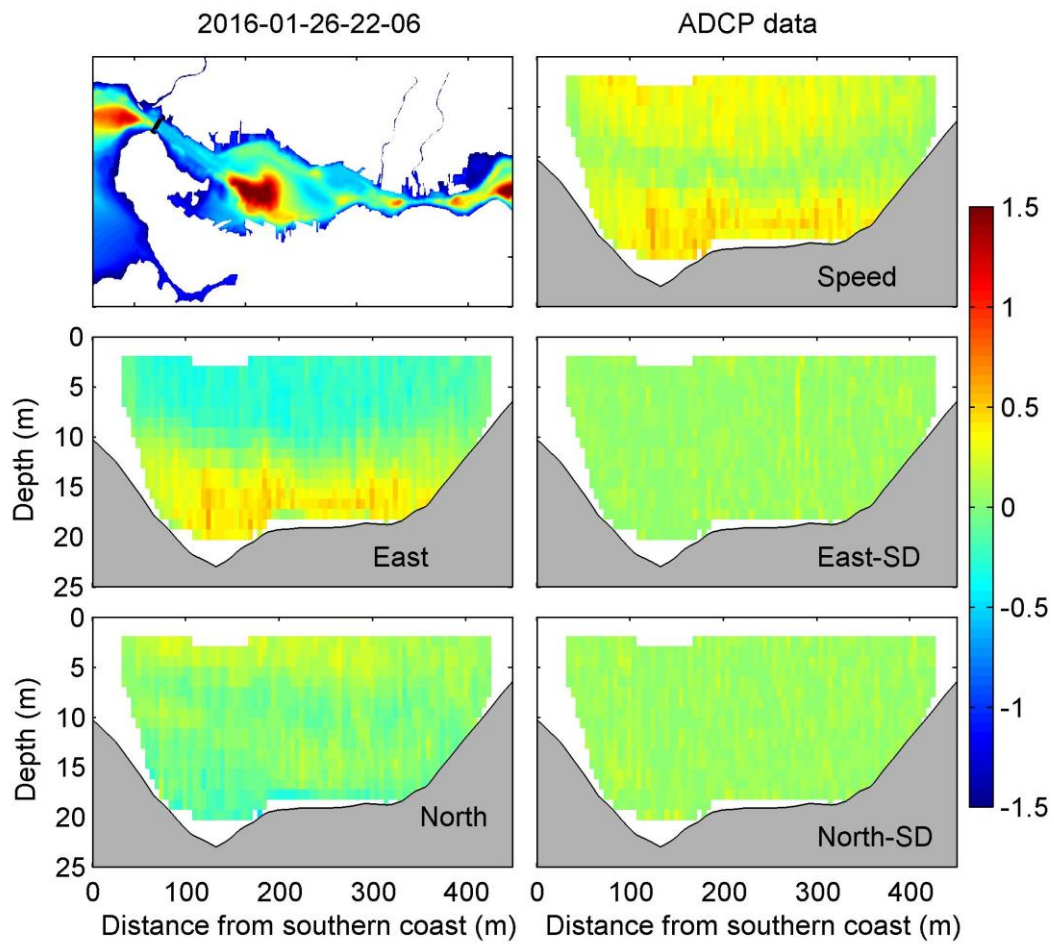


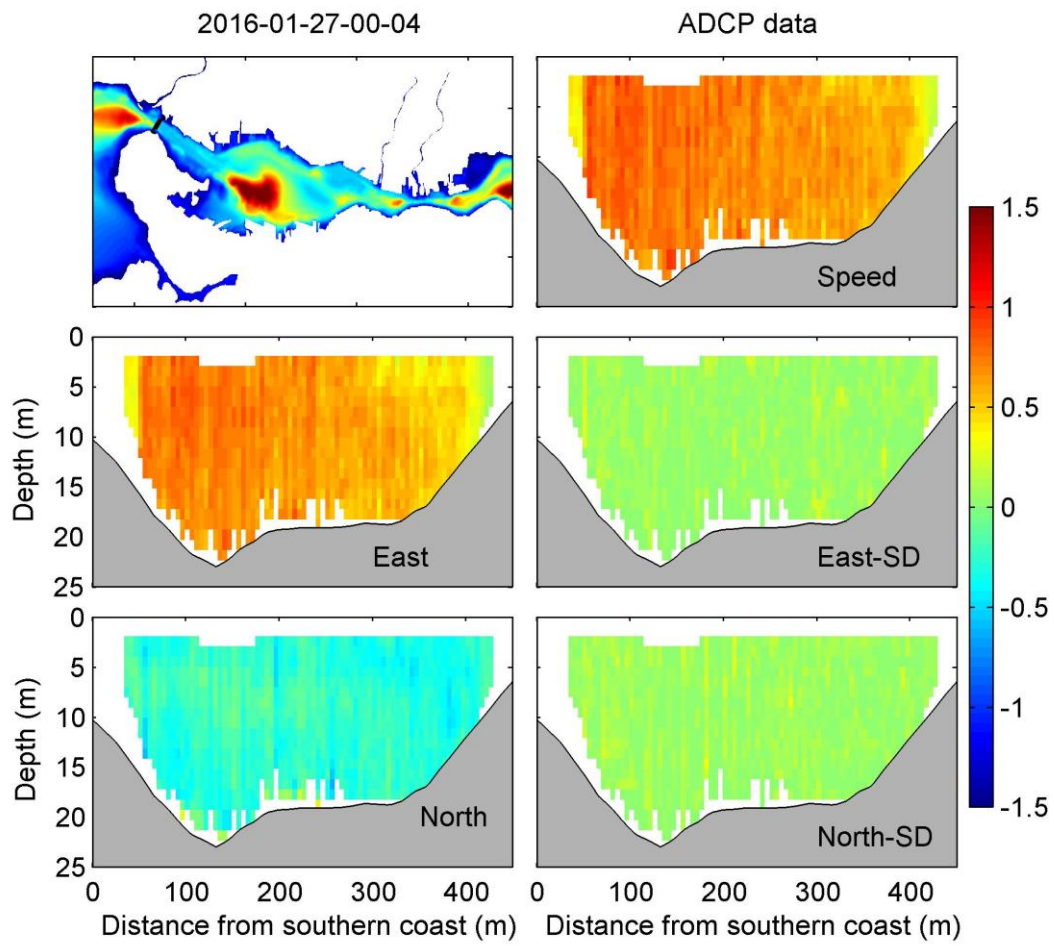


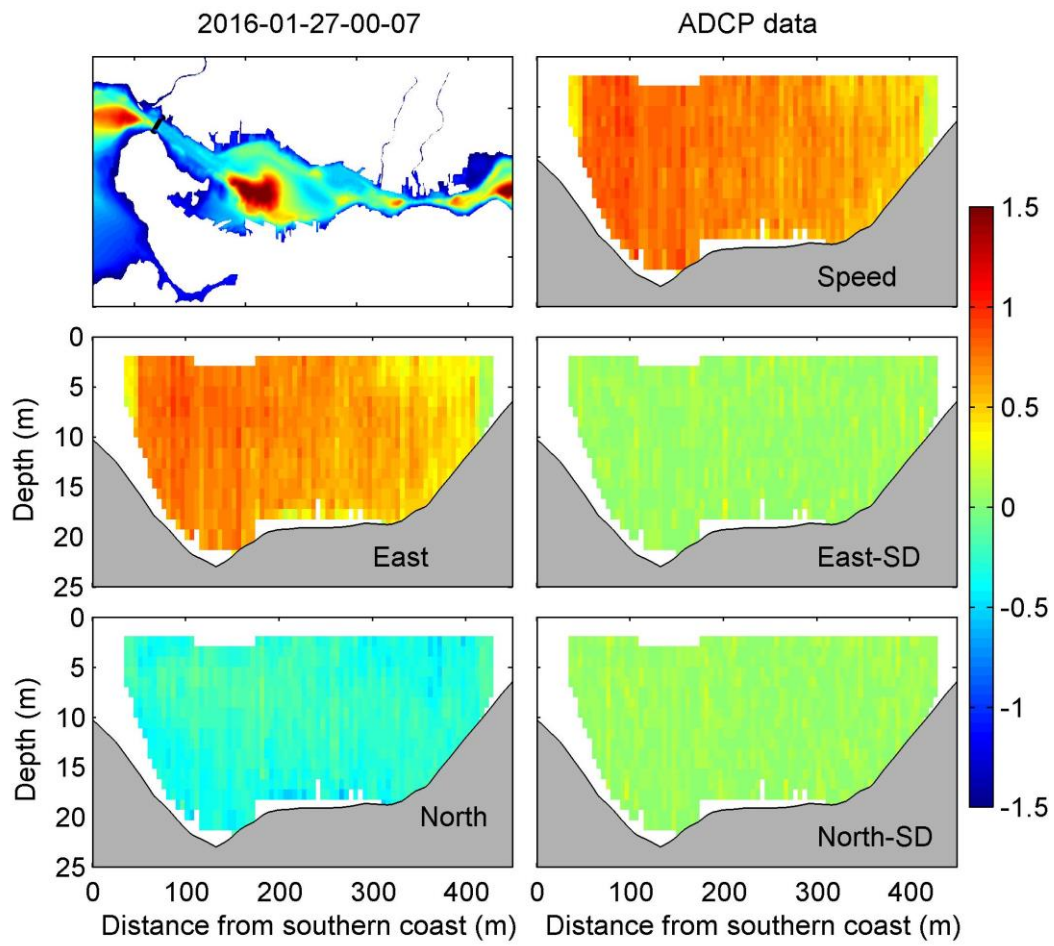


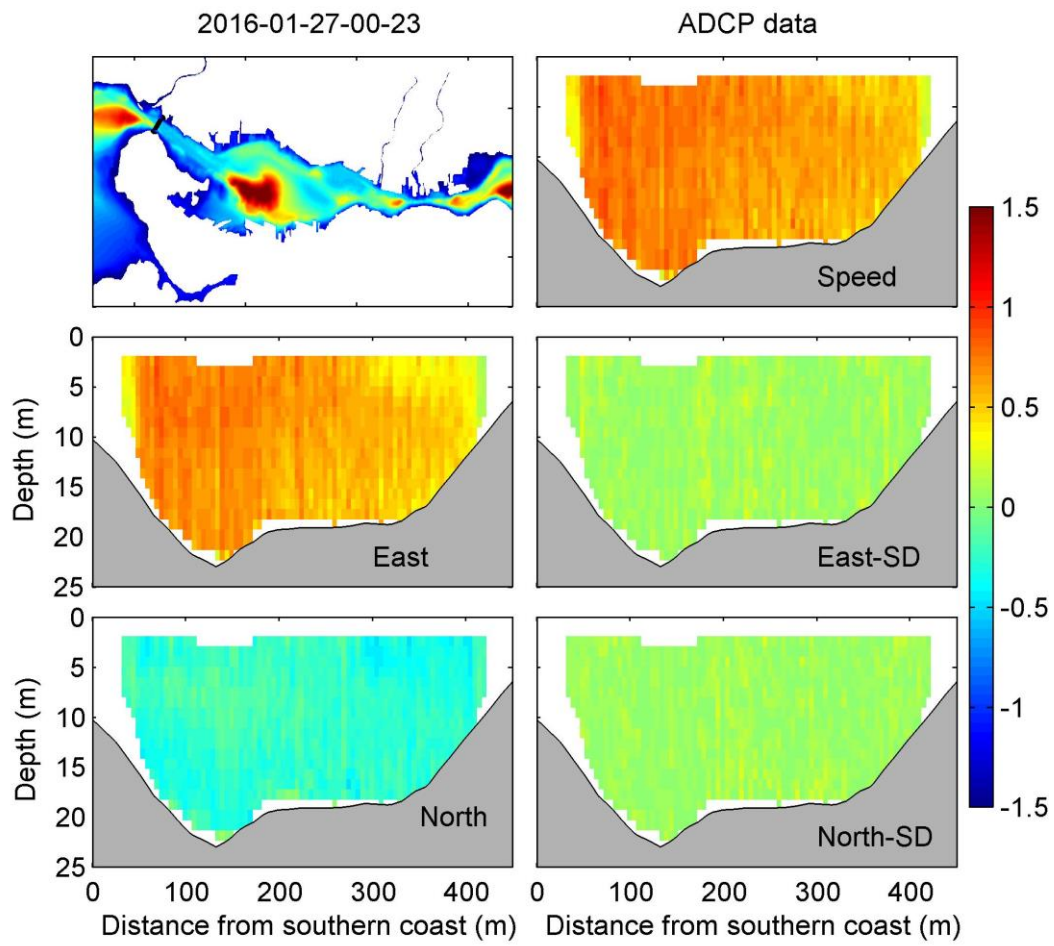


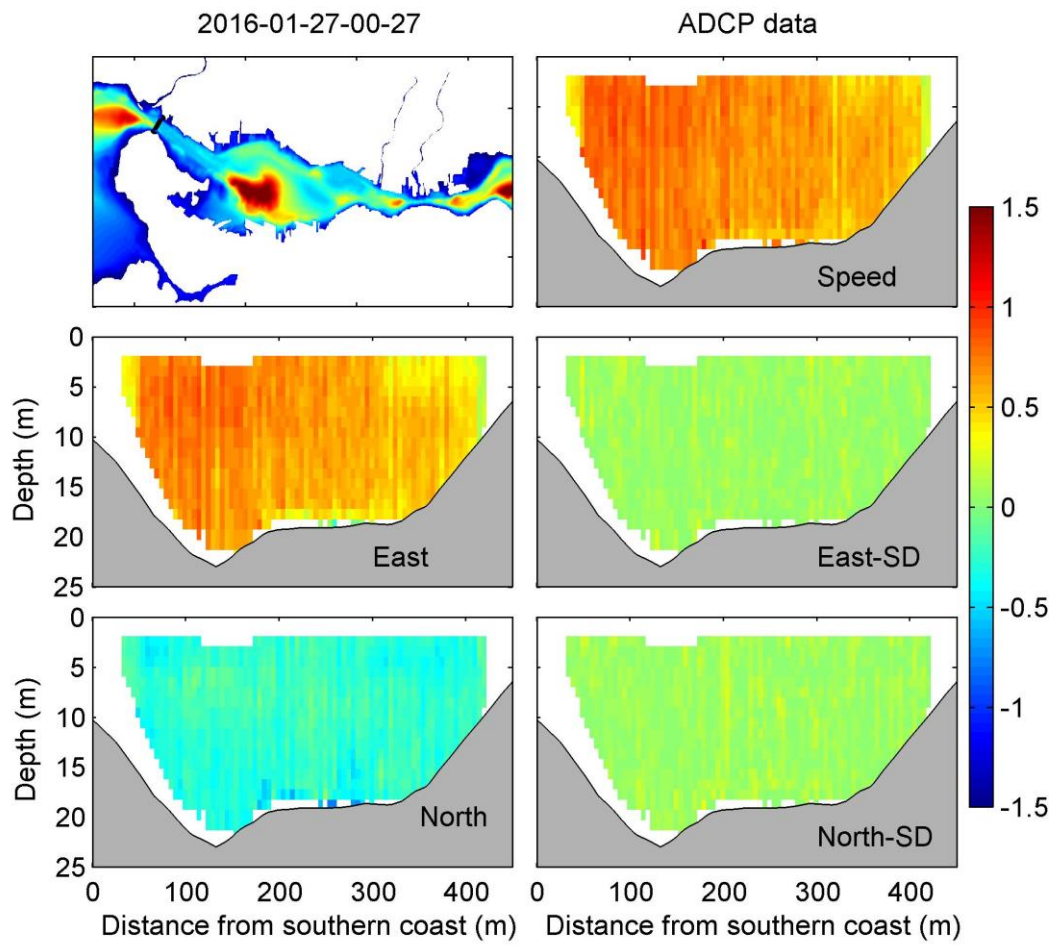


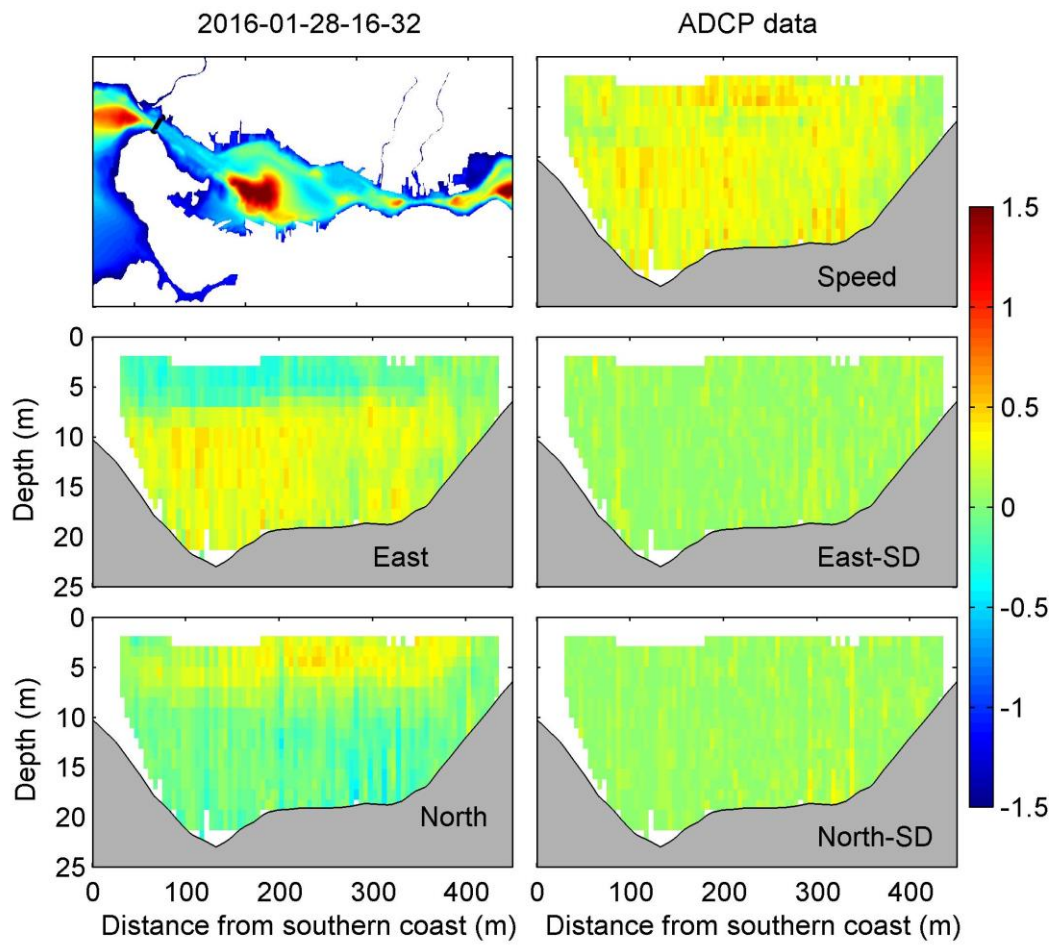


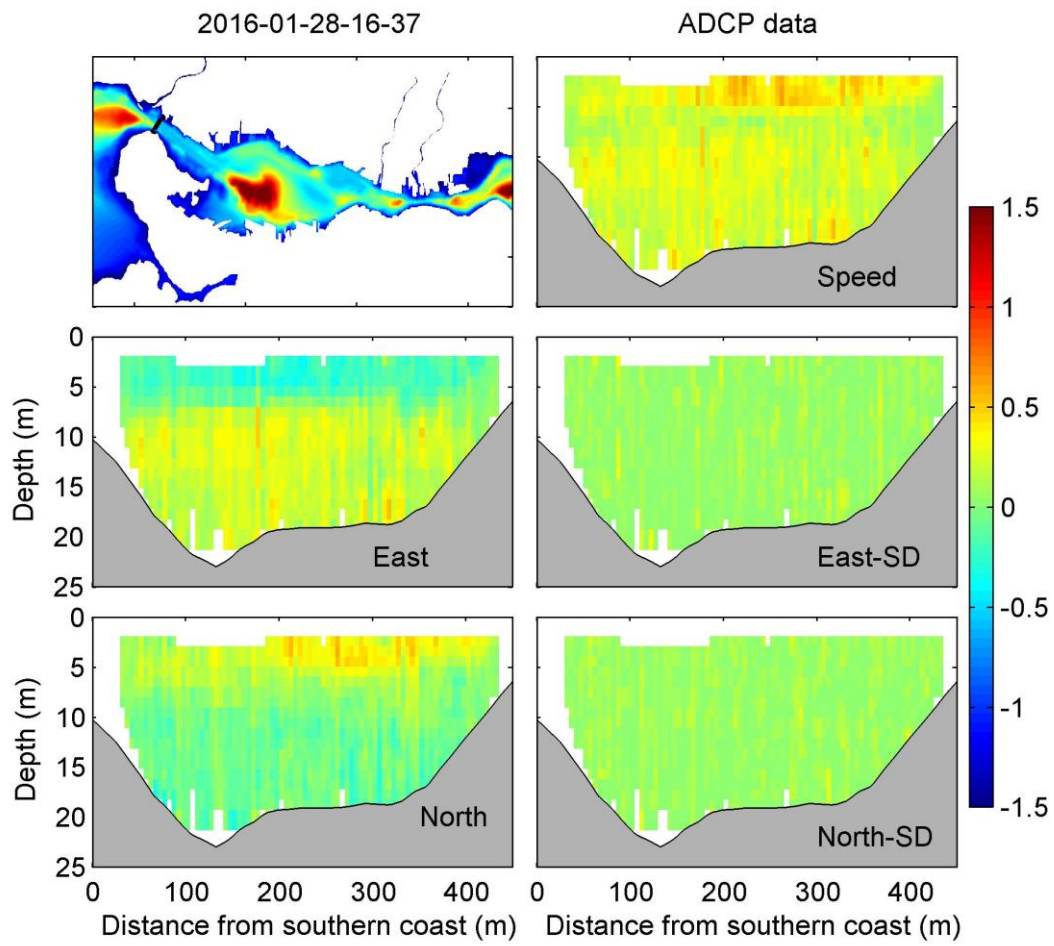


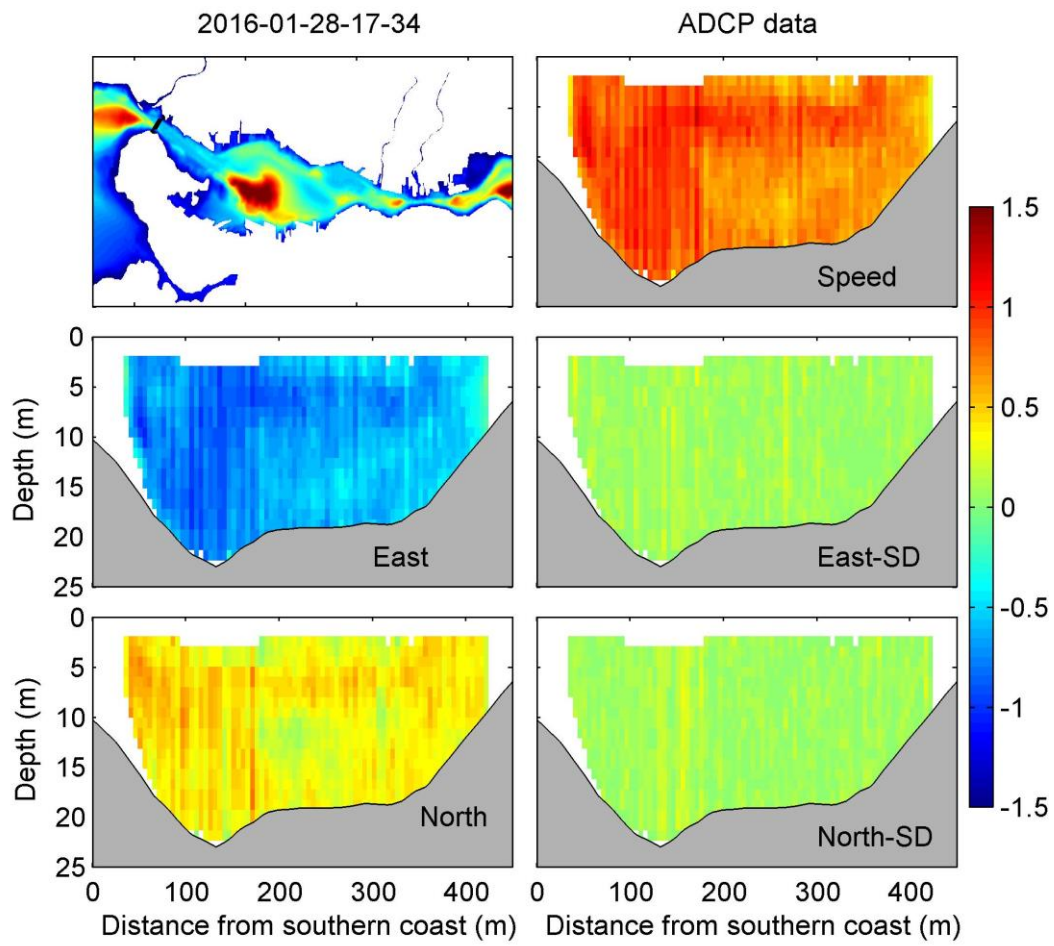


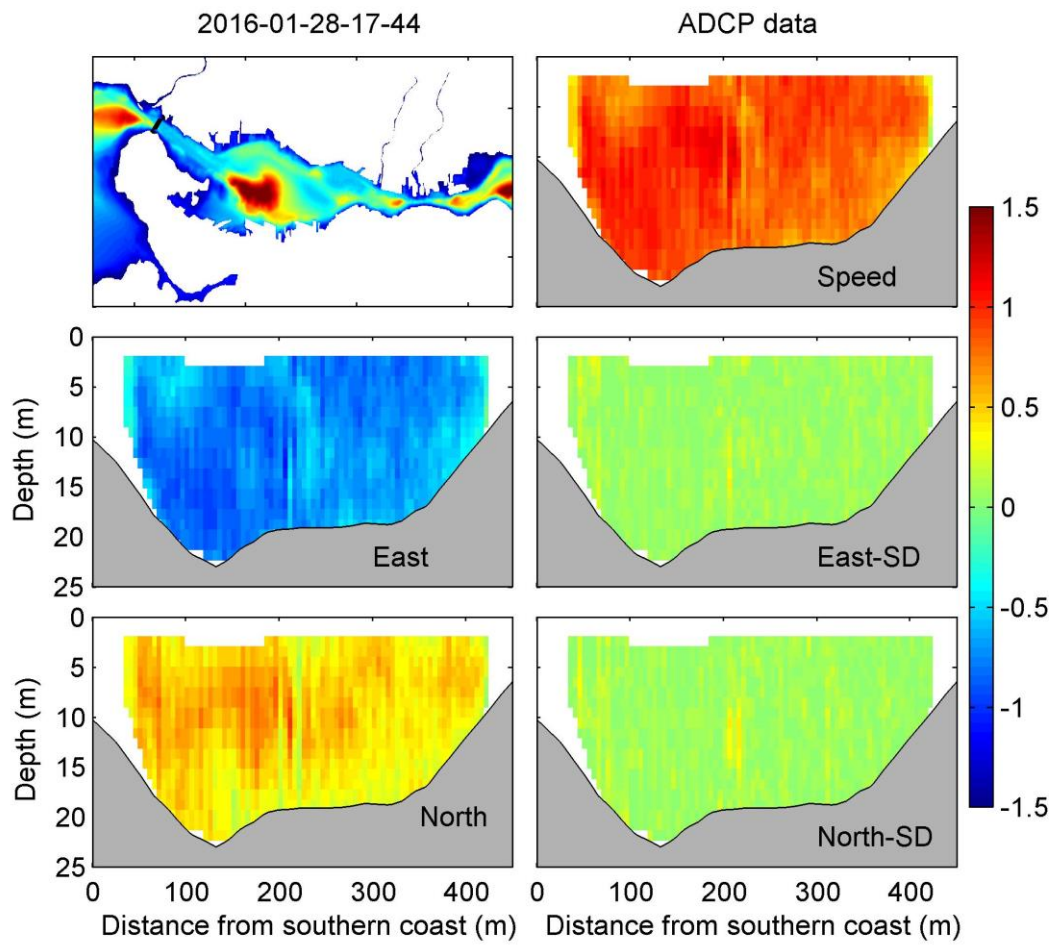


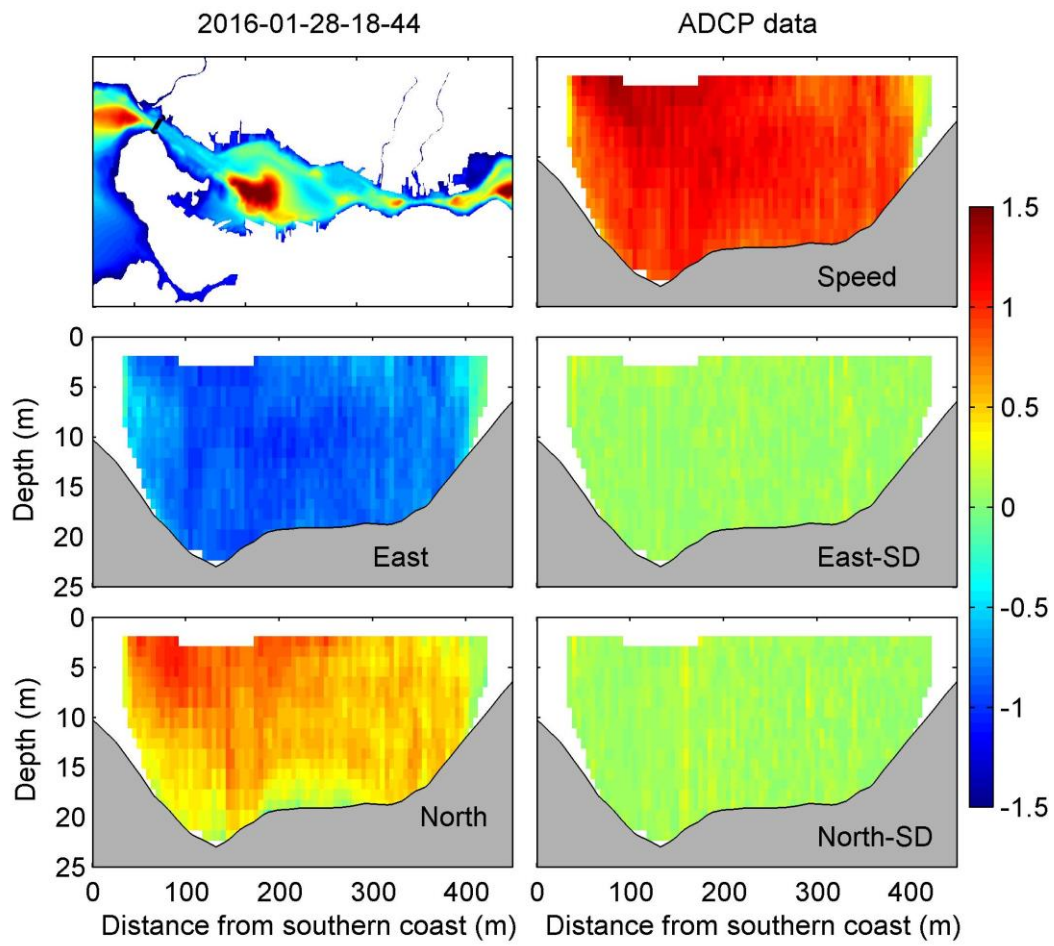


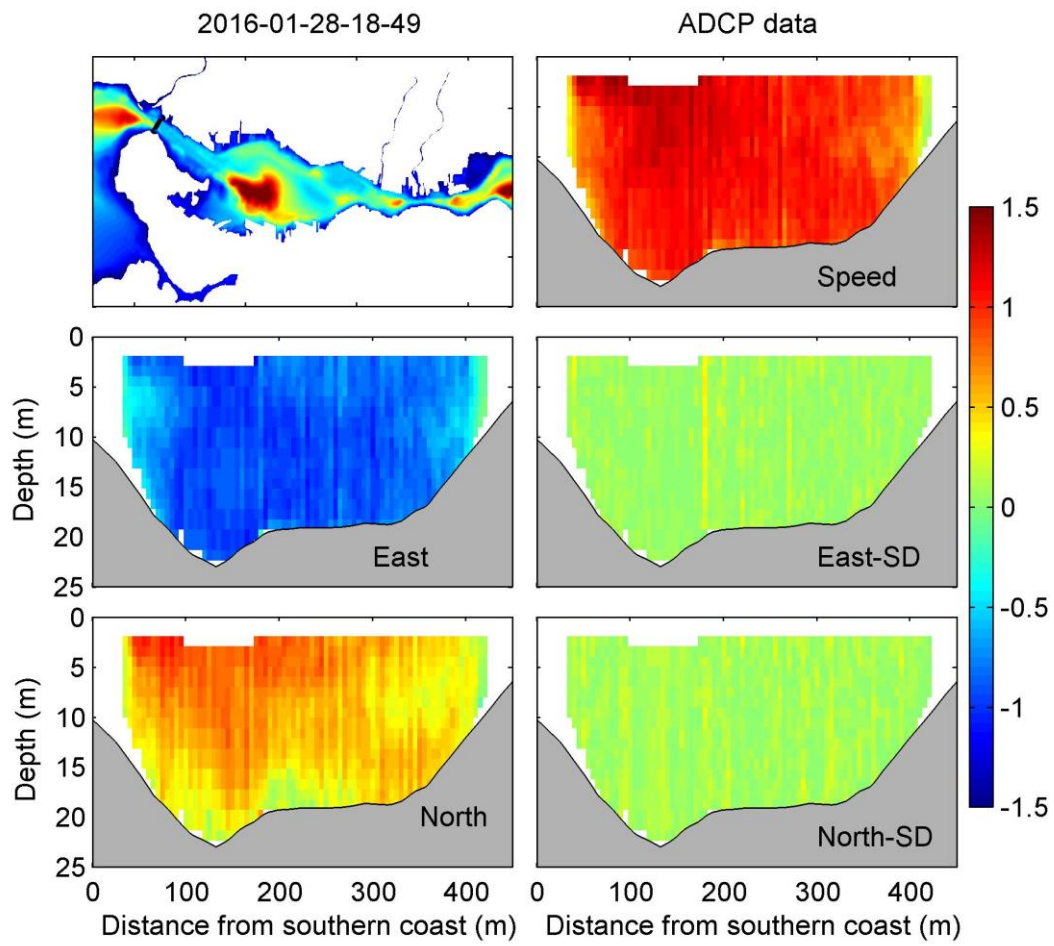


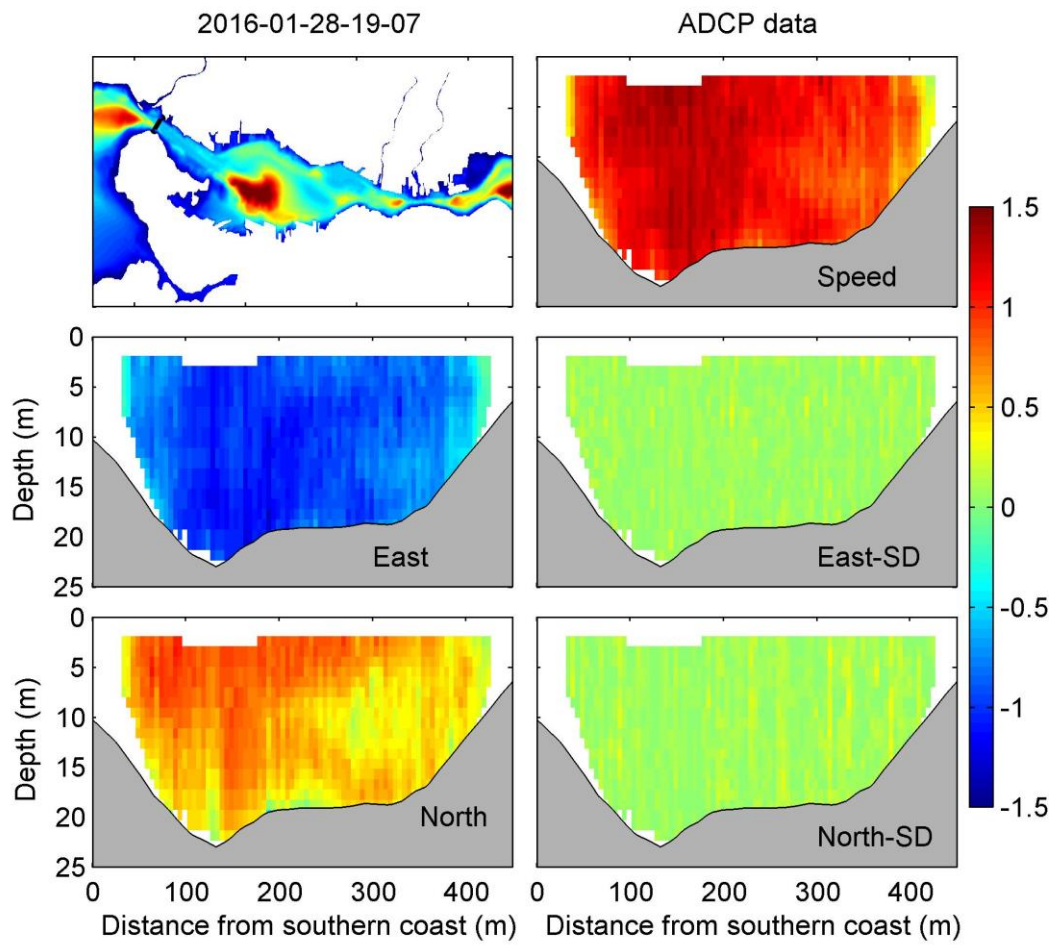


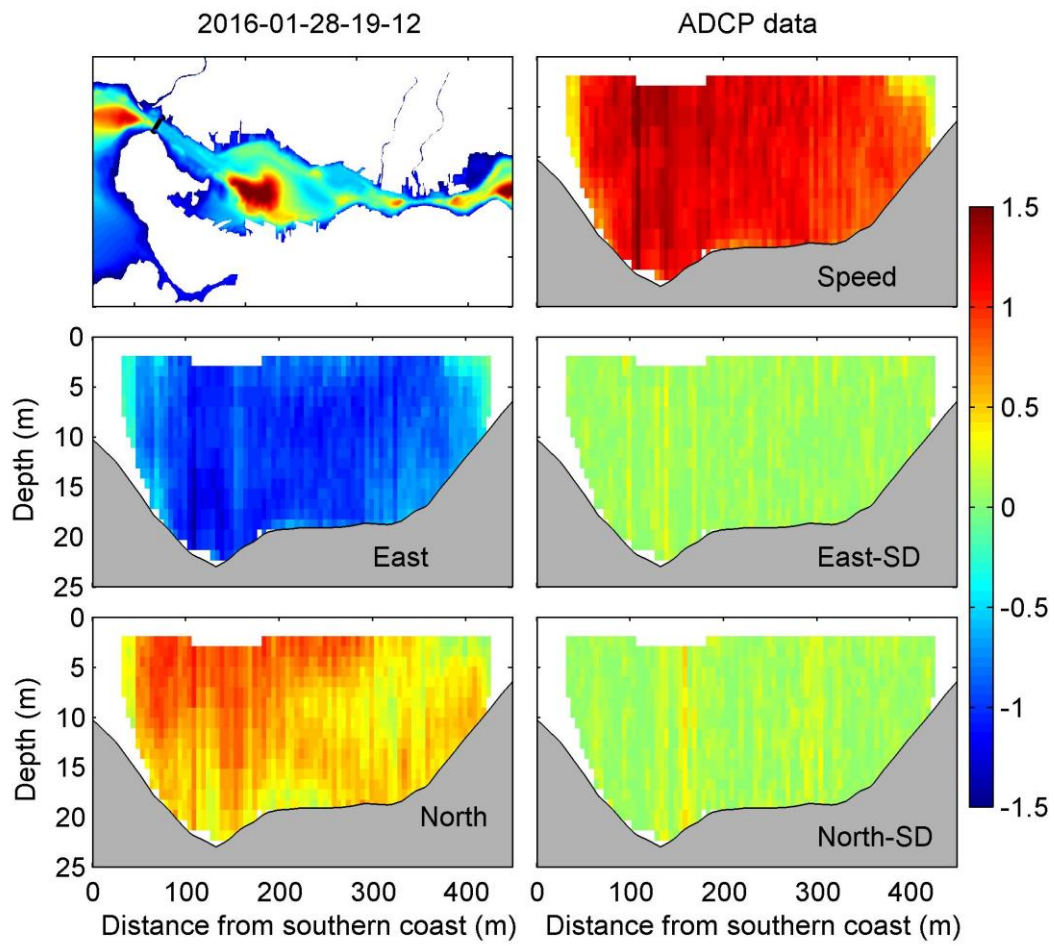


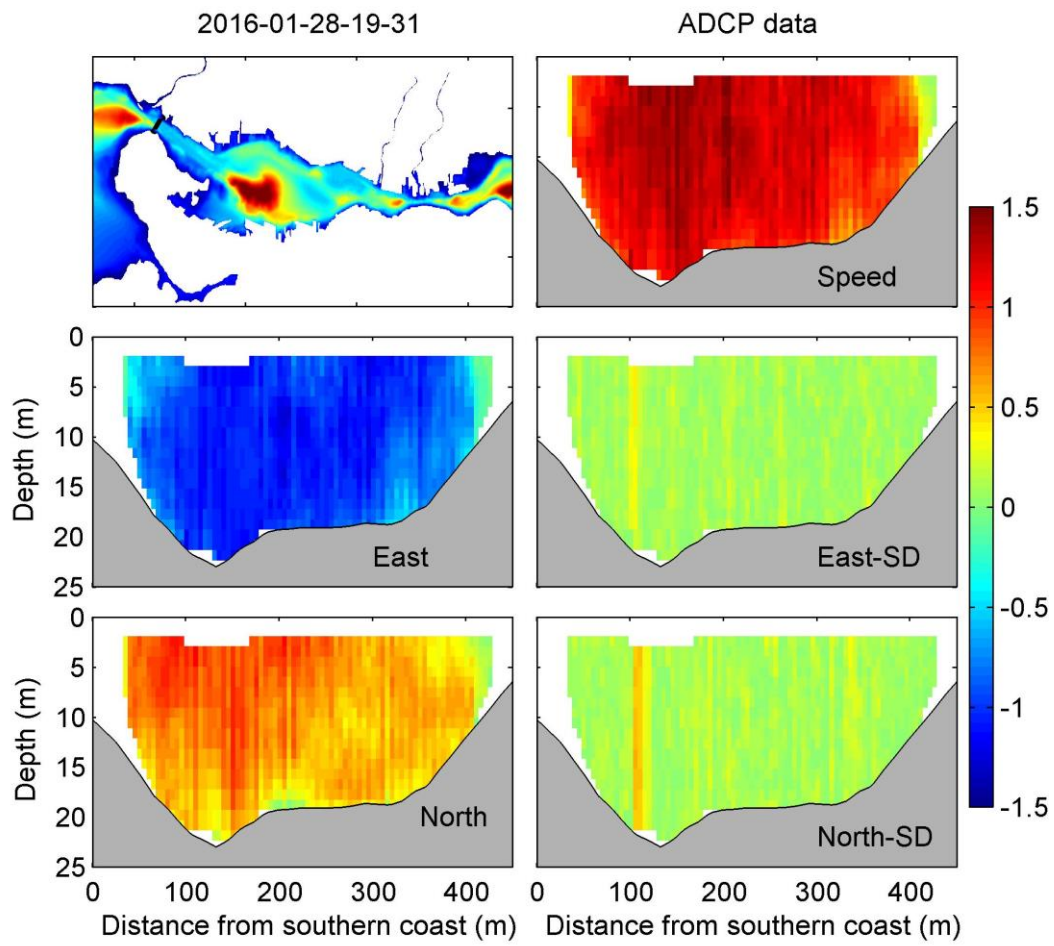


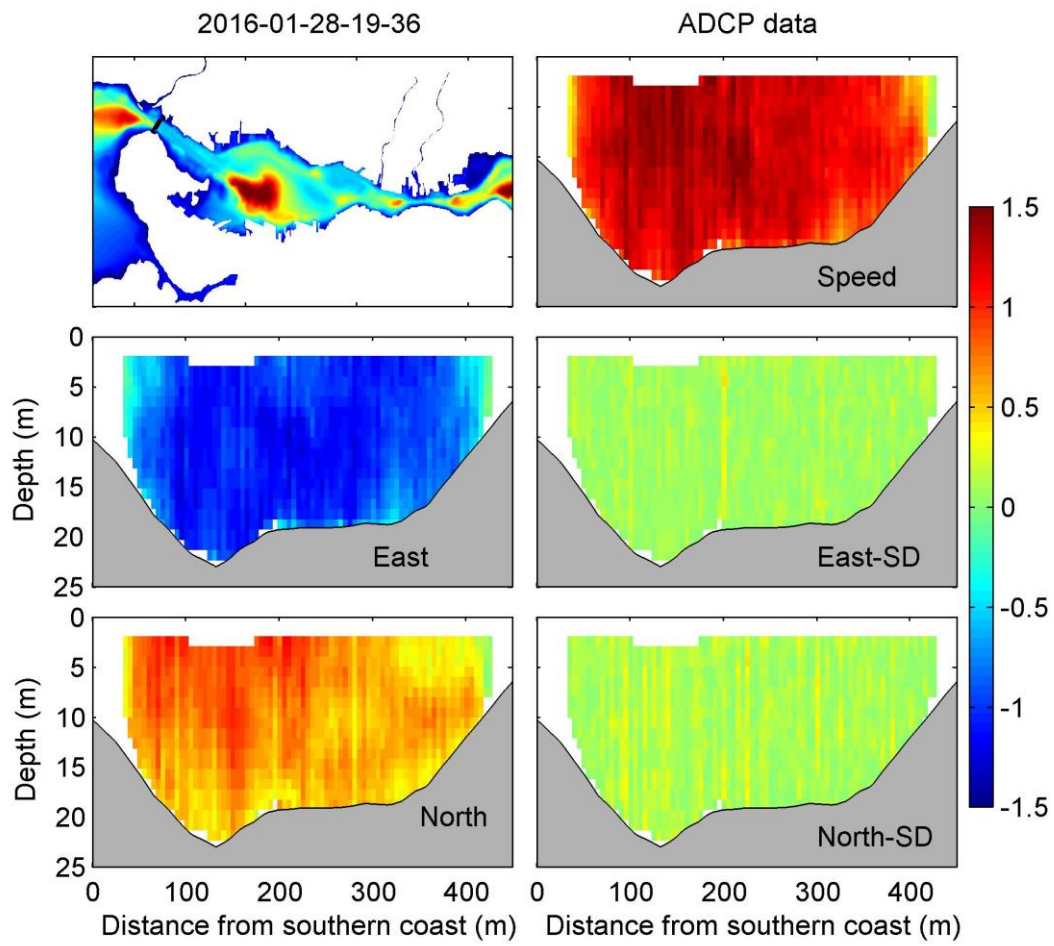


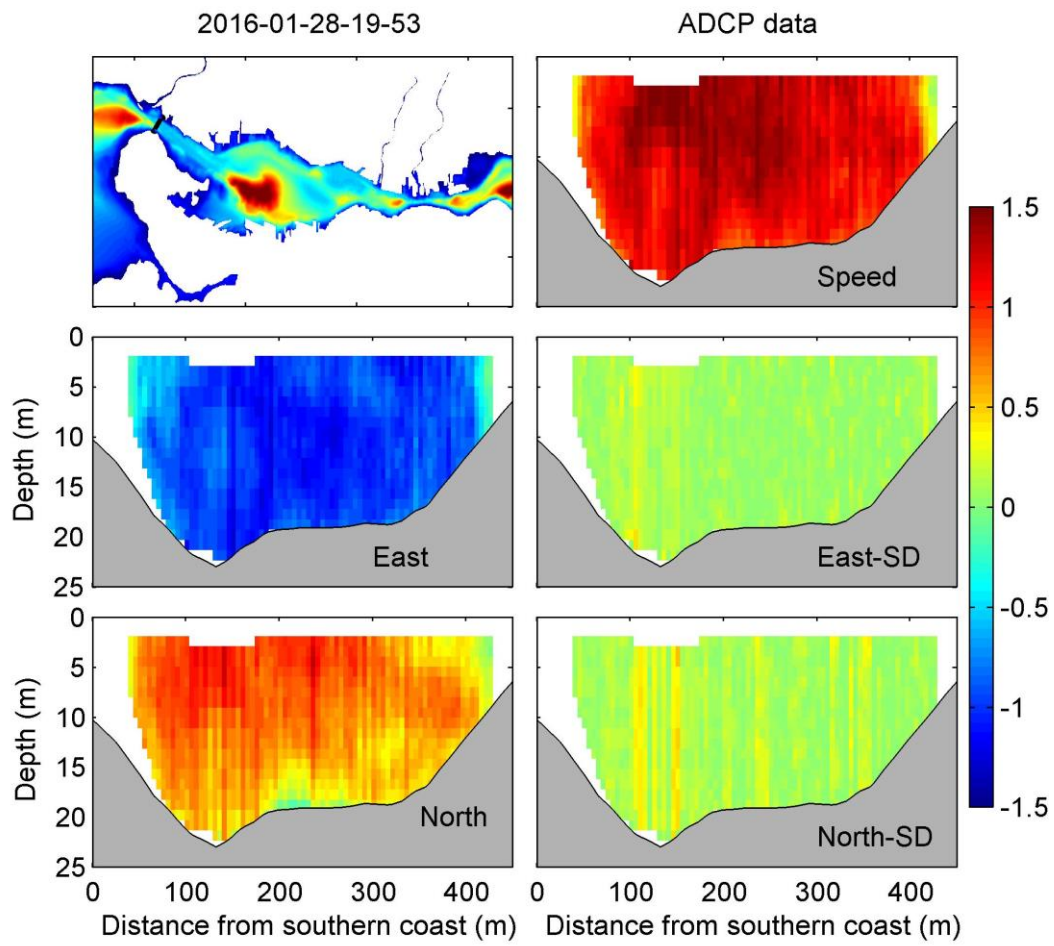


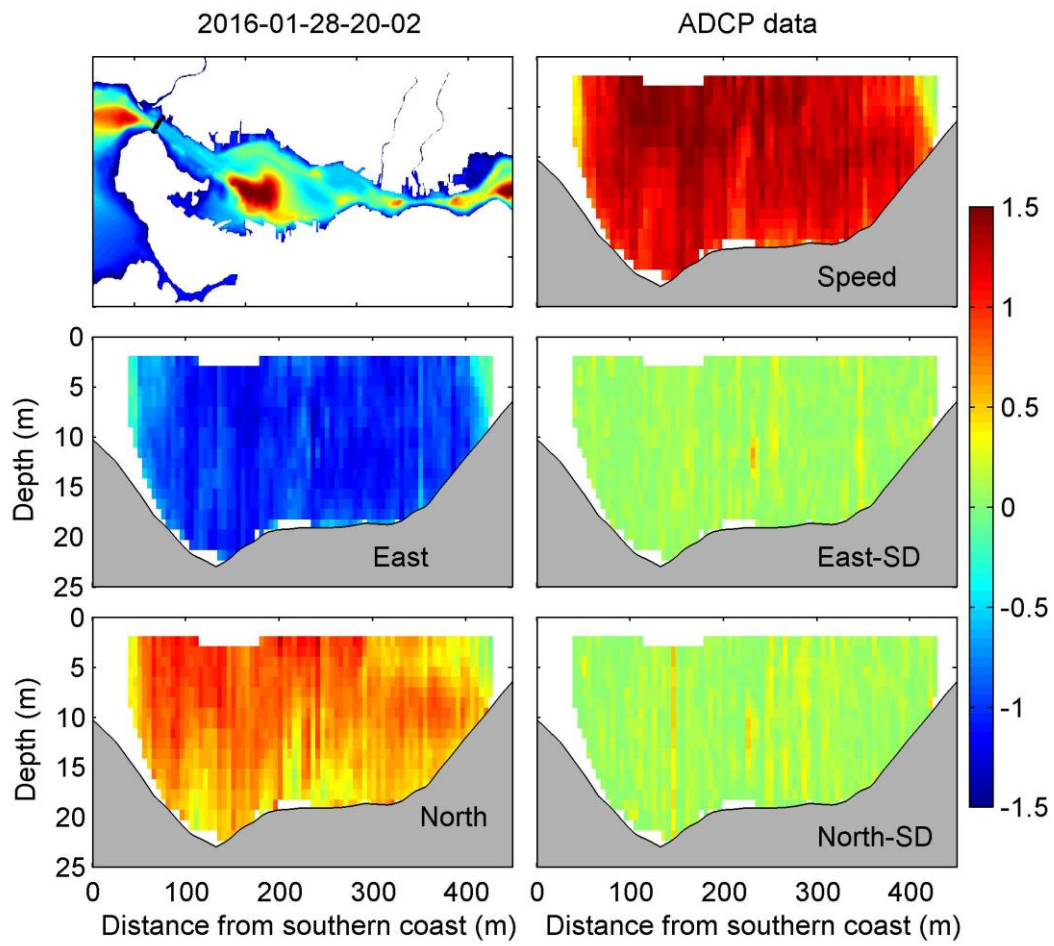


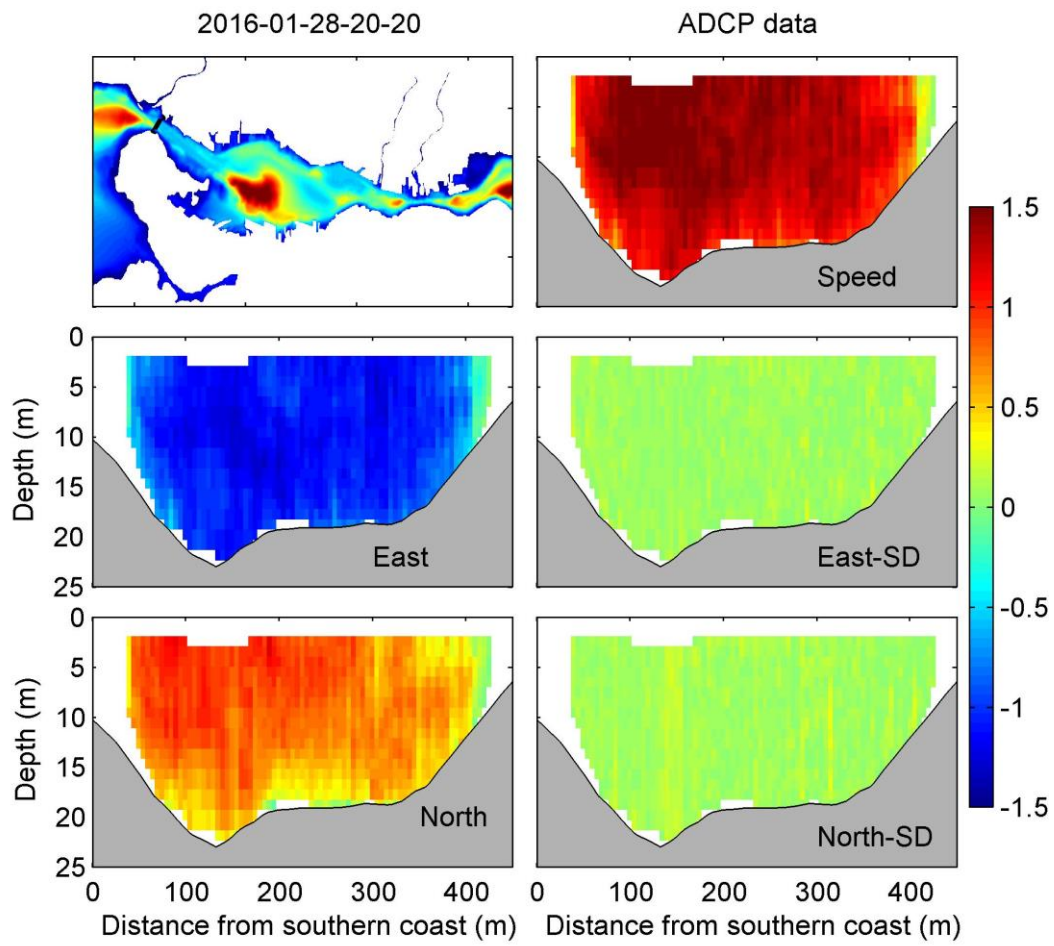


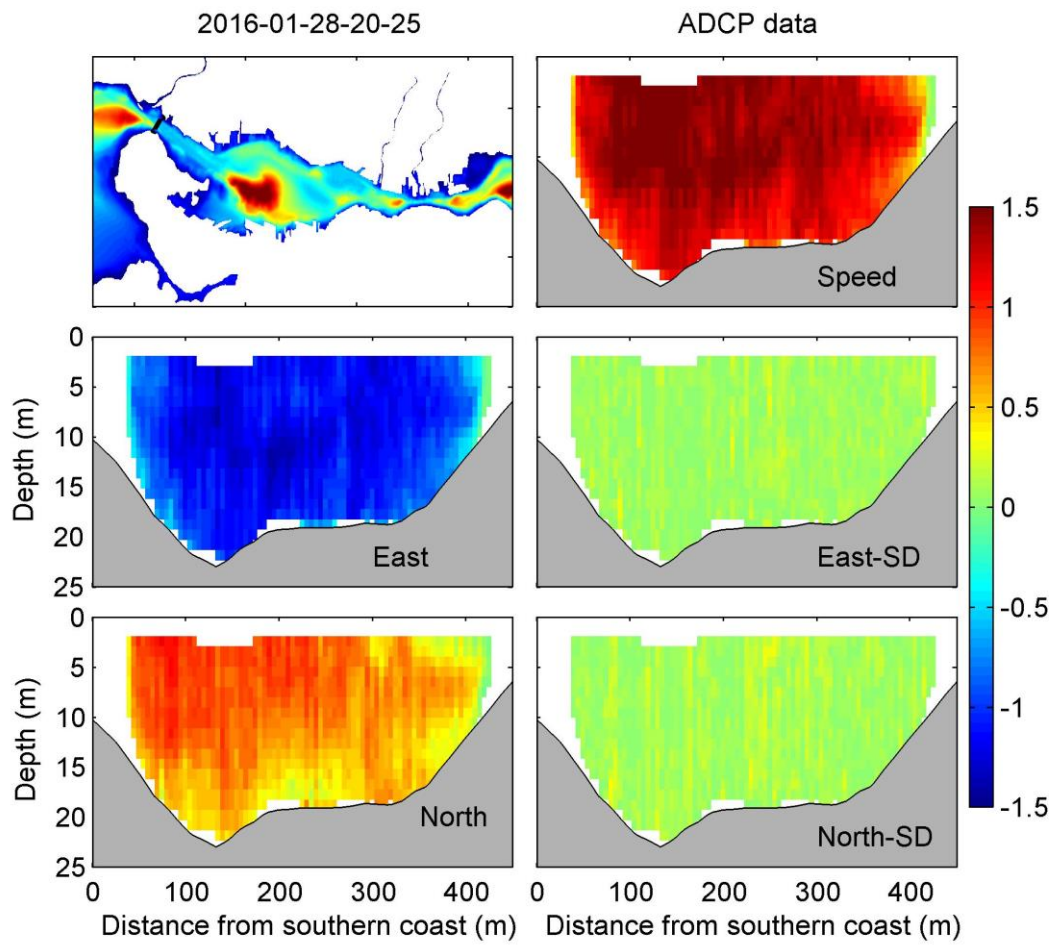


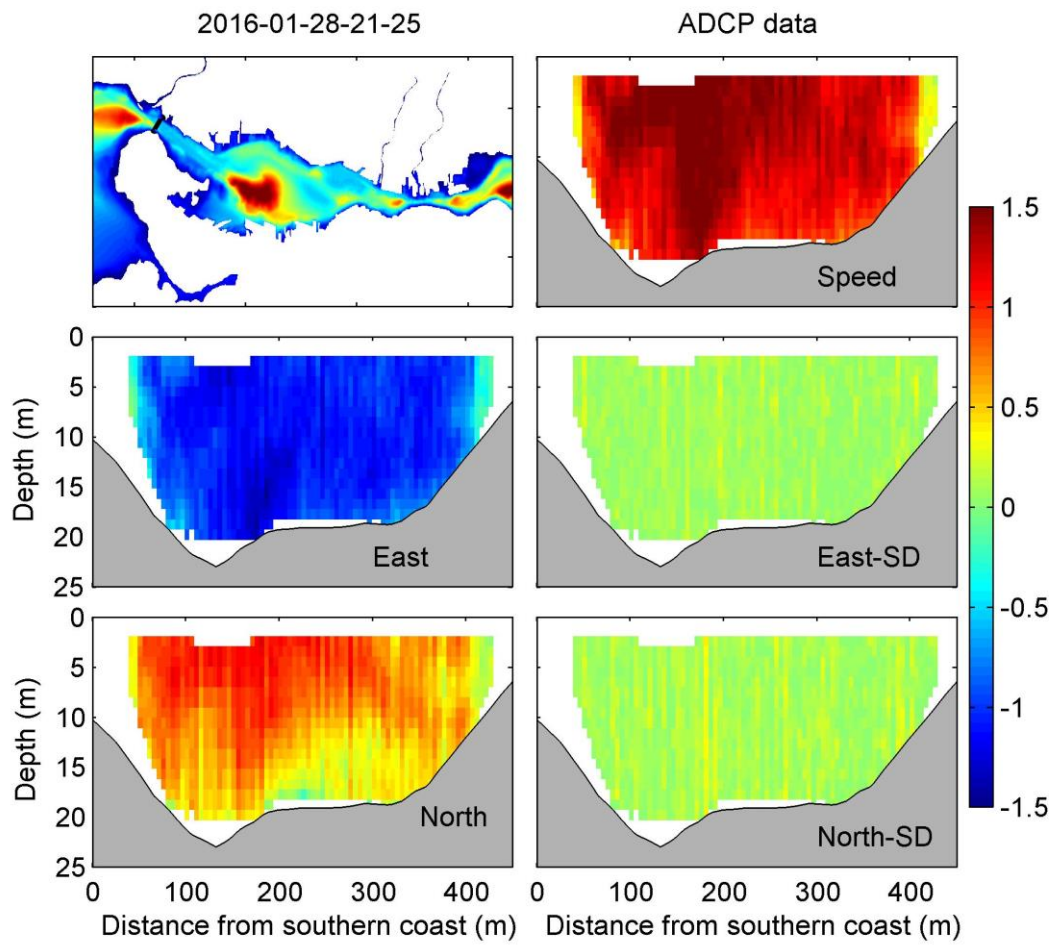


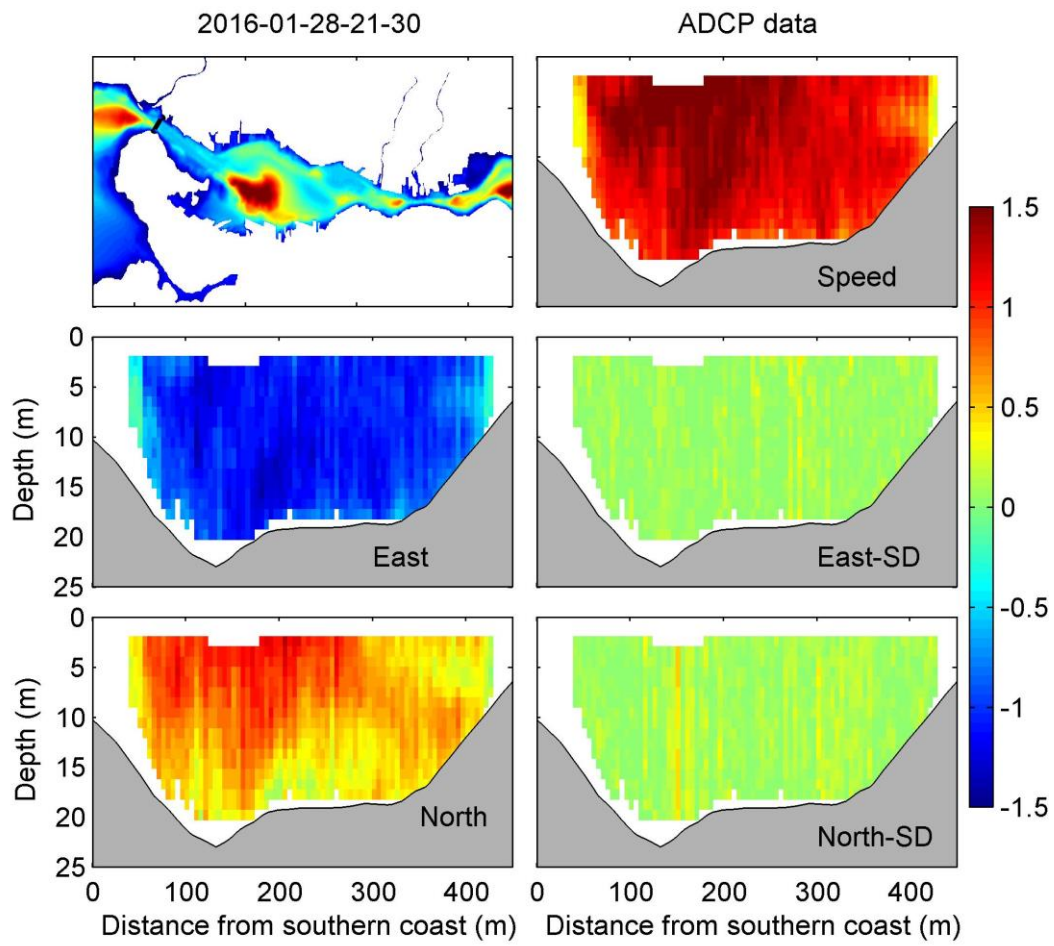


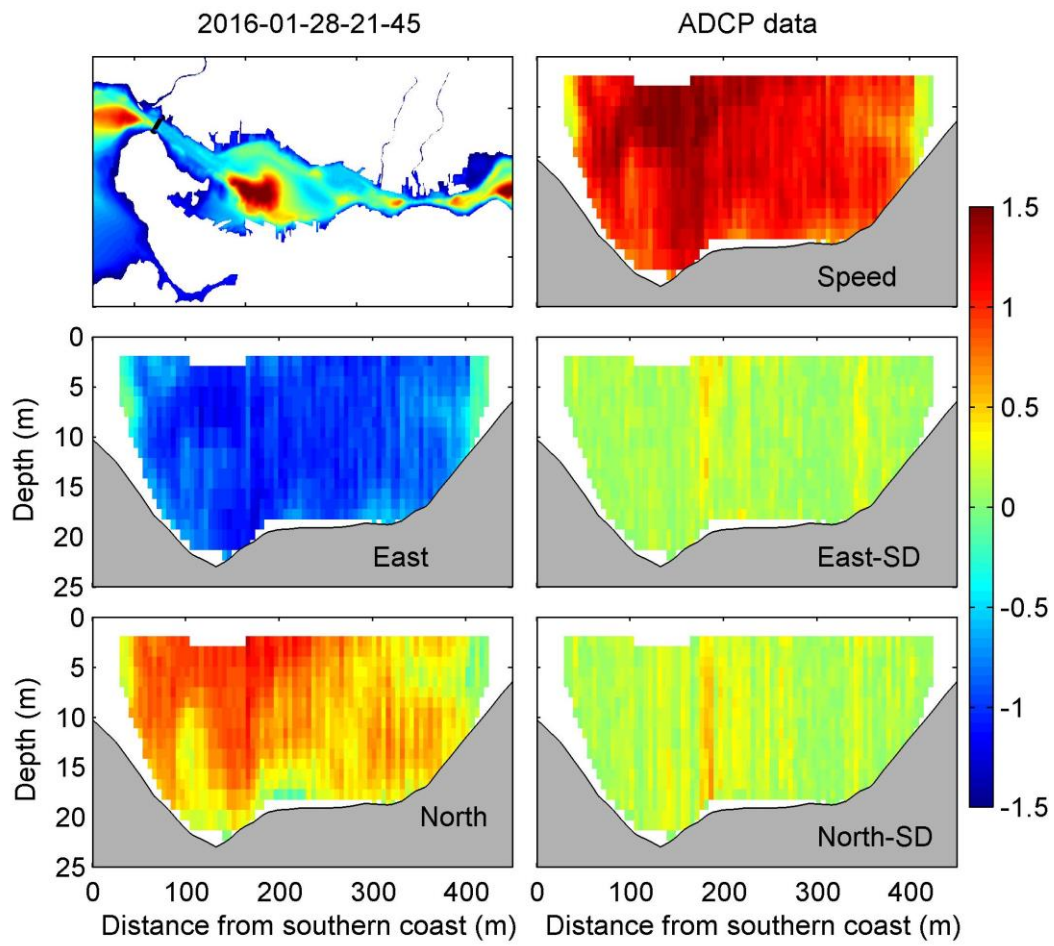


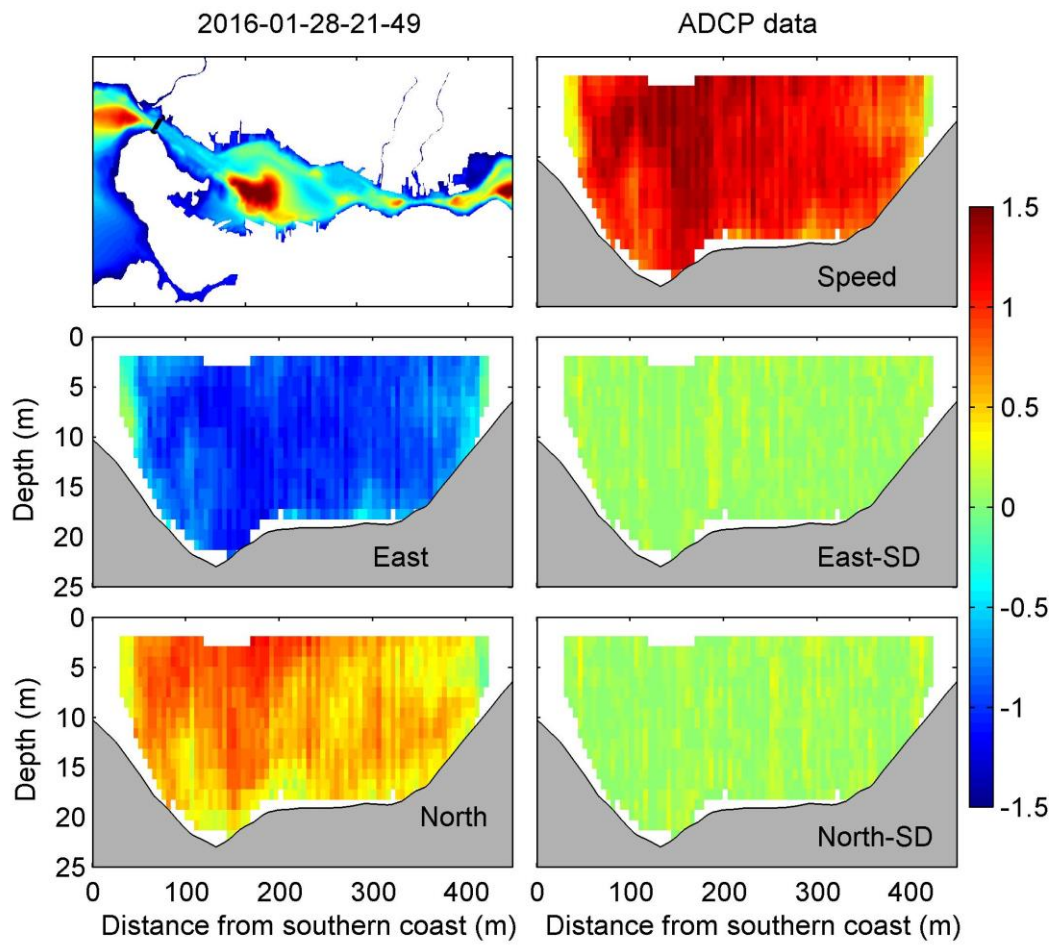


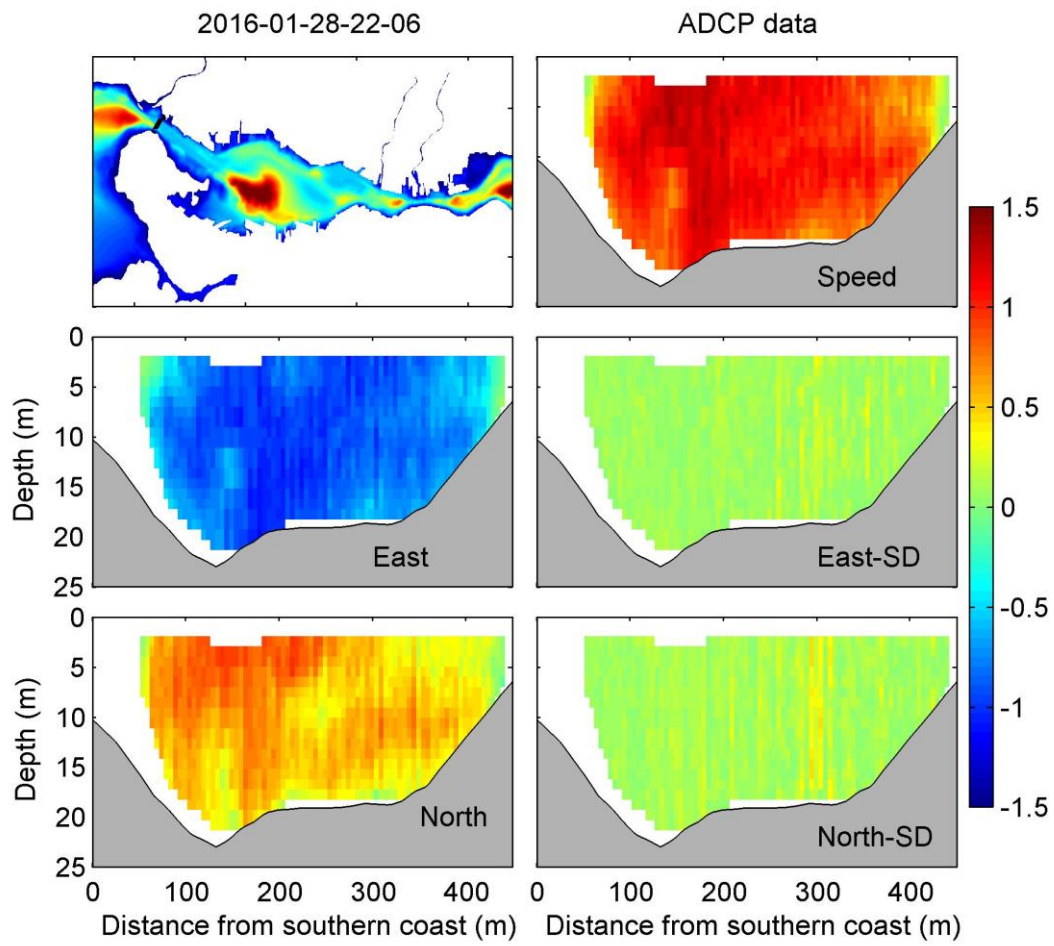


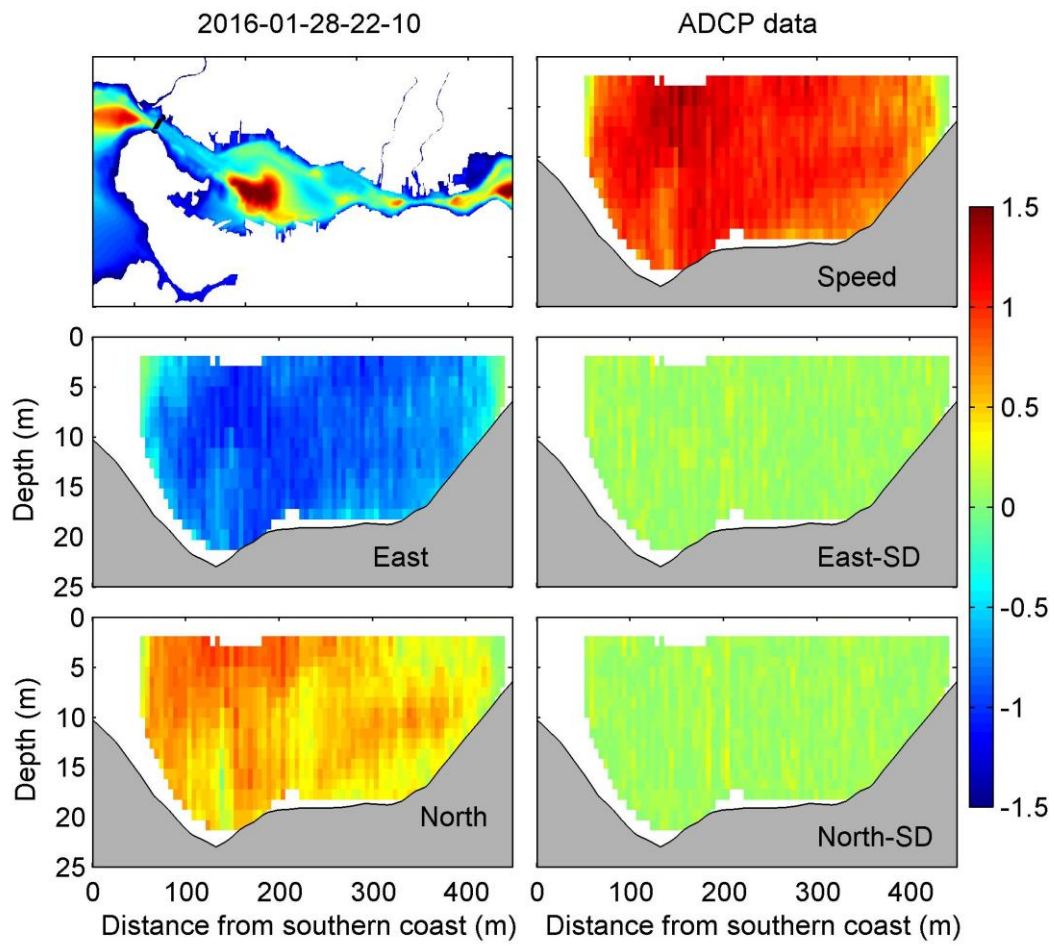


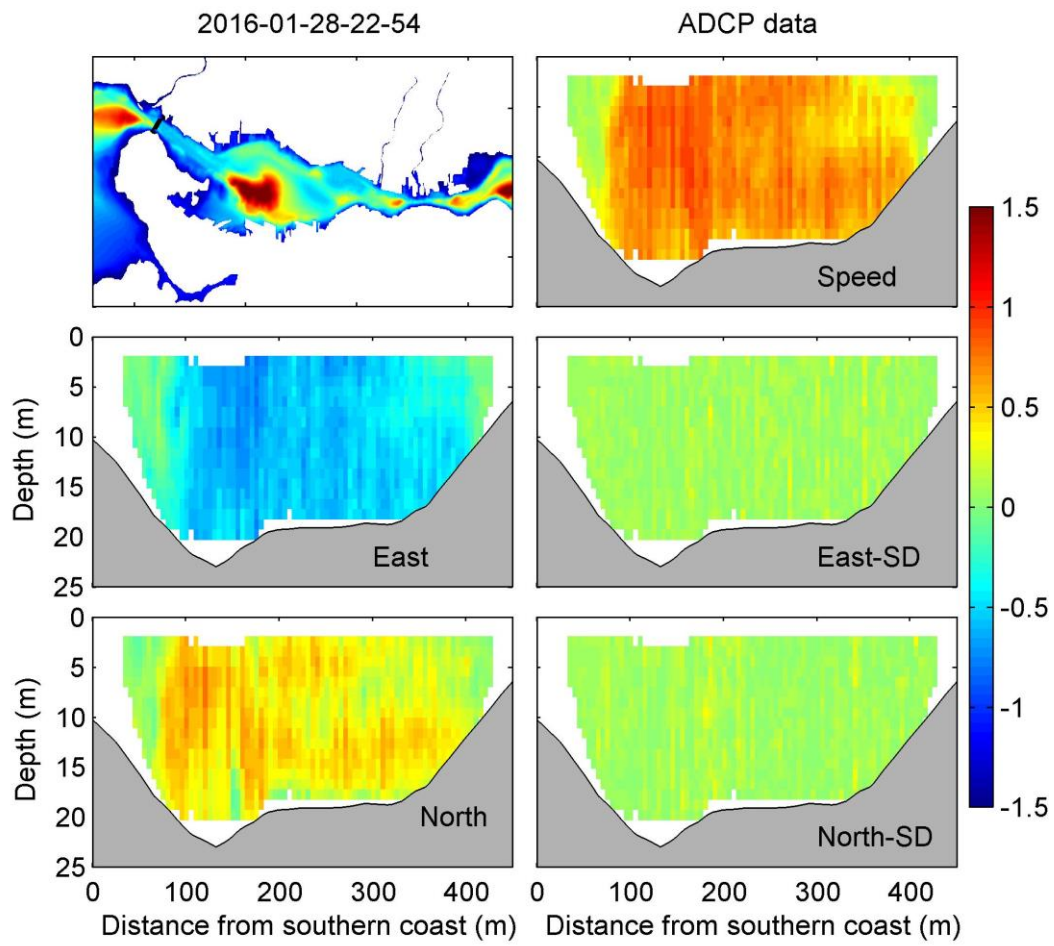


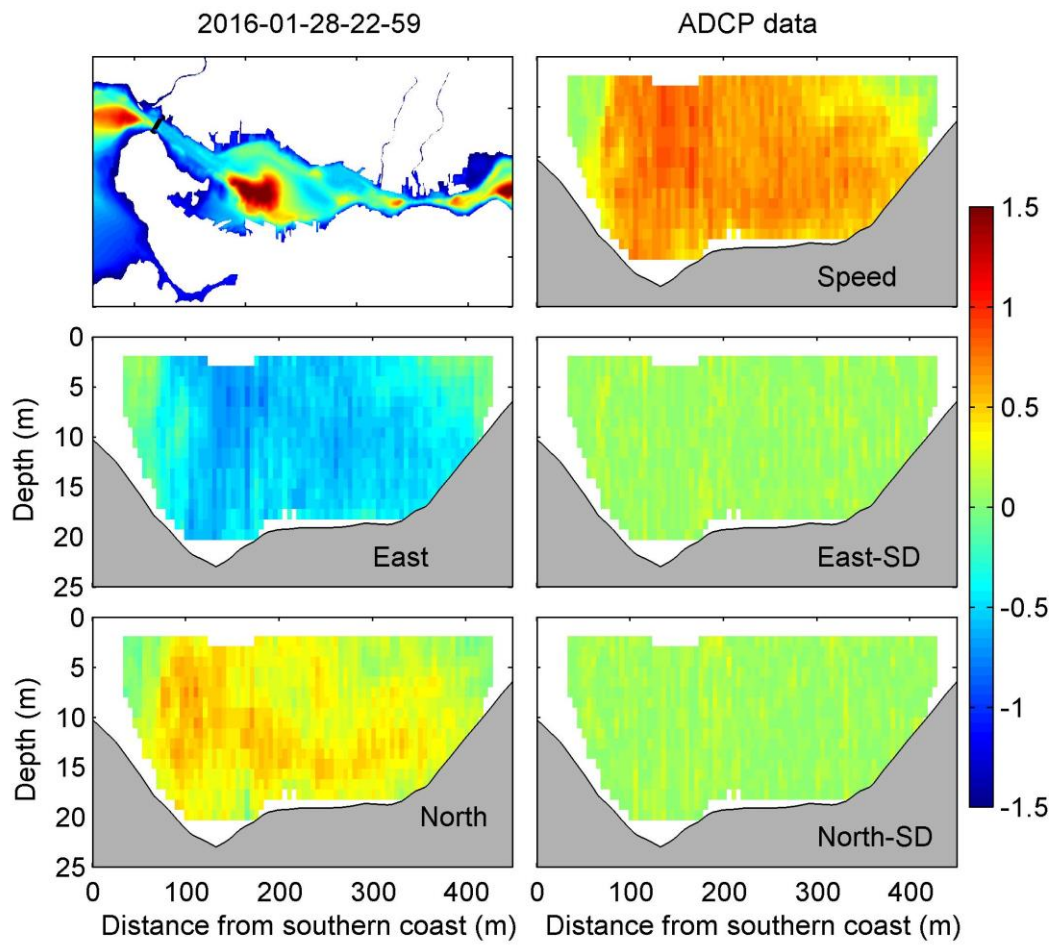


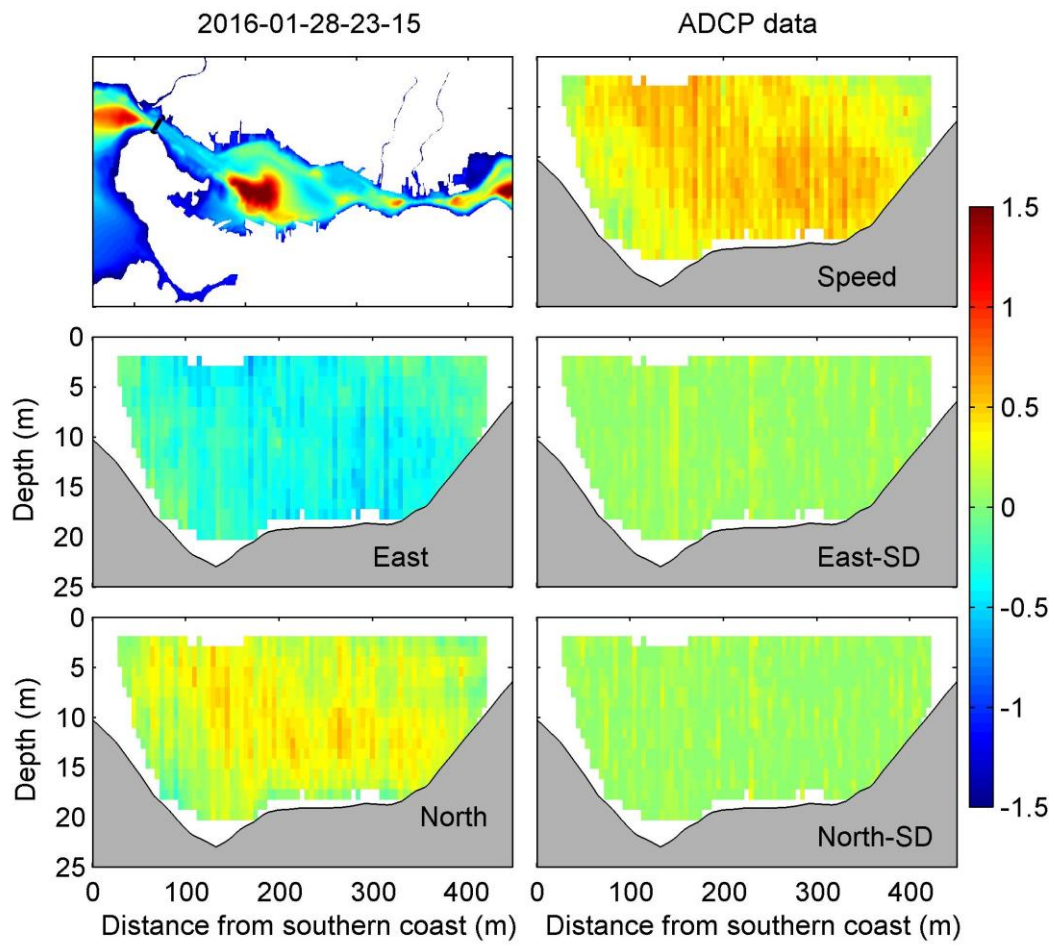


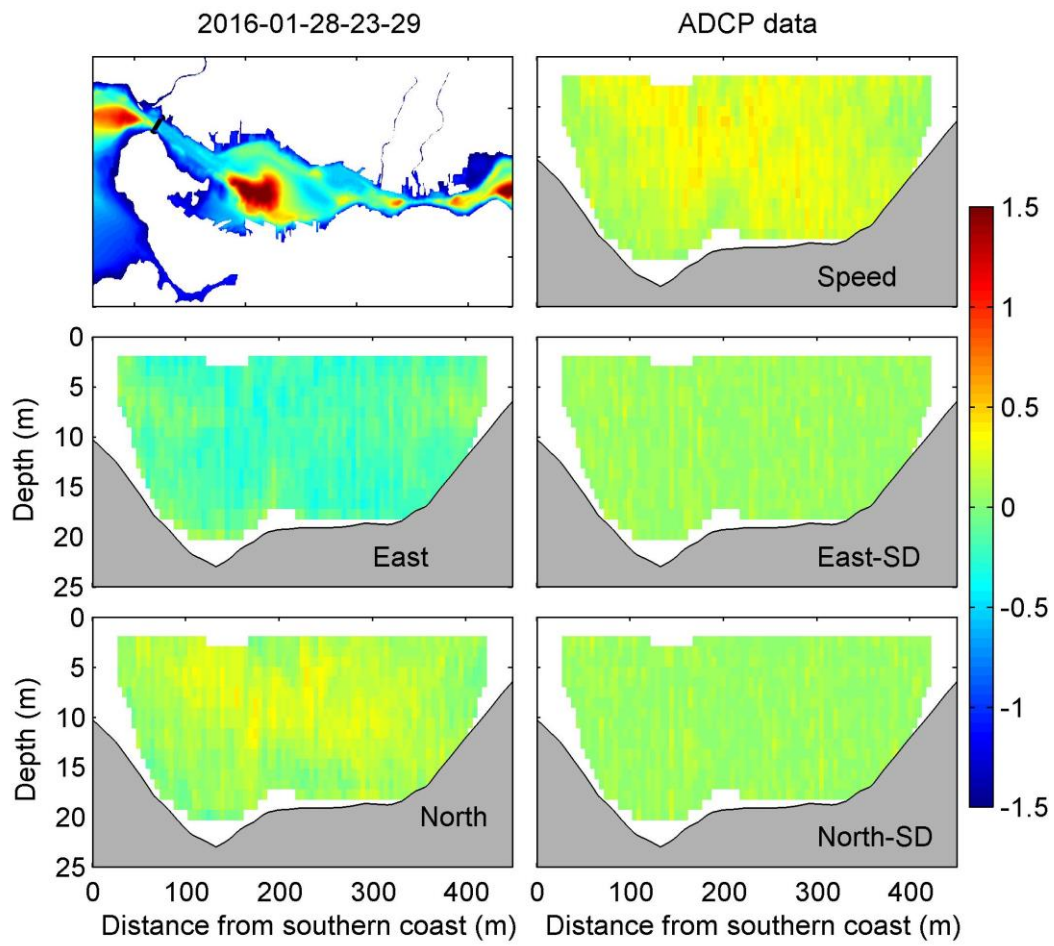


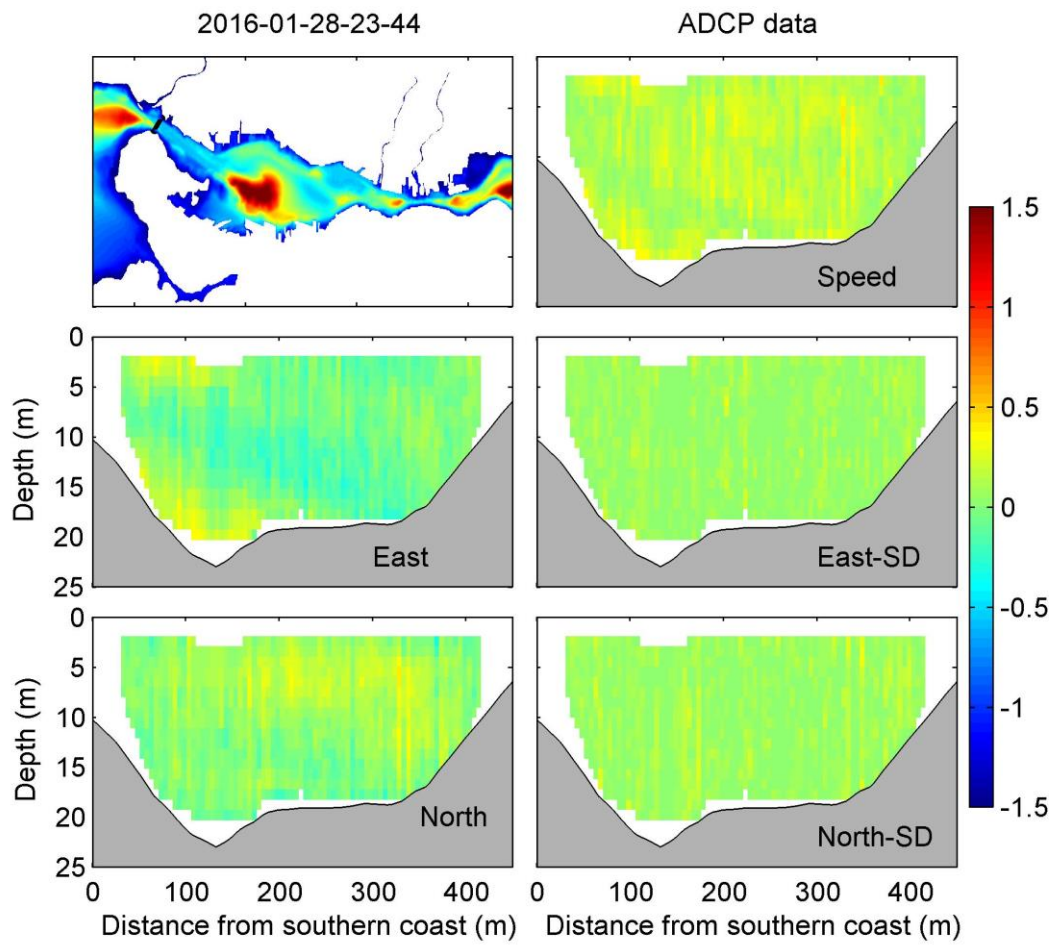


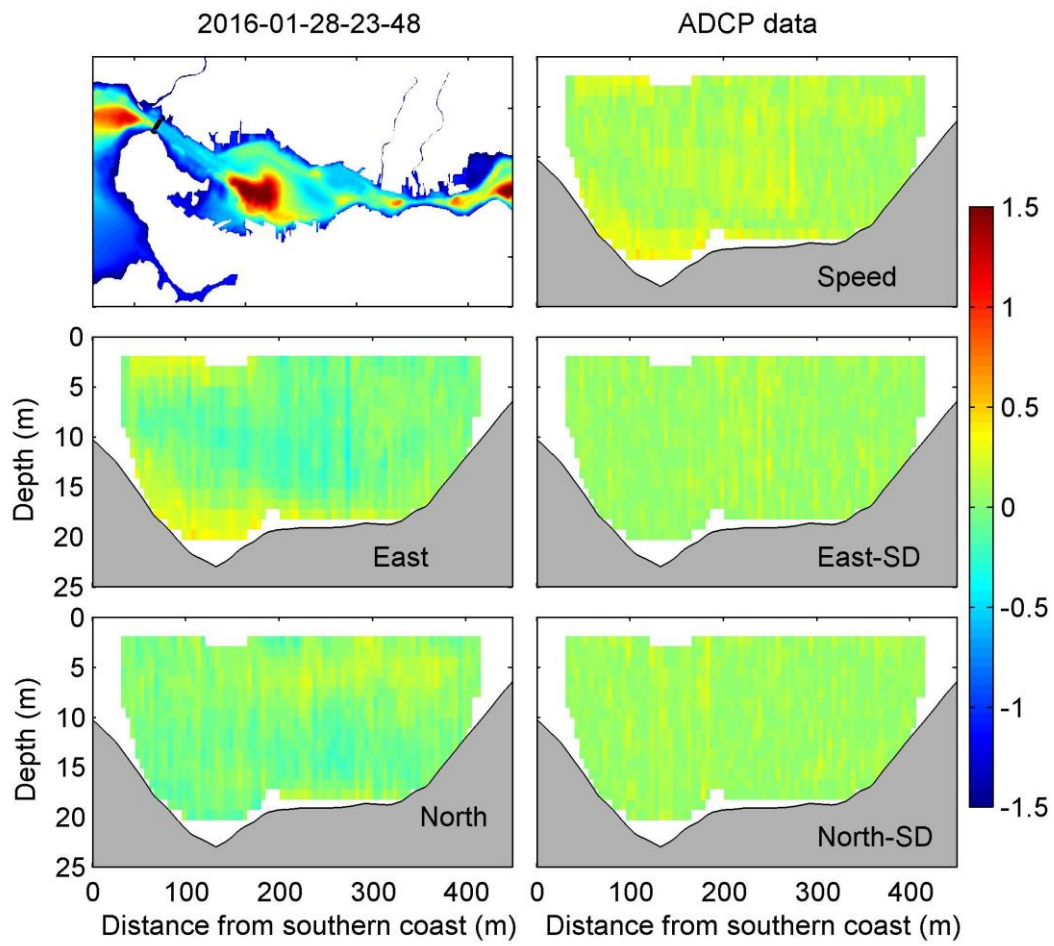


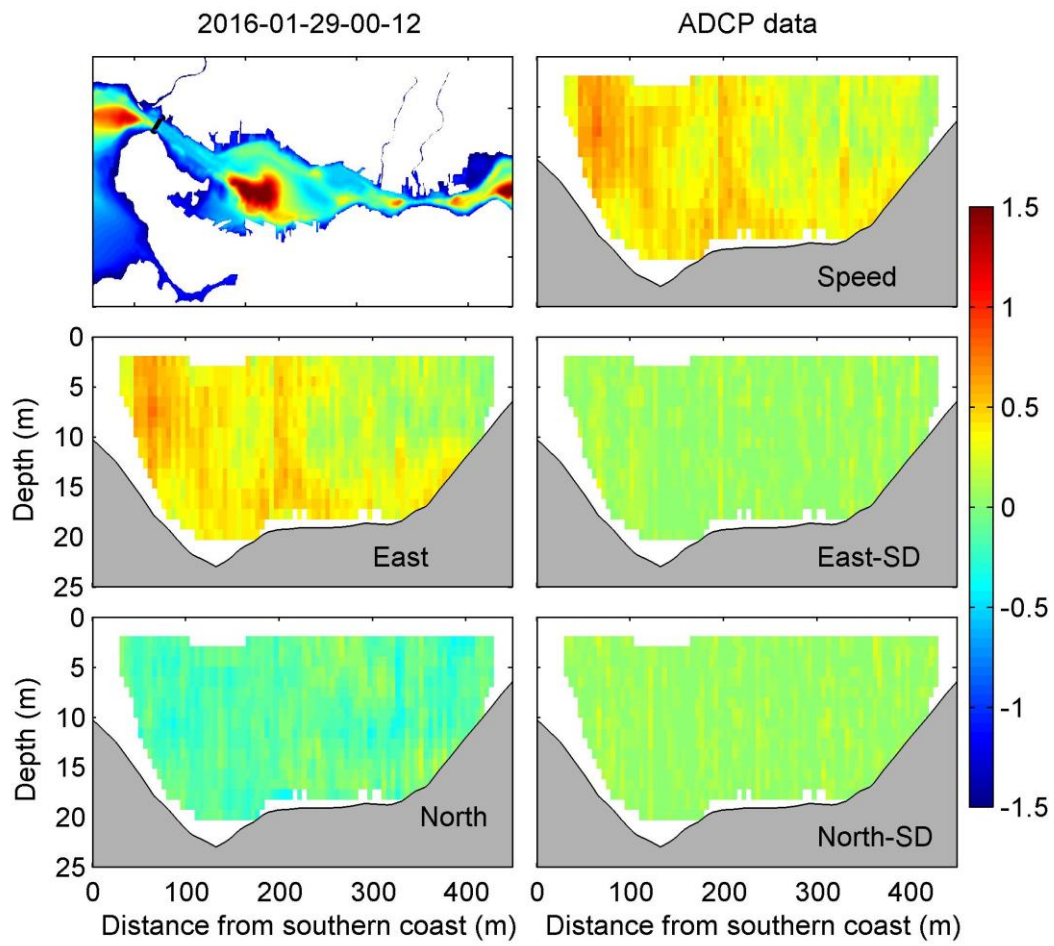


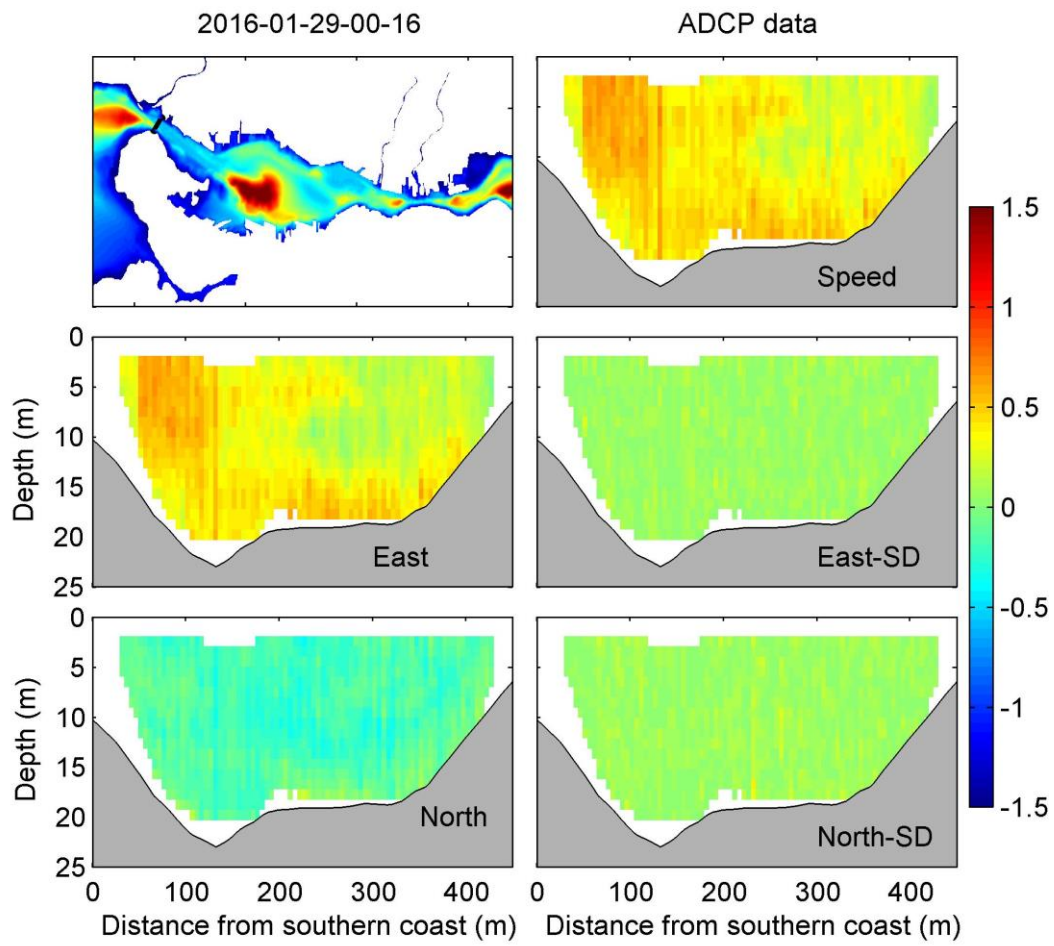


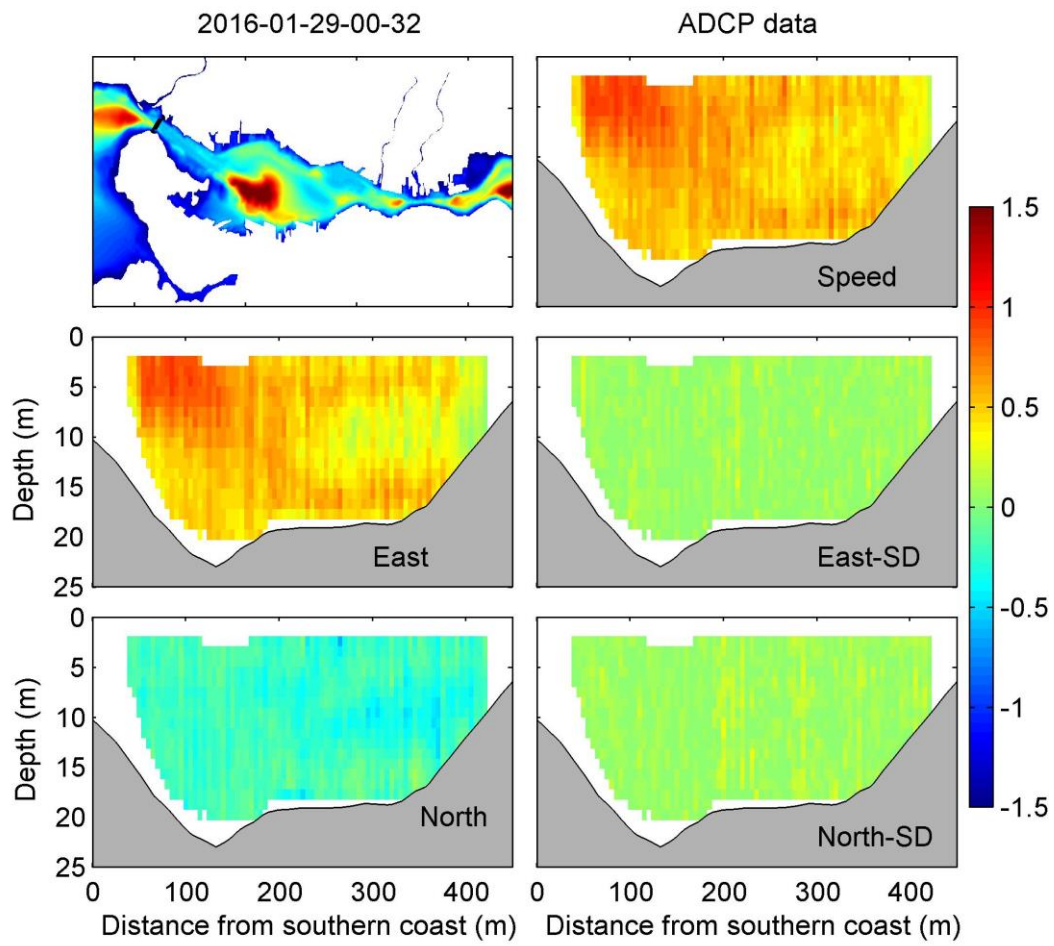


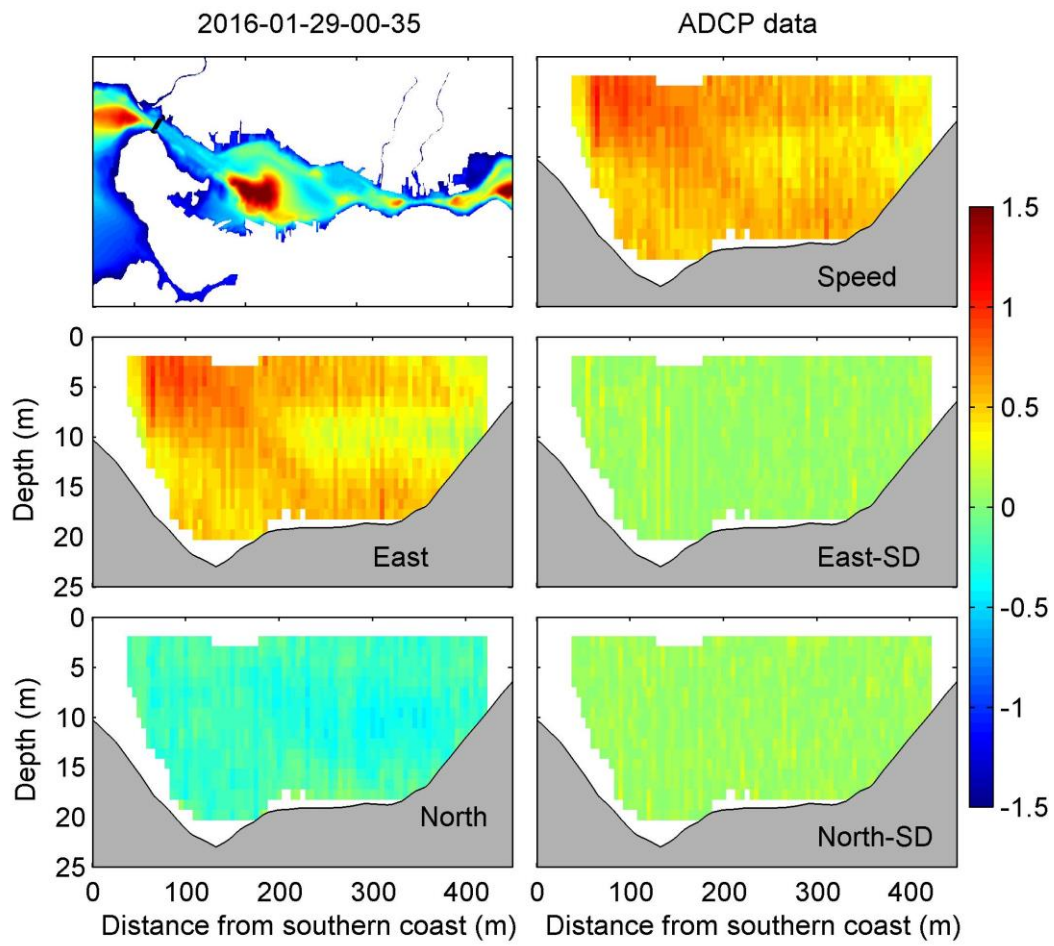


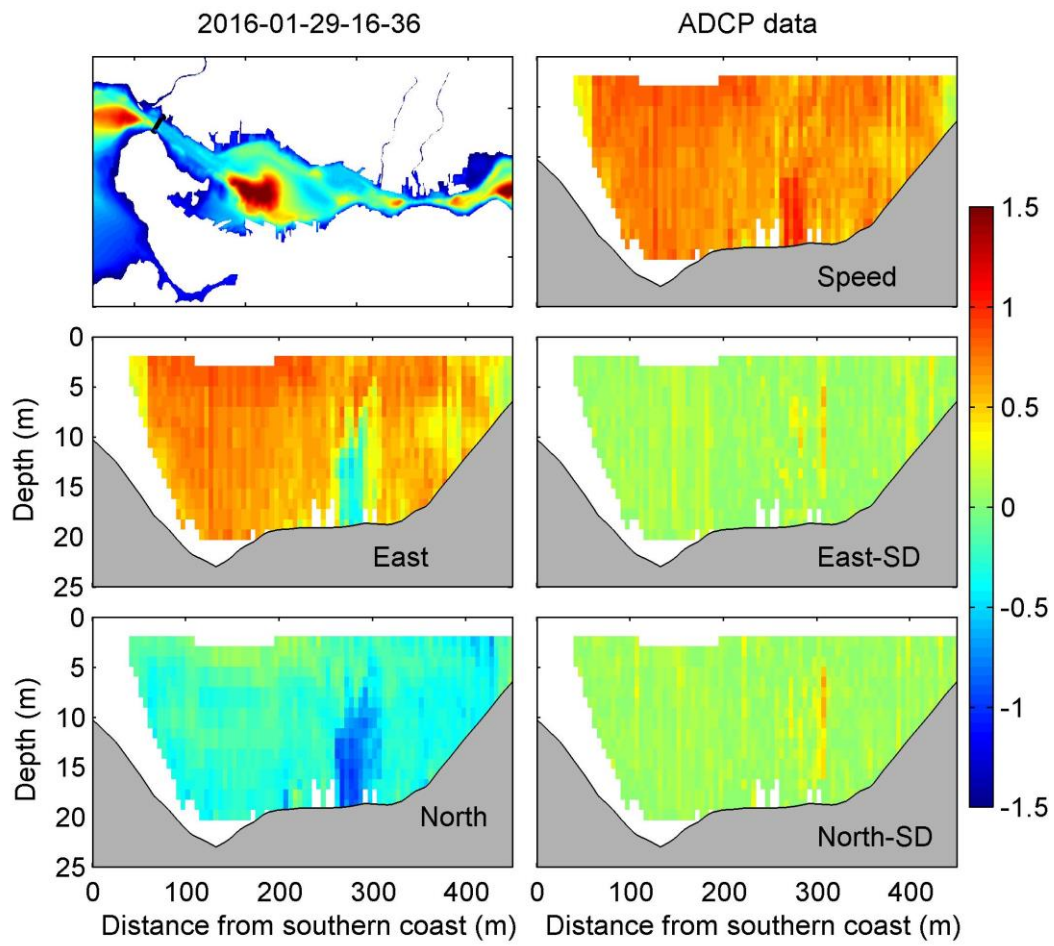


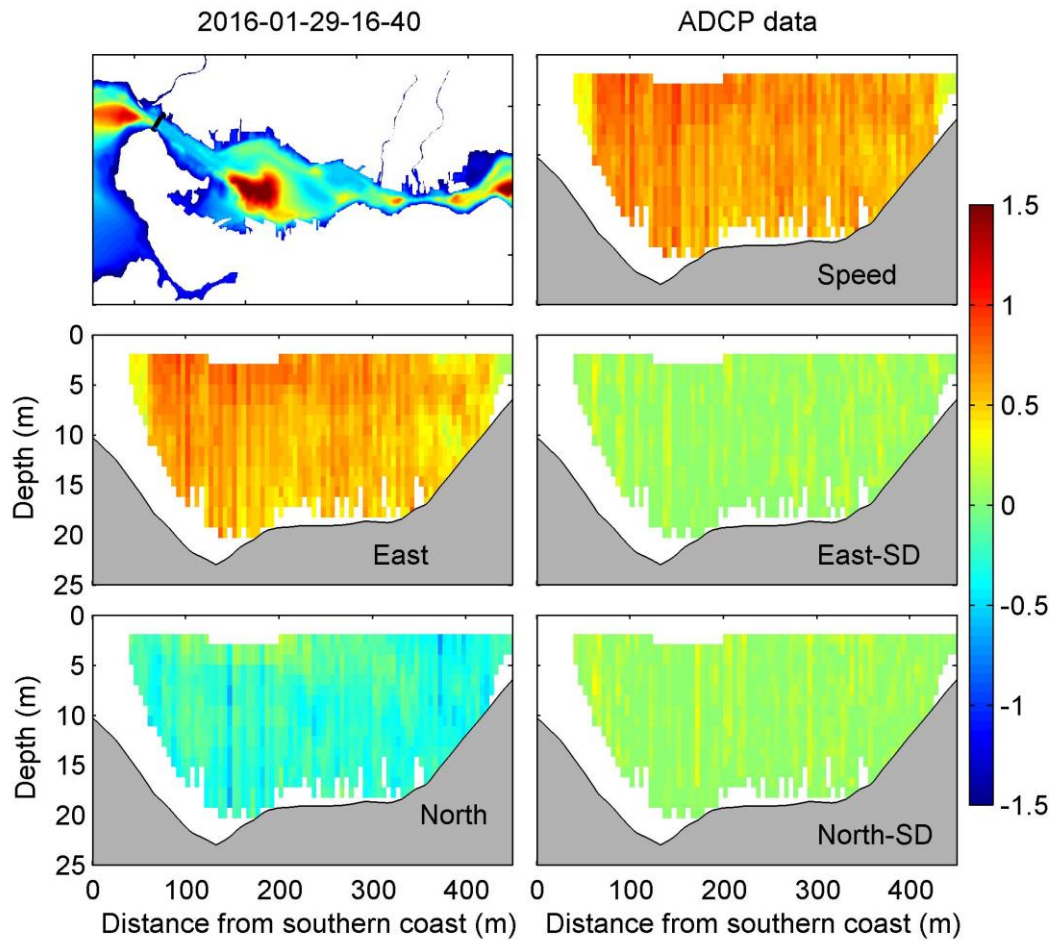






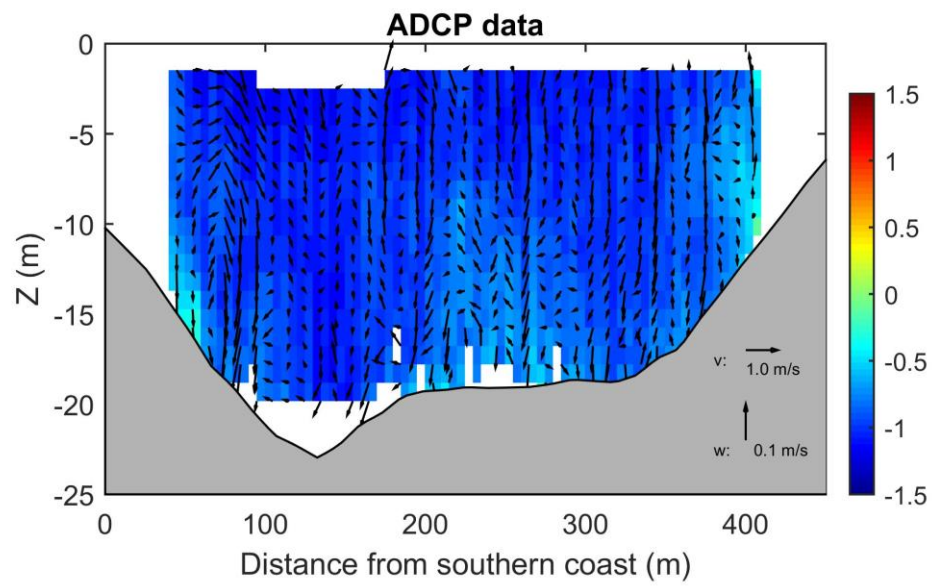
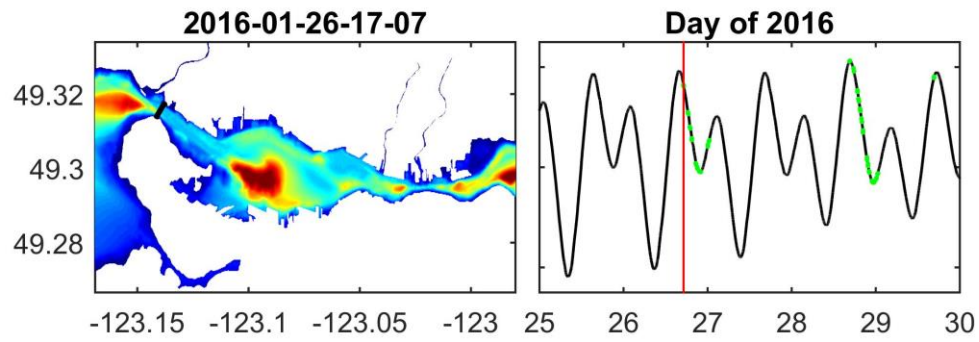


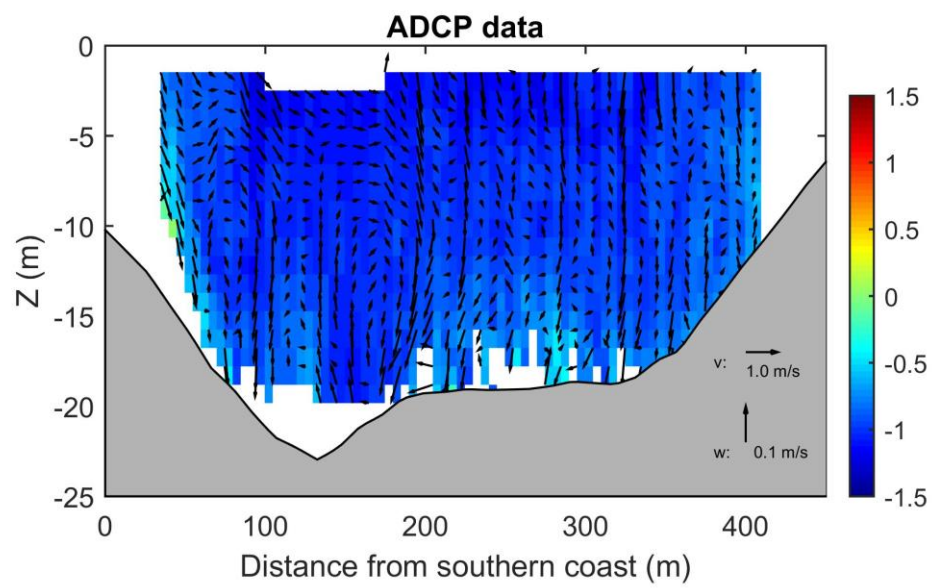
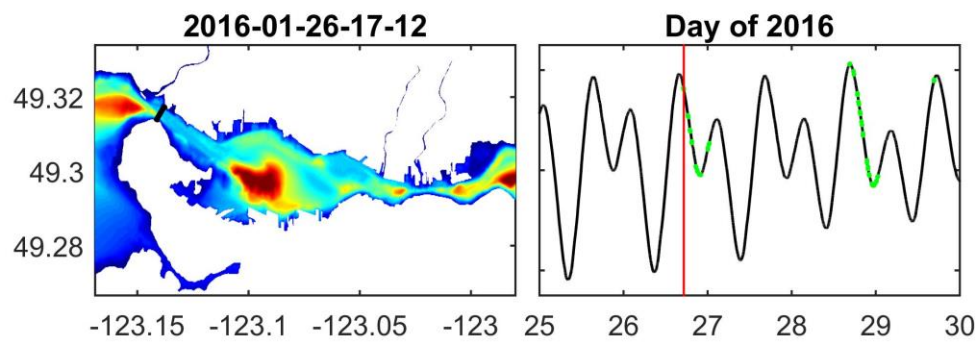


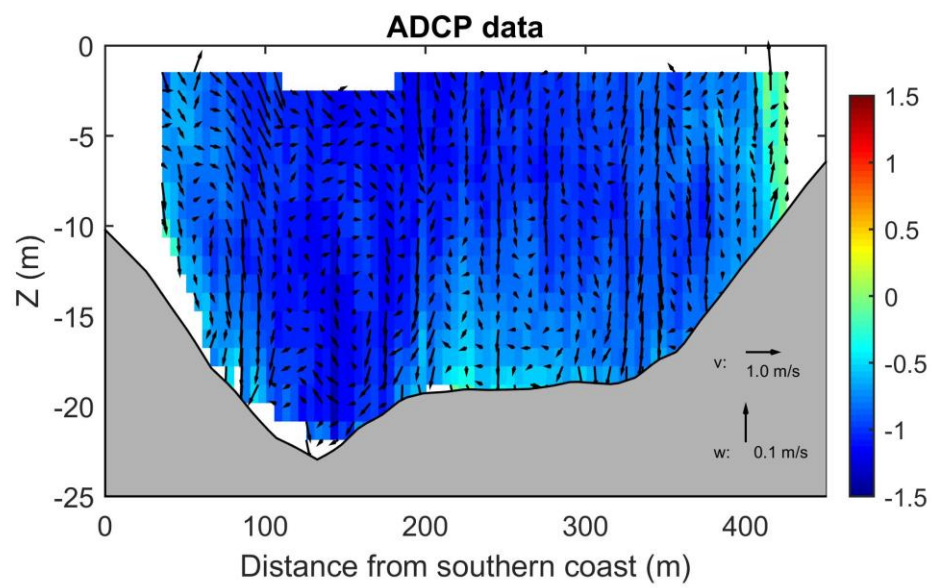
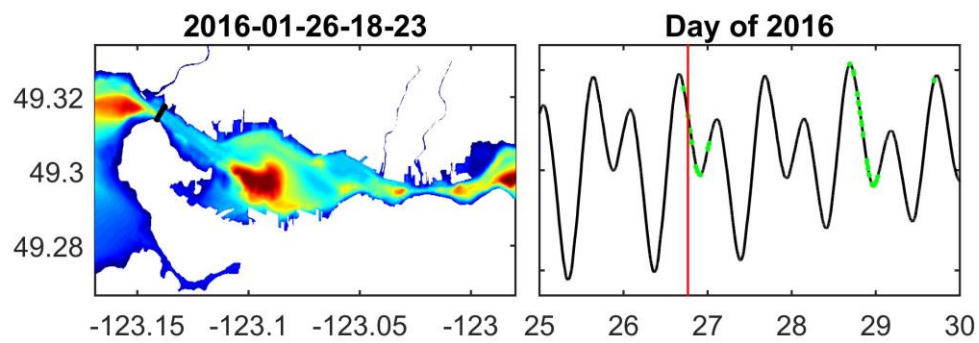


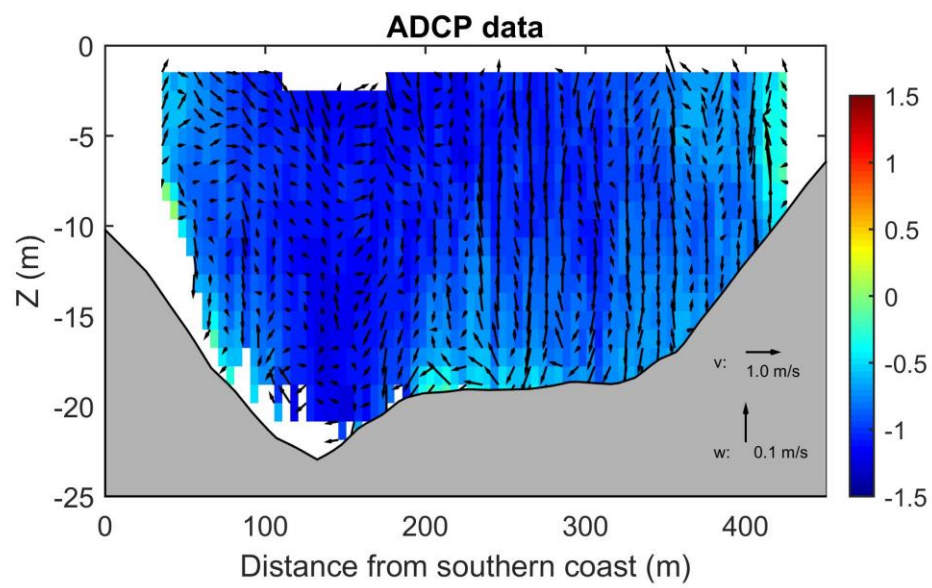
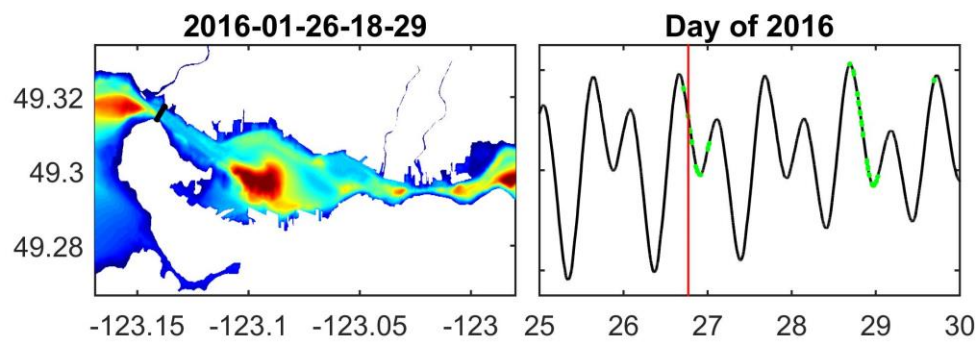
7.2 LINE 1 VERTICAL PROFILE OF VELOCITY VECTORS AND TIDAL CYCLE

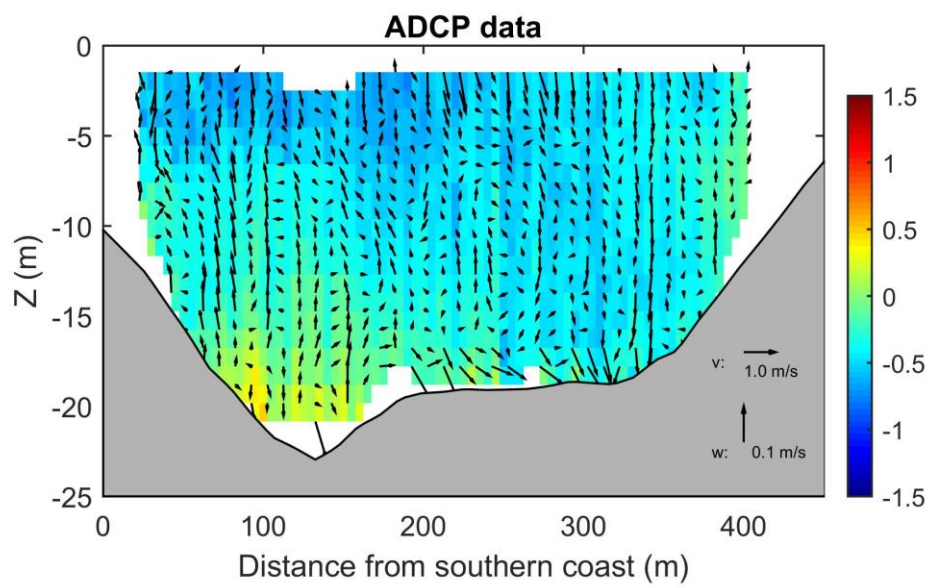
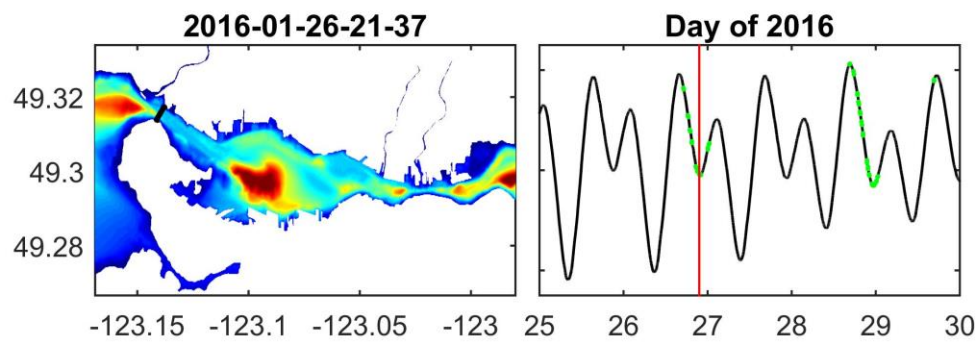
The following figures show vertical profiles of the measured velocity data along Line 1. The figures show the bathymetry map that shows the position of the transect, the point during the tidal cycle when the sampling occurred, and the velocity vectors produced by the data. Units are ms^{-1} .

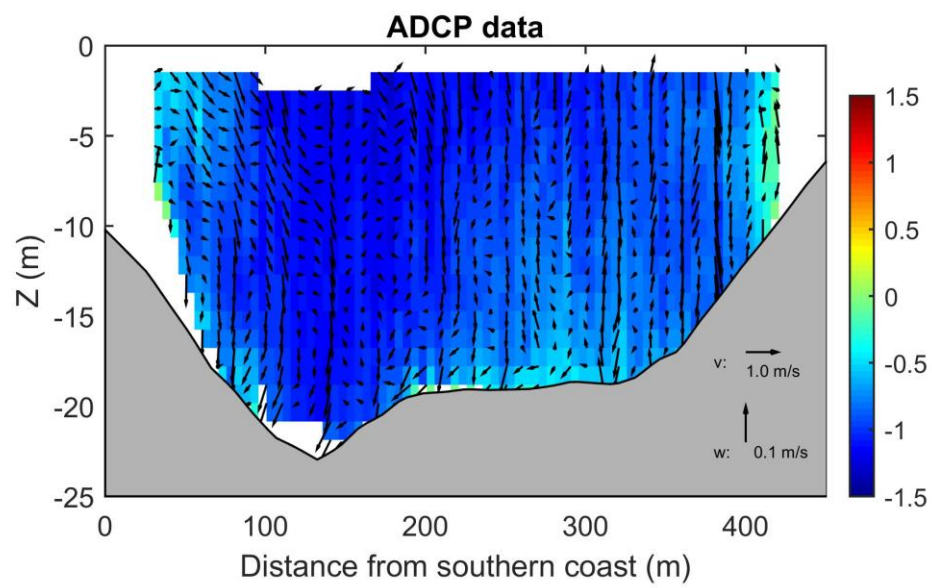
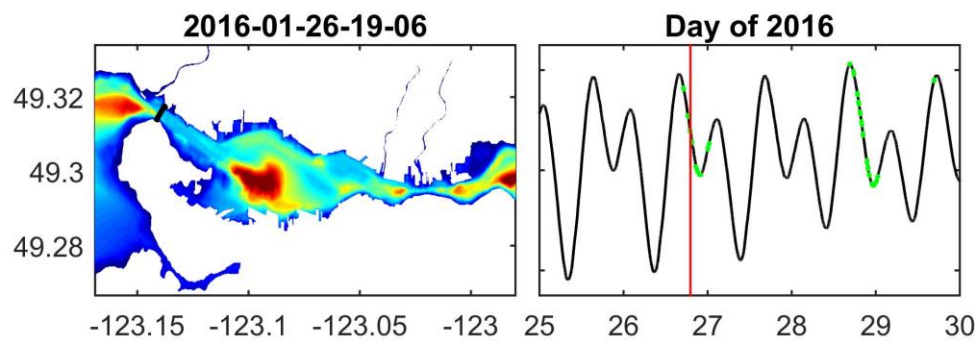


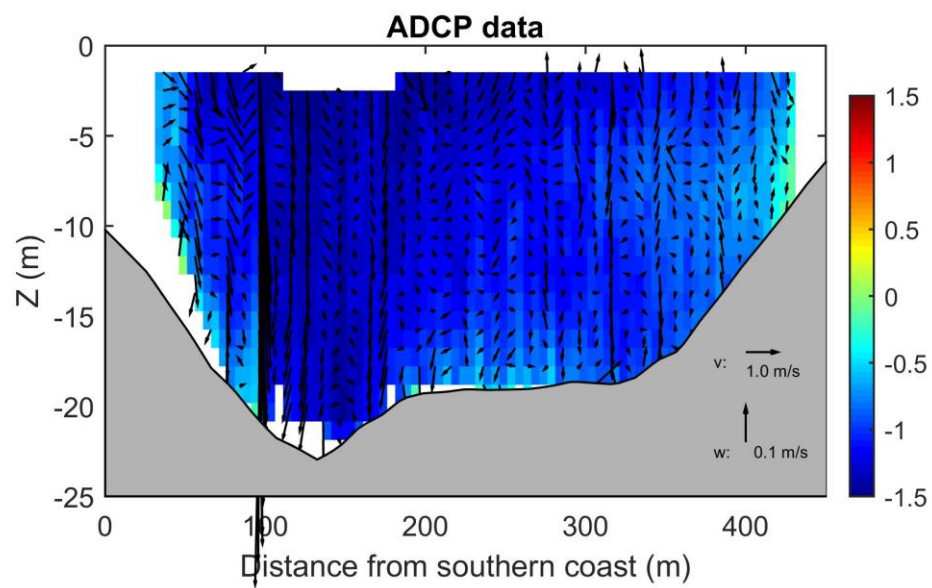
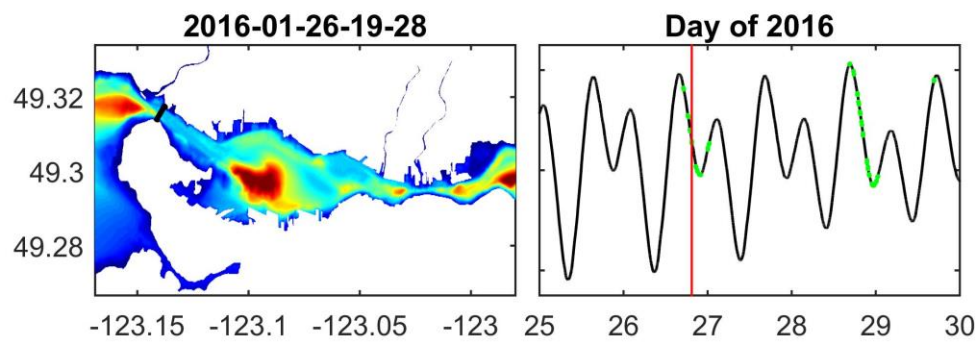


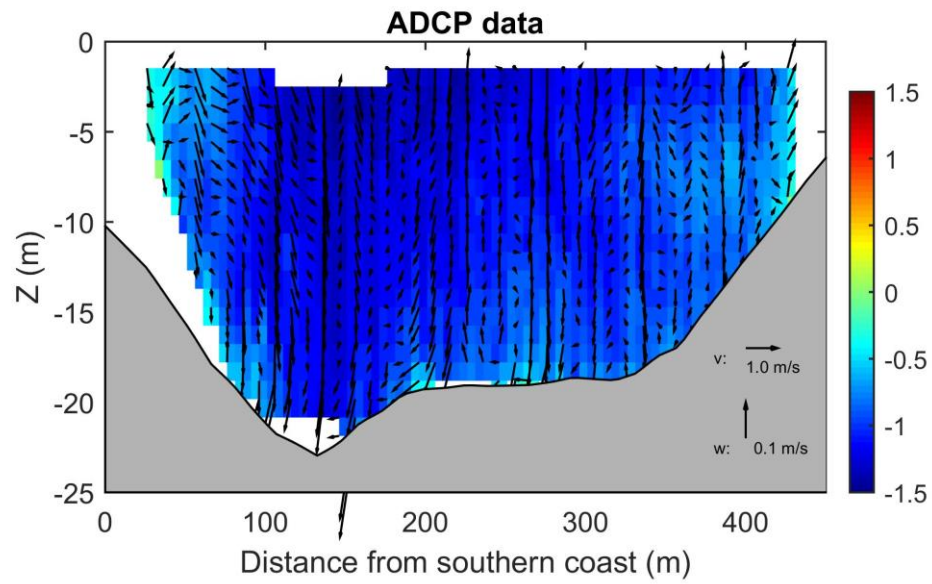
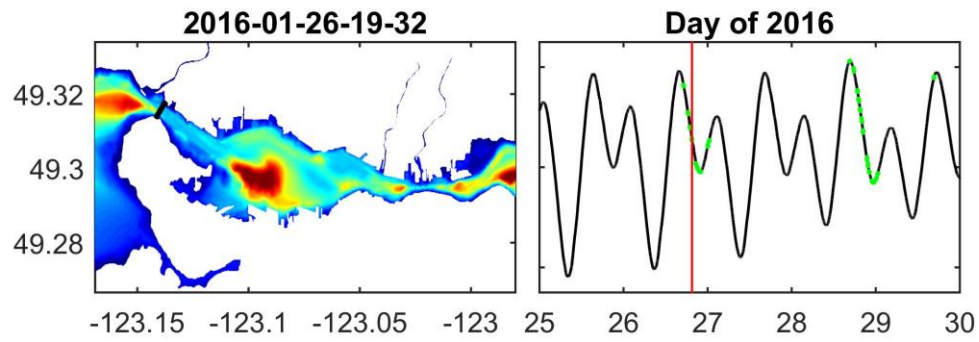


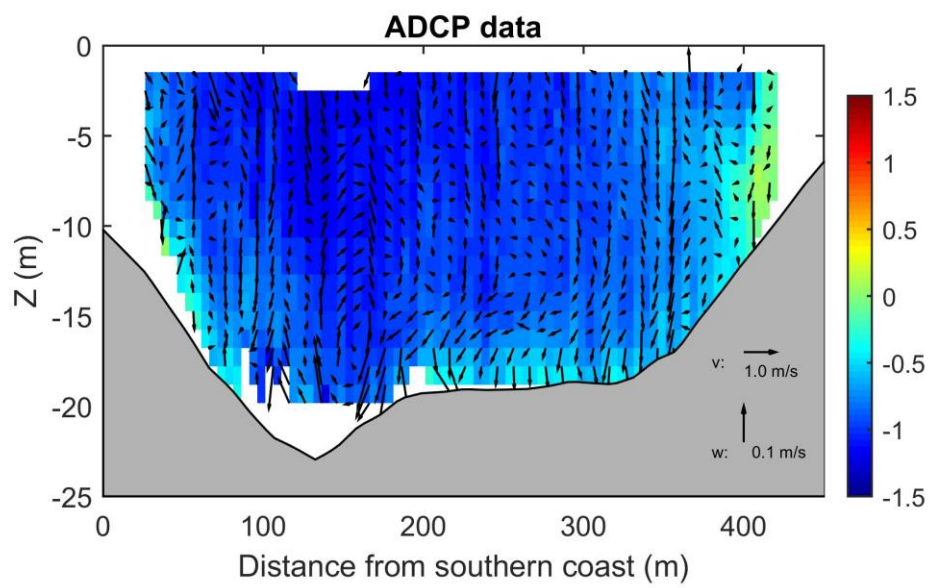
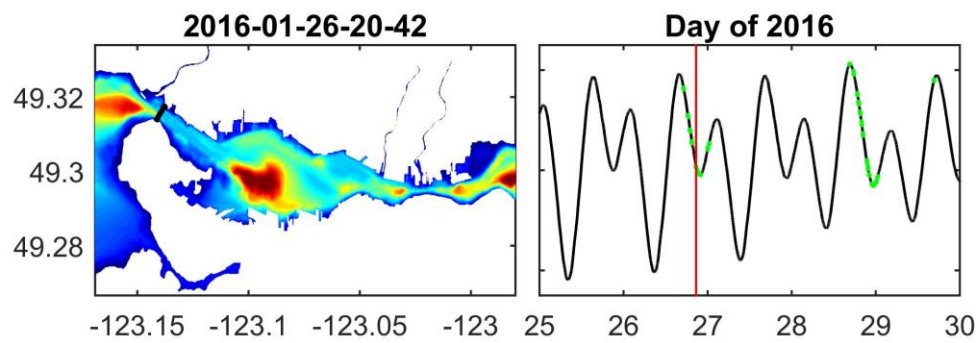


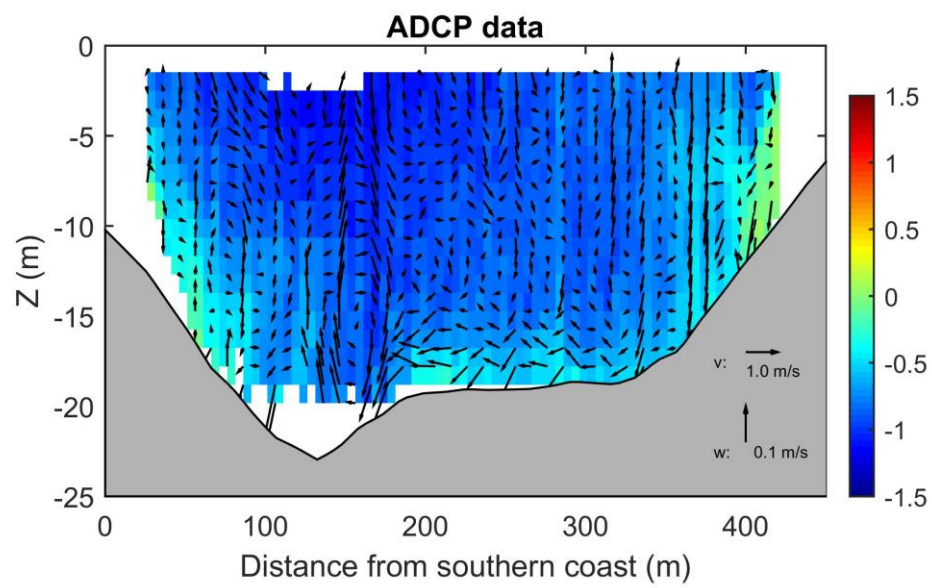
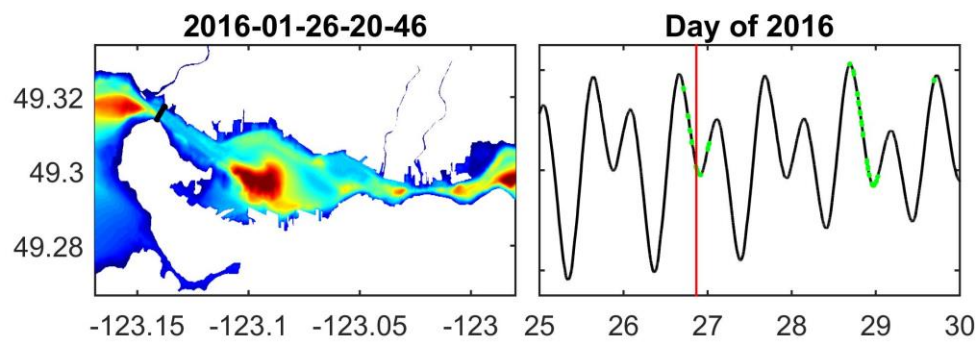


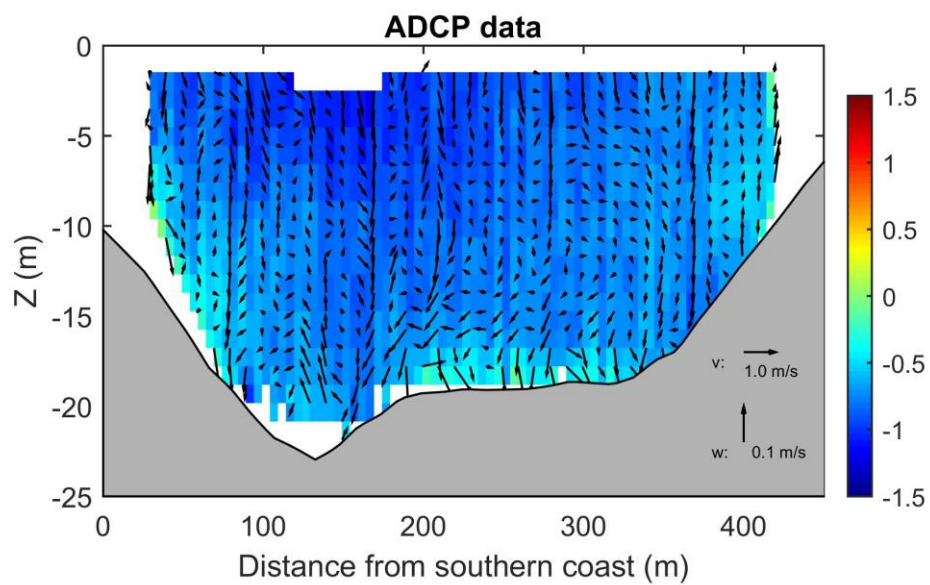
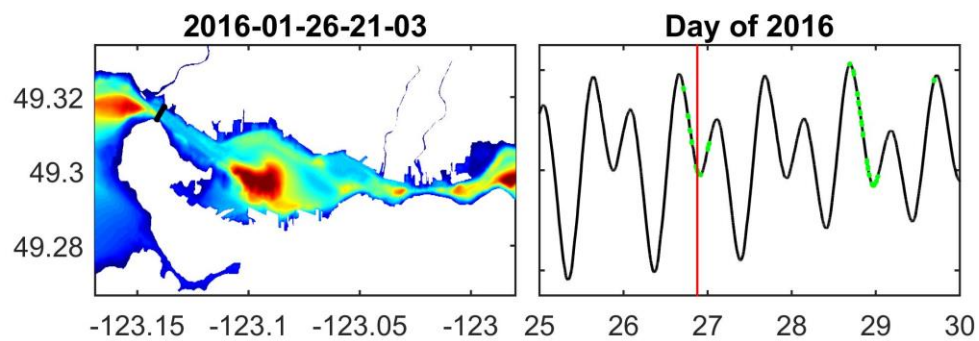


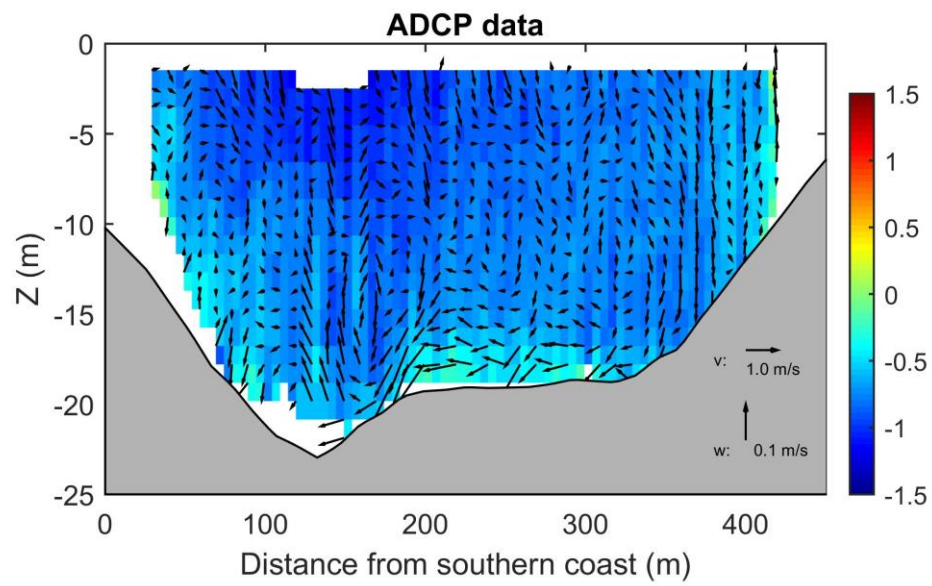
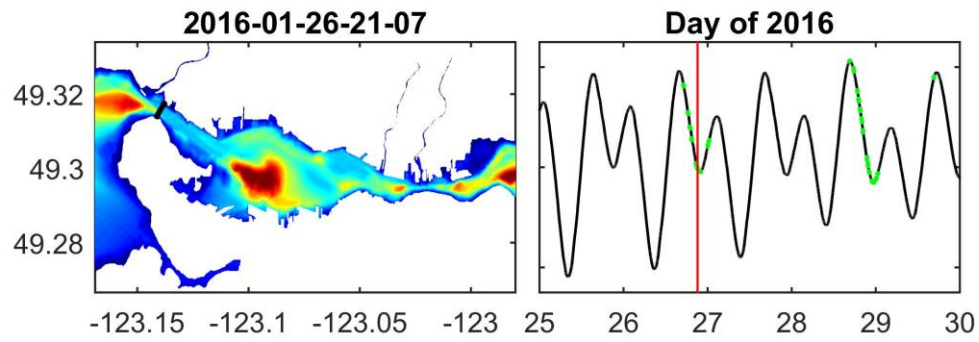


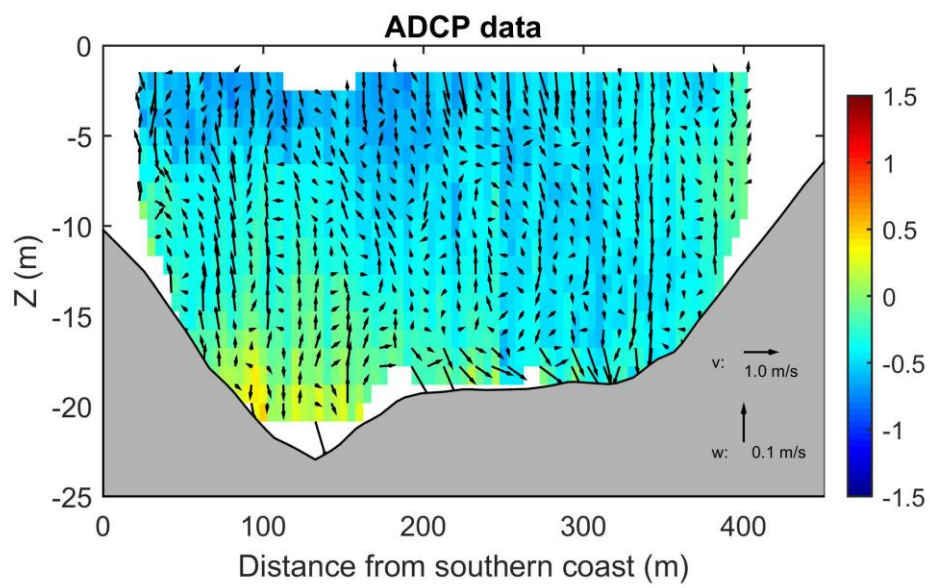
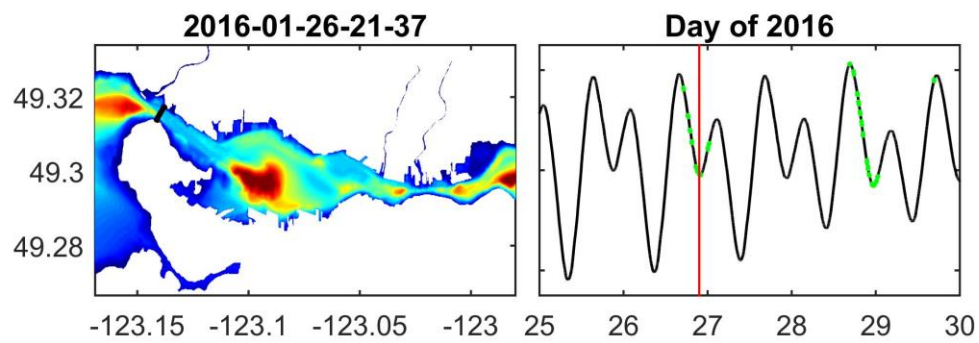


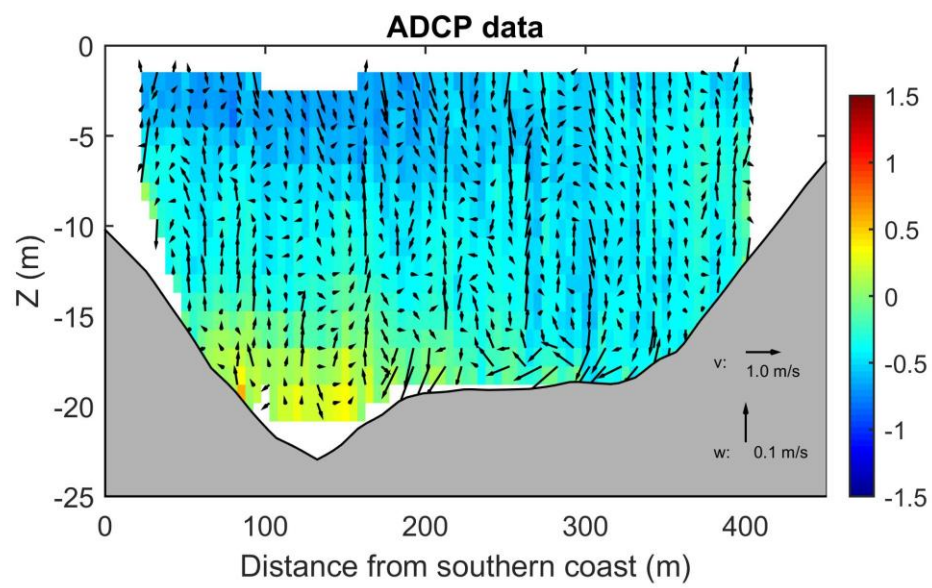
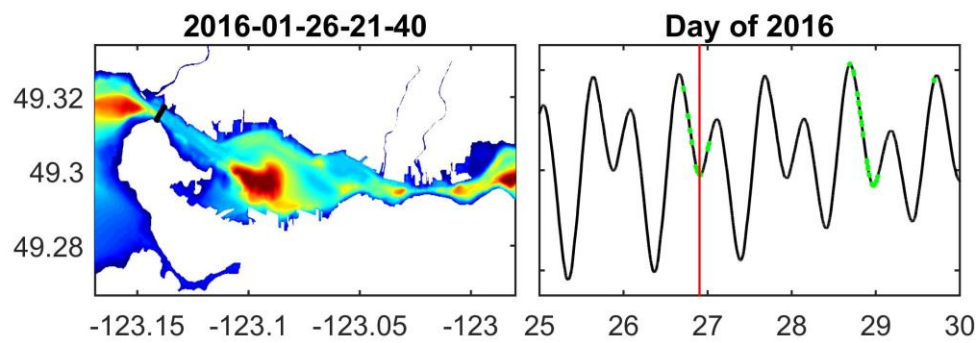


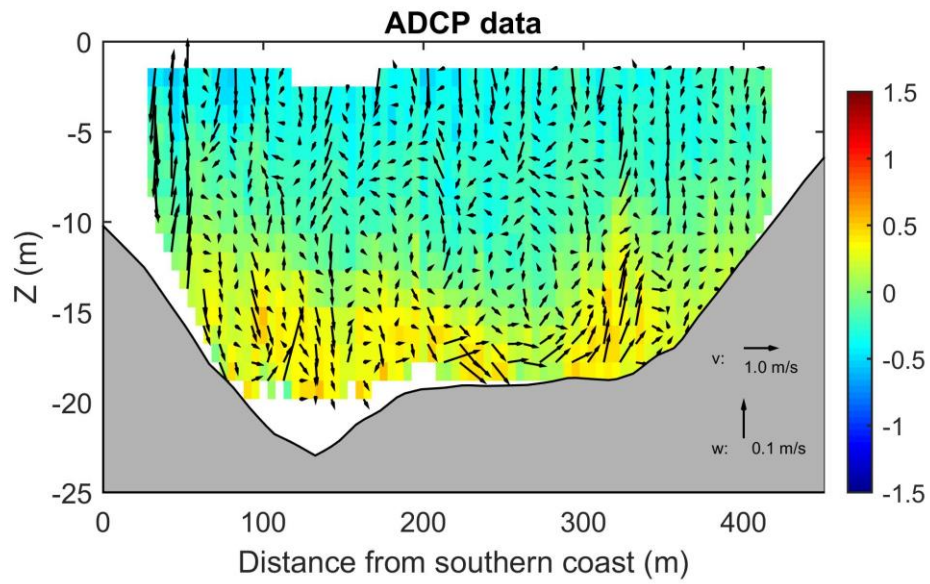
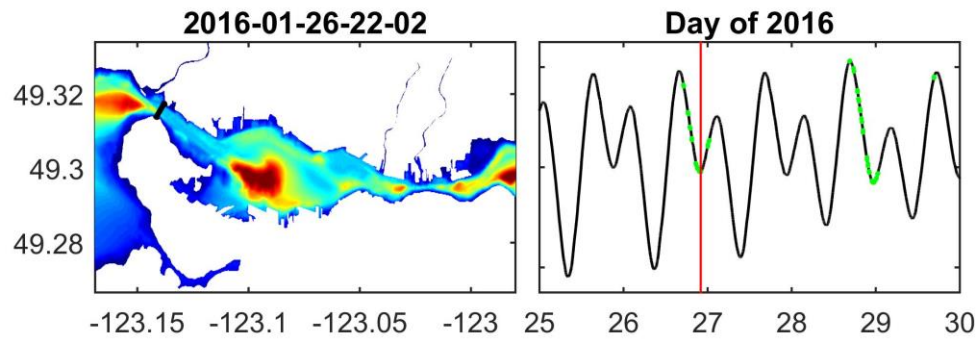


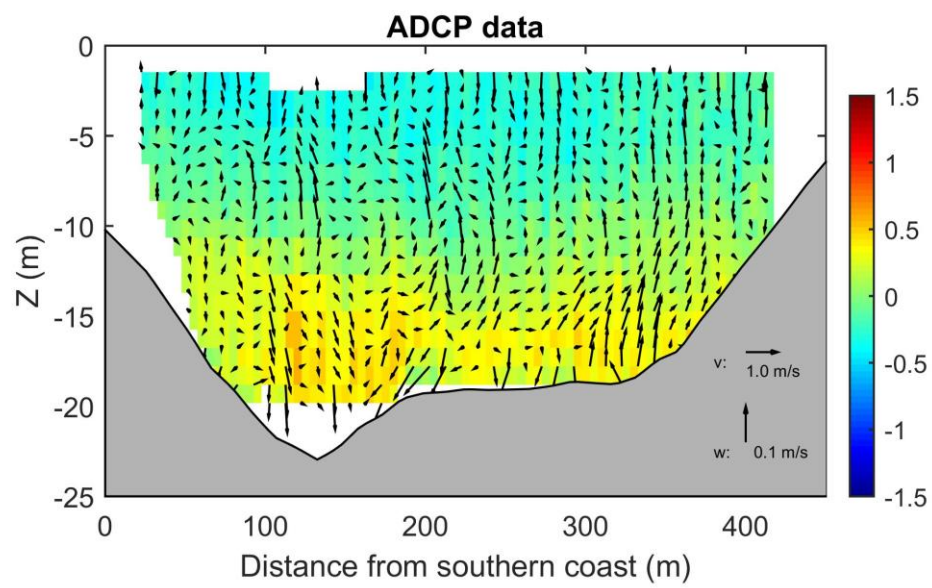
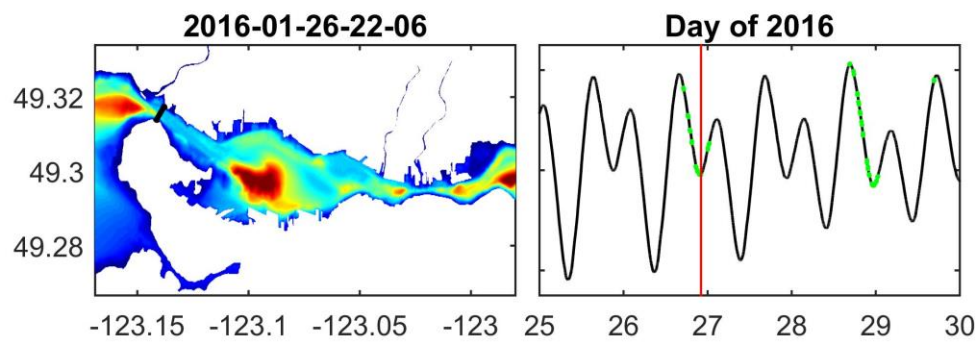


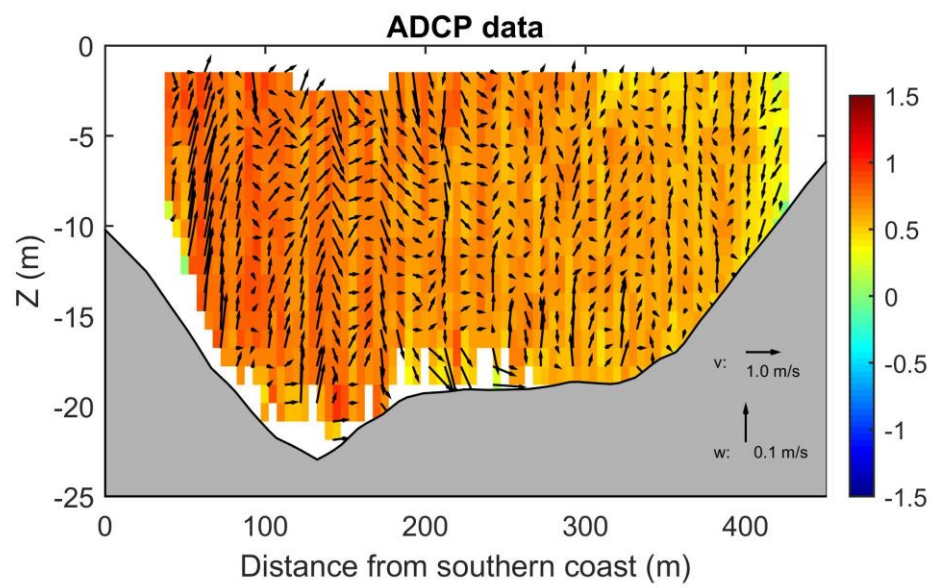
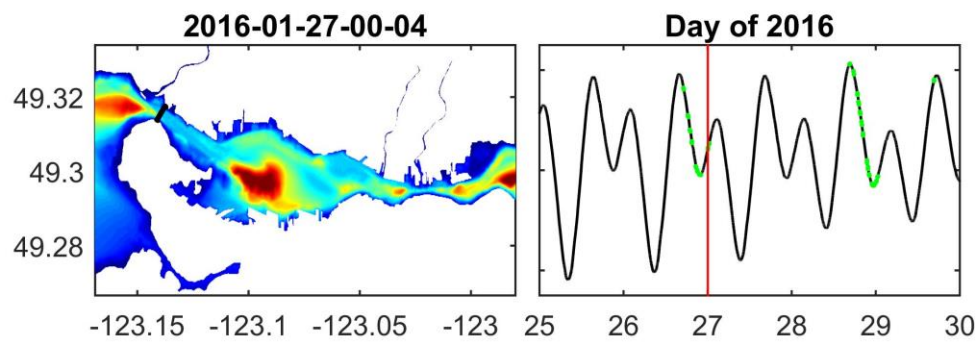


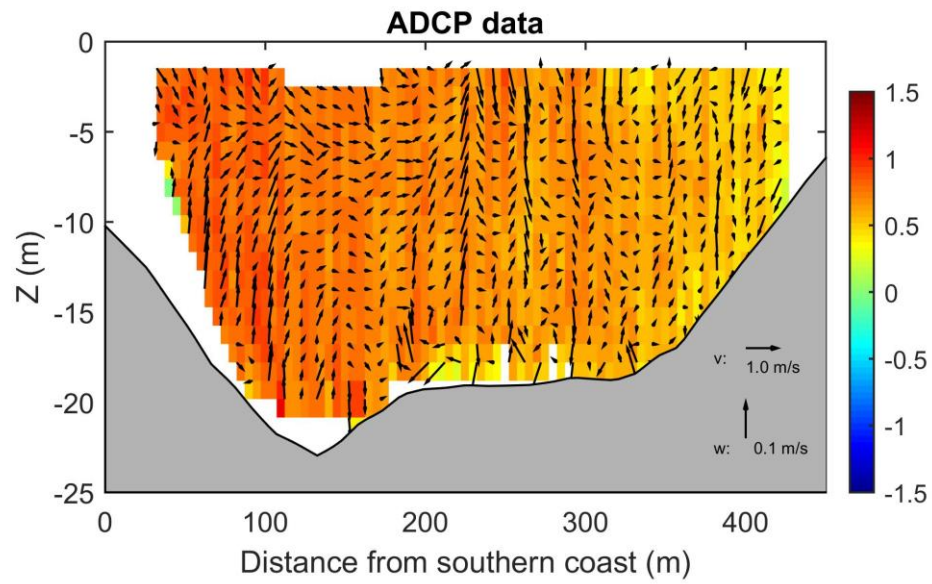
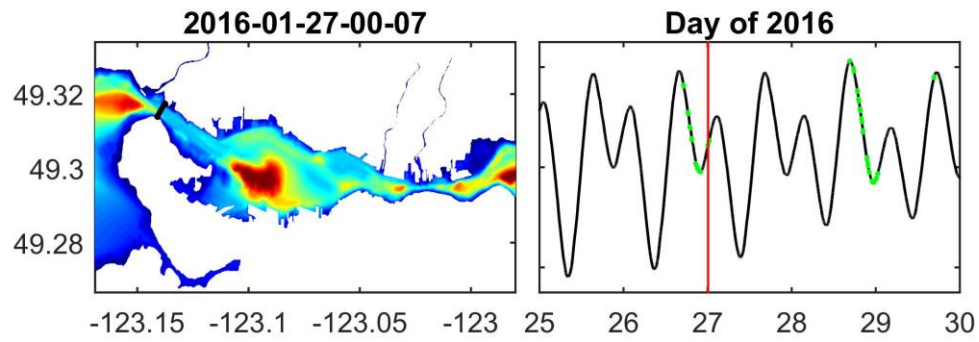


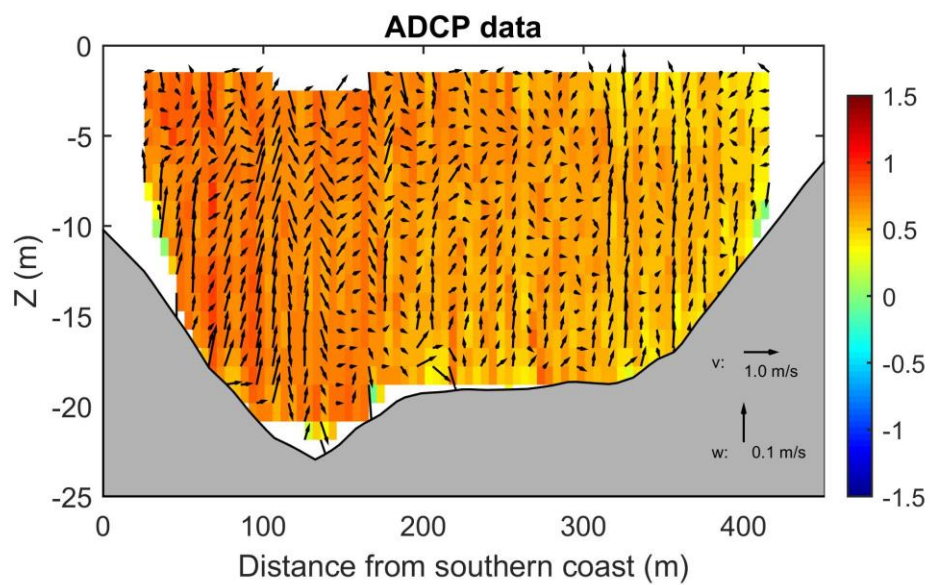
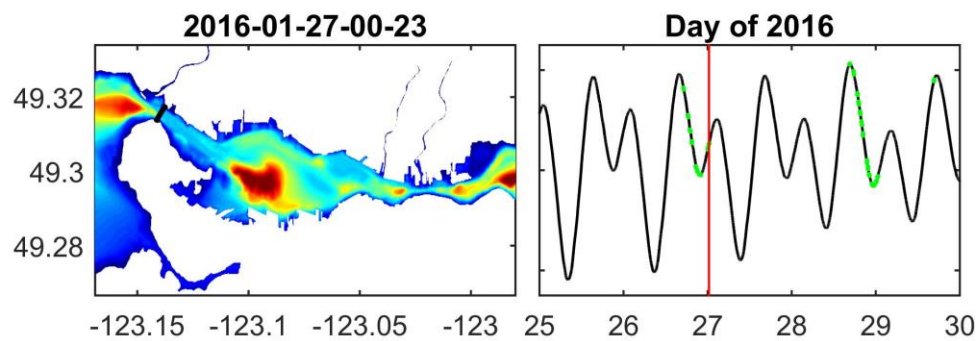


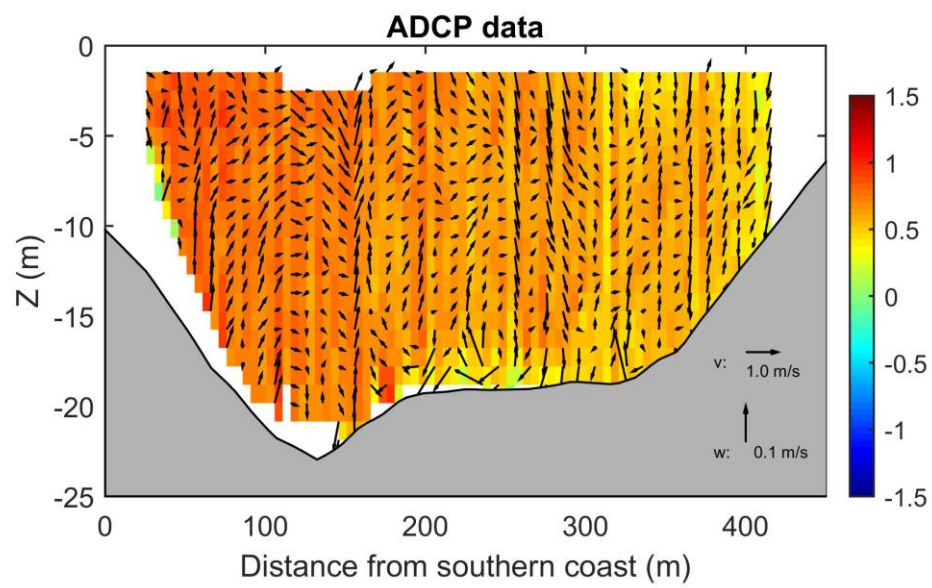
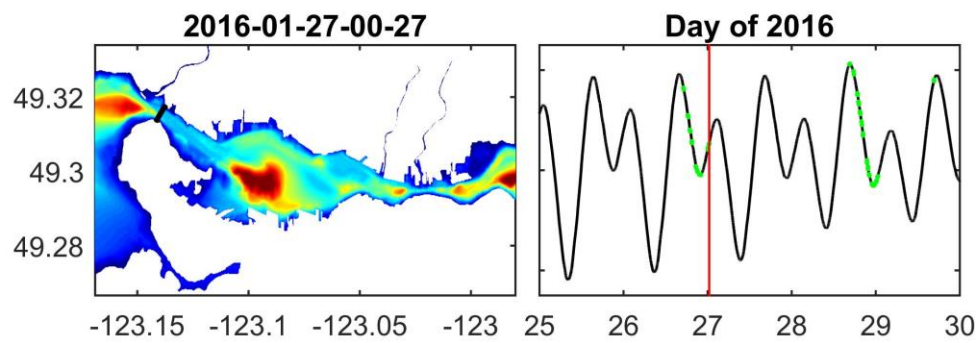


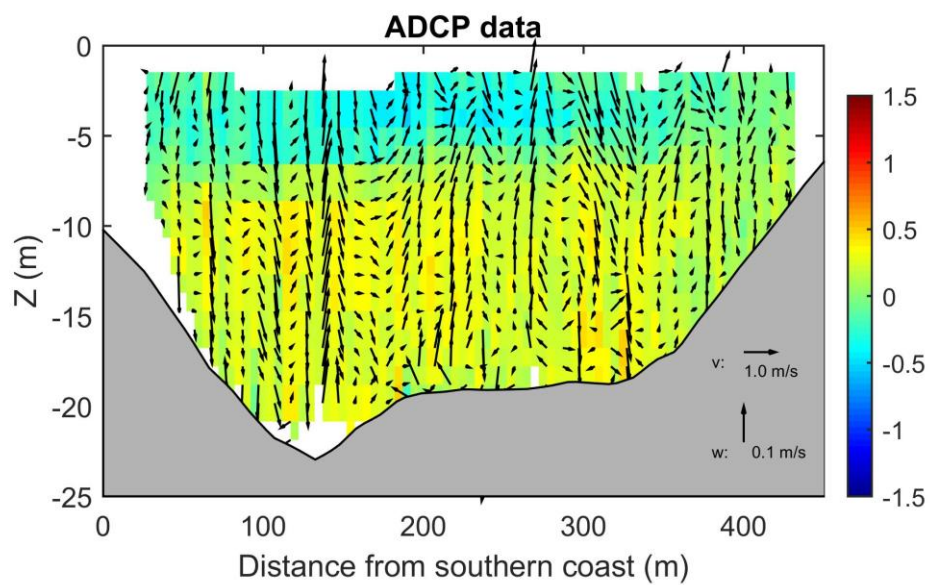
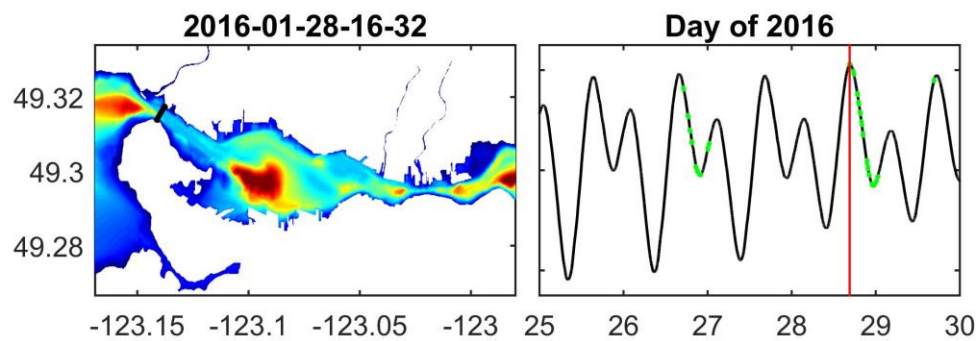


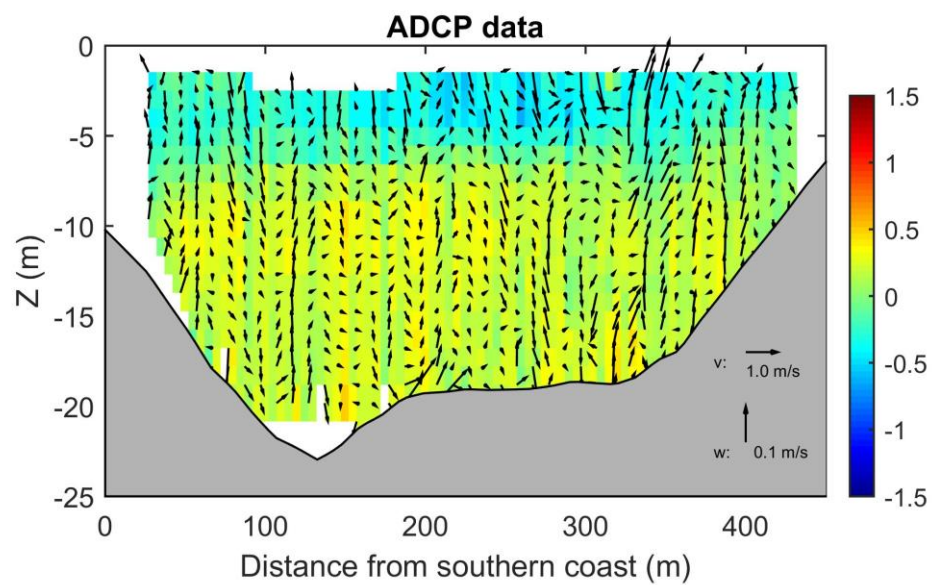
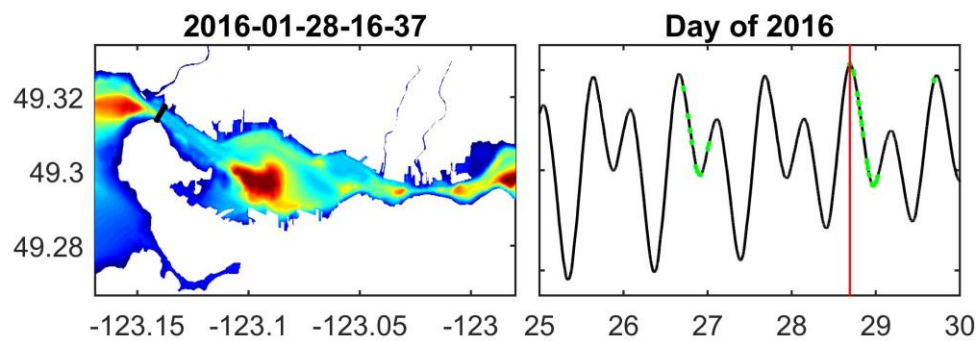


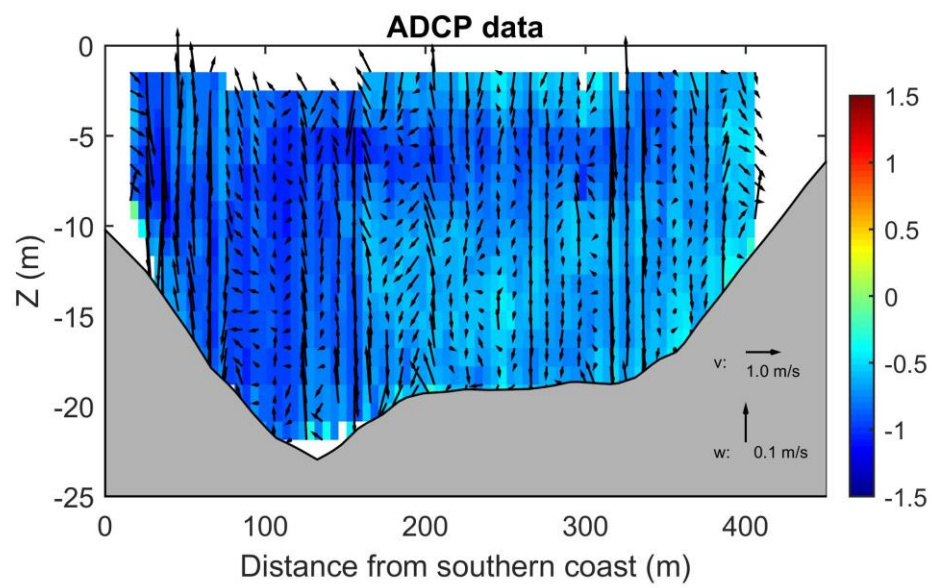
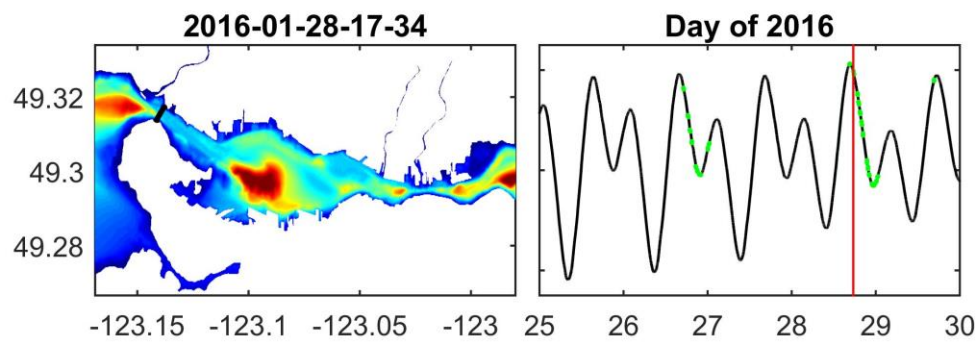


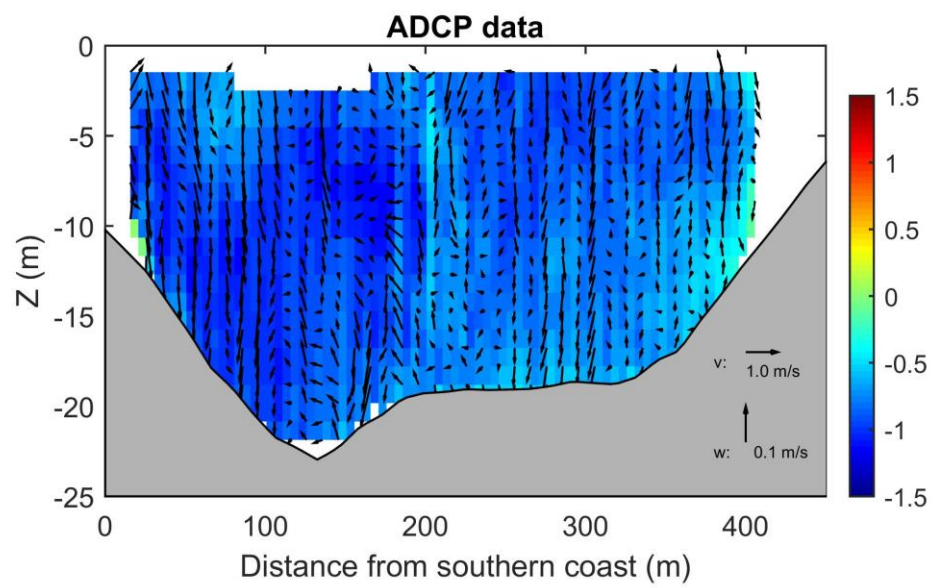
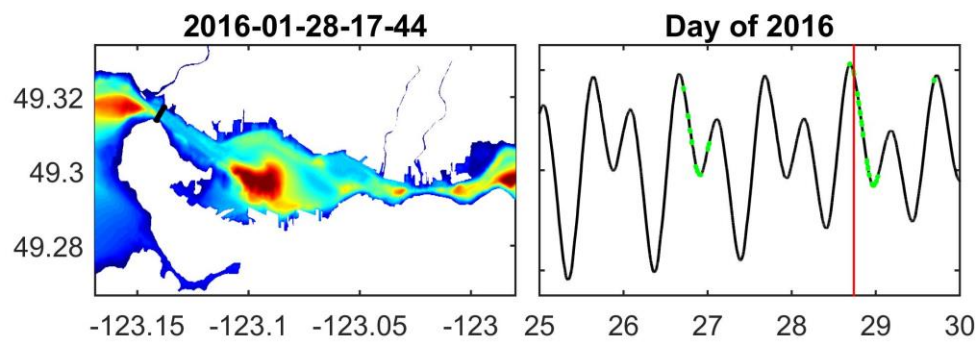


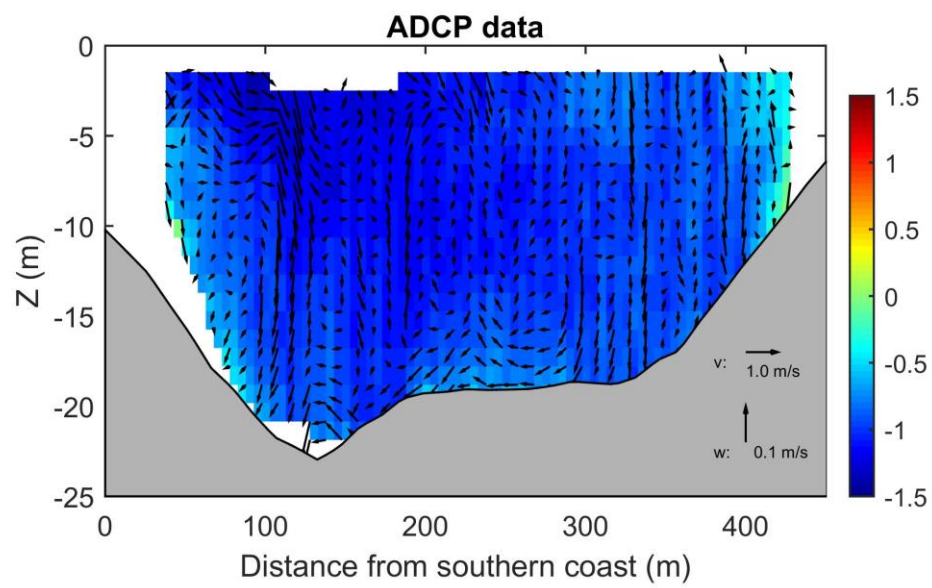
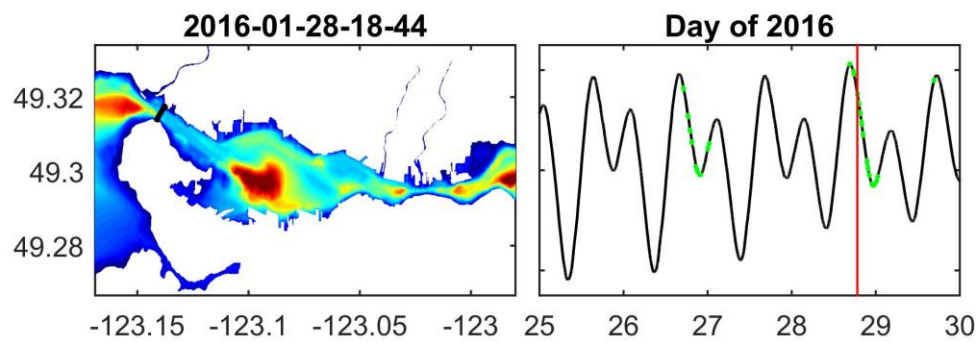


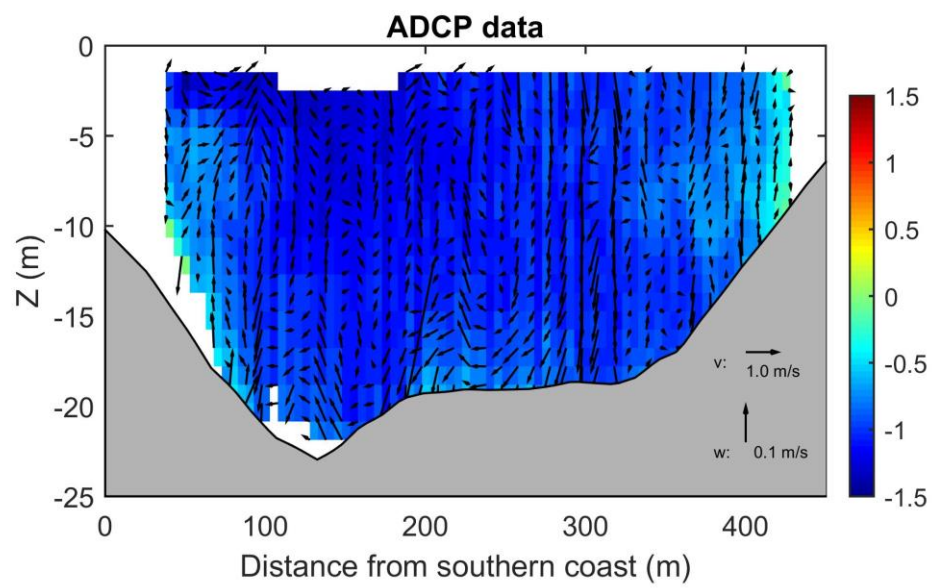
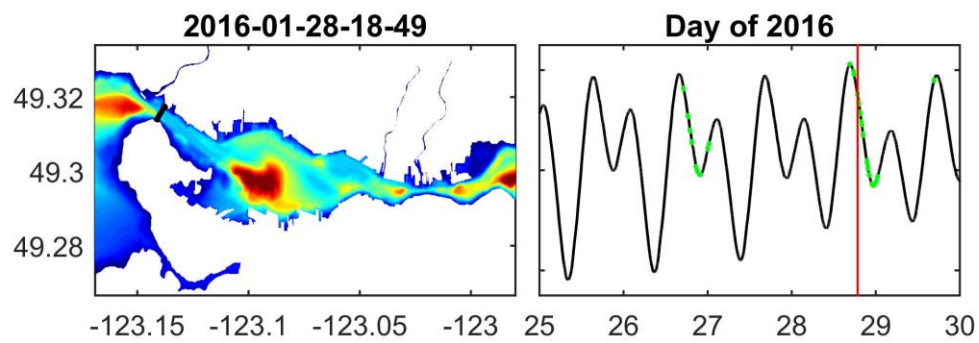


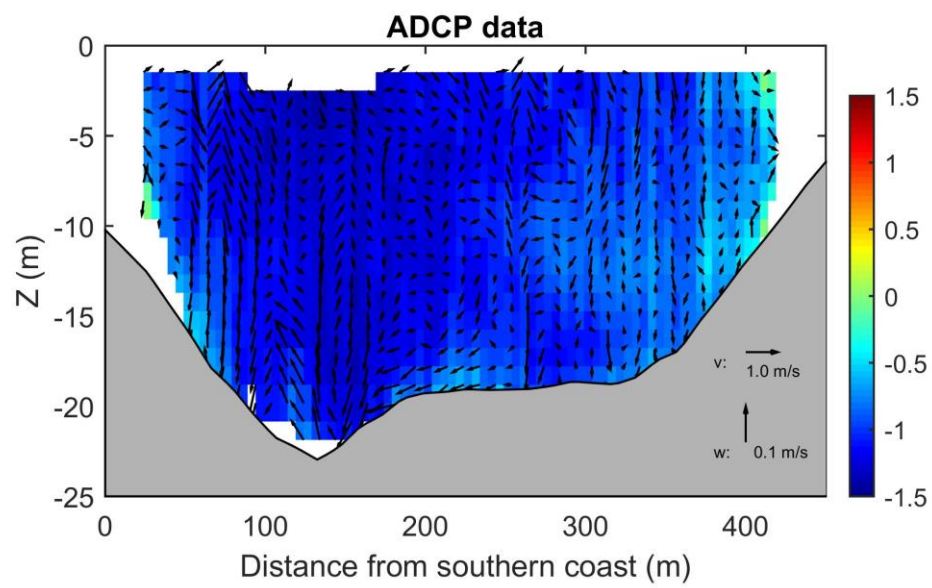
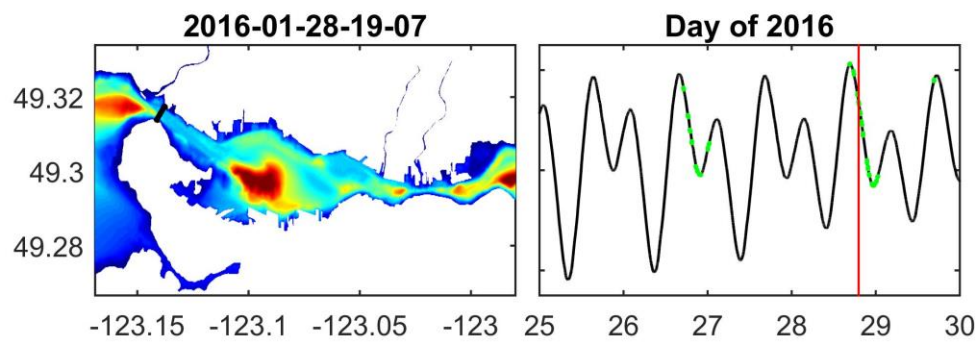


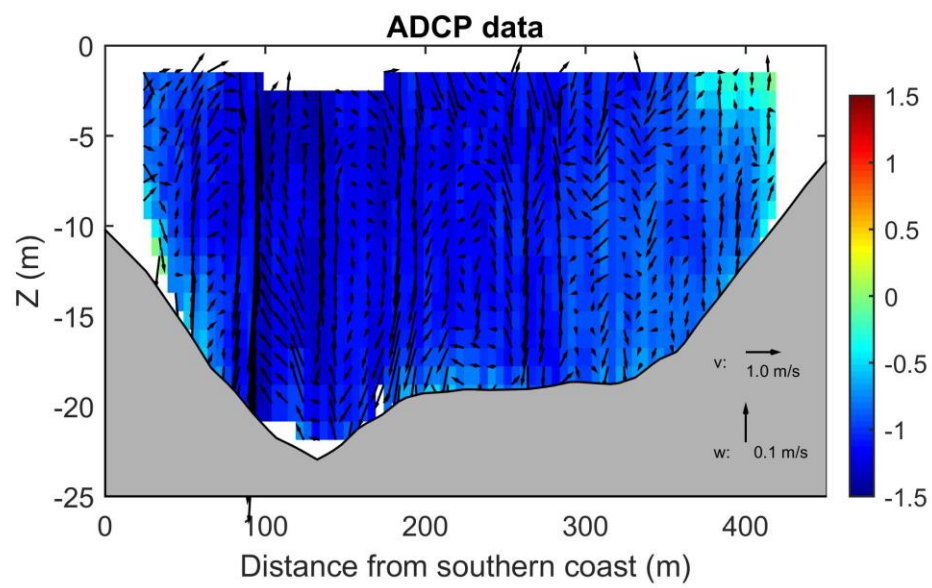
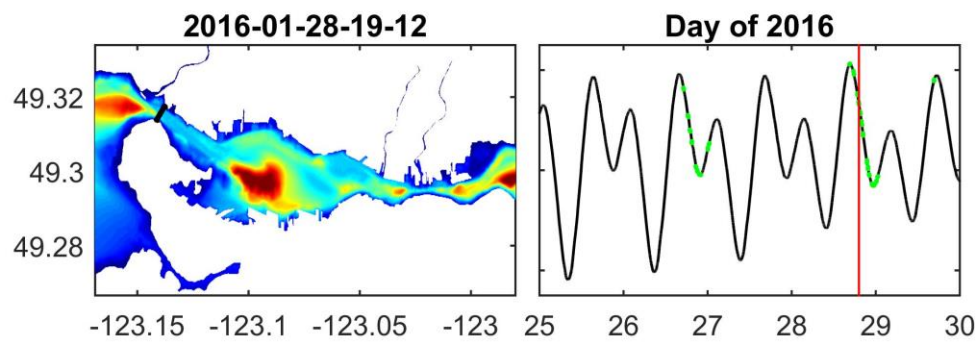


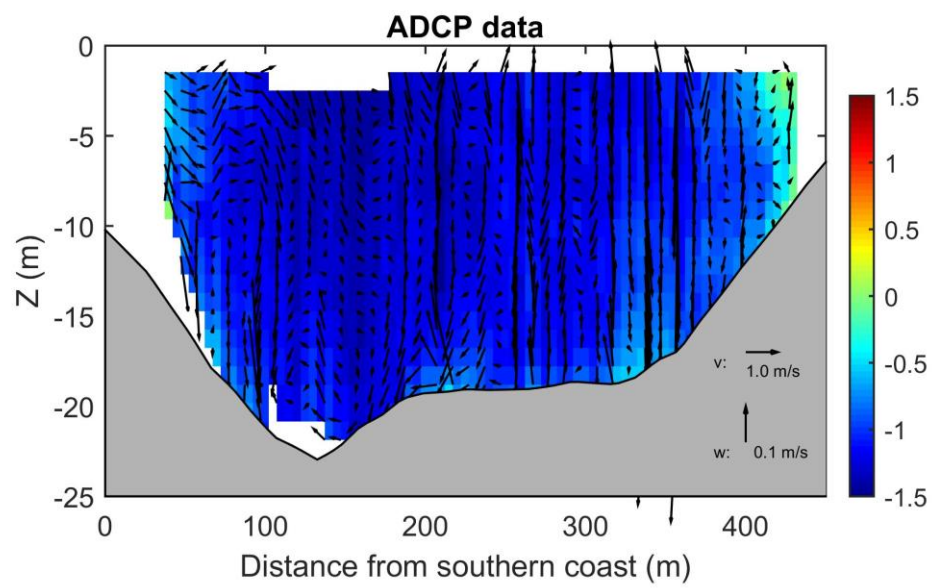
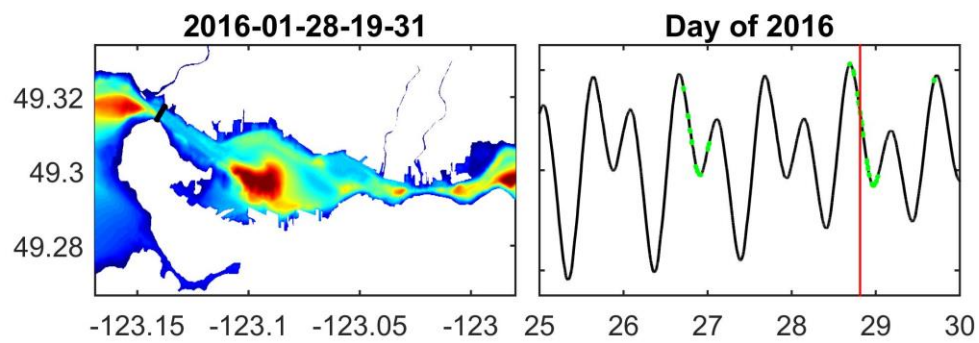


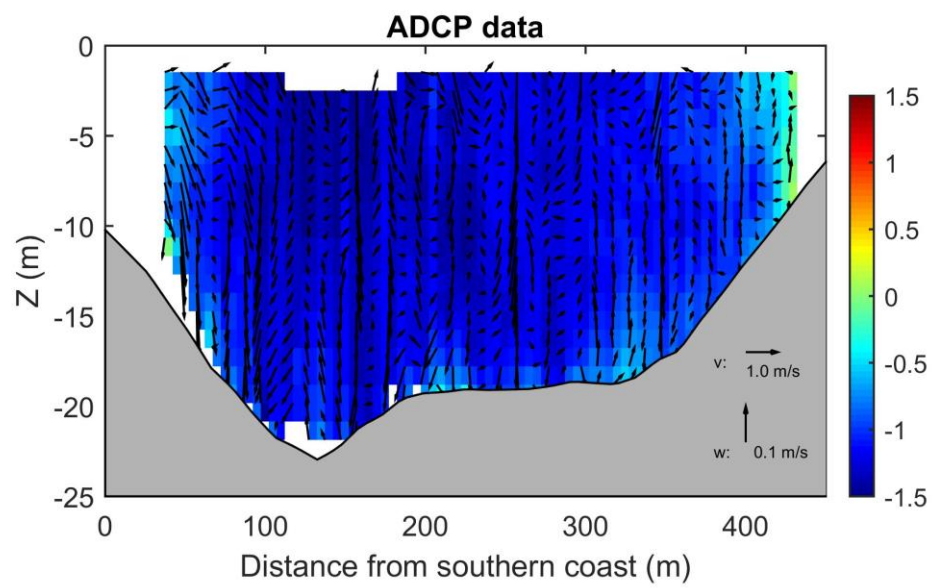
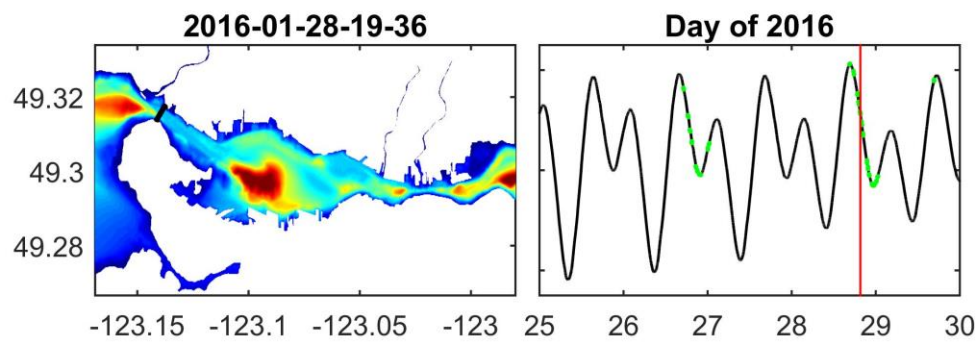


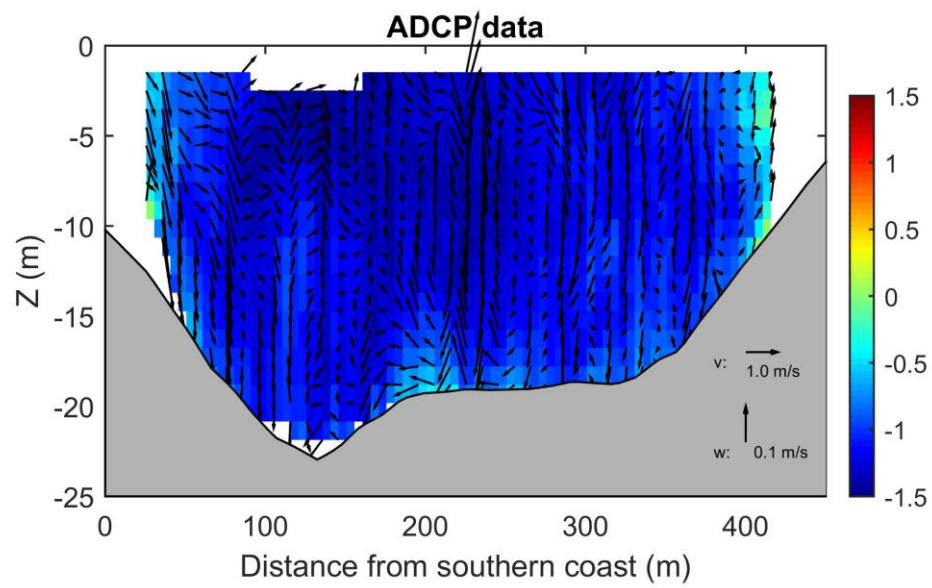
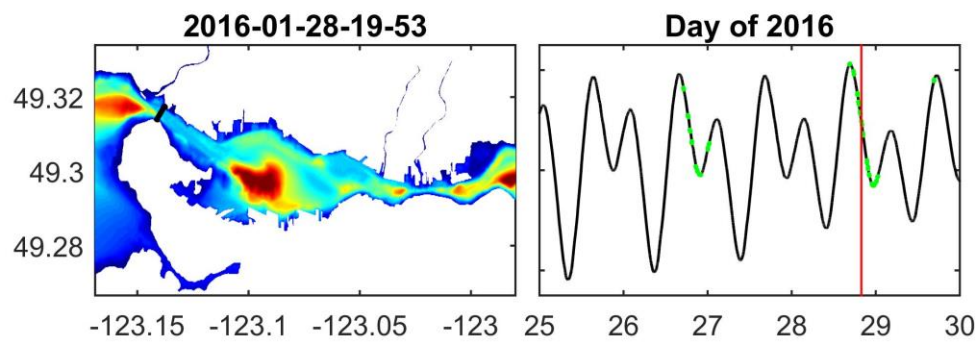


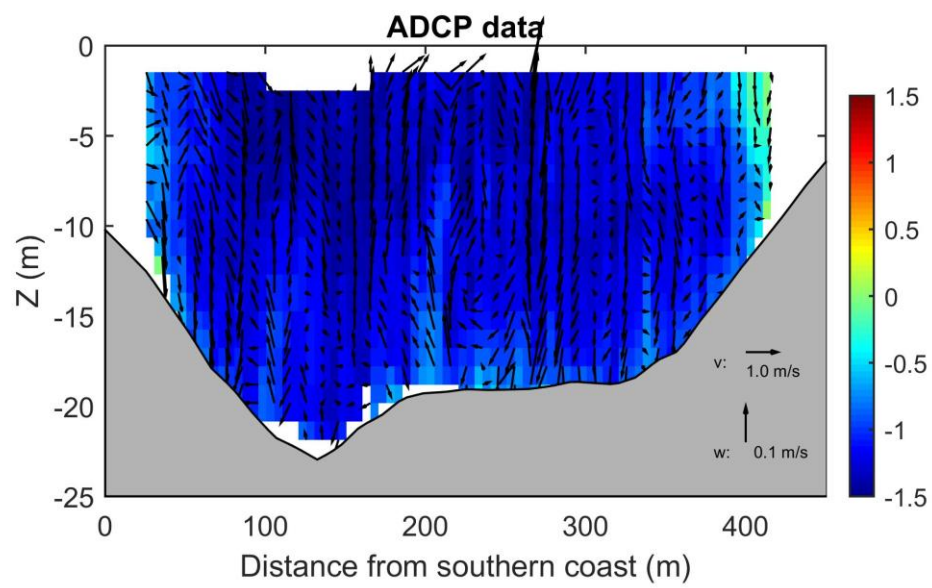
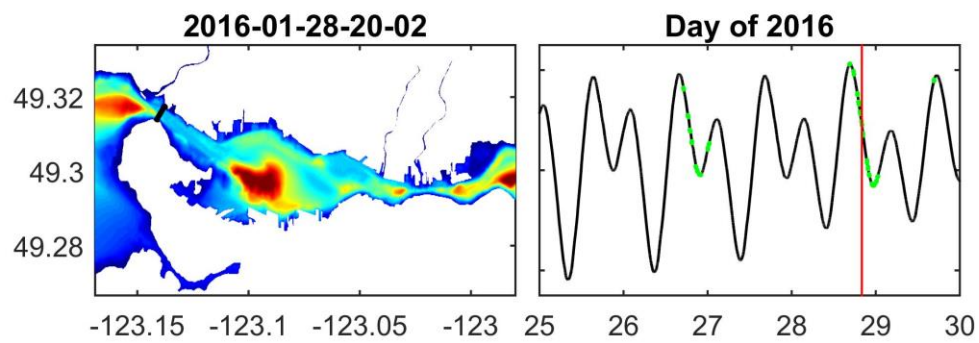


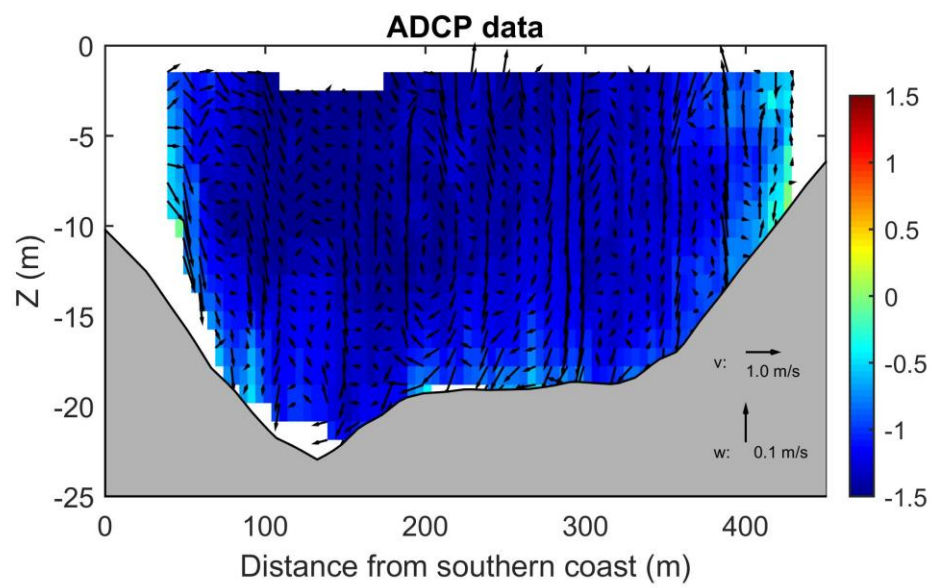
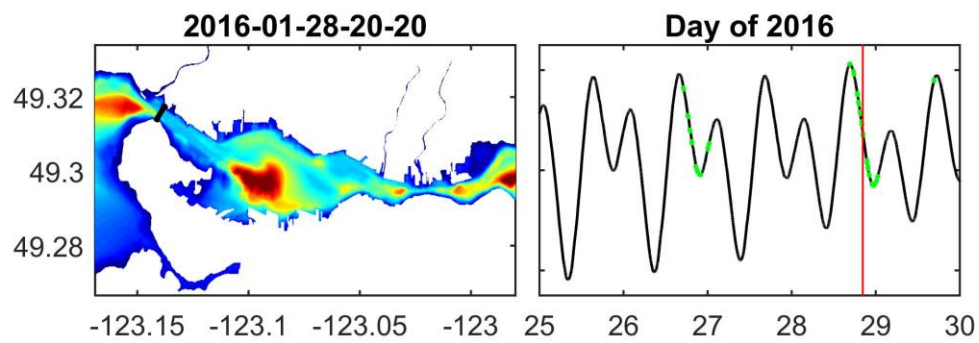


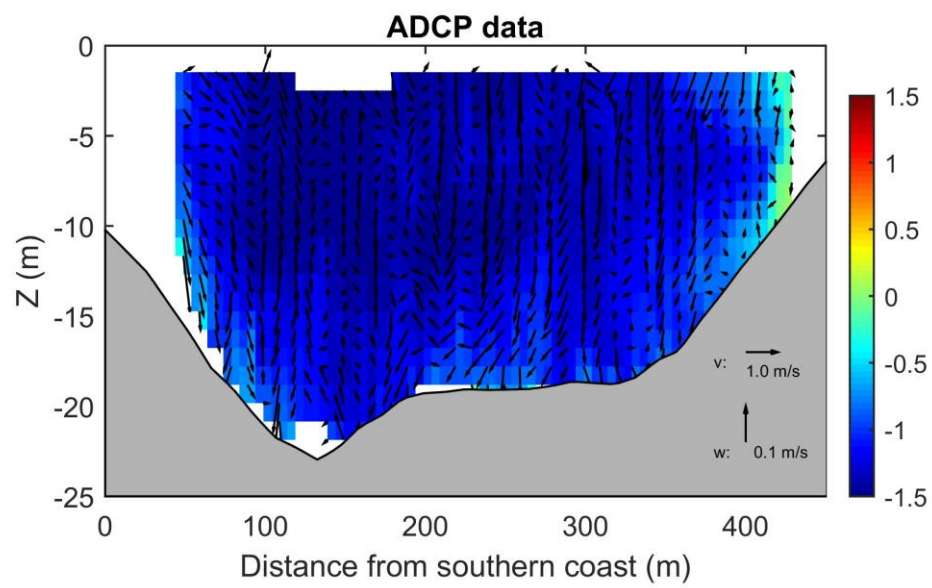
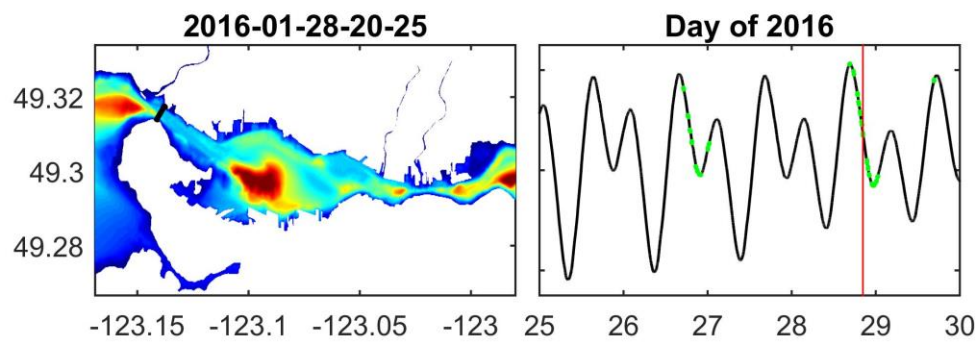


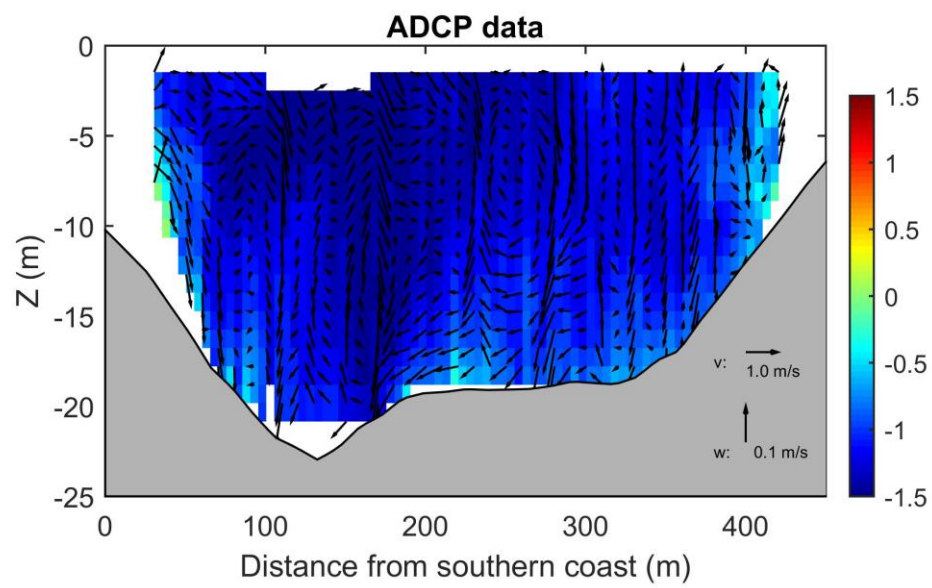
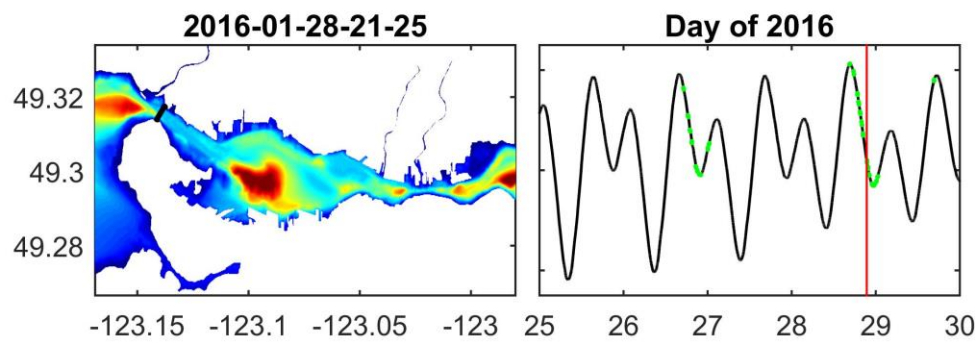


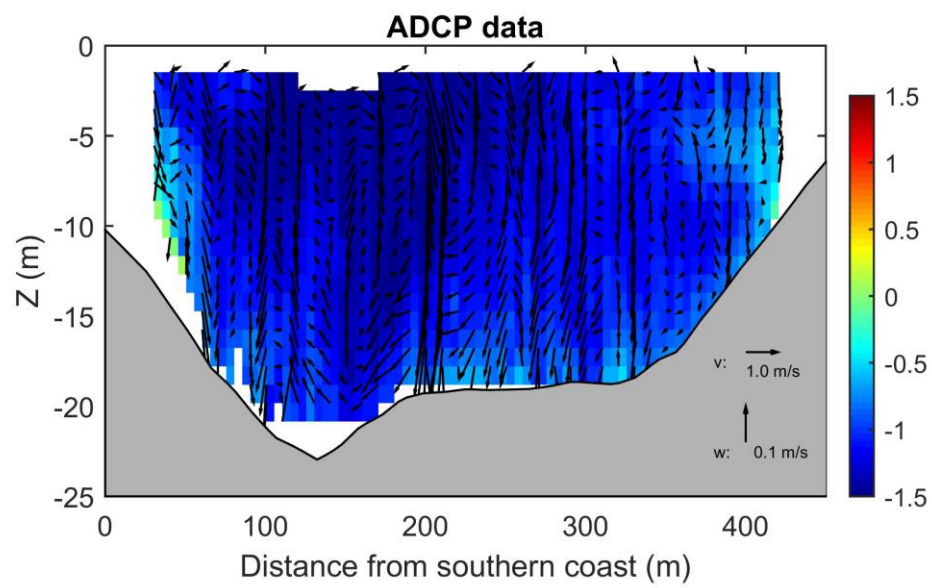
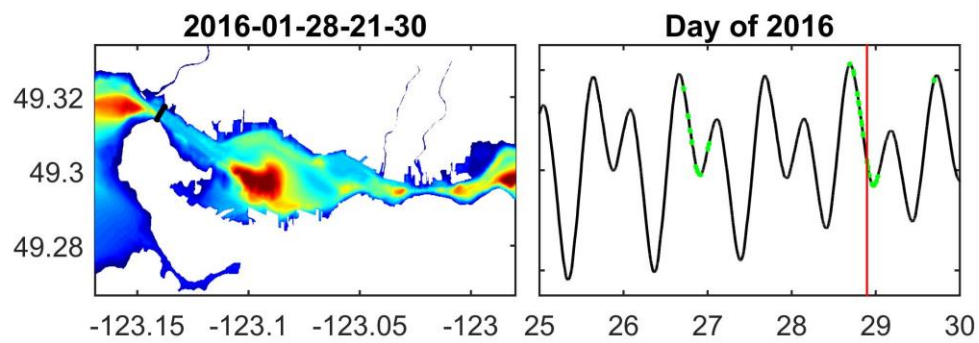


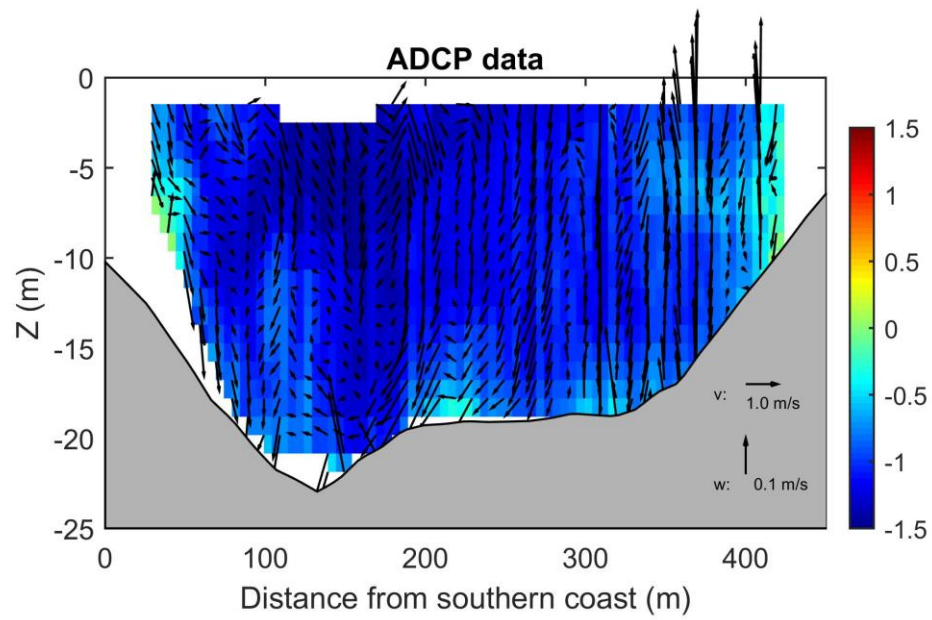
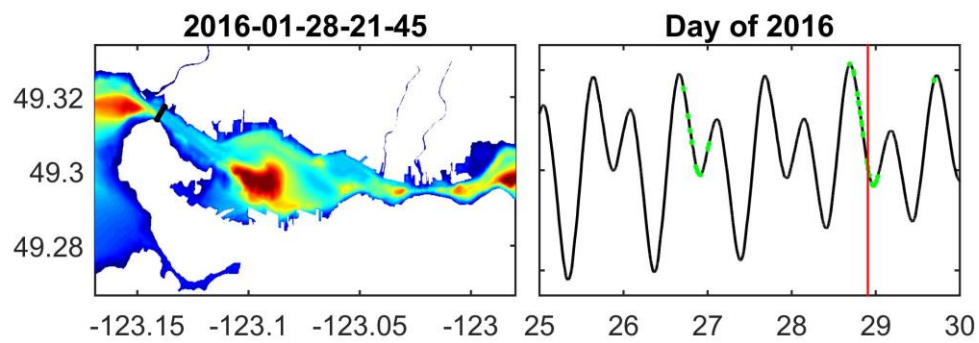


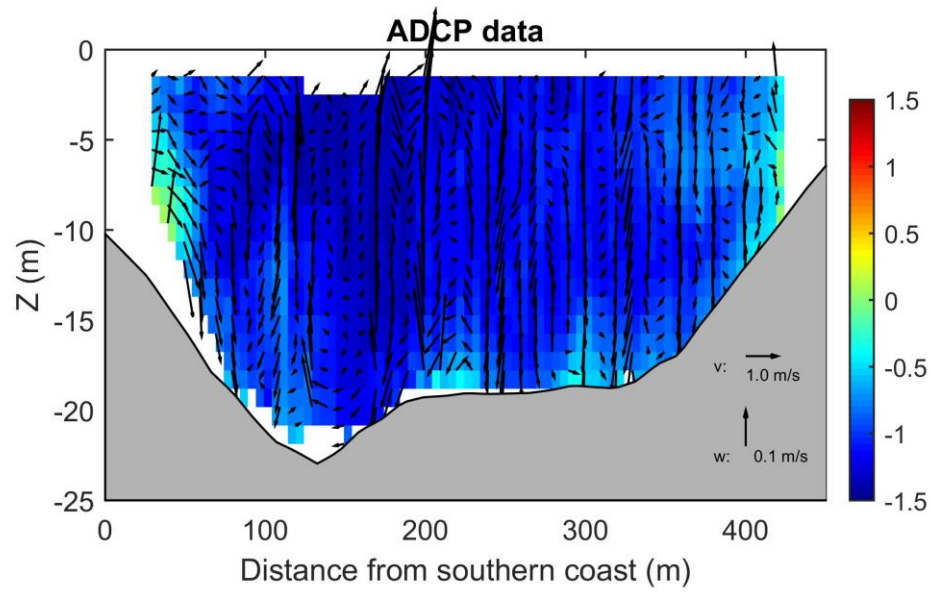
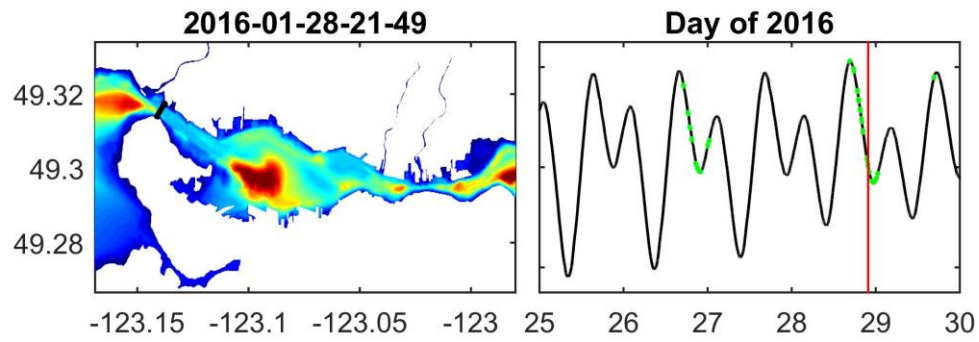


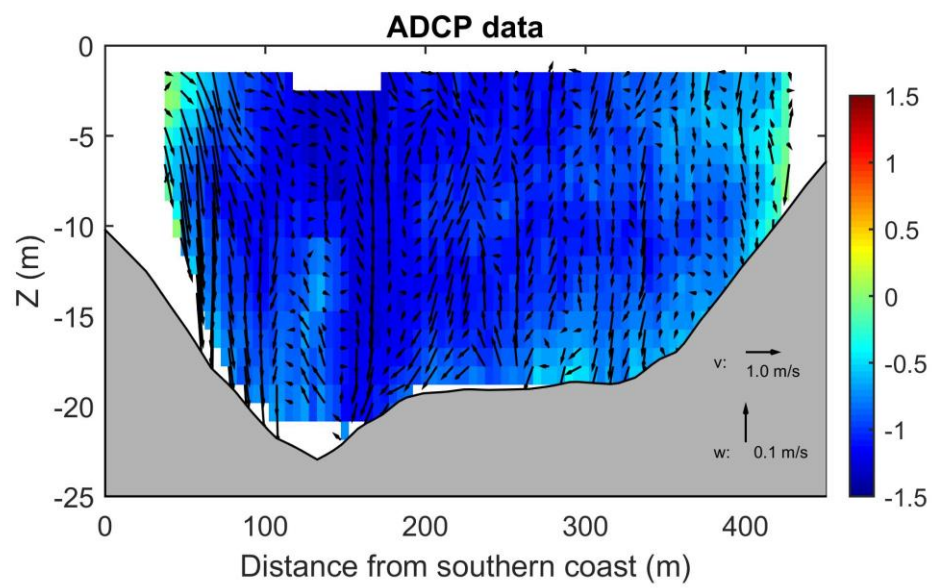
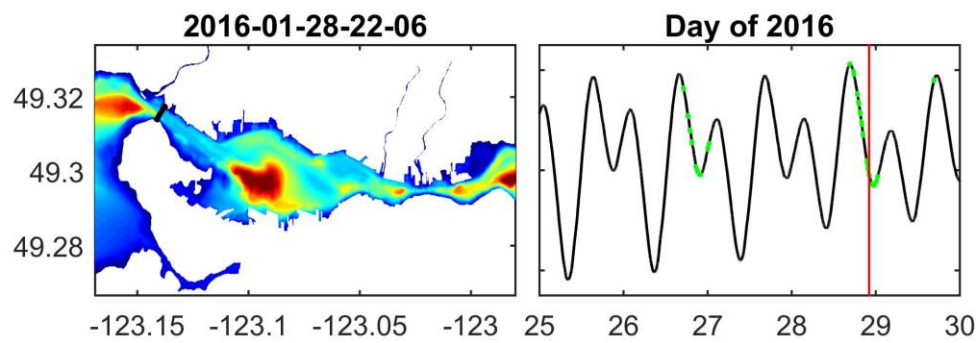


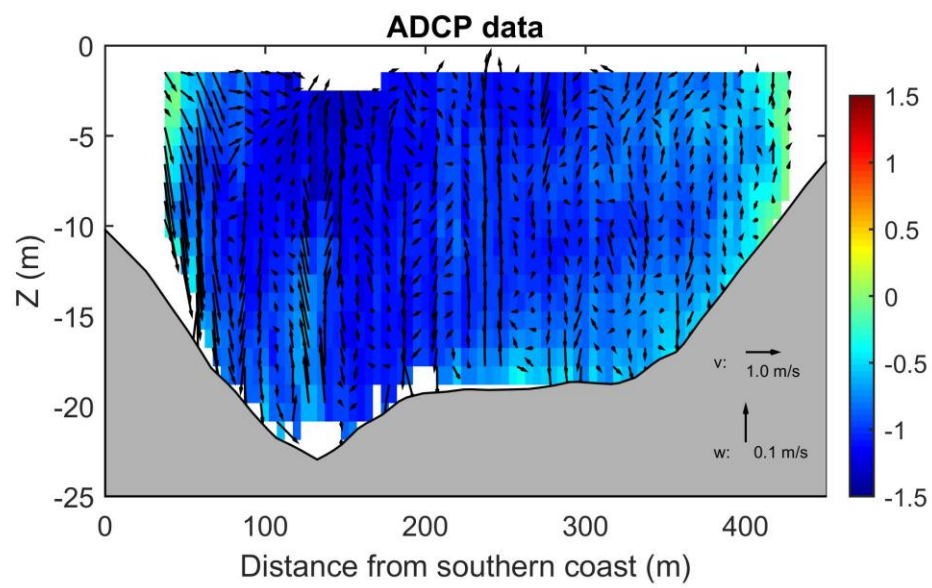
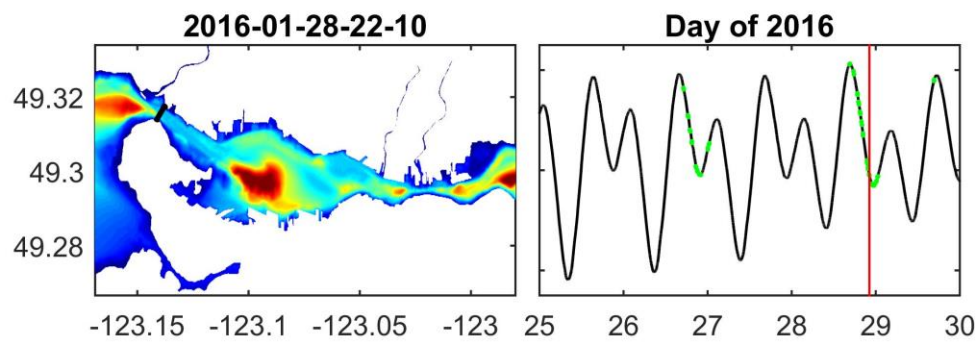


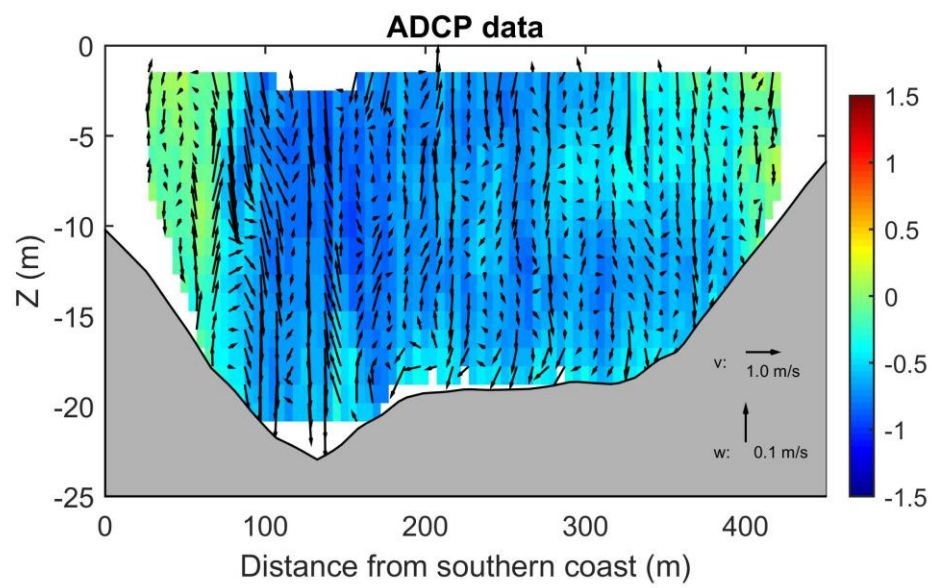
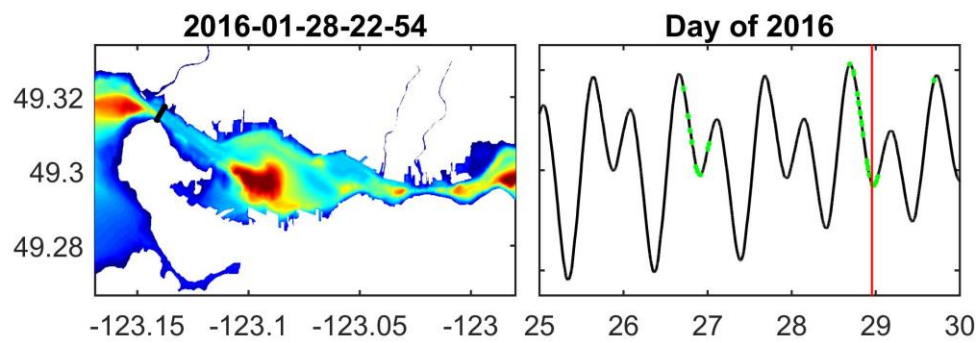


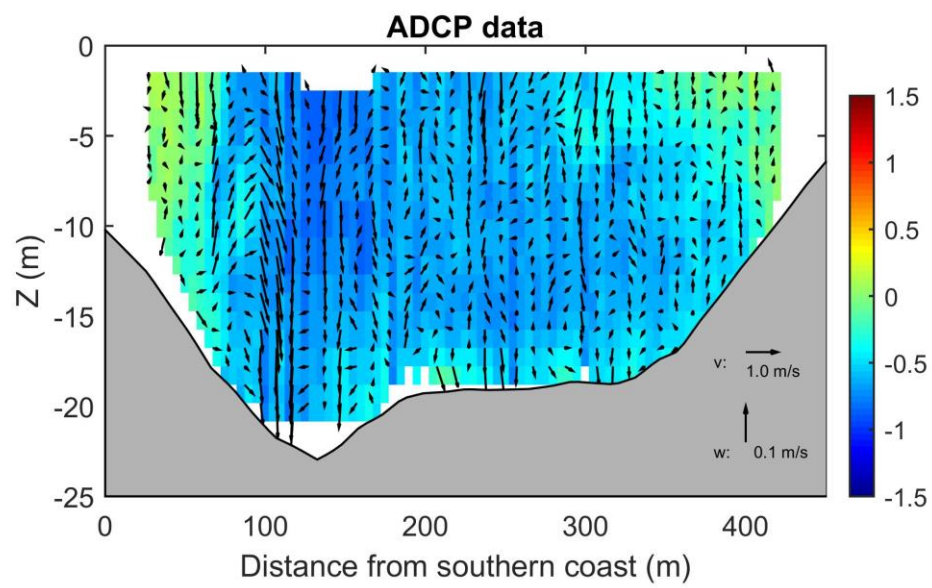
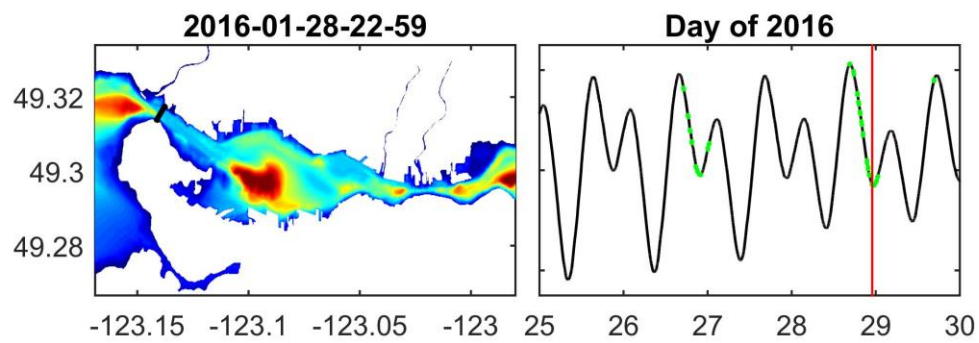


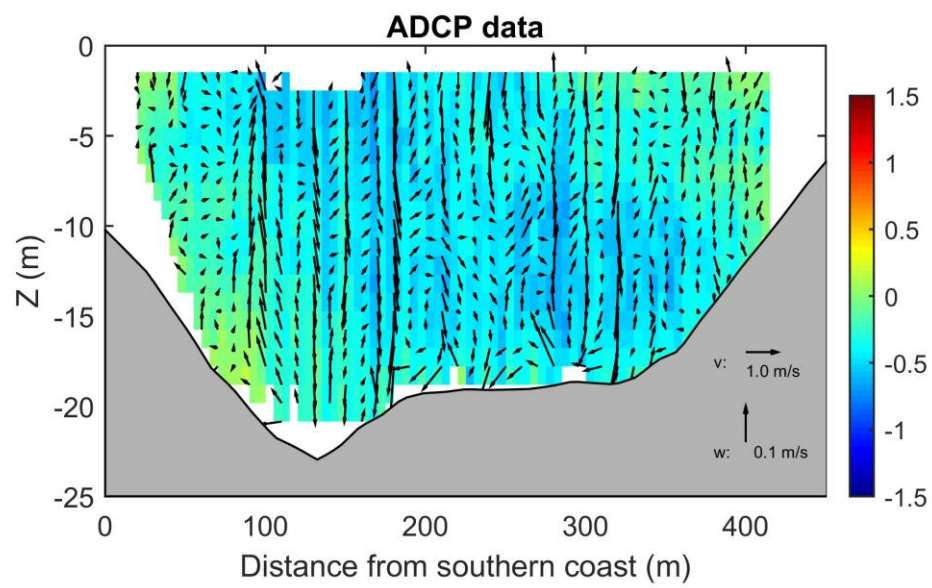
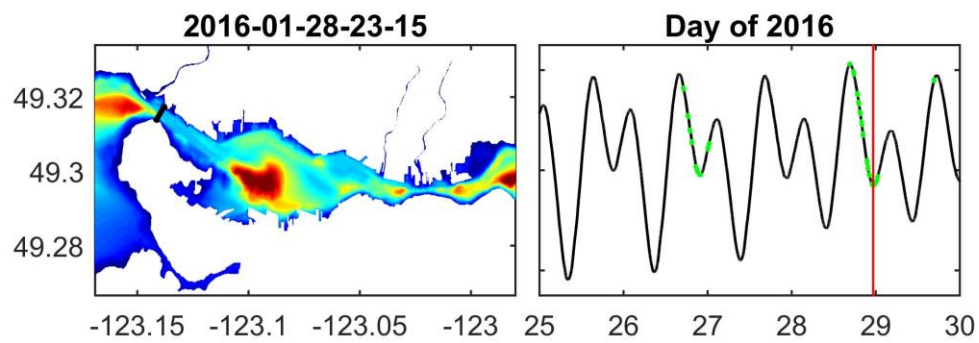


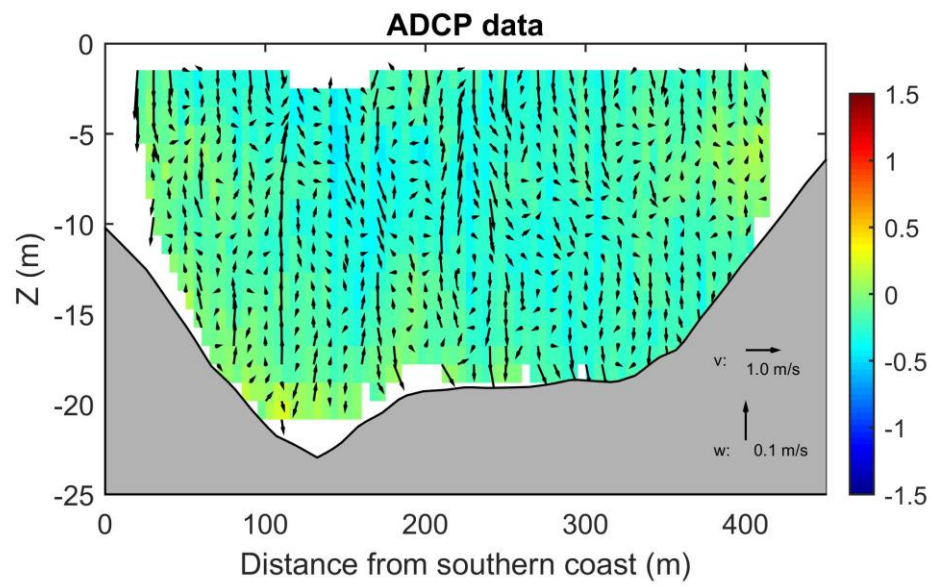
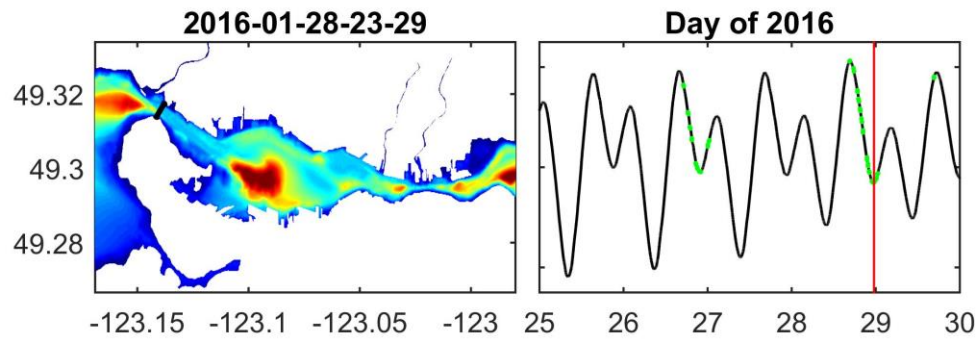


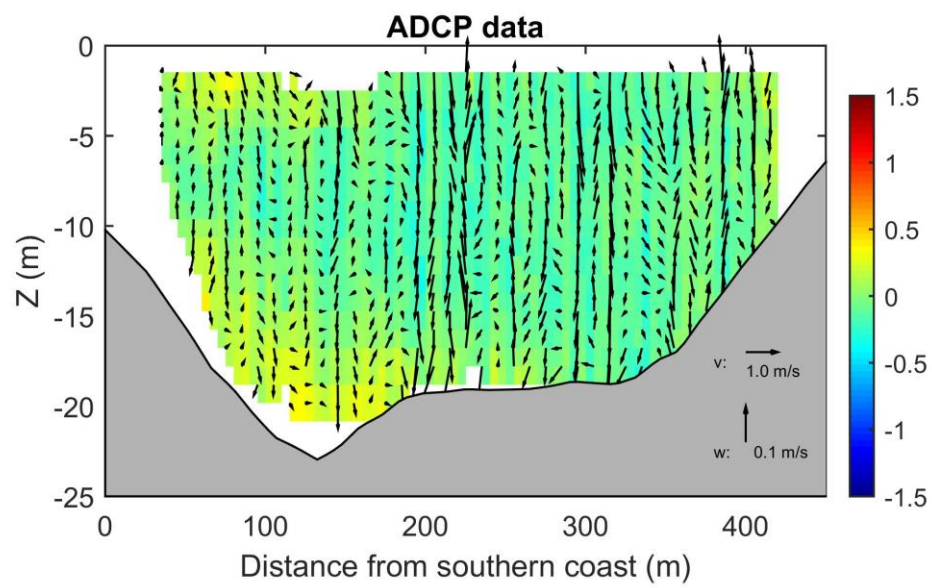
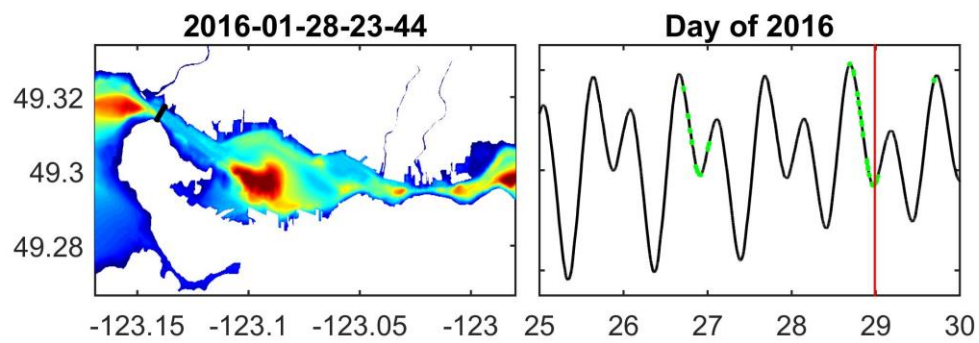


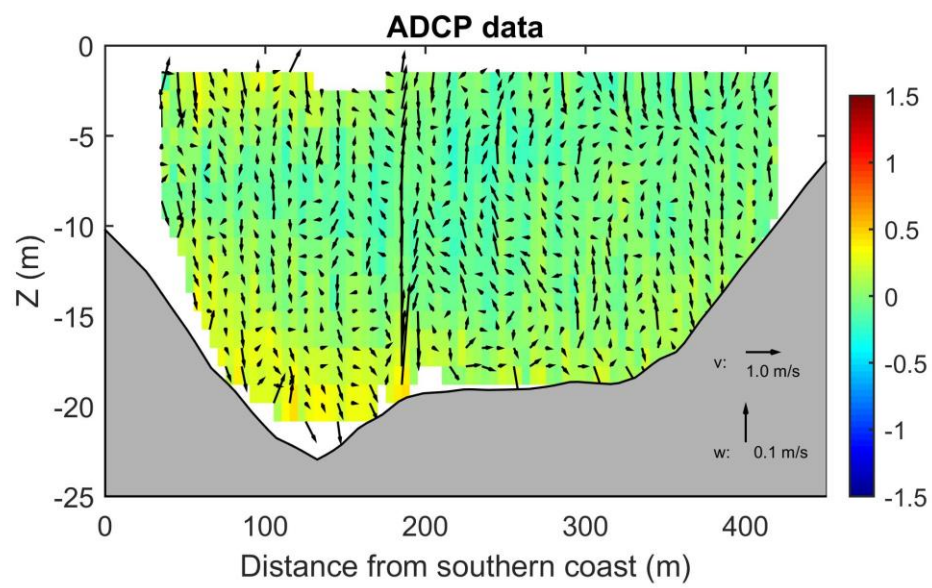
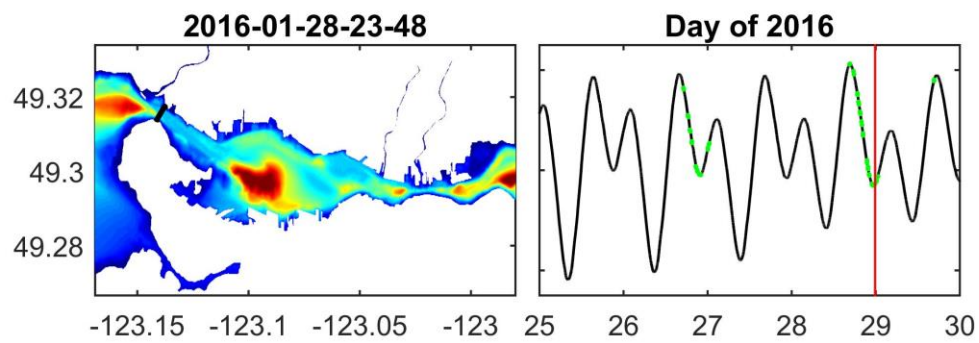


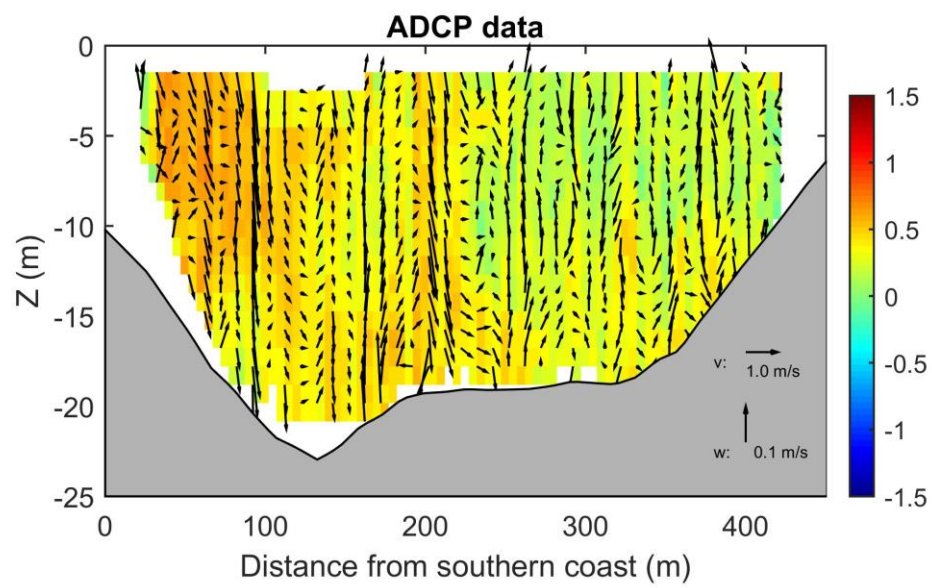
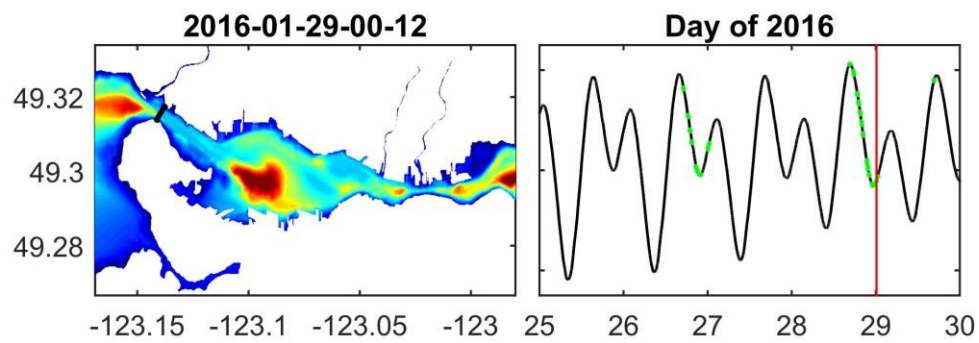


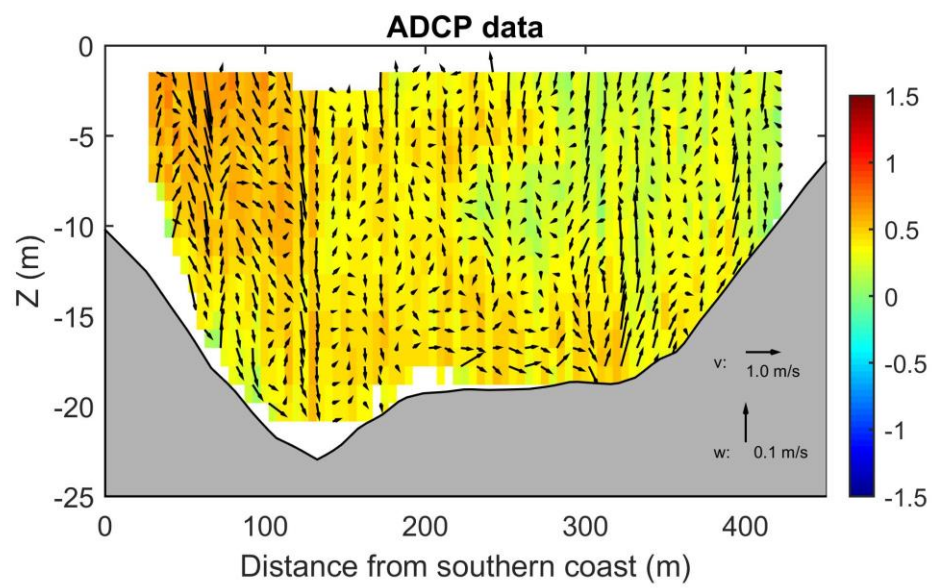
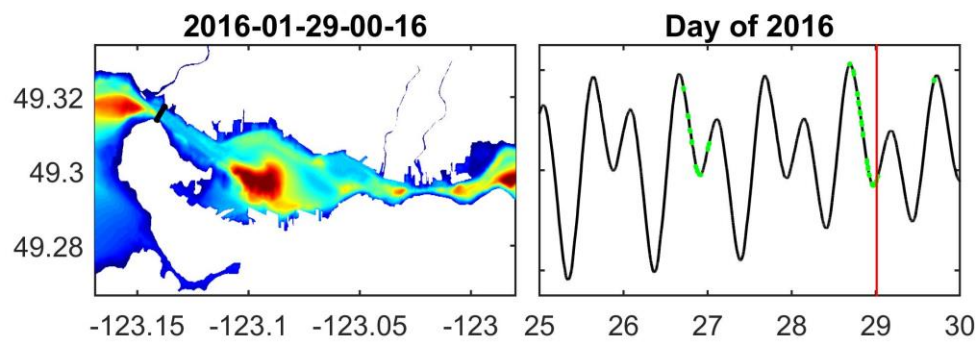


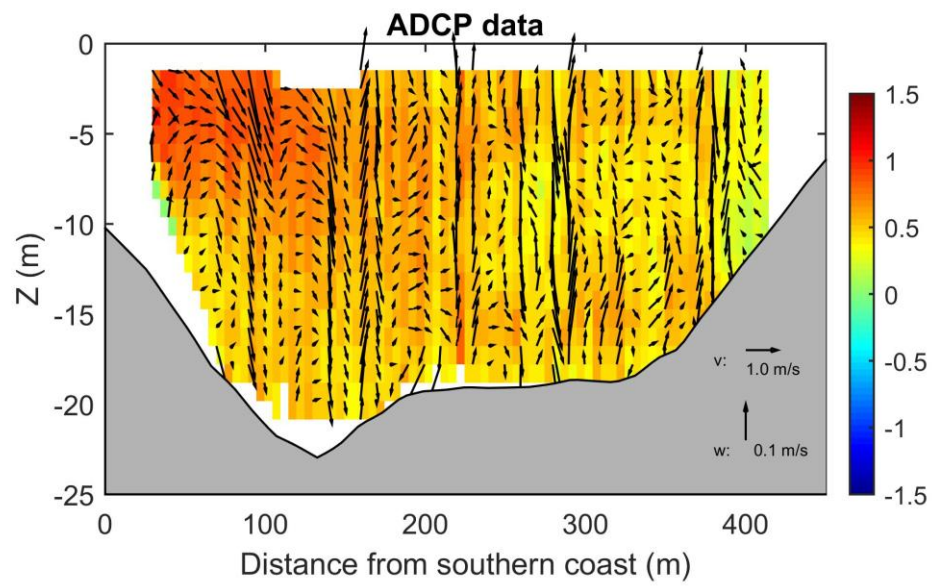
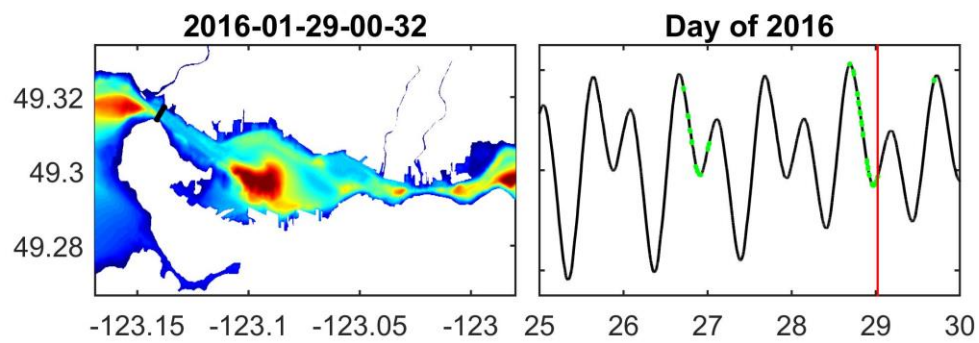


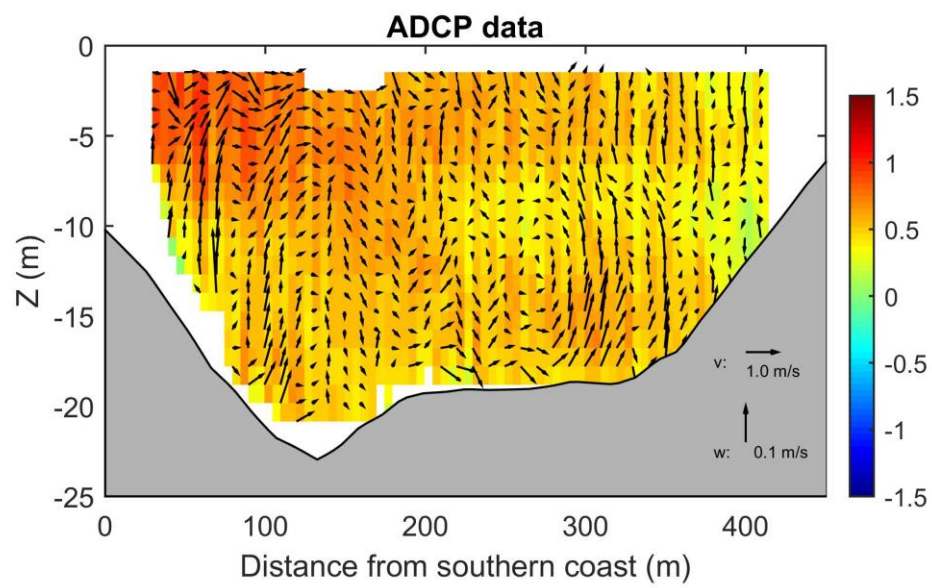
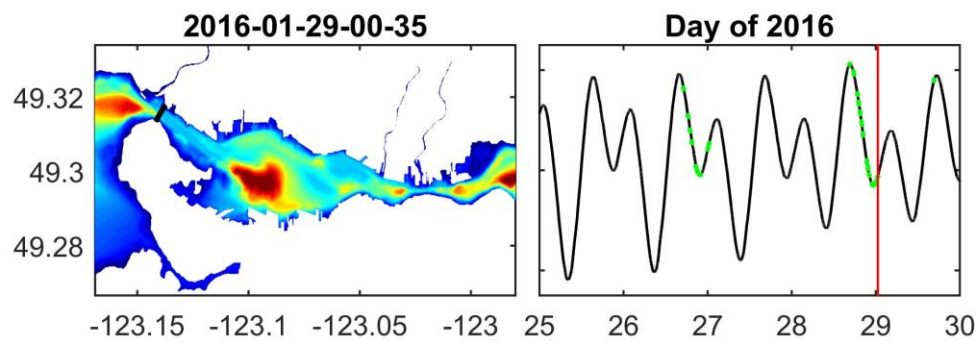


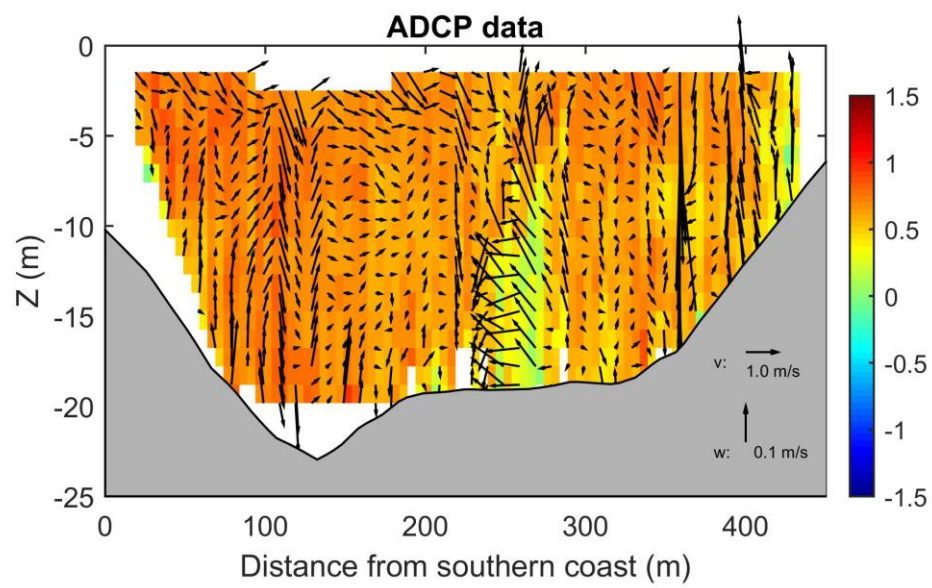
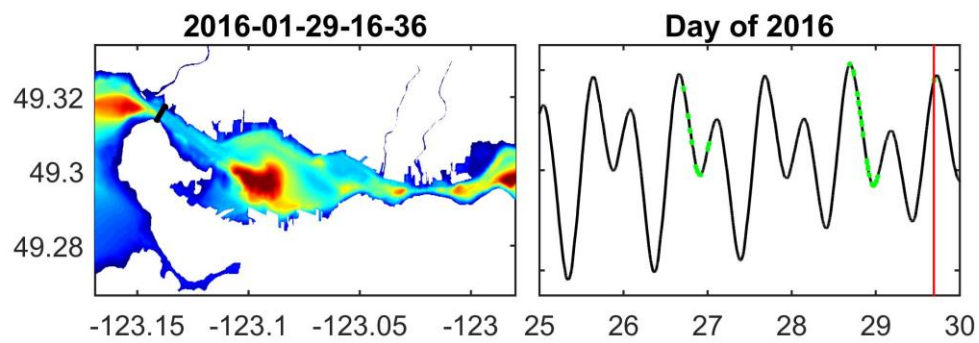


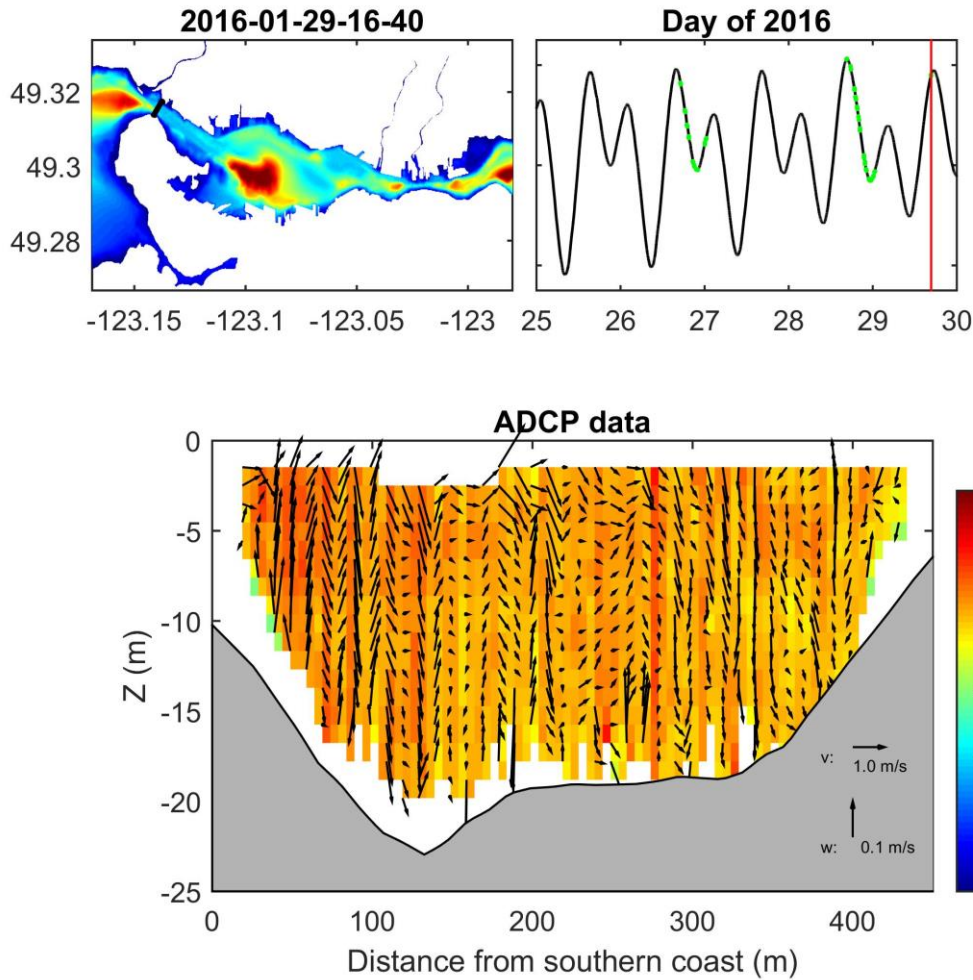






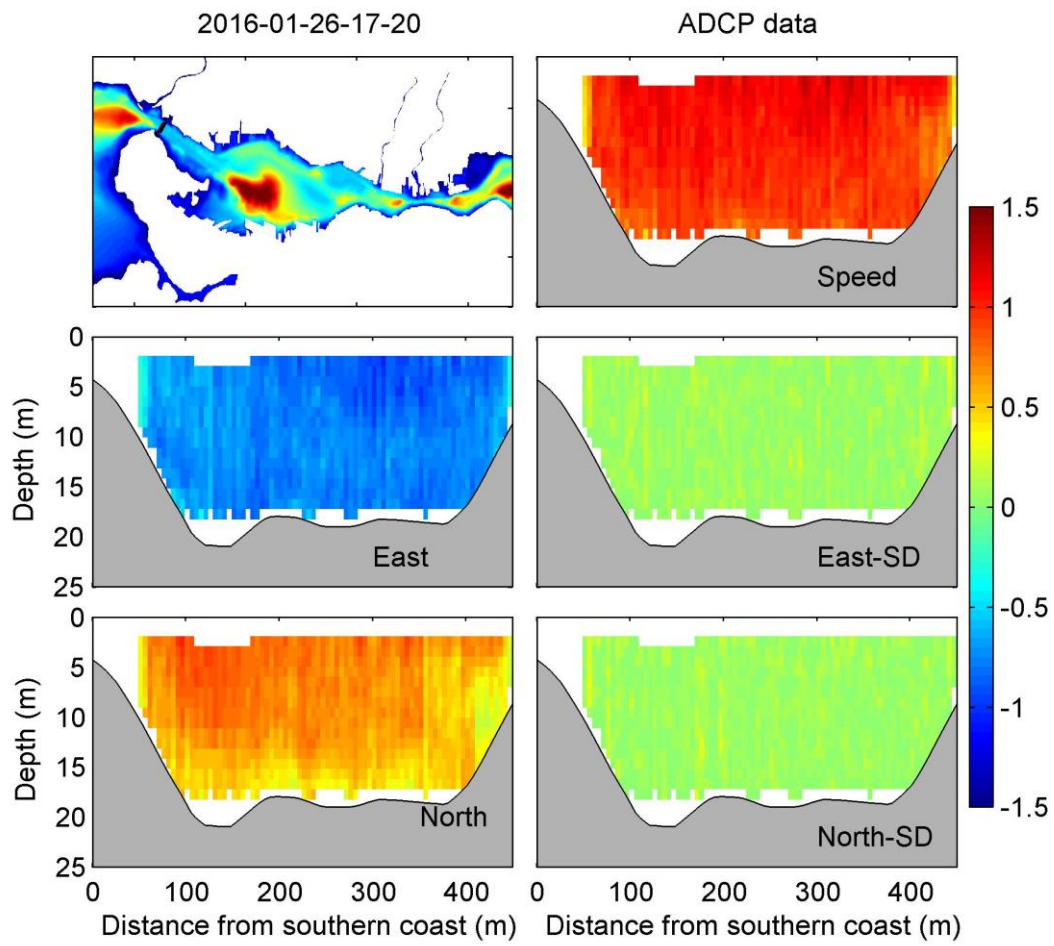


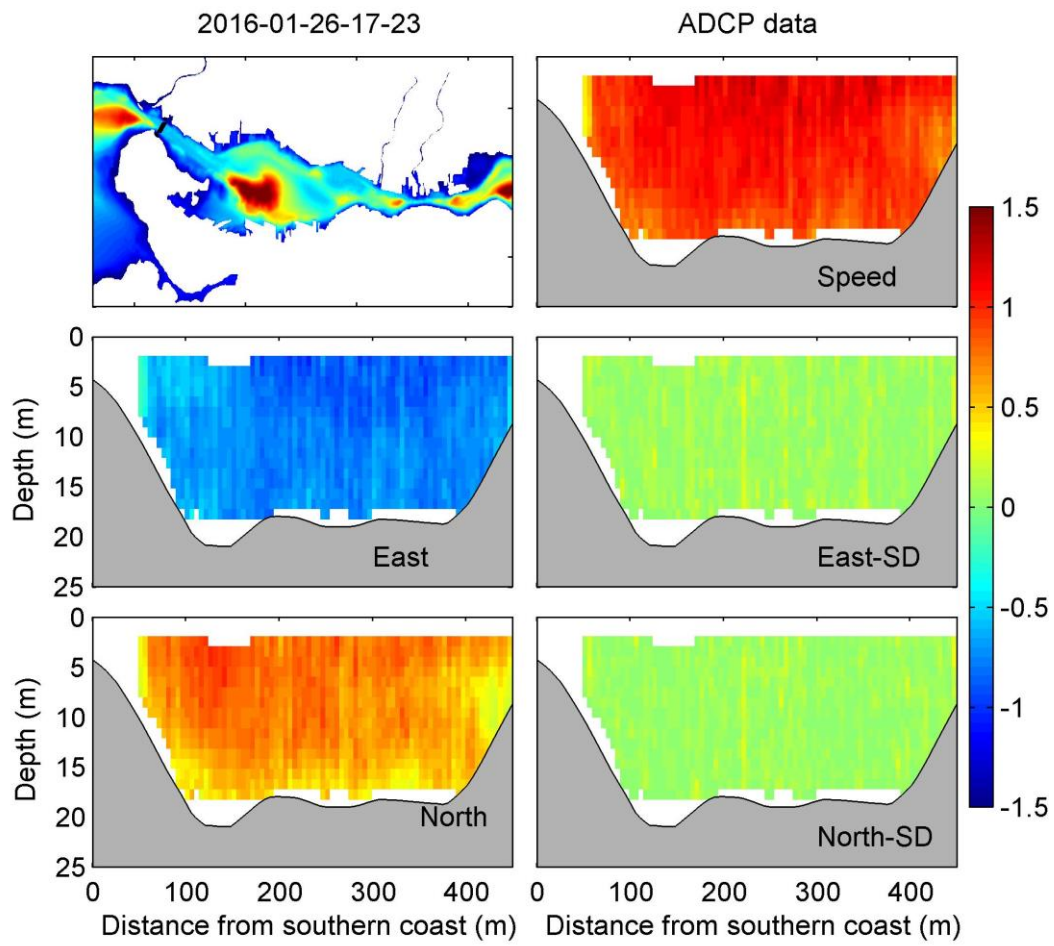


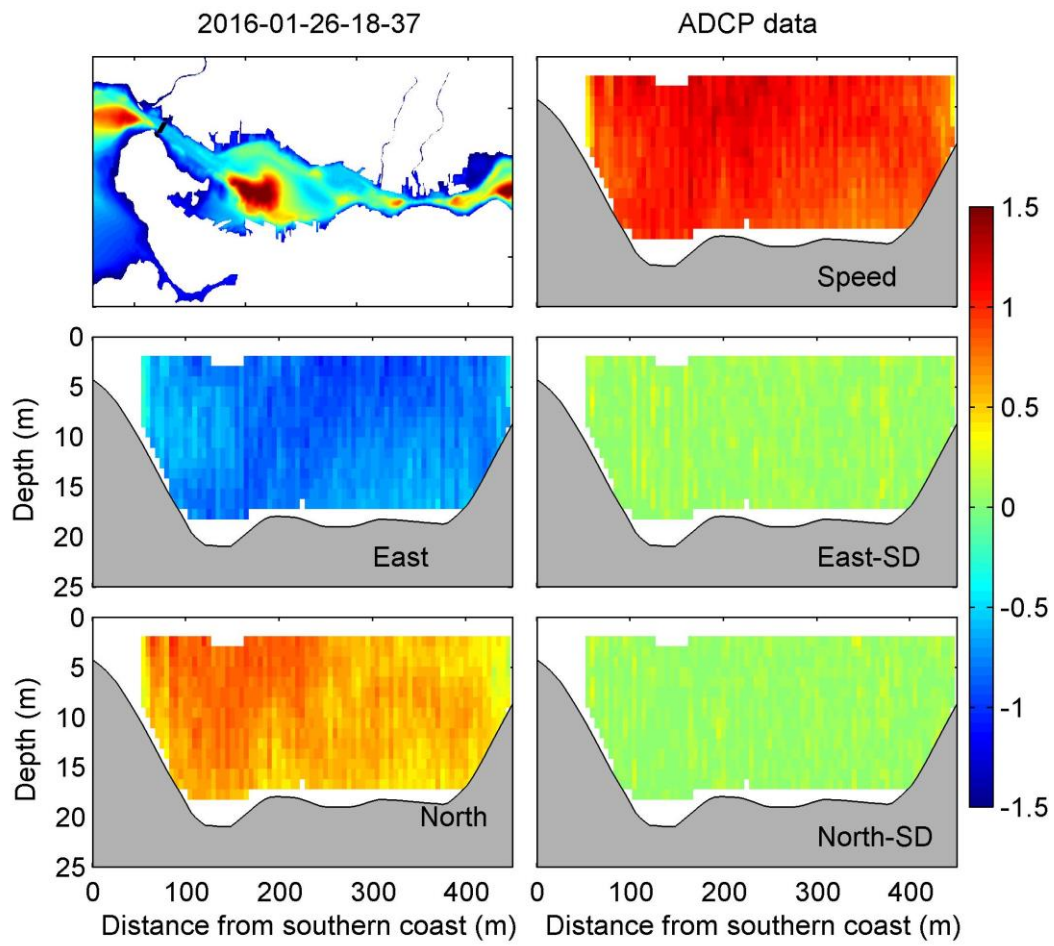


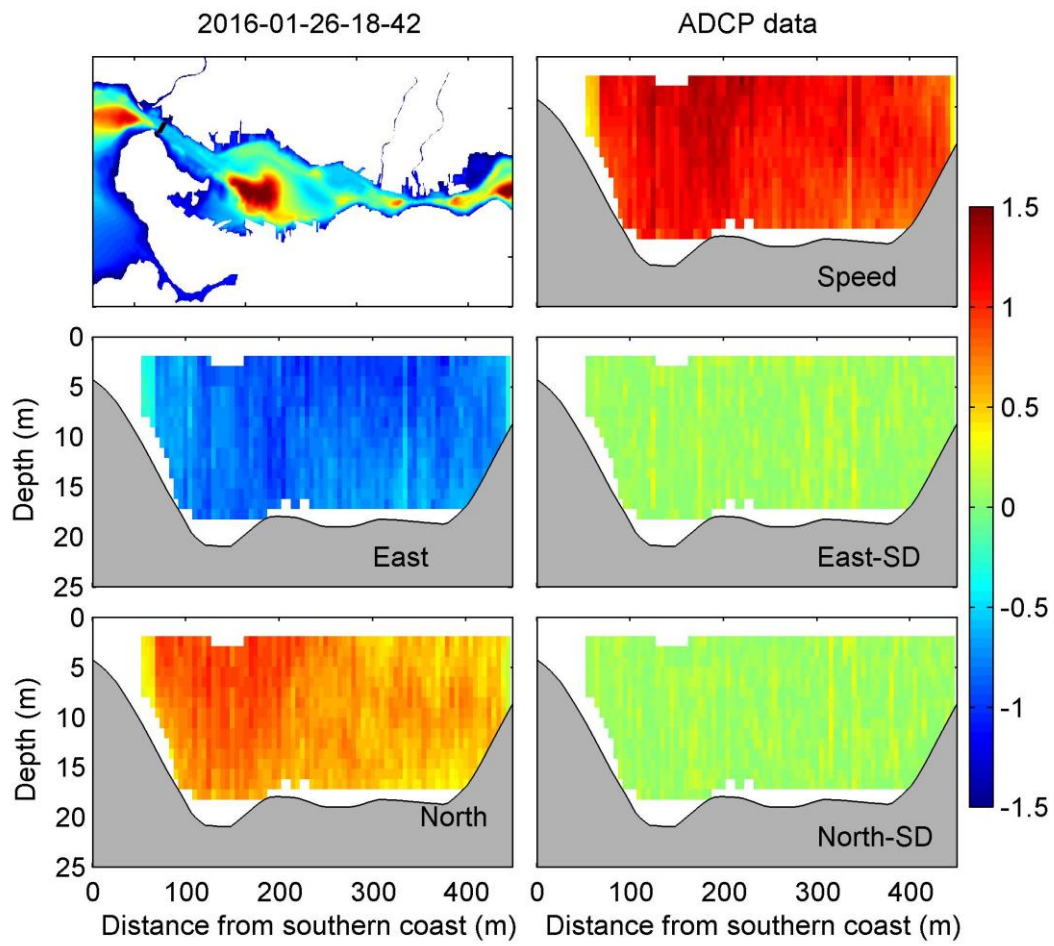
7.3 LINE 2 VELOCITY DATA AND STANDARD DEVIATION

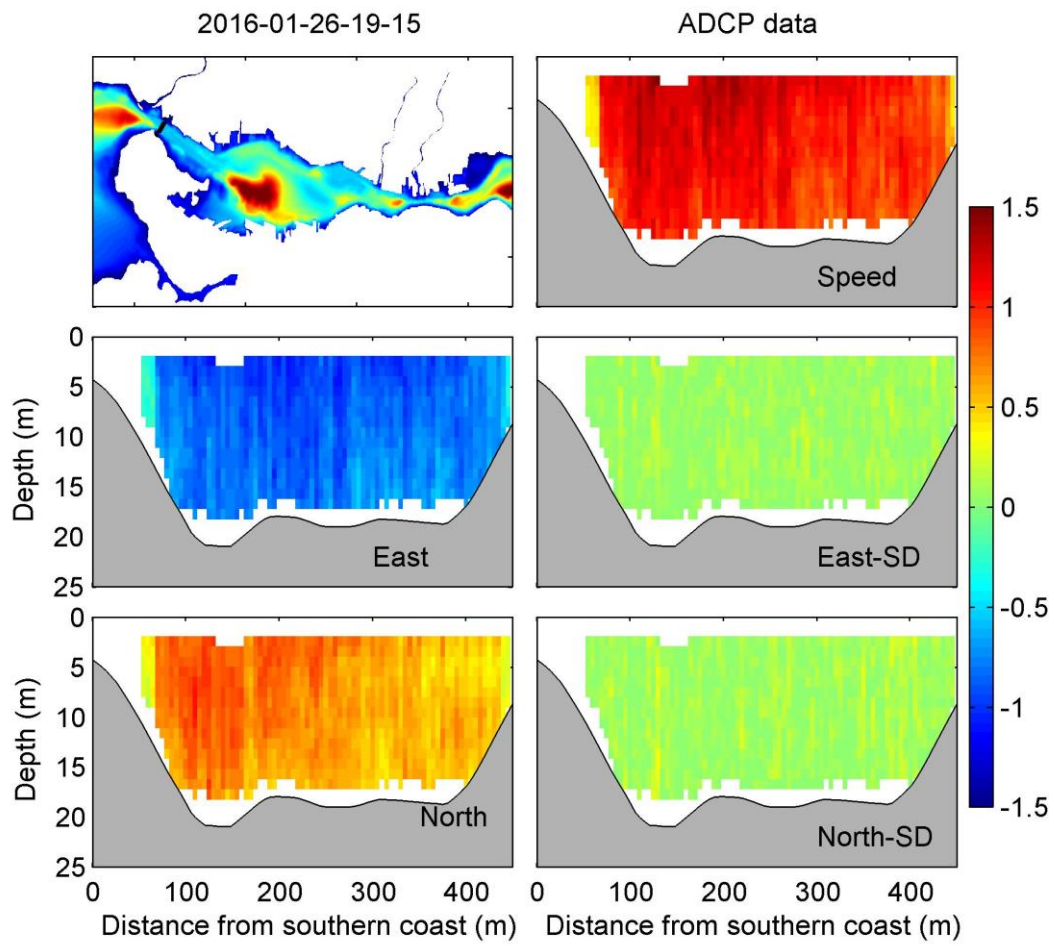
The following figures show vertical profiles of the east and north (u and v) horizontal velocity components for Line 2 measured in First Narrows. The units are in ms^{-1} . The figures include a map of the bathymetry that shows the position of the transect and the vertical profile of the velocity magnitude in the top row. The vertical profiles of the east and north horizontal velocity components with their standard deviations are in the second and third rows. The time of the sample is stated on the figures and in their associated captions.

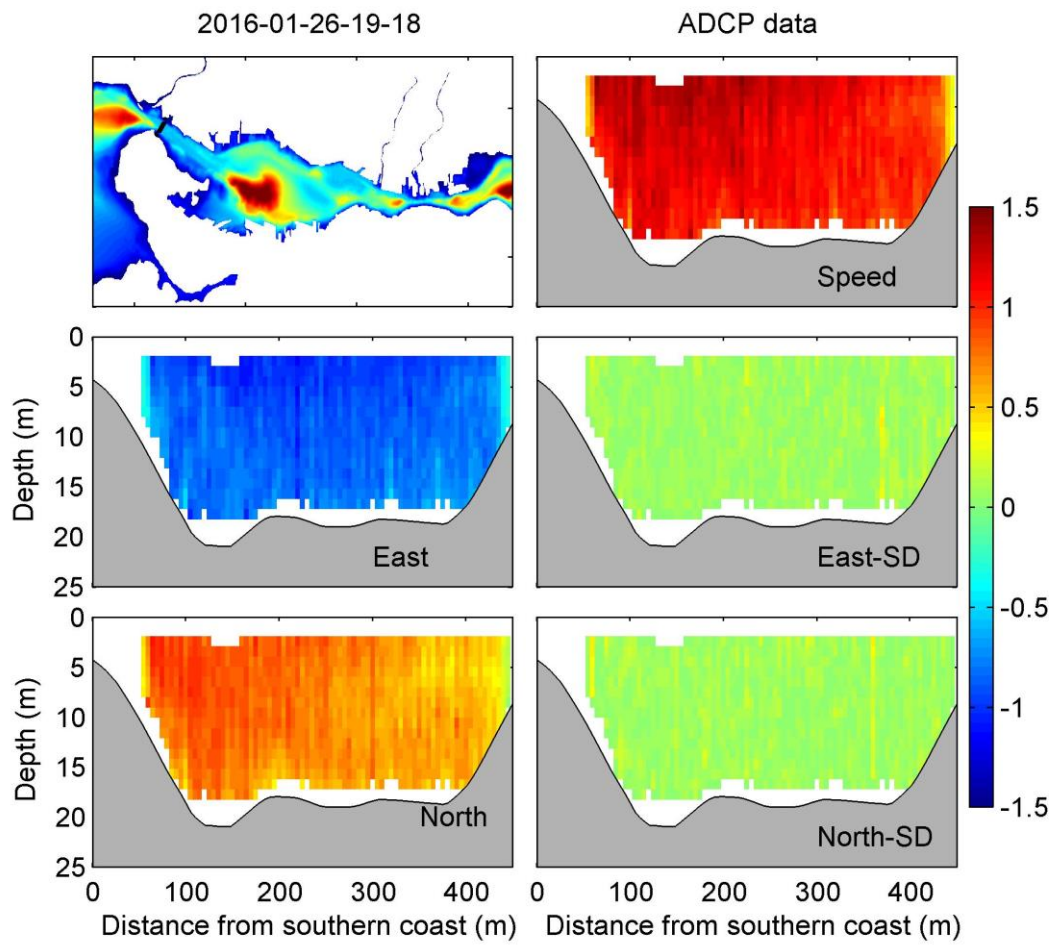


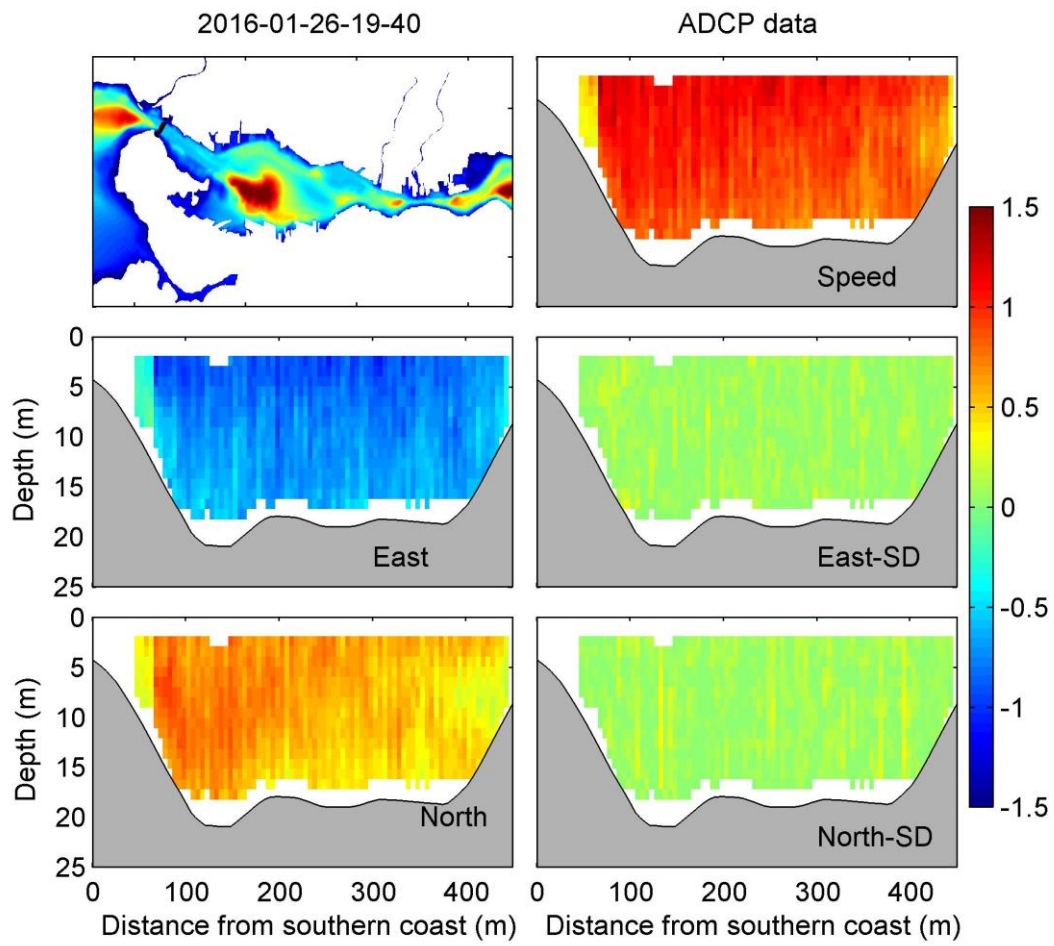


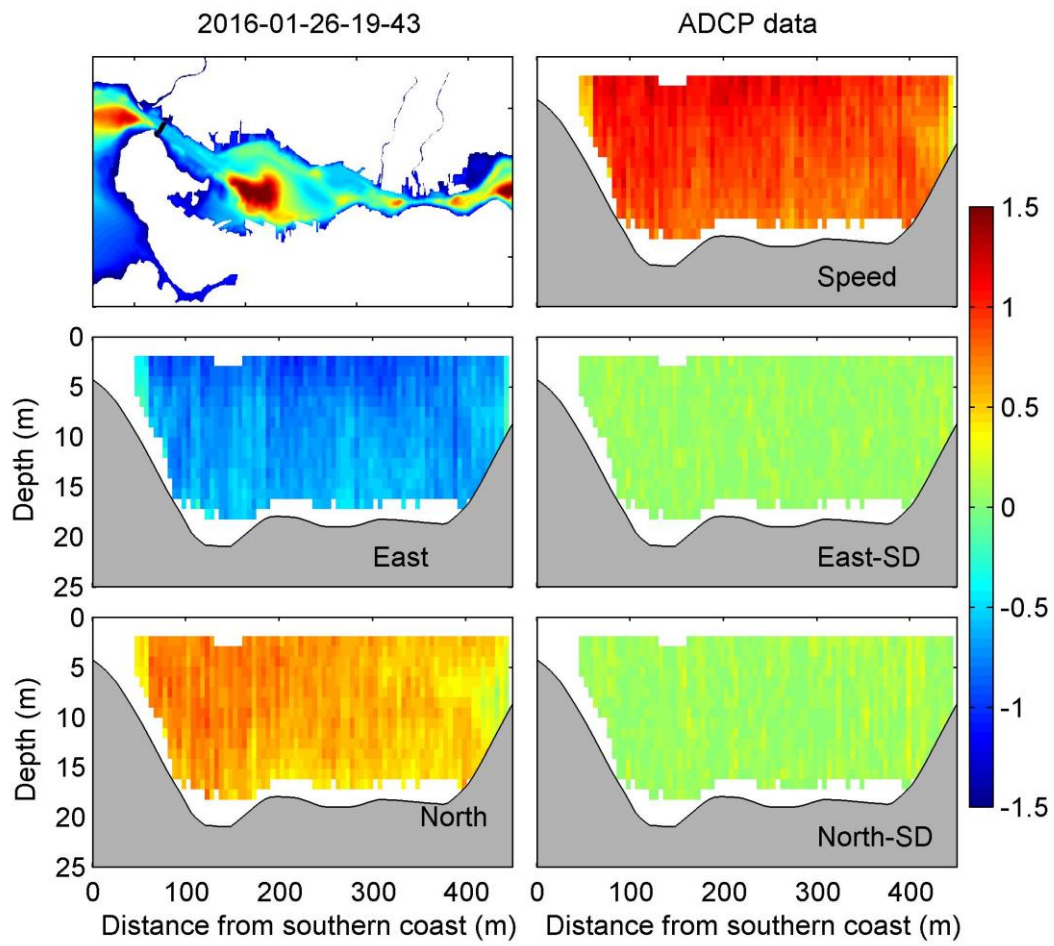


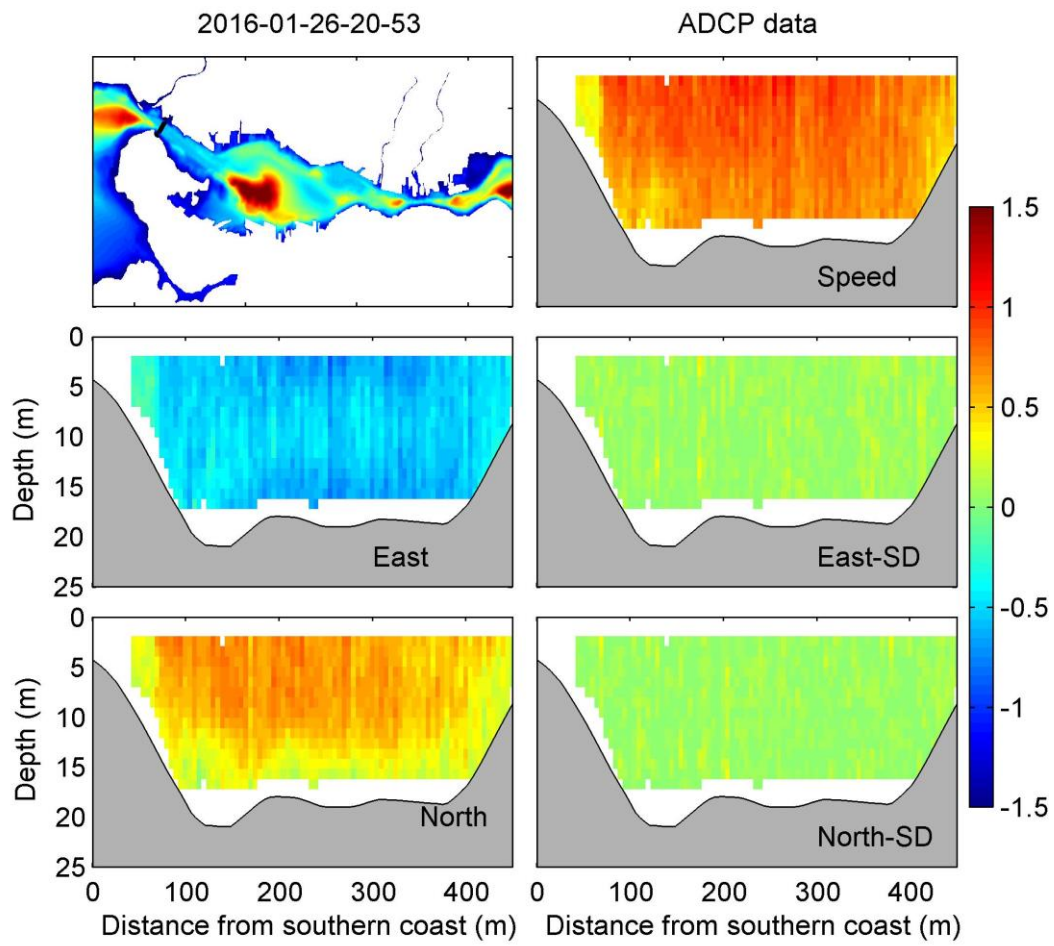


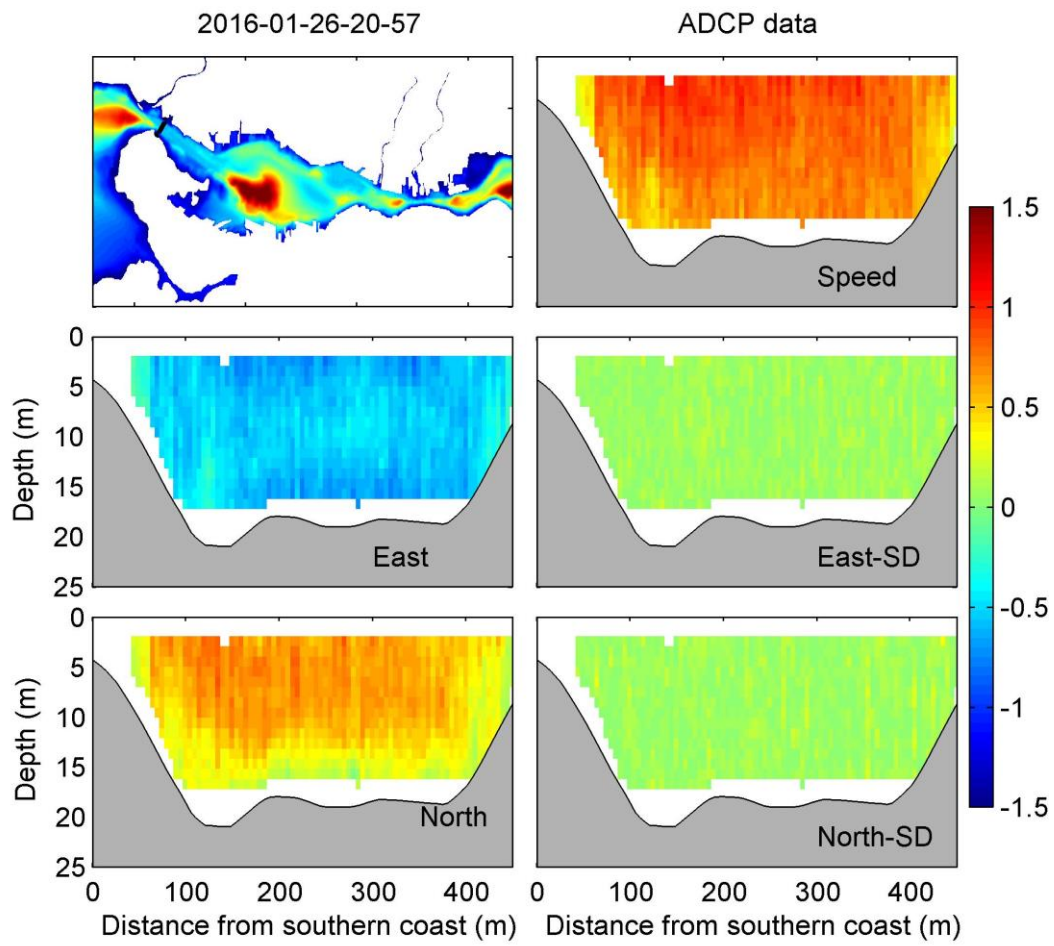


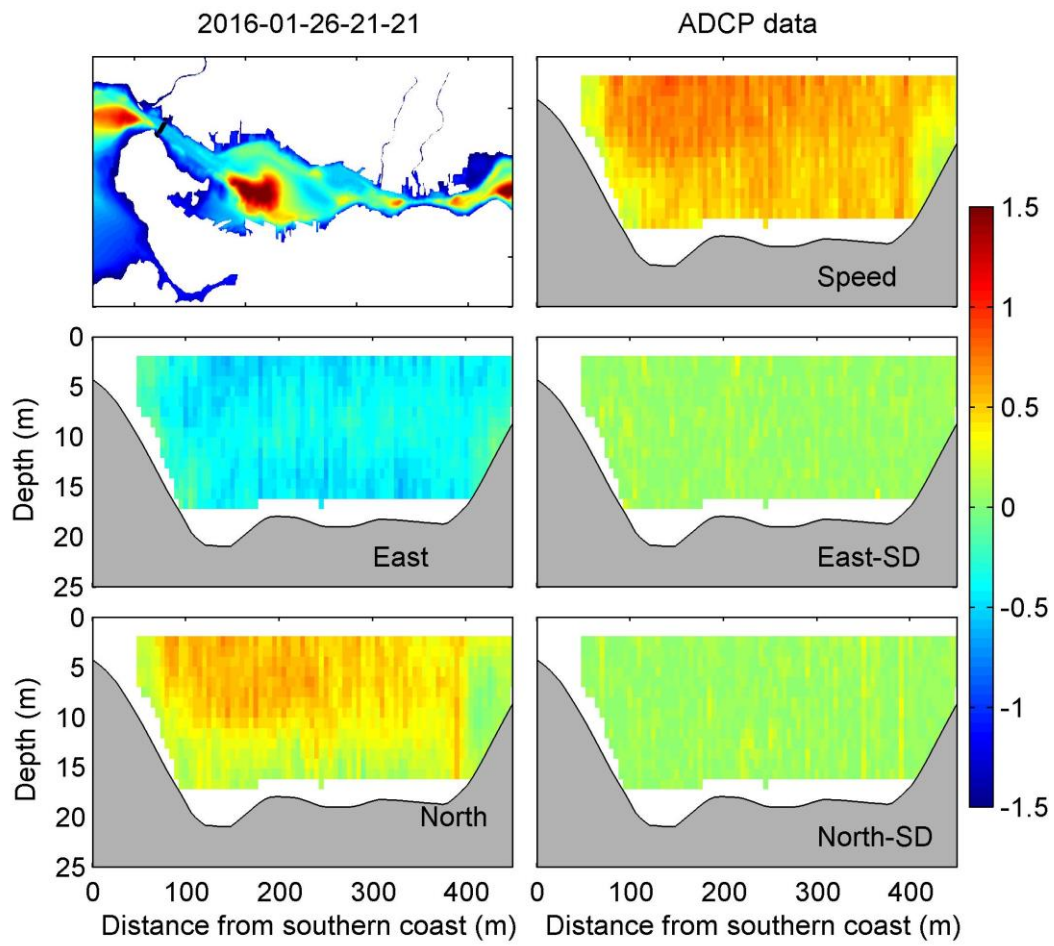


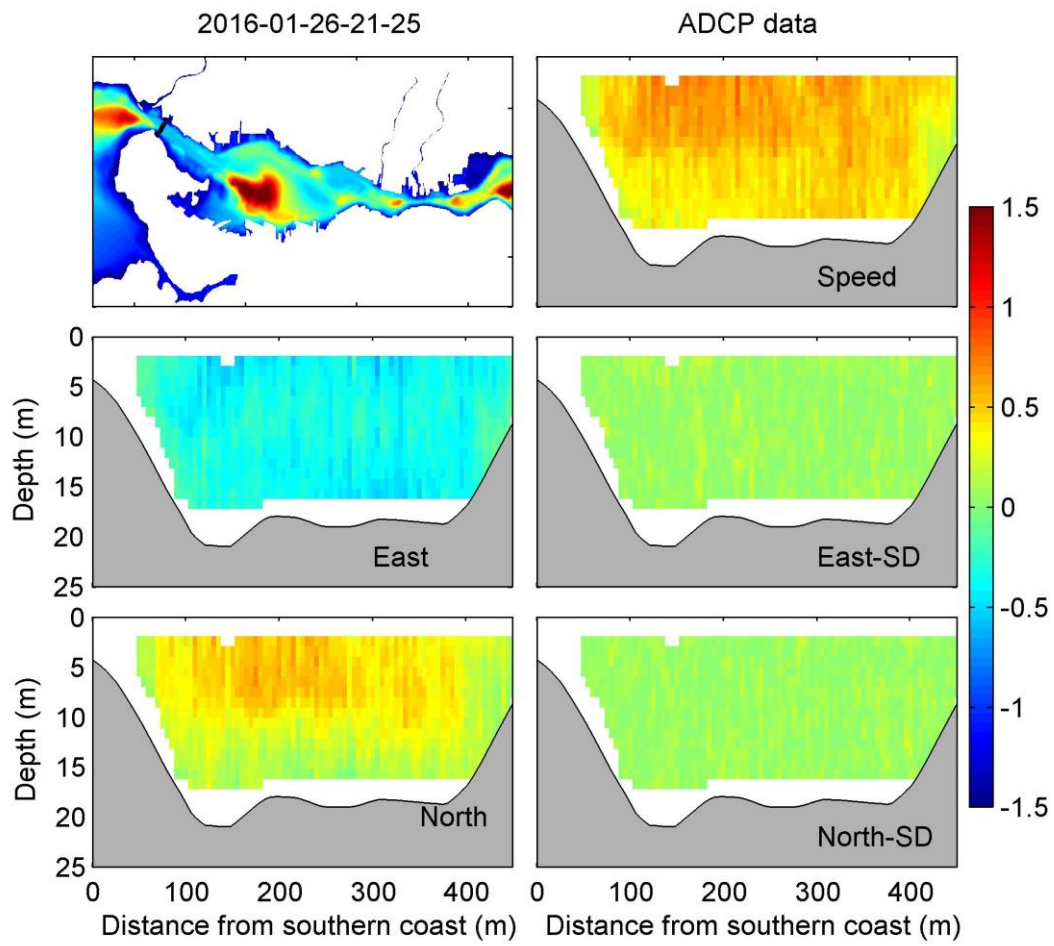


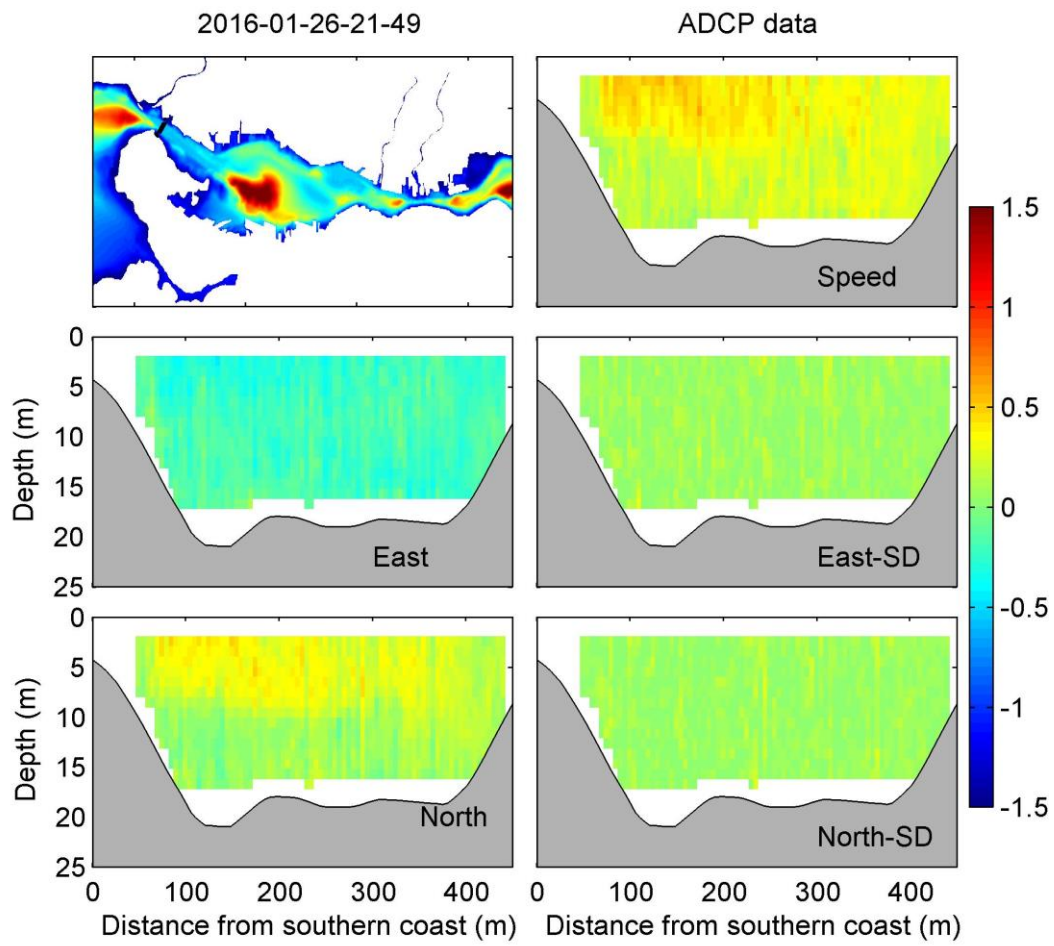


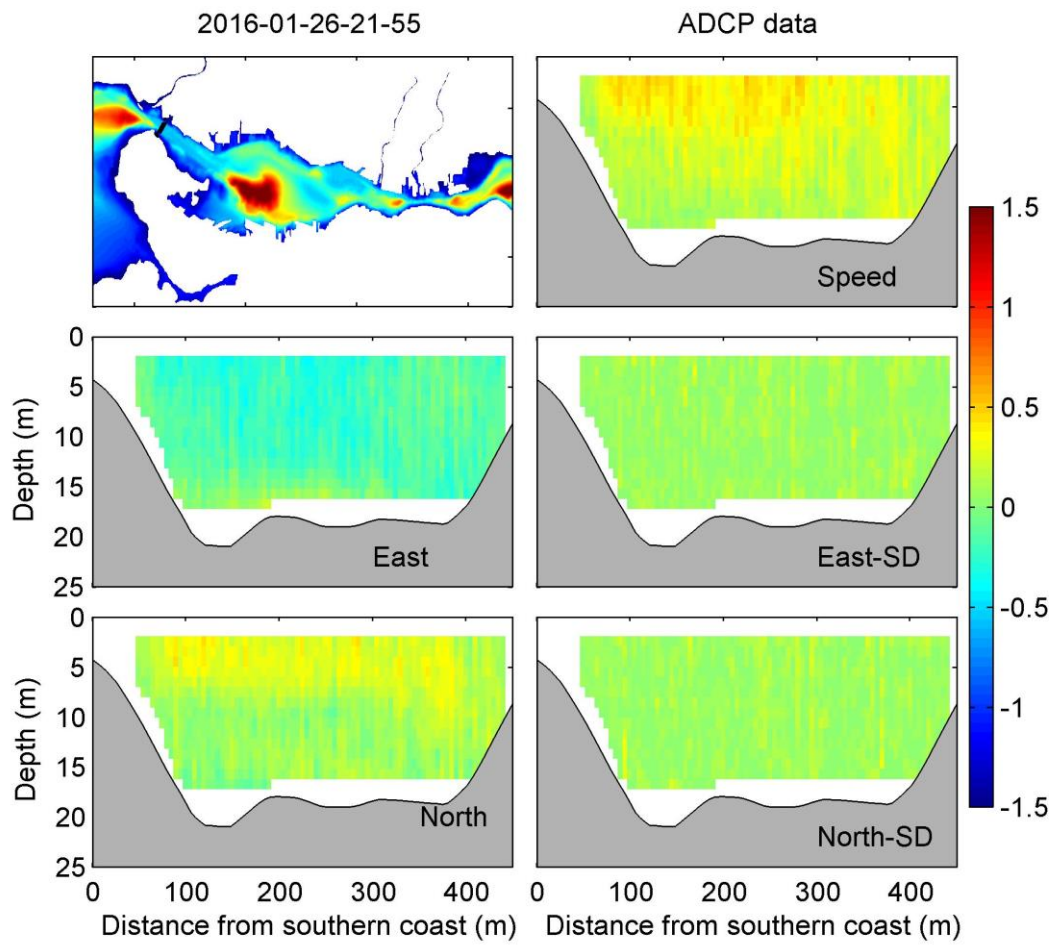


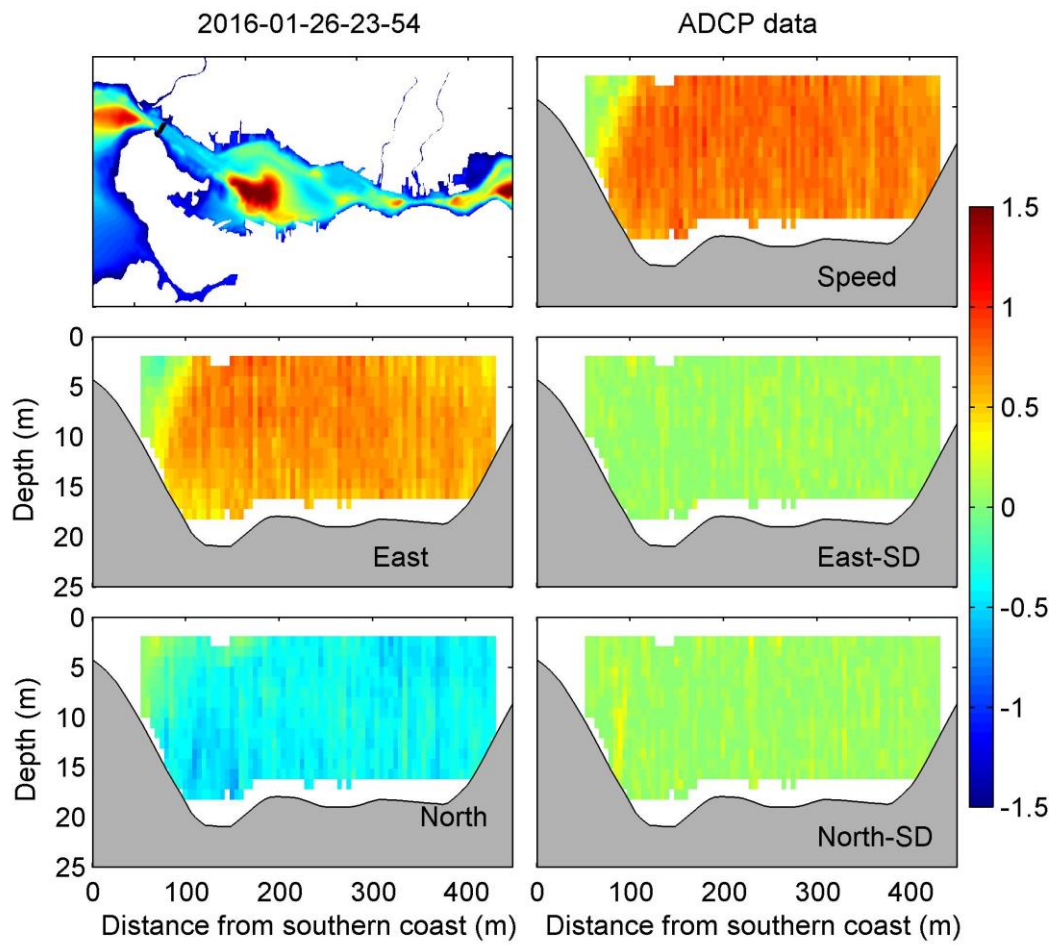


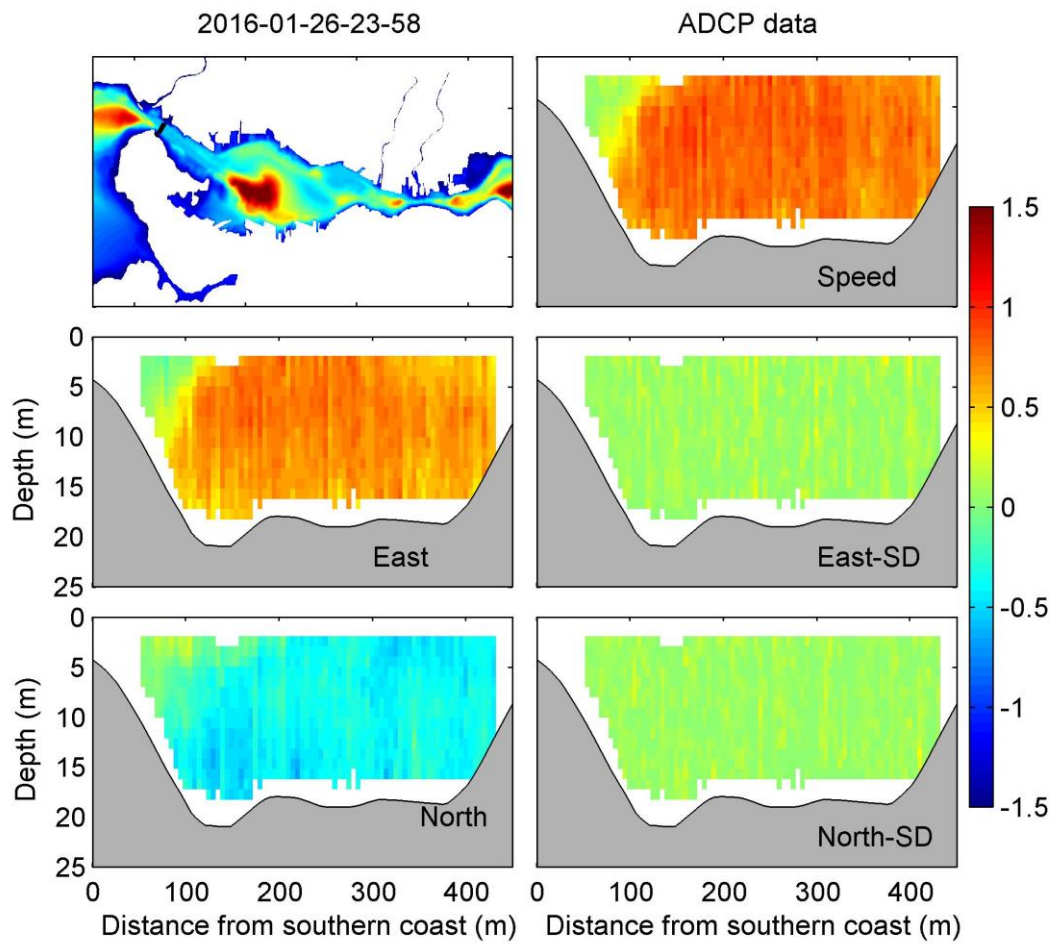


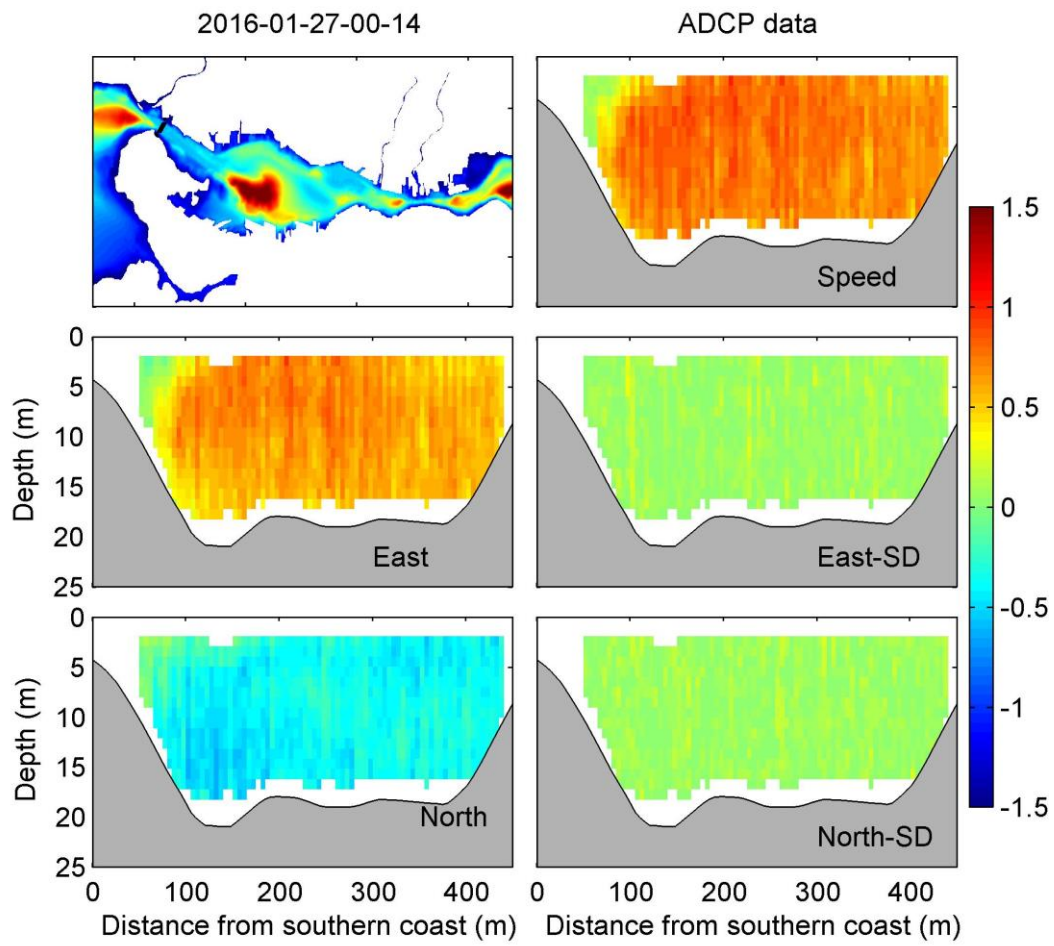


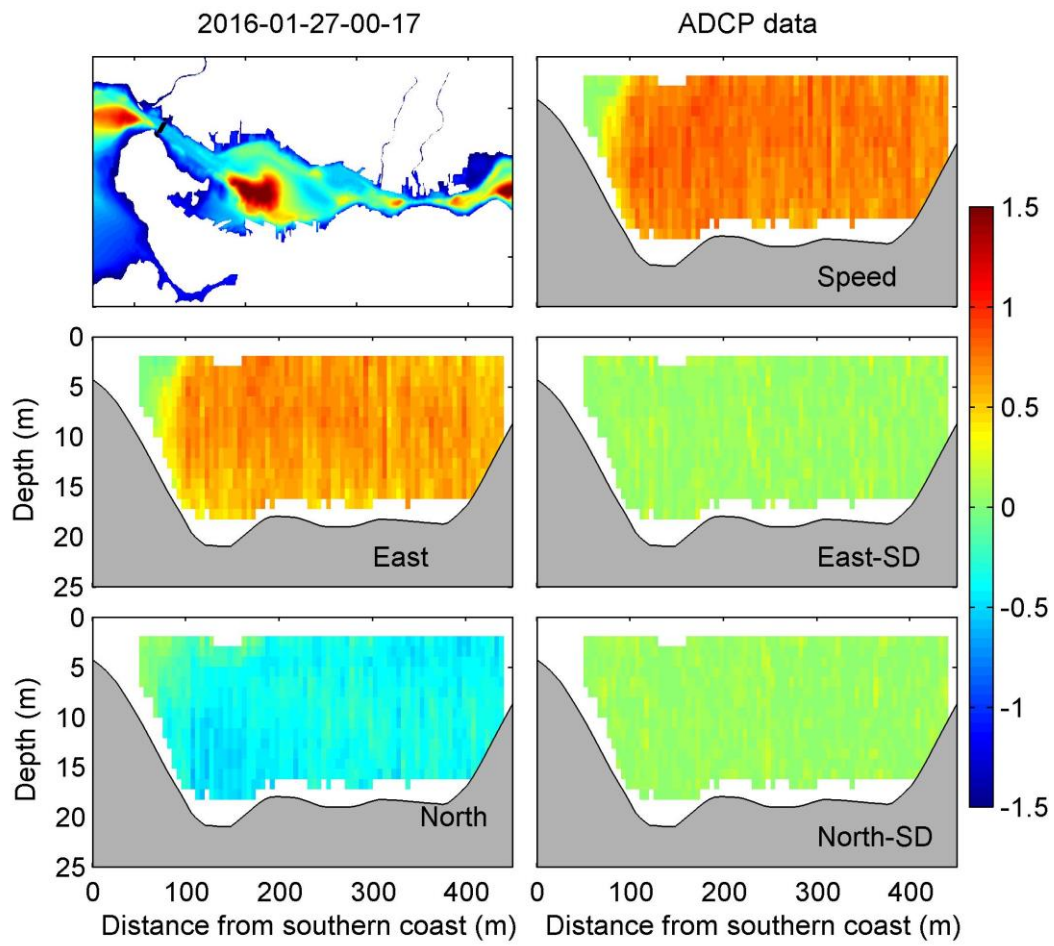


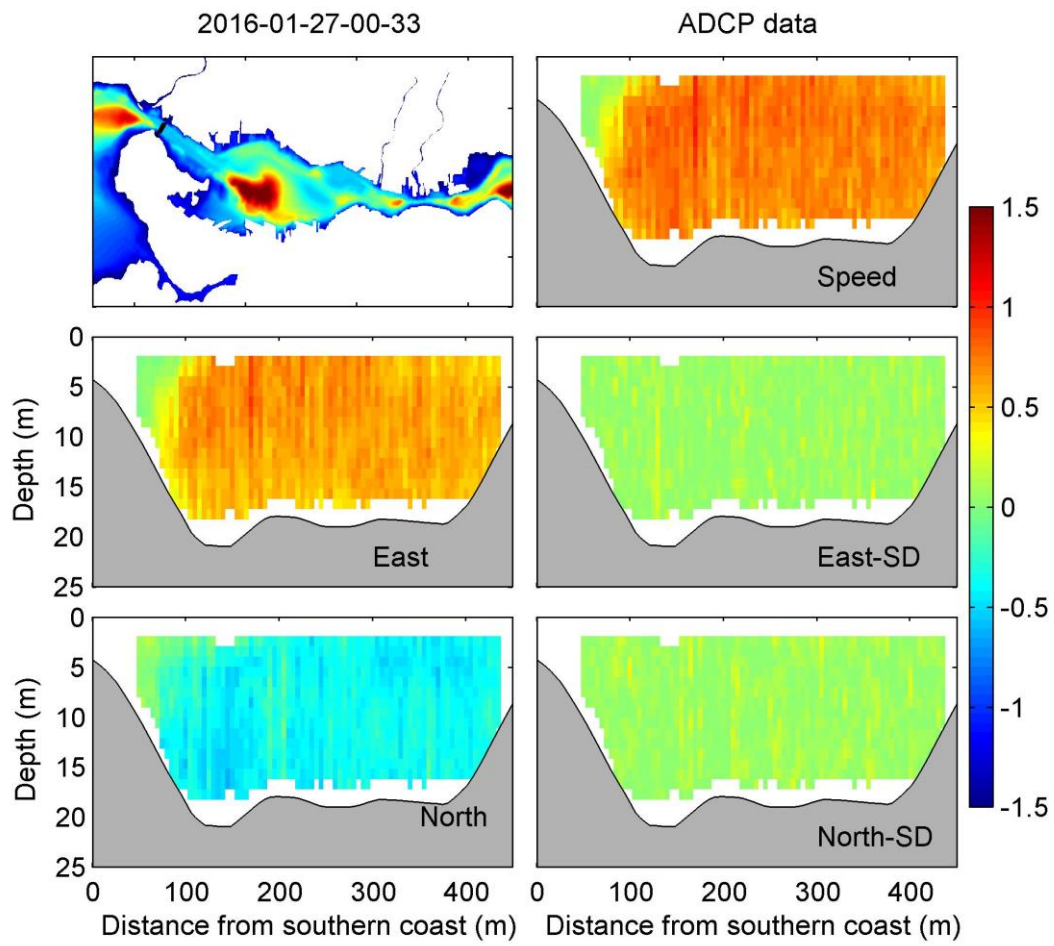


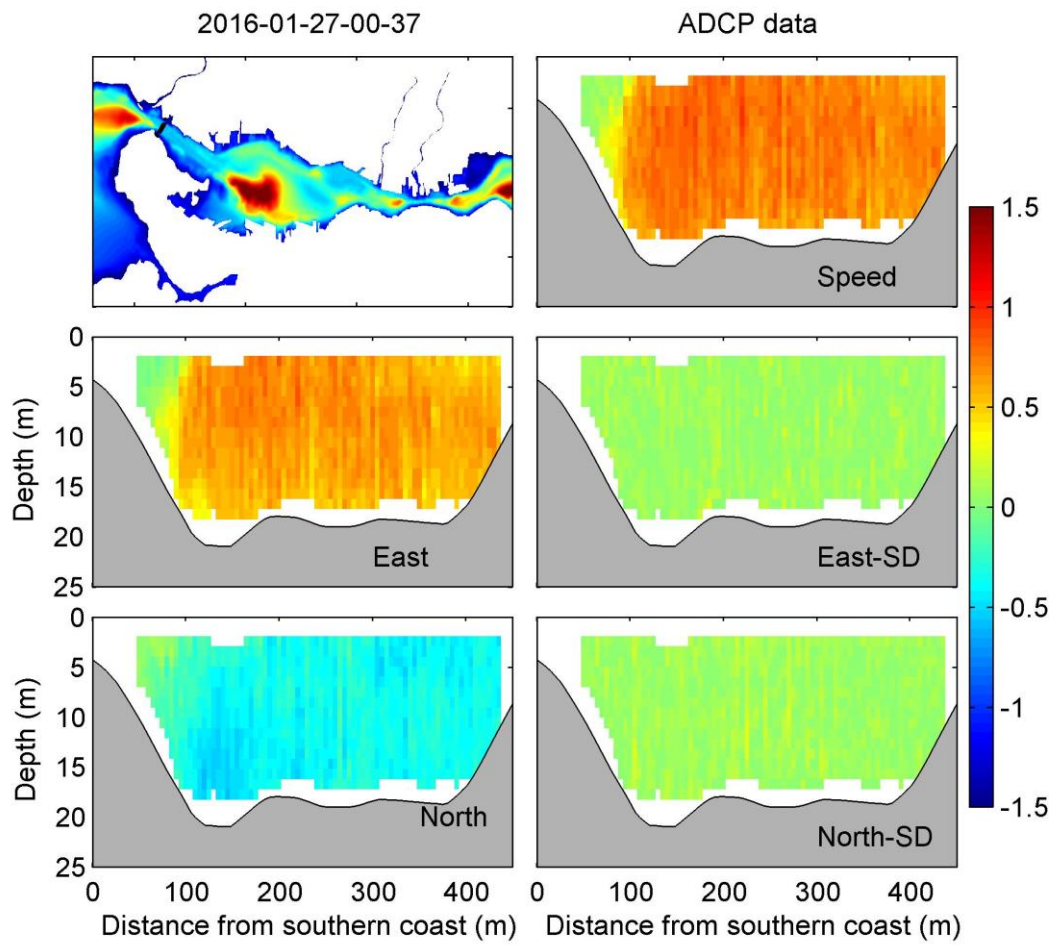


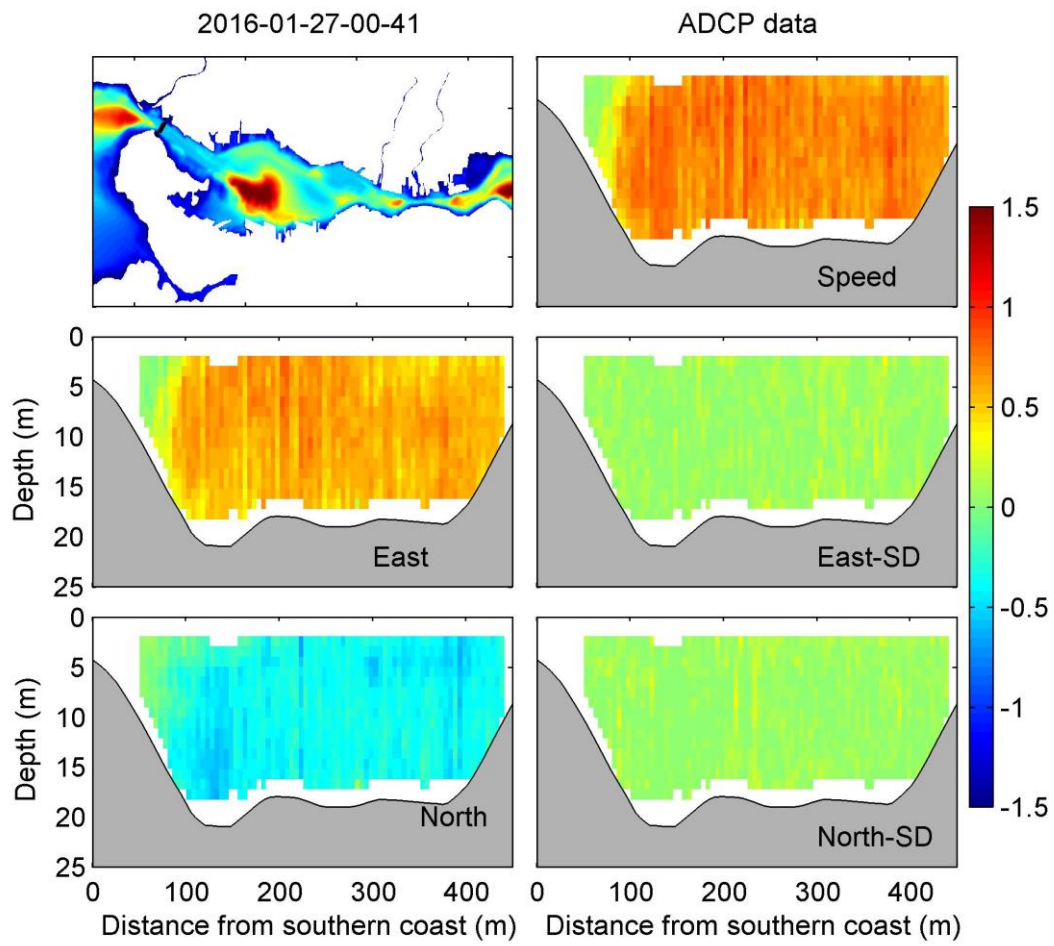


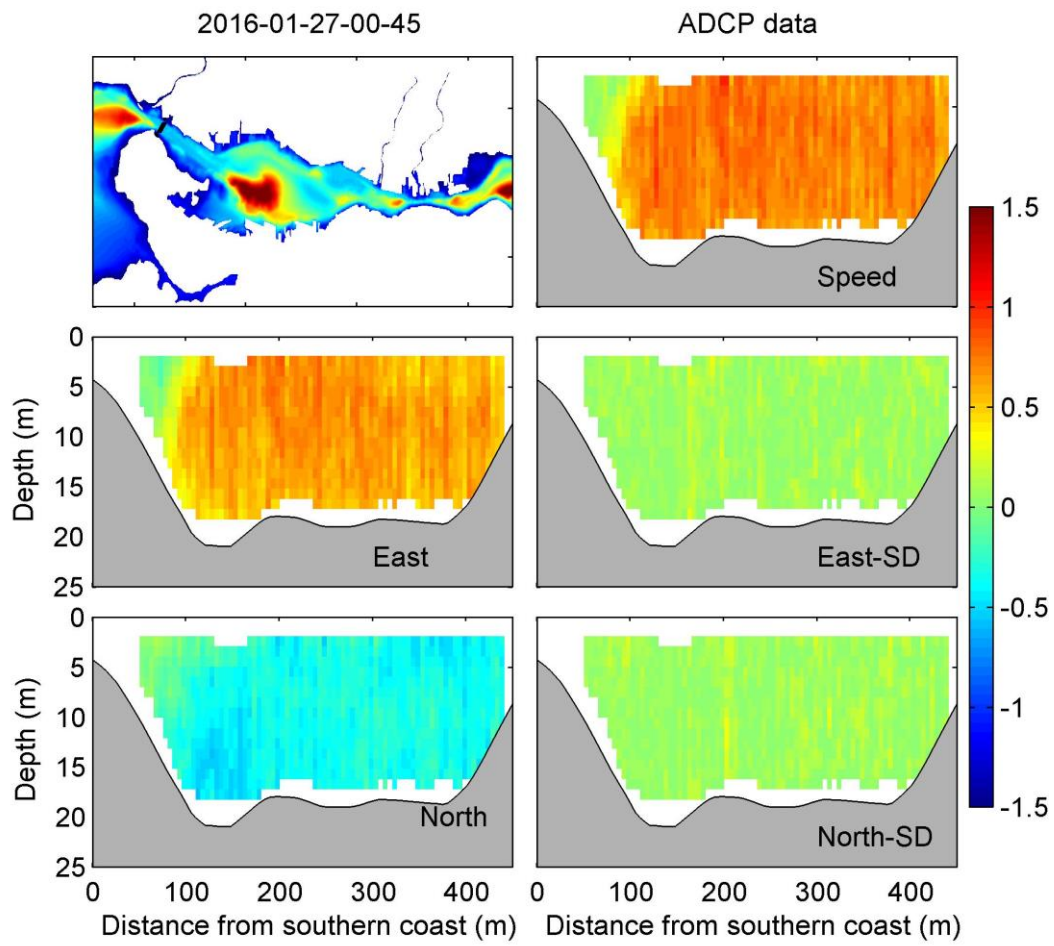


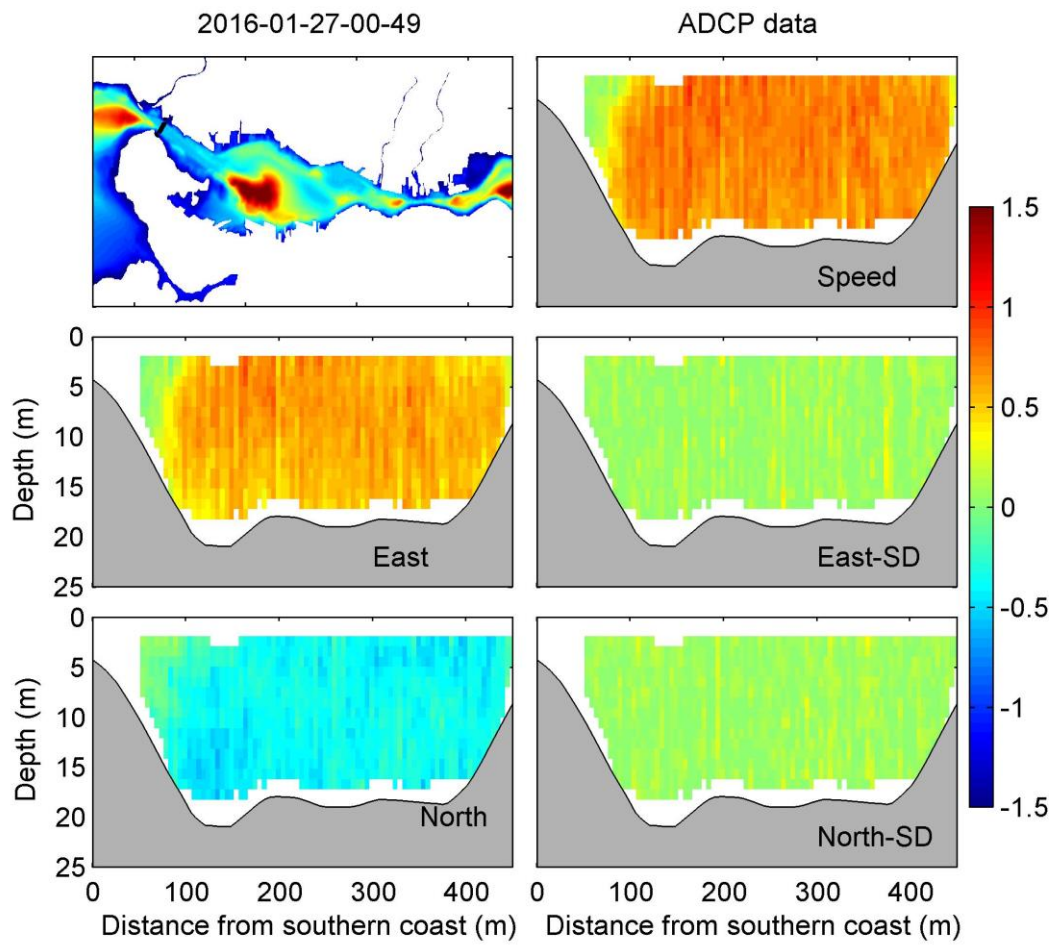


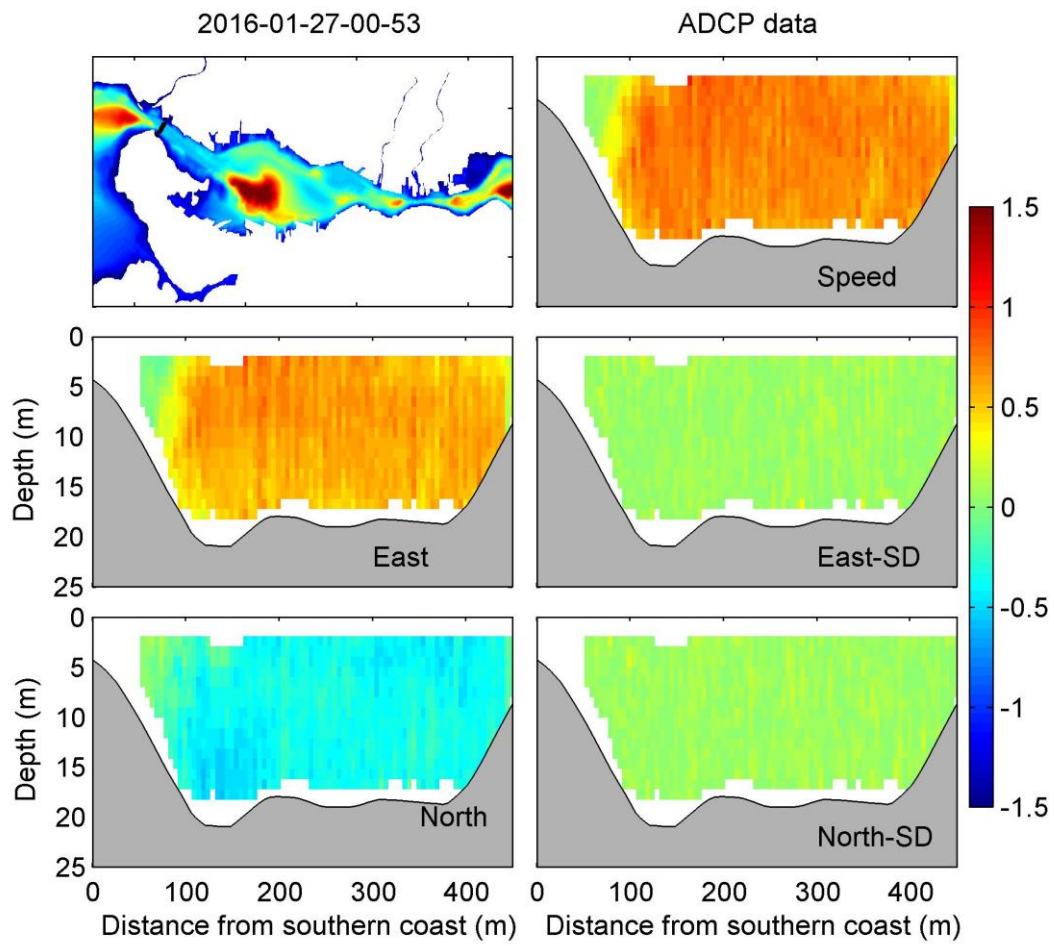


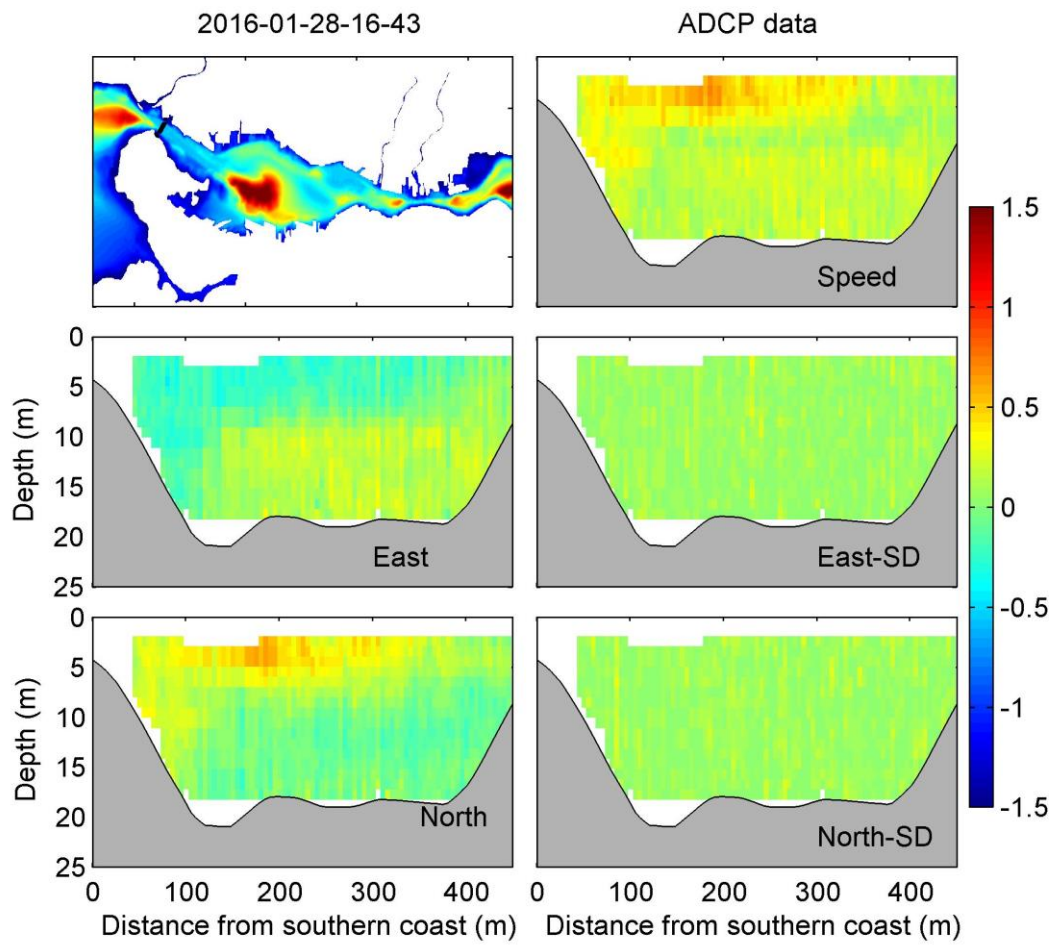


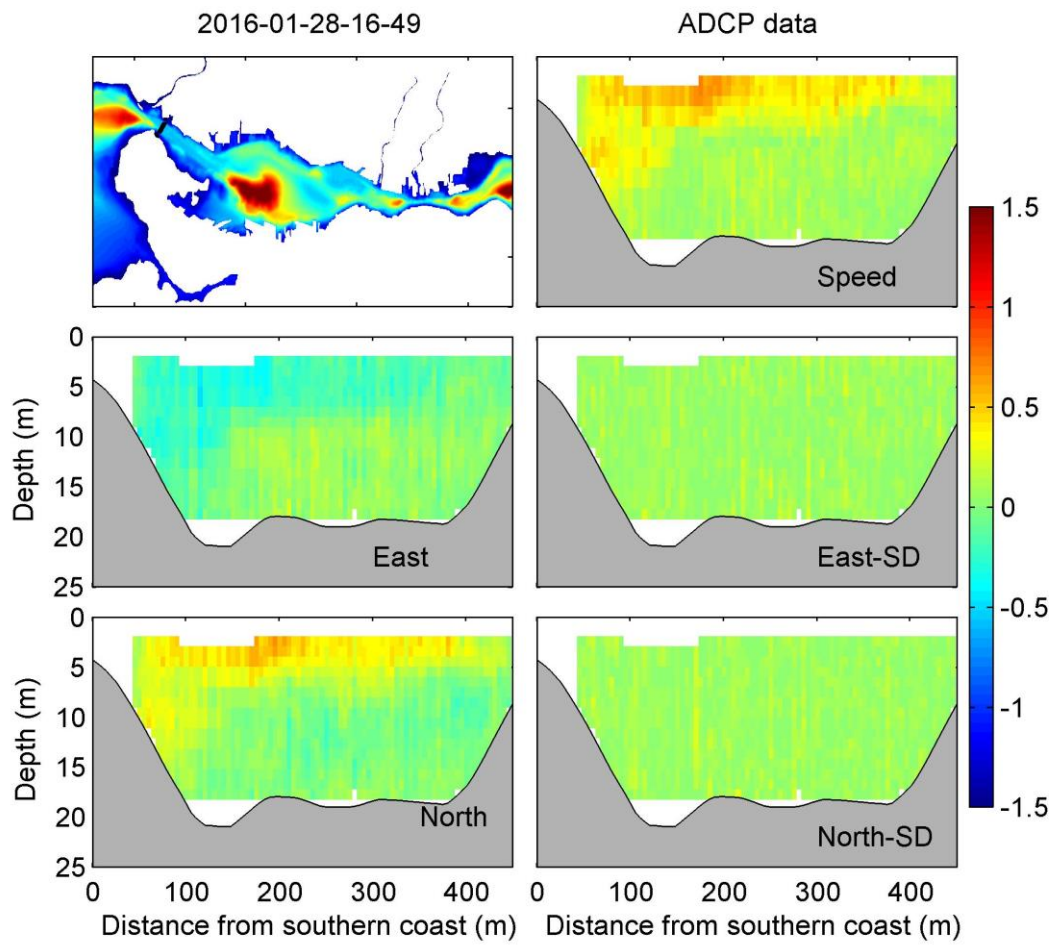


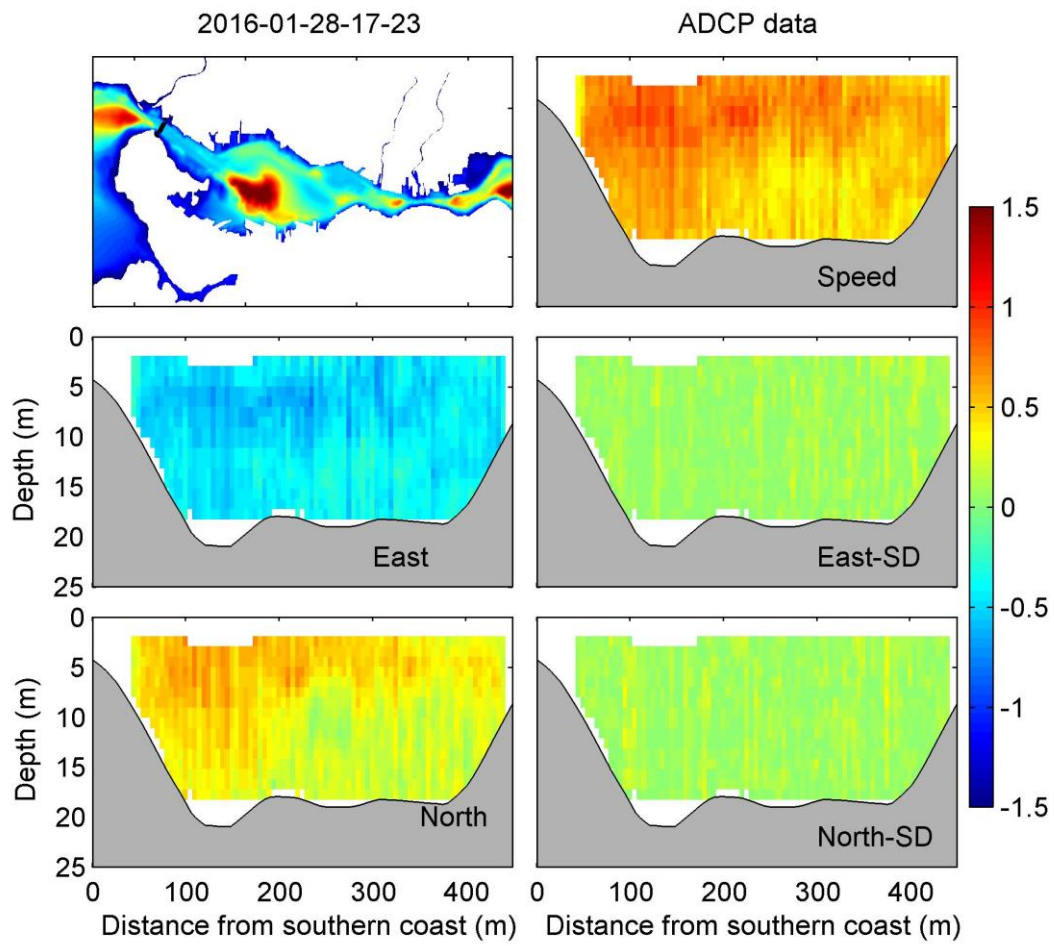


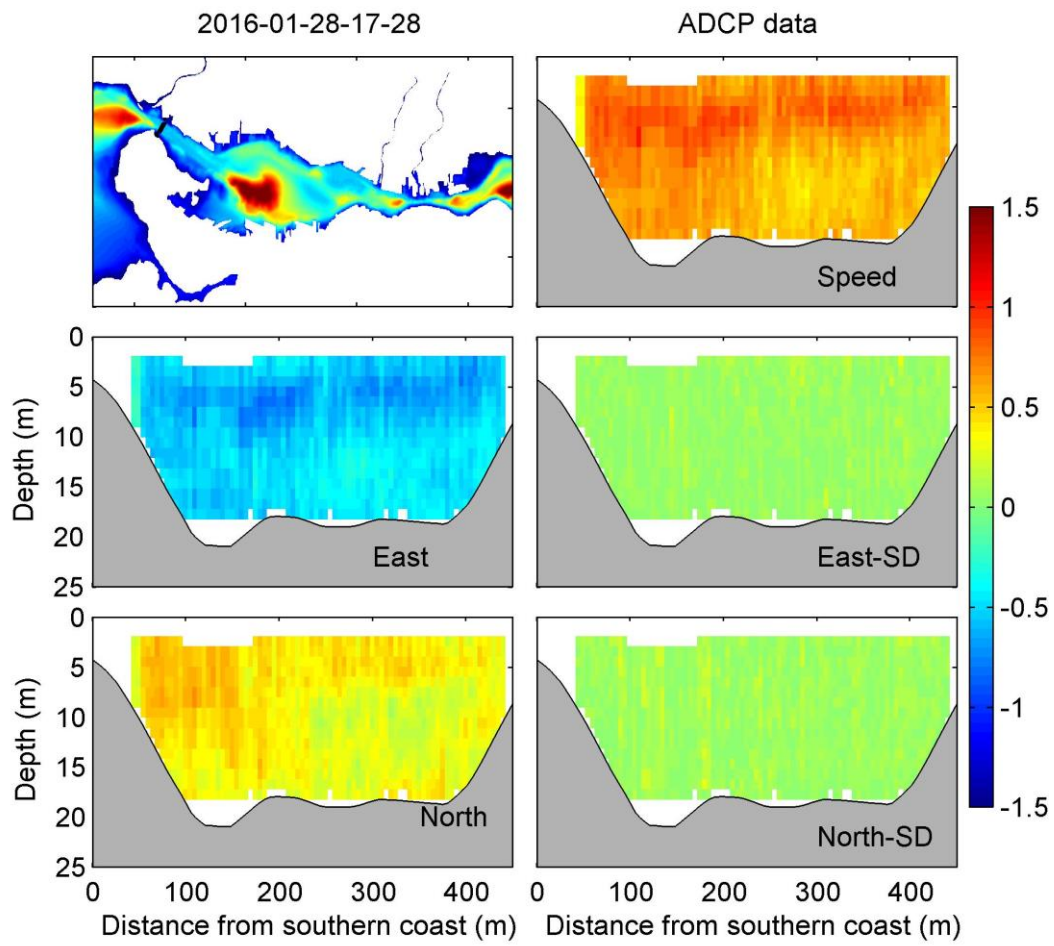


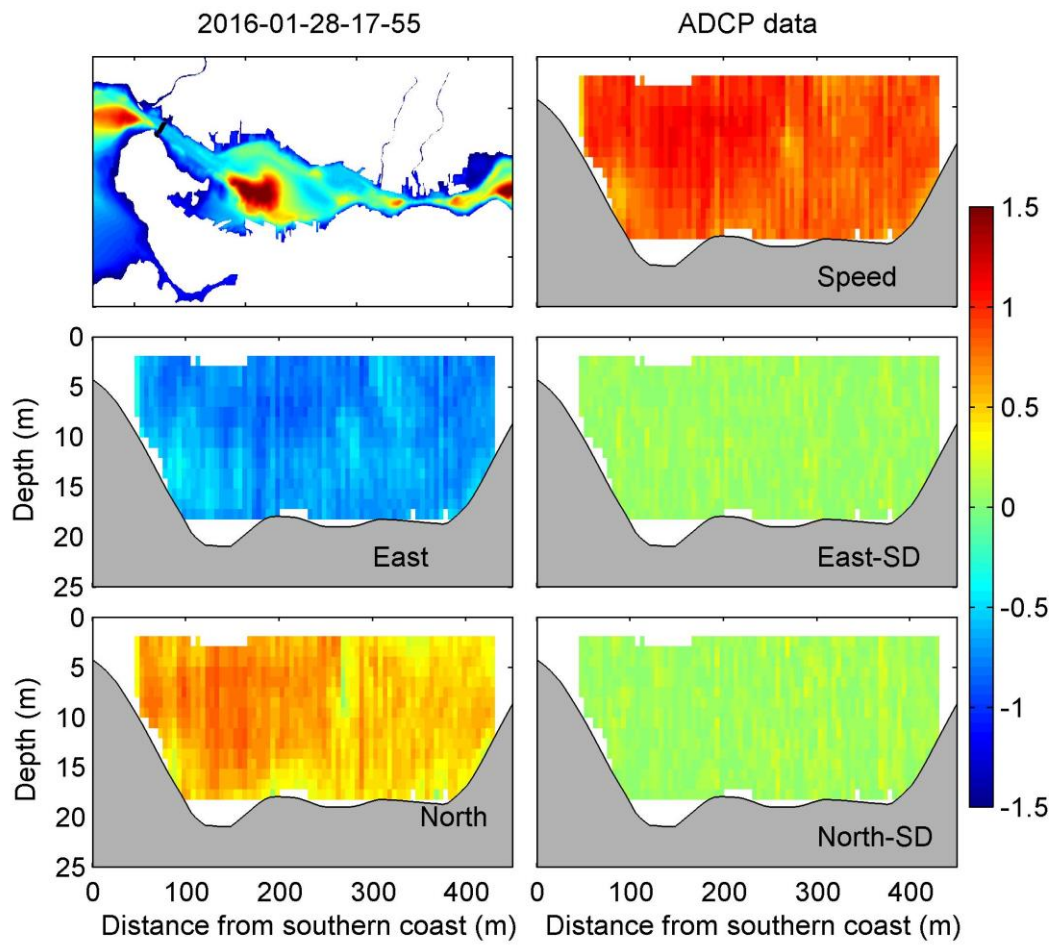


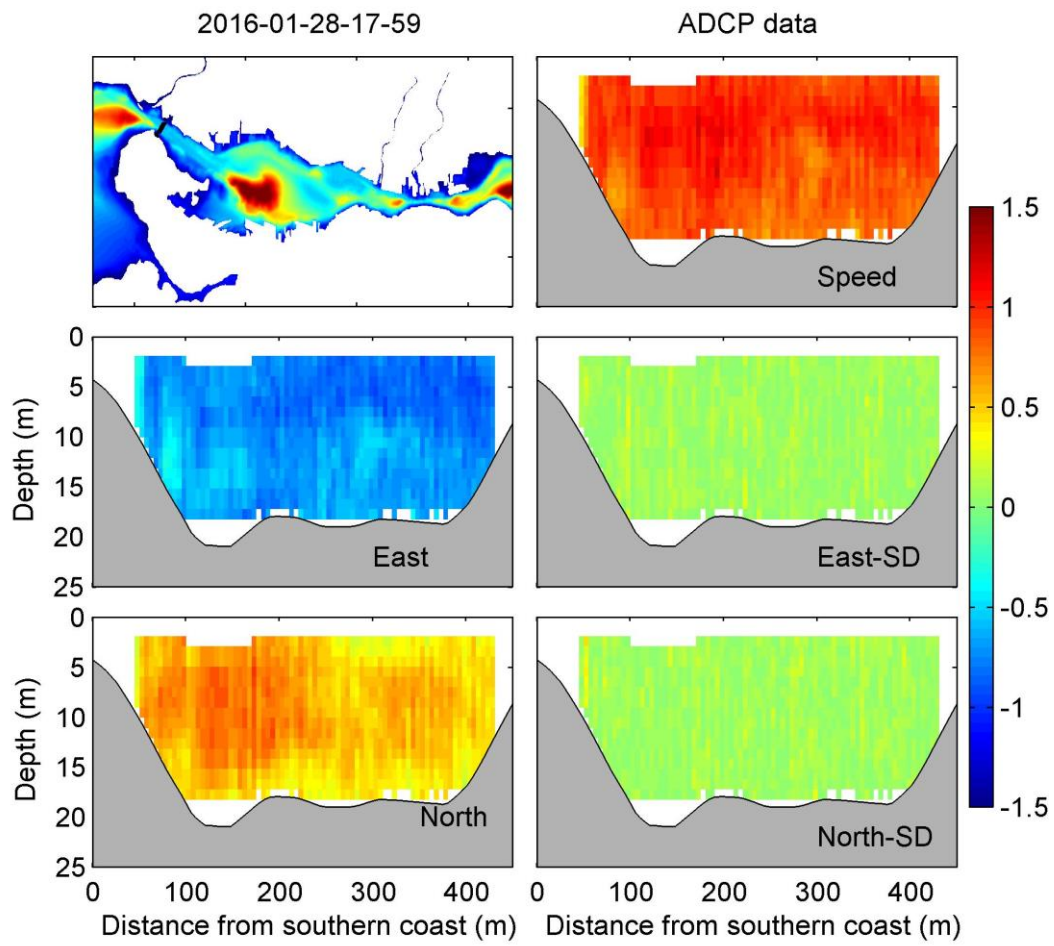


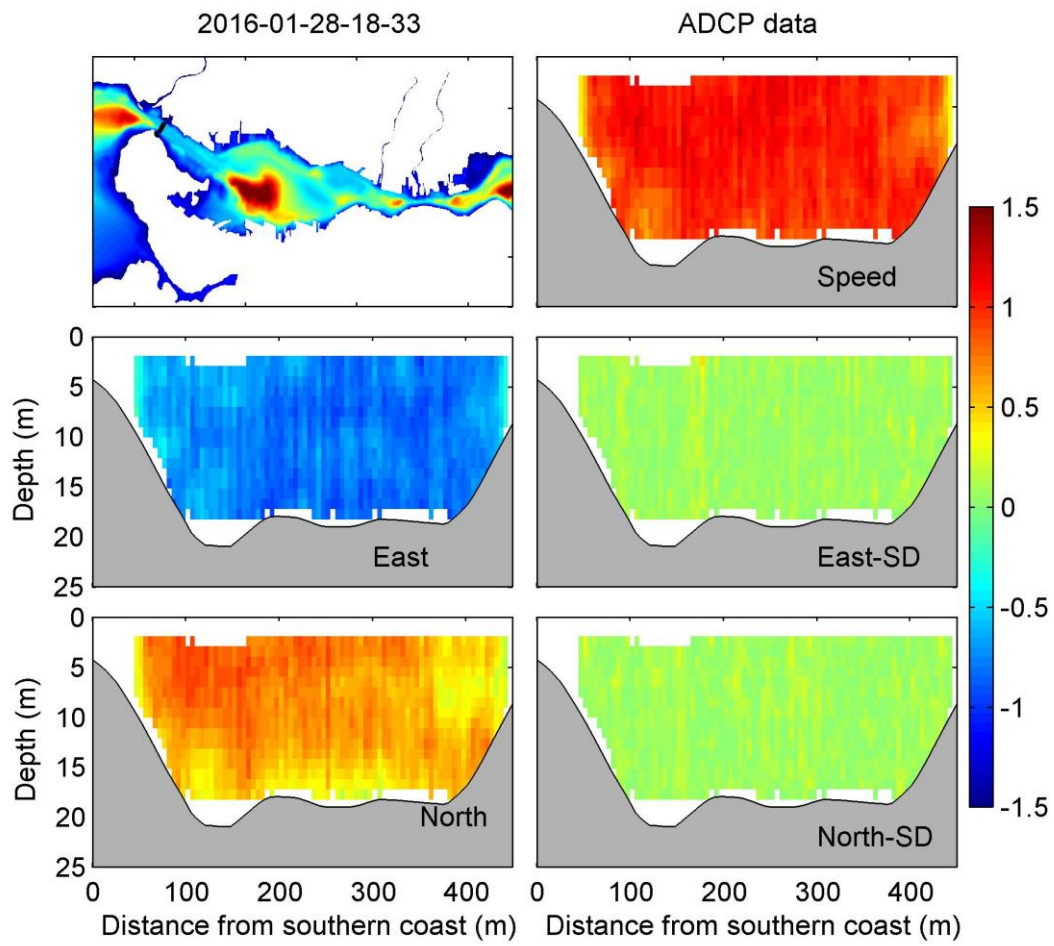


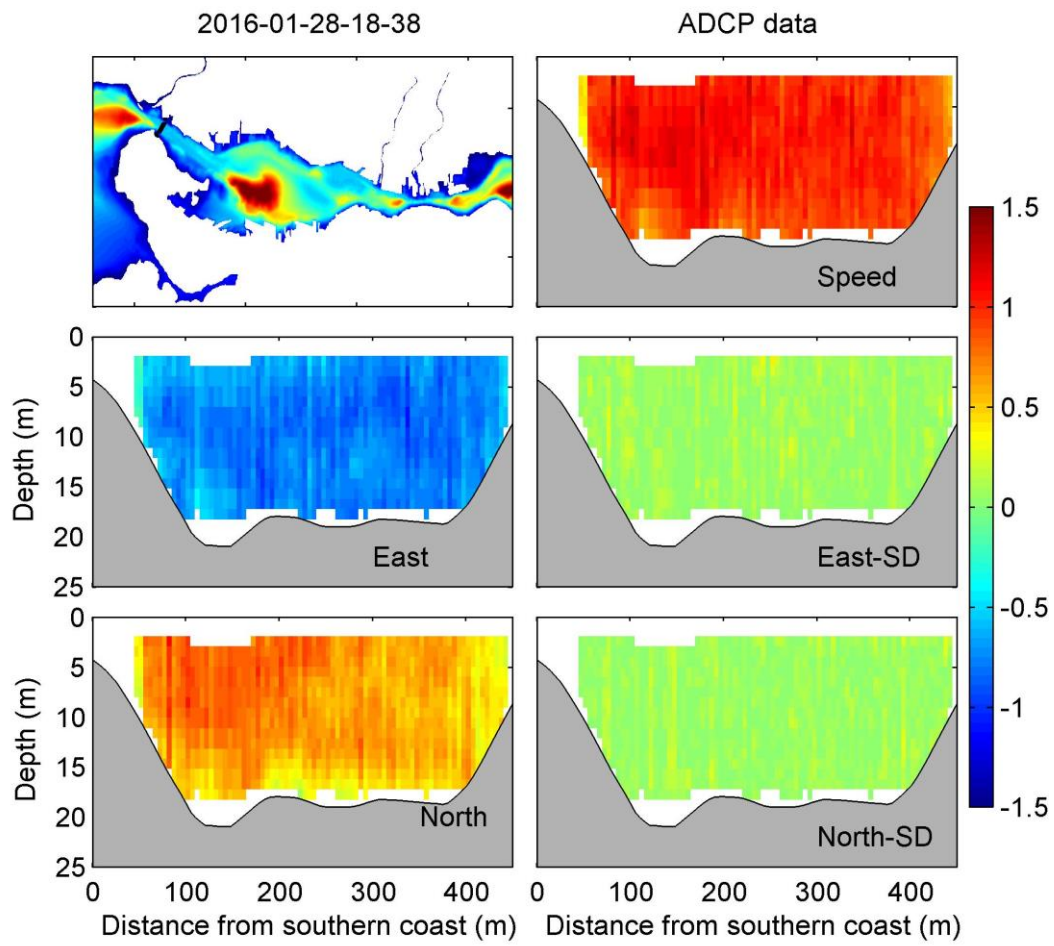


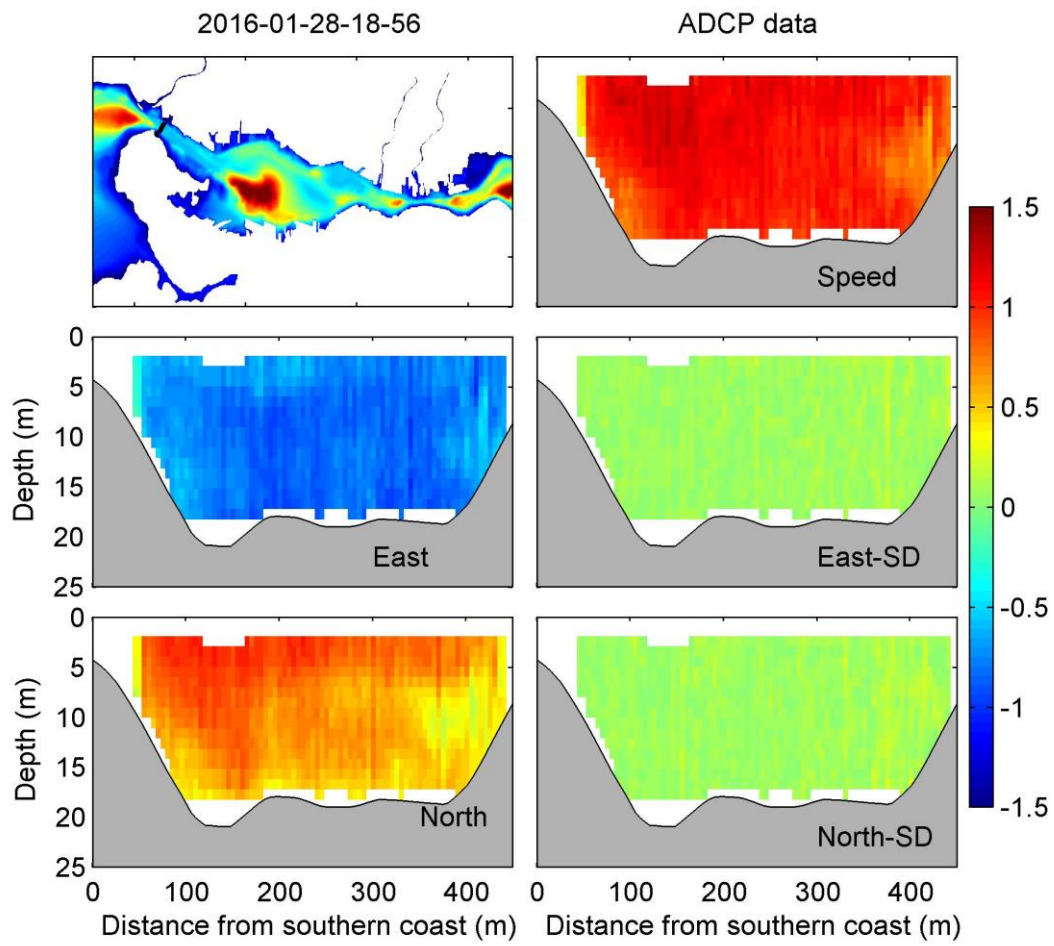


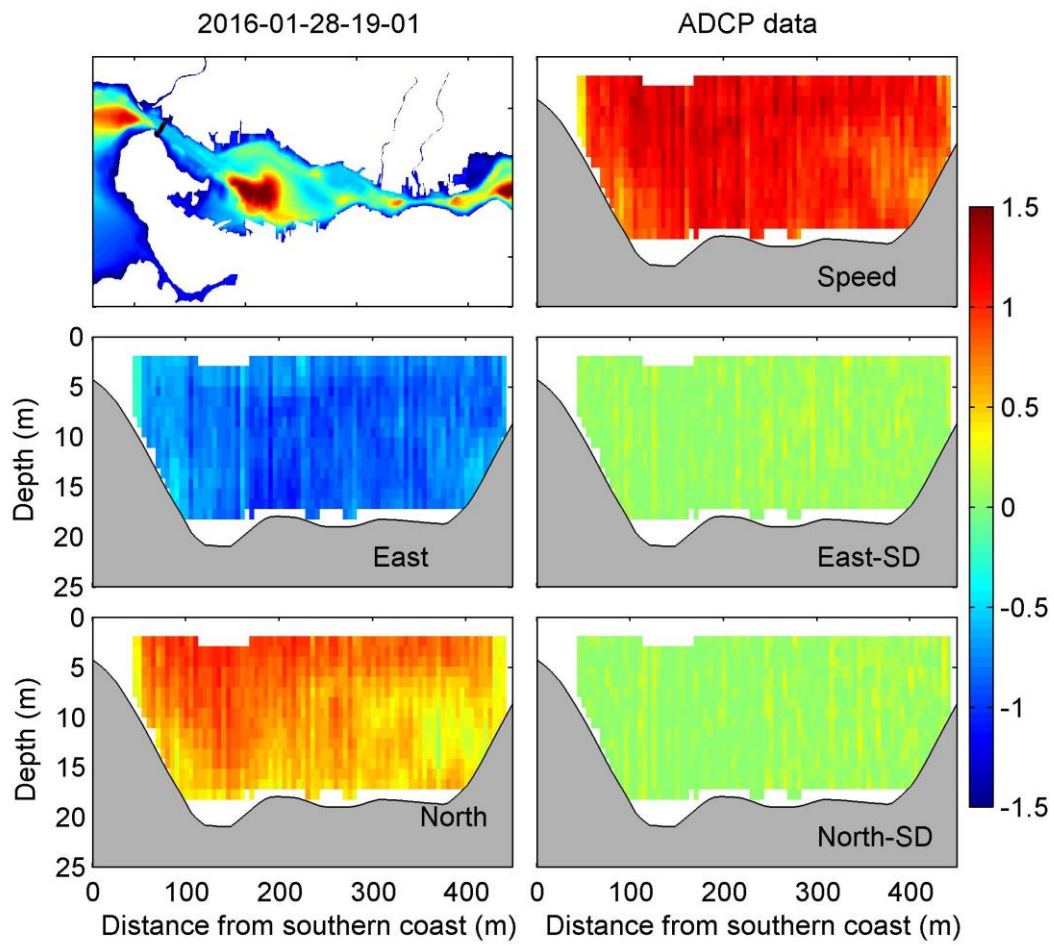


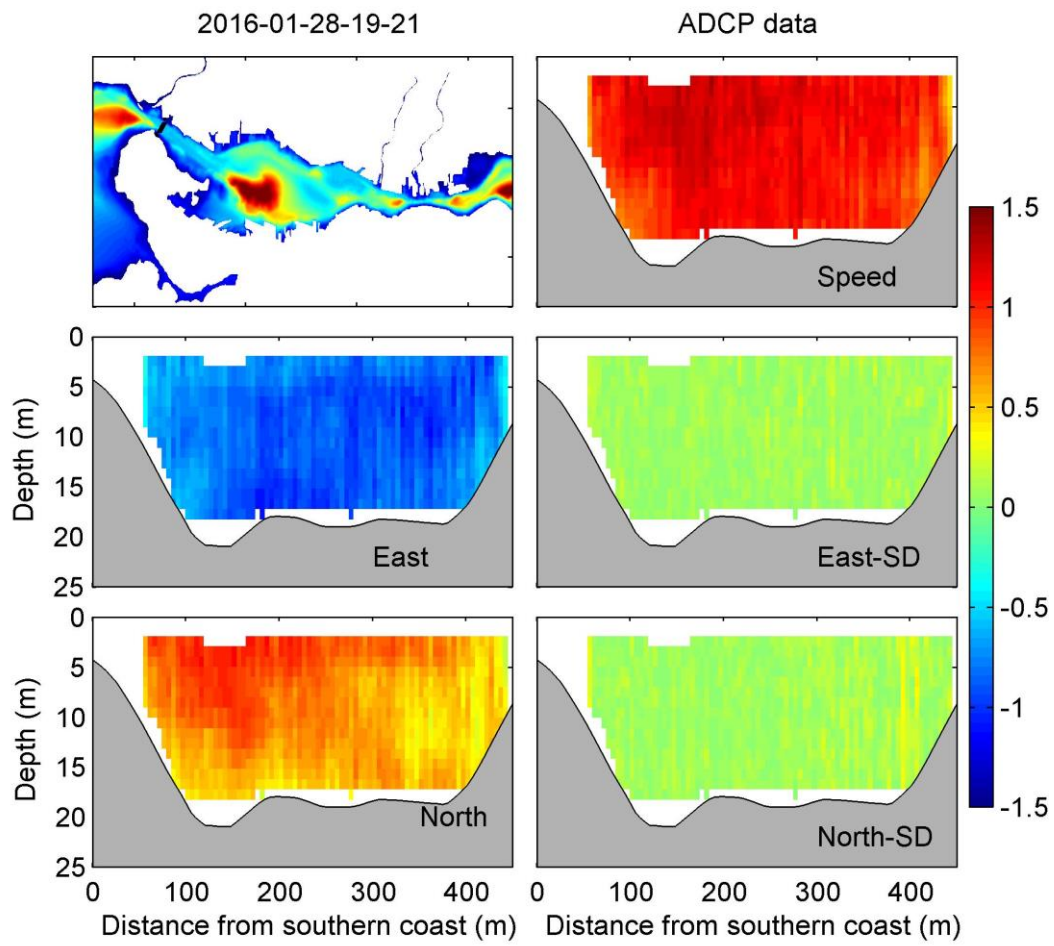


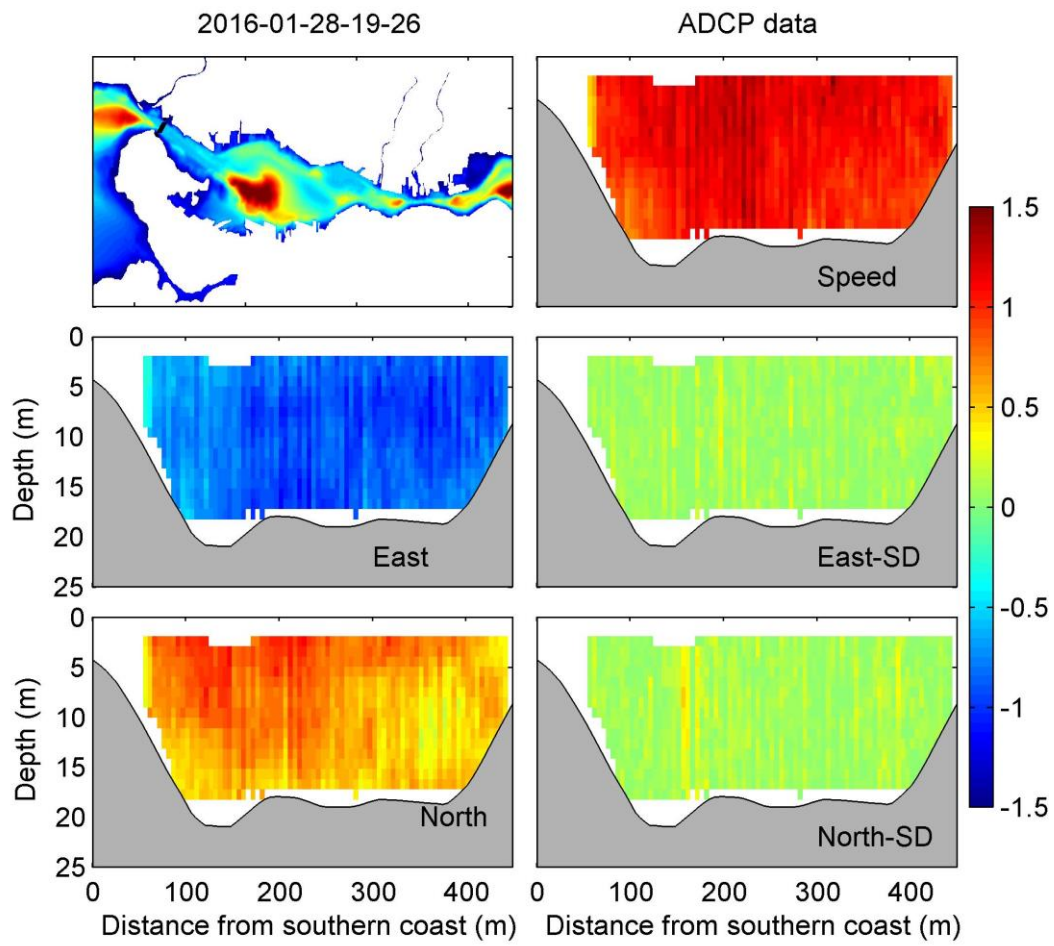


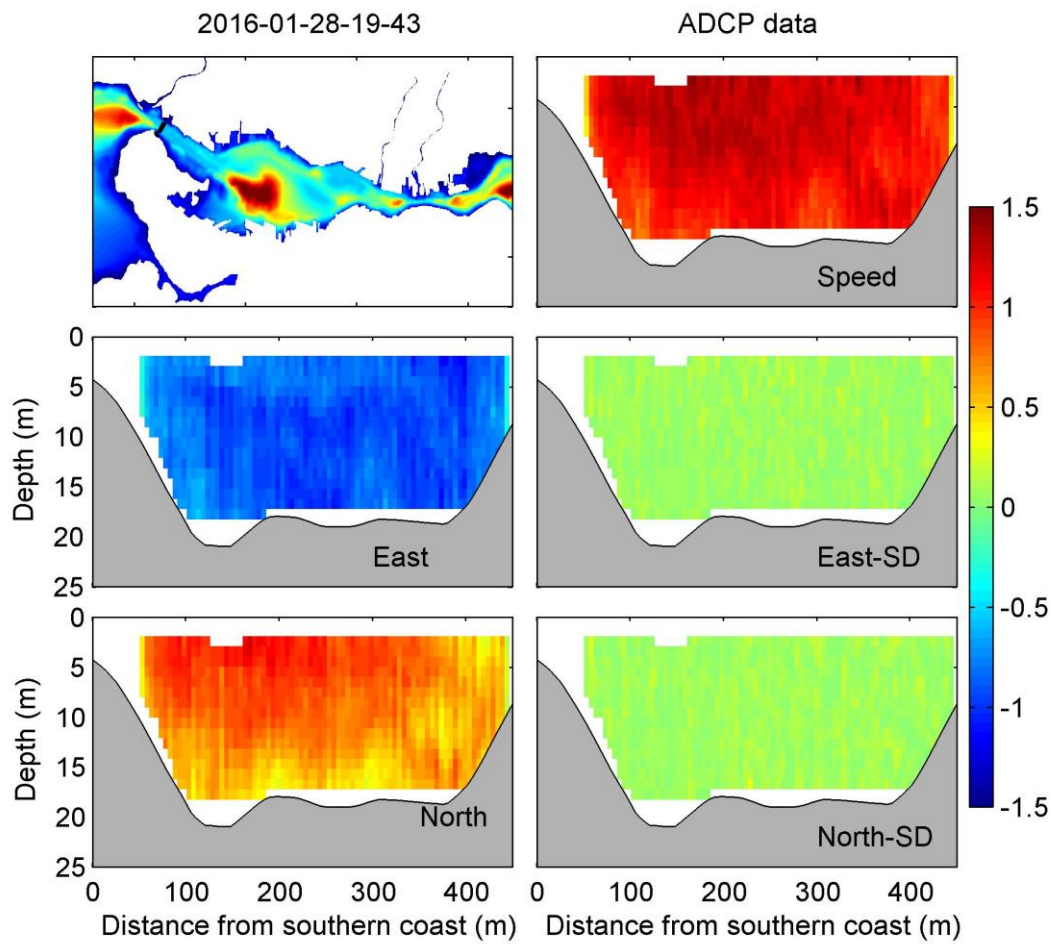


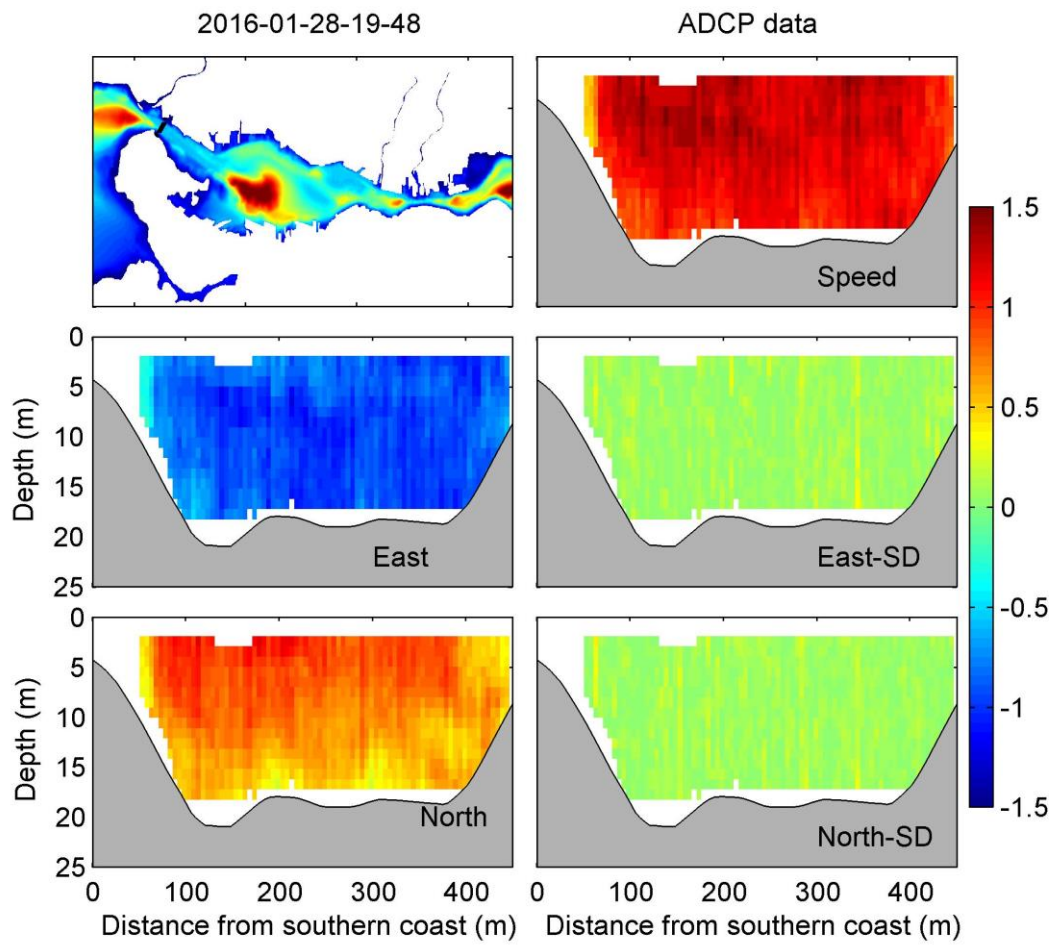


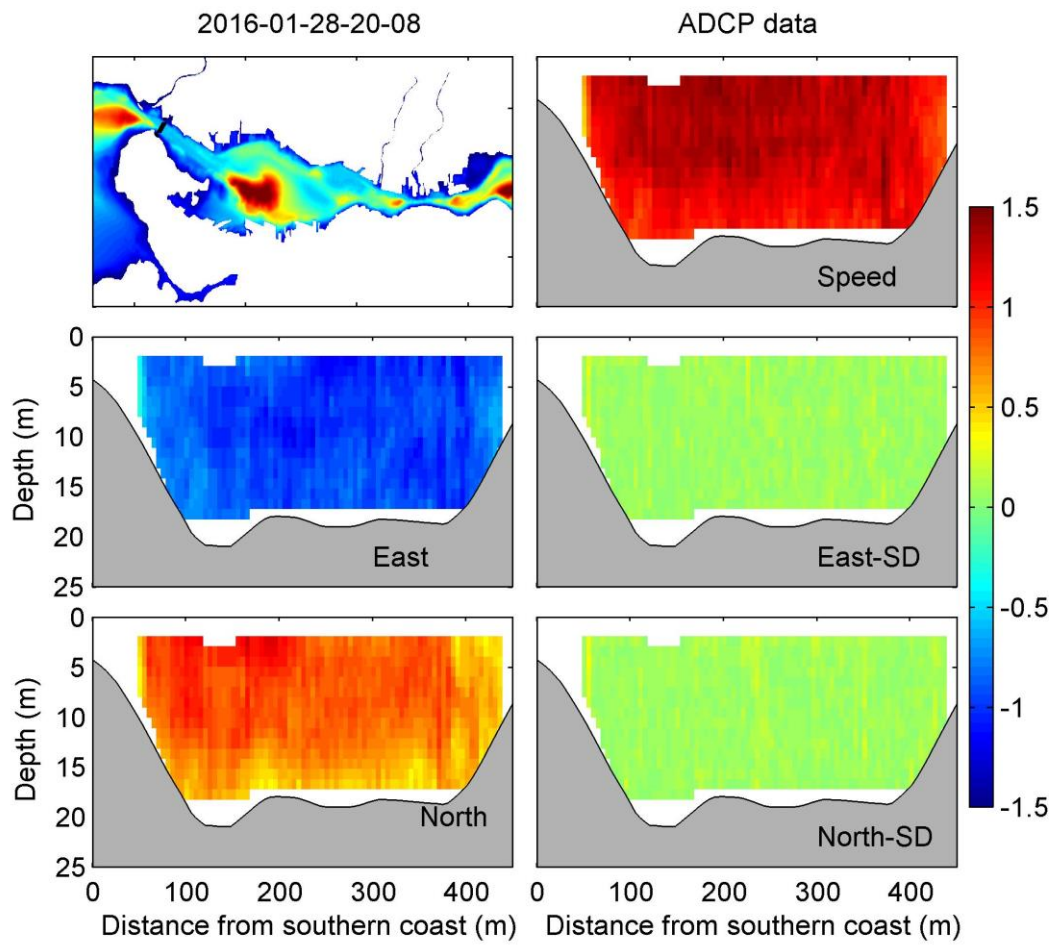


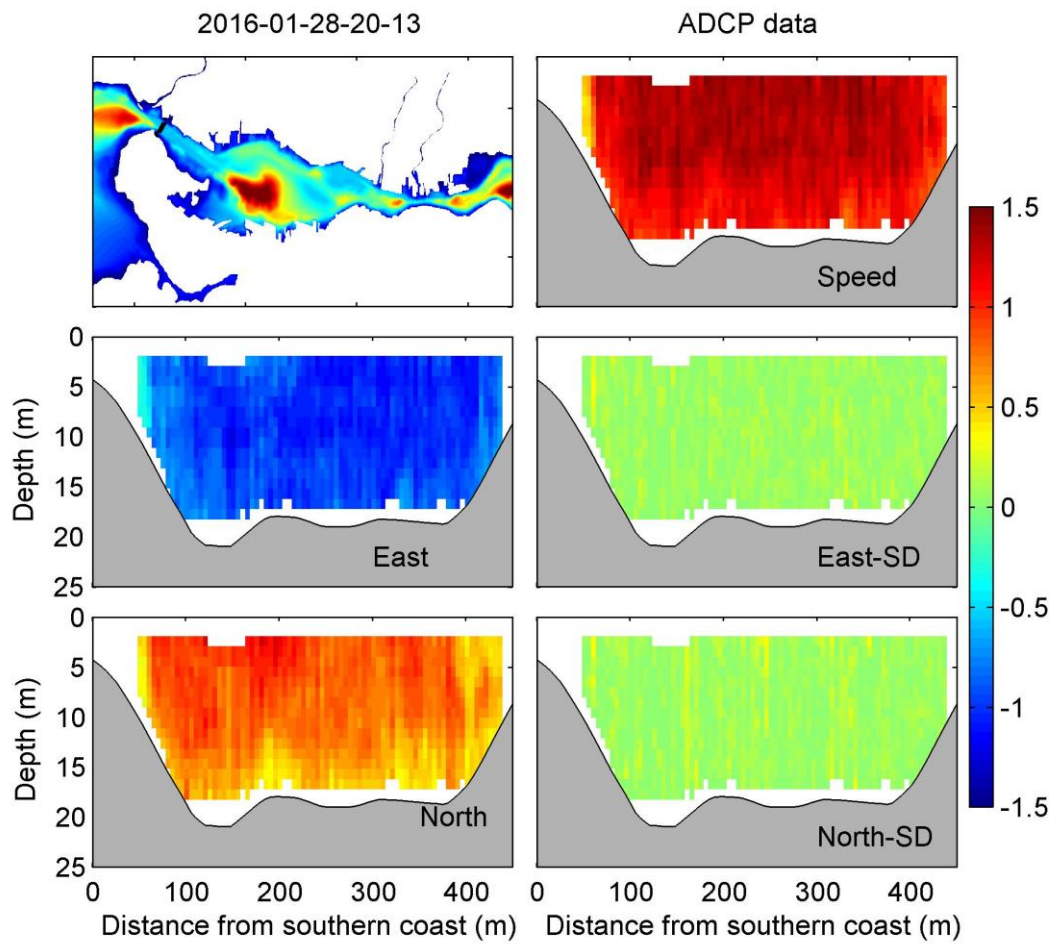


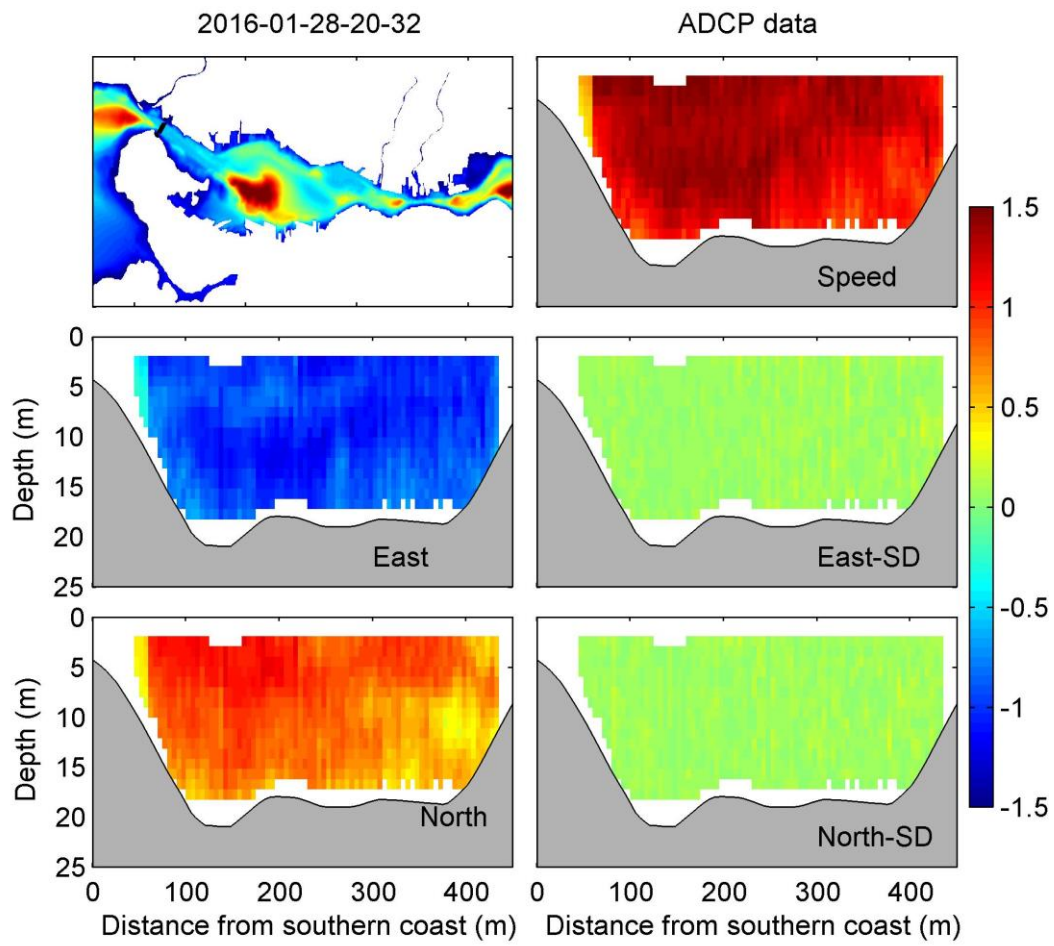


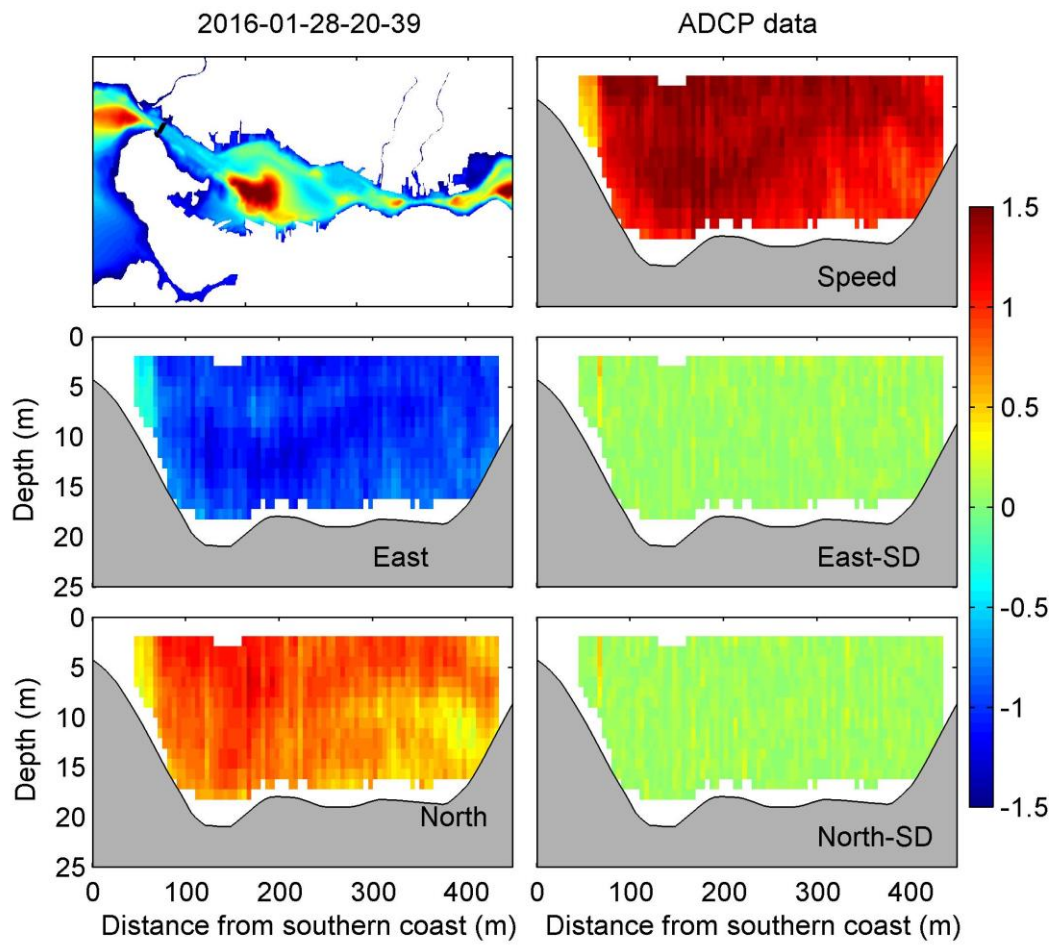


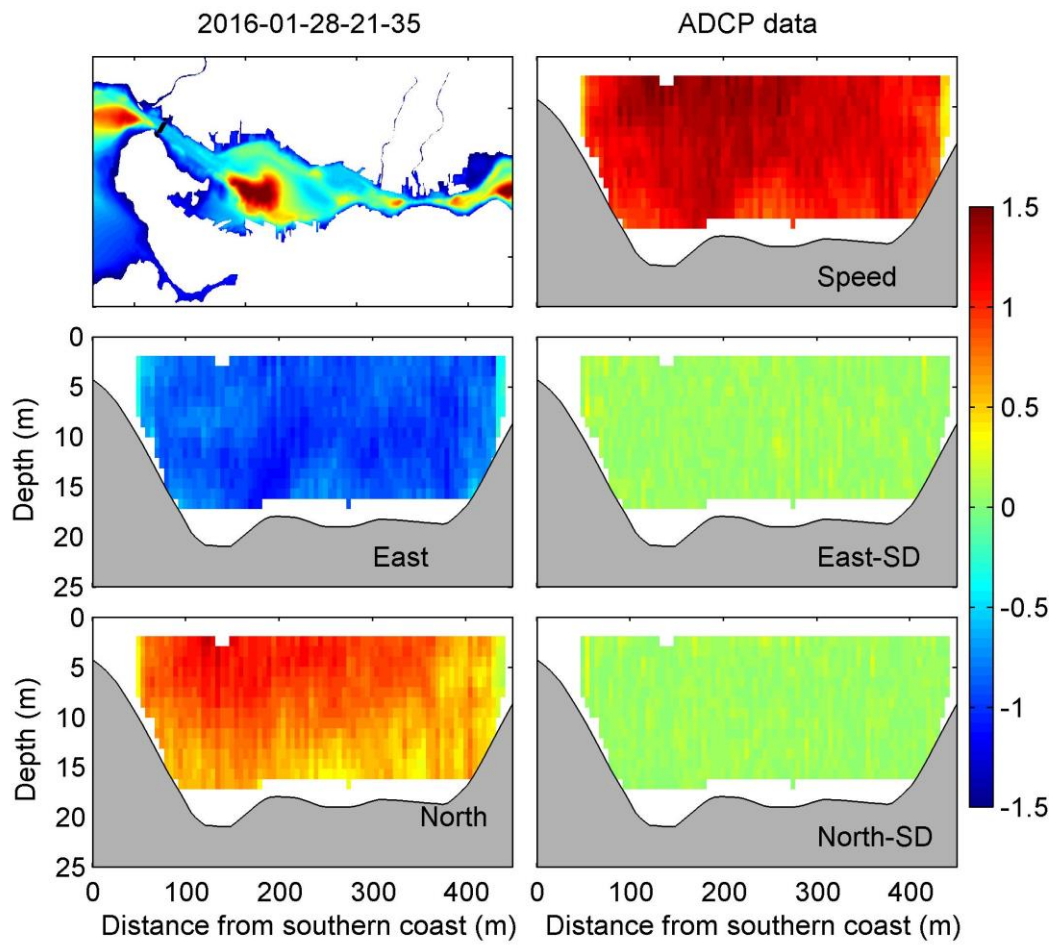


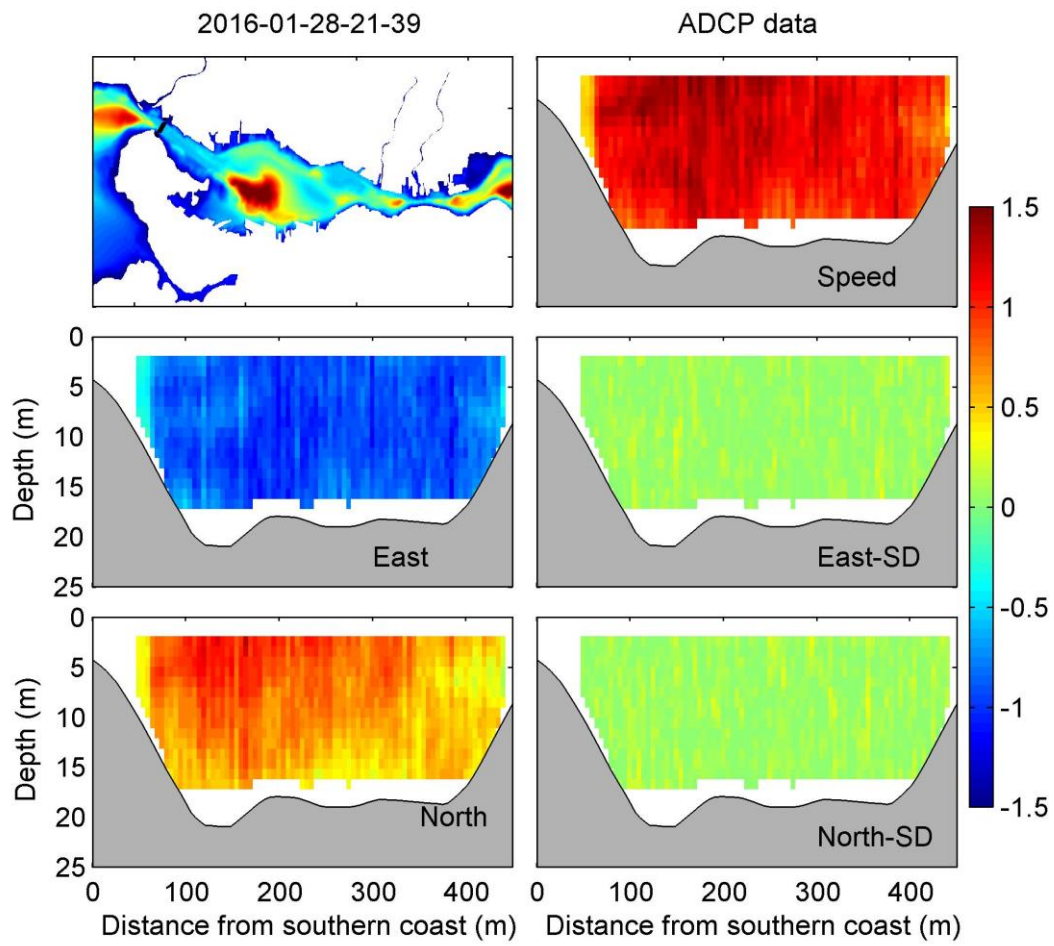


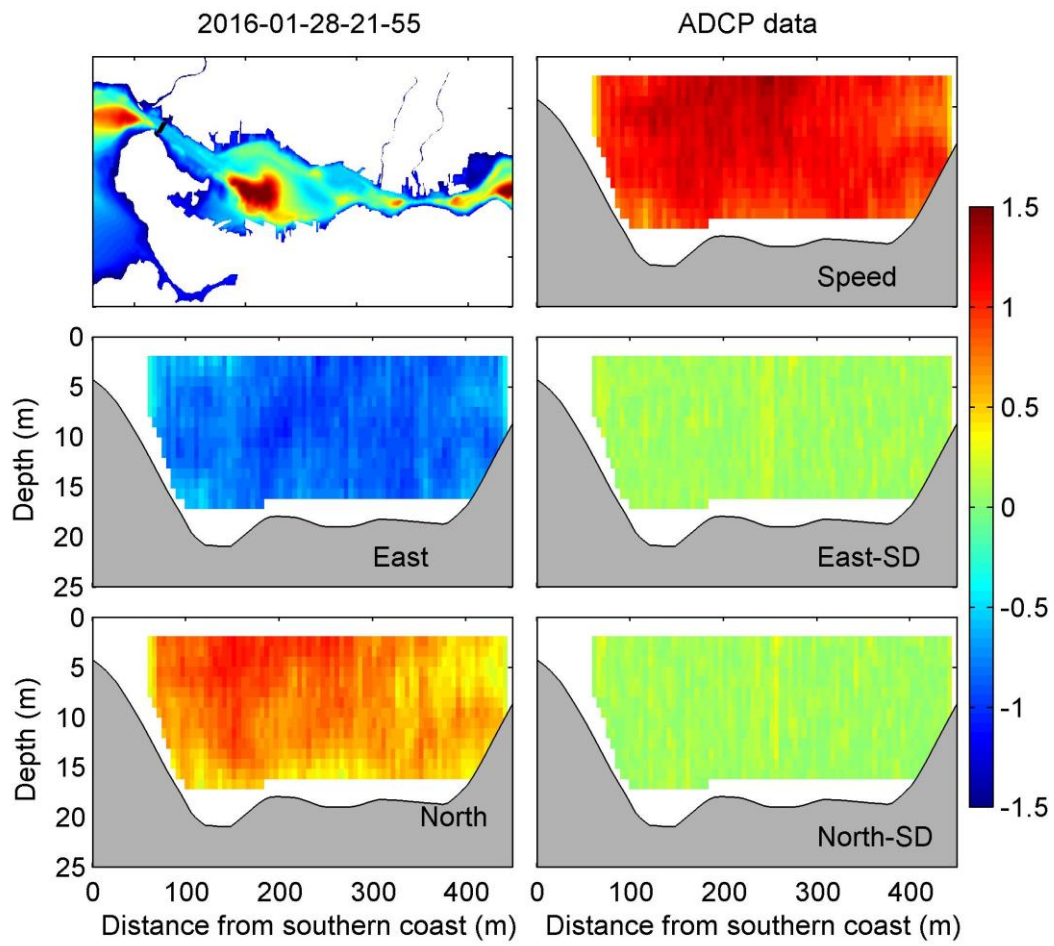


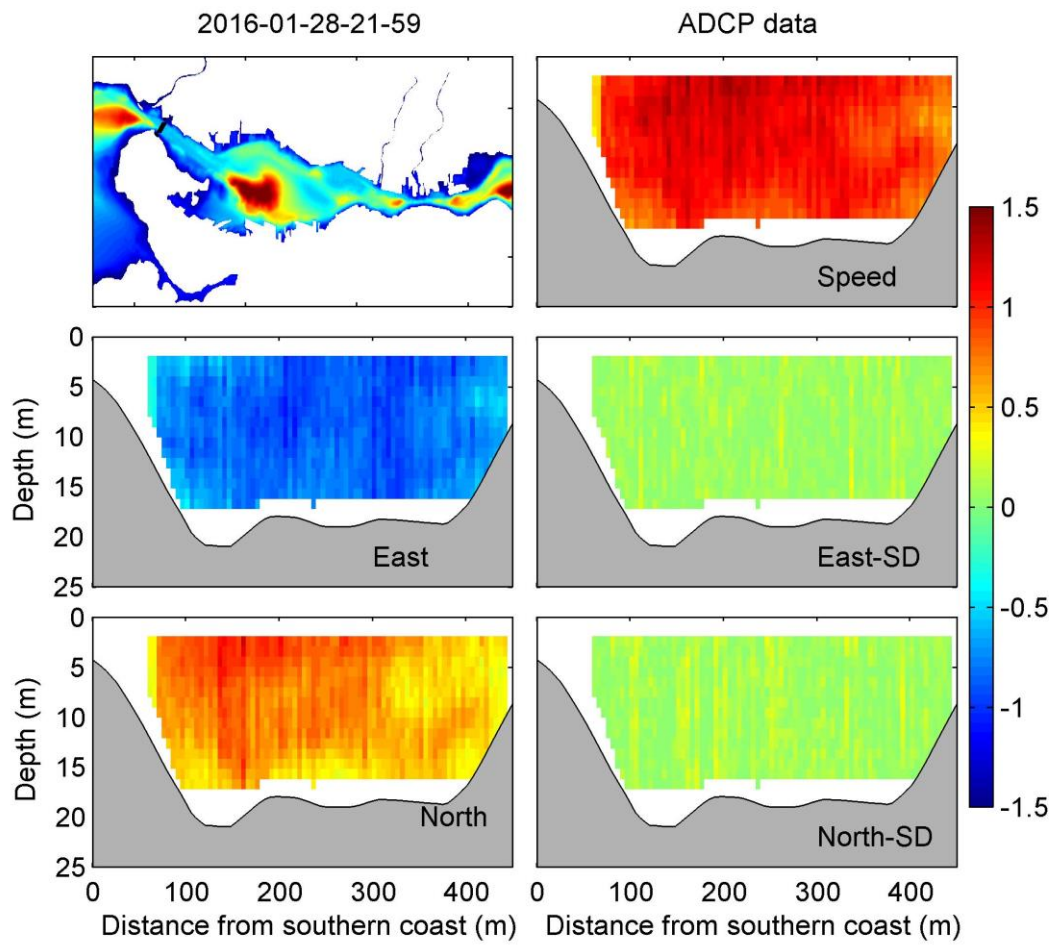


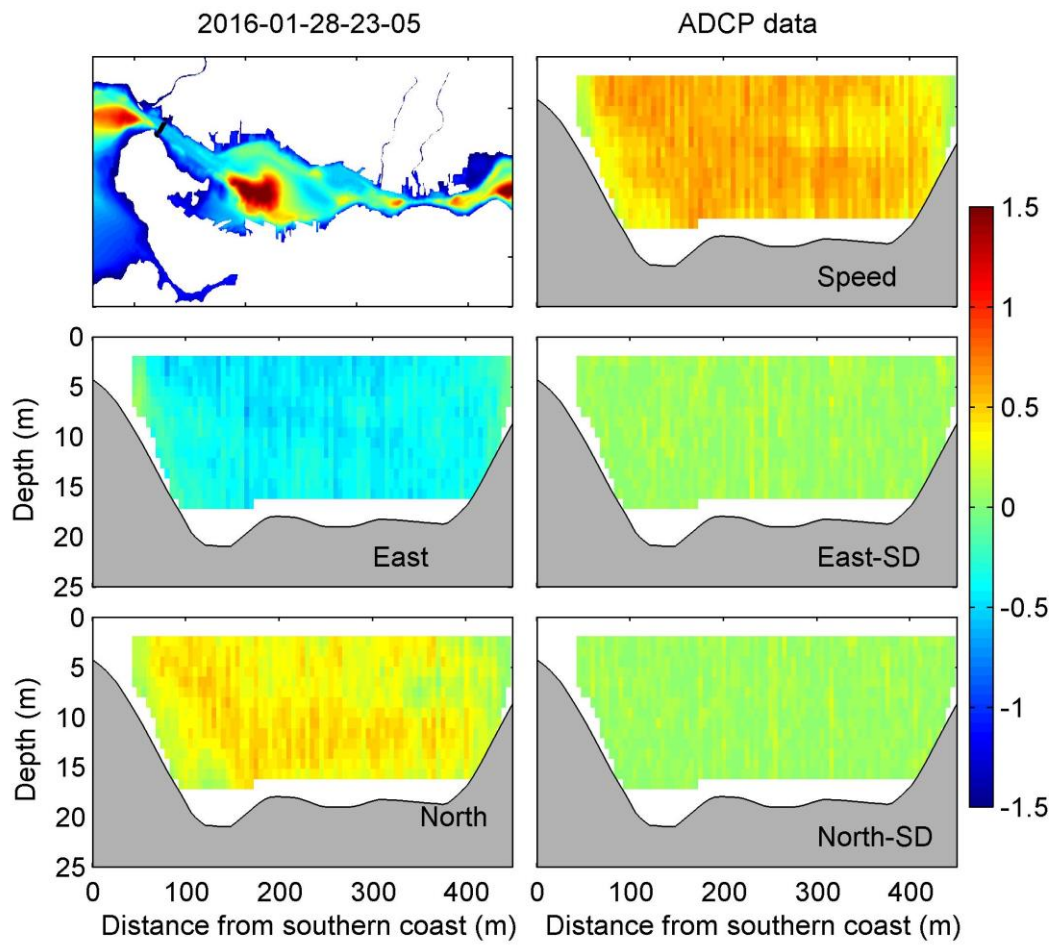


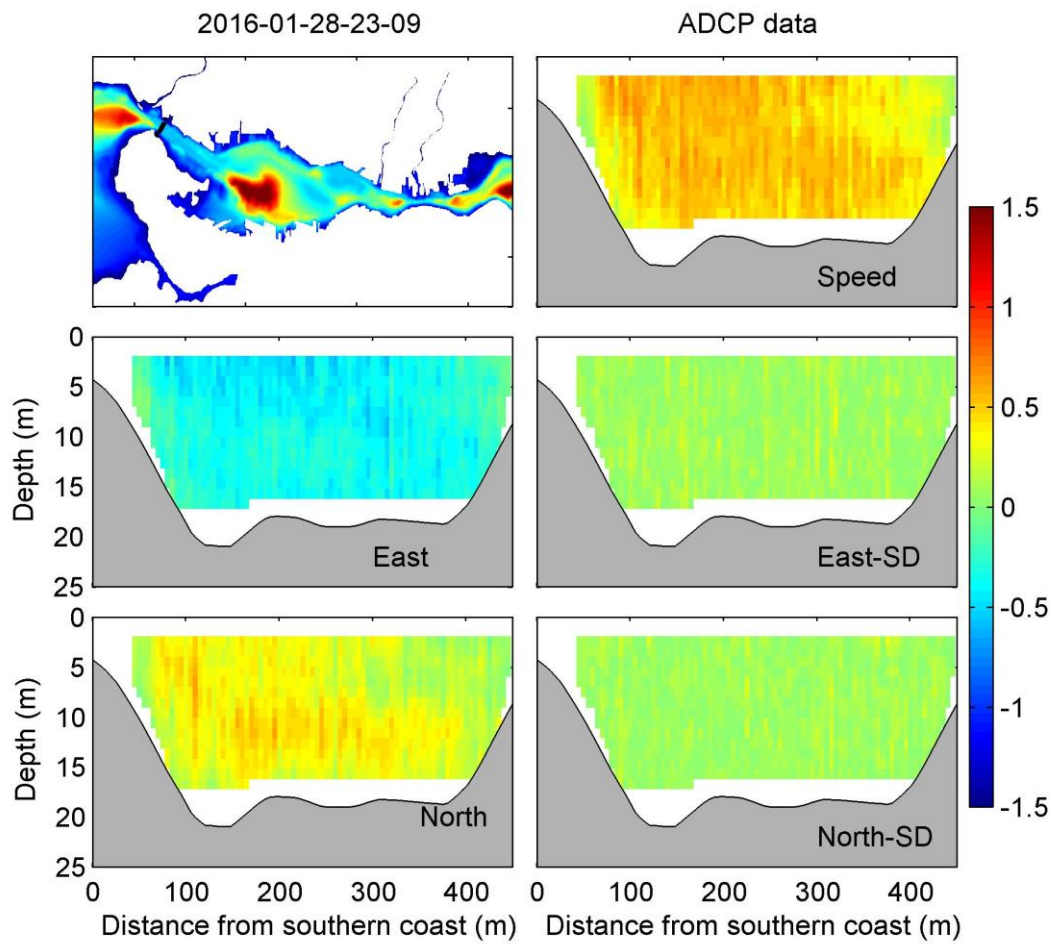


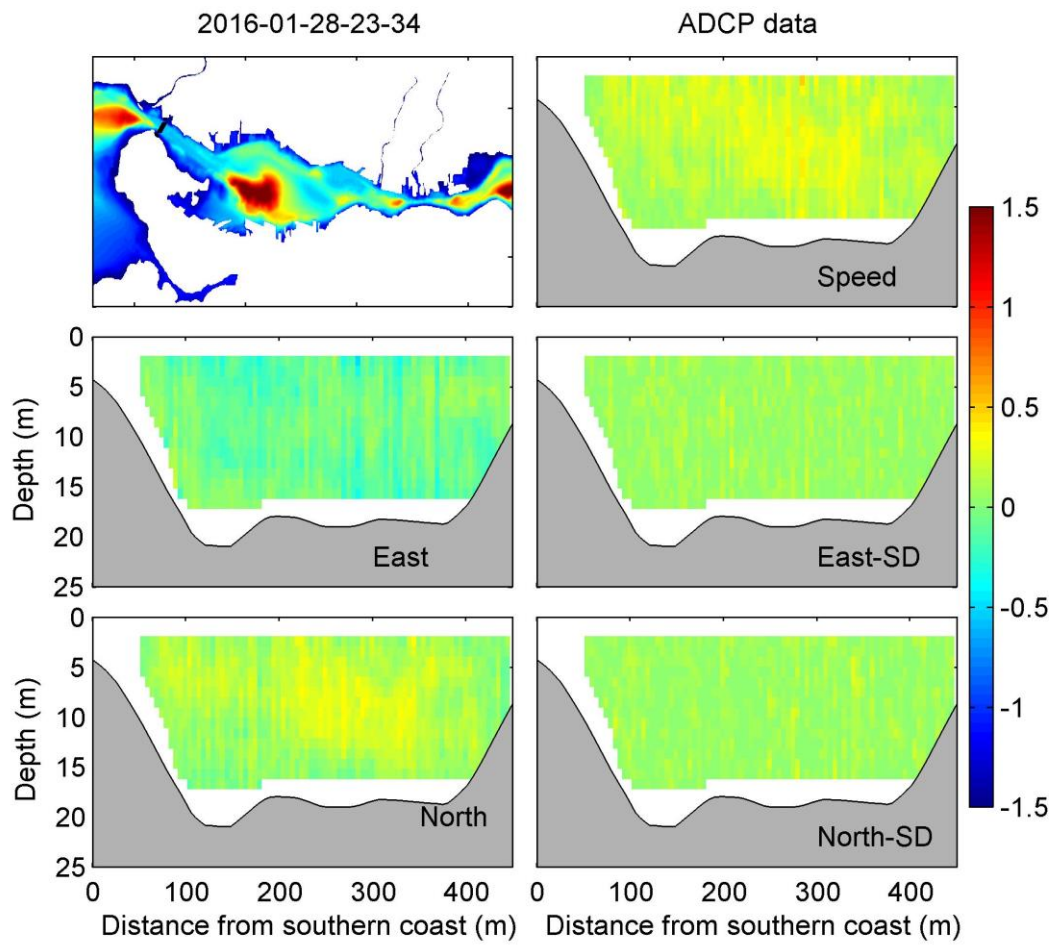


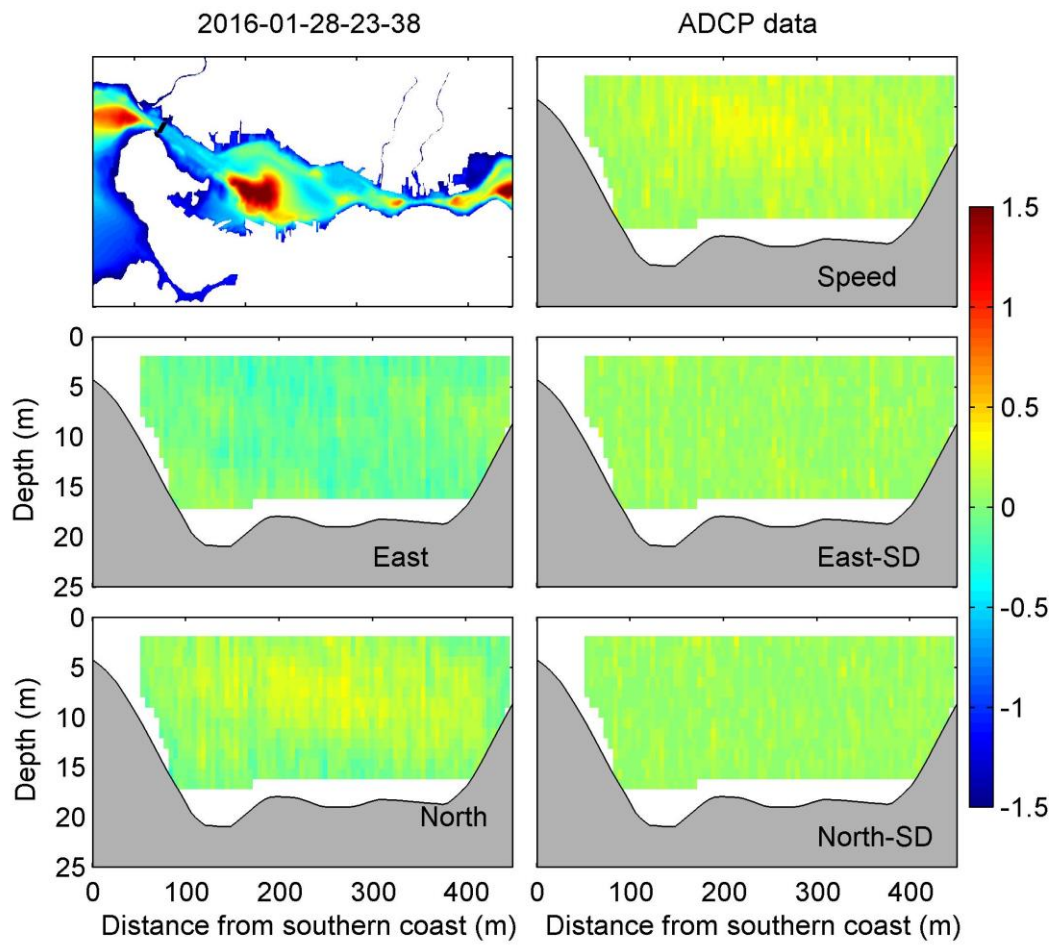


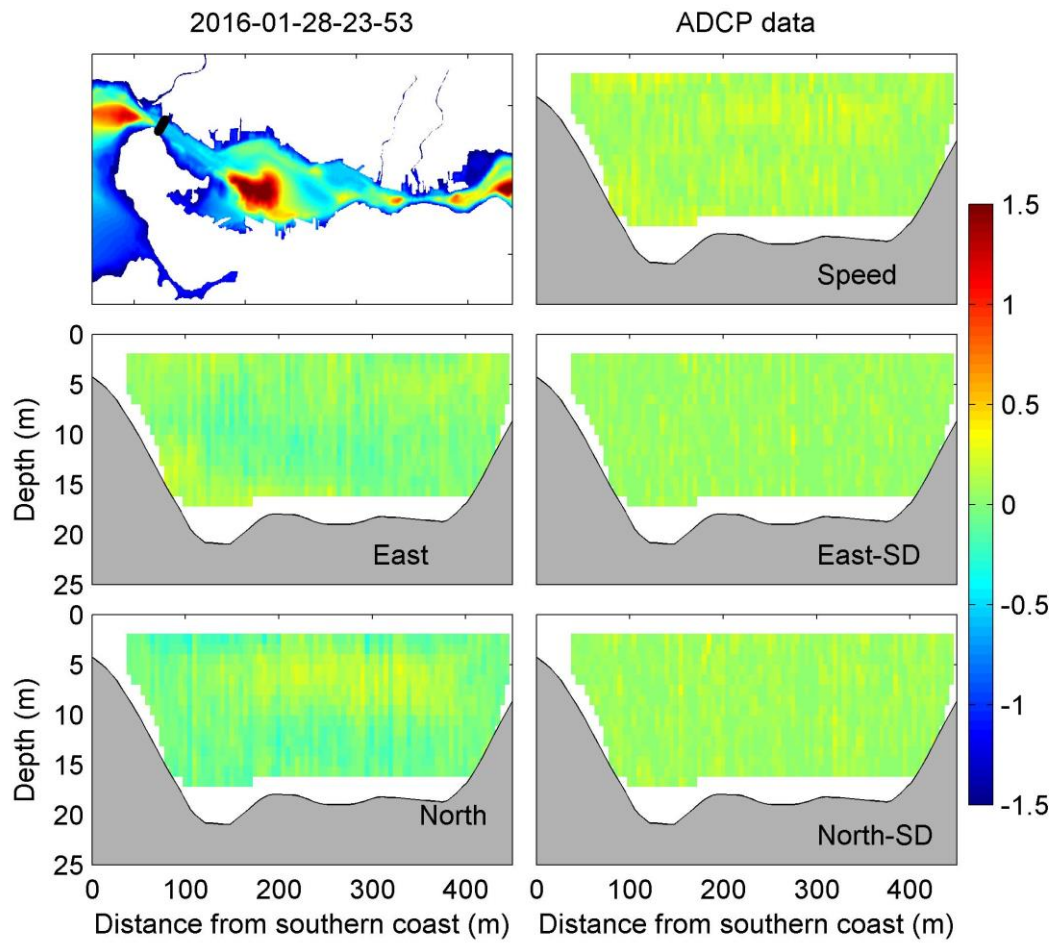


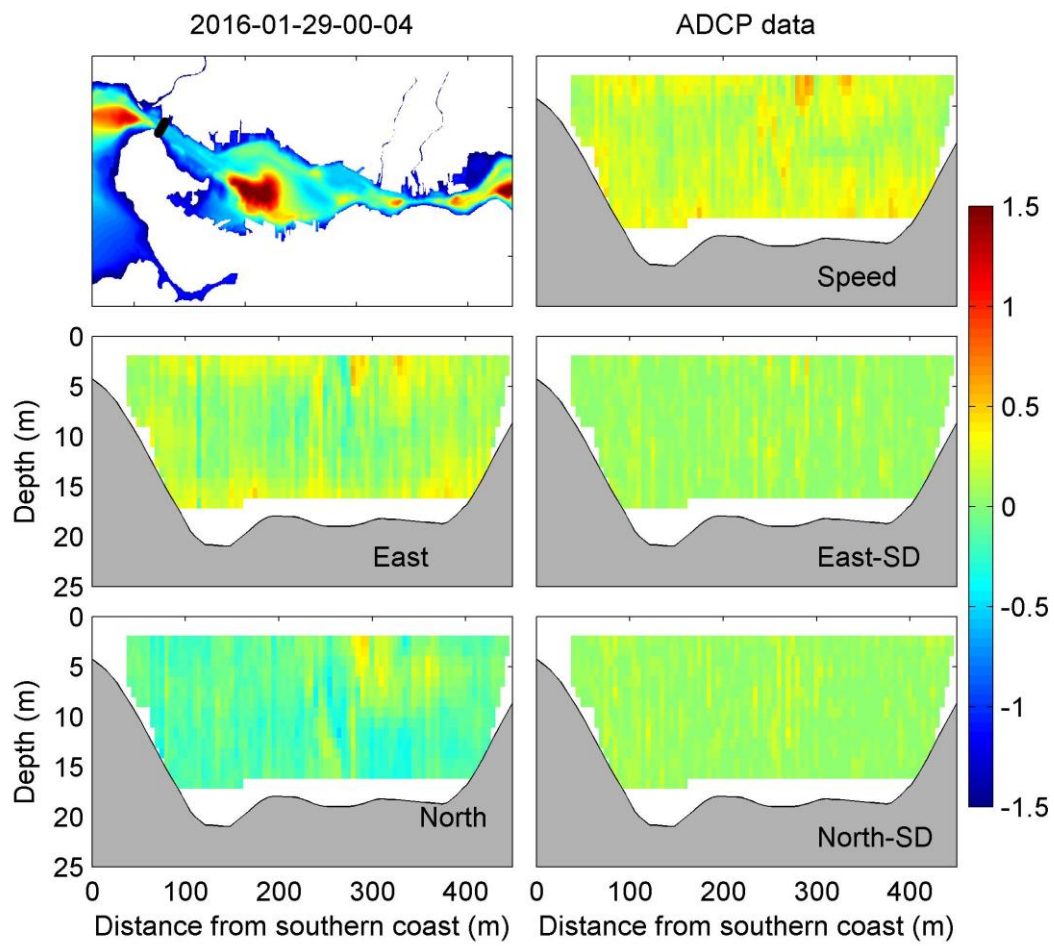


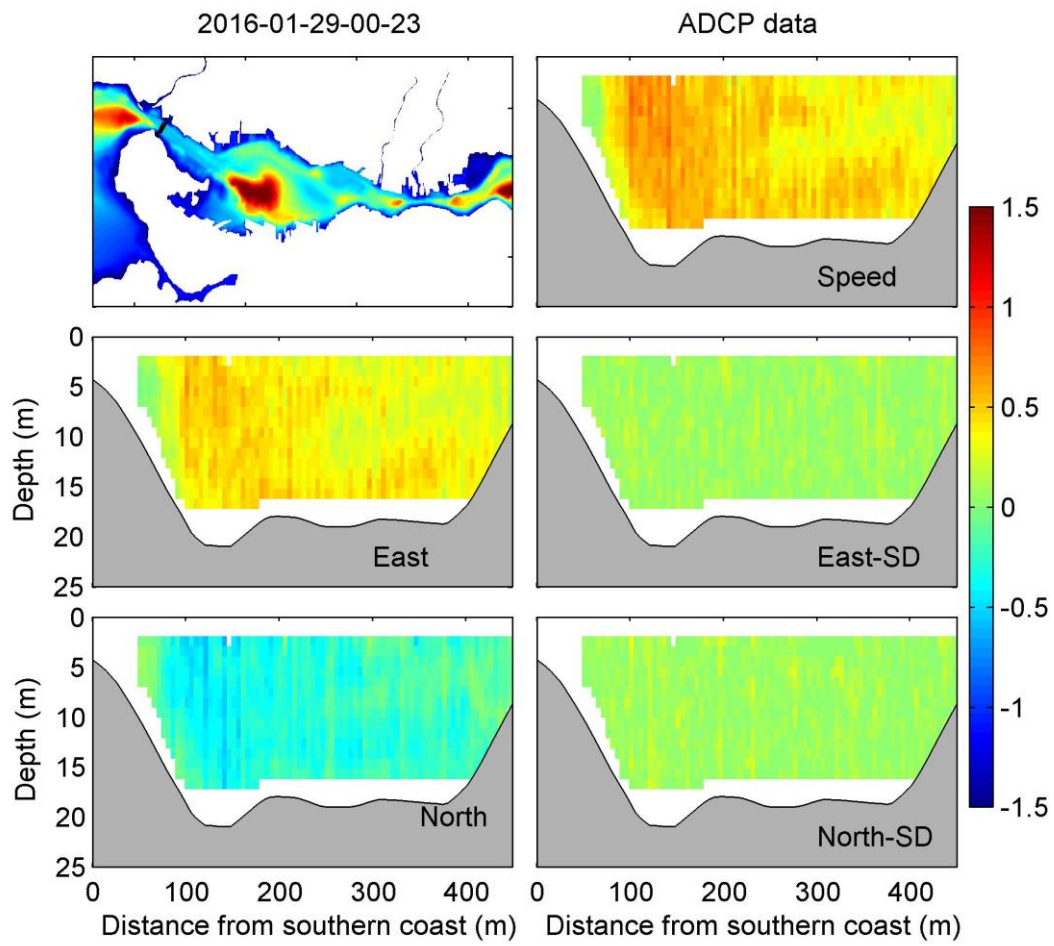


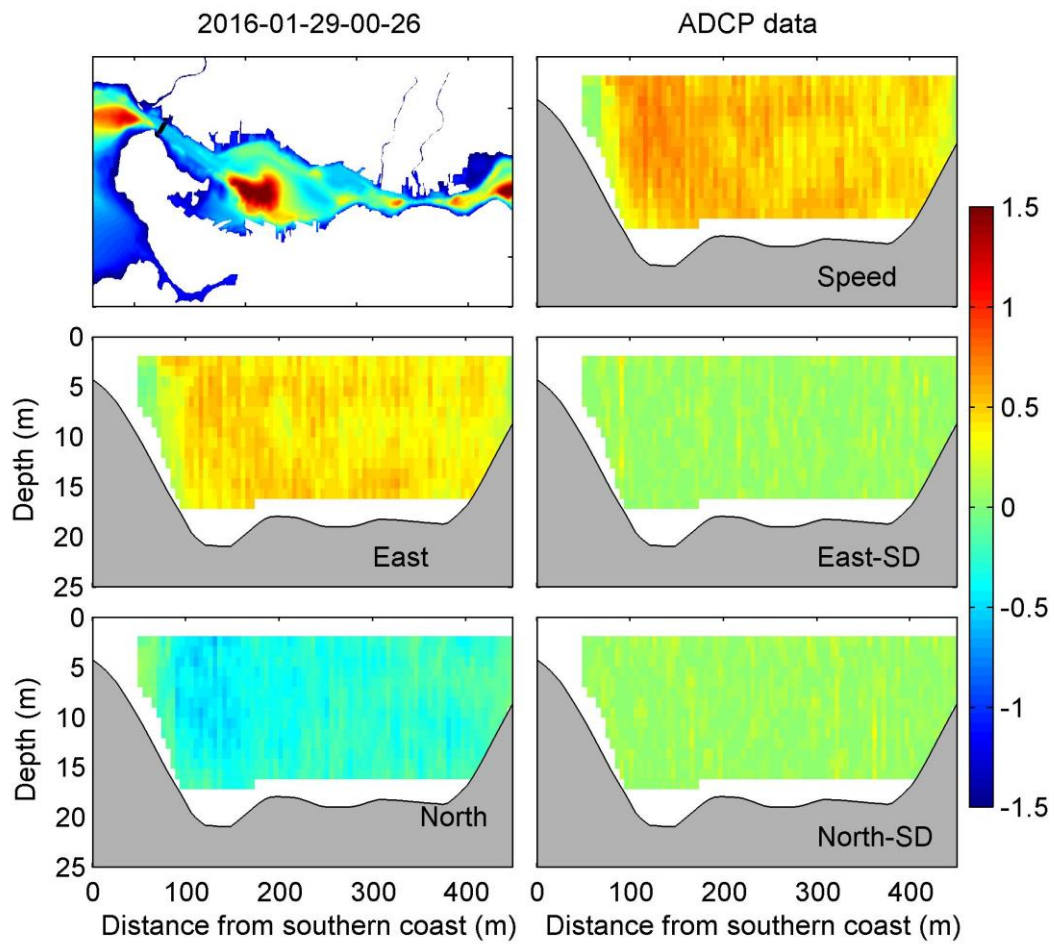


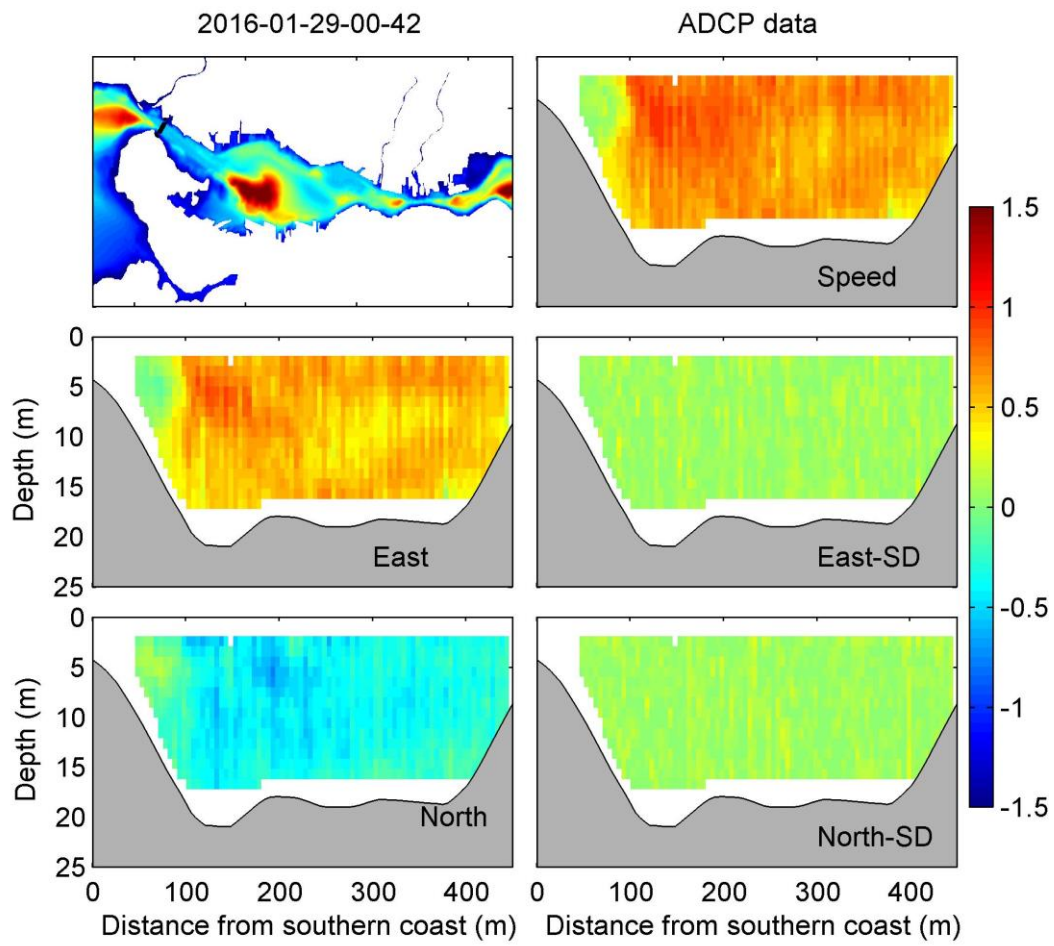


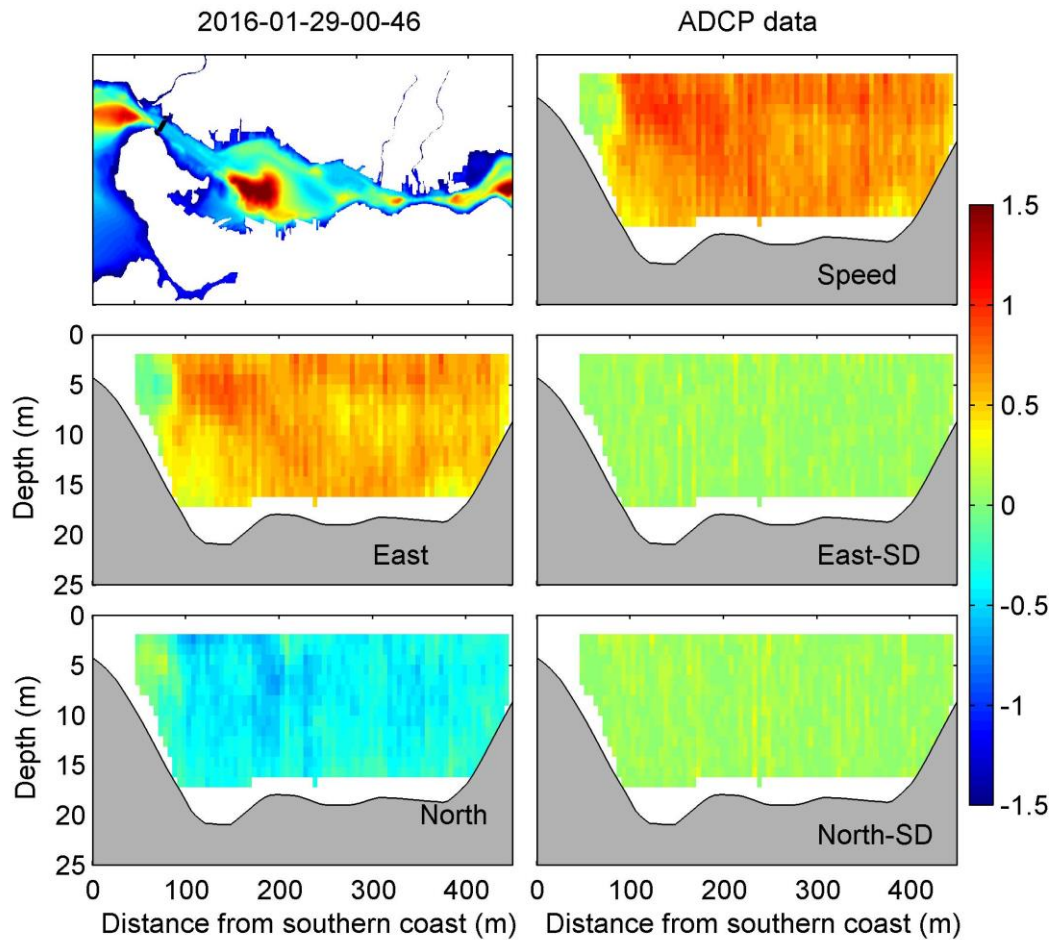






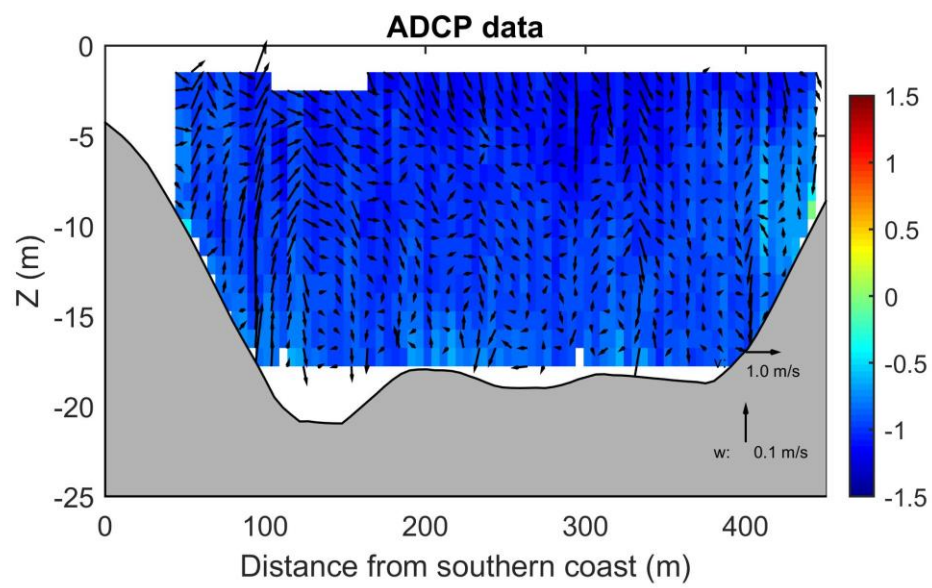
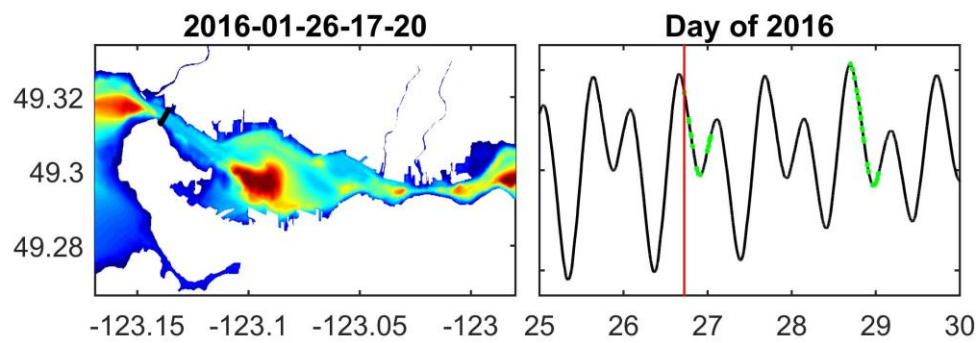


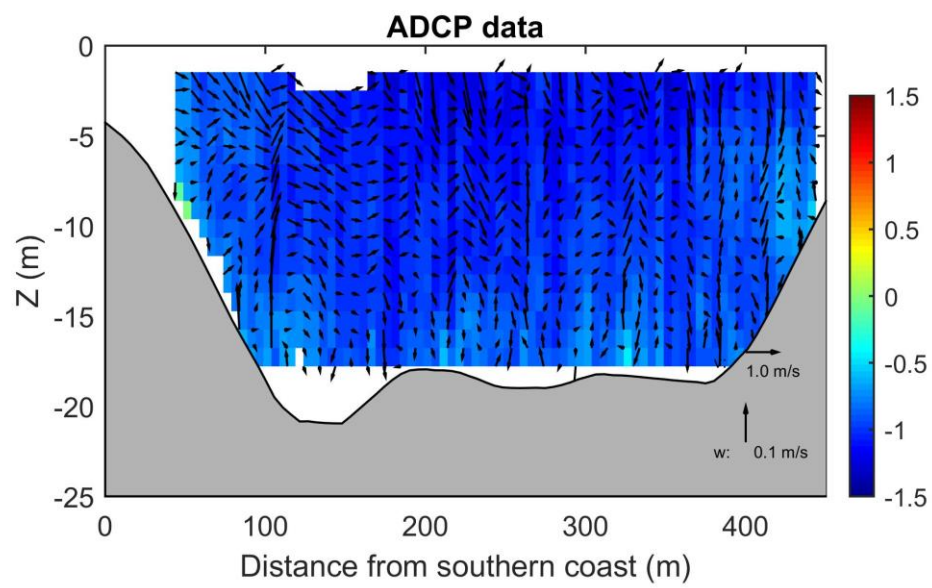
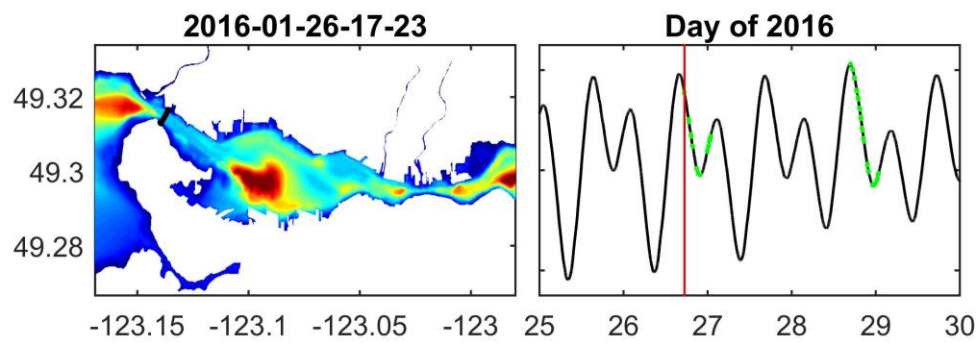


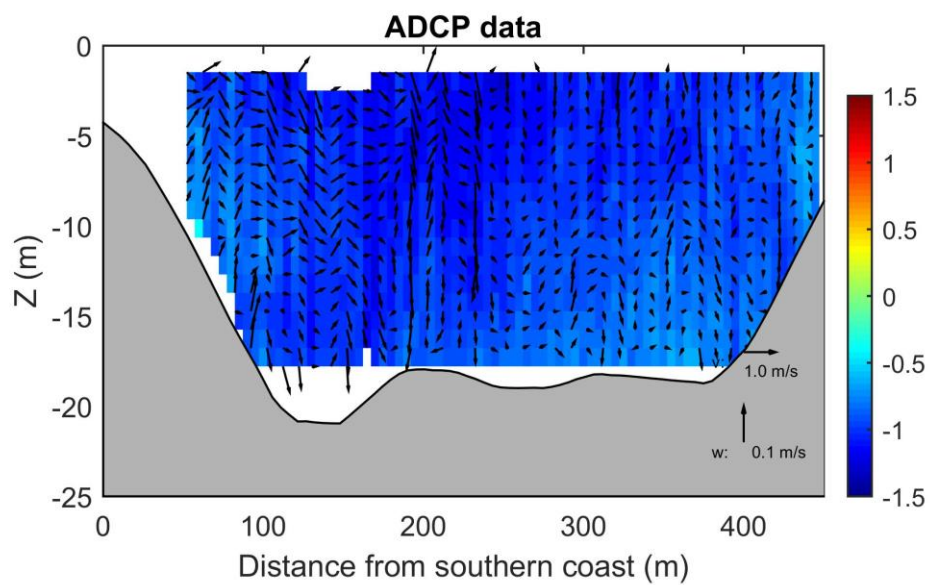
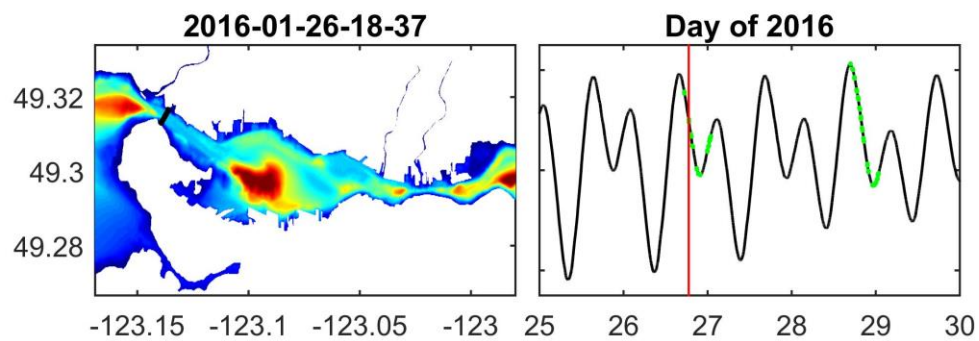


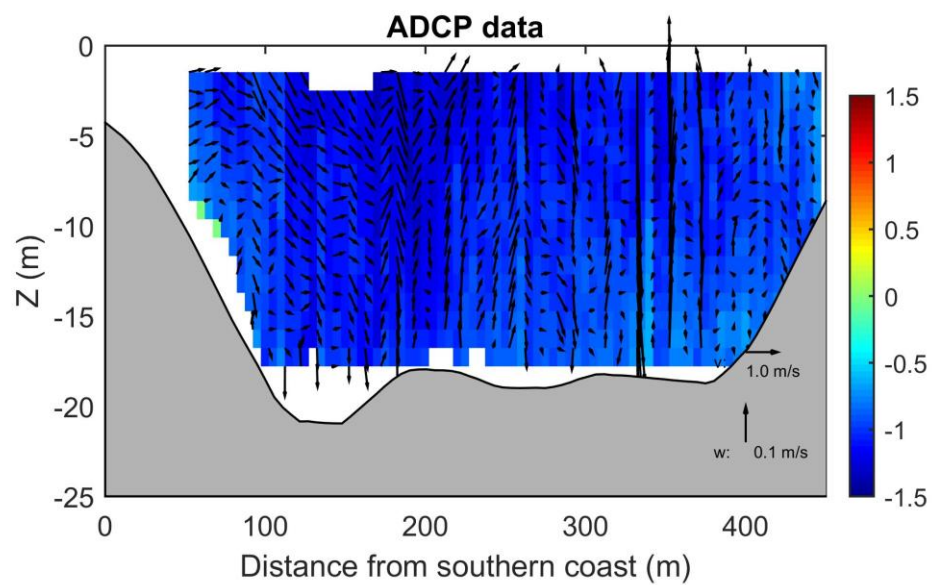
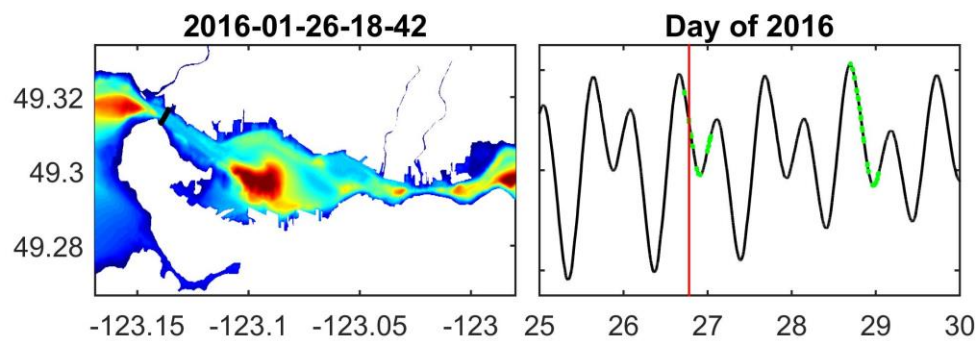
7.4 LINE 2 VERTICAL PROFILE OF VELOCITY VECTORS AND TIDAL CYCLE

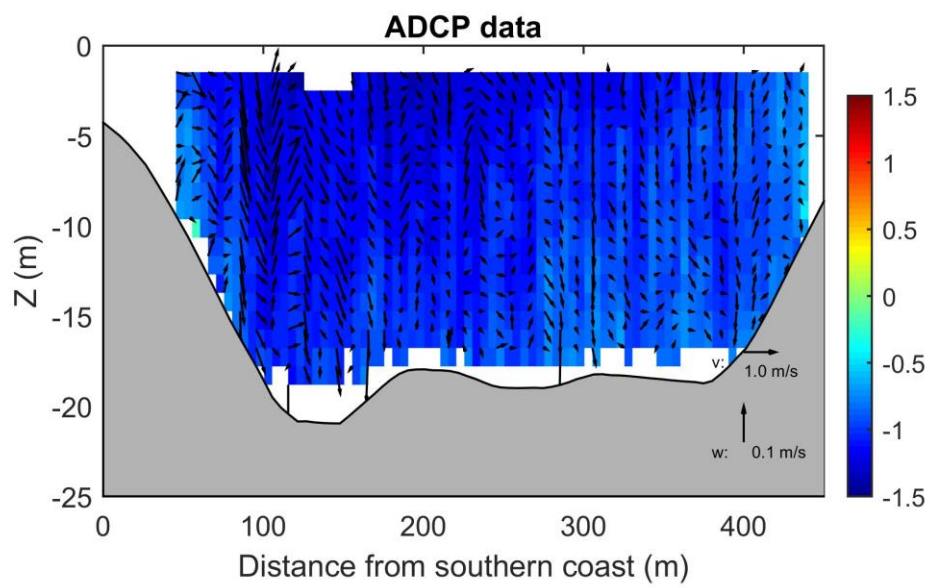
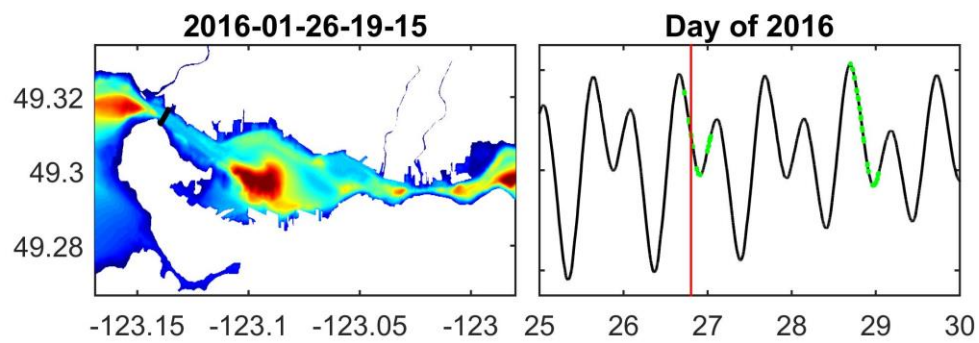
The following figures show vertical profiles of the measured velocity data along Line 2. The figures show the bathymetry map that shows the position of the transect, the point during the tidal cycle when the sampling occurred, and the velocity vectors produced by the data. Units are ms^{-1} .

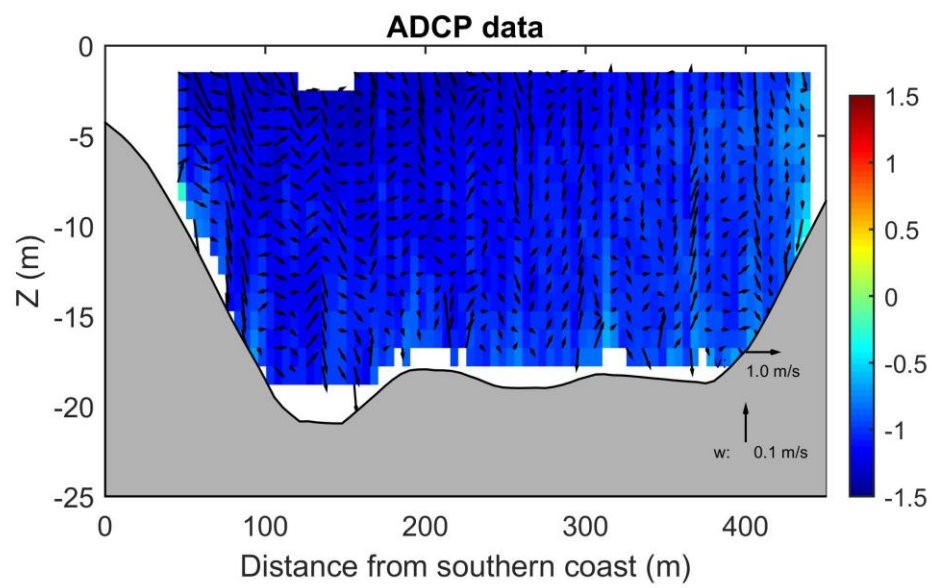
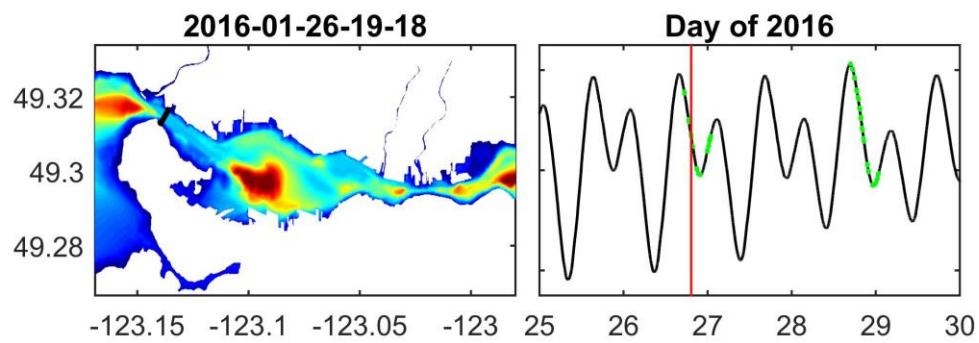


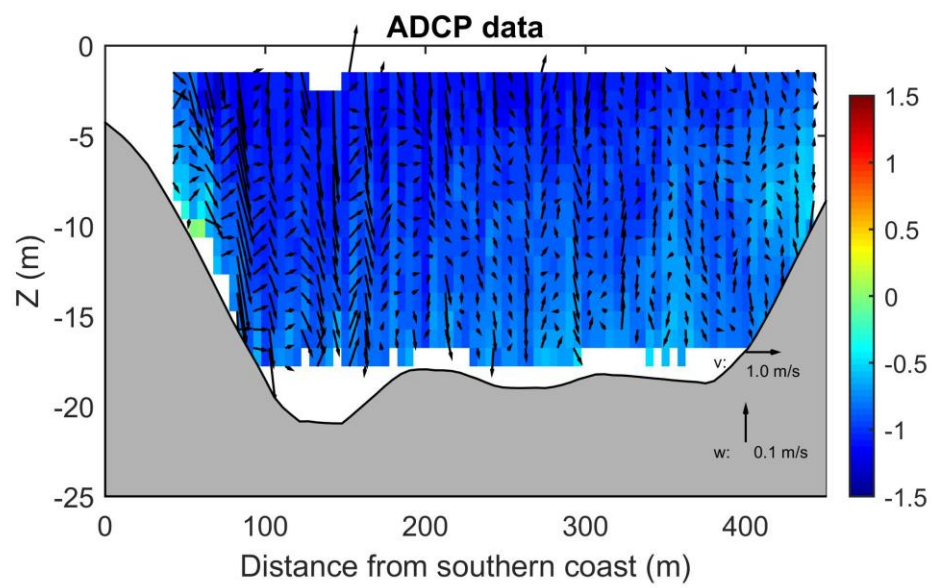
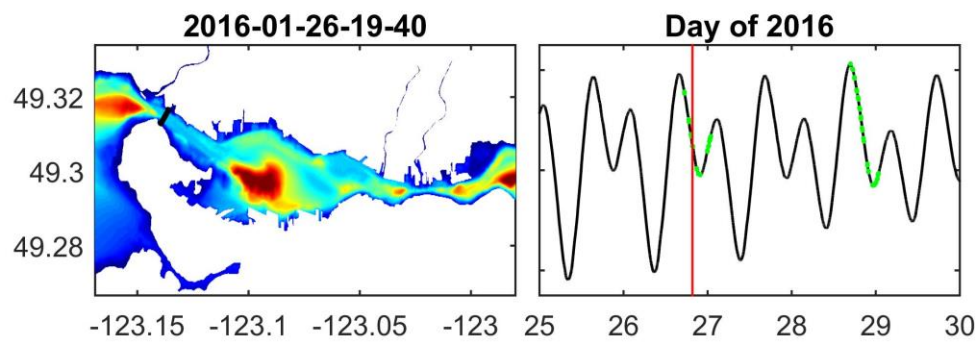


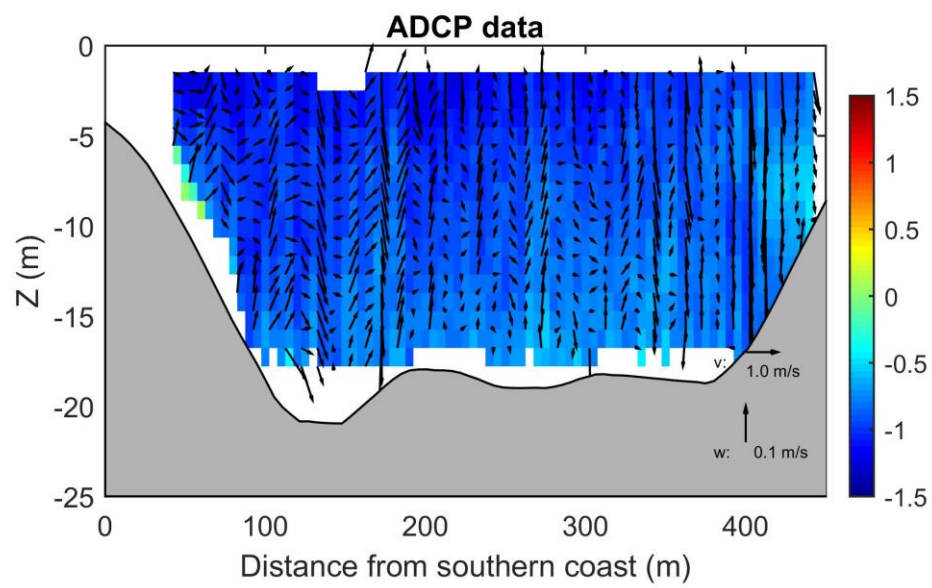
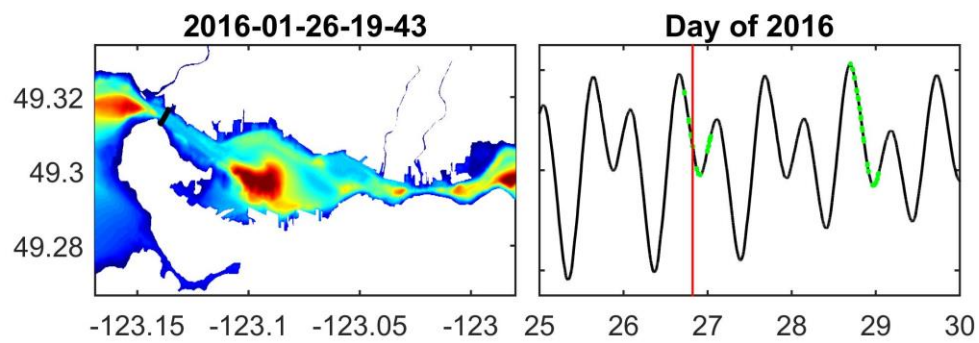


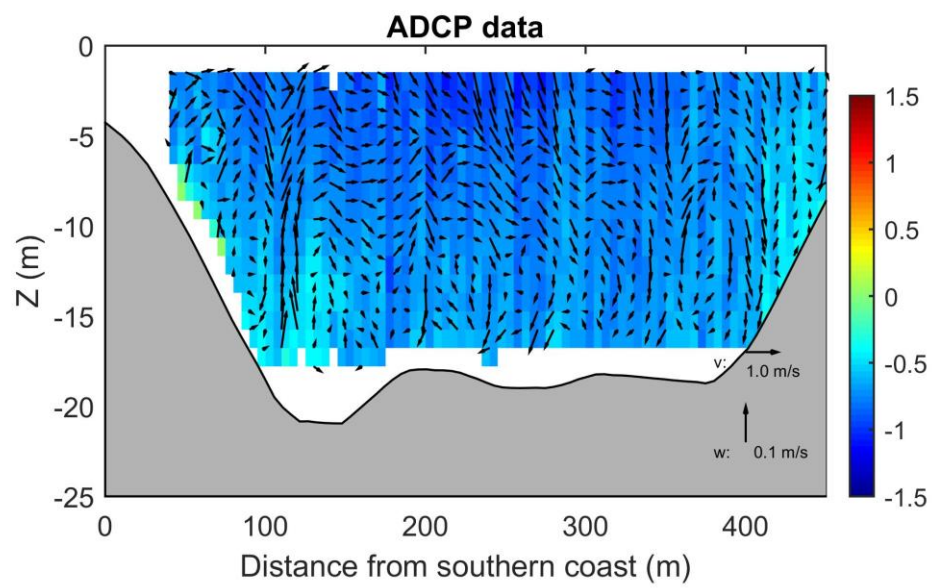
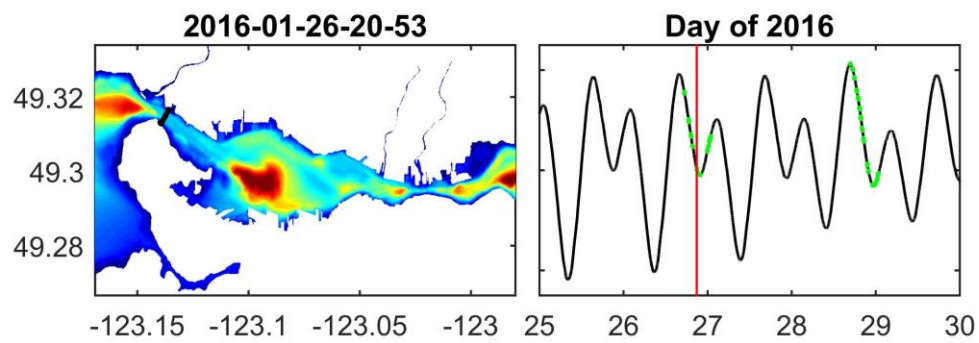


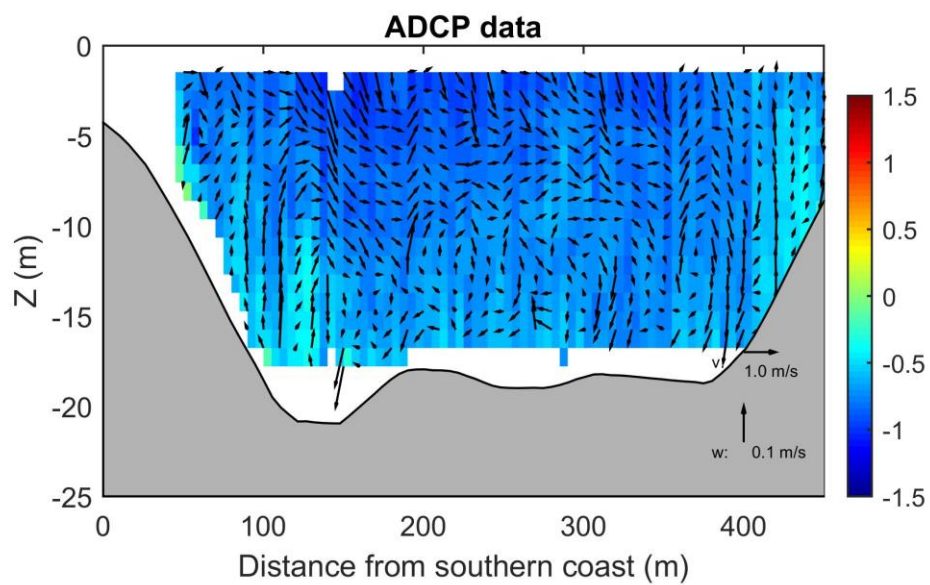
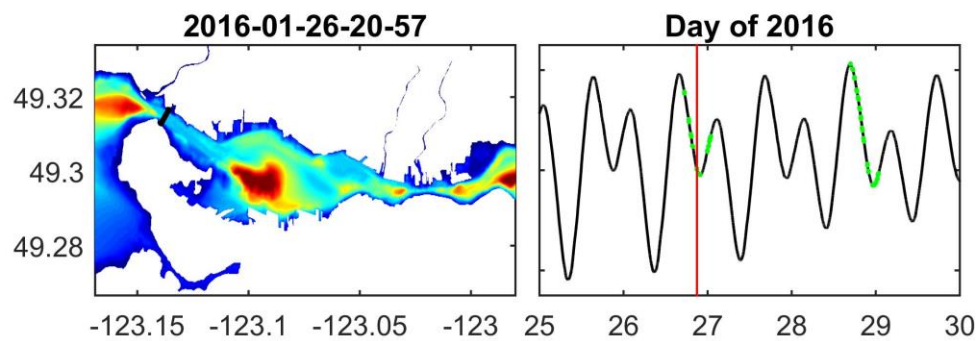


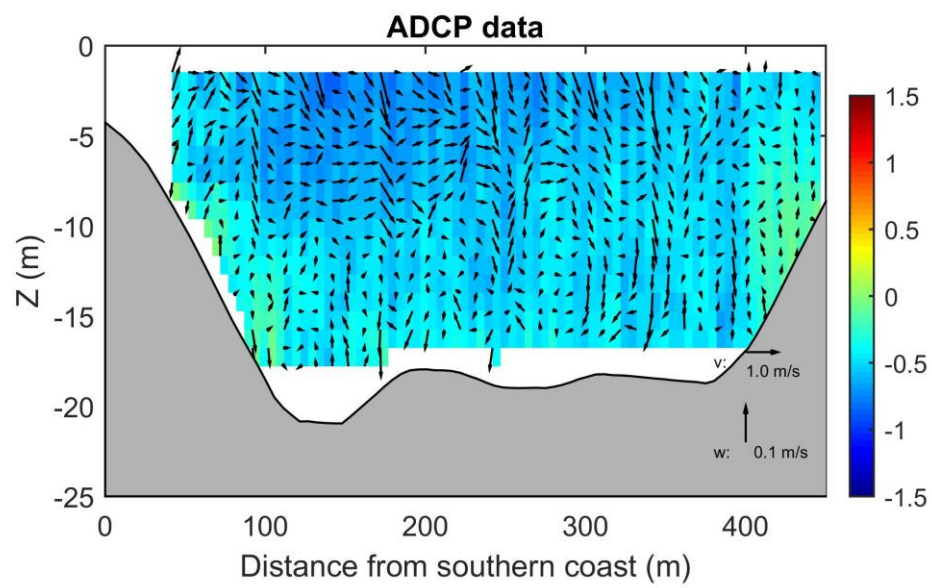
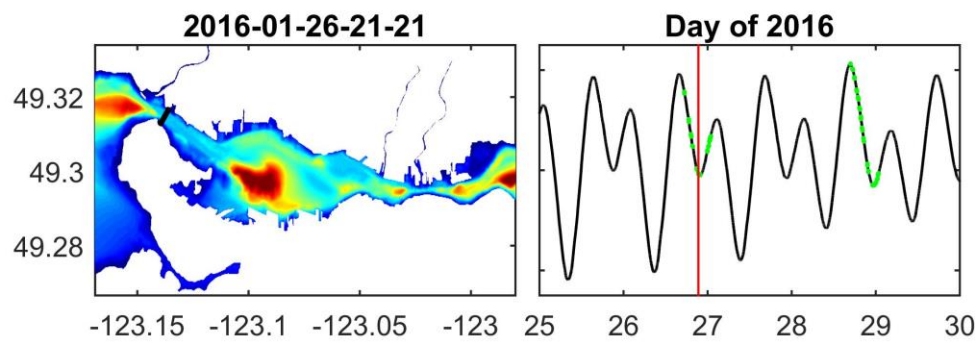


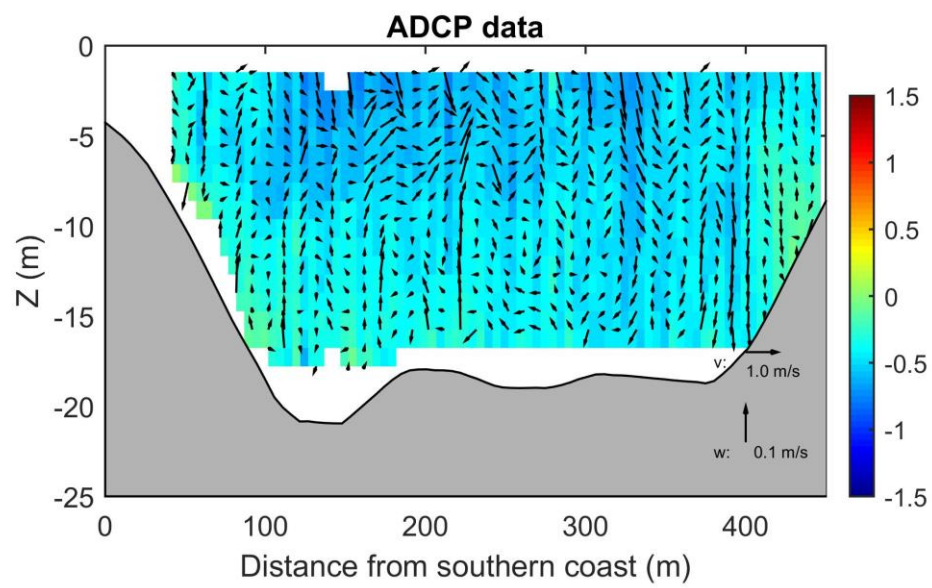
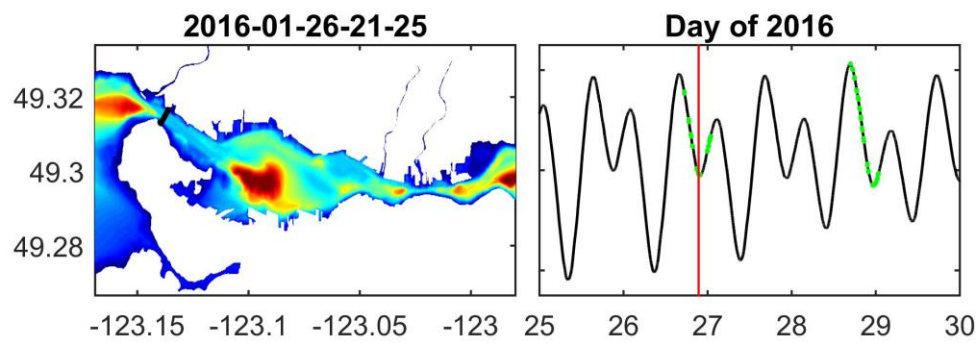


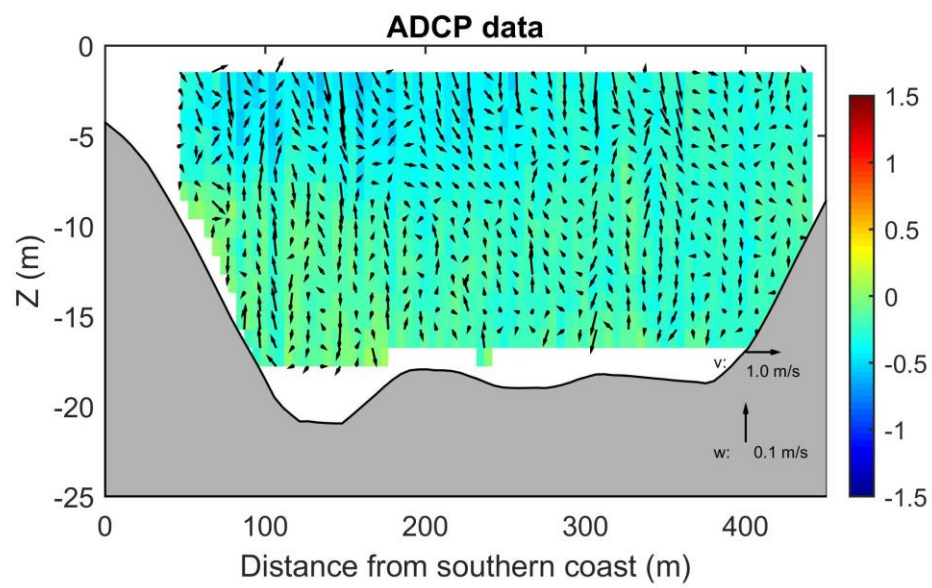
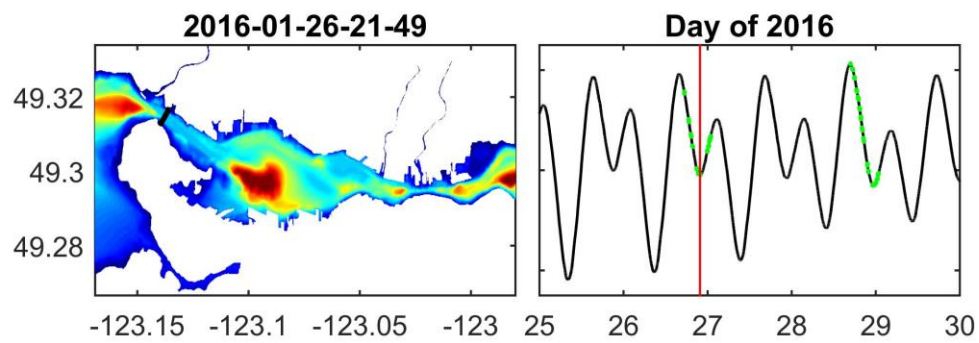


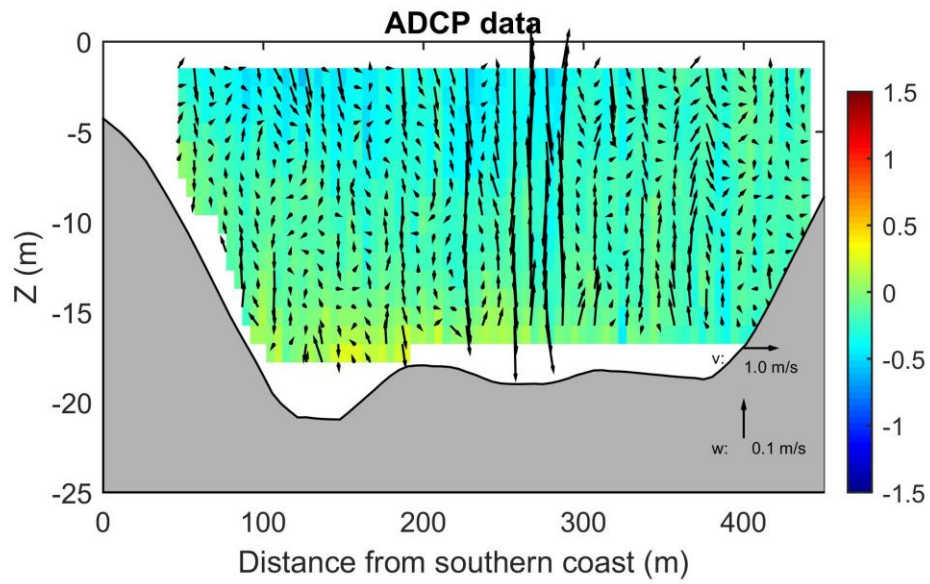
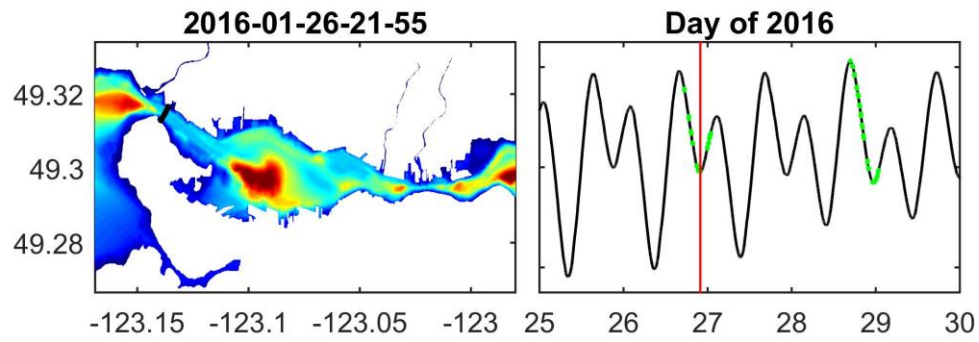


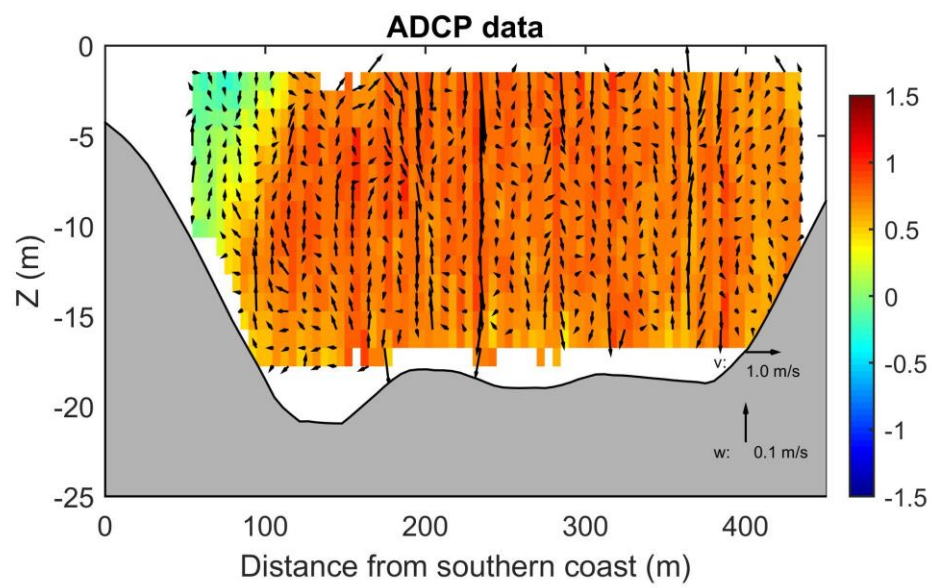
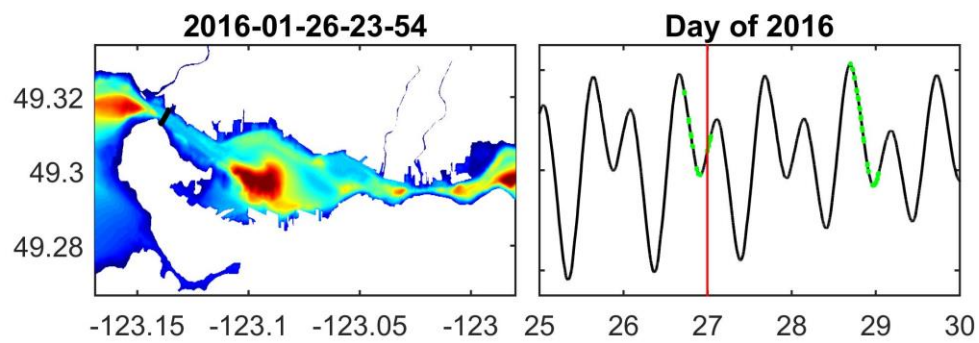


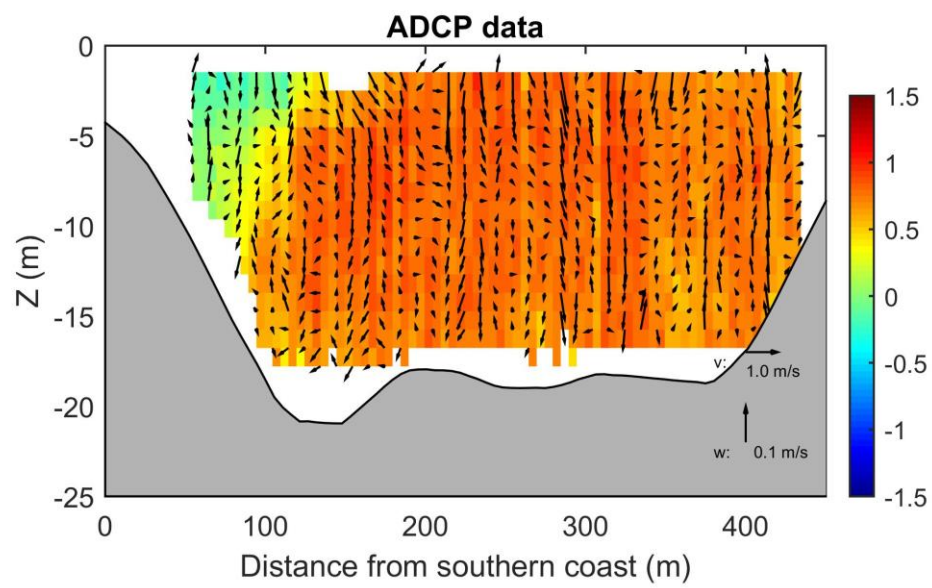
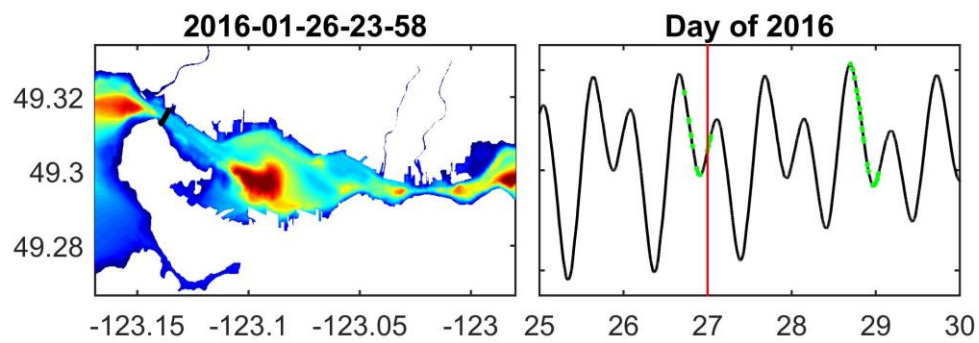


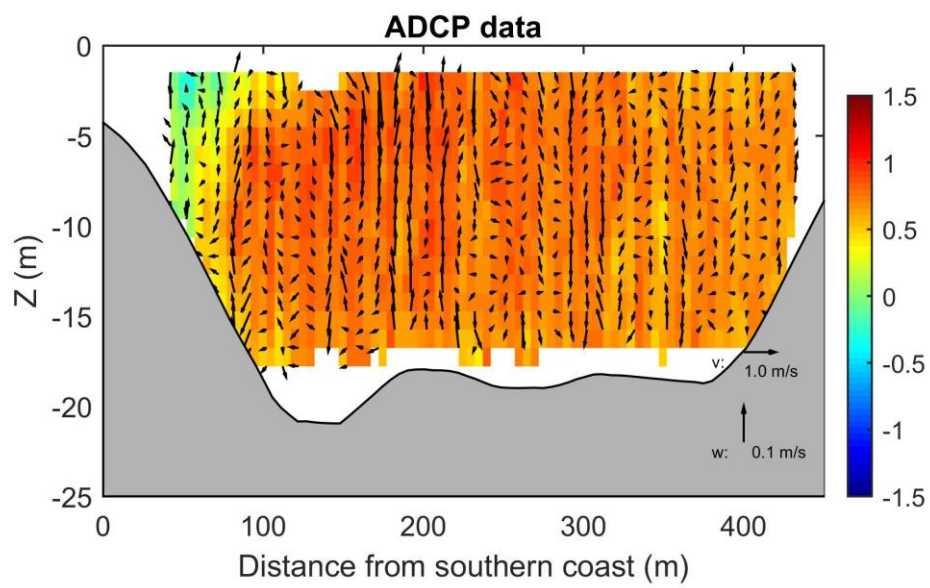
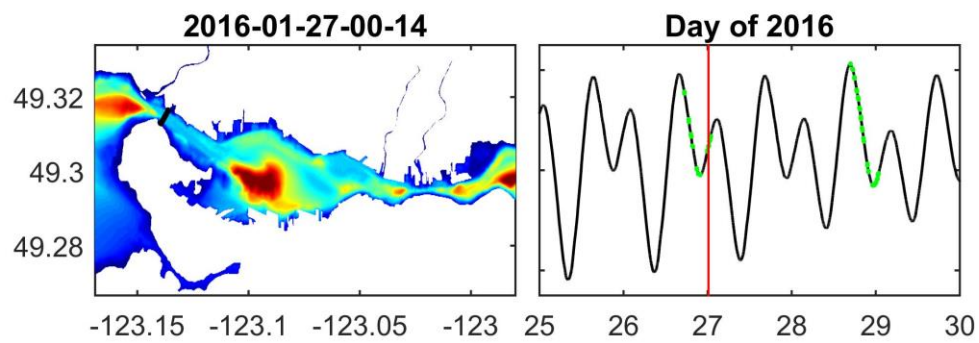


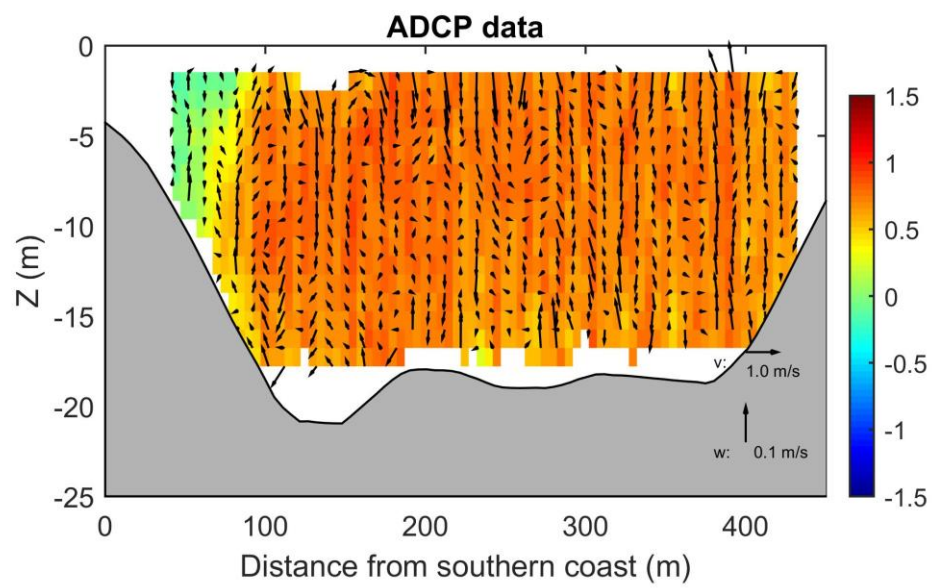
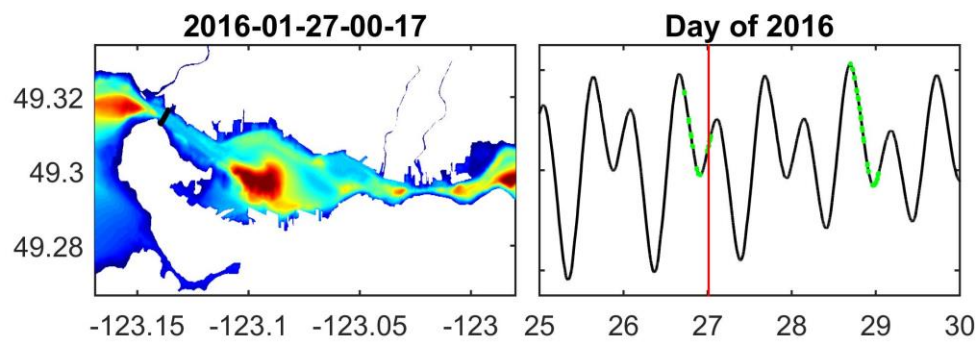


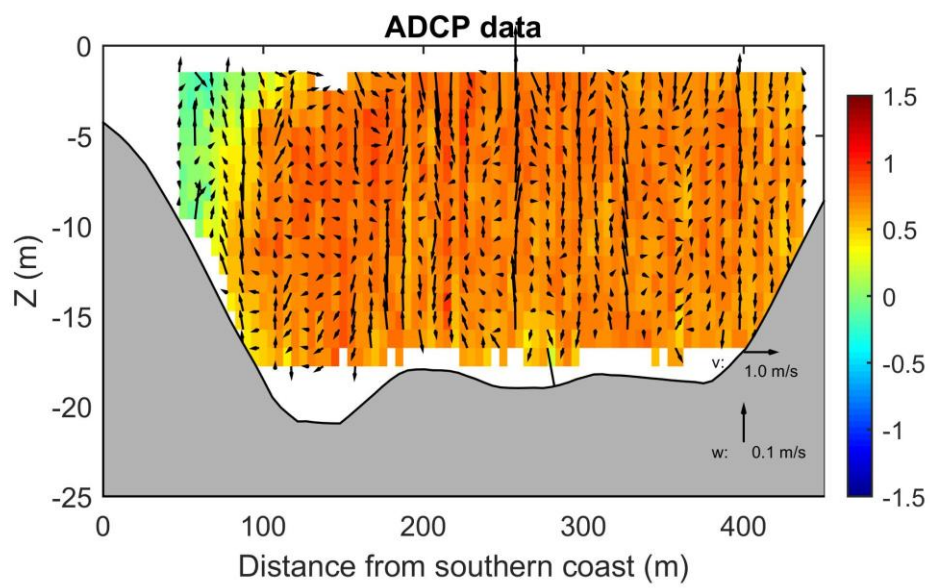
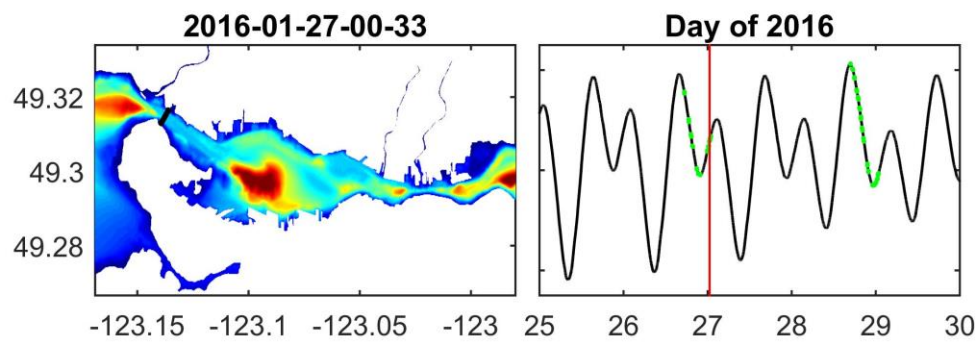


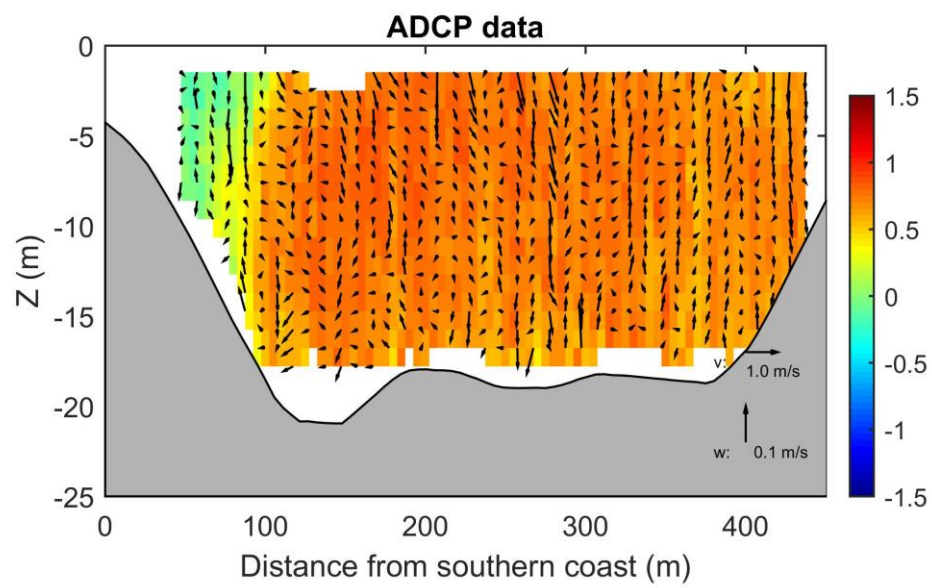
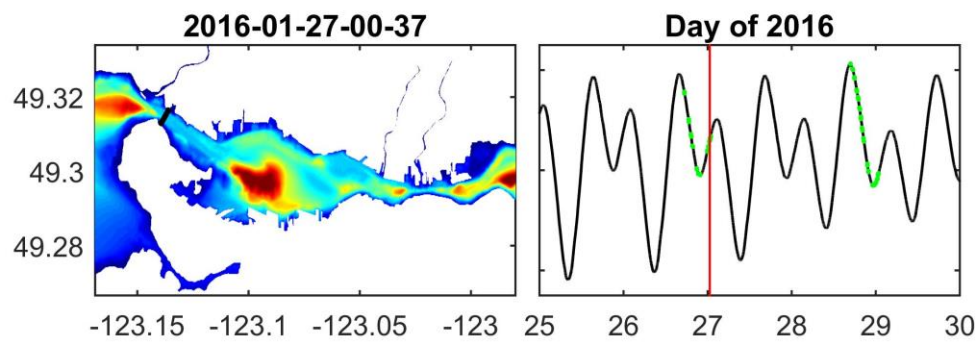


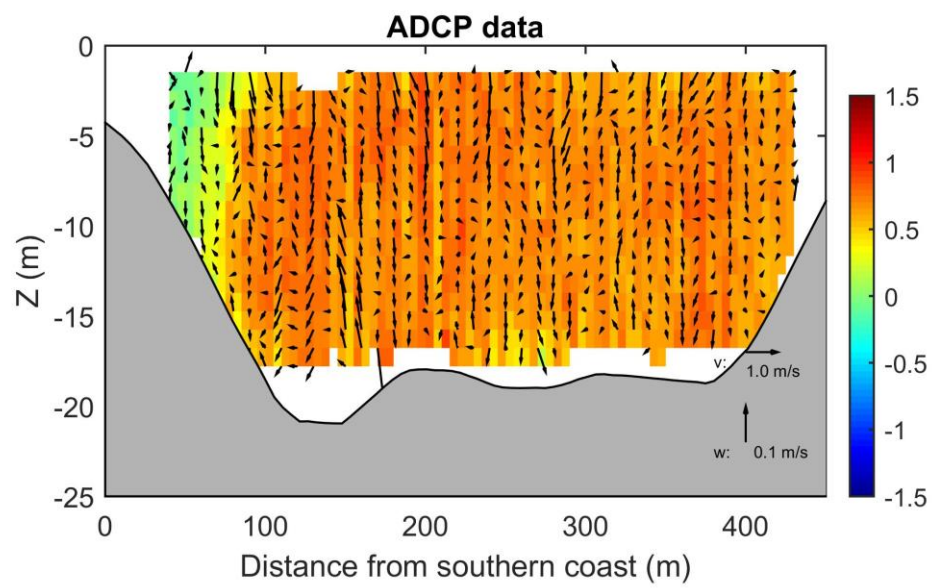
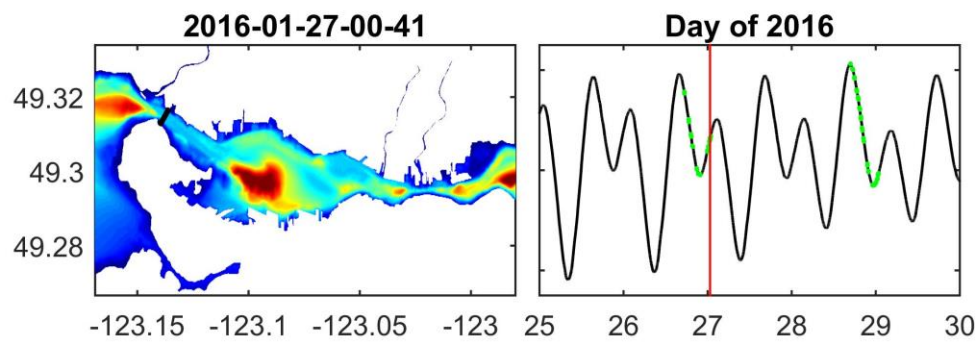


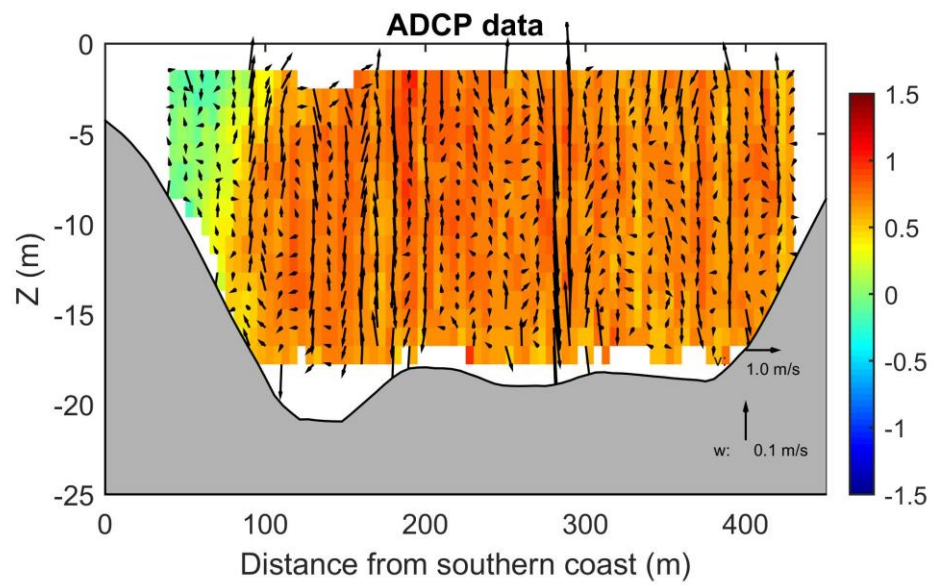
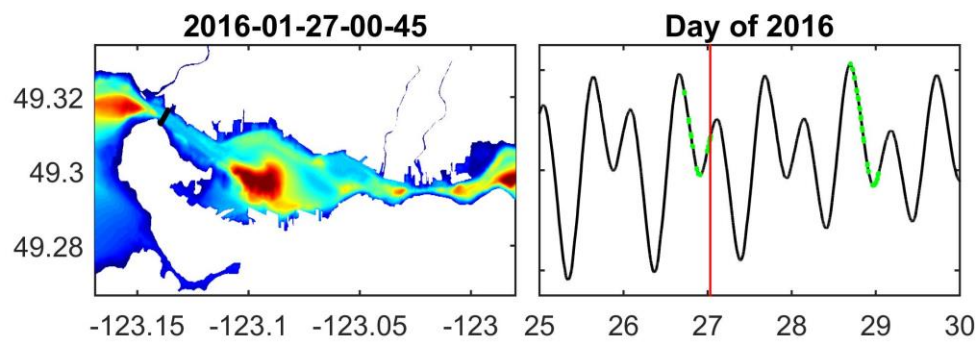


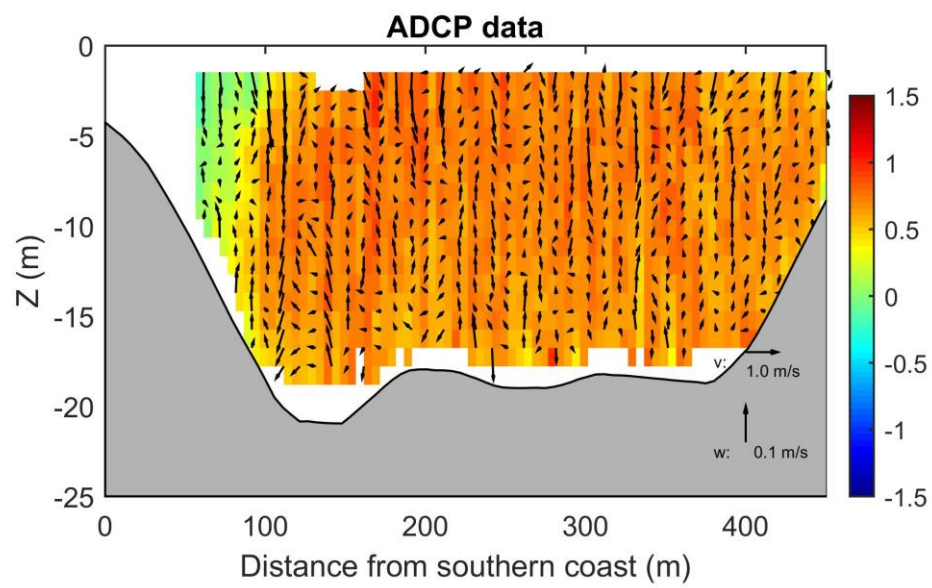
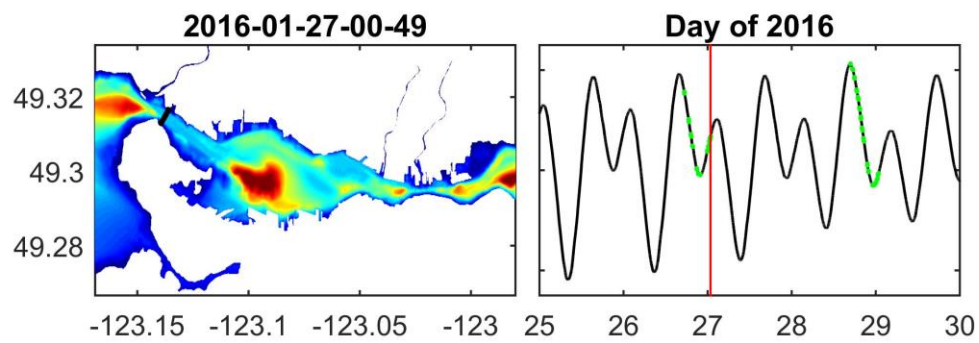


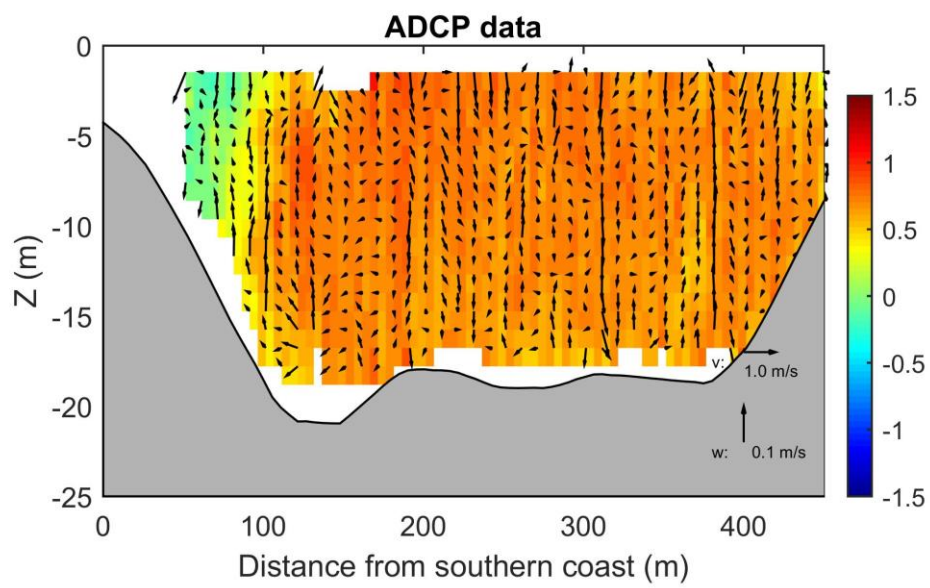
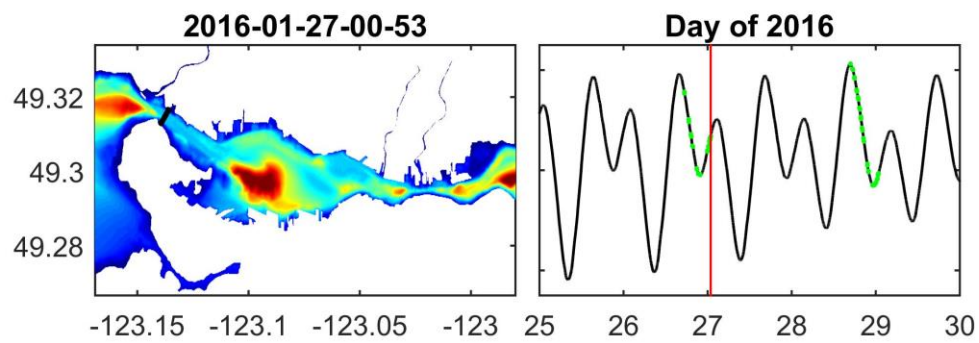


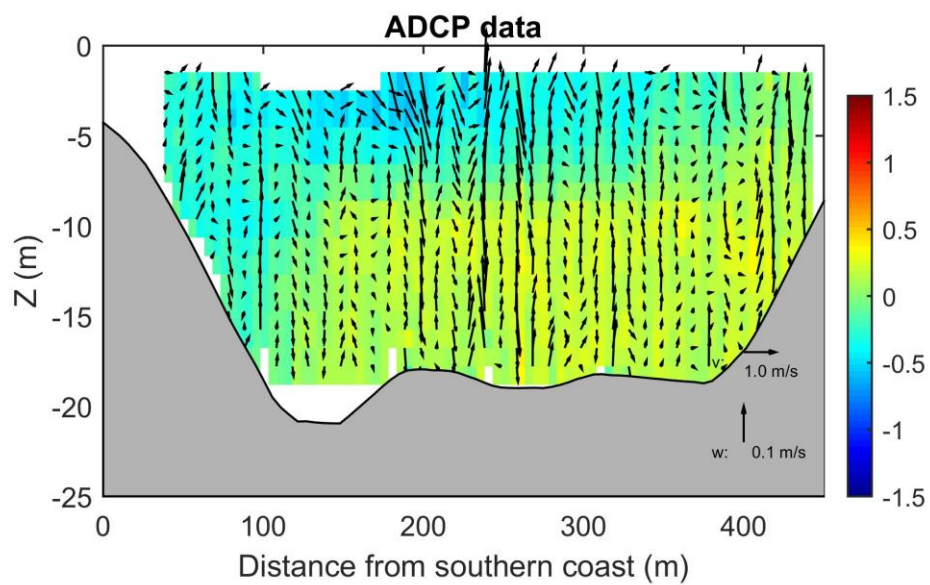
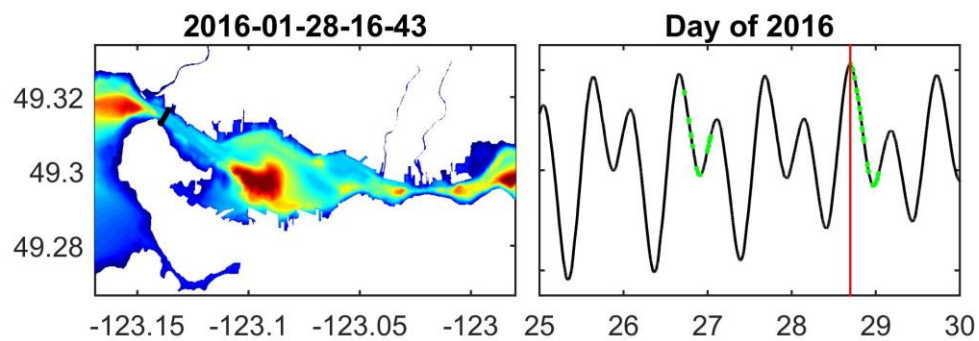


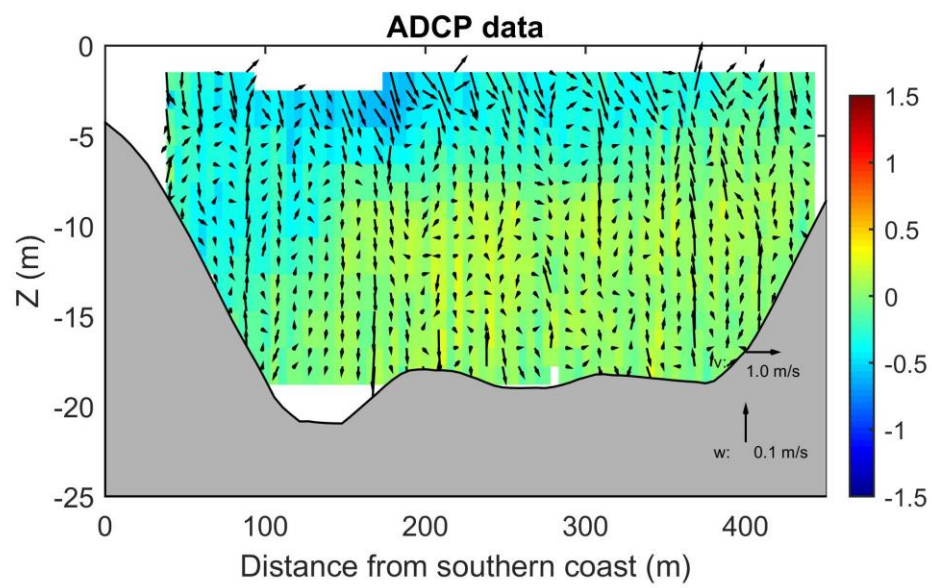
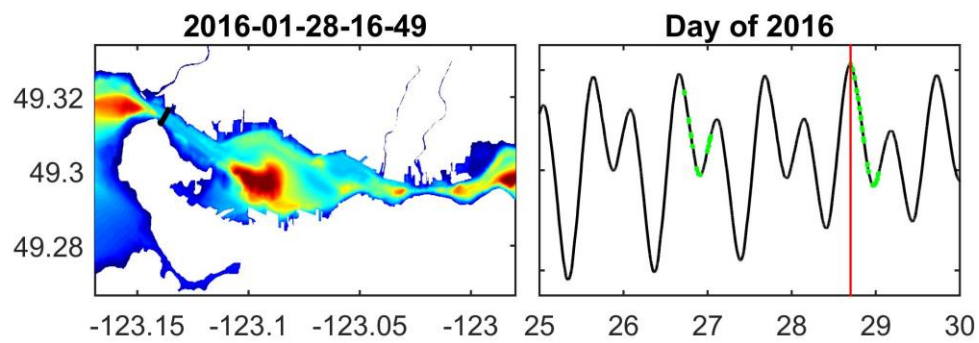


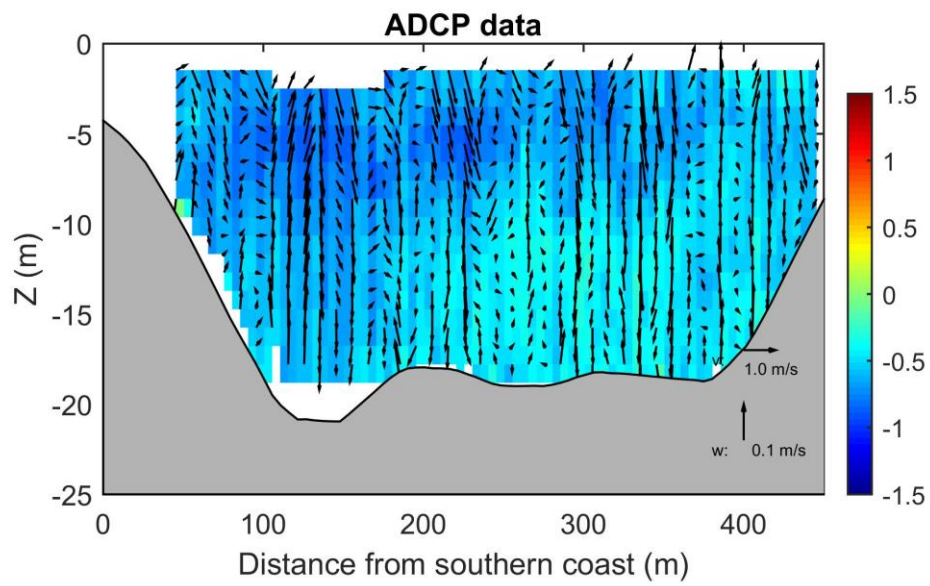
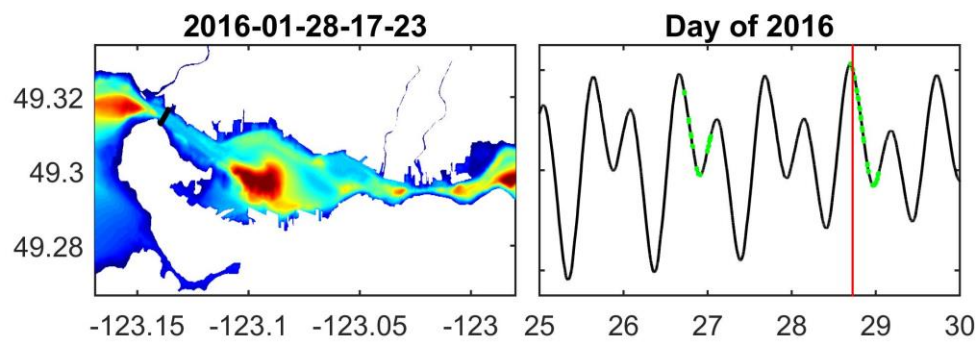


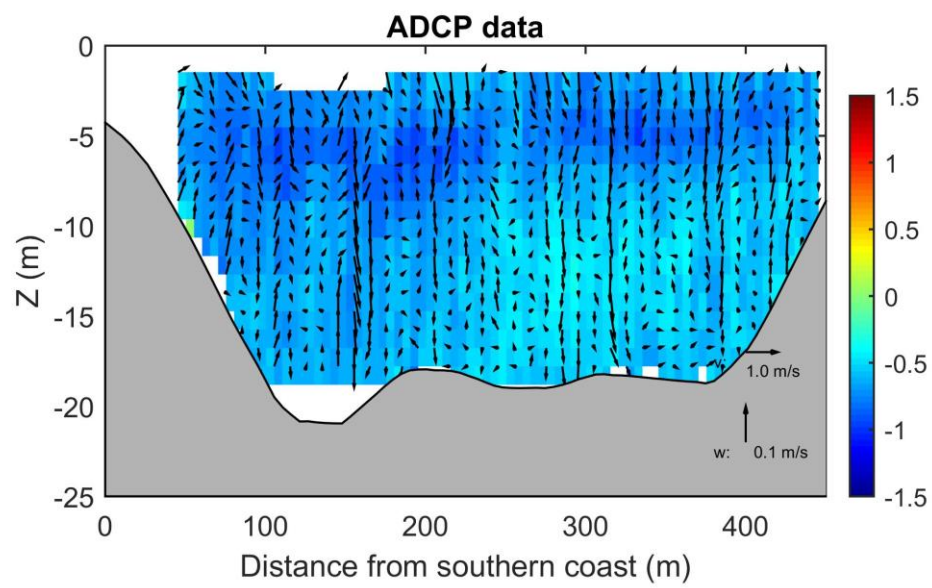
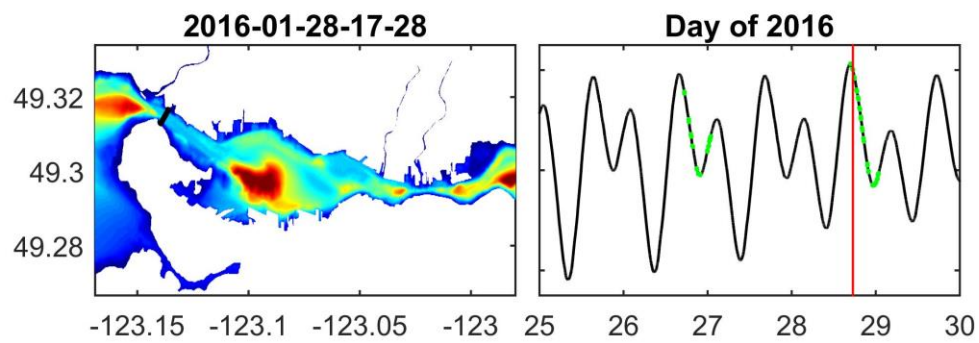


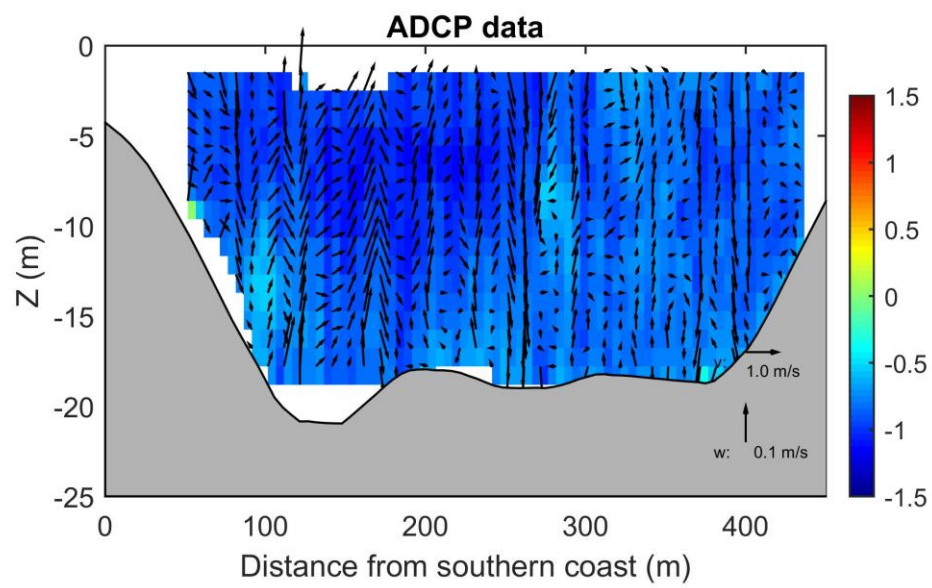
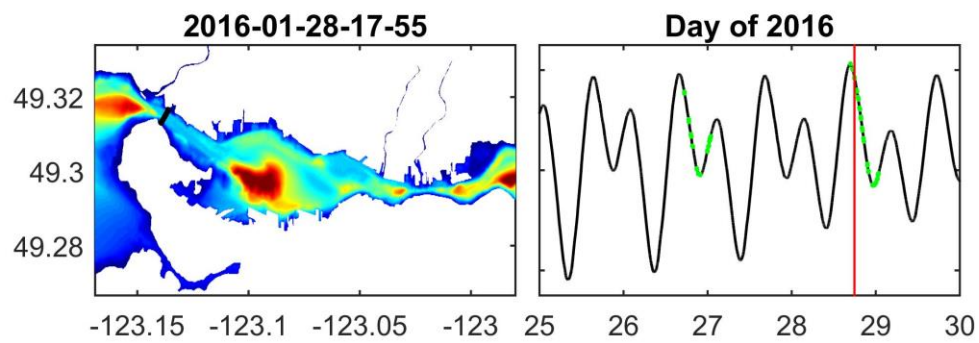


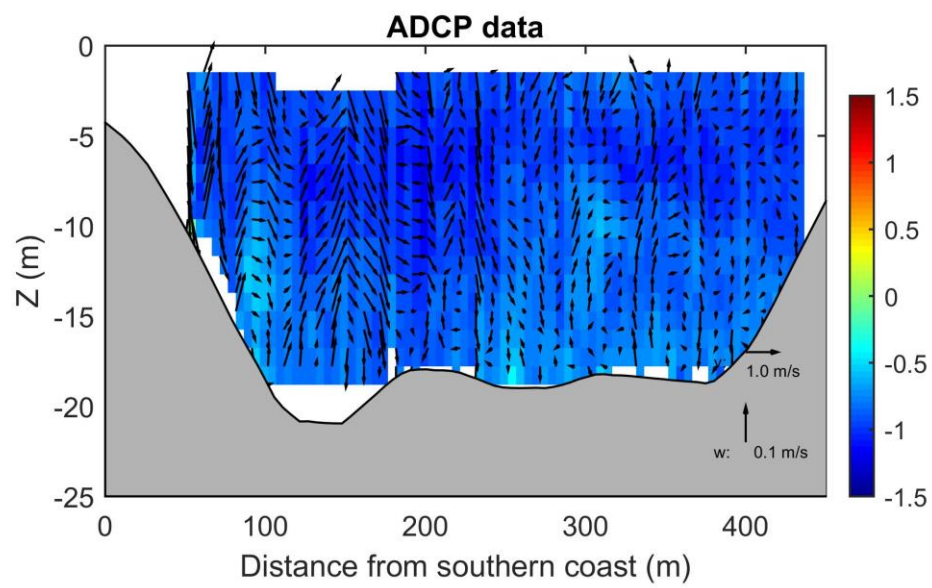
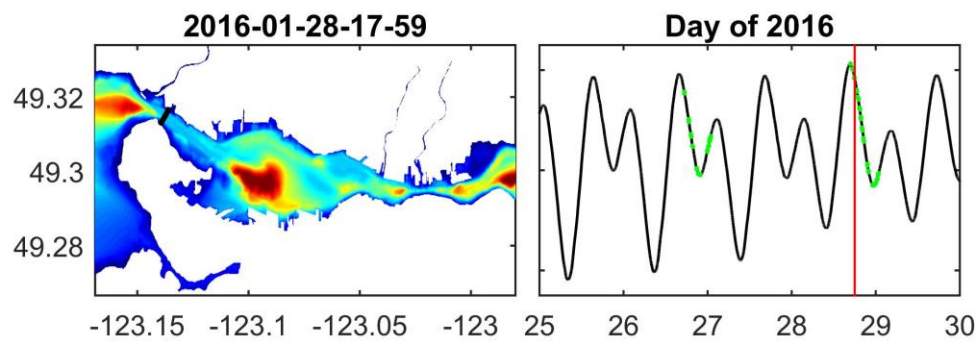


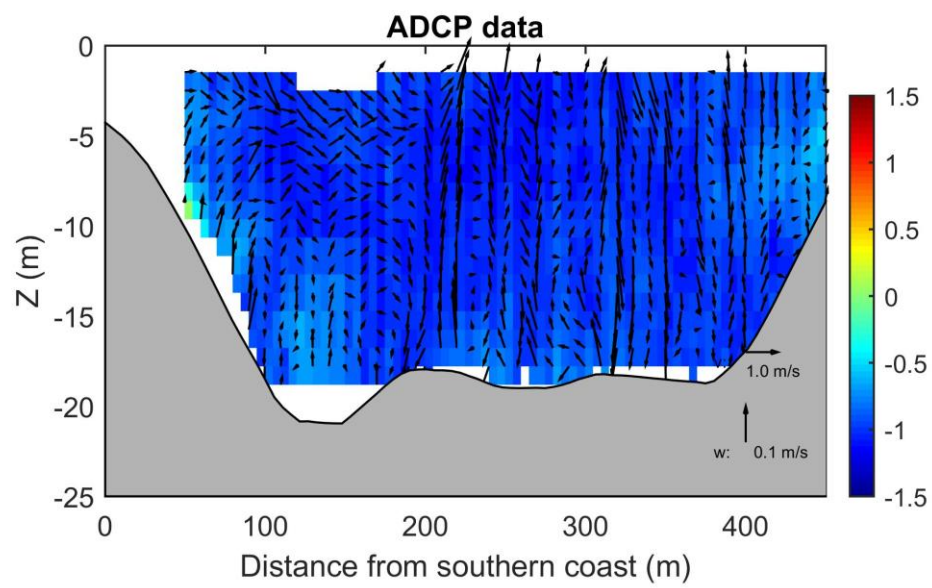
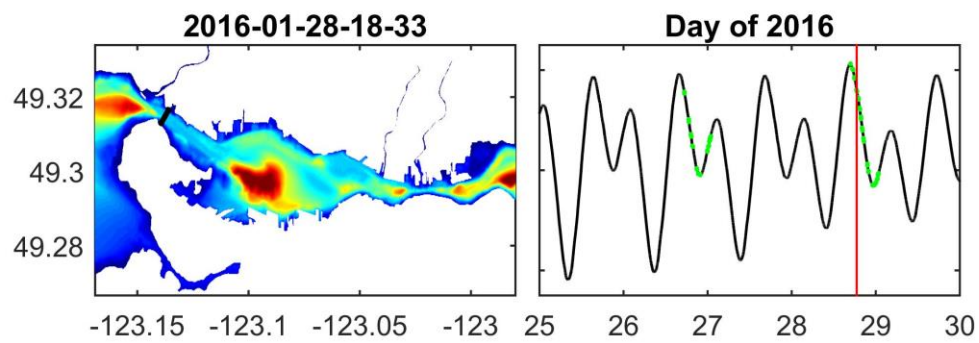


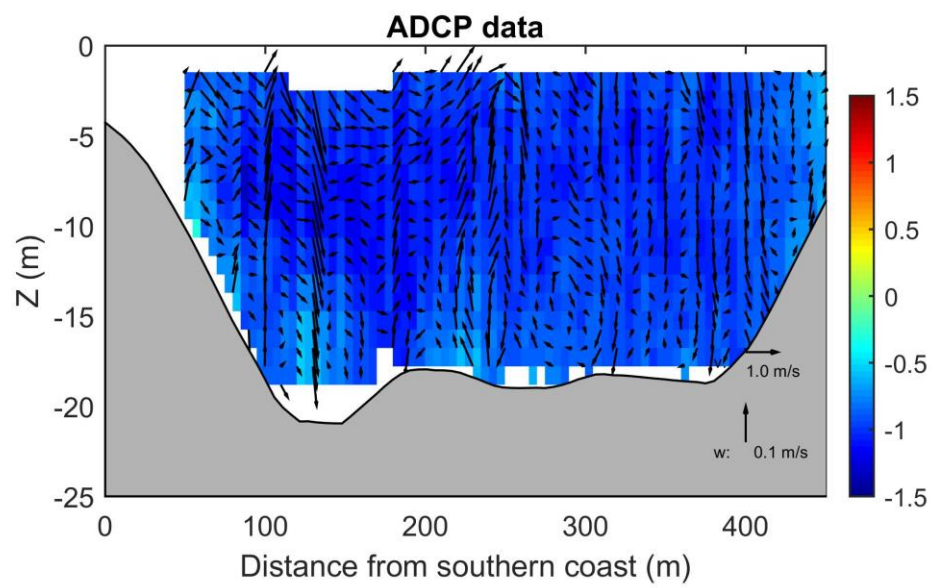
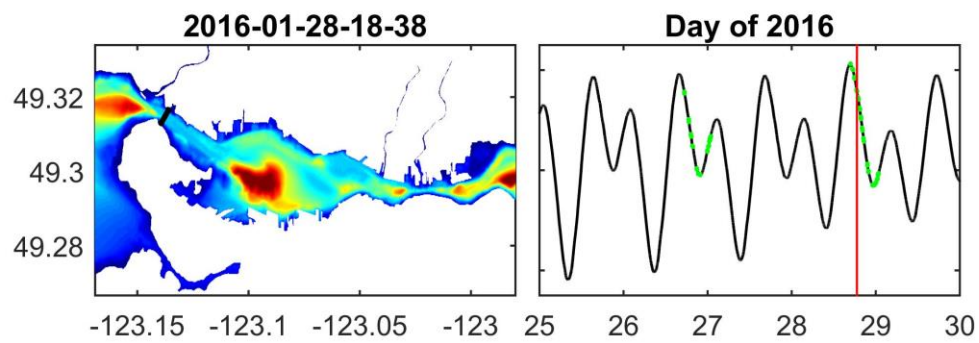


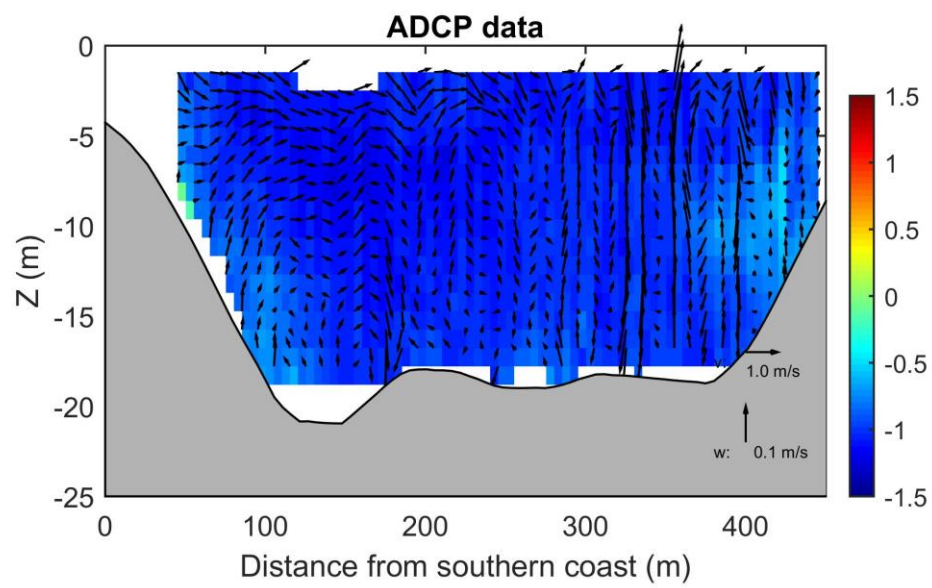
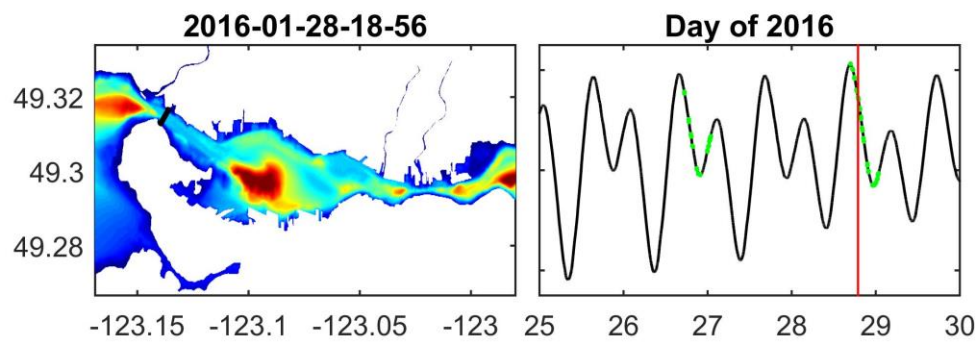


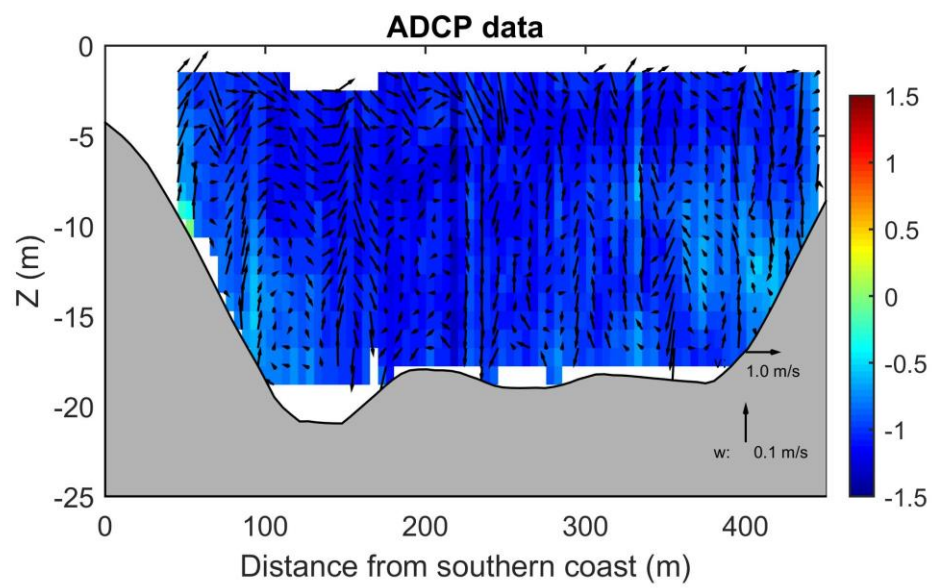
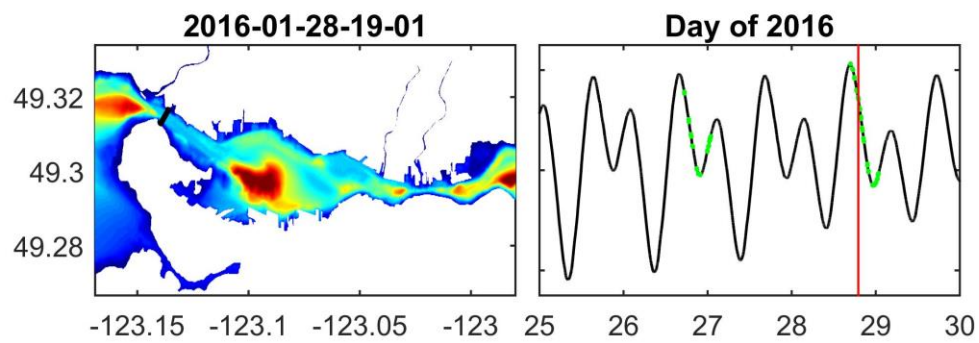


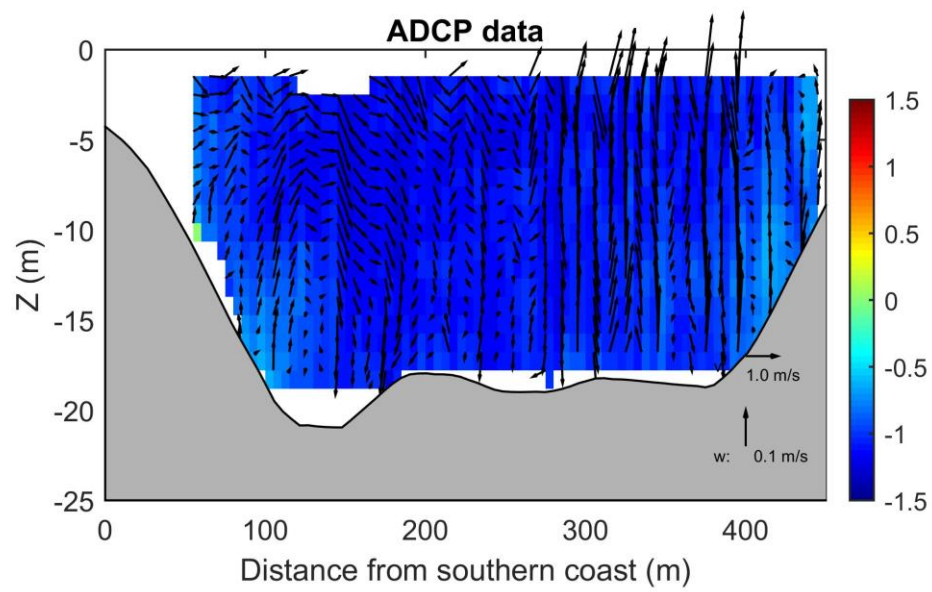
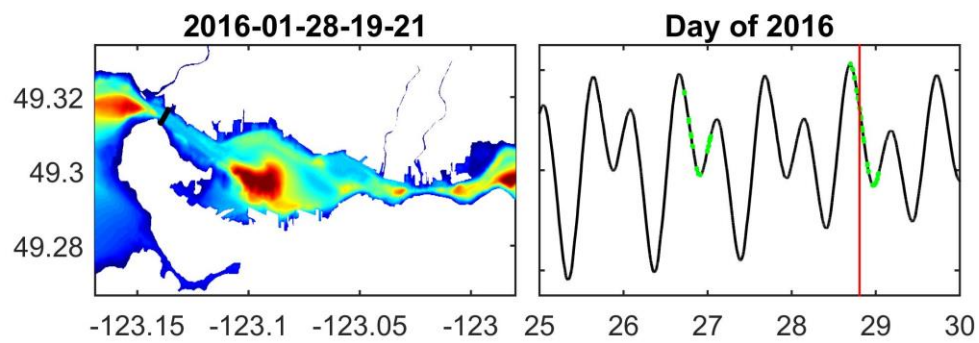


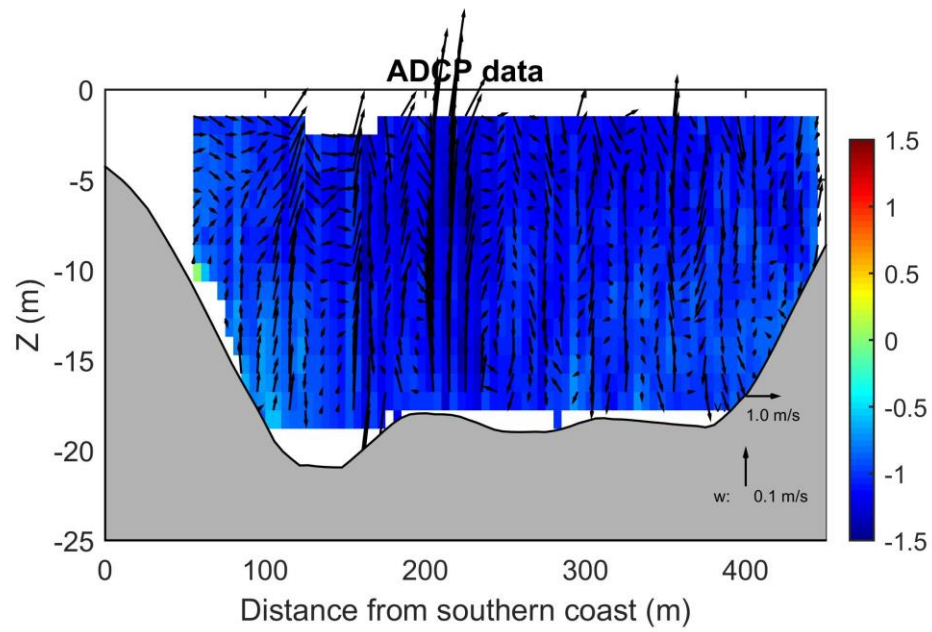
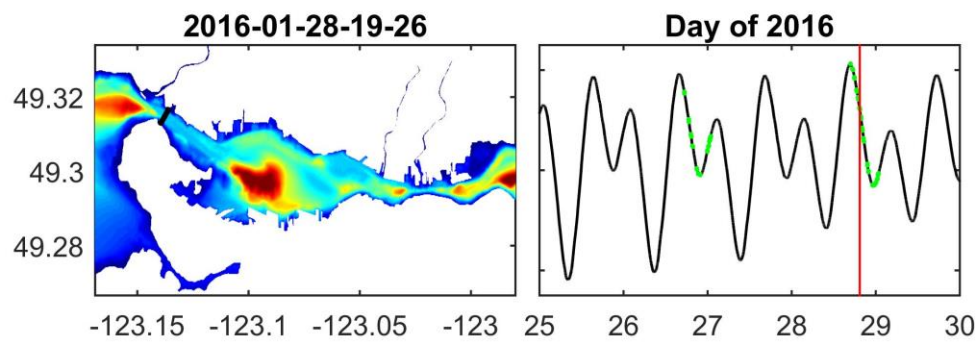


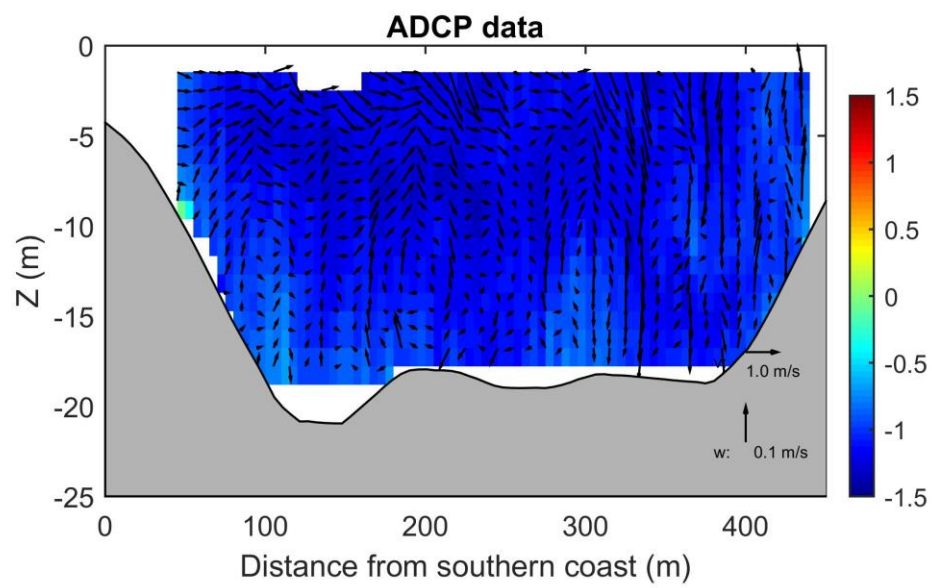
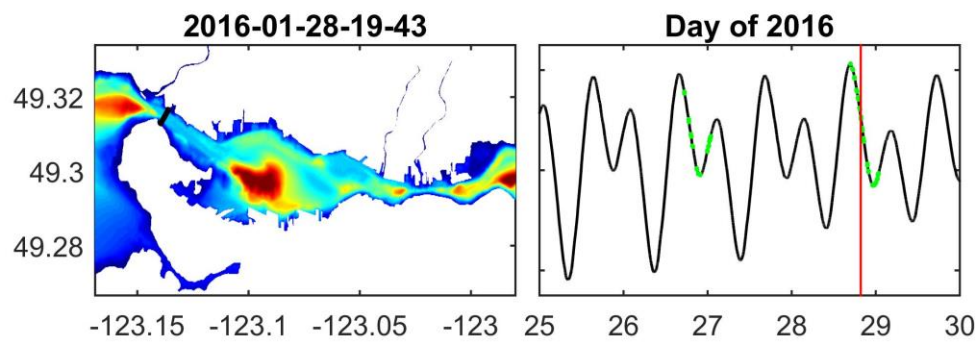


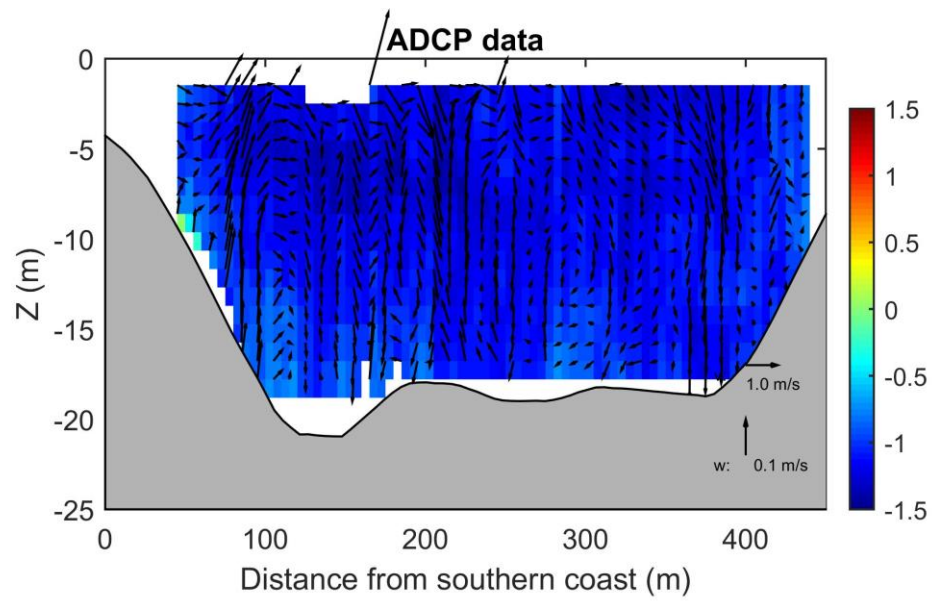
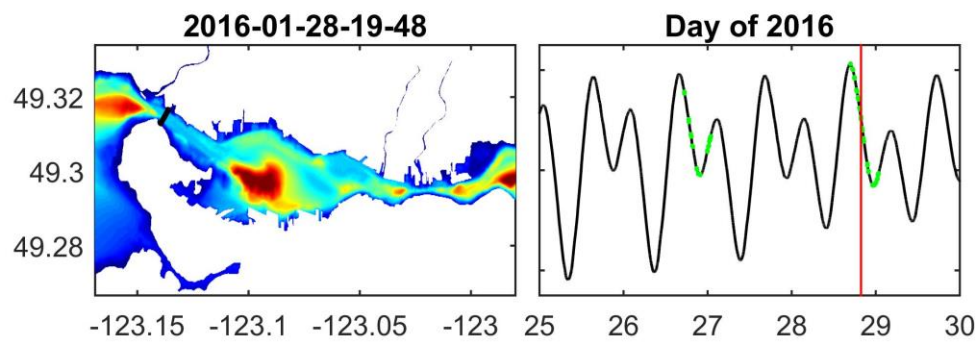


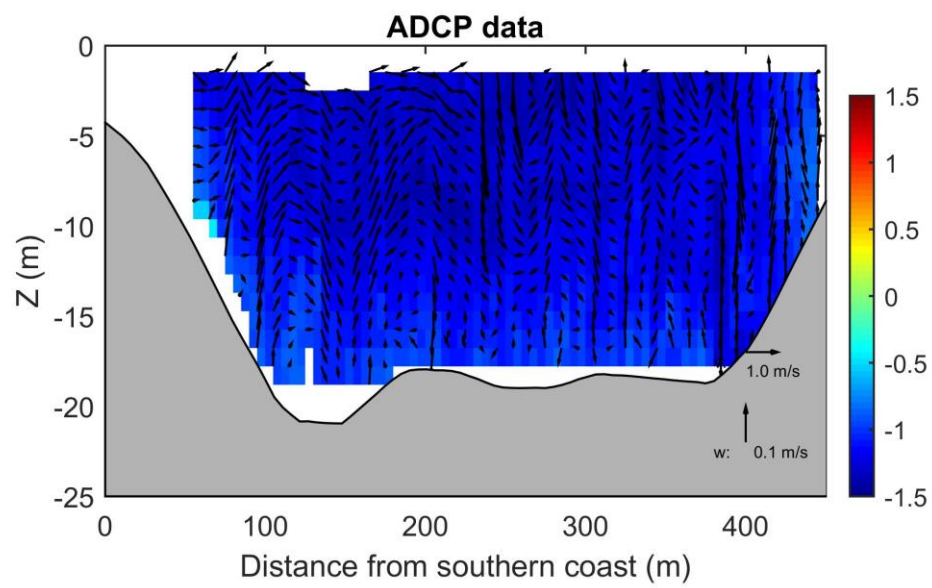
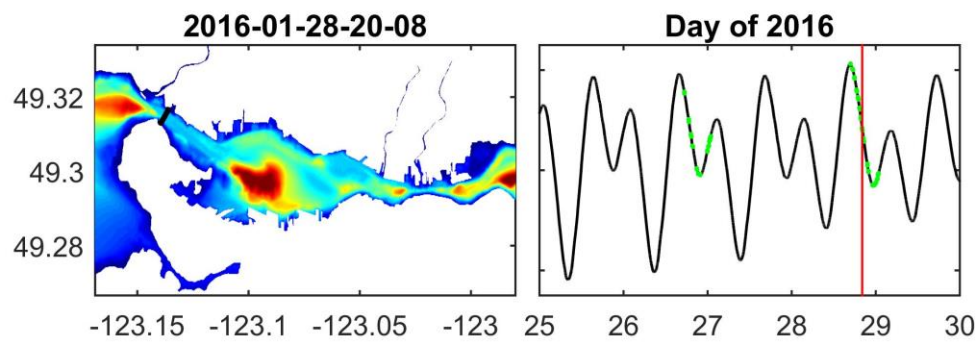


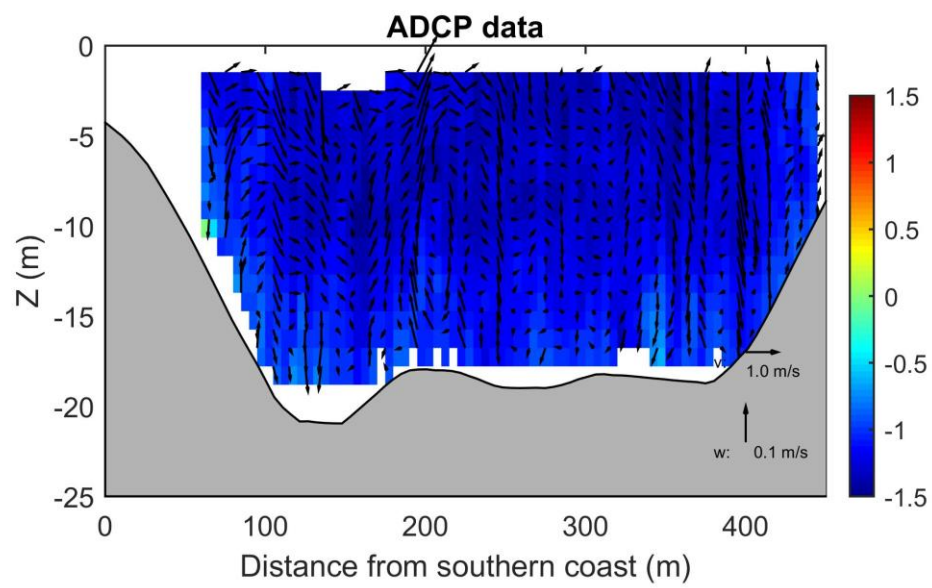
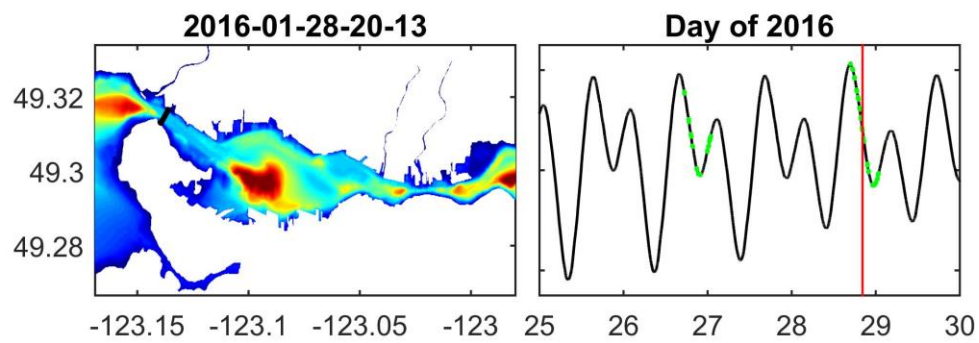


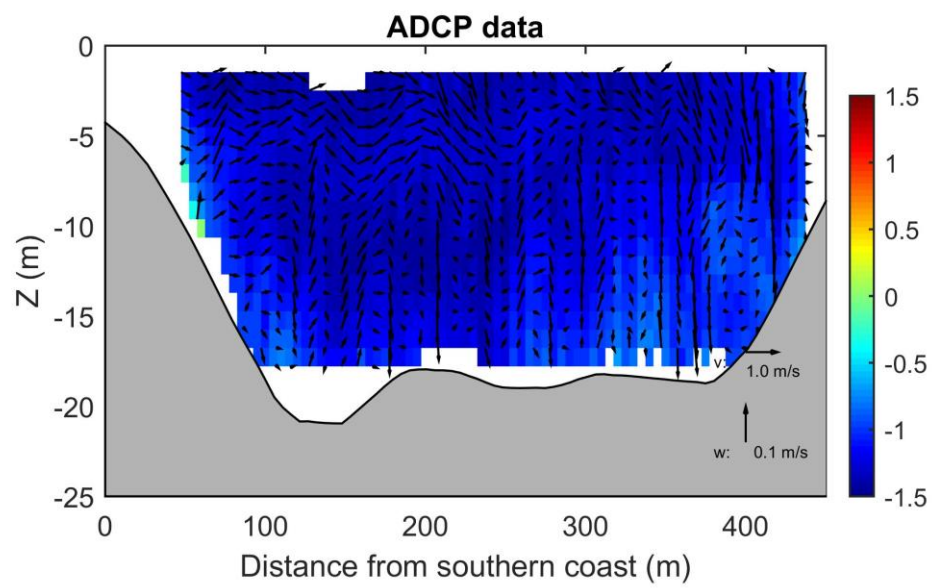
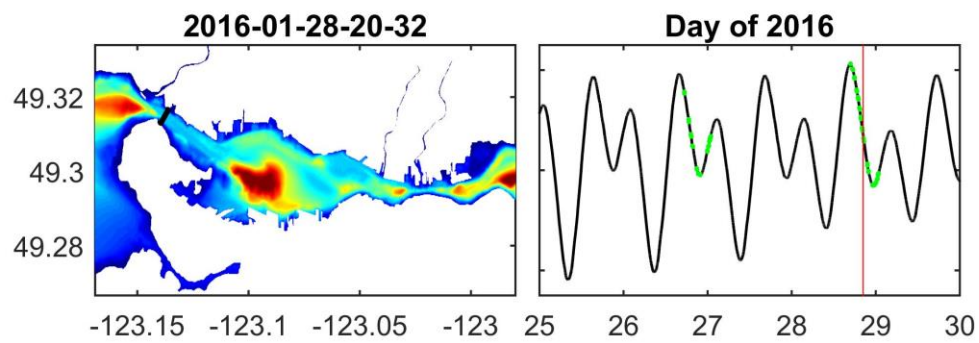


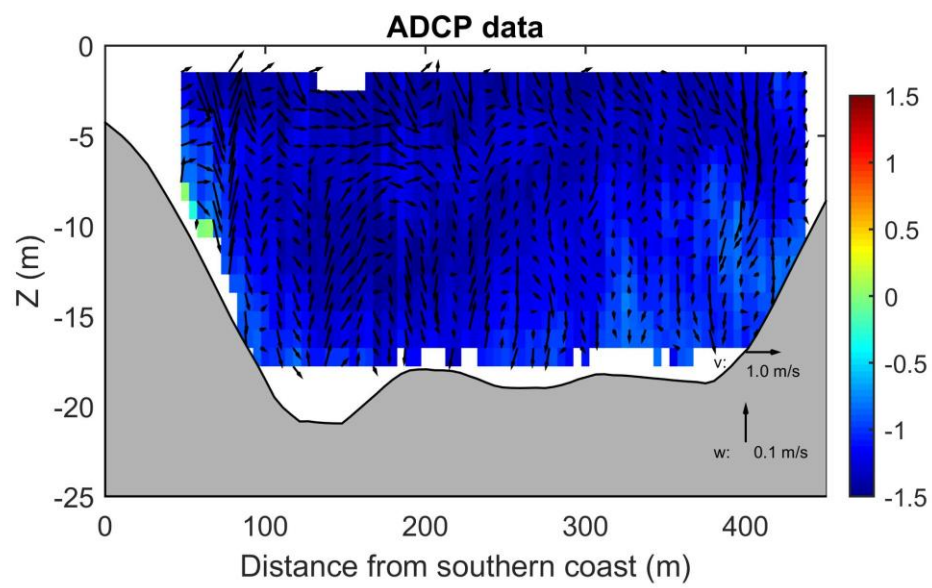
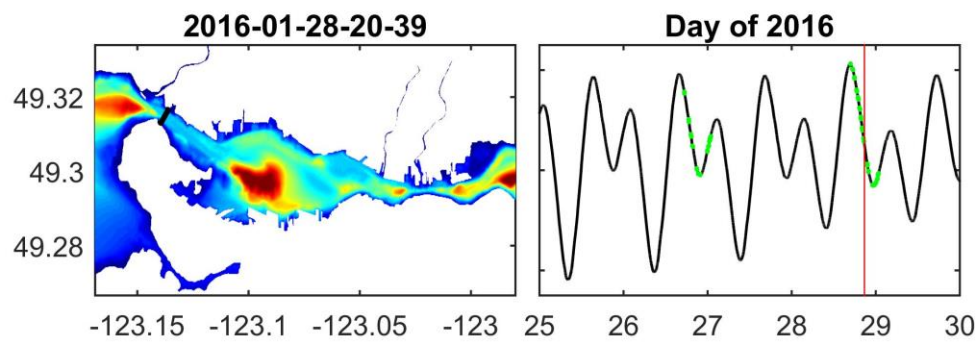


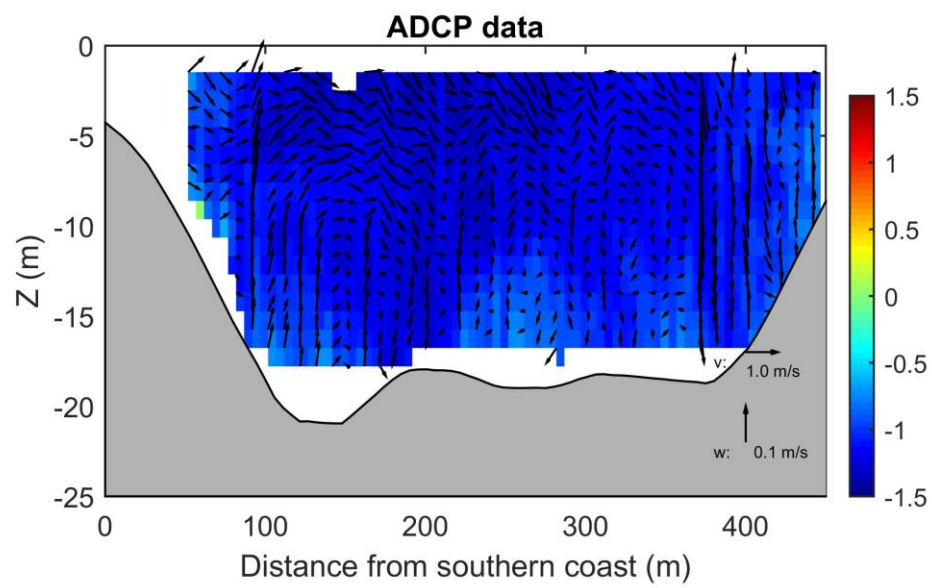
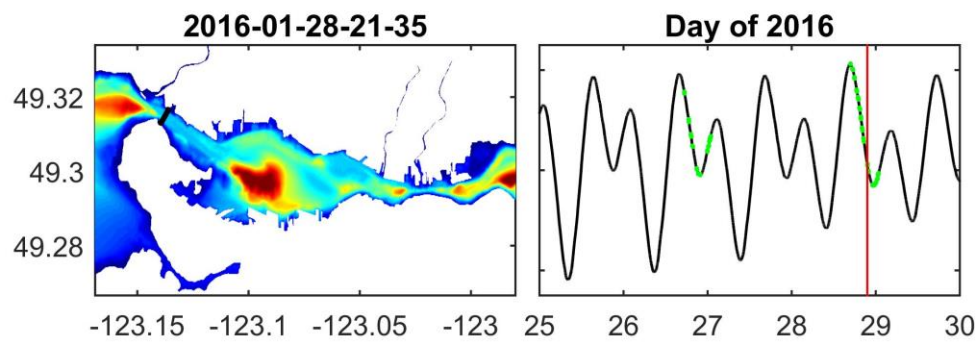


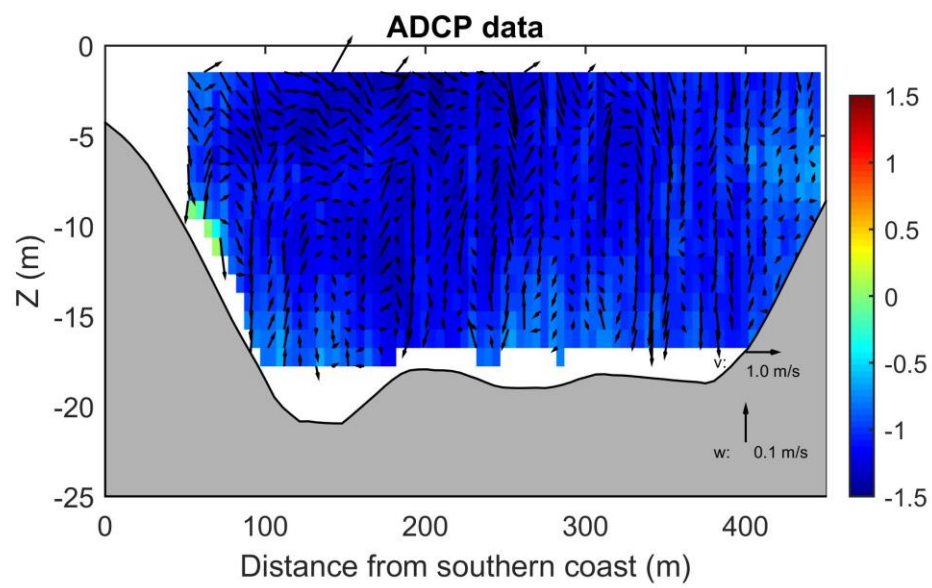
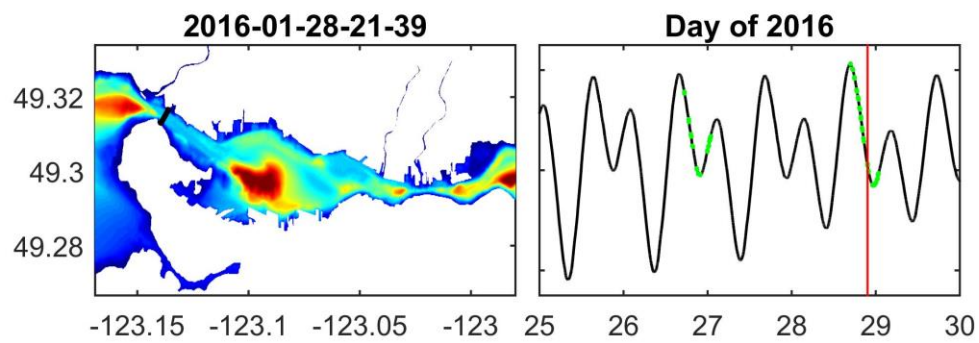


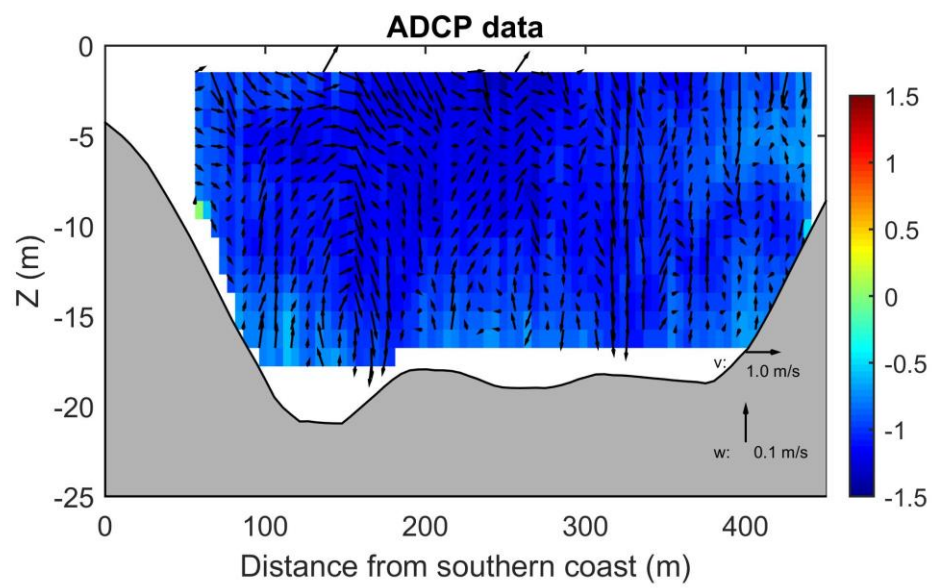
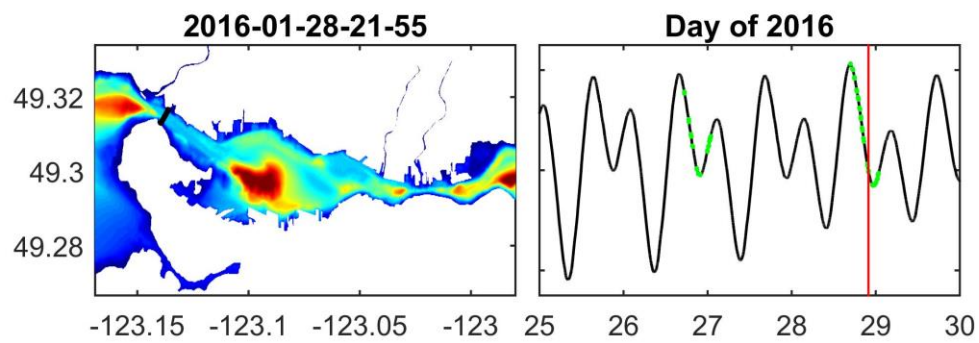


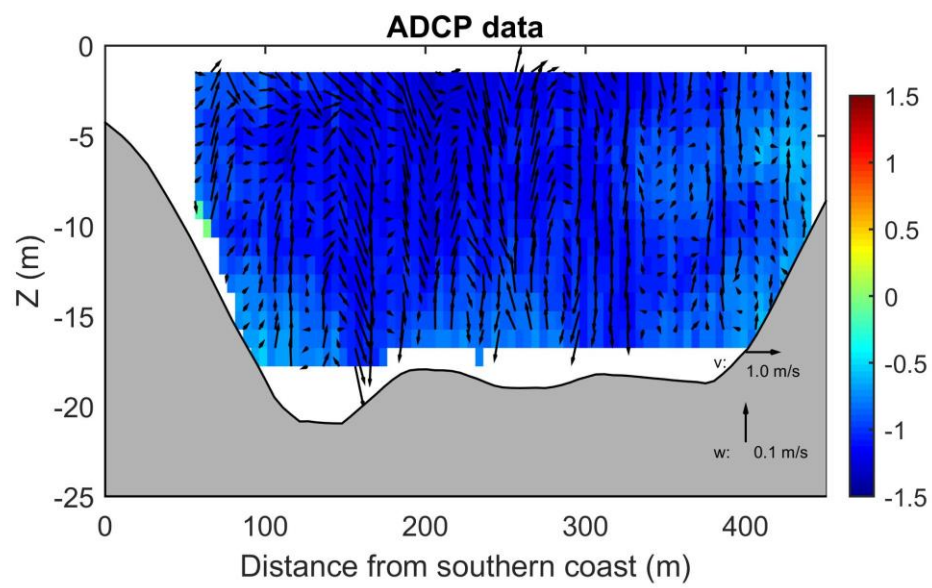
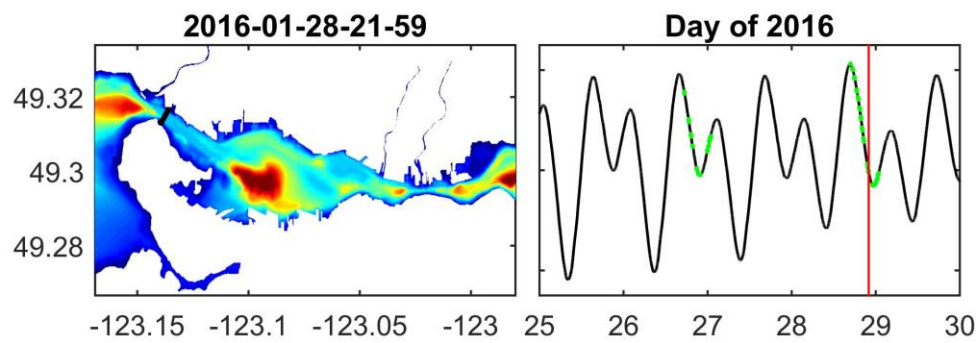


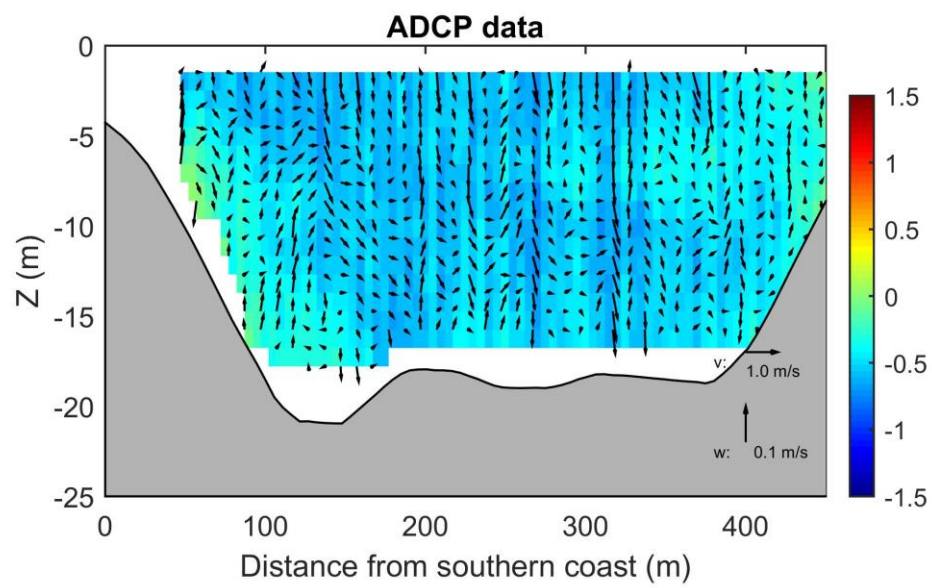
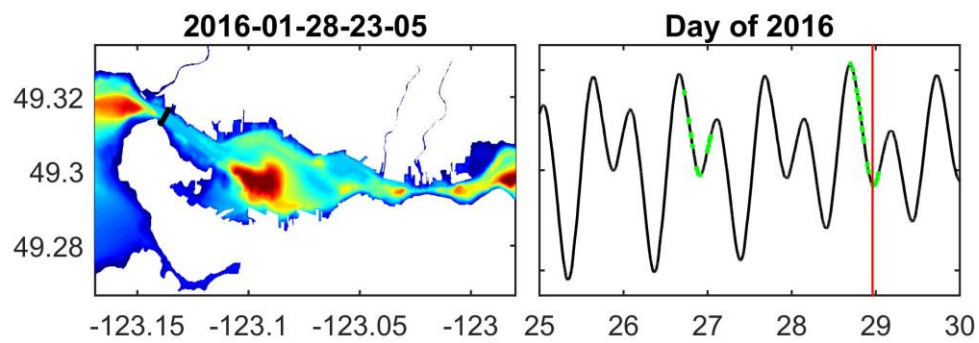


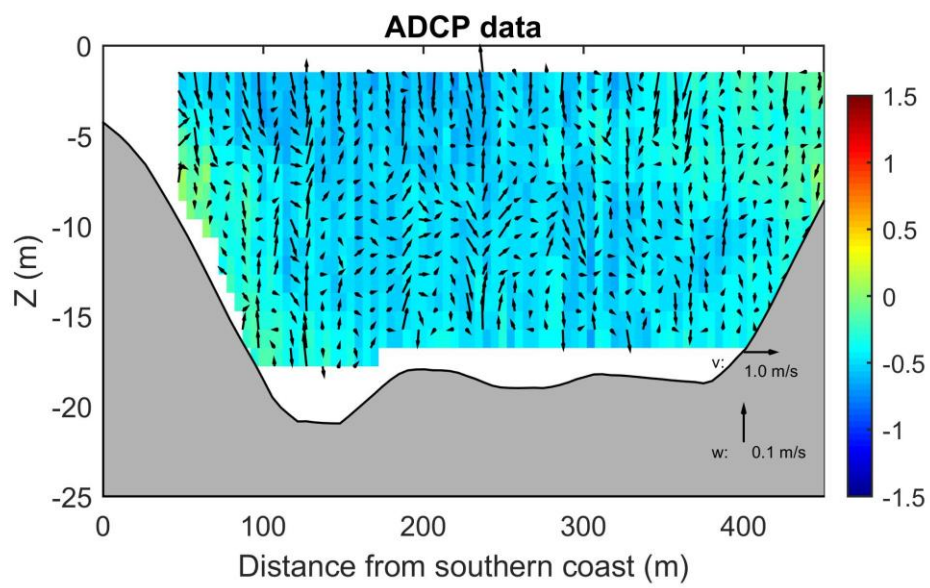
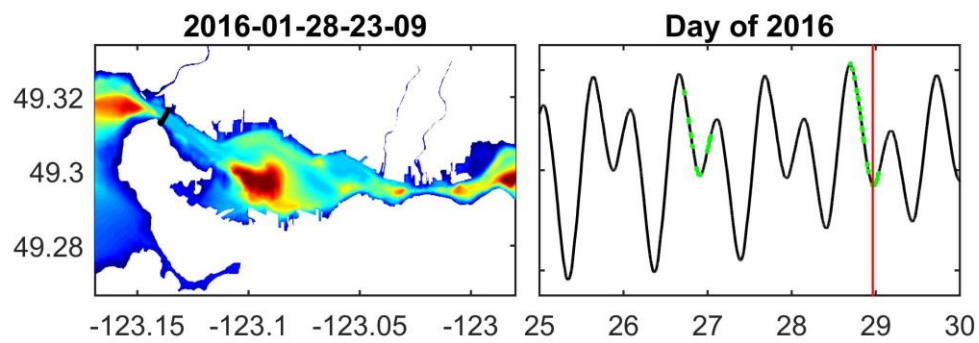


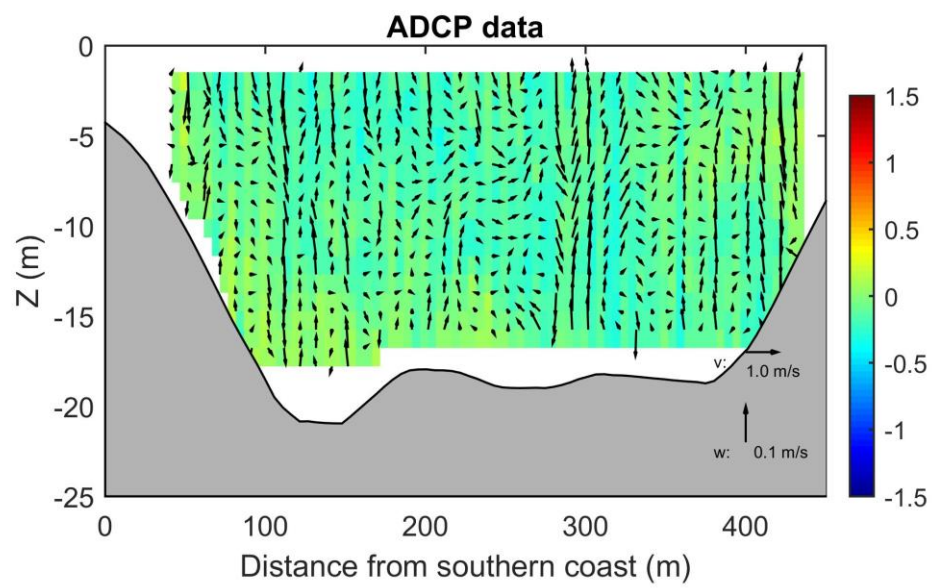
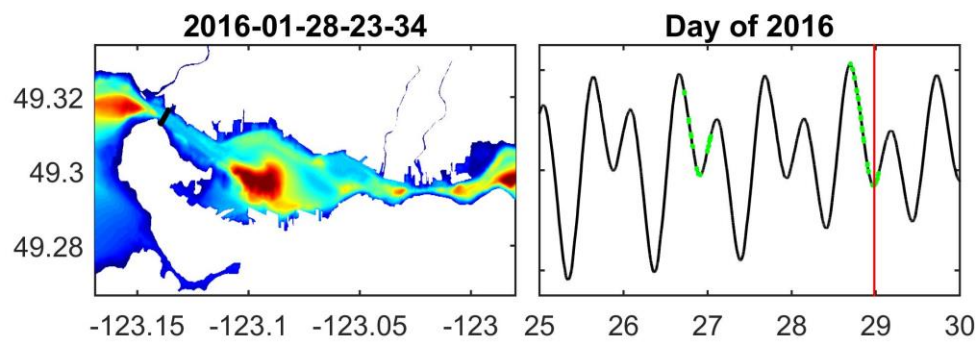


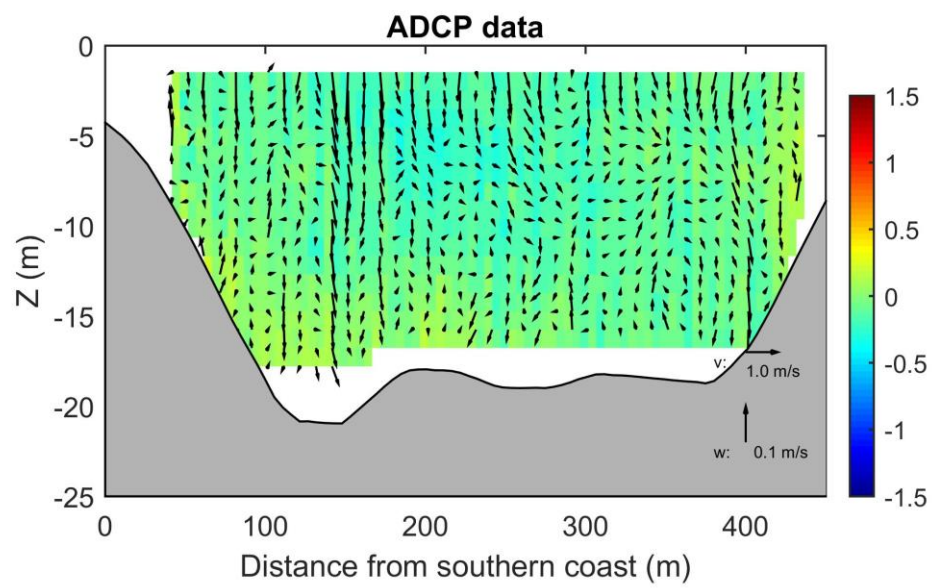
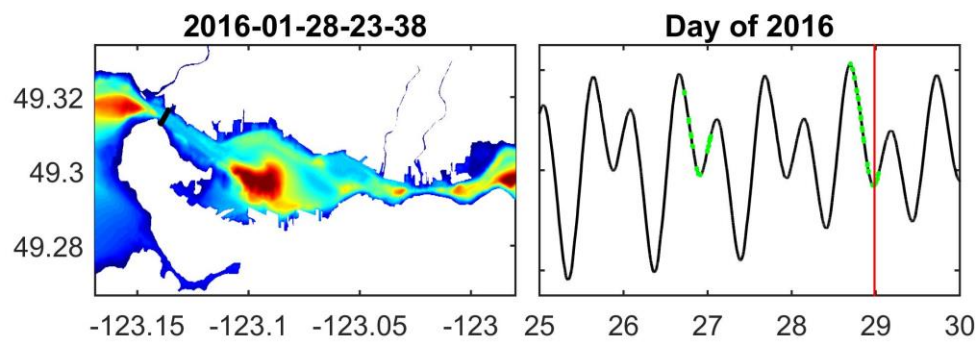


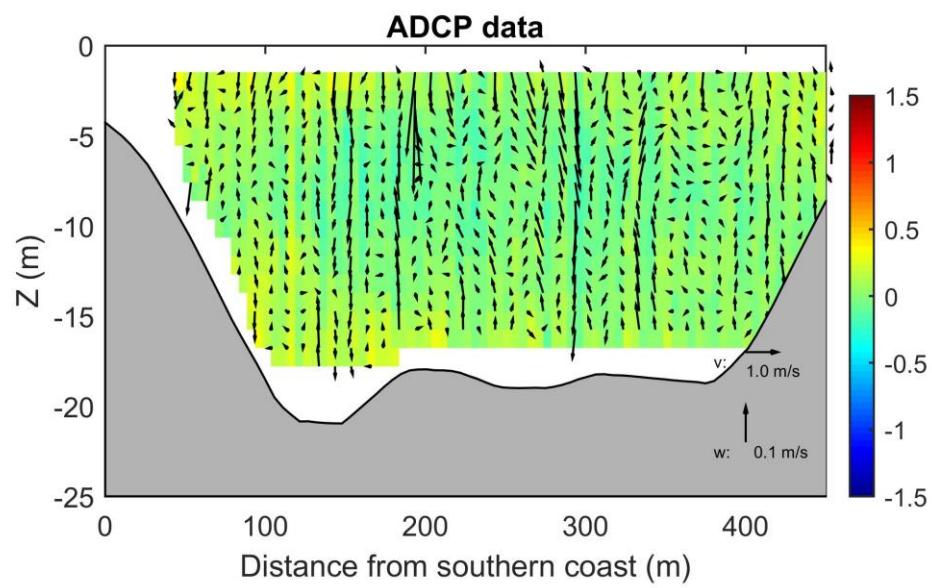
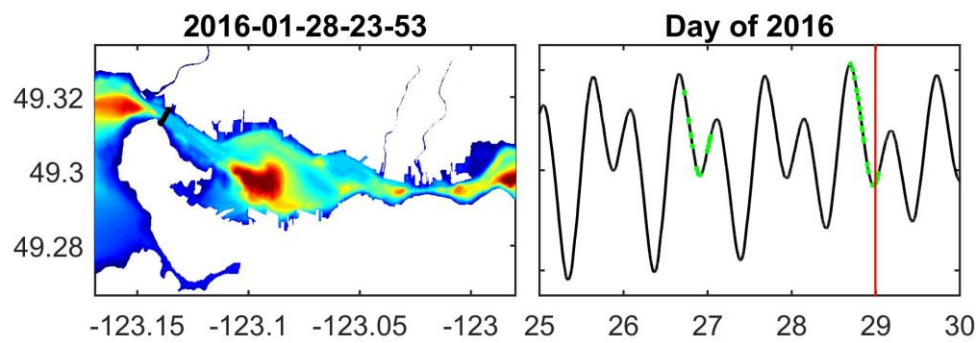


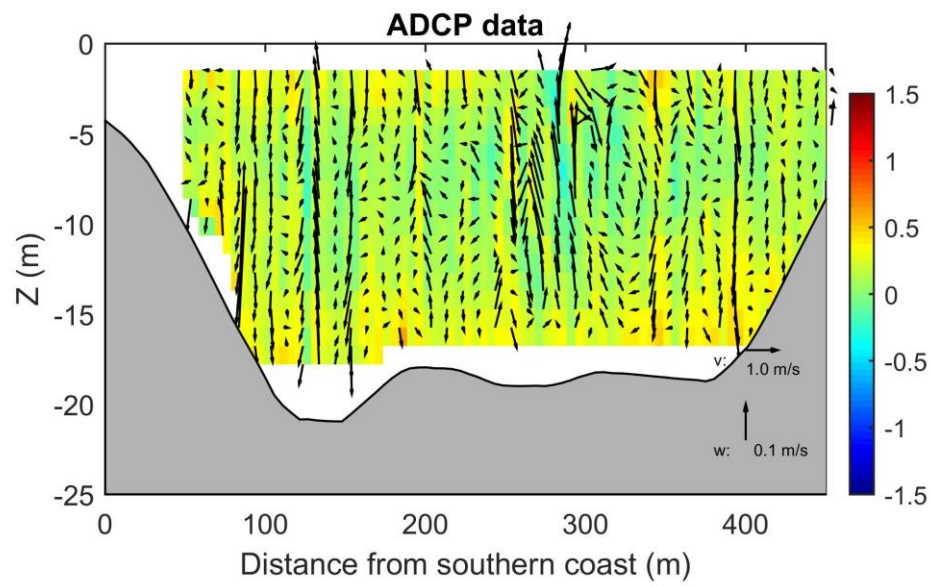
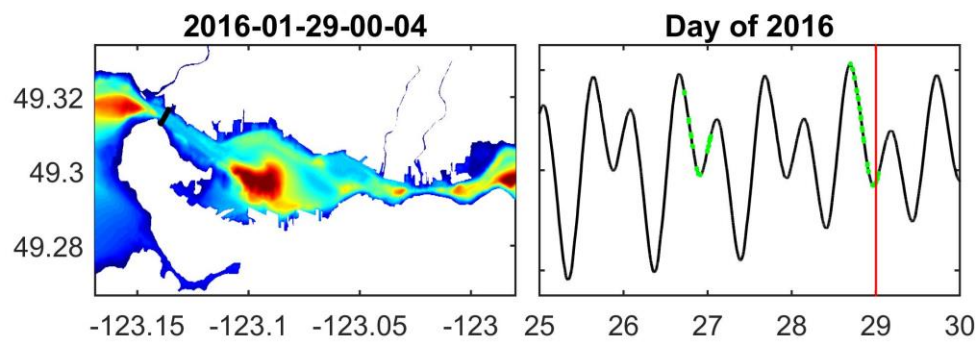


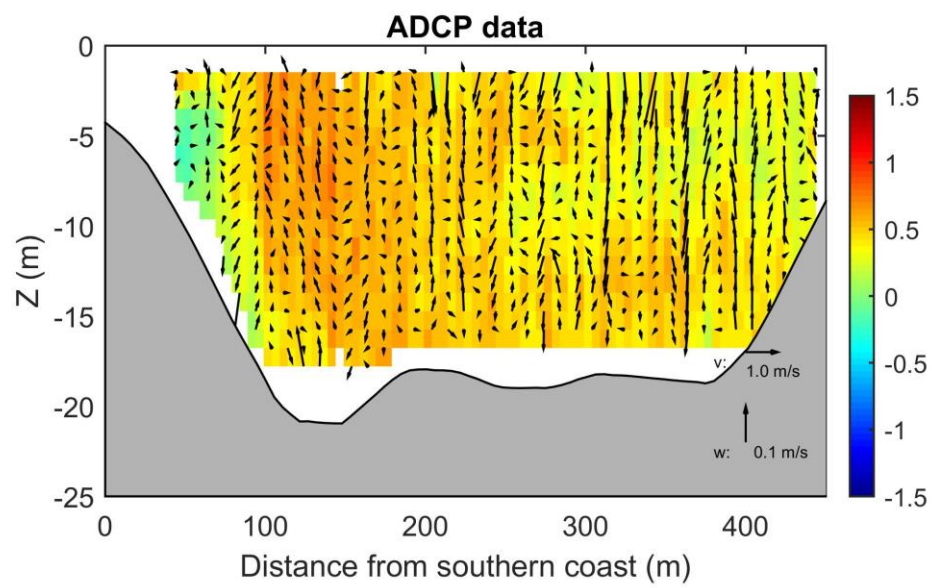
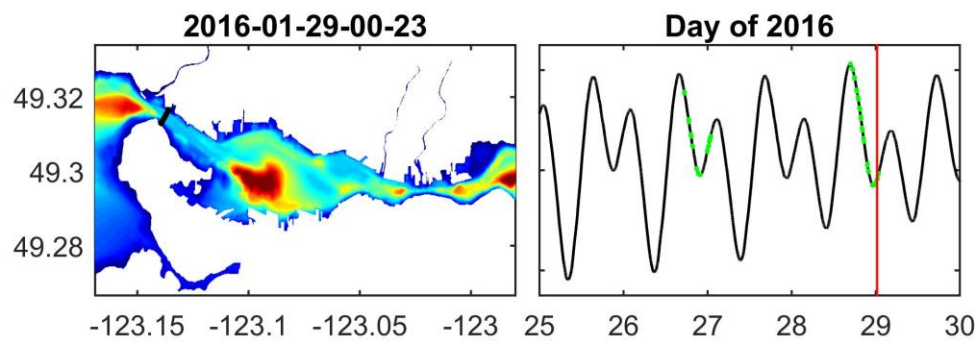


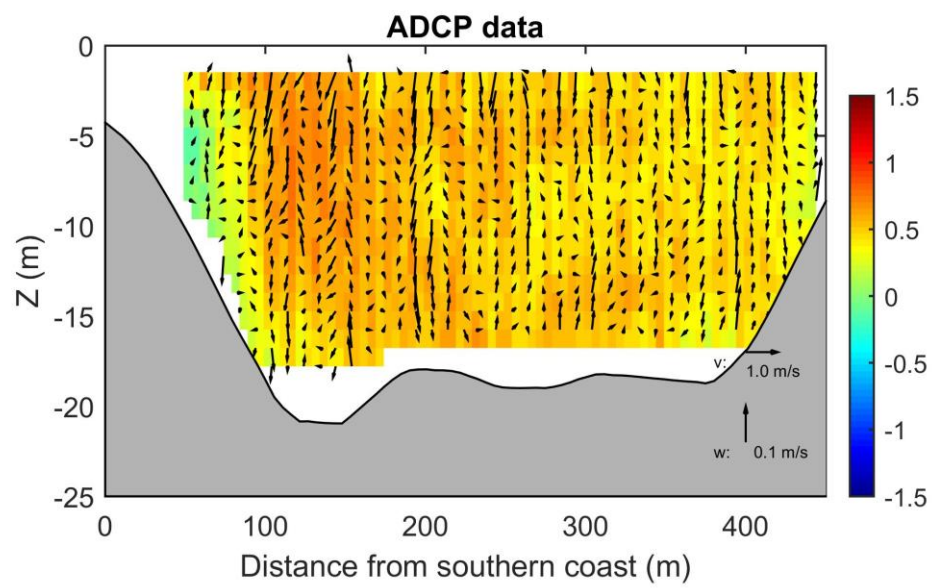
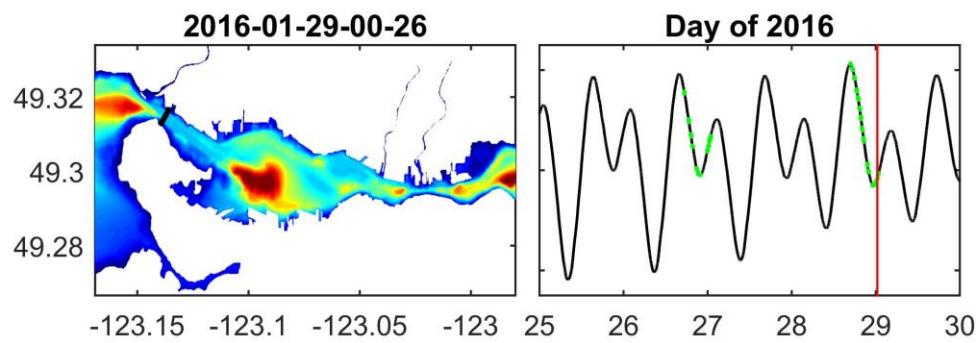


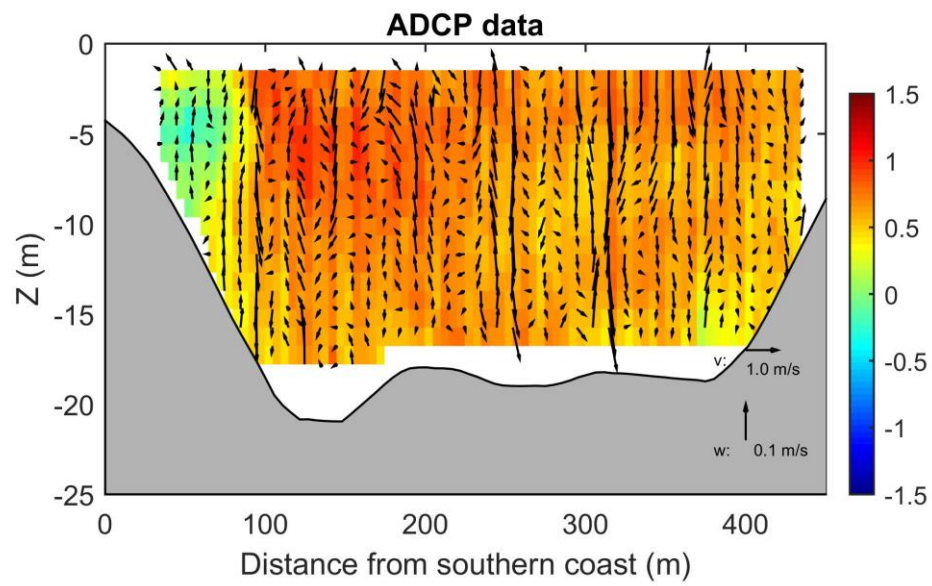
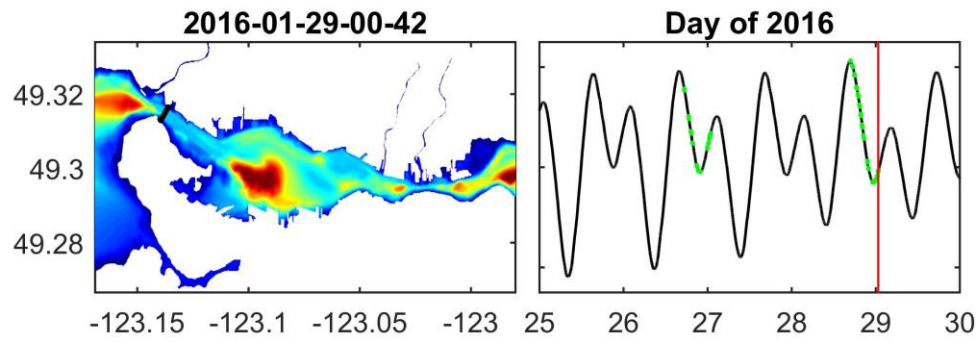


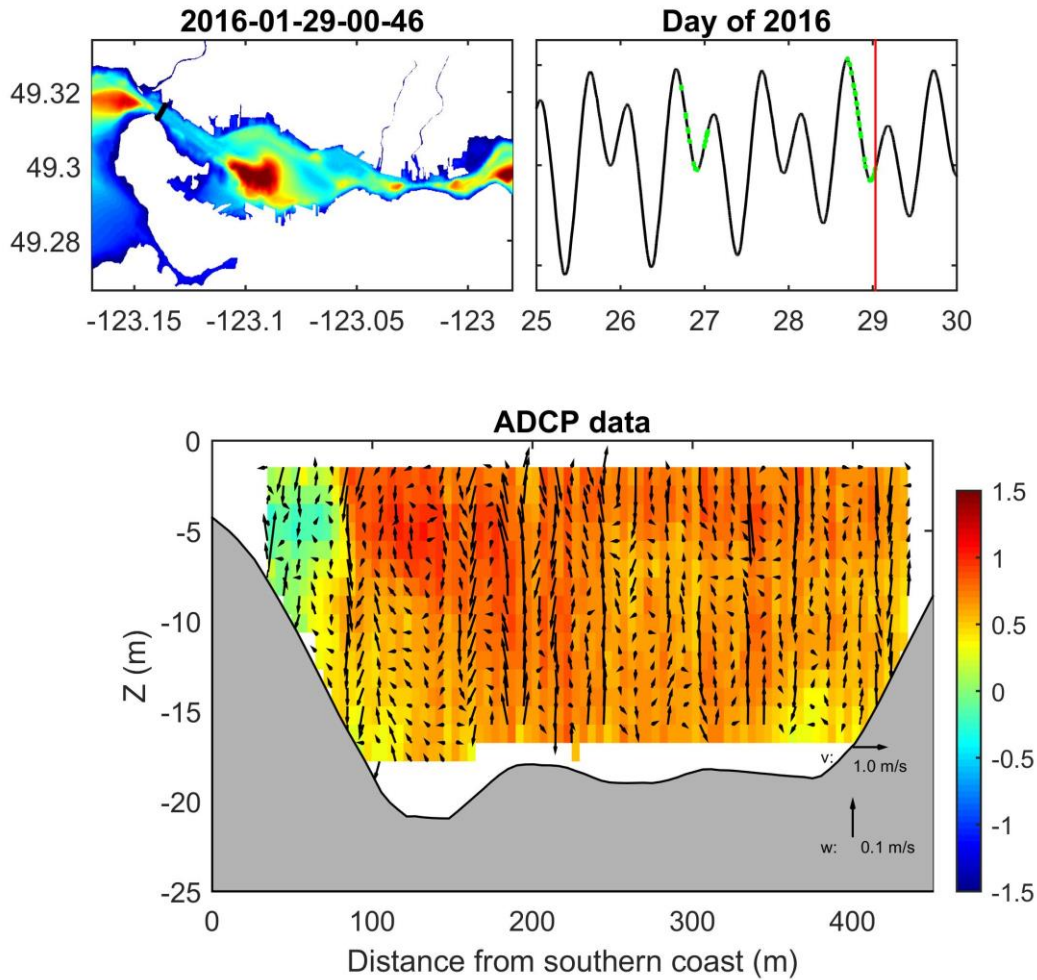






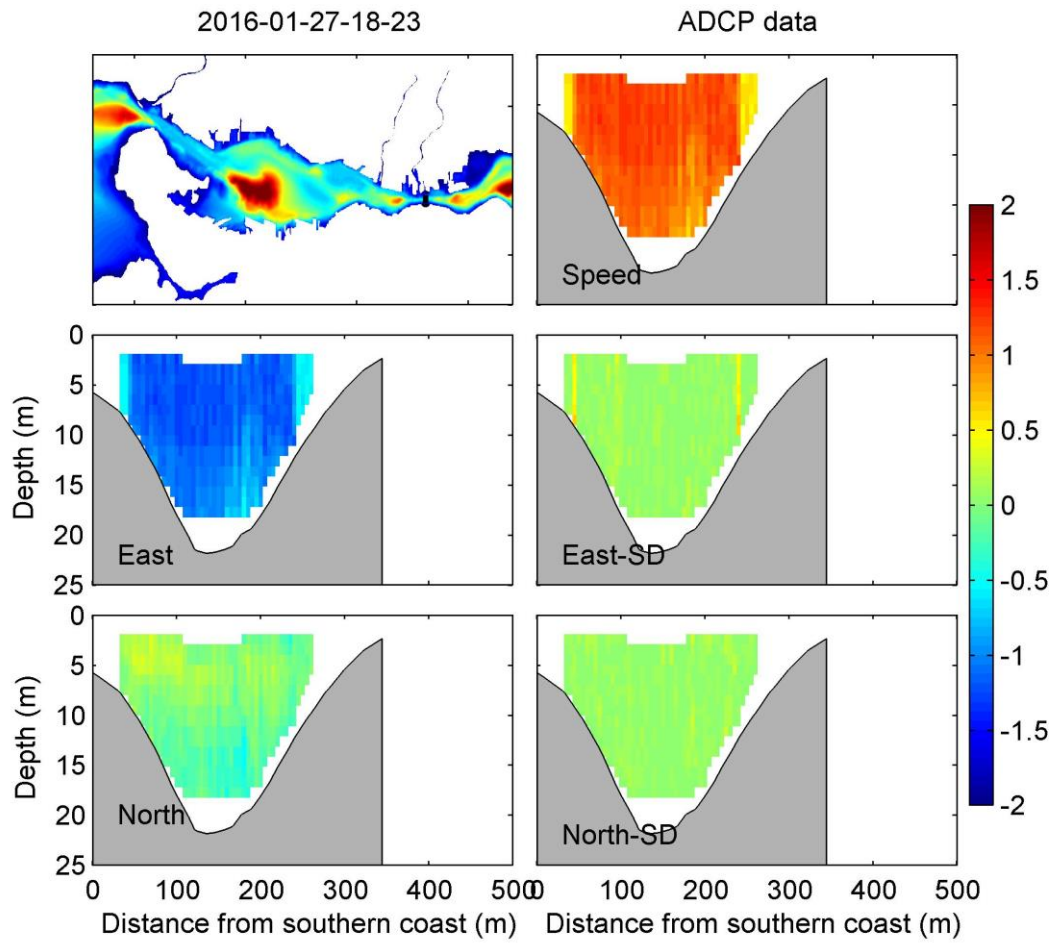


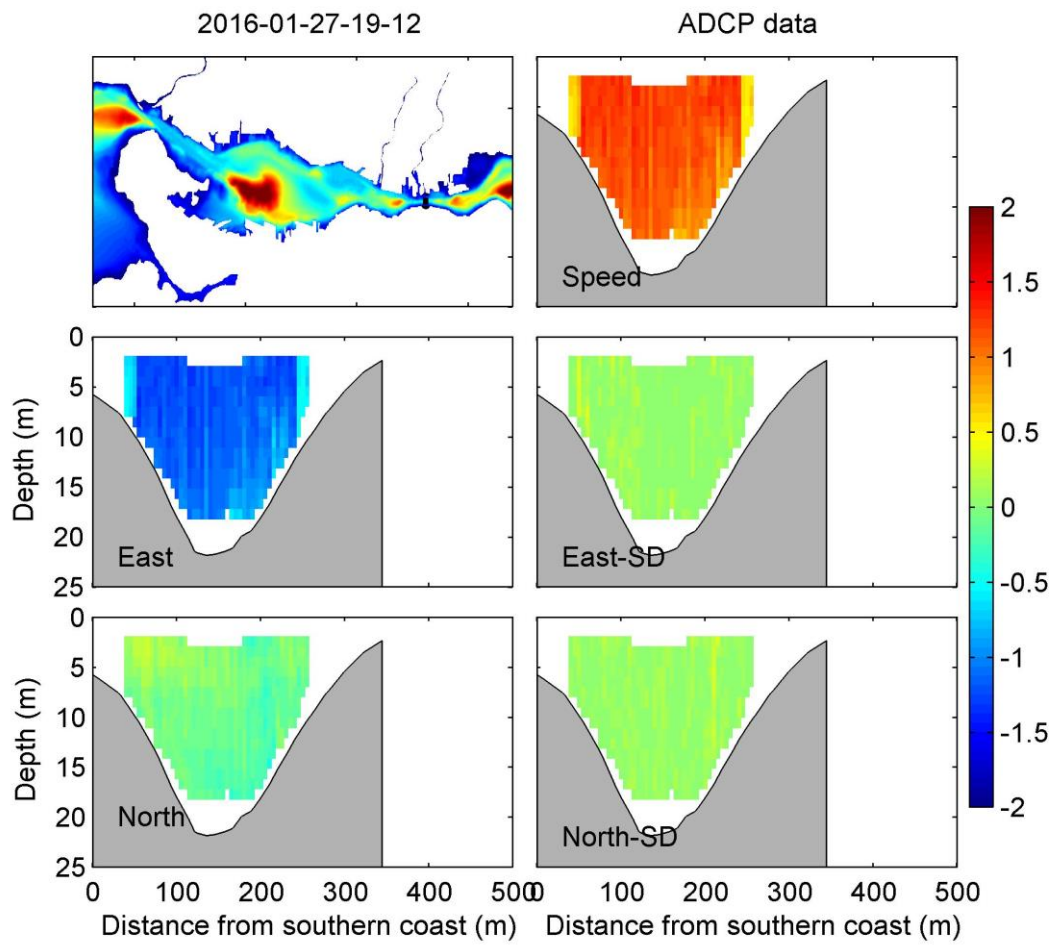


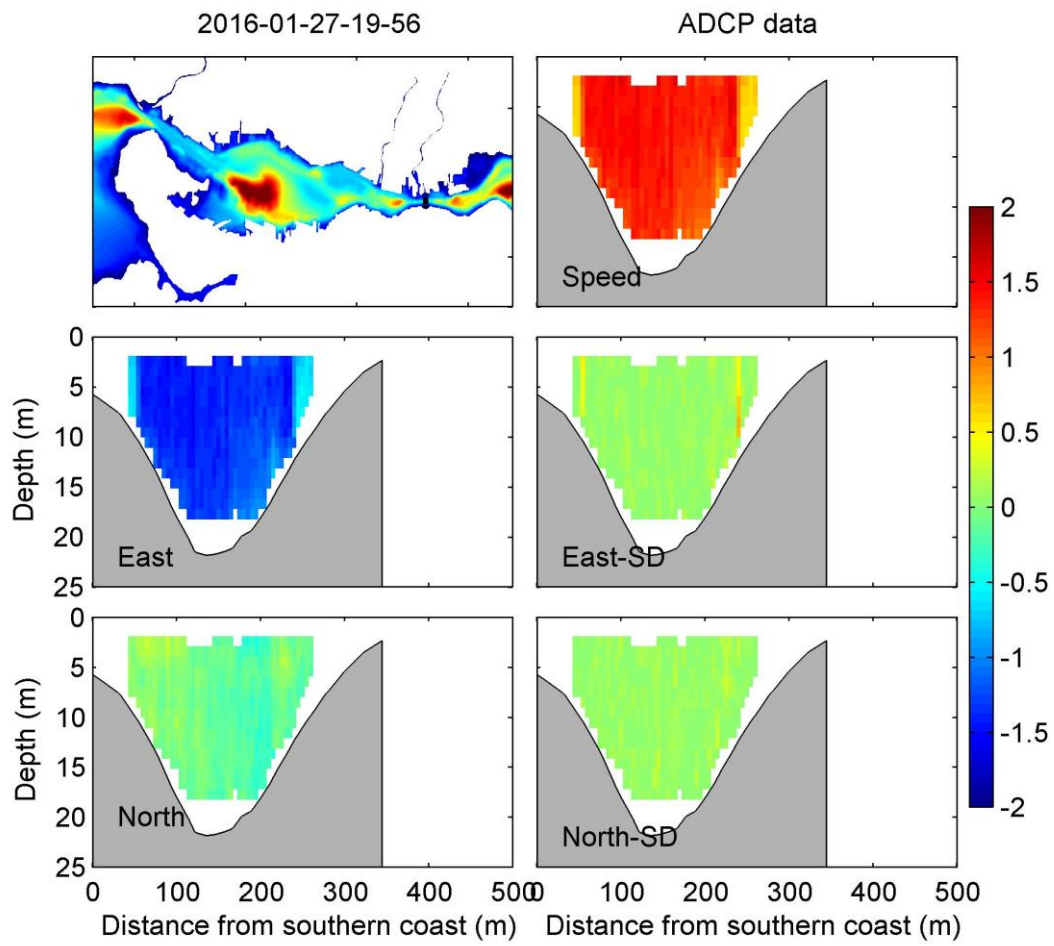


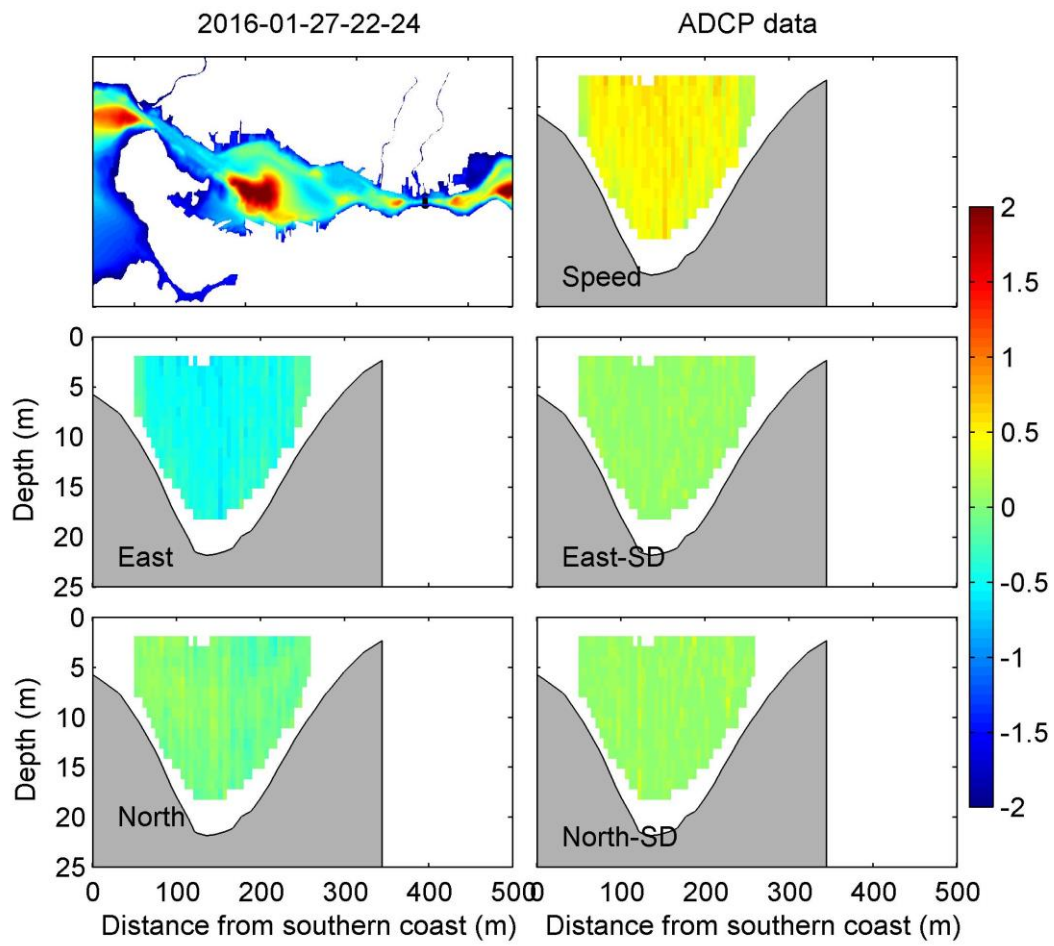
7.5 LINE 3 VELOCITY DATA AND STANDARD DEVIATION

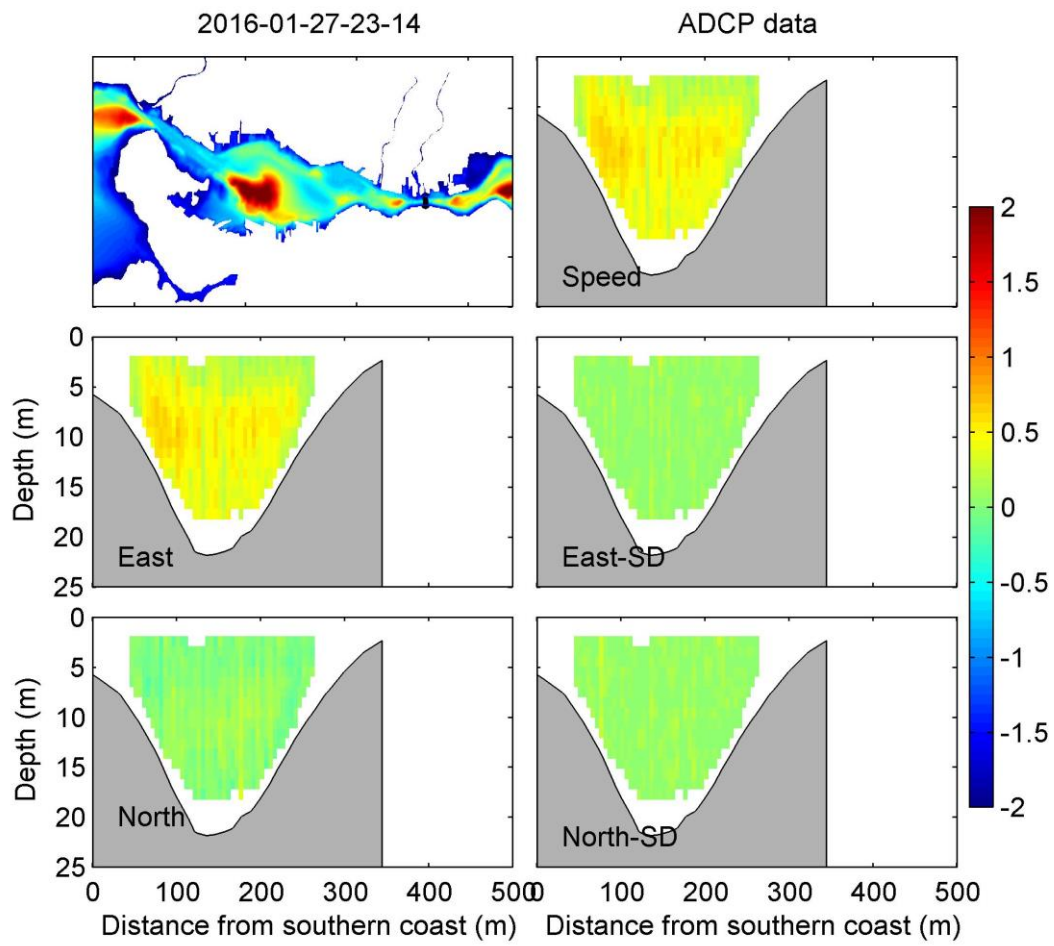
The following figures show vertical profiles of the east and north (u and v) horizontal velocity components for Line 3 measured in First Narrows. The units are in ms^{-1} . The figures include a map of the bathymetry that shows the position of the transect and the vertical profile of the velocity magnitude in the top row. The vertical profiles of the east and north horizontal velocity components with their standard deviations are in the second and third rows. The time of the sample is stated on the figures and in their associated captions.

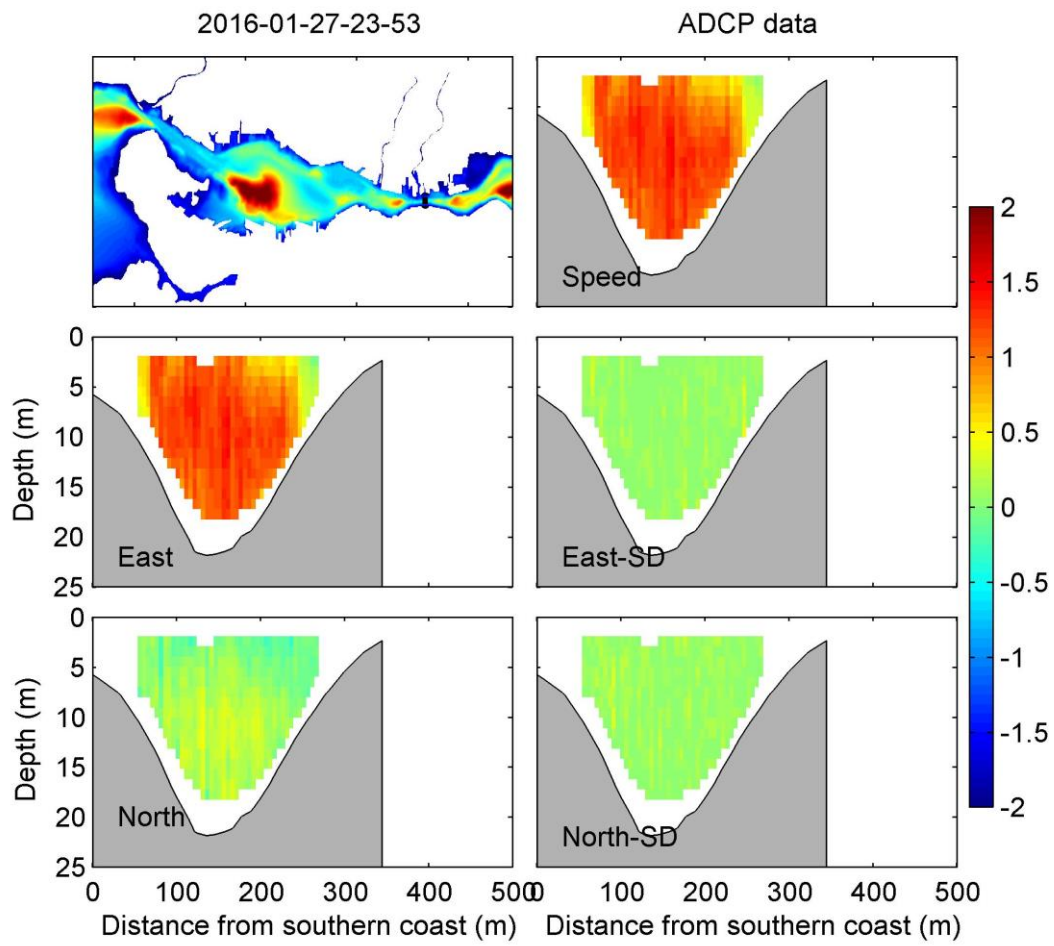


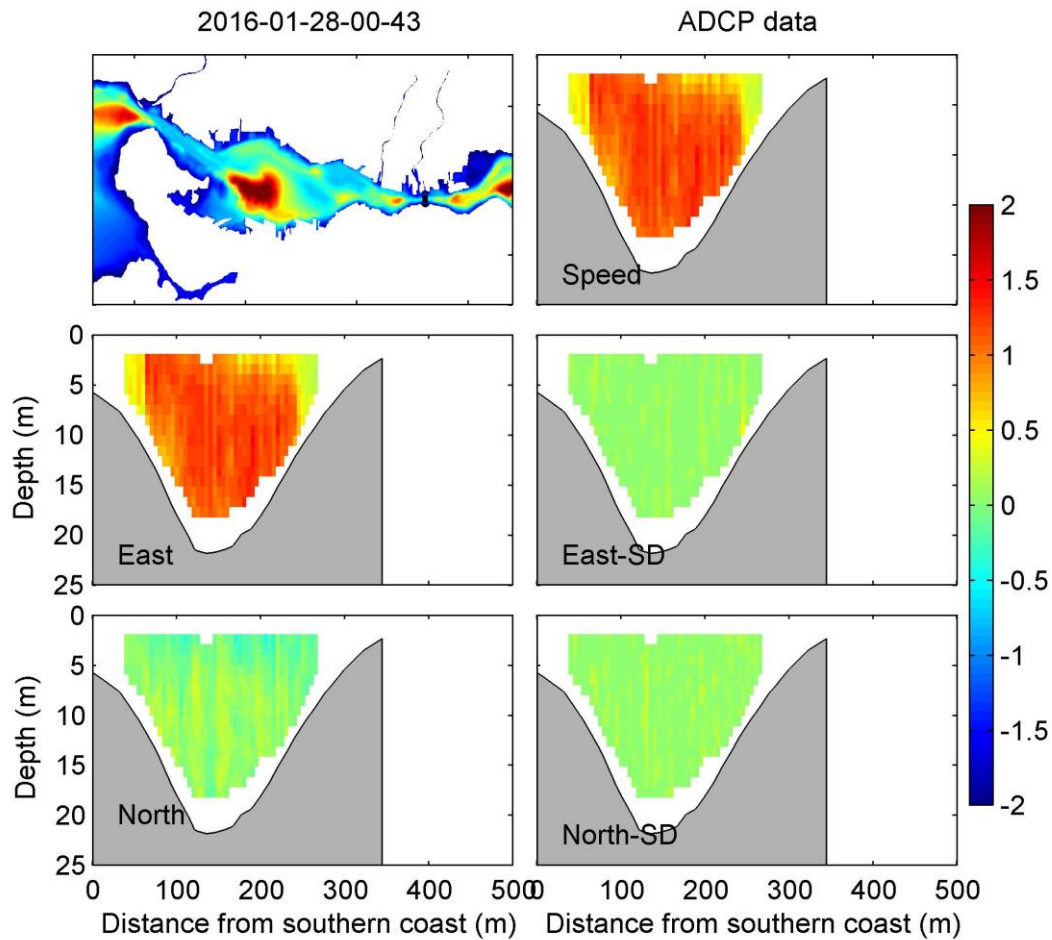






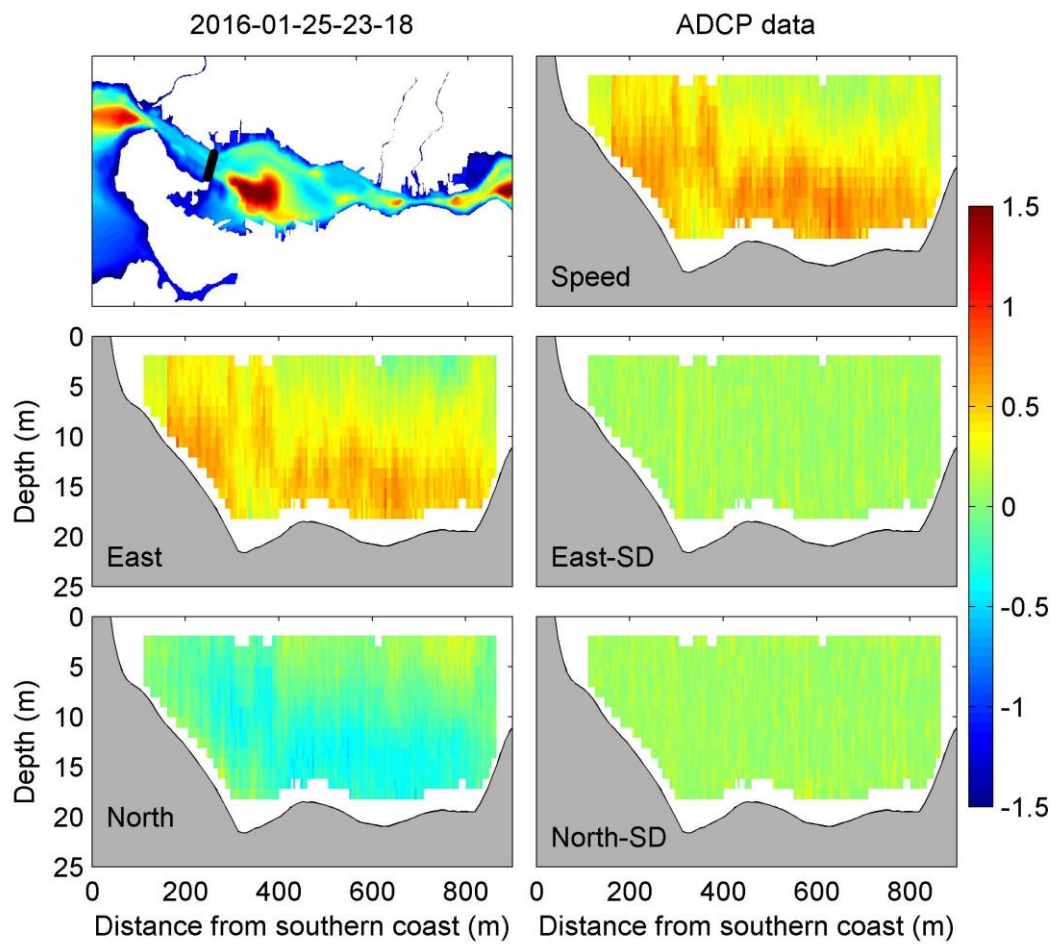


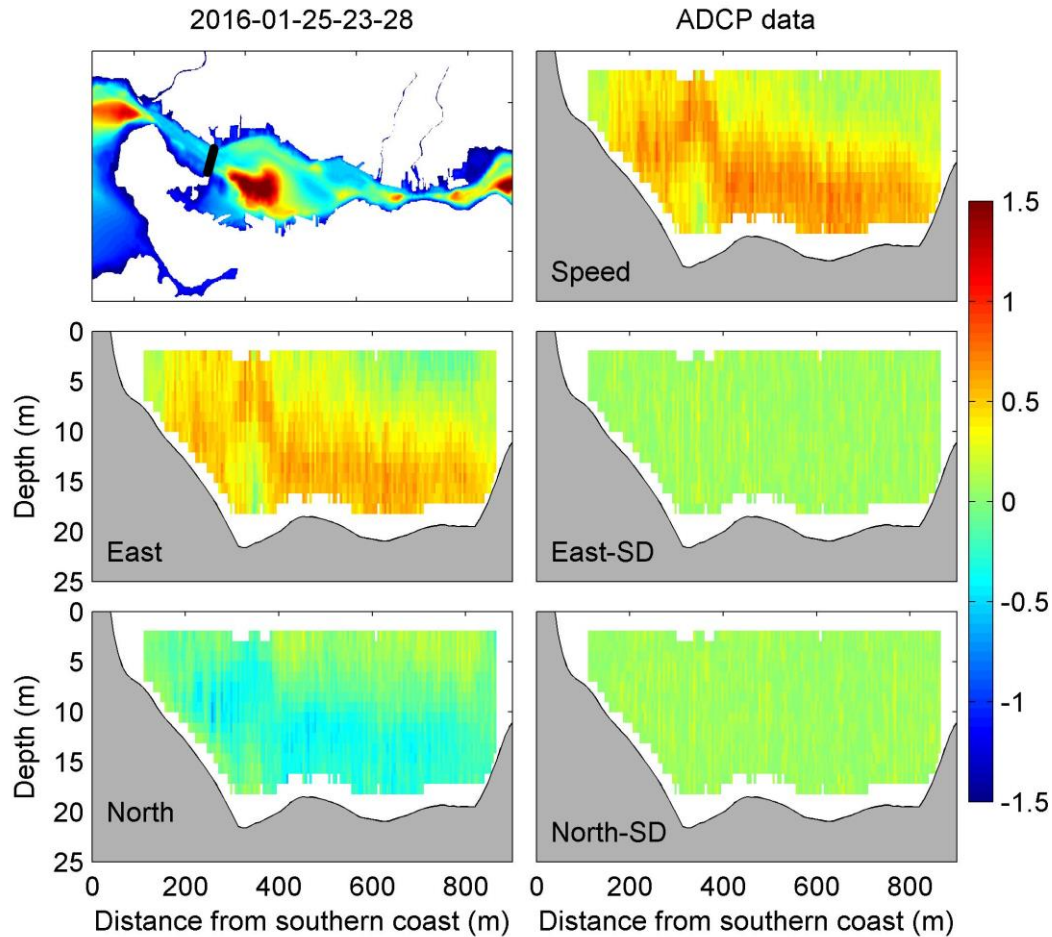




7.6 LINE 4 VELOCITY DATA AND STANDARD DEVIATION

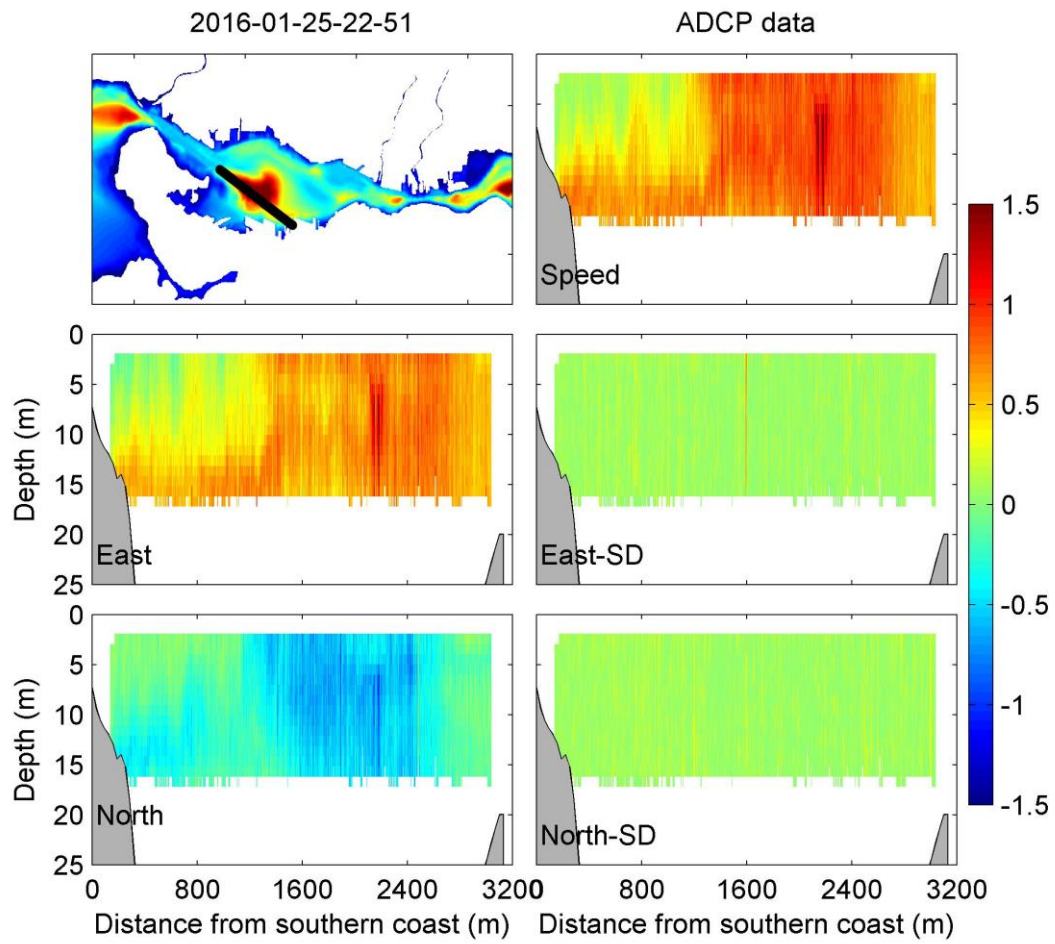
The following figures show vertical profiles of the east and north (u and v) horizontal velocity components for Line 4 measured in First Narrows. The units are in ms^{-1} . The figures include a map of the bathymetry that shows the position of the transect and the vertical profile of the velocity magnitude in the top row. The vertical profiles of the east and north horizontal velocity components with their standard deviations are in the second and north horizontal velocity components with their standard deviations are in the second and third rows. The time of the sample is stated on the figures and in their associated captions.

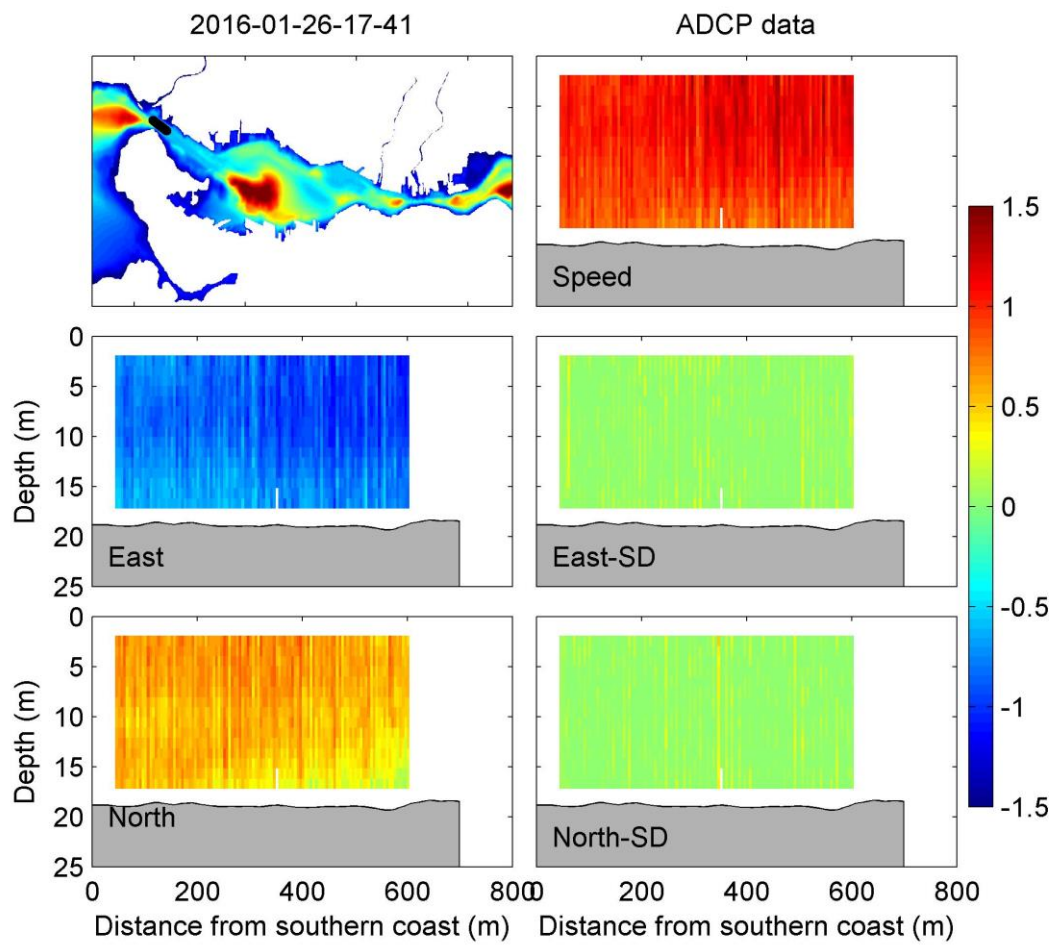


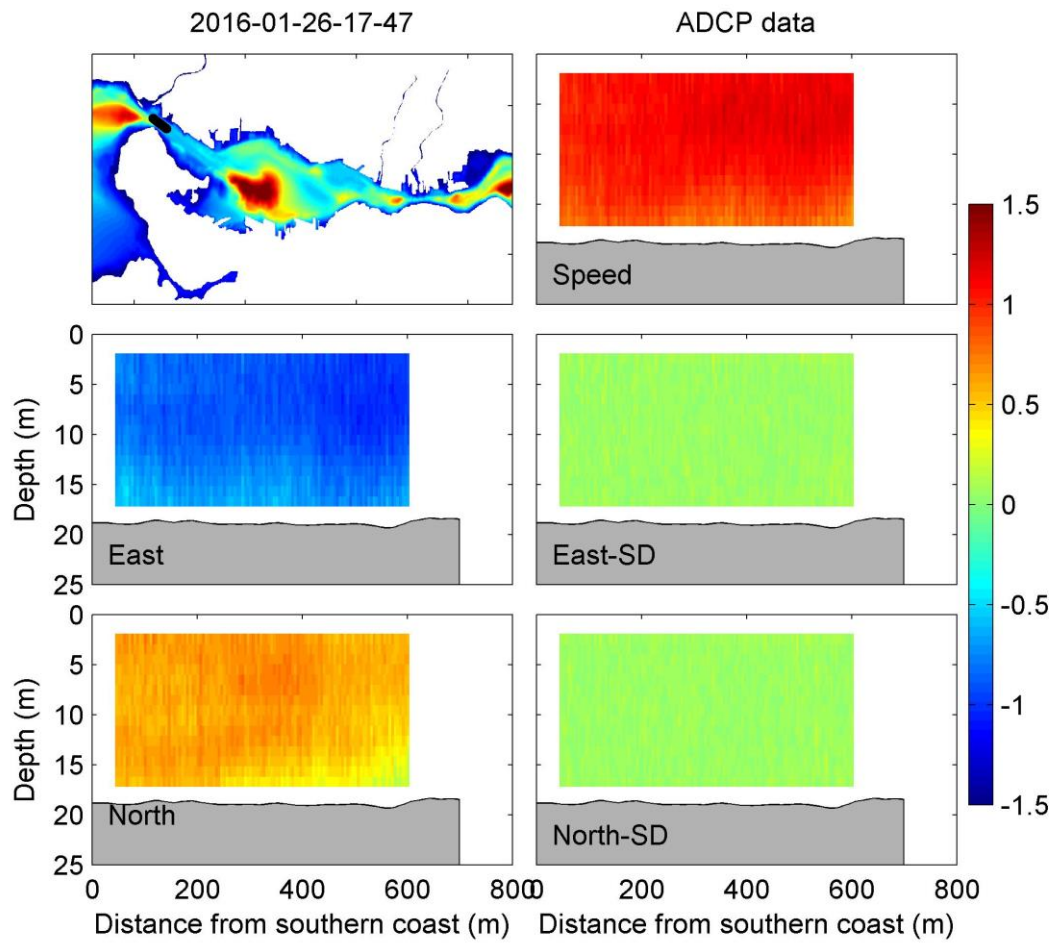


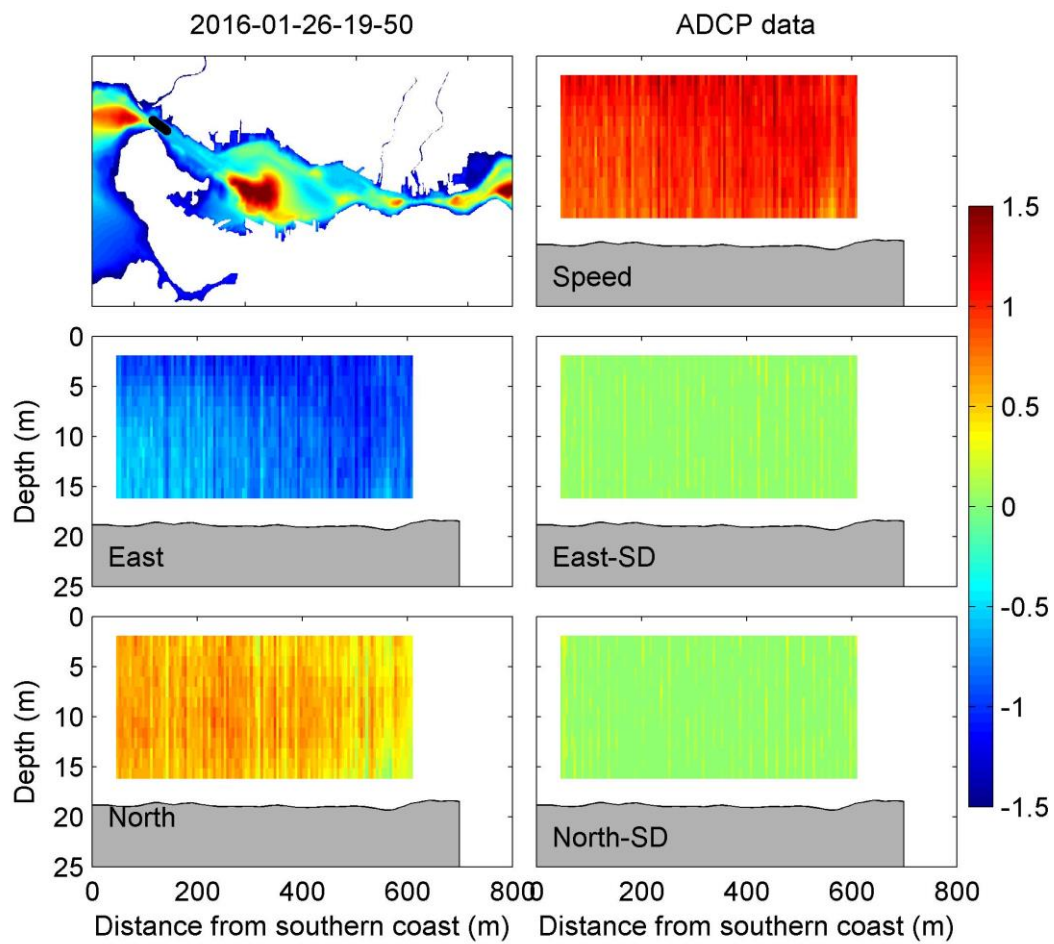
7.7 LINE 5 VELOCITY DATA AND STANDARD DEVIATION

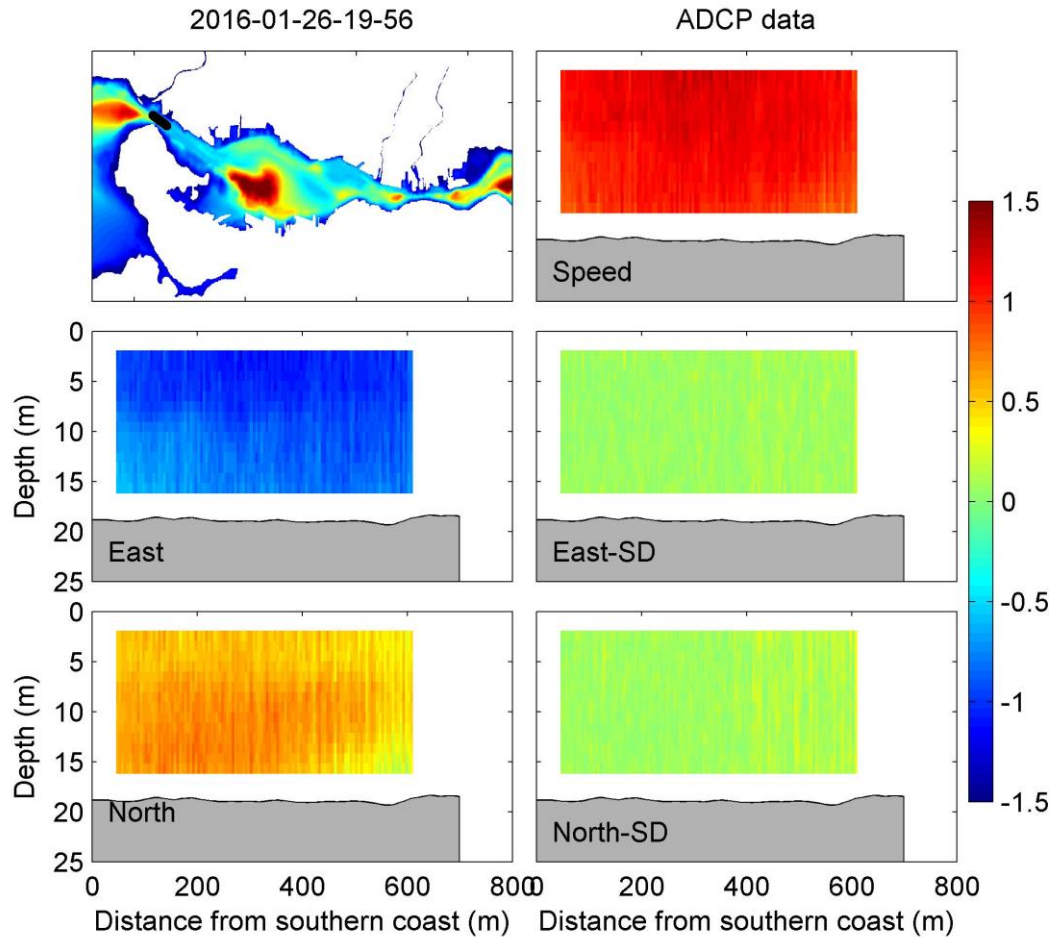
The following figures show vertical profiles of the east and north (u and v) horizontal velocity components for Line 5 measured in First Narrows. The units are in ms^{-1} . The figures include a map of the bathymetry that shows the position of the transect and the vertical profile of the velocity magnitude in the top row. The vertical profiles of the east and north horizontal velocity components with their standard deviations are in the second and north horizontal velocity components with their standard deviations are in the second and third rows. The time of the sample is stated on the figures and in their associated captions.







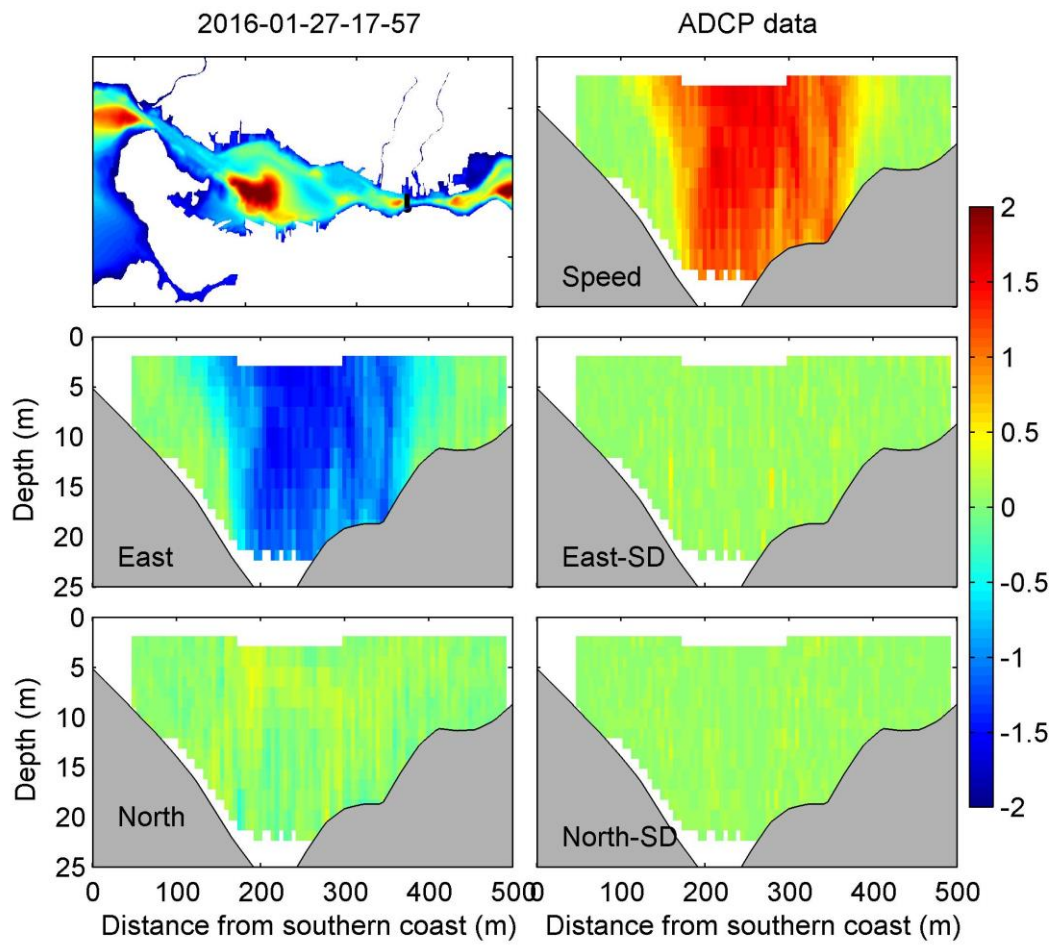


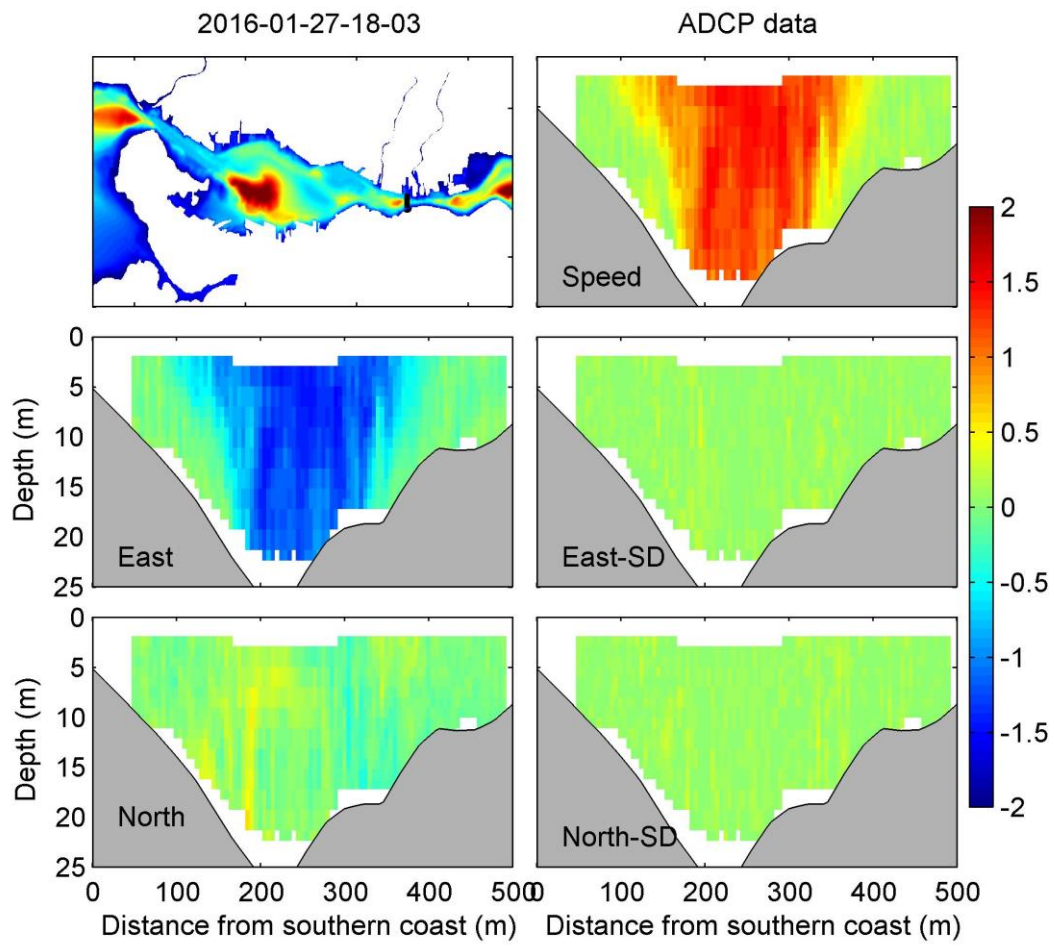


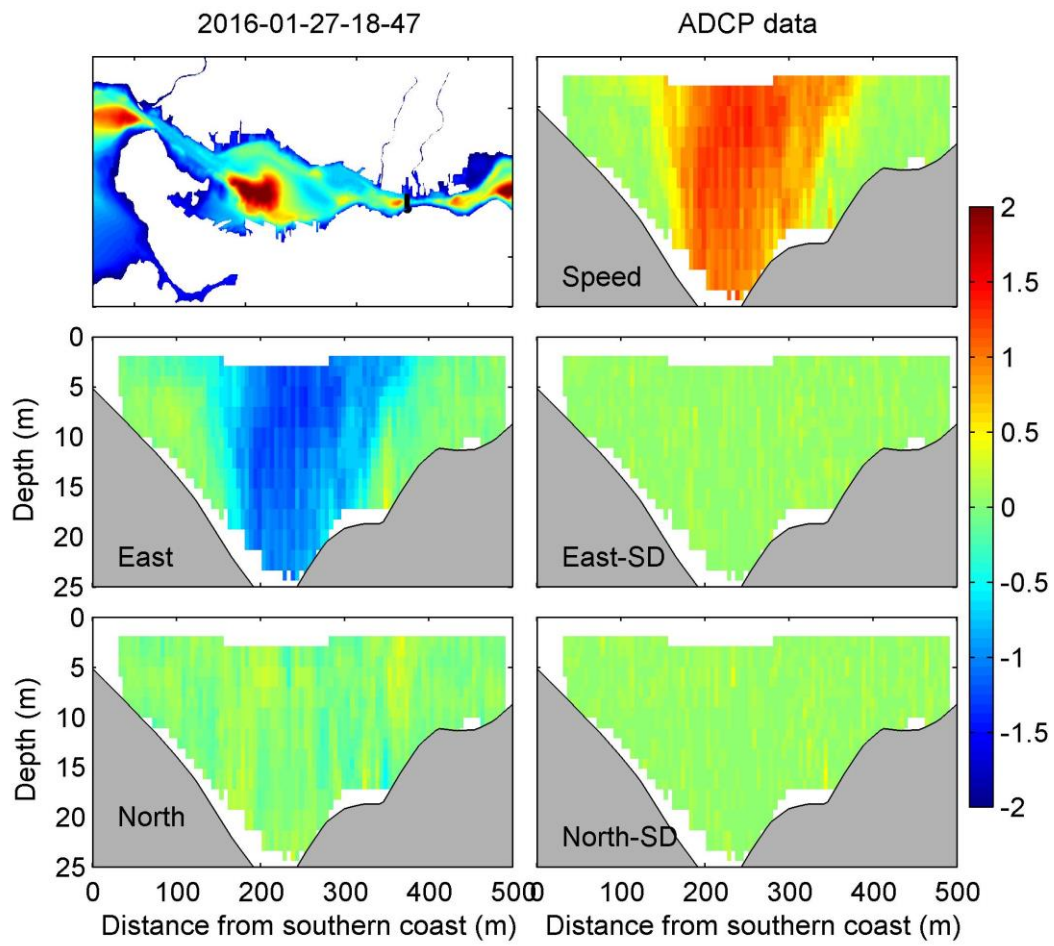
8 APPENDIX 3: VESSEL-MOUNTED ADCP AT SECOND NARROWS

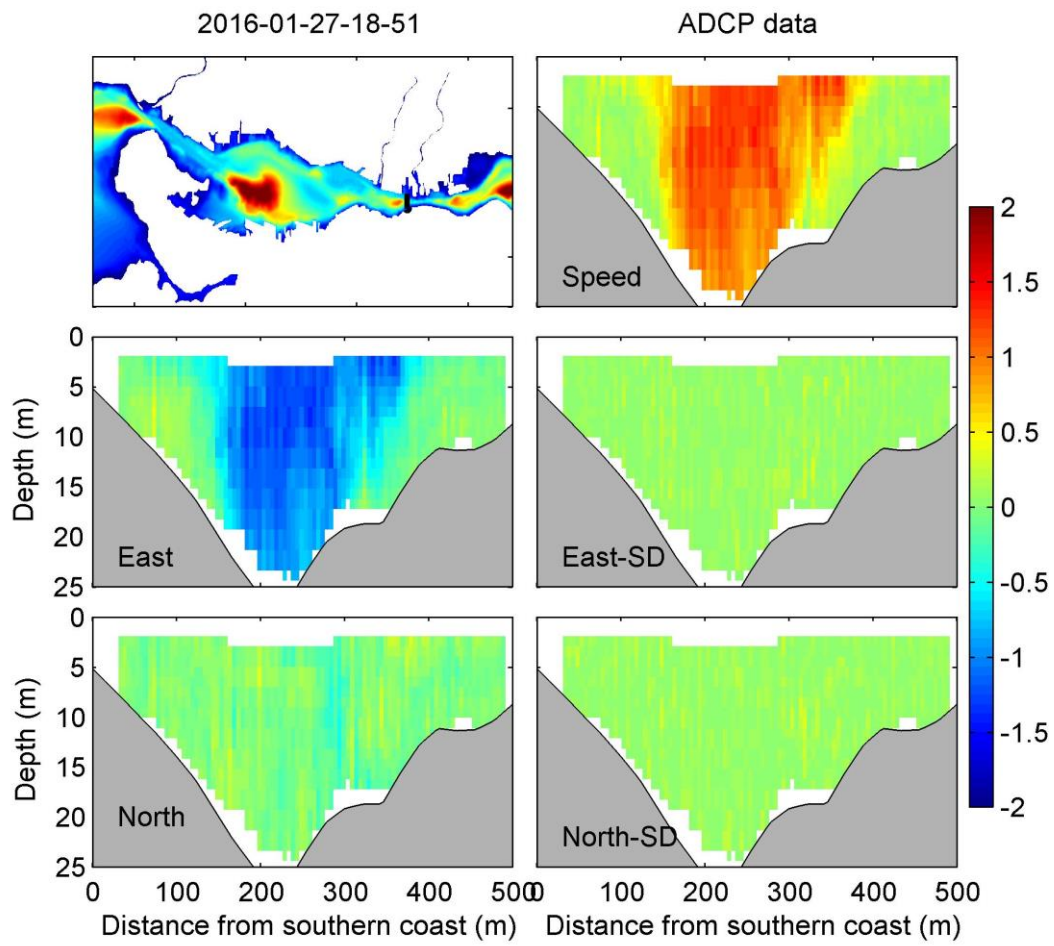
8.1 LINE 1 VELOCITY DATA AND STANDARD DEVIATION

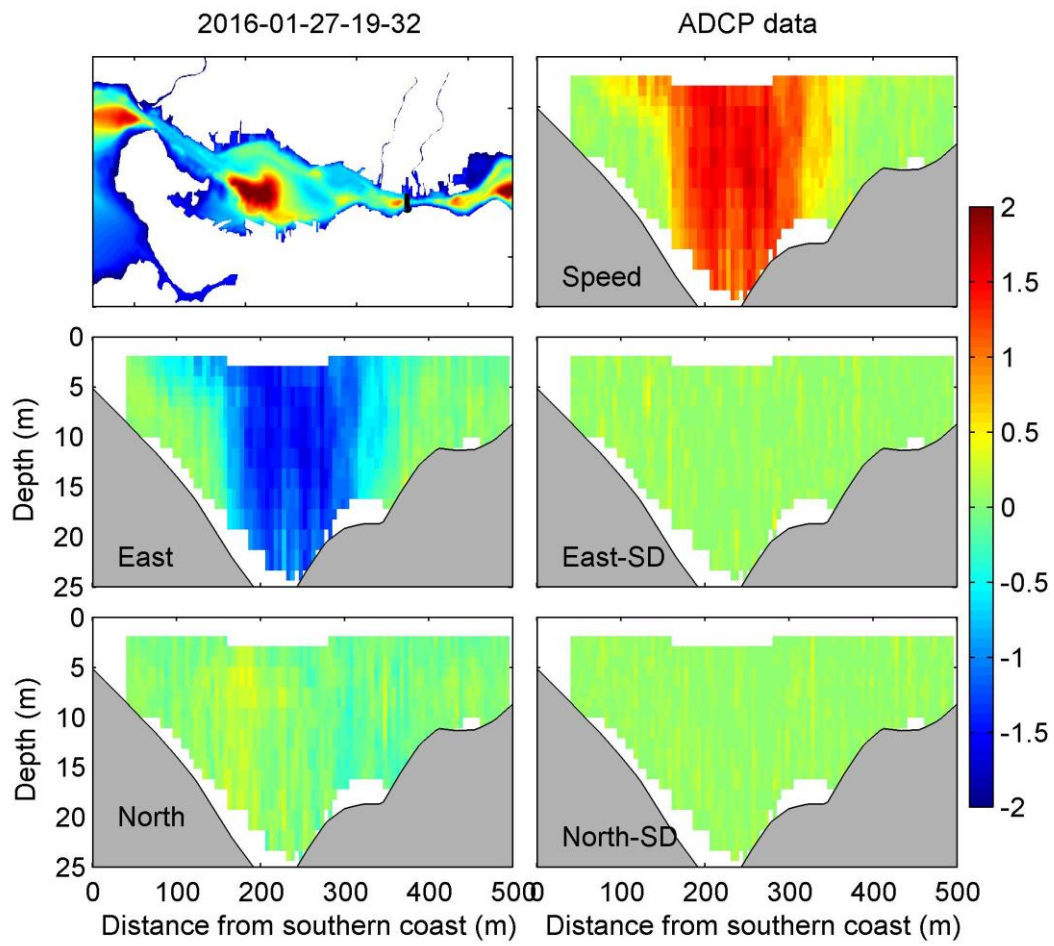
The following figures show vertical profiles of the east and north (u and v) horizontal velocity components for Line 1 measured in Second Narrows. The units are in ms^{-1} . The figures include a map of the bathymetry that shows the position of the transect and the vertical profile of the velocity magnitude in the top row. The vertical profiles of the east and north horizontal velocity components with their standard deviations (SD) are in the second and third rows. The time of the sample is stated on the figures.

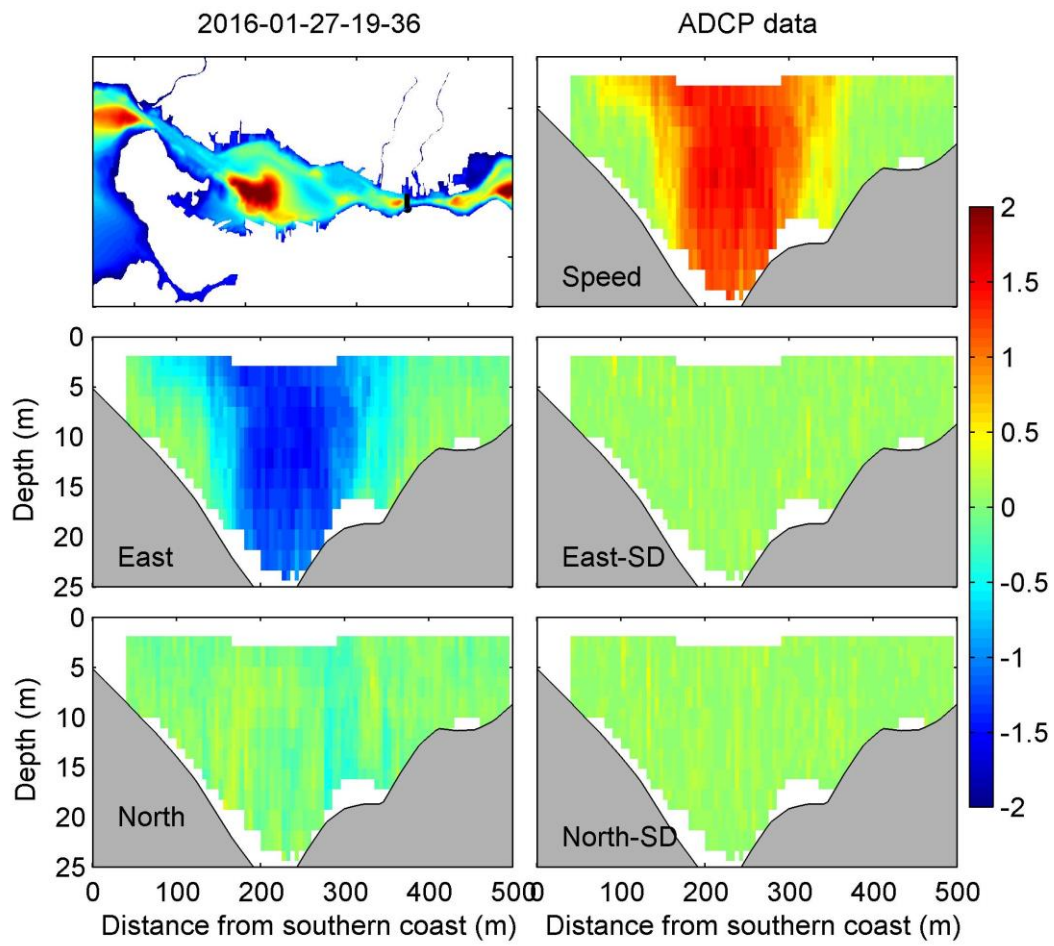


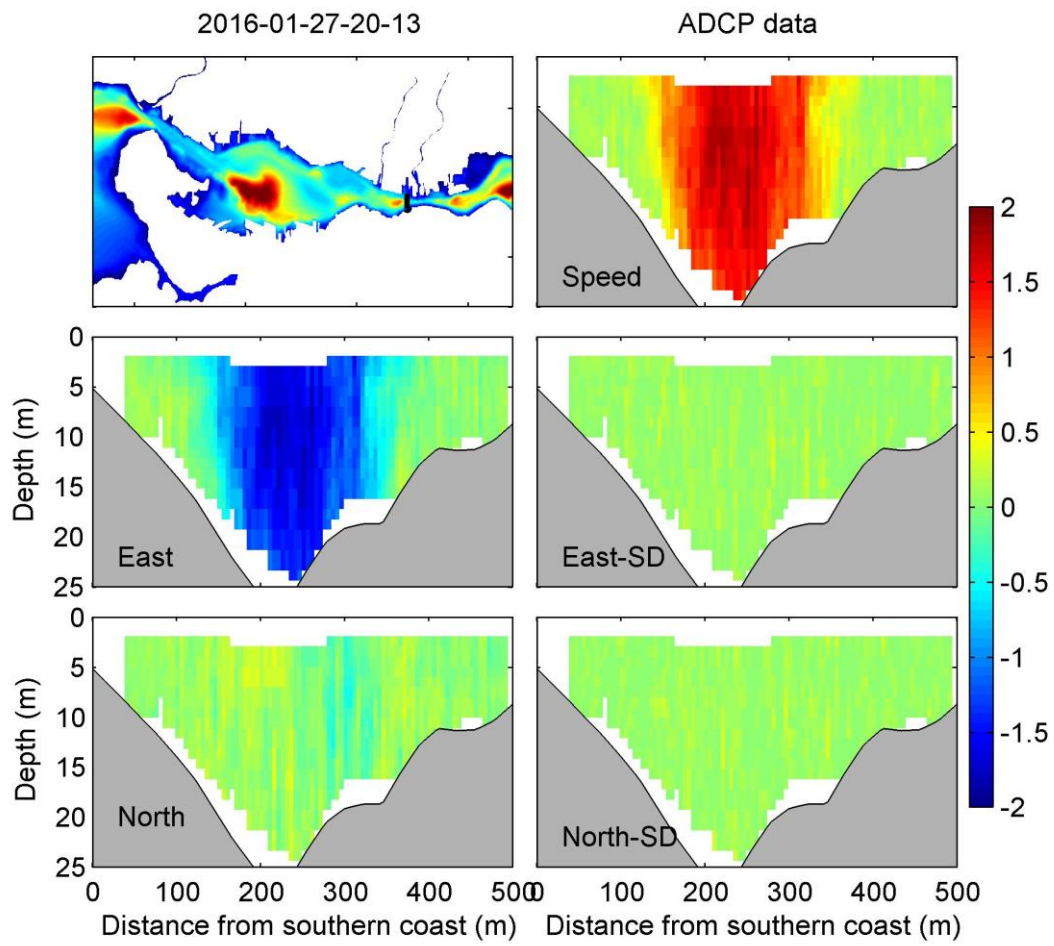


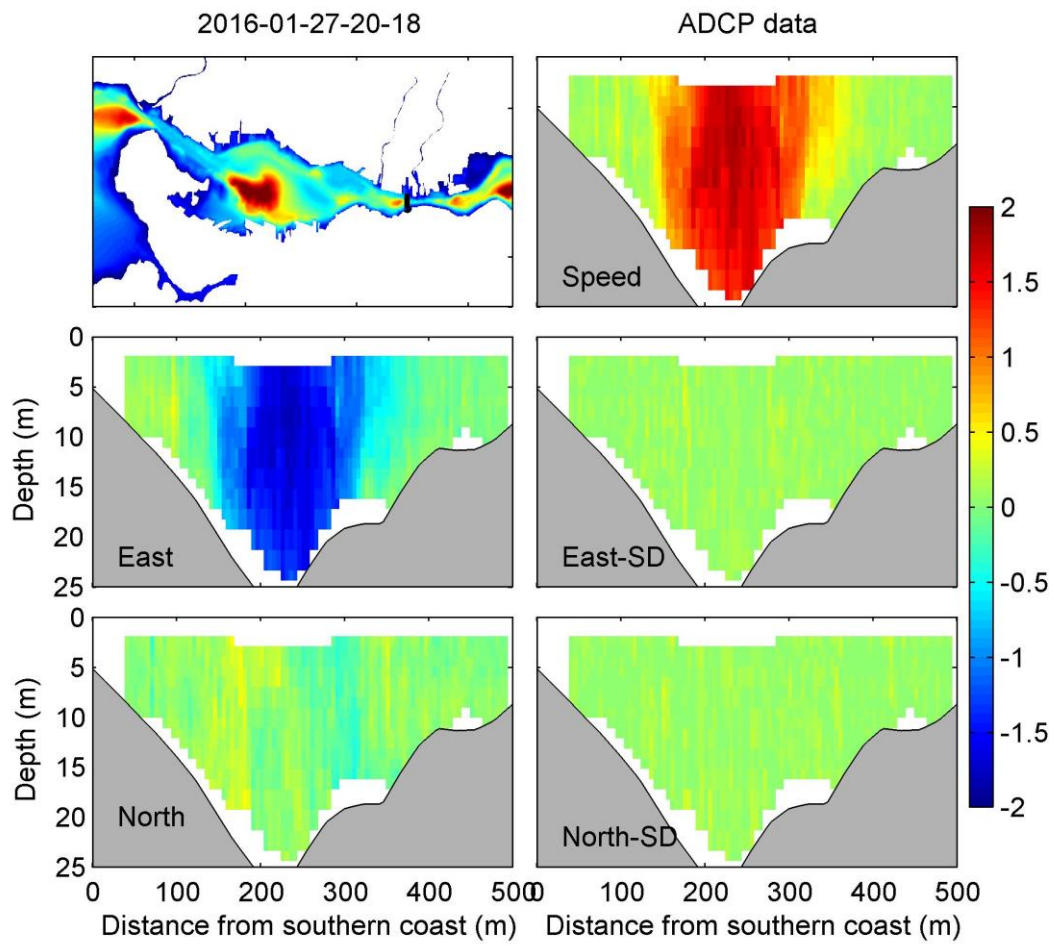


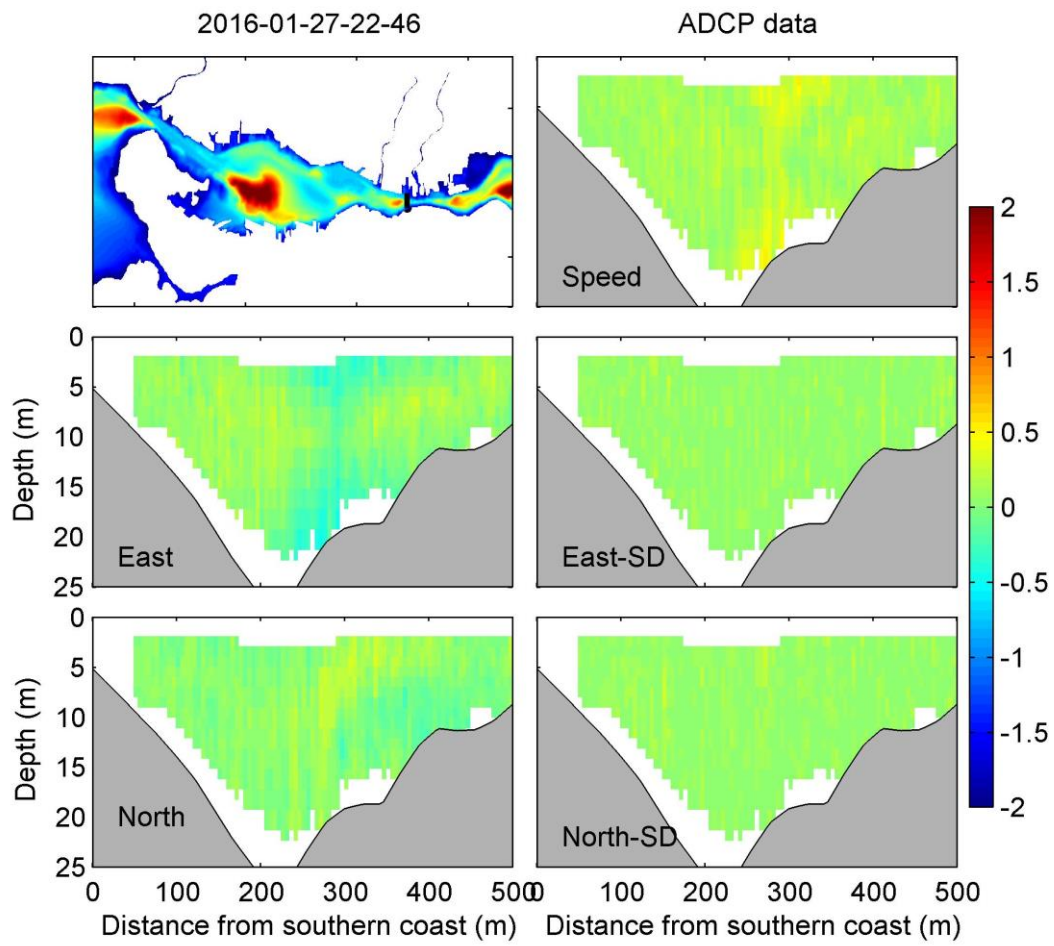


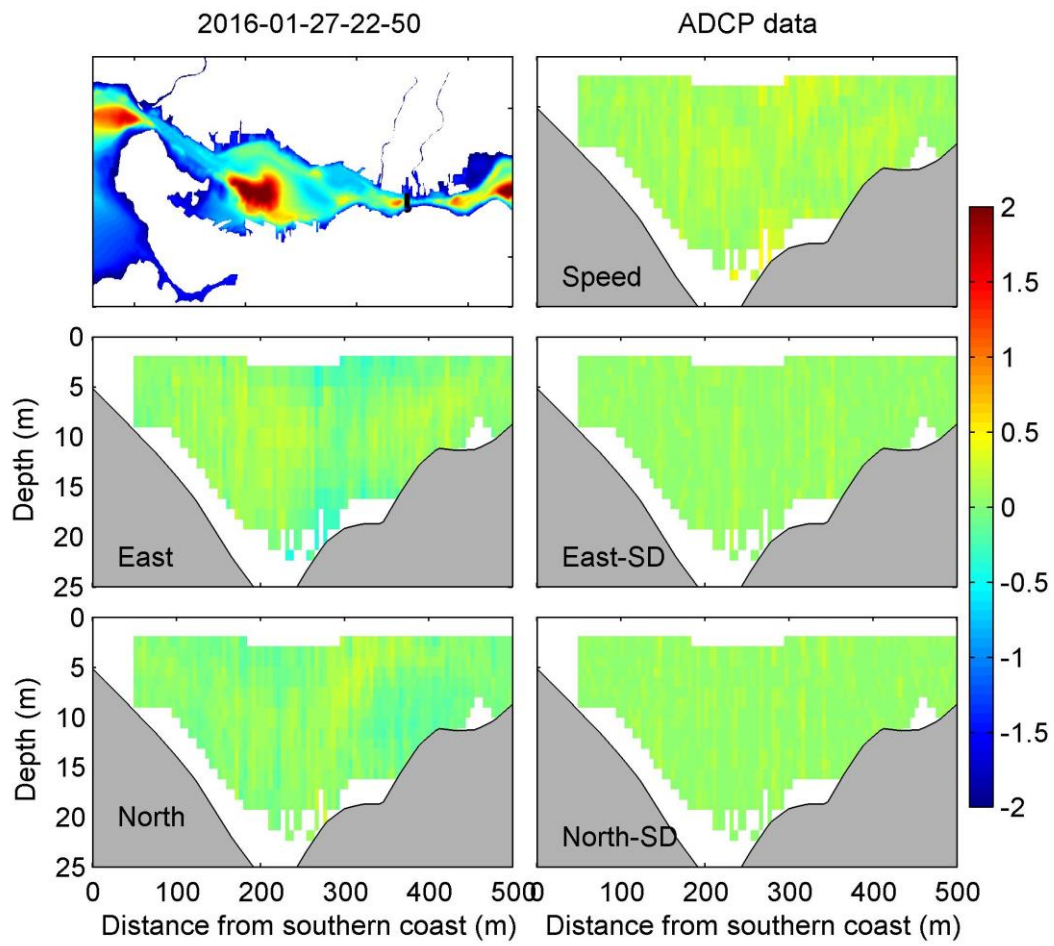


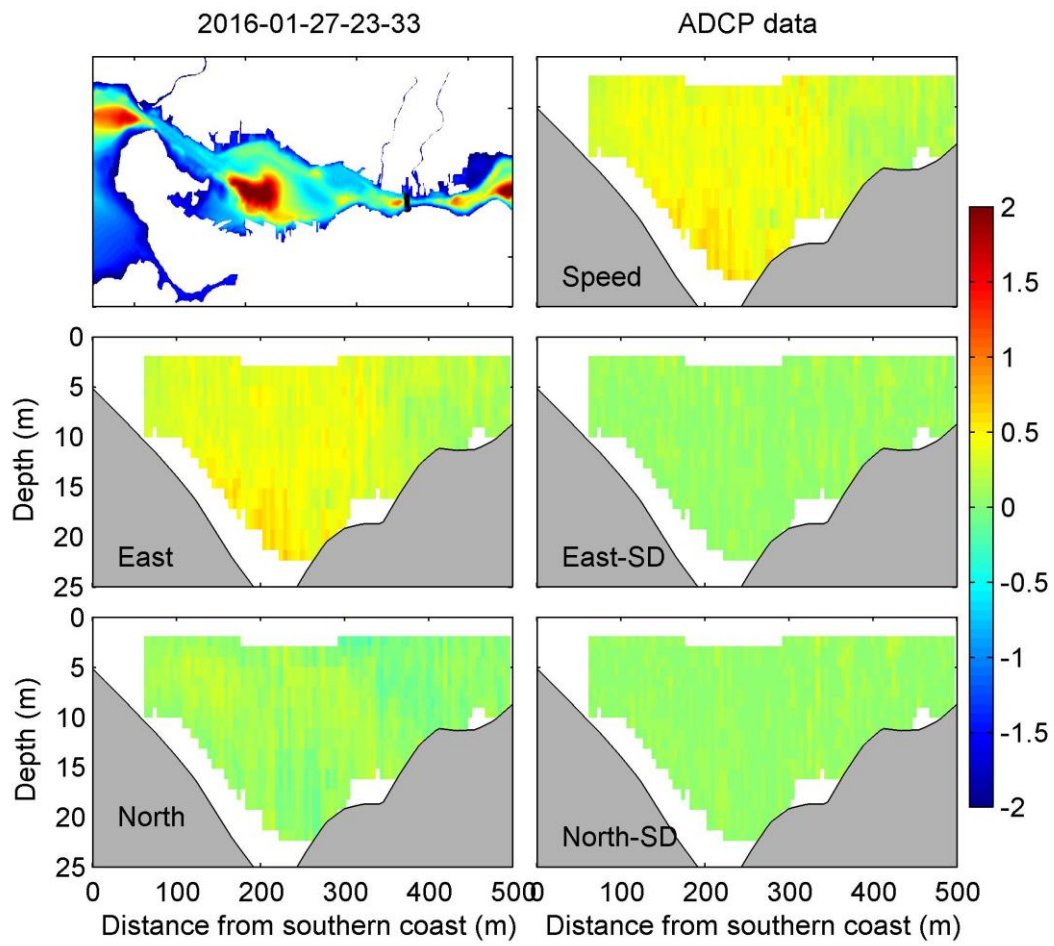


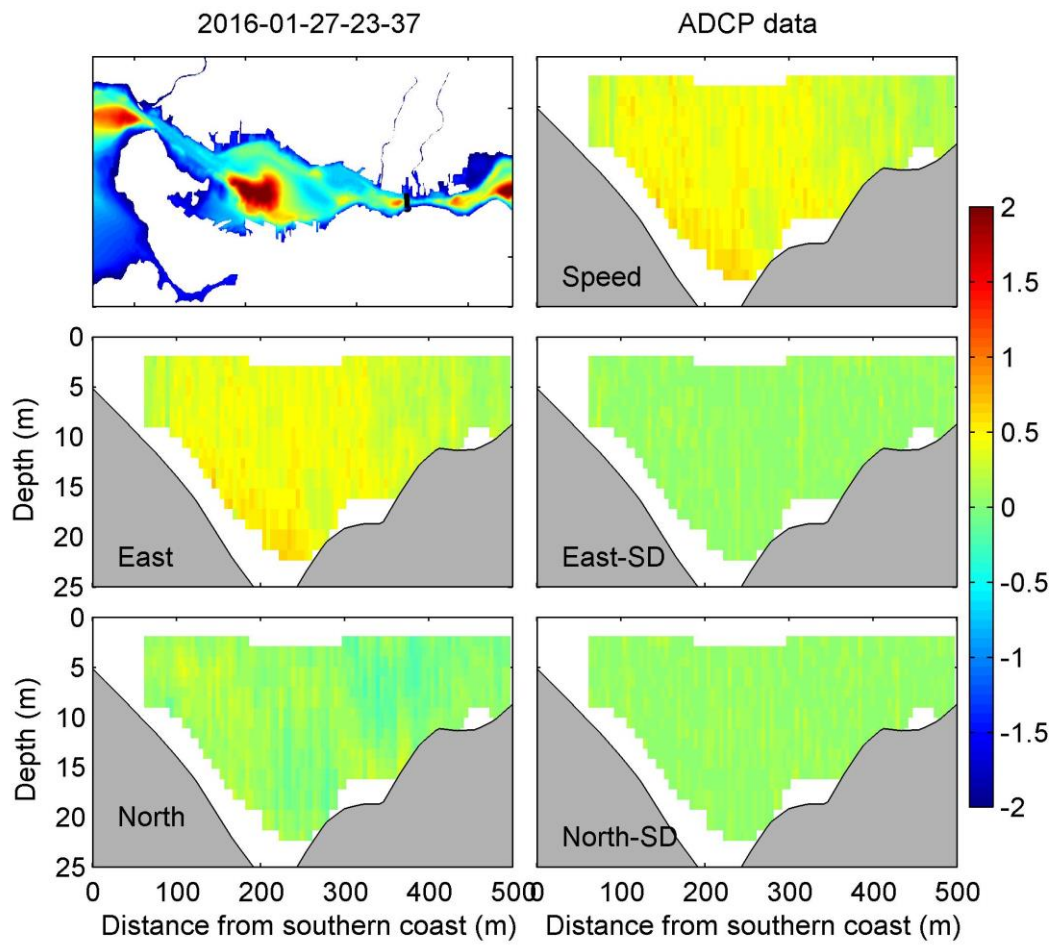


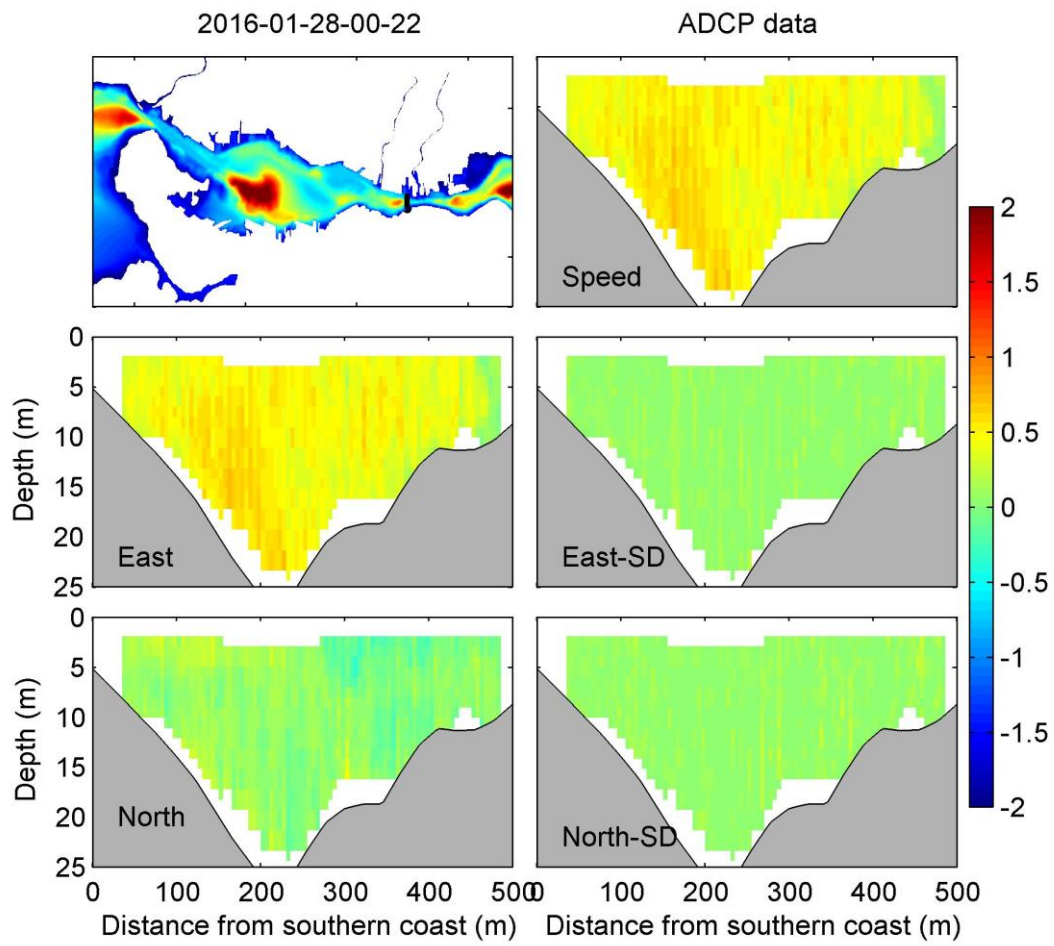


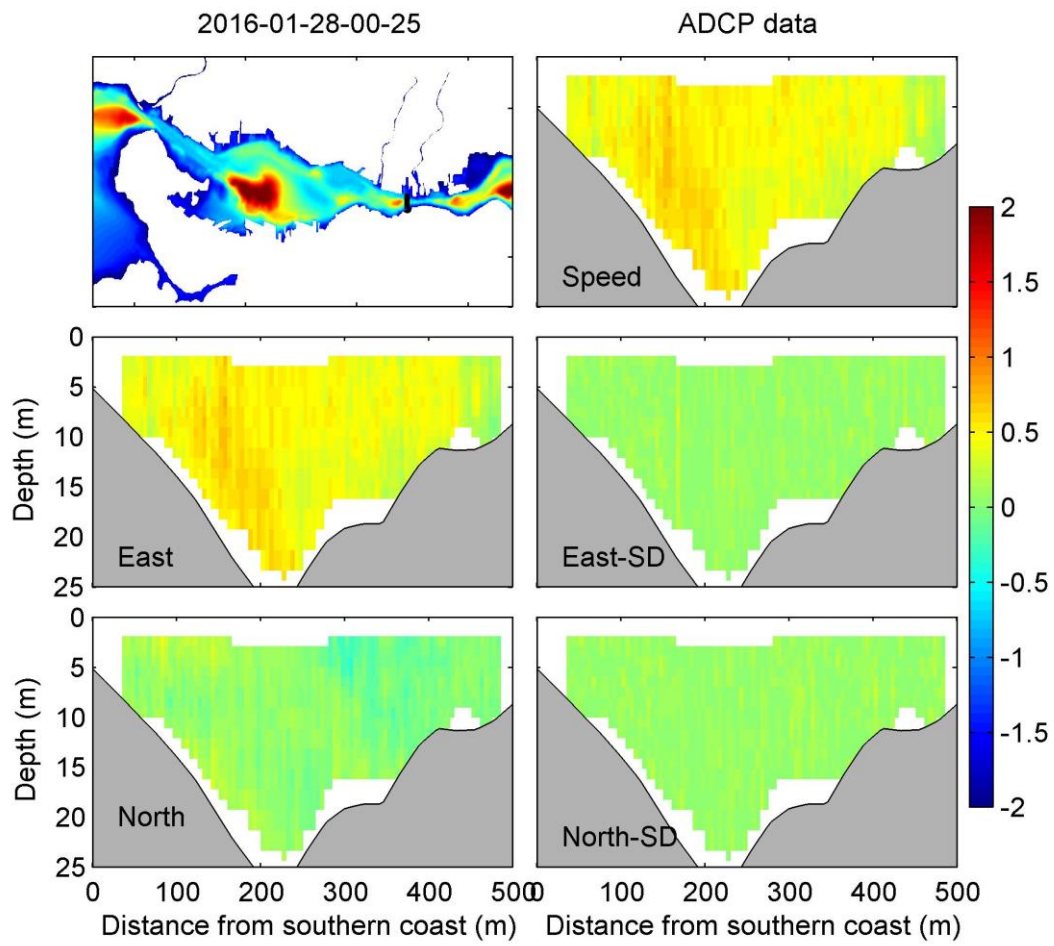


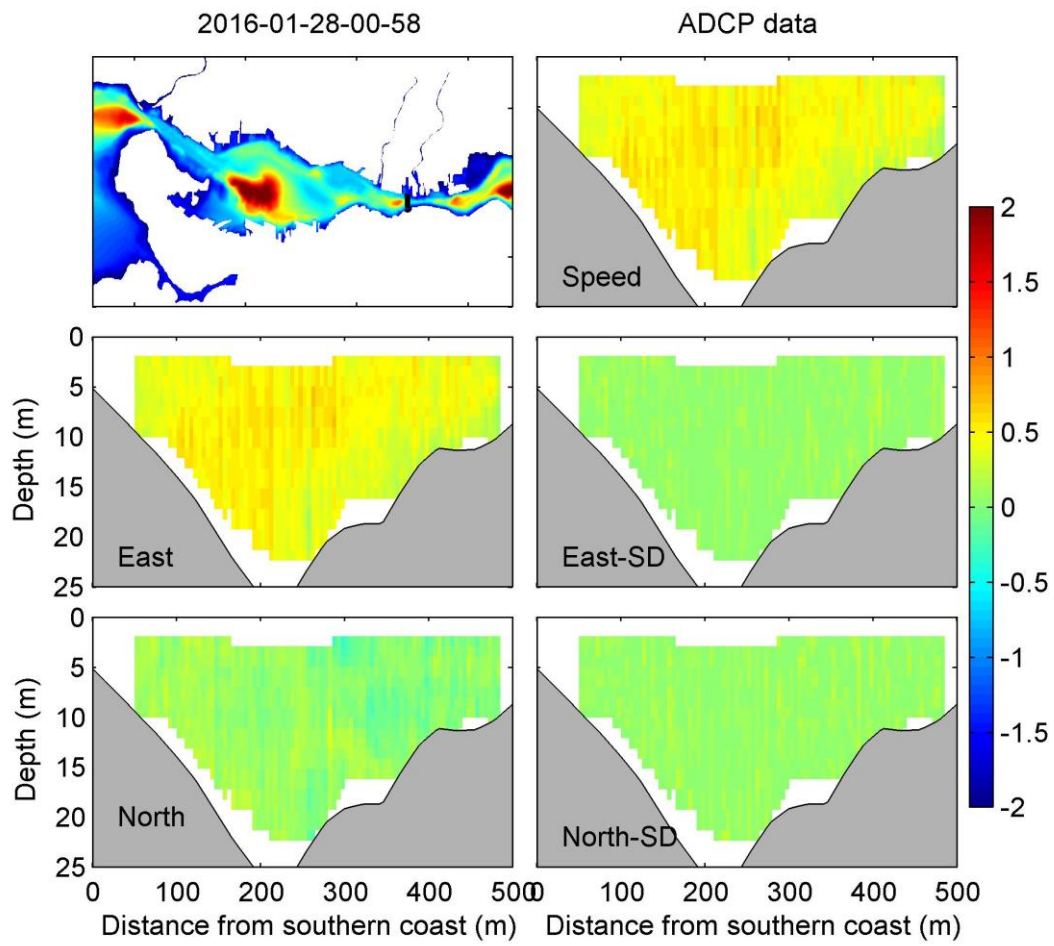


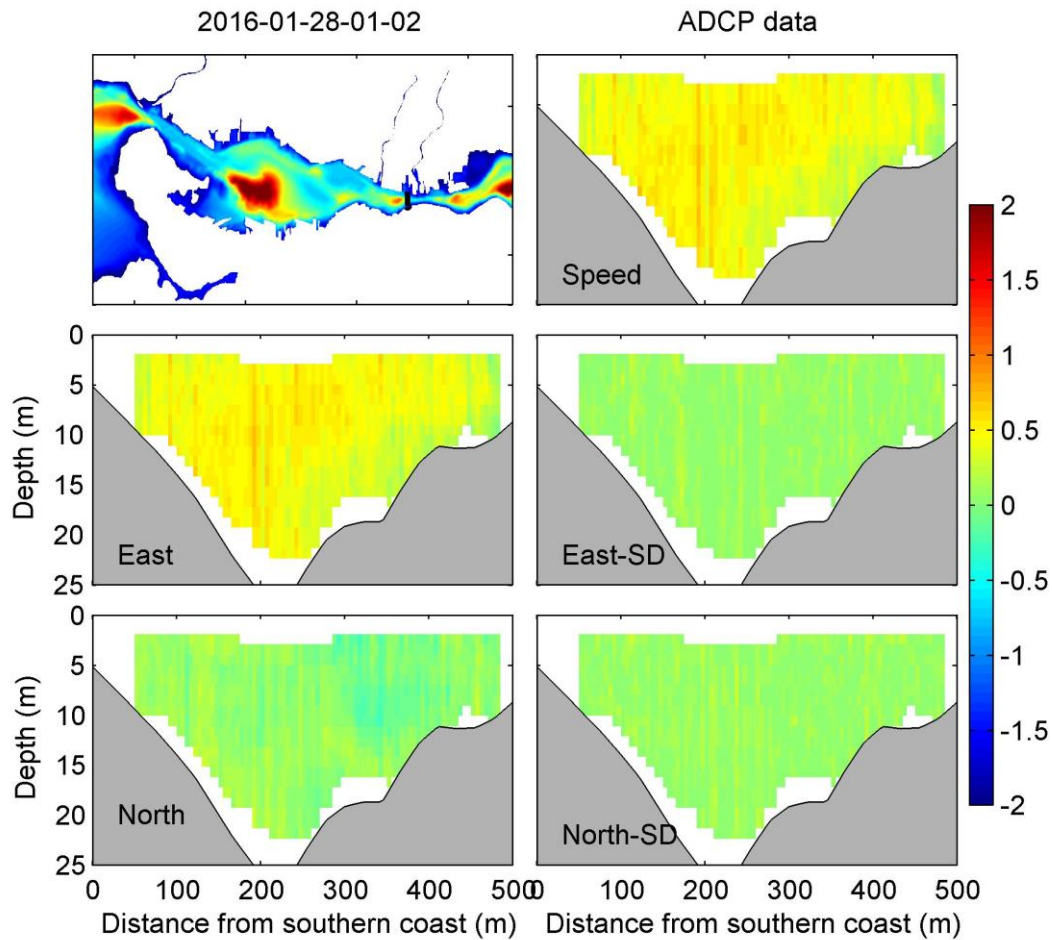






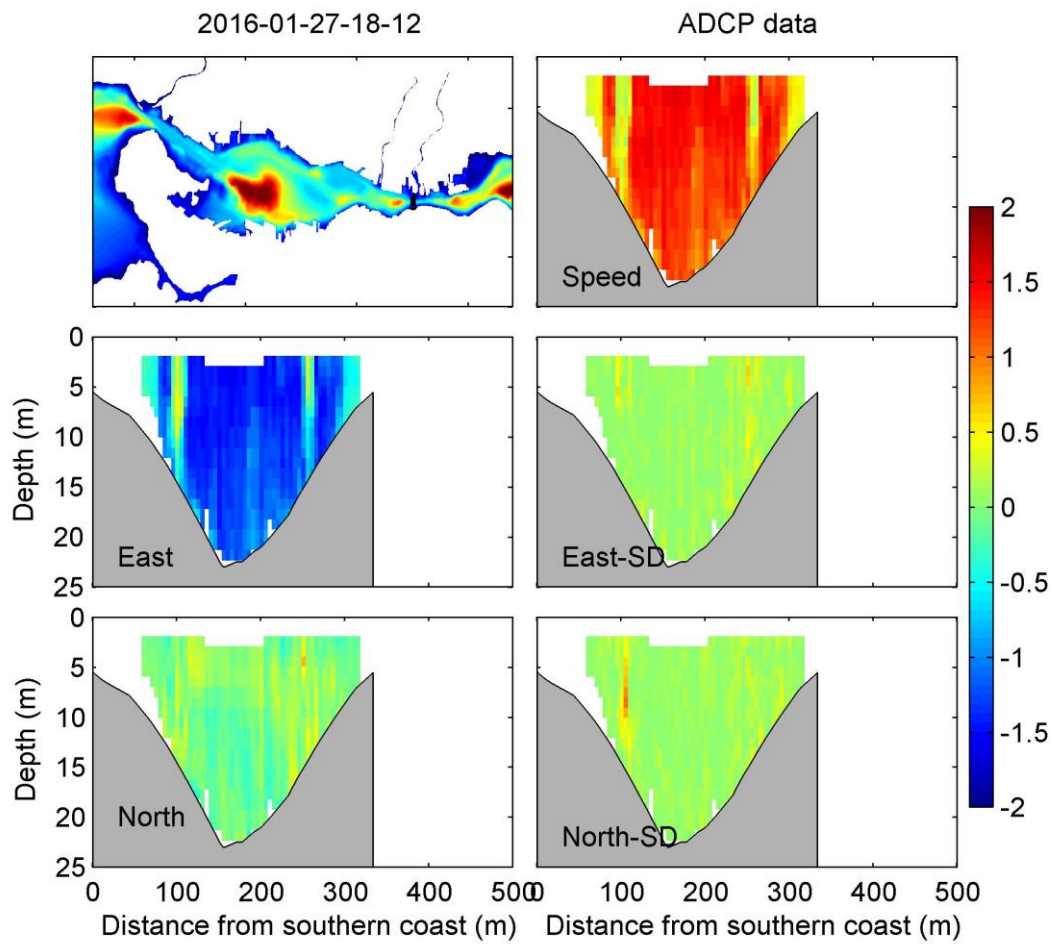


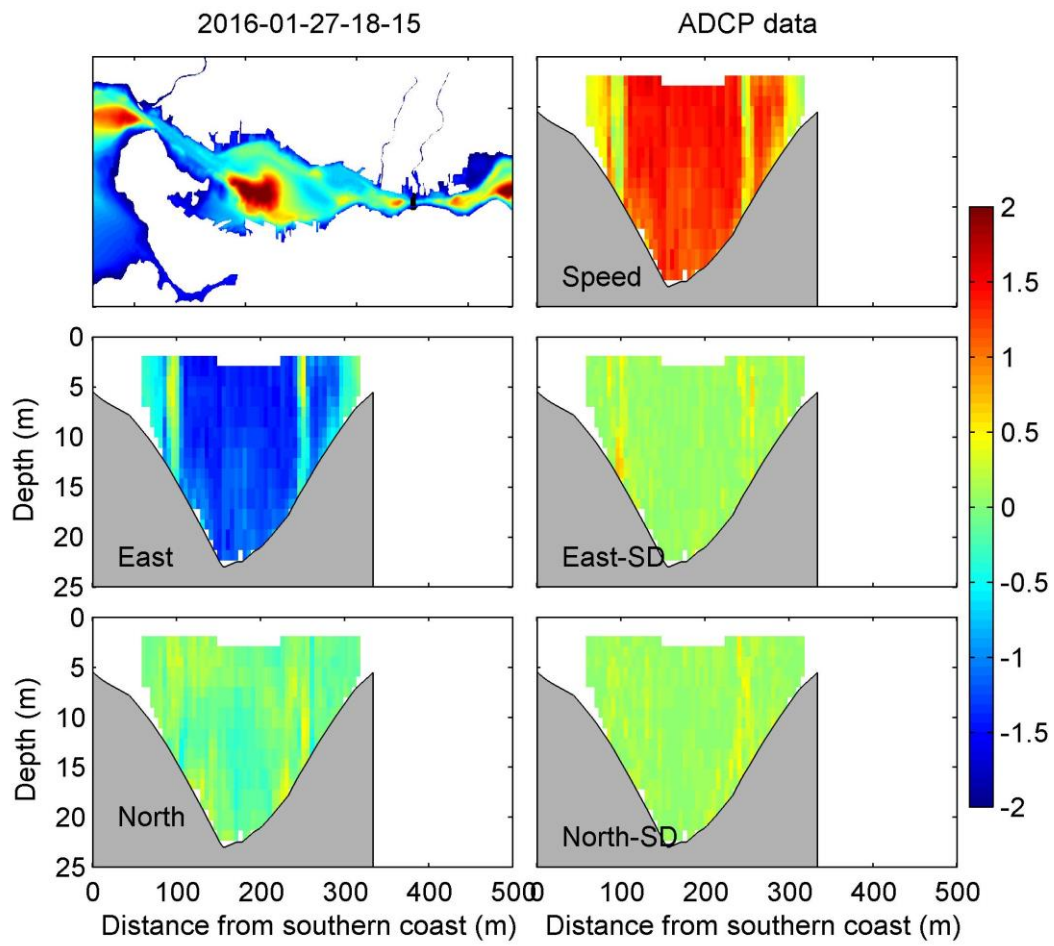


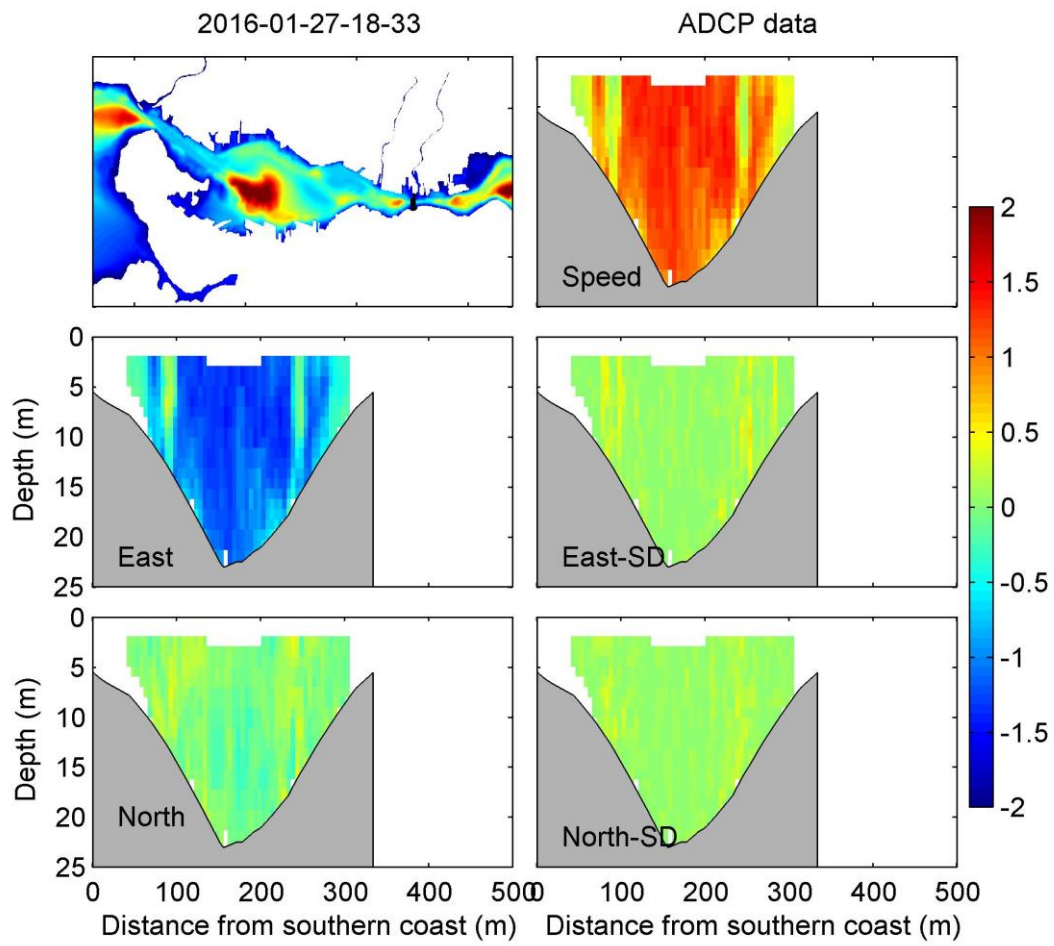


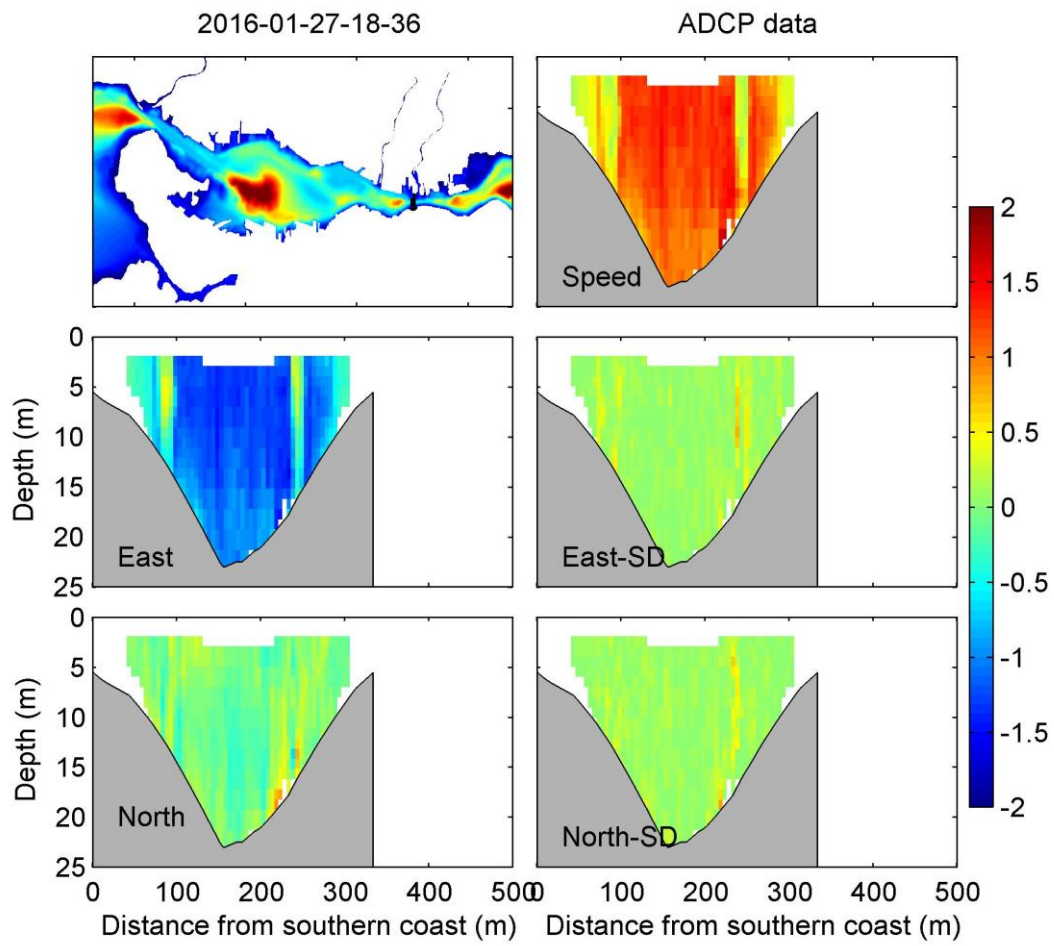
8.2 LINE 2 VELOCITY DATA AND STANDARD DEVIATION

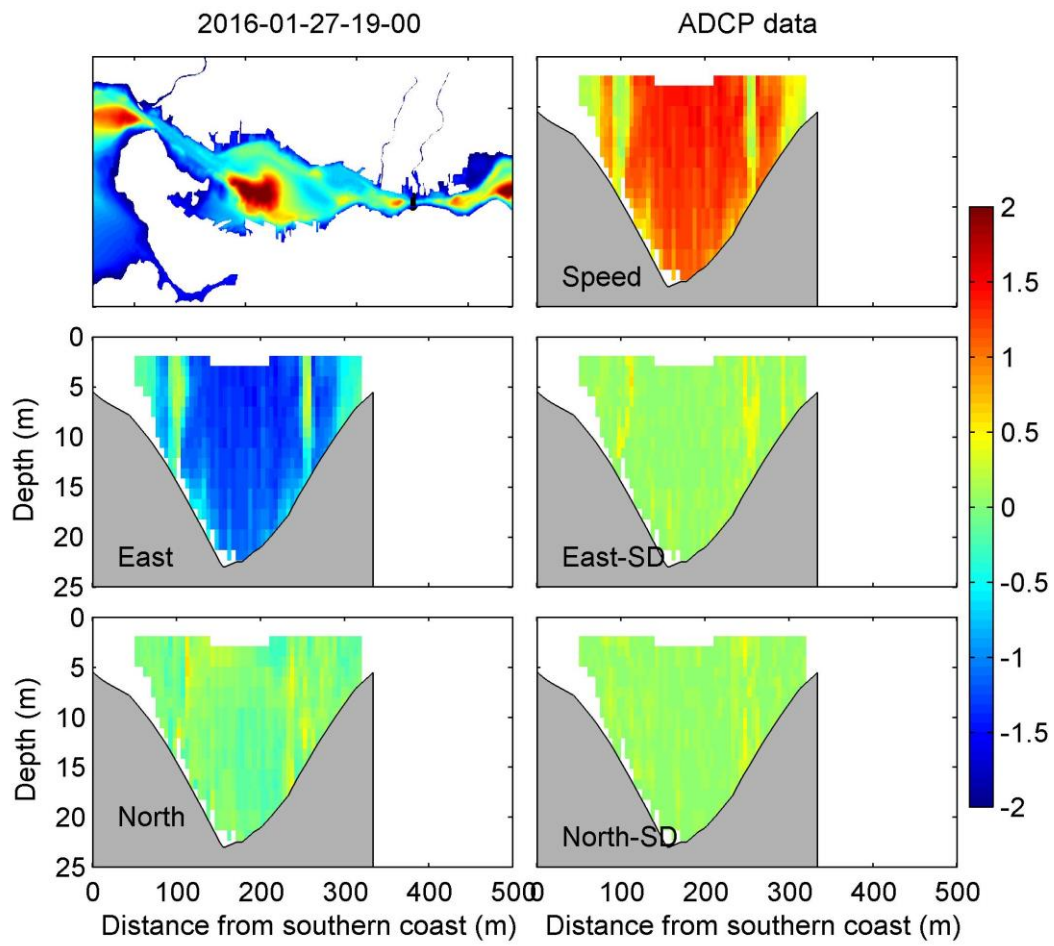
The following figures show vertical profiles of the east and north (u and v) horizontal velocity components for Line 2 measured in Second Narrows. The units are in ms^{-1} . The figures include a map of the bathymetry that shows the position of the transect and the vertical profile of the velocity magnitude in the top row. The vertical profiles of the east and north horizontal velocity components with their standard deviations are in the second and third rows. The time of the sample is stated on the figures and in their associated captions.

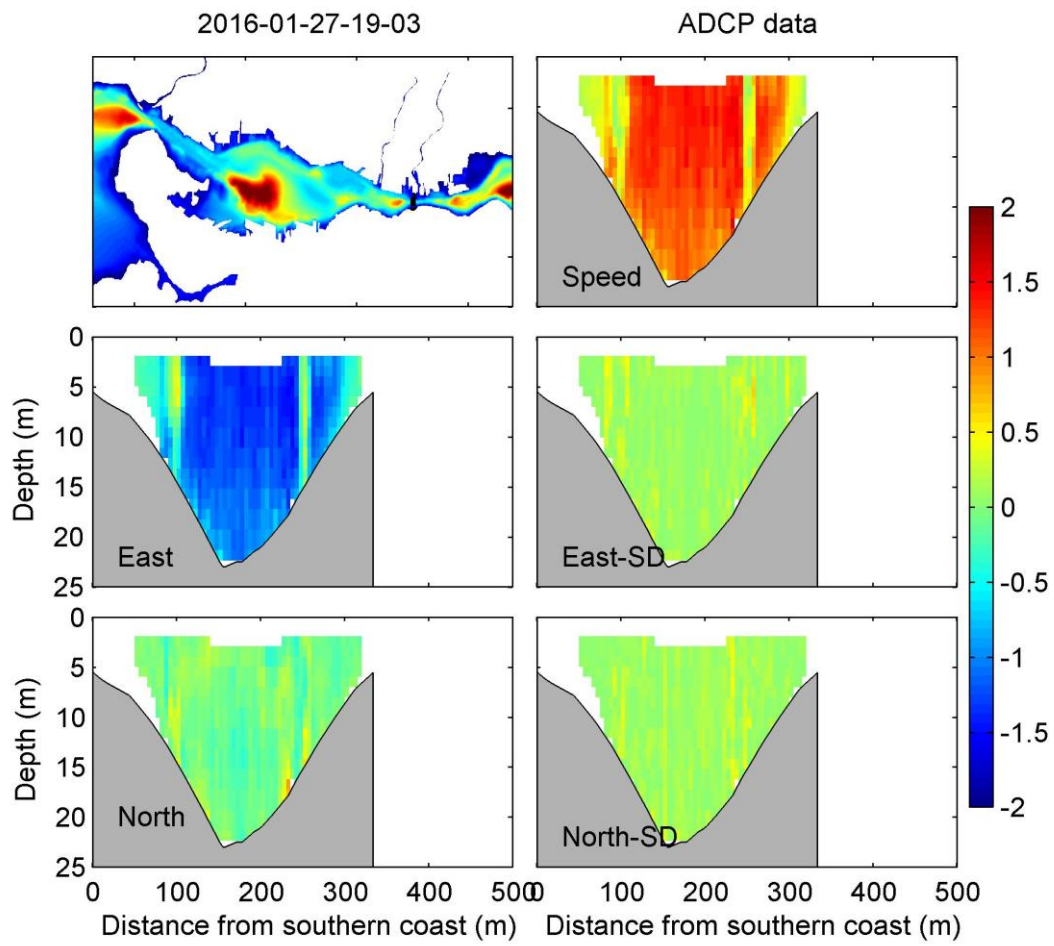


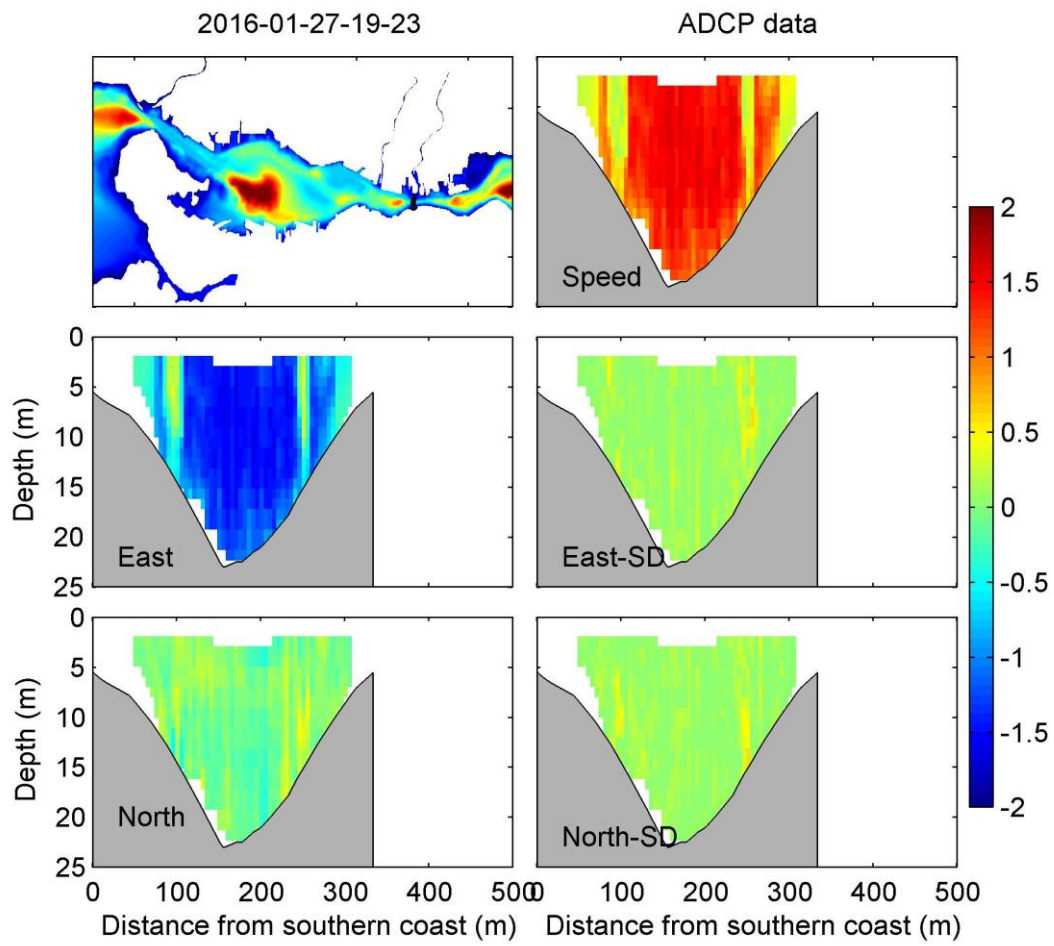


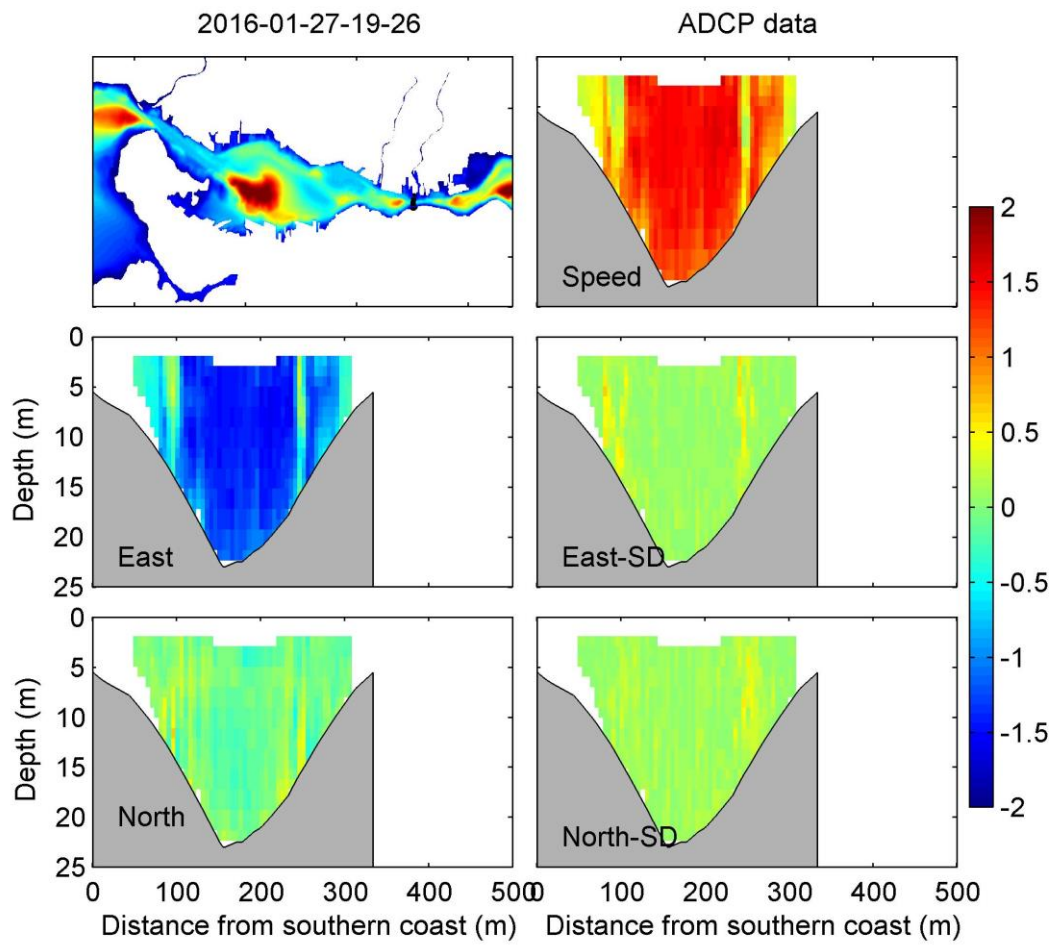


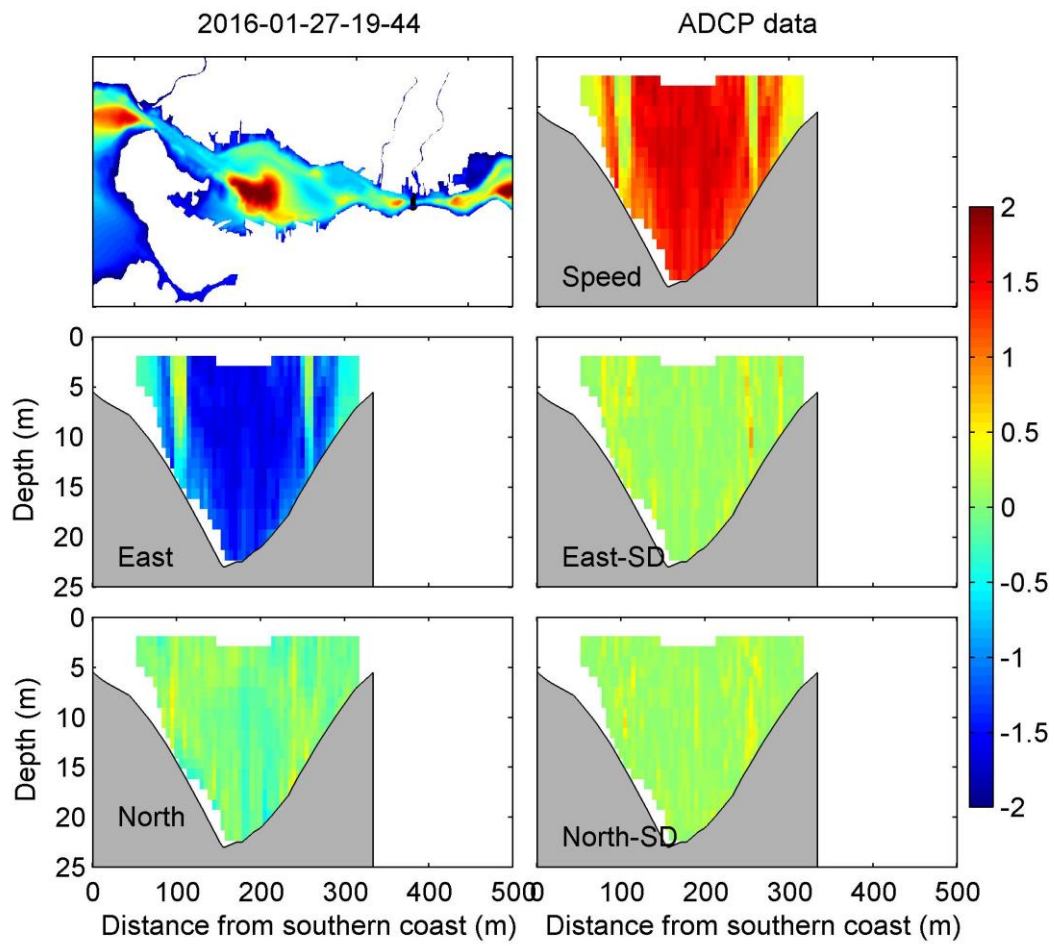


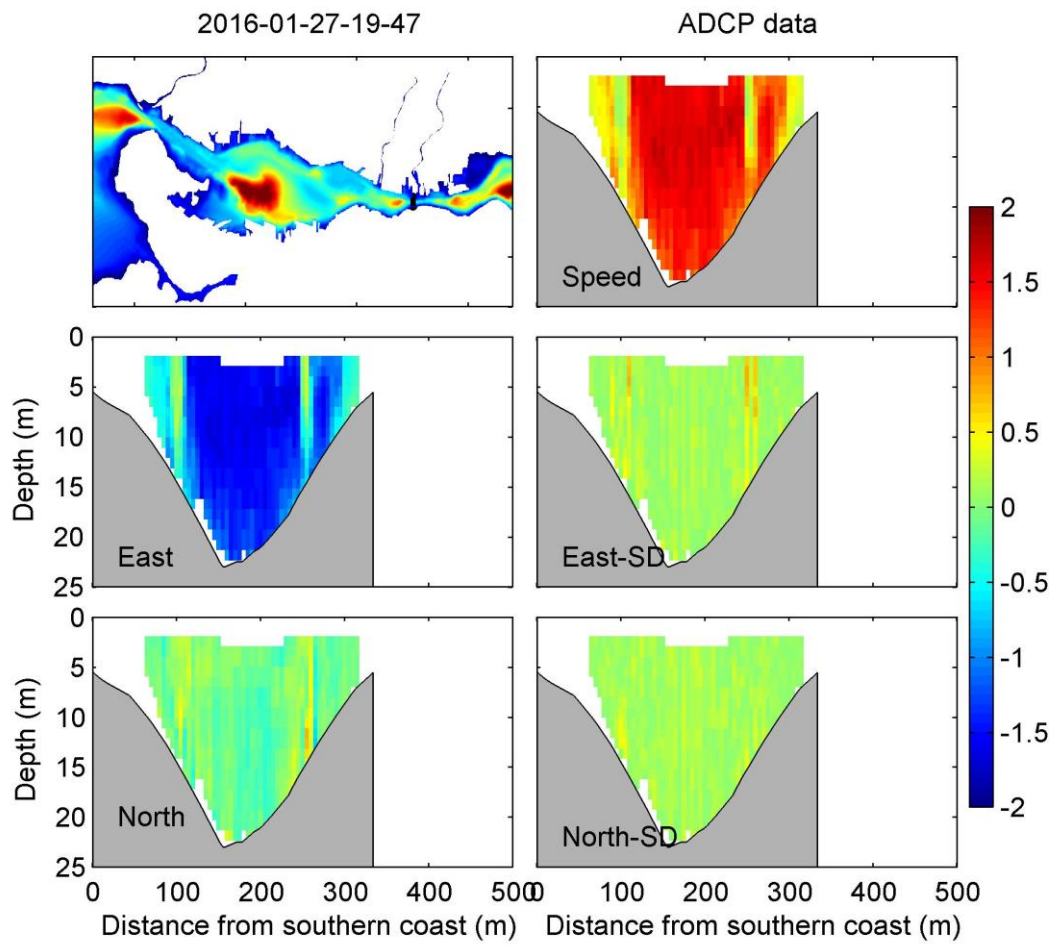


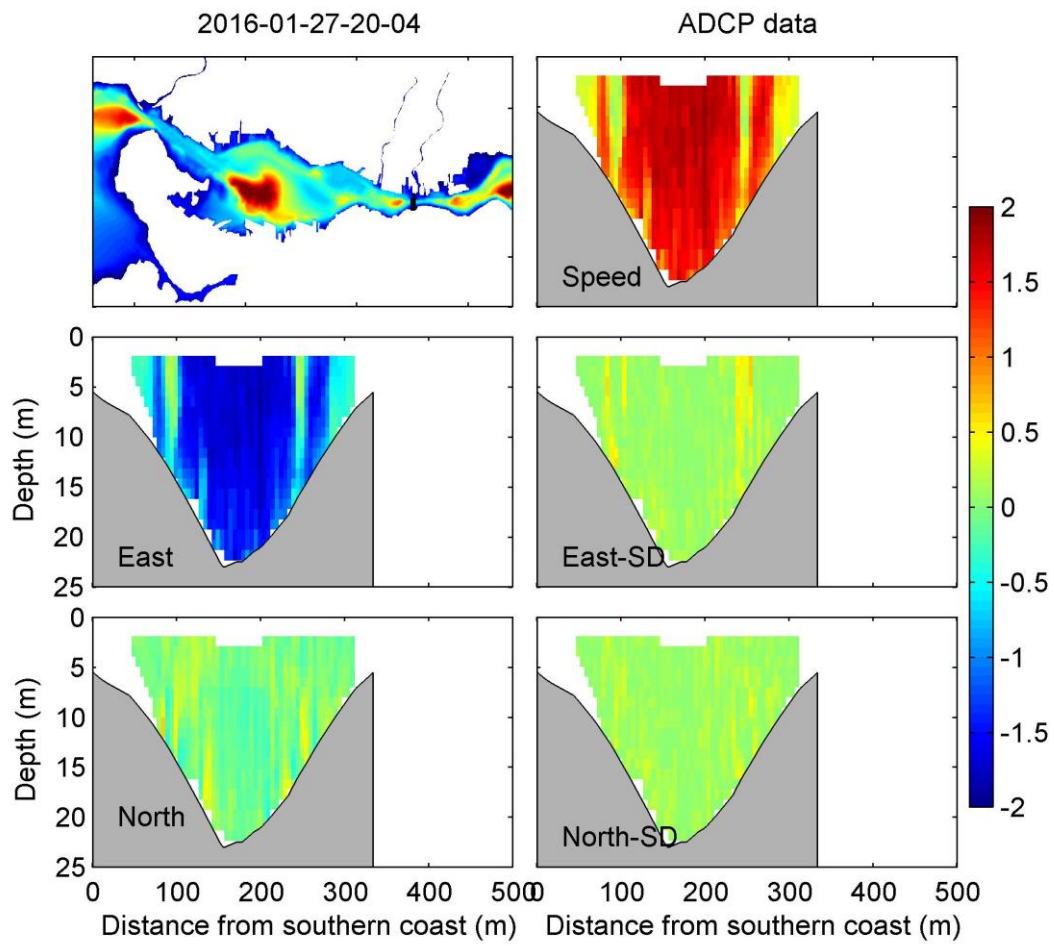


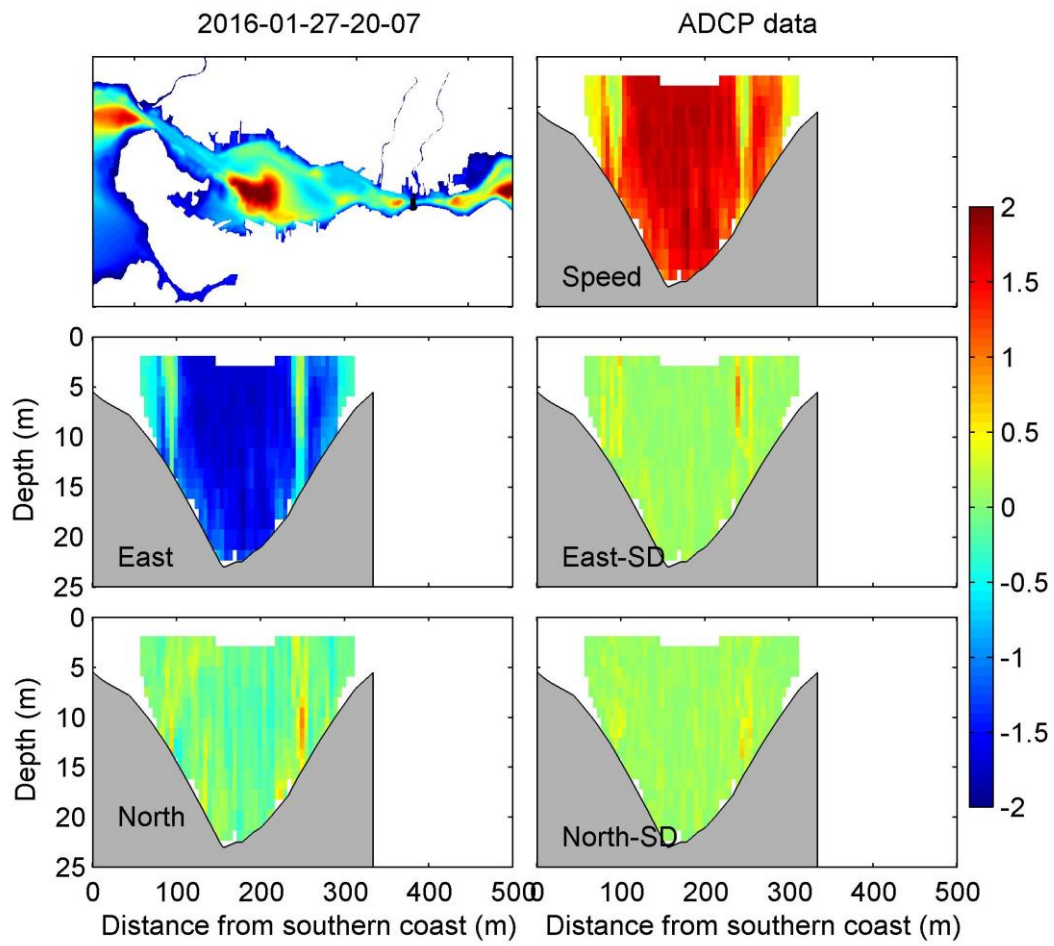


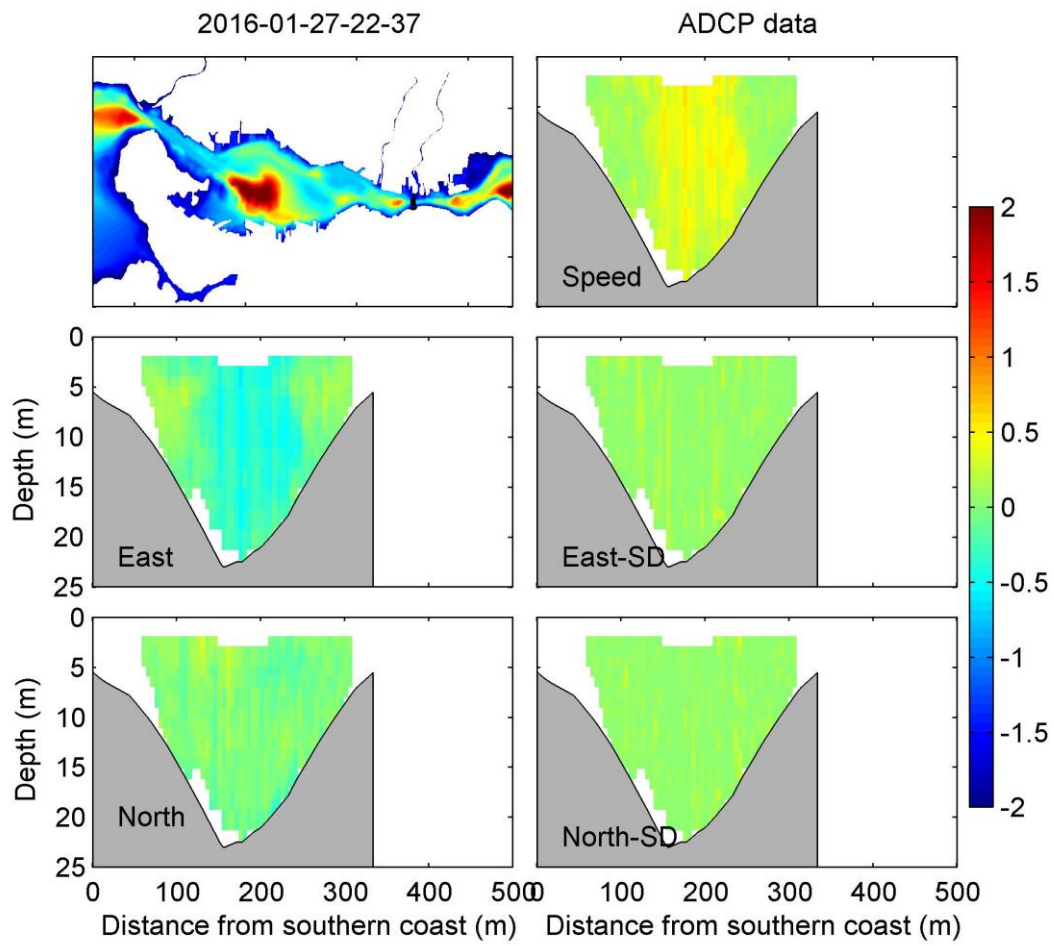


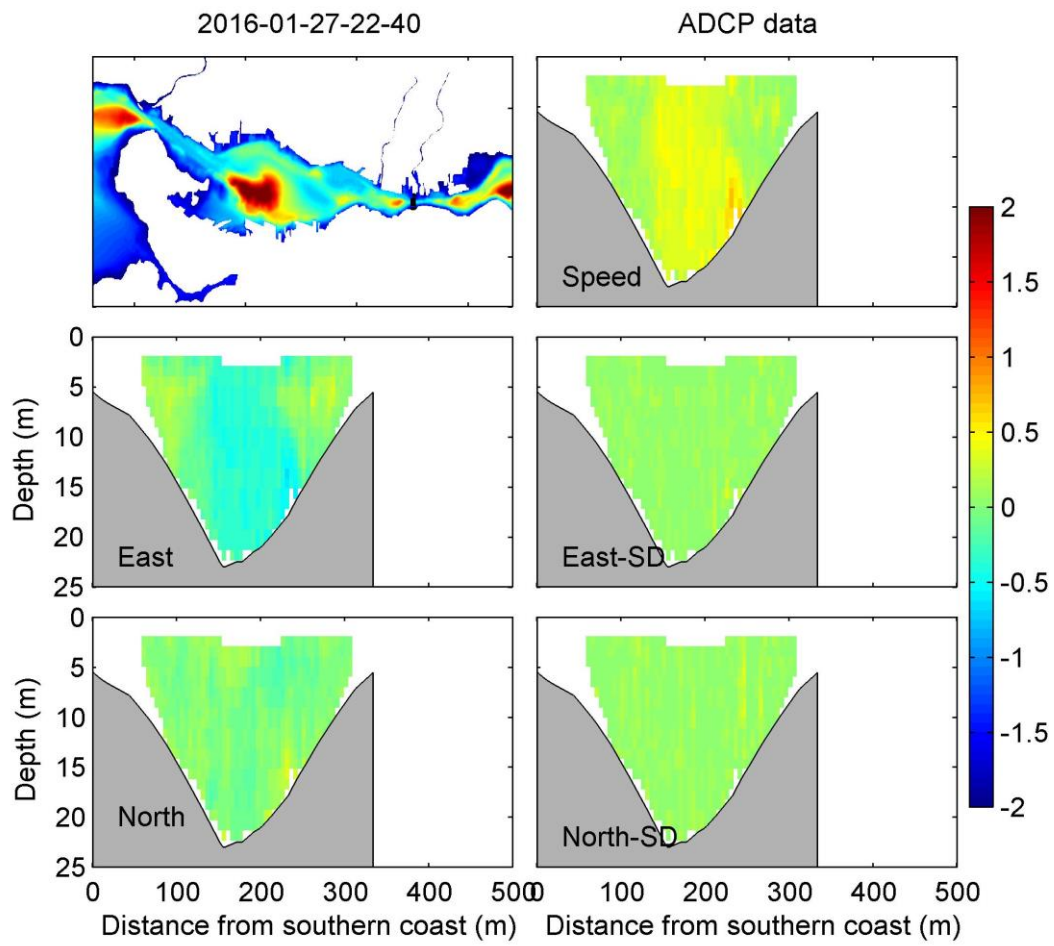


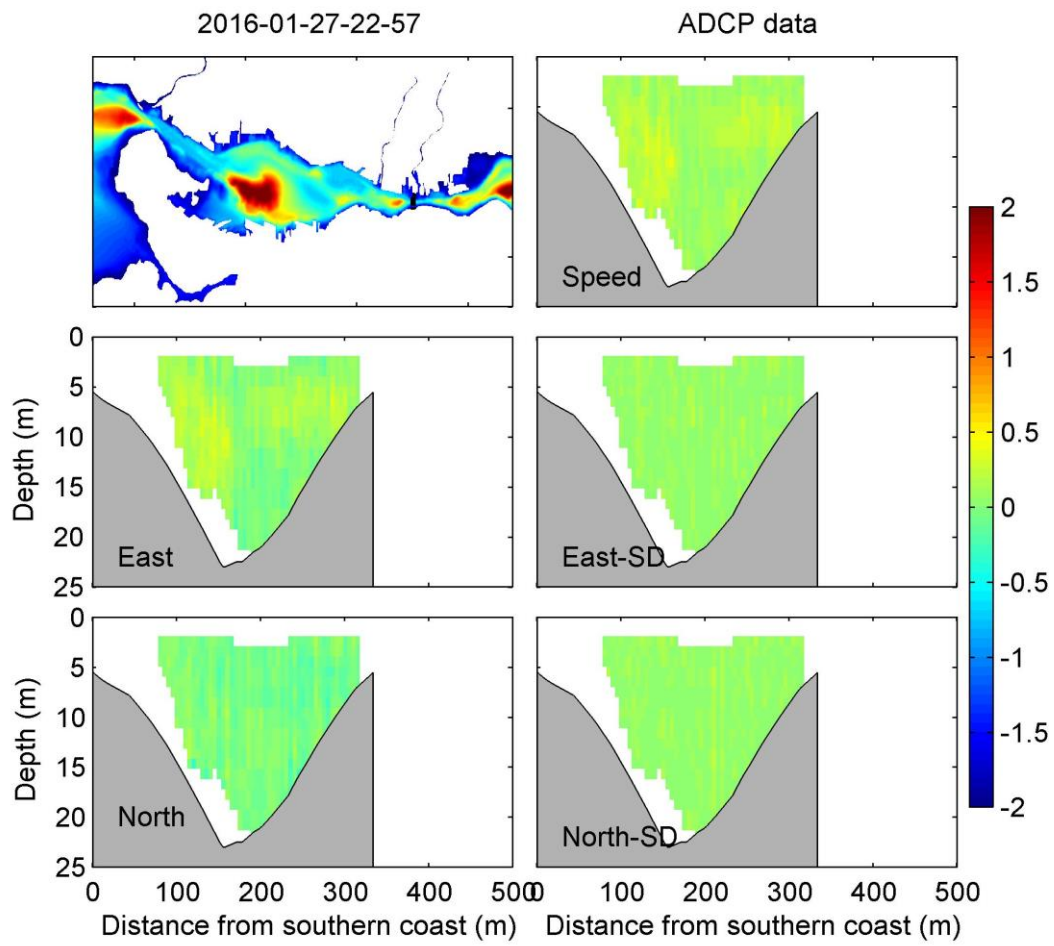


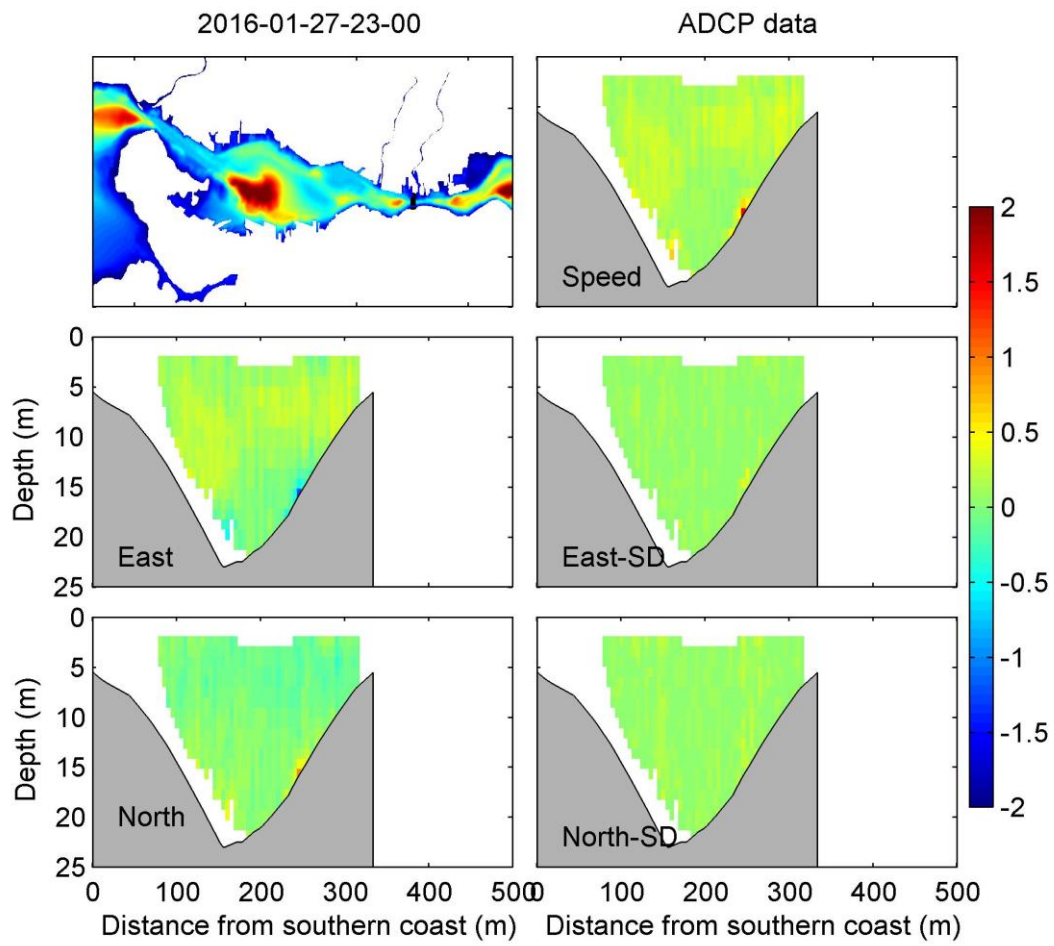


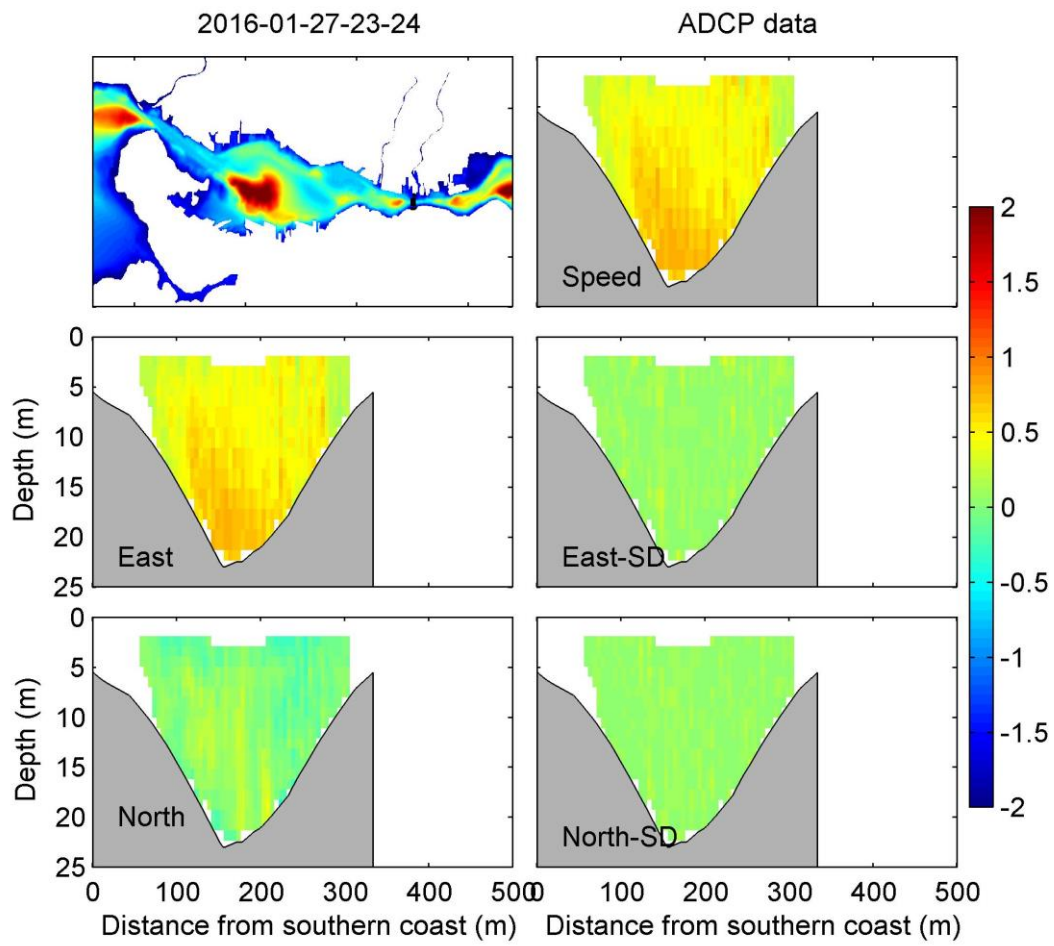


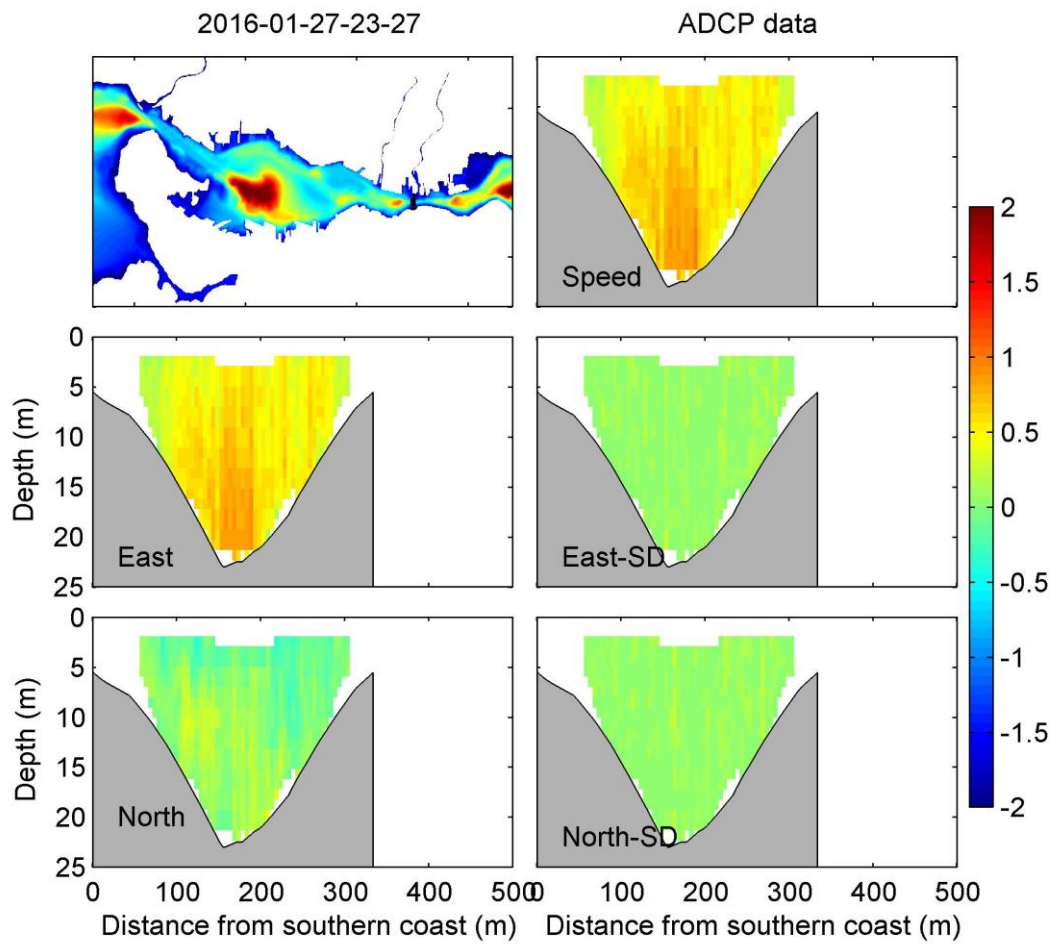


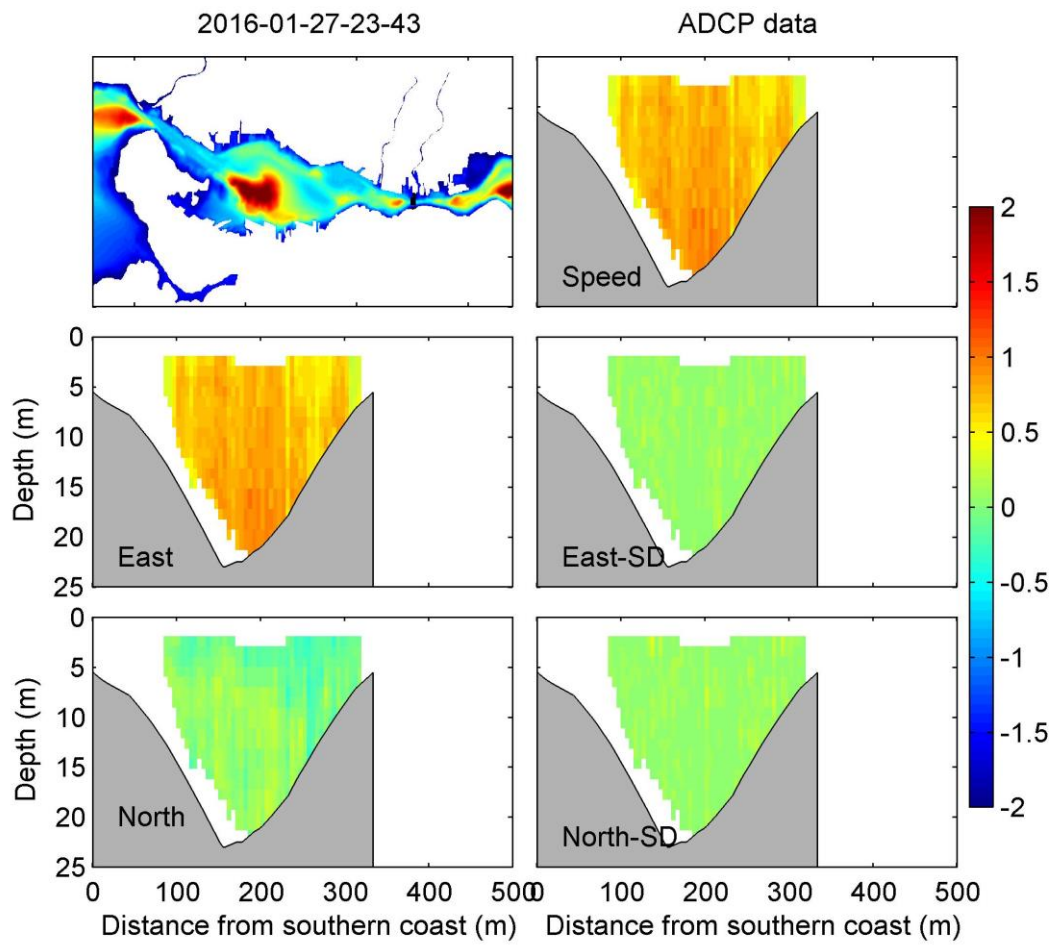


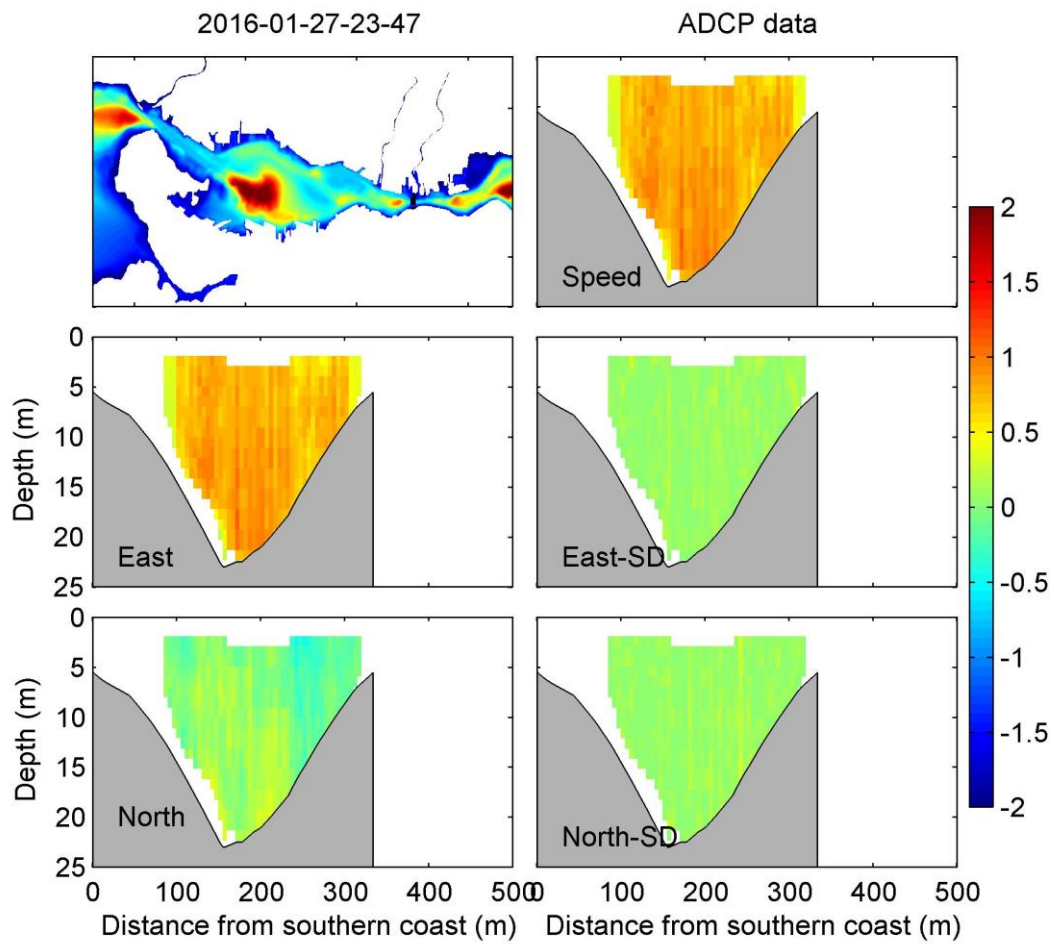


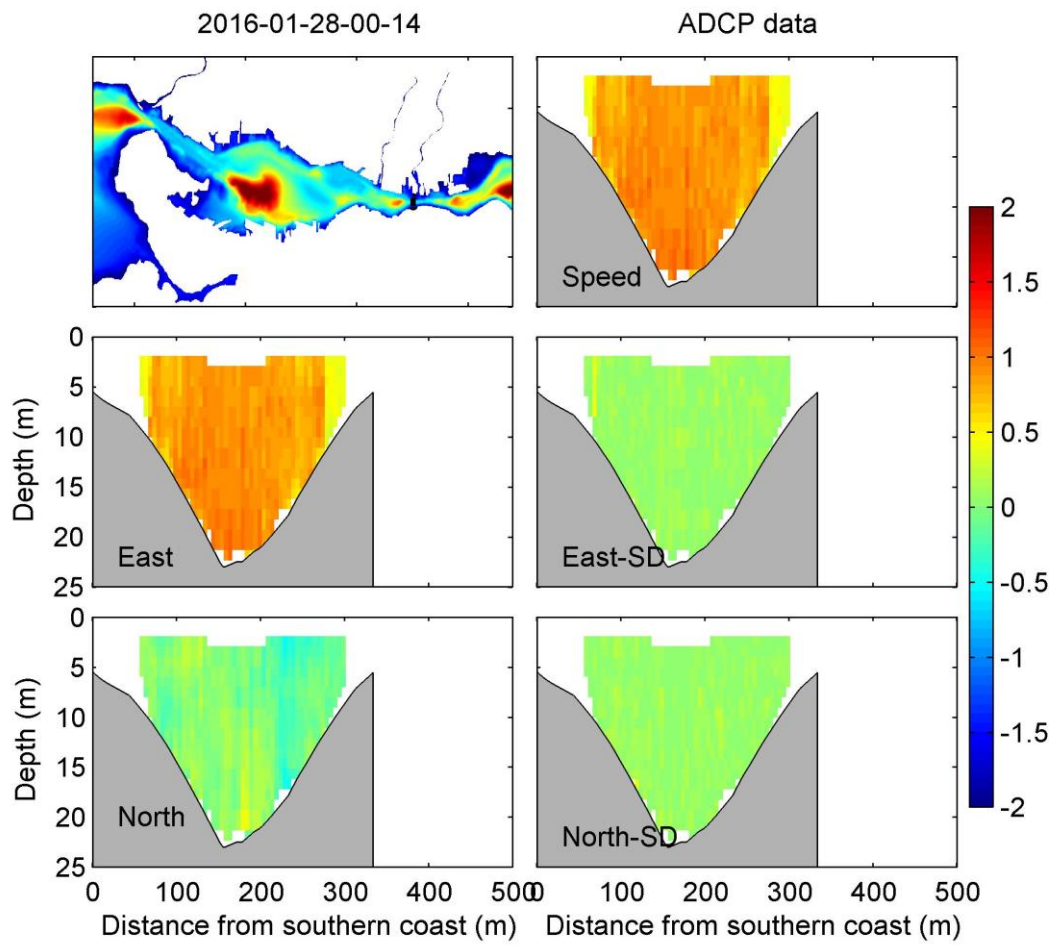


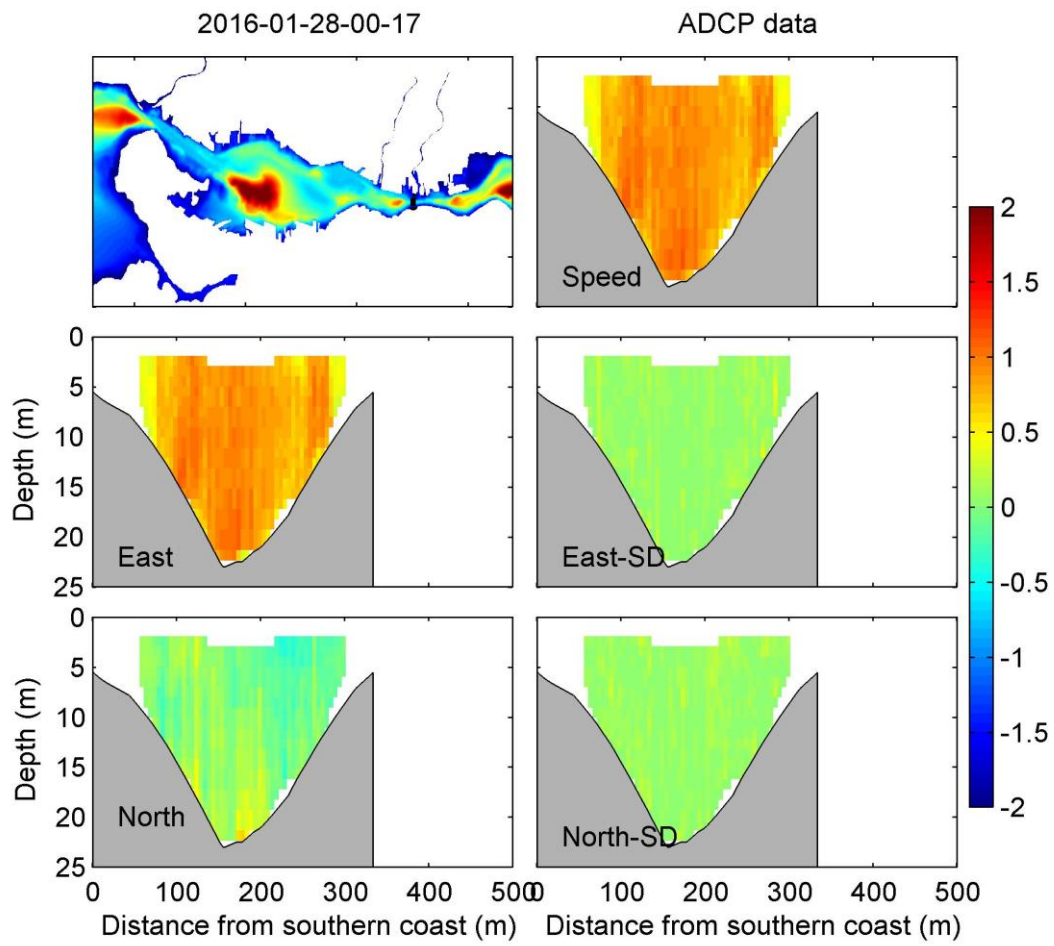


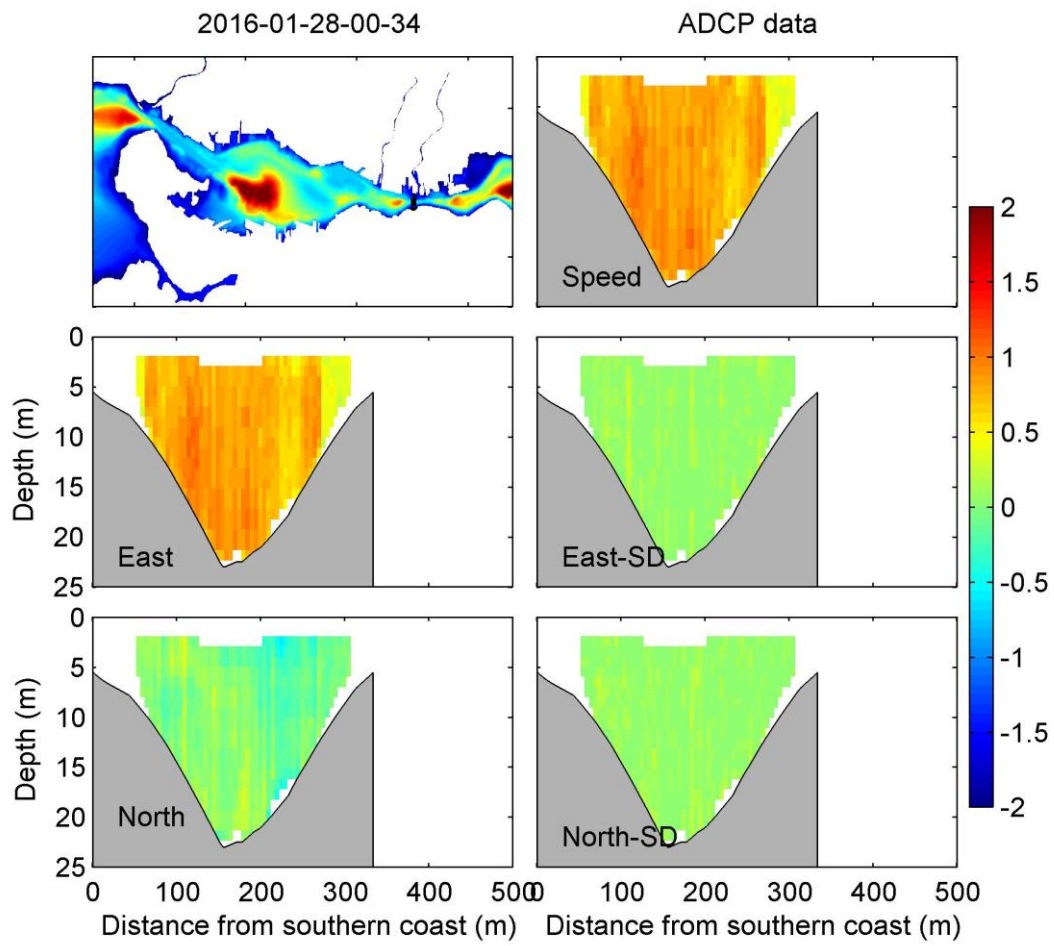


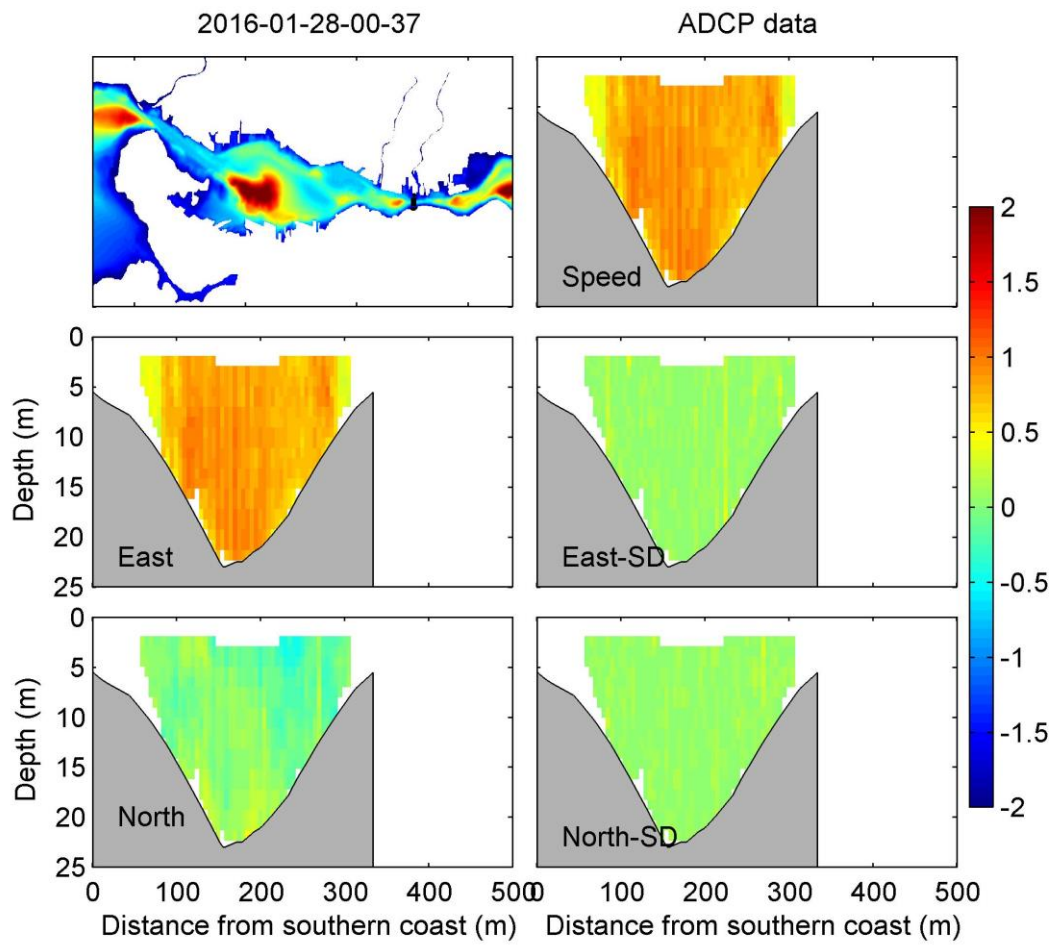


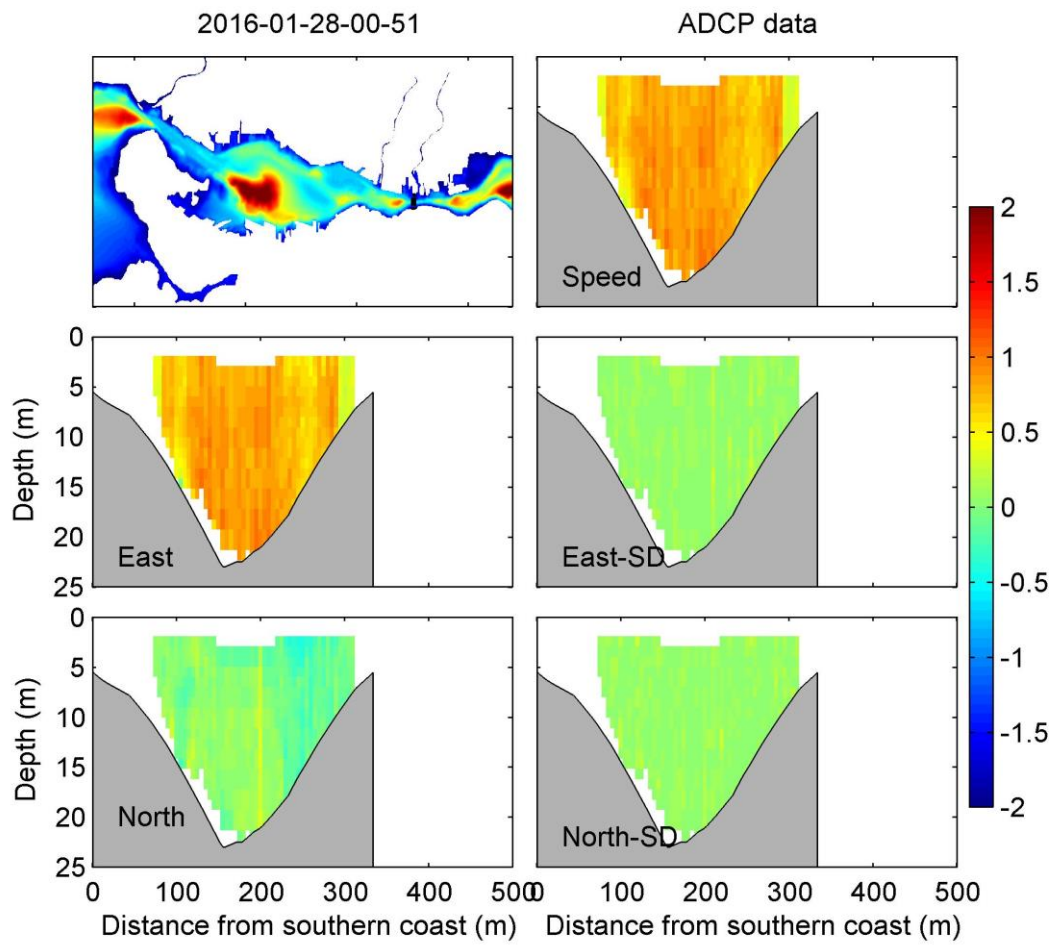


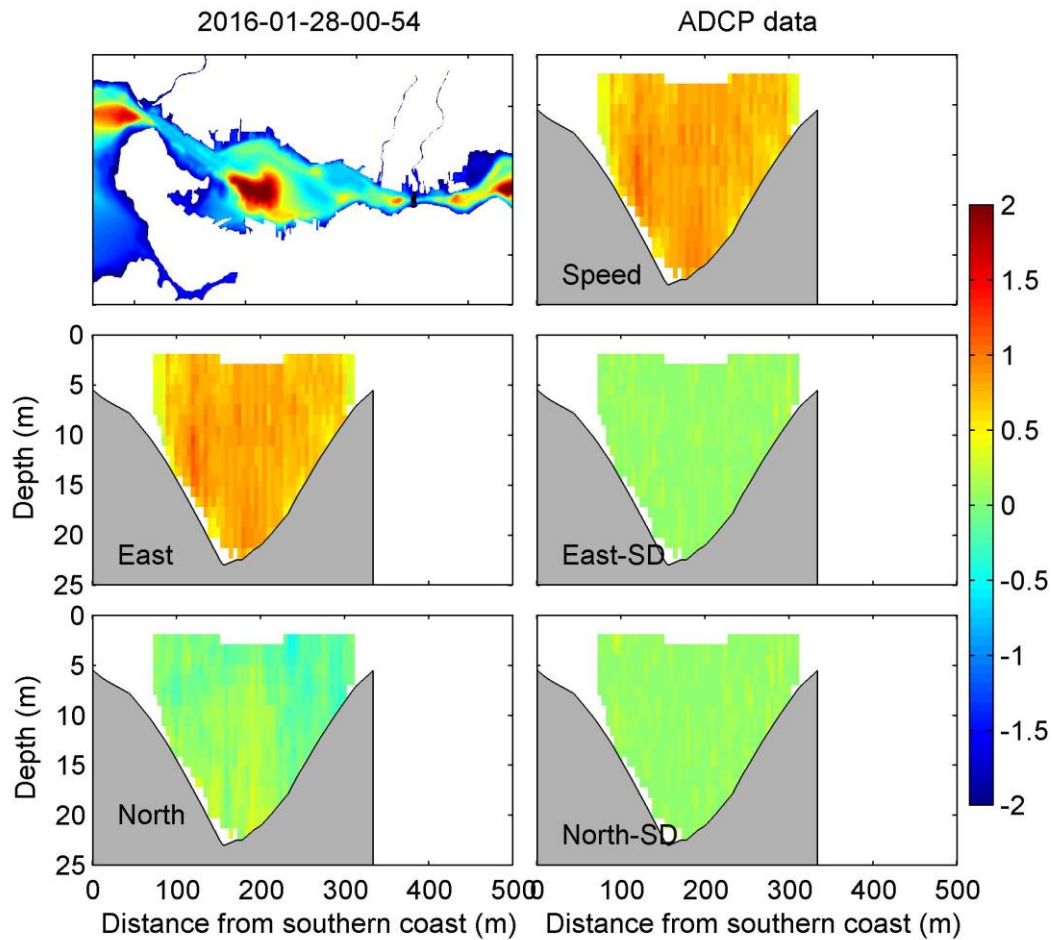






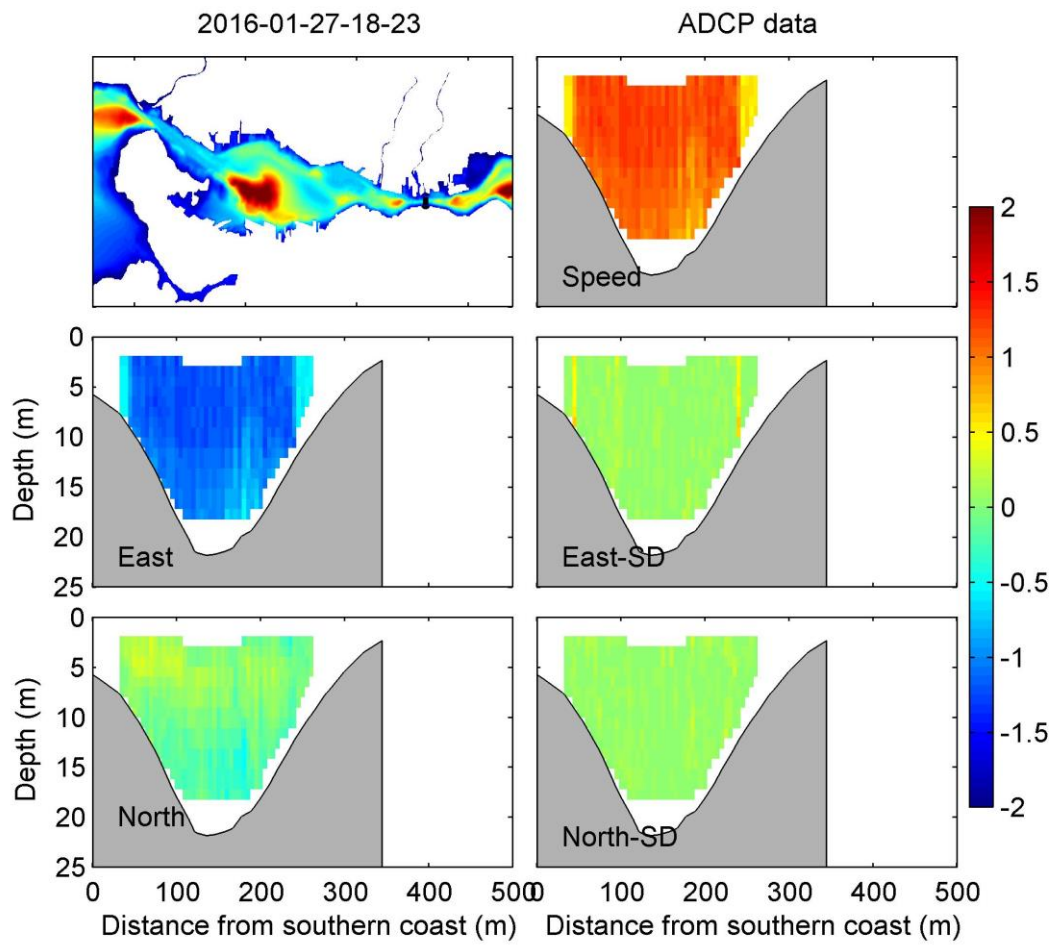


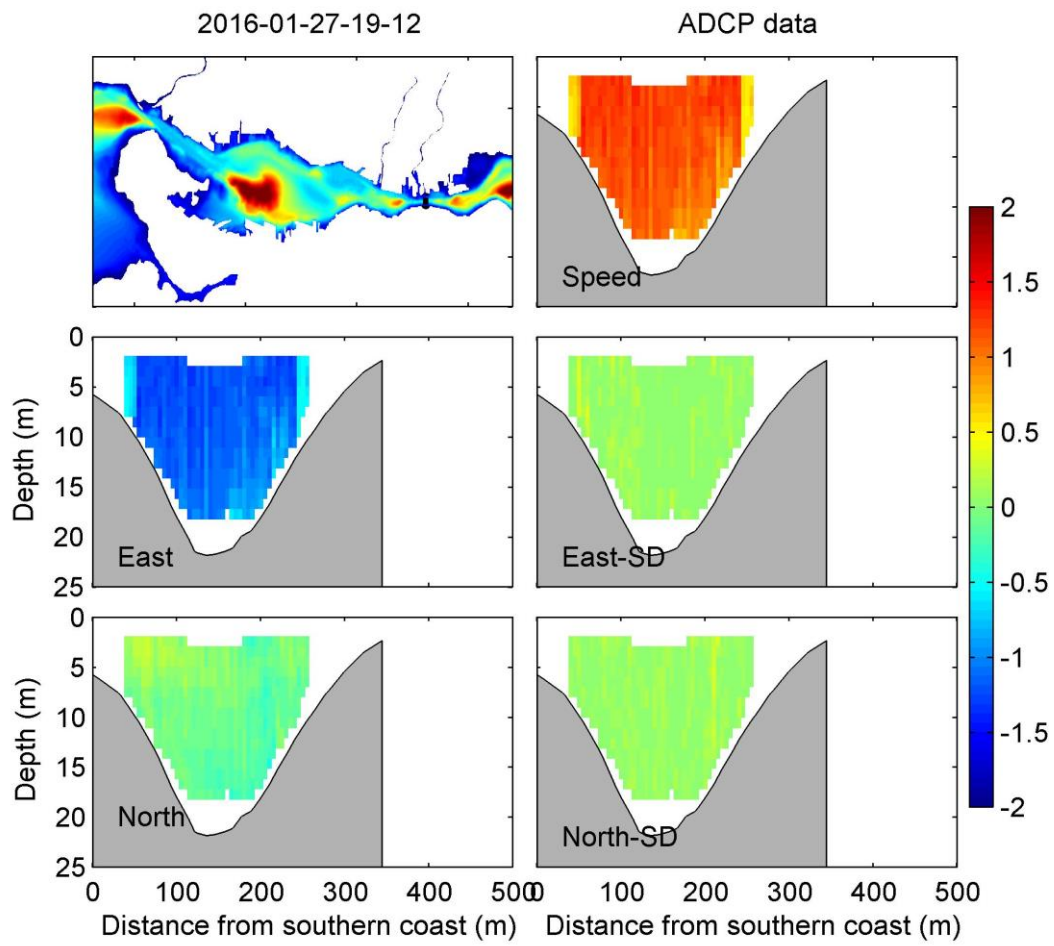


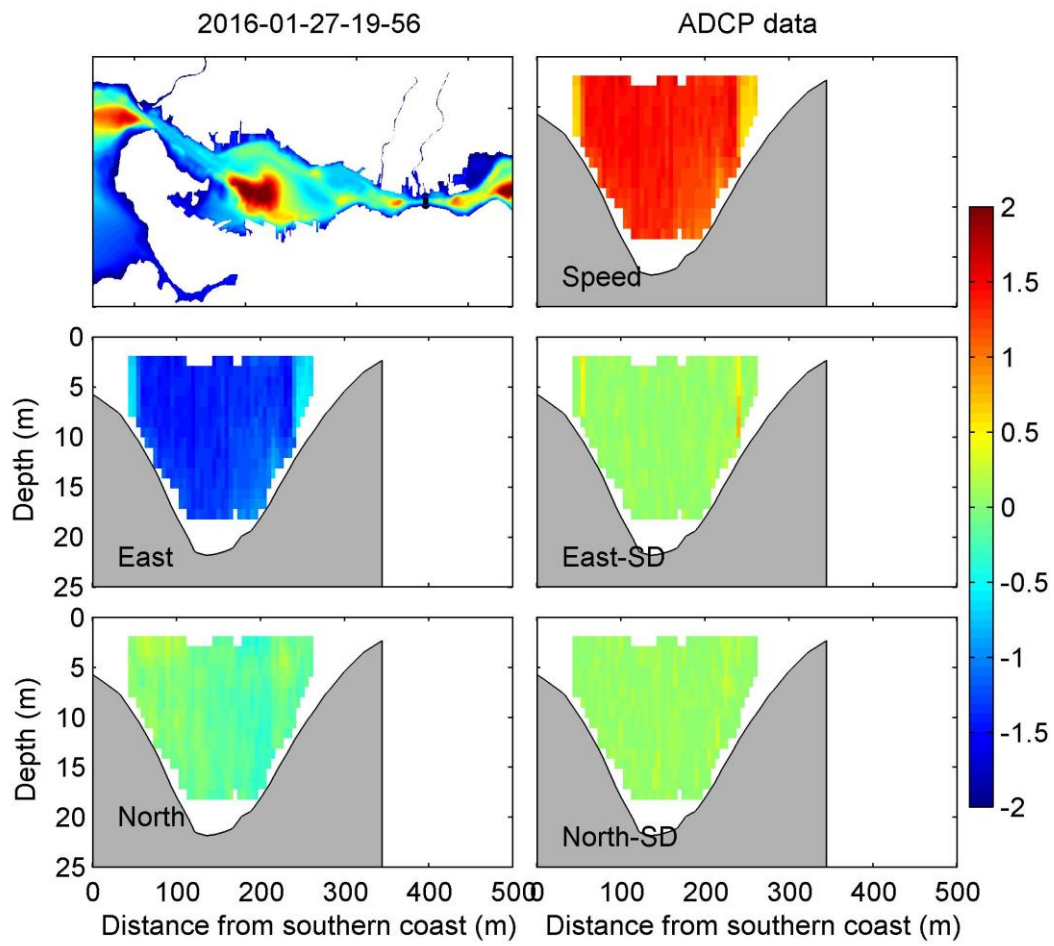


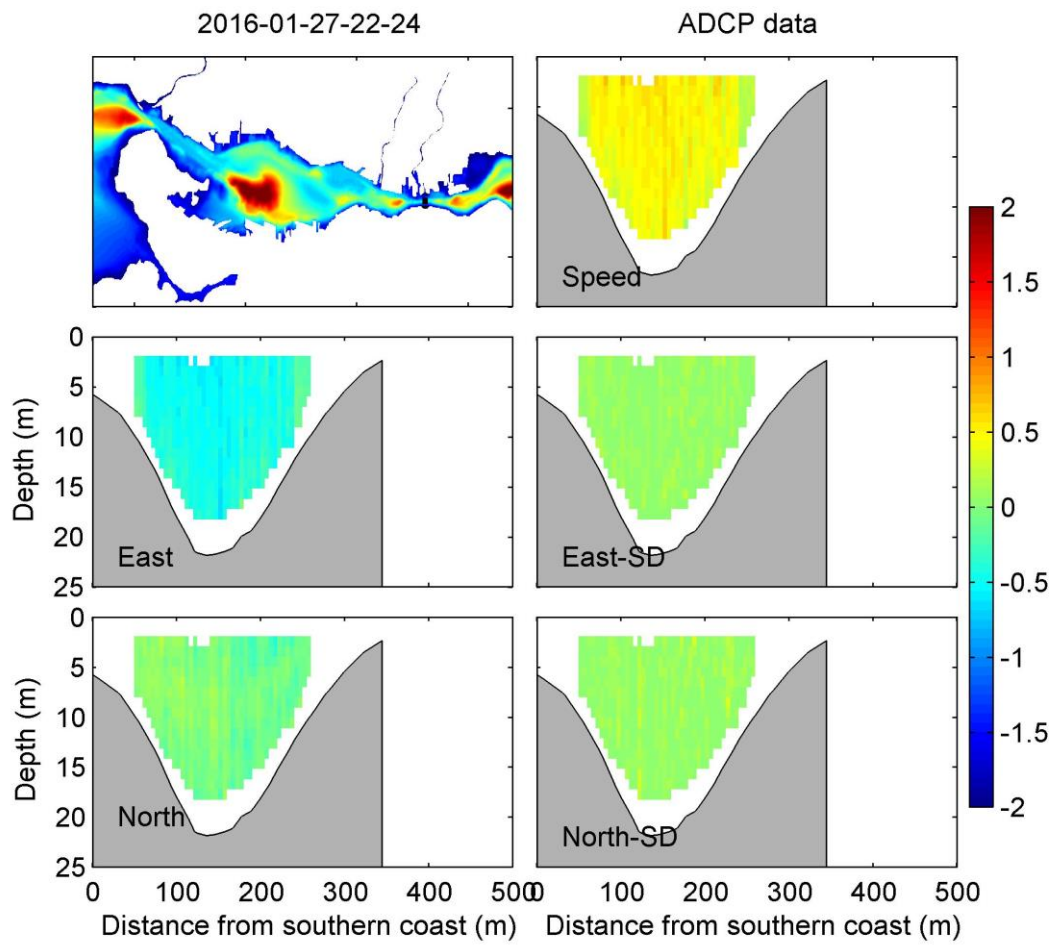
8.3 LINE 3 VELOCITY DATA AND STANDARD DEVIATION

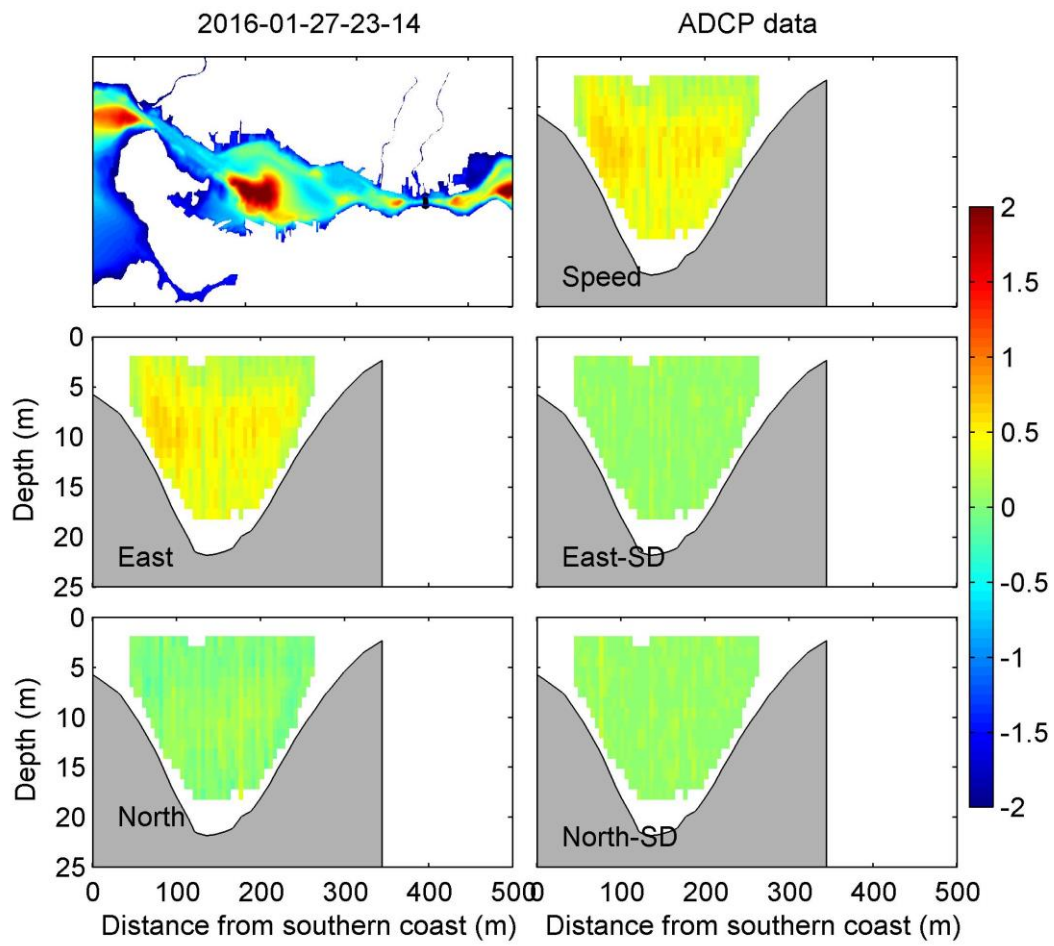
The following figures show vertical profiles of the east and north (u and v) horizontal velocity components for Line 3 measured in Second Narrows. The units are in ms^{-1} . The figures include a map of the bathymetry that shows the position of the transect and the vertical profile of the velocity magnitude in the top row. The vertical profiles of the east and north horizontal velocity components with their standard deviations are in the second and third rows. The time of the sample is stated on the figures and in their associated captions.

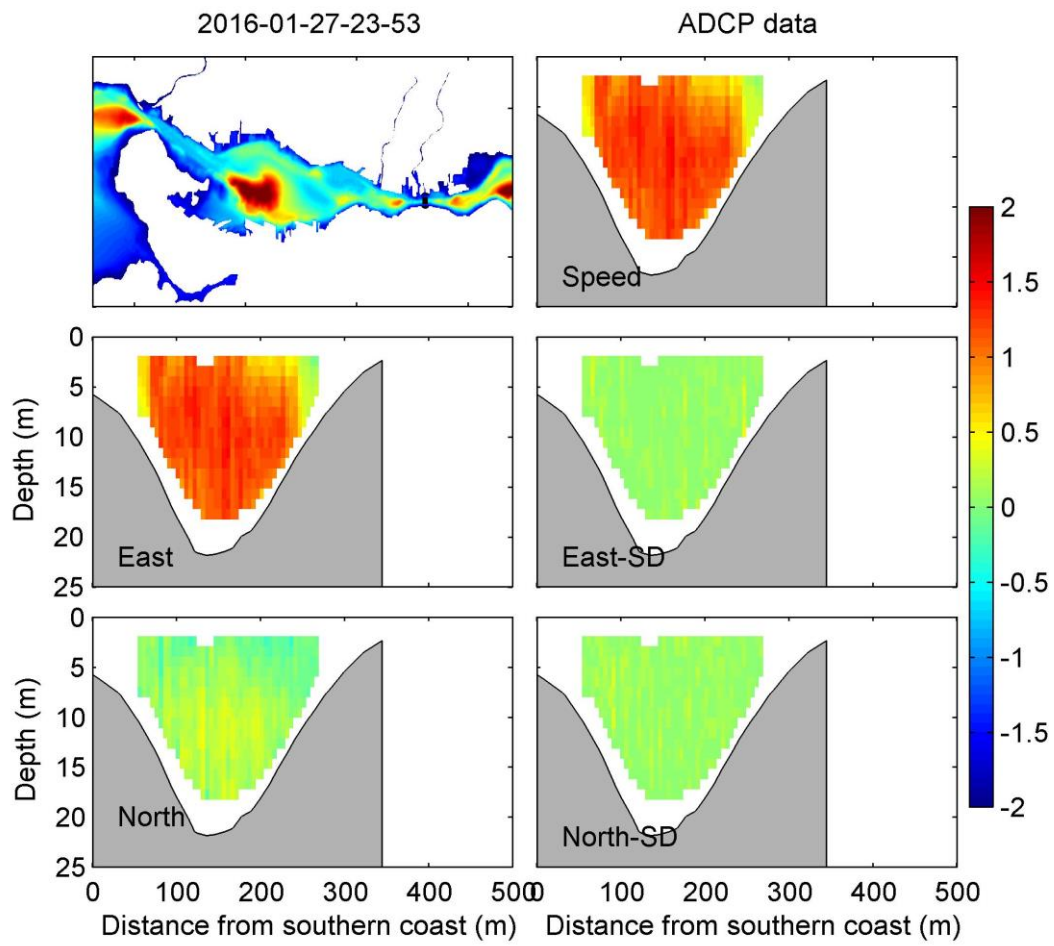


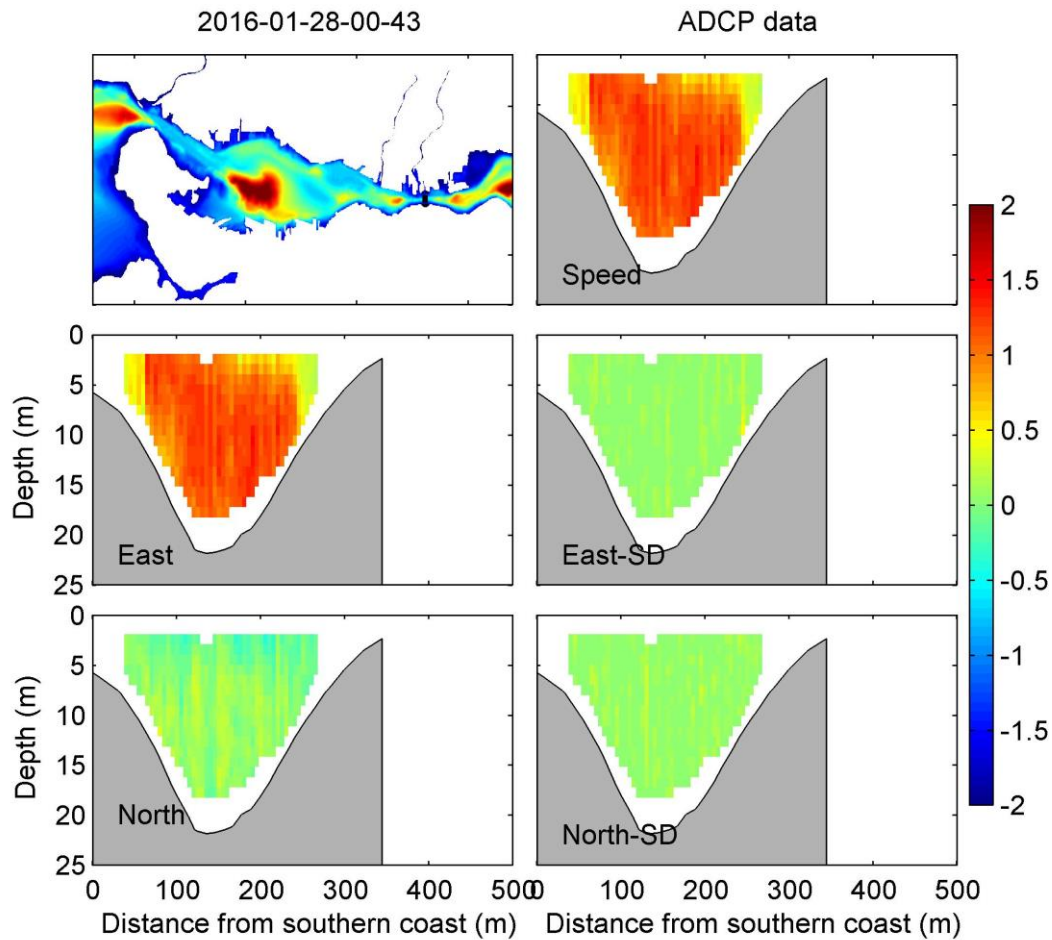






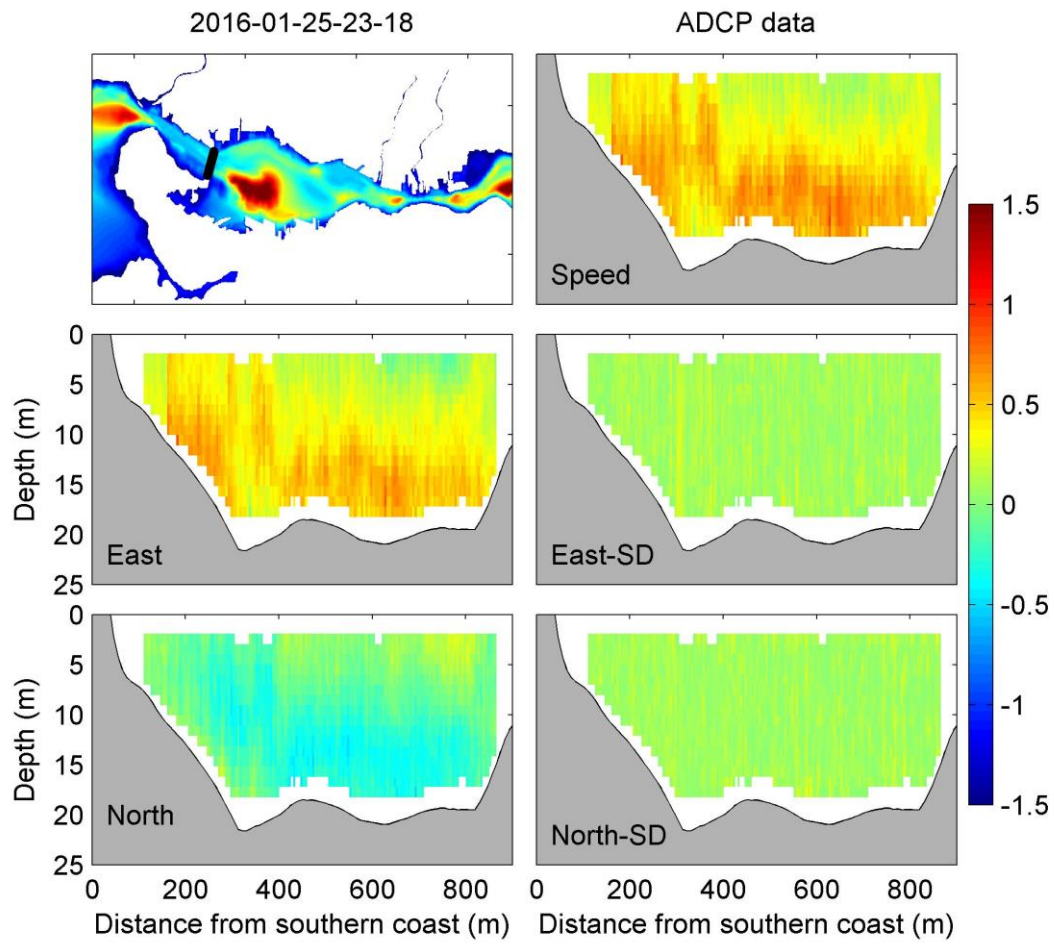


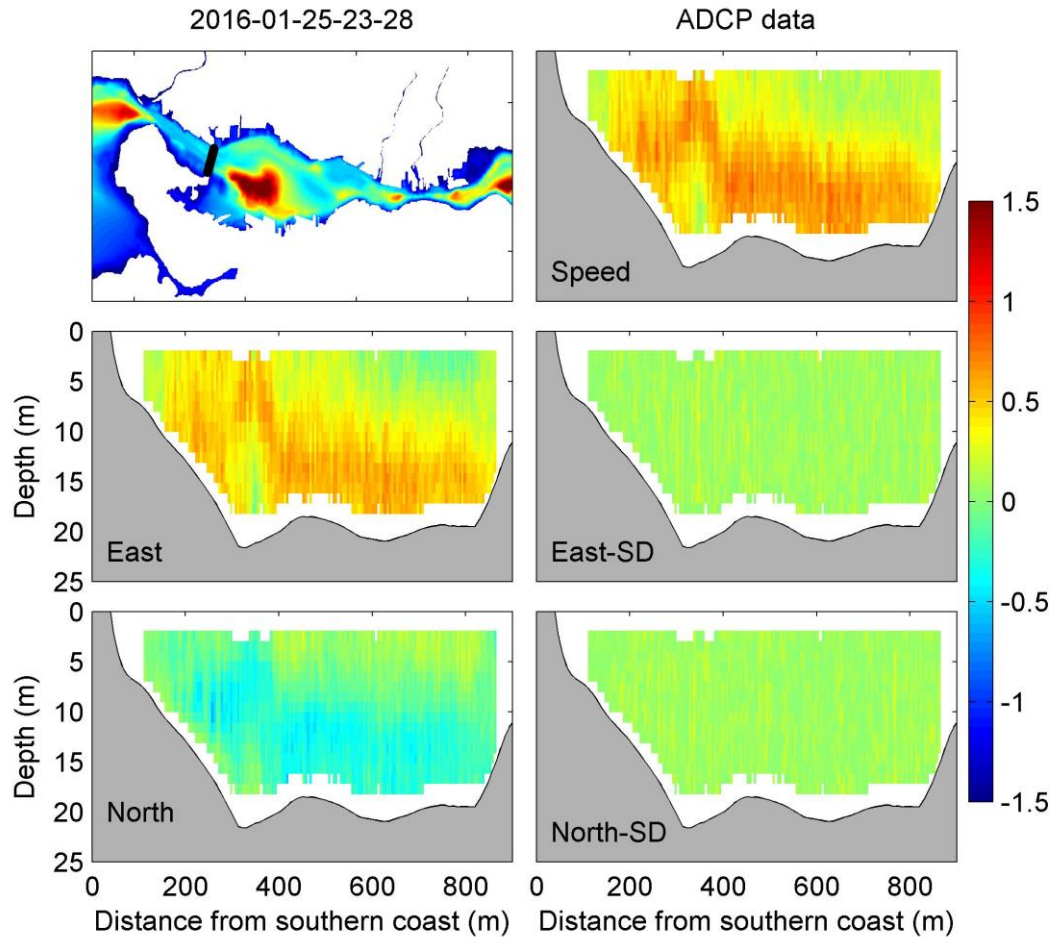




8.4 LINE 4 VELOCITY DATA AND STANDARD DEVIATION

The following figures show vertical profiles of the east and north (u and v) horizontal velocity components for Line 4 measured in Second Narrows. The units are in ms^{-1} . The figures include a map of the bathymetry that shows the position of the transect and the vertical profile of the velocity magnitude in the top row. The vertical profiles of the east and north horizontal velocity components with their standard deviations are in the second and third rows. The time of the sample is stated on the figures and in their associated captions.





8.5 LINE 5 VELOCITY DATA AND STANDARD DEVIATION

The following figures show vertical profiles of the east and north (u and v) horizontal velocity components for Line 5 measured in Second Narrows. The units are in ms^{-1} . The figures include a map of the bathymetry that shows the position of the transect and the vertical profile of the velocity magnitude in the top row. The vertical profiles of the east and north horizontal velocity components with their standard deviations are in the second and third rows. The time of the sample is stated on the figures and in their associated captions.

