

FY 2019 ANNUAL REPORT (01/01/2019 - 12/31/2019)

Study Title: Texas Coastal Ocean Dynamics Applications Radar (CODAR) System

Study Number: PAIS-00132

Sponsors:

**Texas A&M System through the Chancellor's Research Initiative
Gulf of Mexico Coastal Ocean Observing System (GCOOS)
Texas General Land Office (TGLO) Oil Spill Prevention and Response Program
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Purpose

Through the Texas A&M system's Chancellor's Research Initiative, the Geochemical and Environmental Research Group (GERG) is funded to install six high frequency radars along the Texas coast to measure and map near-surface ocean currents in coastal waters in near-real time. One of the installation locations is within Padre Island National Seashore. Ultimately, the goal is to daisy chain the high frequency radar systems along the Texas coast to build a network from the Texas-Louisiana border to the United States-Mexico border to measure surface currents up to 110 mi (177 km) offshore. Data from the systems will be publicly available through the Gulf of

Mexico Coastal Ocean Observing System (GCOOS) website (data.gcoos.org), and the National Oceanic and Atmospheric Administration's High Frequency Radar National Server (hfradar.ndbc.noaa.gov) in near-real time.

The near-surface current maps of large areas off the coast in near-real time provided by the high frequency radar systems can significantly contribute to the determination of search radii for search and rescue efforts, placement of response assets in the event of an oil spill, improvements of forecasts for harmful algae blooms, and monitoring contaminant dispersion. Furthermore, since the data will be publicly available, anyone wishing to know the current sea state (within the measured bounds) for commercial, recreational, or management needs can access the information. This is also valuable to researchers as the data can be used as inputs to coastal ocean models, forecasting, and eventually seasonal and annual data at relatively low cost, which has the potential to expand the knowledge of coastal ocean processes along the Texas coast.

Findings

The Texas high frequency radar network is intended to be a long-term ocean observing network along the Texas coast, and it is the responsibility of GERG to operate and maintain this network. As such, GERG needs to ensure the quality of data collected from each radar system. Therefore, an operational assessment of the Padre Island National Seashore (PINS) and Aransas National Wildlife Refuge (ANWR) high-frequency radars and comparative statistical assessment of the PINS and ANWR systems to the Texas Automated Buoy System (TABS) is presented for data collected between January 1, 2019 and December 31, 2019. For this report, the assessment will compare the radial data from both sites to TABS Buoy D, which is within the radar footprint of both systems (PINS & ANWR). During 2019, the PINS system was operational for greater than 90% of the calendar year while the ANWR system was operational approximately 60%. Both systems collected data consistent with the general circulation offshore at the one-year time scale.

A combination of two or more high frequency radars is needed to provide surface current information offshore. High frequency radar system pairs operating at the 5 MHz frequency, which is the frequency of the current Texas radars, must be located approximately 74-111 km apart and within 150 meters of the water. In September 2018, GERG installed another high frequency radar system on Matagorda Island within Aransas National Wildlife Refuge (ANWR), which pairs with the system located at PINS. It is now possible to estimate combined surface current velocities by pairing the ANWR and PINS sites.

The in situ data collected by the TABS buoys will help ground truth the radar radial data from each site (ANWR and PINS), which are used to calculate the combined current velocity vector directly offshore of PINS. A high correlation between the TABS buoys and radar radials in theory will yield more accurate surface current vectors. In general, there was a moderate correlation with TABS Buoy D for PINS and low correlation with Buoy D for ANWR.

Operational Performance Assessment (OPA): January 1, 2019 – December 31, 2019

Spatial and Temporal Resolution

The radial population percentage for the PINS and ANWR high frequency radar systems from January 1, 2019 through December 31, 2019 are shown in Figures 1 and 3, respectively. These plots illustrate the percentage of time a radial vector was measured over the selected time period assuming one vector every hour at every location. This yields a total of 8,760 possible vectors per location for 100% population. For all of the sites, the maximum range is approximately 233 km offshore. The population percentage for both sites during this time period is slightly misleading as there was a setting change that caused the vectors to appear outside of the acceptable tolerance to be considered the same point; thereby creating a new vector location for a portion of the time series.

For the ANWR 2019 population percentage shown in Figure 2, the secondary vector location is a small portion of the overall time series (less than 10%). Therefore, by looking at the vector locations associated with the longer time series at ANWR, a population percentage of approximately 60% covers a large portion of the possible coverage. However in the overall vector coverage for the PINS system in Figure 1, the secondary vector location is about 30% of the overall time series. Coupled with the primary vector location with coverage of 65% of the possible coverage, it is estimated the PINS location operated at greater than 90% of 2019.

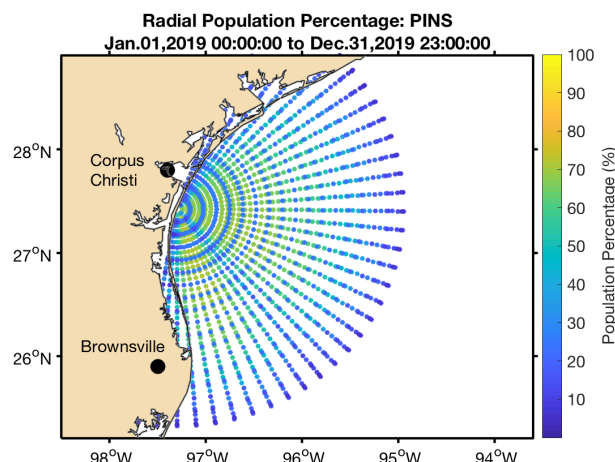


Figure 1. Data availability at PINS in 2019.

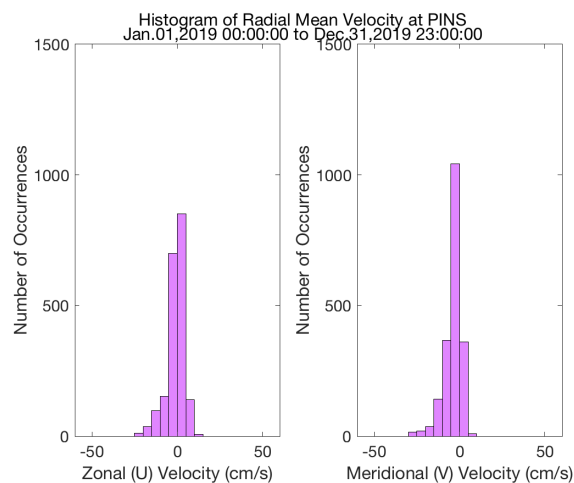


Figure 2. Histogram of radial mean zonal (left) and meridional (right) components in 5cm/s bins for PINS.

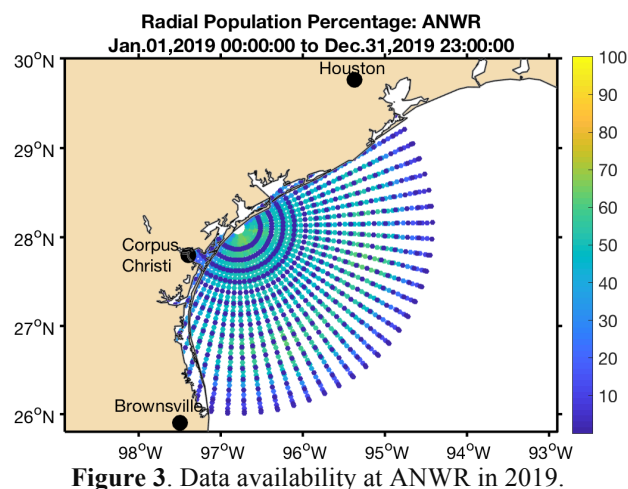


Figure 3. Data availability at ANWR in 2019.

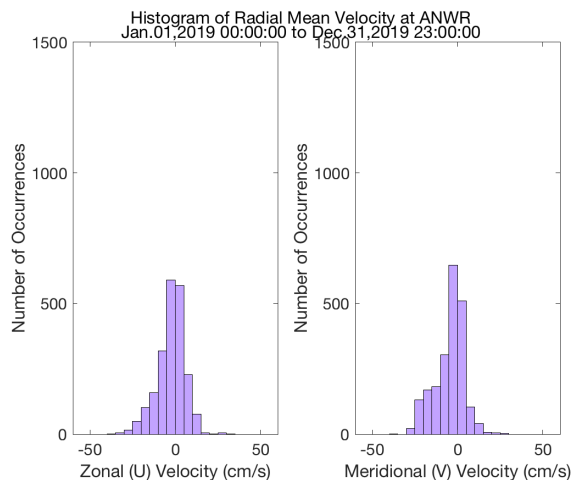


Figure 4. Histogram of radial mean zonal (left) and meridional (right) components in 5cm/s bins for ANWR.

Metrics

Table 1 summarizes the basic statistical metrics for the PINS and ANWR high frequency radar systems between January 1, 2019 and December 31, 2019, supplemented with the corresponding mean velocity distribution histograms in Figures 2 and 4, respectively. The distribution of the mean zonal and meridional velocity components for the PINS and ANWR sites is negatively skewed. This would indicate general circulation down coast over the year time period, which is characteristic for the Texas coast over this time scale. The spatial distributions of the mean velocities are depicted in Figures 5 - 8, and the corresponding standard deviations are presented in Figures 9 - 12.

Table 1: Minimum, maximum, mean, and standard deviation (std) between January 1, 2019 and December 31, 2019 for the high frequency radar system at Padre Island National Seashore (PINS) and Aransas National Wildlife Refuge (ANWR).

Site	Zonal Component (cm/s)				Meridional Component (cm/s)			
	Minimum	Maximum	Mean	Std. of Mean	Minimum	Maximum	Mean	Std. of Mean
PINS	-144.6	22.8	-0.9	5.1	-136.2	140.1	-3.7	5.2
ANWR	-143.6	123.6	-2.3	8.2	-95.6	142.8	-4.6	8.7

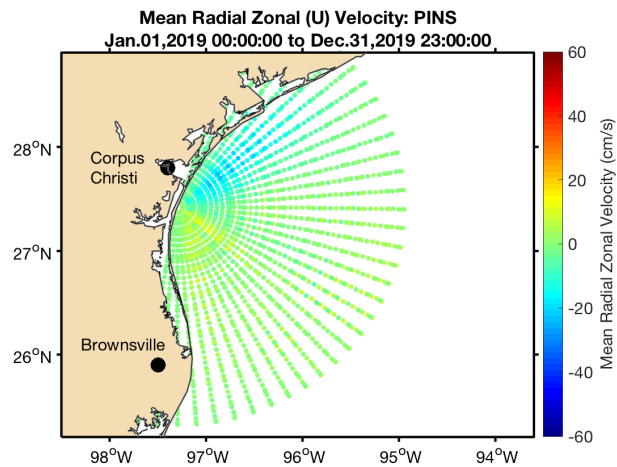


Figure 5. Mean zonal (U) speed in cm/s at PINS.

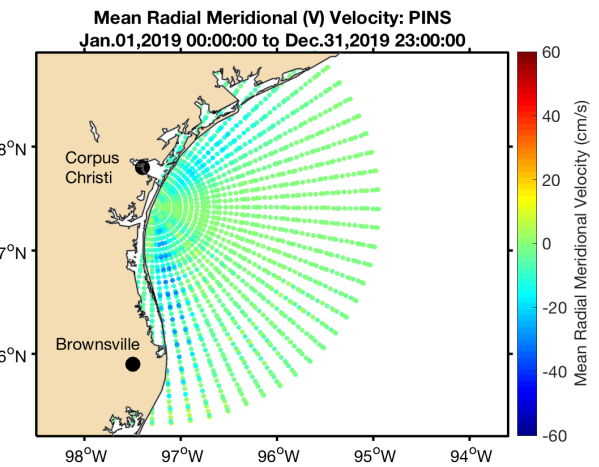


Figure 6. Mean meridional (V) speed in cm/s at PINS.

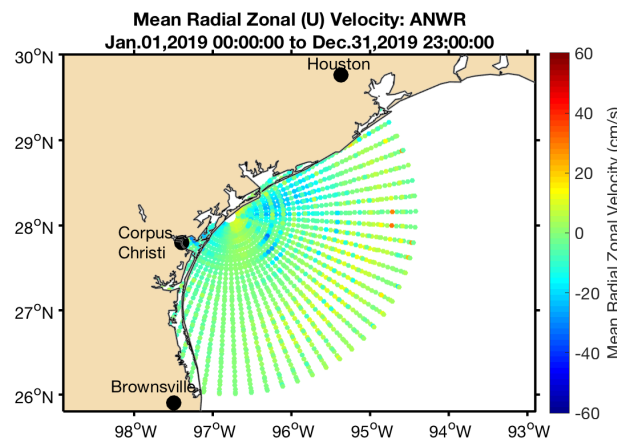


Figure 7. Mean zonal (U) speed in cm/s at ANWR.

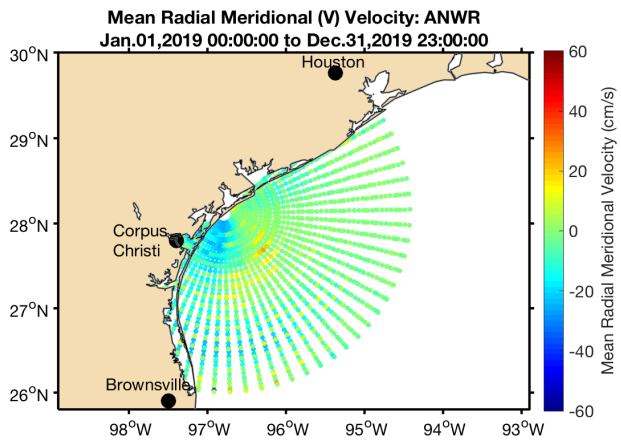


Figure 8. Mean meridional (V) speed in cm/s at ANWR.

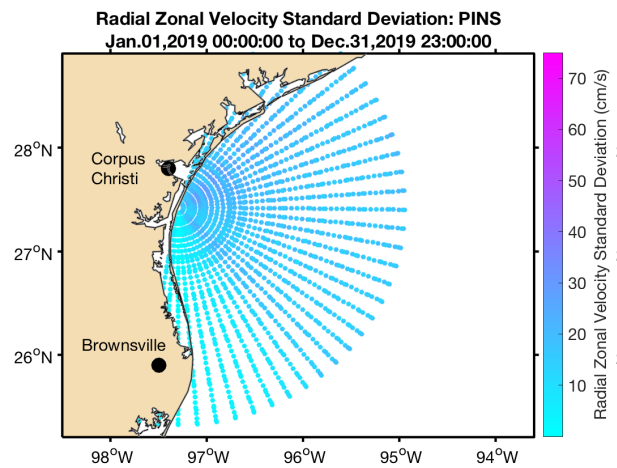


Figure 9. Mean zonal (U) standard deviation in cm/s at PINS.

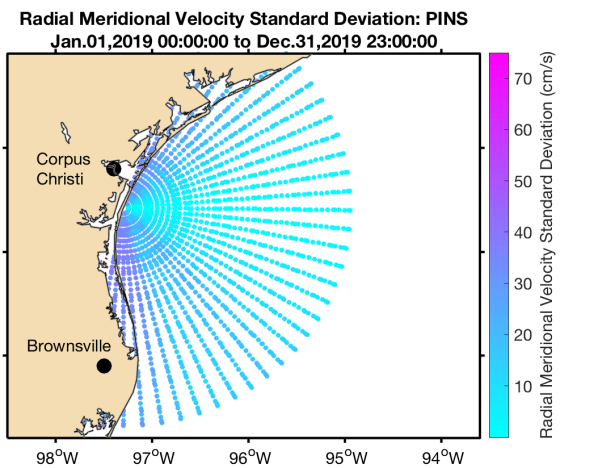
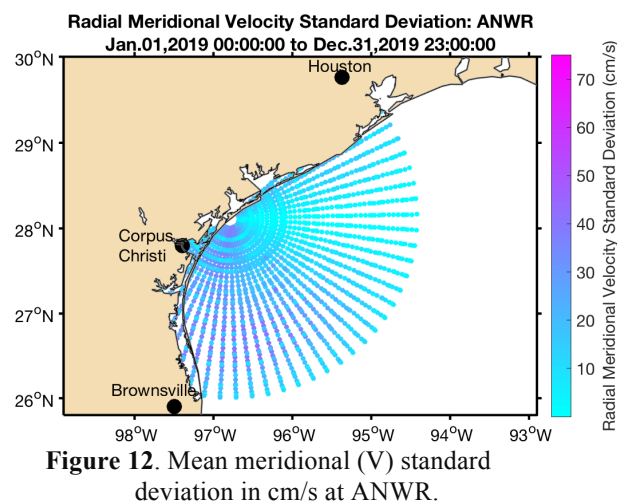
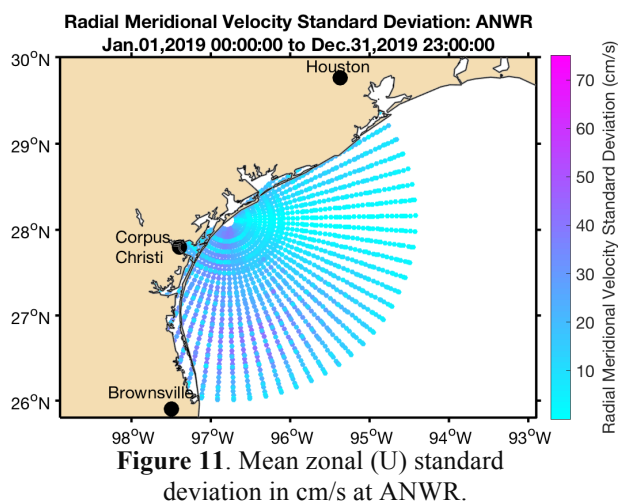


Figure 10. Mean meridional (V) standard deviation in cm/s at PINS.



Comparative Statistical Assessment: January 1, 2019 - December 31, 2019

The comparative statistical assessment (CSA) compares the zonal and meridional components of the PINS and ANWR radial vectors within 6 km of the closest Texas Automated Buoy System measurement. The radar and buoy sites included in the analysis are:

- PINS and Buoy D
- ANWR and Buoy D

Data for each radar and buoy pair is presented by month and overall time period to identify trends. Figures 13 - 14 are time series plots and corresponding histograms of the zonal and meridional components of PINS and Buoy D and ANWR and Buoy D, respectively, over the 2019 calendar year. Tables 2 - 3 correspond to Figures 13 - 14 and calculate the maximum, minimum, mean, standard deviation, correlation coefficient, and p-value for the radial time series location closest to the identified buoy and the projected velocity from the buoy onto the high frequency radar radial every month and over a one year period (2019). Correlation coefficients (R) closest to 1 indicate the strong positive correlation. Data from Buoy D was unavailable from January 1 – April 26, and August 11 – October 15, 2019, as it was not deployed during this time.

Similar to the 2018 comparison, there is an overall moderately positive correlation (0.621) between Buoy D and PINS in 2019. The highest correlations were in summer (June-August) with values ranging between 0.558 and 0.636, which is also the longest stretch of continuous Buoy D data for the assessment period. Correlation coefficients during the remainder of the calendar year were between 0.247 and 0.431 with October having the lowest value.

The correlation coefficient for ANWR and Buoy D is 0.348 over the year (2019) period, which is much lower than expected. The highest correlations were from April-August with values ranging between 0.493 and 0.784. During the fall, there was negative correlation, which brought the

overall correlation for the year down to 0.348. In August of 2019, it was discovered that there was a problem with one of the system components for the high frequency radar at ANWR. To prevent burn out, the system was placed in passive mode, where it only received data and did not transmit. For an individual system to accurately calculate surface current velocity, it uses the Doppler shift, which is the frequency change from the transmitted and received signal. Because the system did not transmit after August 2019, it makes sense that the received data has poor correlation with Buoy D during this time.

Issues Encountered

Unfortunately, TABS Buoy X was only deployed for two days in 2019 (January 7th and 8th) due to power issues with the acoustic Doppler current profiler (ADCP) and transmission problems with the Iridium modem. Although Buoy X is not in the radial coverage of ANWR, the use of a secondary buoy to validate the coverage of PINS would further help to ground truth the data from this system. Buoy X is ready for deployment on the next TABS maintenance cruise, which should occur by March 2020.

Planned Actions in the Next Reporting Period

GERG personnel are working to install another high frequency radar system south of PINS near Port Mansfield. This proposed system would be the southern most Texas site and is the final planned long range high frequency radar system along the Texas coast. Like the ANWR system, the proposed system will pair with the PINS radar and extend the network coverage nearly to the Mexican border. The anticipated installation of this system is May 2020.

Due to planned development at PINS in 2021, the high frequency radar located at this site must to be moved to another location within the park in 2020. GERG will work with the Science and Resource Manager, Shelley Todd, to identify another location, file permits, and install the system at the new location. The estimated timeline (subject to change) for the move is to identify the secondary location by early April, file and receive permits by late May, and install the system in the early summer (June).

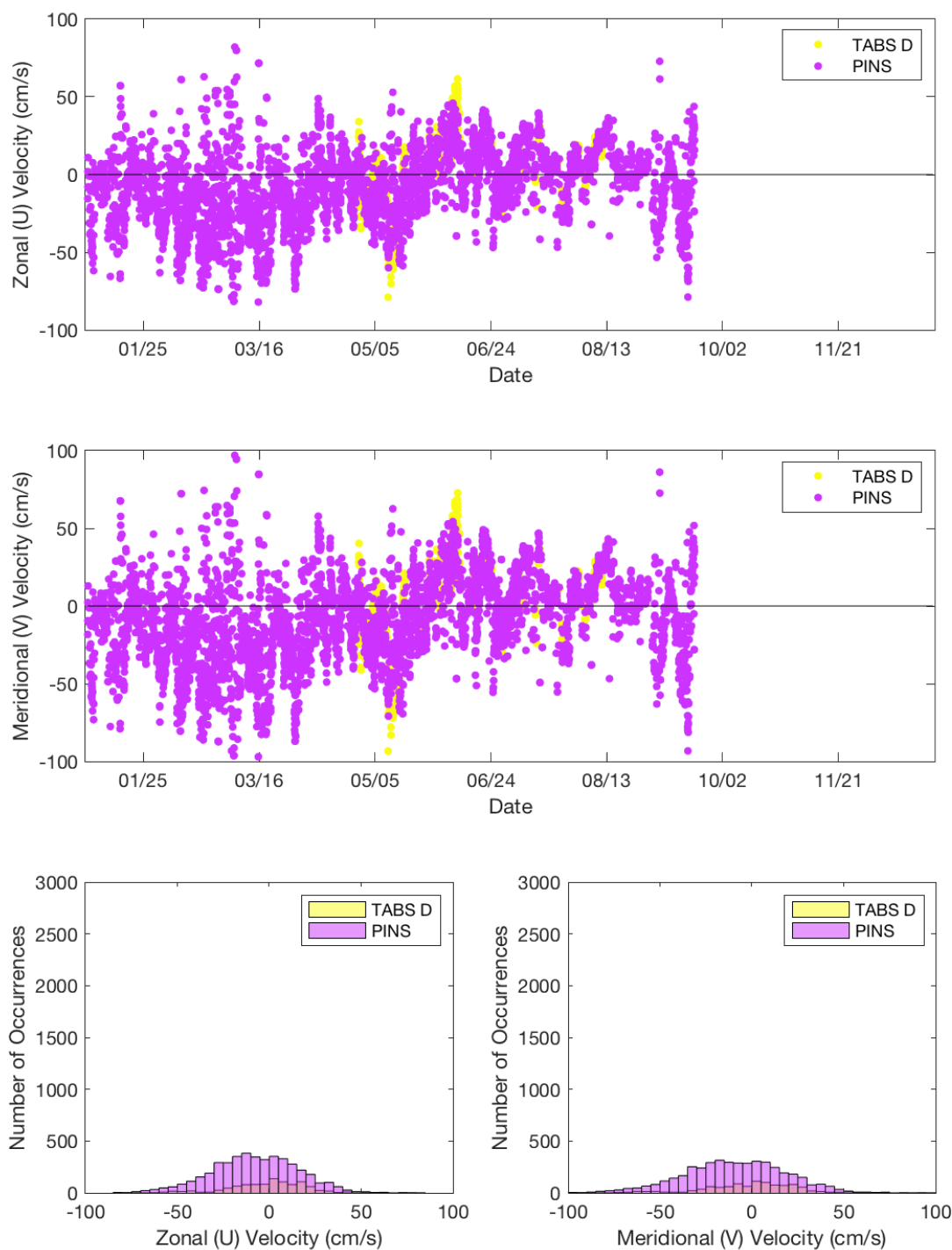


Figure 13. Zonal (top) and meridional (middle) time-series of the closest radial data from PINS (magenta) to TABS buoy D and the projected buoy D data (yellow) along the PINS radial. Corresponding histograms of the zonal (bottom left) and meridional (bottom right) velocity components for buoy D and PINS are also shown.

Table 2: Maximum, minimum, mean, and standard deviation (std) for the PINS radial time series location closest to buoy D and the projected velocity from buoy D onto the PINS radial. Correlation coefficients (R) and P-values (P) for the two time series are also shown. Each parameter is presented for the U (zonal) and V (meridional) components and calculated by month and total time series (January – December 2019).

Site	Parameter	Jan. 2019	Feb. 2019	Mar. 2019	Apr. 2019	May 2019	Jun. 2019	Jul. 2019	Aug. 2019	Sep. 2019	Oct. 2019	Nov. 2019	Dec. 2019	Jan. - Dec. 2019
PINS vs. Buoy D (Projected)	R_u	-	-	-	0.364	0.418	0.558	0.594	0.636	-	0.247	0.271	0.431	0.621
	R_v	-	-	-	0.364	0.418	0.558	0.594	0.636	-	0.247	0.271	0.431	0.621
	P_u	-	-	-	2.08 e-3	1.60 e-19	5.21 e-22	3.57 e-18	7.54 e-12	-	7.06 e-05	1.49 e-12	1.84 e-32	2.06 e-109
	P_v	-	-	-	2.08 e-3	1.59 e-19	5.21 e-22	3.56 e-18	7.55 e-12	-	7.06 e-05	1.49 e-12	1.85 e-32	2.05 e-109
PINS	U_{max} (cm/s)	57.1	62.9	82.1	48.9	52.9	45.9	39.5	36.5	72.9	41.9	48.9	45.8	82.1
	V_{max} (cm/s)	67.6	74.3	97.0	57.8	62.6	54.3	46.8	43.2	86.1	49.6	57.9	54.2	97.0
	U_{min} (cm/s)	-66.8	-73.8	-82.1	-58.4	-60.0	-47.0	-46.8	-39.5	-78.9	-68.3	-68.7	-54.1	-82.1
	V_{min} (cm/s)	-78.9	-87.2	-97.0	-69.1	-70.9	-55.5	-55.3	-46.8	-93.2	-80.8	-81.3	-64.0	-97.0
	U_{mean} (cm/s)	-9.8	-21.9	-20.3	-4.7	-11.1	8.3	3.2	8.6	-11.1	-14.7	-15.0	-8.2	-7.8
	V_{mean} (cm/s)	-11.6	-25.9	-24.0	-5.6	-13.1	9.8	3.8	10.2	-13.1	-17.4	-17.8	-9.7	-9.3
	U_{std} (cm/s)	19.7	23.3	26.0	18.9	19.5	19.6	16.7	12.5	24.6	18.2	15.9	14.7	23.4
	V_{std} (cm/s)	23.3	27.6	30.8	22.4	23.1	23.1	19.8	14.8	29.0	21.5	18.8	17.4	27.7
Buoy D (Projected)	U_{max} (cm/s)	-	-	-	34.1	30.8	61.6	31.9	24.3	-	21.3	15.3	11.4	61.6
	V_{max} (cm/s)	-	-	-	40.3	36.4	72.8	37.7	28.7	-	25.2	18.1	13.5	72.8
	U_{min} (cm/s)	-	-	-	-34.8	-79.0	-26.8	-30.7	-7.6	-	-38.0	-51.5	-47.7	-79.0
	V_{min} (cm/s)	-	-	-	-41.2	-93.3	-31.7	-36.2	-9.0	-	-45.0	-61.0	-56.5	-93.3
	U_{mean} (cm/s)	-	-	-	-5.9	-11.5	14.9	3.5	9.2	-	-10.2	-17.3	-10.6	-0.1
	V_{mean} (cm/s)	-	-	-	-7.0	-13.6	17.7	4.1	10.9	-	-12.1	-20.5	-12.5	-0.1
	U_{std} (cm/s)	-	-	-	14.3	21.2	18.2	12.3	8.5	-	12.3	12.5	11.9	21.0
	V_{std} (cm/s)	-	-	-	16.9	25.1	21.5	14.5	10.1	-	14.6	14.7	14.1	24.8

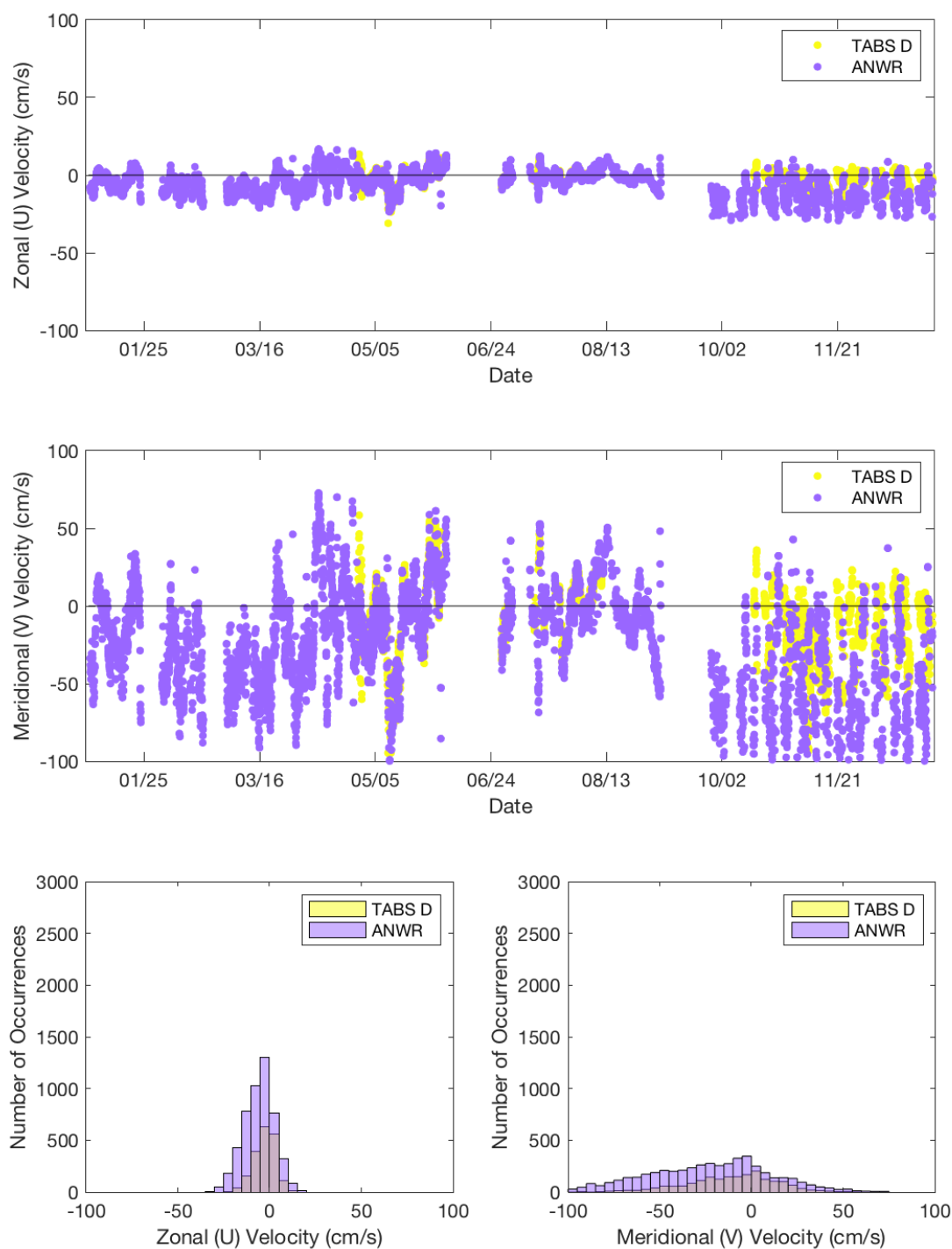


Figure 14. Zonal (top) and meridional (middle) time-series of the closest radial data from ANWR (purple) to TABS buoy D and the projected buoy D data (yellow) along the PINS radial. Corresponding histograms of the zonal (bottom left) and meridional (bottom right) velocity components for buoy D and ANWR are also shown.

Table 3: Maximum, minimum, mean, and standard deviation (std) for the ANWR radial time series location closest to buoy D and the projected velocity from buoy D onto the ANWR radial. Correlation coefficients (R) and P-values (P) for the two time series are also shown. Each parameter is presented for the U (zonal) and V (meridional) components and calculated by month and total time series (January – December 2019).

Site	Parameter	Jan. 2019	Feb. 2019	Mar. 2019	Apr. 2019	May 2019	Jun. 2019	Jul. 2019	Aug. 2019	Sep. 2019	Oct. 2019	Nov. 2019	Dec. 2019	Jan. - Dec. 2019
ANWR vs. Buoy D (Projected)	R_u	-	-	-	0.556	0.832	0.762	0.493	0.784	-	-0.041	-0.414	-0.314	0.348
	R_v	-	-	-	0.556	0.832	0.762	0.493	0.784	-	-0.041	-0.414	-0.314	0.348
	P_u	-	-	-	1.04 e-7	4.09 e-138	4.48 e-14	1.25 e-11	2.68 e-33	-	0.620	7.23 e-18	9.78 e-10	1.95 e-55
	P_v	-	-	-	1.04 e-7	4.06 e-138	4.48 e-14	1.25 e-11	2.63 e-33	-	0.623	7.17 e-18	9.73 e-10	1.96 e-55
ANWR	U_{max} (cm/s)	7.7	6.2	10.6	16.8	14.1	12.9	12.2	11.6	11.1	7.4	9.9	8.6	16.8
	V_{max} (cm/s)	33.6	27.2	46.2	72.9	61.3	55.8	52.9	50.5	48.2	32.3	42.8	37.2	72.9
	U_{min} (cm/s)	-17.2	-20.3	-21.0	-17.9	-23.6	-19.7	-15.8	-6.1	-26.3	-29.1	-29.3	-27.4	-29.3
	V_{min} (cm/s)	-75.0	-88.1	-91.3	-77.7	-102.3	-85.5	-68.6	-26.5	-113.9	-126.4	-127.2	-118.7	-127.2
	U_{mean} (cm/s)	-3.3	-8.4	-8.4	-1.5	-3.0	1.0	-1.1	0.8	-10.8	-12.3	-12.6	-11.6	-5.6
	V_{mean} (cm/s)	-14.6	-36.8	-36.3	-6.4	-12.8	4.3	-4.6	3.5	-46.7	-53.4	-54.6	-50.4	-24.2
	U_{std} (cm/s)	5.2	4.9	5.9	7.6	6.9	6.0	4.8	3.8	5.8	7.9	8.1	7.9	8.0
	V_{std} (cm/s)	22.5	21.5	25.7	33.2	29.8	26.1	20.9	16.7	25.0	34.1	35.1	34.4	34.7
Buoy D (Projected)	U_{max} (cm/s)	-	-	-	13.5	12.7	11.0	10.6	6.7	-	8.3	5.4	5.1	13.5
	V_{max} (cm/s)	-	-	-	58.5	54.9	47.7	46.2	29.0	-	36.1	23.2	22.3	58.5
	U_{min} (cm/s)	-	-	-	-13.9	-31.0	-8.0	-8.4	-2.4	-	-12.3	-21.6	-13.5	-31.0
	V_{min} (cm/s)	-	-	-	-60.1	-134.6	-34.6	-36.6	-10.3	-	-53.5	-93.5	-58.5	-134.6
	U_{mean} (cm/s)	-	-	-	-1.6	-2.8	-0.6	1.1	1.8	-	-2.5	-5.5	-3.1	-2.5
	V_{mean} (cm/s)	-	-	-	-7.0	-12.1	-2.5	4.8	7.7	-	-10.8	-23.8	-13.4	-11.0
	U_{std} (cm/s)	-	-	-	5.3	6.9	4.7	3.6	2.2	-	4.7	4.9	4.3	5.6
	V_{std} (cm/s)	-	-	-	23.2	30.0	20.3	15.7	9.5	-	20.3	21.1	18.6	24.4