

# Characteristics of coastal currents based on High Frequency radar and ADCP observations in the Strait of Georgia

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**Abstract.** A good understanding of the water body movement in Strait of Georgia is of great importance and significance for a variety of economic and environmental applications. Circulation of surface currents in this region is influenced by a variety of factors such as tide, wind and river discharge. Hourly maps of surface currents are obtained through combining the radial currents from more than two stations. In order to explore performance of High Frequency (HF) CODAR radar system, currents observed by HF radars were compared with ADCP (Acoustic Doppler Current Profile) measurements. Results indicated that surface current data from HF radars generally had similar trend as the ADCP data.

## 1. Introduction

Vancouver is Canada's third largest city and busiest sea port. Since it sits on the east shore of the Strait of Georgia. As such, these local waters are heavily used for commercial transportation, public ferries, commercial fisheries, recreational boating, cruising, and fishing. A good understanding of the water body movement in the region is of great importance and significance for a variety of economic and environmental applications. Ocean Networks Canada (ONC), an initiative of the University of Victoria, operates four high frequency CODAR radars in the Strait of Georgia by March, 2017. It is the first time that synoptic patterns of surface flows are monitored over a large domain in fine temporal and spatial resolution for Strait of Georgia (SOG). In this paper, analysis of surface currents' characteristics was undertaken based on High Frequency radar data and ADCP data.

Structure of this paper is outlined as follows. Section 2 presents the introduction of the study region the Strait of Georgia. Ocean current observation from radars and ADCP are presented in Section 3, followed by detailed validation of ocean currents between radars and ADCP observations in Section 4. Conclusions are listed in Section 5.

## 2. Study Domain

The study area, Strait of Georgia, is located between Vancouver Island and the mainland coast of British Columbia, Canada. The maximum water depths in Strait of Georgia is more than 400 m in the central/



northern region. To the south, the Strait borders onto the Gulf Islands and San Juan Islands, connecting through Haro and Juan de Fuca straits to the Pacific Ocean. At the far northern end, it connects through Johnstone Strait around the north end of Vancouver Island to the Pacific Ocean. Circulation of surface currents in this region is influenced by tide, wind and river discharge from Fraser River.

### 3. Observational Data

#### 3.1. High Frequency Radar Data

With the development of the electronic communication technology, High-Frequency (HF) radar system has been broadly applied to monitor the water parameters such as currents, wave significant height and wave period in coastal areas due to its advantages: ultra-horizon, wide range, all-weather and low cost. At present, a variety of companies and institutes are developing the radar ocean surface current observation system, such as SWR-503 systems Raytheon Canada Limited (RCL), United States' CODAR (Coastal Ocean Dynamics Applications Radar) SeaSonde radar HF system, WERA (Wellen Radar) by the University of Hamburg in Germany and OSMAR (Ocean State Monitoring and Analyzing Radar) by Wuhan University in China.

Principles of the ocean surface current observation systems are generally based on that rough ocean surface information is gained by the radar signal which scatters in many directions [1,2]. When the radar signal scatters off a wave whose wave length is exactly equal to half of the transmitted signal wavelength [3,4], the radar signal can return measurement information. Detailed introduction about radar ocean surface current measurement is presented in [5,6].

A SeaSonde CODAR HF radar system had been installed in the Strait of Georgia, one is located at the Westshore Coal Terminal in Tsawwassen since 2011; the other is installed at the Iona Breakwater, near Vancouver Airport since 2012; Two additional arrays were installed in May 2016 and March 2017, one at Point Atkinson near West Vancouver, and one at the lighthouse on Main Island at Georgina Point. Latitude and longitude of each deployment station are presented in Table 1. Each single radar station is able to measure the radial velocities towards and away from the station's antenna—of ocean currents in the Strait of Georgia. Hourly maps of north-south and east-west ocean currents are created by combining the radial currents from the two stations. Operation frequency for all radar stations is 25 MHz. Spatial resolution of the total current maps is 1km.

Table 1 Location of CODAR radar stations (degrees)

Location	Latitude	Longitude
Georgina Point (VGPT)	48.87372	-123.29102
Iona (VION)	49.21587	-123.20538
Point Atkinson (VATK)	49.33007	-123.26443
Westshore Coal Terminal (VCOL)	49.01805	-123.17188

HF radars is taken as a novel marine monitoring technology to capture useful information of water parameters. There are various advantages such as super sight distance, wide range, all-weather conditions and relatively low cost. Land-based HF radars can extract information of sea state, such as wind field, wave field and flow field from radar echo. However, due to rough ocean surface and variation of atmosphere, coverage of surface currents captured by radar varied in space and time. Figure 1 coverage of total vectors with the contribution of the four radial sites.

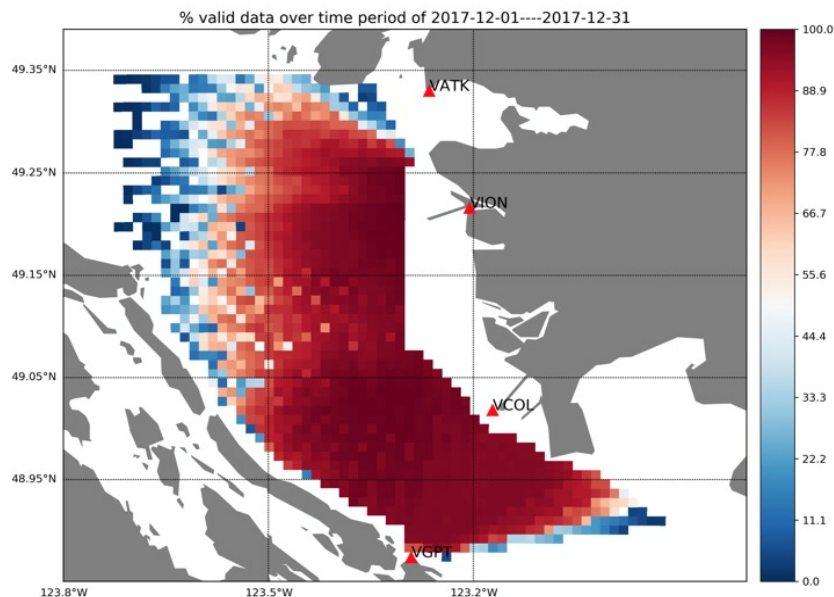


Figure 1 Deployment location of CODAR radar stations in the Strait of Georgia with four radial sites are noted by red triangles. Colours indicate percentage of valid data coverage.

### 3.2. ADCP Data

A bed-mounted ADCP was deployed in the CODAR radar coverage domain in the Strait of Georgia. Operating frequency of RDI Workhorse Quartermaster ADCP deployed in the Strait of Georgia is 150 kHz. Current speeds and directions were recorded with 2m depth increment over depth. The water depth is 170 m at measurement site. The last cell close to the surface cannot be measured due to the side lobes interference area with the 2 m depth cells. Data were recorded since 2007. Hourly averaged ADCP currents were used in this research.

### 3.3. Quality Assurance and Quality Control (QA/QC)

ONC aims for the highest standards of data Quality Assurance and Quality Control (QA/QC) testing and reporting and has adopted the guidelines of the Quality Assurance of Real-Time Oceanographic Data (QARTOD) Working Group. The QARTOD Working Group is a US-based, multi-agency effort to address the quality assurance and quality control issues of the integrated Ocean Observing System (IOOS) and its regional associations.

Version 1.0 of the QARTOD Manual for Real-Time Quality Control of High Frequency Radar Surface Current data was released in May, 2016, which documents established and proposed QC tests and suggested test thresholds for HF radar surface current data. QC tests are defined at each processing stage of HF radar data from: 1) signal (or spectral) processing, to 2) radial components of surface current, to 3) estimation of total current vectors. Spectral tests are all embedded in SeaSonde software. ONC has applied the three required tests for both radial (syntax test, maximum speed threshold test, and valid location tests) and total vectors (data density threshold test, geometric dilution of precision (GDOP) test, and maximum speed threshold test). Specifically, GDOP values are calculated based on HFR Progs (Kaplan, D. Cook, M. and Atwater, D., 2007). Threshold of GDOP test and maximum speed threshold can be adjusted in order to meet different levels of science research. Examples of QA/QC tests for both radials at VION station and total vectors are shown in Figure 2 and Figure 3, respectively.

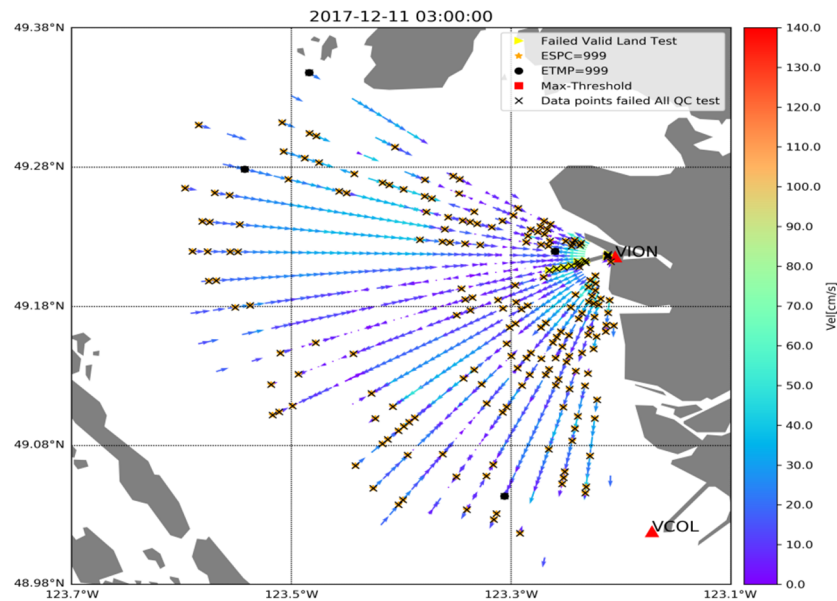


Figure 2 Radial data from VION station for 03:00:00 UTC hour on 11-Dec-2017 showing data failing QAQC tests. Individual test failures are delineated by shape and colour. Data points failing any tests are indicated by an 'X'

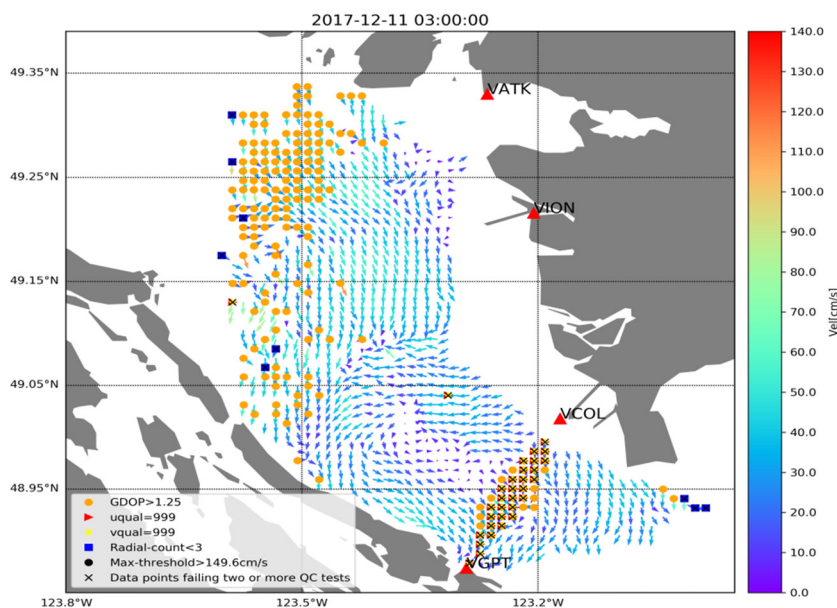
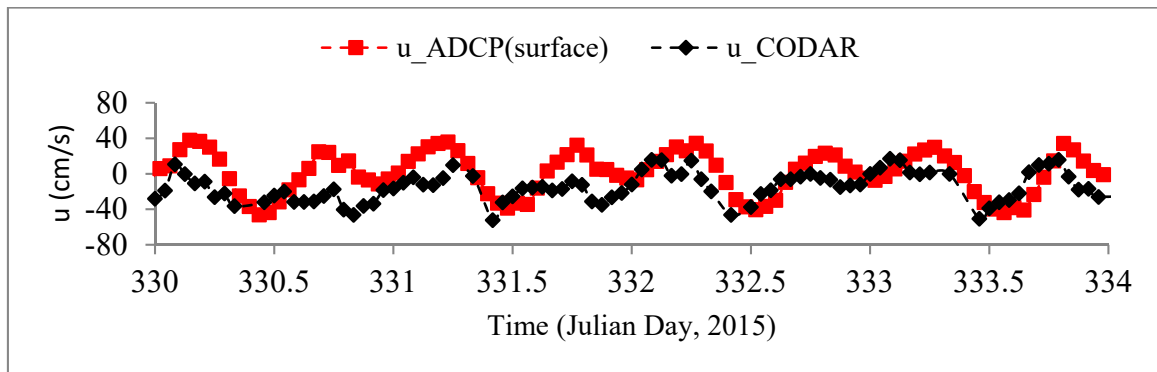
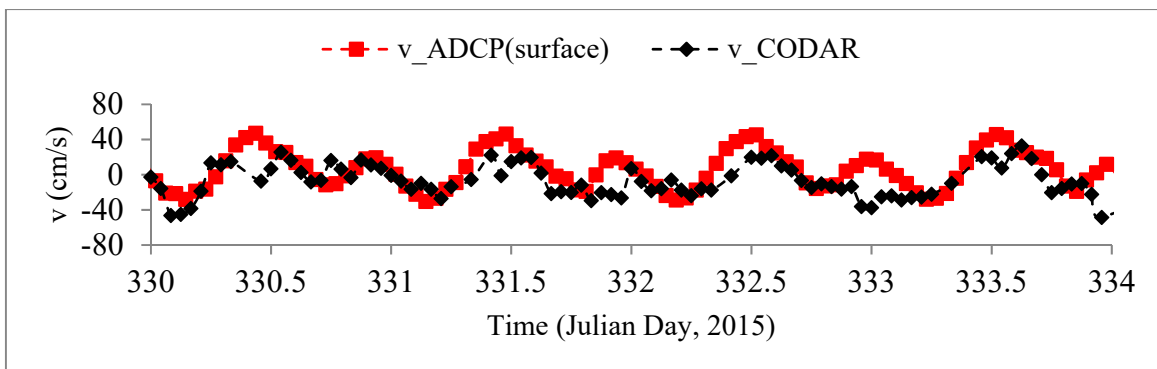


Figure 3 Total surface currents for the Strait of Georgia for 03:00:00 UTC on 11-Dec-2017. Individual test failures are delineated by shape and colour. Data points failing two or more tests are indicated by an 'X'.

#### 4. Results

ADCP and HF radar data are two useful tools to understand process and principles of coastal currents. To study performance of HF radar deployed in the SOG area, comparison of velocity components between HF radar data and ADCP data was implemented in this research, as shown in Figure 4-6.

Figure 4 Time series of  $u$  velocity component between CODAR and ADCPFigure 5 Time series of  $v$  velocity component between CODAR and ADCP

Since HF radars monitor near surface currents, ADCP data of the top bin were used for comparison in this research. Figure 4-5 shows that time series of surface velocity components between CODAR data and ADCP data. In general, both surface velocity components had a relatively good agreement between CODAR and ADCP data. Trend of  $v$  velocity component between CODAR data and ADCP data was better than that of  $u$  velocity component. In order to show distribution of surface current direction, rose maps of currents measured by CODAR and ADCP were shown in Figure 6.

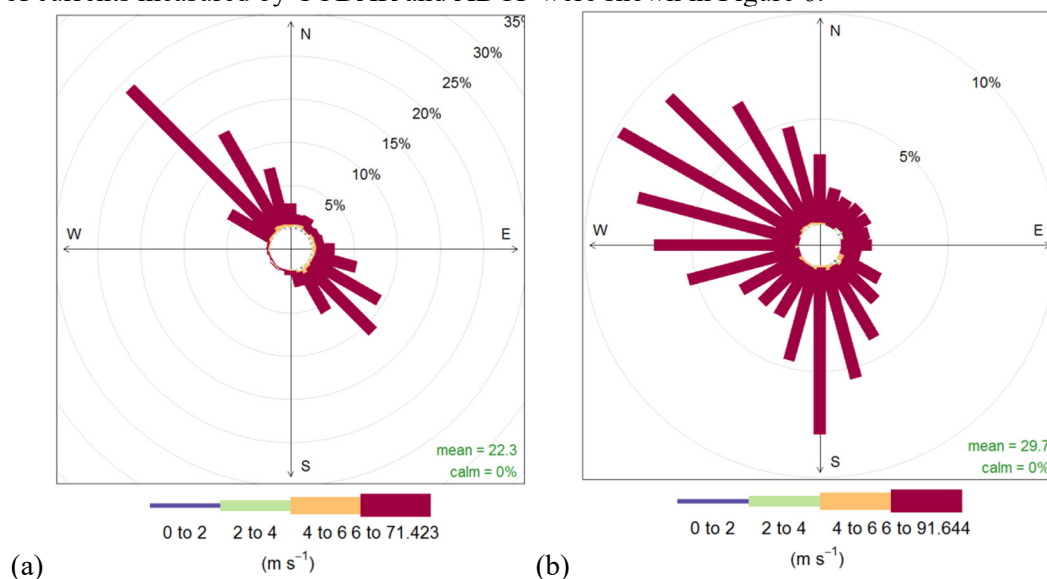


Figure 6 Rose of currents ((a) ADCP data, (b) CODAR)

In general, dominant trend of flows in both ADCP and CODAR data is northwest and southeast, as shown in Figure 6. However, percentage of northeaster flows was quite low for ADCP data and relatively high percentage of southern and southwester flows existed. Variation of flows was more significant for CODAR data maybe due to varying winds in time.

## 5. Conclusions

ADCP and CODAR system are two useful tools to monitor coastal currents. CODAR system provides surface vector fields over a large domain in fine temporal and spatial resolution. Currents from ADCP close to the surface was compared with surface currents observed by the CODAR system. Results indicated that generally good agreement existed between CODAR and ADCP data. But variation of currents from the CODAR system was more varying than the ADCP due to effects of wind on the surface water.

Since the environmental conditions in Strait of Georgia are relatively complicate, it is interesting and of great importance to investigate the currents patterns in this domain using available measurements from a variety of observation devices. In addition, a hydrodynamic model can be useful to learn about the dynamic process of water body in Strait of Georgia. Data assimilation techniques can be applied to improving modelling initial conditions by combining the CODAR data.

## References

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