NCSU Coastal Hazards Lab - ADCP Quality Control Plan for the "Hydrodynamic Monitoring of Frying Pan Shoals"

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July 2024

1 Project Overview

The NCSU Coastal Hazards Lab was tasked by Moffatt & Nichol, on behalf of the Town of Oak Island, to supplement the hydrodynamic monitoring of Frying Pan Shoals by UNCW and NCSU as part of an ongoing Bureau of Ocean Energy Mangement (BOEM) project with additional measurements within borrow areas of particular interest to the Town of Oak Island. The measurements collected as part of this task will be used by Moffatt & Nichol to assess the viability of these areas as a potential sediment source for beach nourishment by the Town of Oak Island through numerical modeling.

NCSU will deploy two bottom-mounted acoustic doppler current profilers (ADCPs; Figure 2) at the locations shown in Figure 1. The ADCPs will be deployed along the flanks of FPS, in 10-m water depth, as close as possible to the crest of FPS but still within the borrow areas. There will be two deployments of the ADCPs, each spanning 20 days. The ADCPs will collect measurements of water column currents, waves, and water levels (all at 16 Hz). Collectively, this data will inform a sediment transport model, developed by Moffatt & Nichol, to estimate sediment recharge times after dredging.

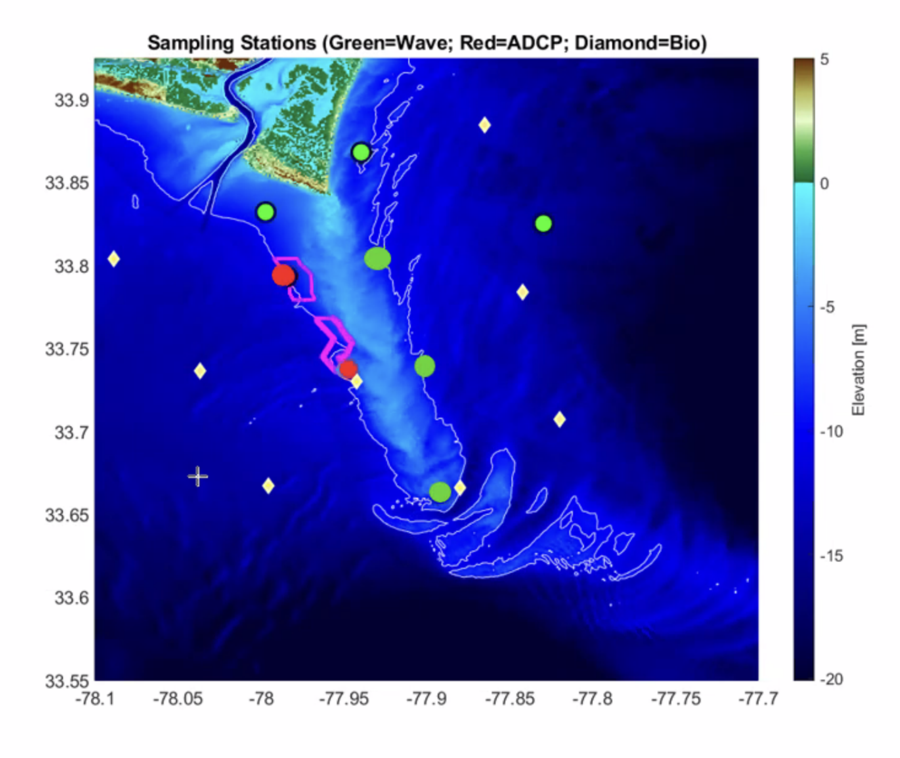


Figure 1: Deployment locations for the acoustic doppler current profilers (ADCPs). Red circles indicate the NCSU ADCP locations and Green circles indicate ADCP locations occupied by UNCW.

The latitude and longitude values at the deployment location will be recorded using the onboard GPS system for the deployment vessel as well as a handheld GPS.

2 Instrument Overview

For this data collection we are using Nortek's Signature 1000 HR (High Resolution) ADCP. An ADCP is a kind of velocimeter that uses the doppler effect to measure the velocities of suspended particles in the water column. This means that the instrument can only detect velocities moving towards or away from it. In order to acquire useful directional data, there are four angled pulse emitters/receivers and a fifth vertical emitter/receiver. We call these emitters/receivers "beams". The high resolution feature of the Signature 1000 allows for high accuracy on individual pings for the vertical beam. It does this by emitting two pings in succession and comparing the phase difference between them. This is called "pulse-coherent profiling" and allows for the measurement of small scale turbulence.

Figure 2: Nortek's Signature 1000 acoustic doppler current profiler (ADCP) shown alongside two different sized external battery canisters.

2.1 Common sources of instrument error

There are several sources of error that affect the quality of ADCP data. In this section, we identify the common sources of error and strategies to minimize error.

- **Phase wrapping**: When using pulse-coherent methods, the paired acoustic pings must be fired one after another. If one ping is fired before the other ping returns, phase wrapping occurs. This phase wrapping causes the measurements to be recorded 360 degrees out-of-phase (Figure 3). In order to avoid phase wrapping you have to ensure the settings of your instrument are correct for expected flow conditions. This is done by specifying the maximum velocity the ADCP can measure before phase wrapping occurs (i.e., the ambiguity velocity).

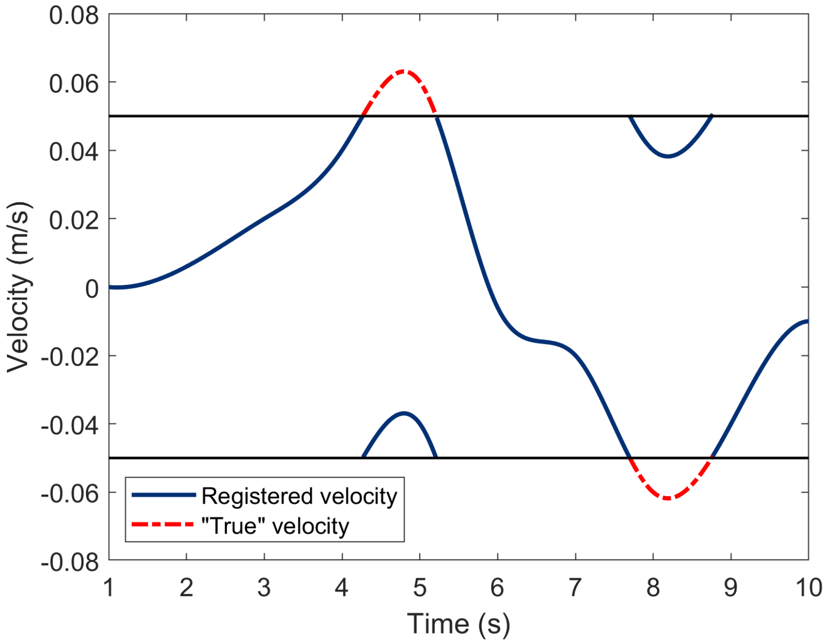


Figure 3: An example of how phase wrapping can alter velocity data measured by an ADCP. Errors associated with phase wrapping are minimized by specifying a maximum velocity range. Image from (Nortek Support, 2022).

- **Magnetic error**: When an ADCP is mounted to large metal frames, or is installed together with external batteries and internal batteries, there are heading errors that can occur due to interference from these magnetic components. In order to avoid magnetic errors, before deployment of the ADCP, the compass is calibrated within the mount (with the batteries installed).

- **Biofouling**: Biofouling refers to any damage or measurement impedance the ADCP may sustain from sea life and biological growth on the sensing nodes during deployment. A film is used to minimize biofouling on the sensing beams. Powder is also applied on the body of the ADCP in order to avoid barnacle growth and other sea life growth. Outside of the case of full burial, accumulation of sand and sea debris on top of the ADCP is not typically enough to interfere with data.

- **Speed of sound**: The speed of sound in marine water bodies changes with temperature, salinity, and depth. Spatially variable speeds of sound can be a source of error for the vertical beam measurements due to the speed of sound changing from the transducer to the site of the reflector. This change does not effect the horizontal beams (Teledyne RD Instruments, 2010). In order to correct speed of sound differences we can use the equation $v_{corrected} = v_{uncorrected}\frac{c_{TRUE}}{c_{ADCP}}$ where c_{TRUE} is the true velocity at the transducer and c_{ADCP} is the velocity the ADCP has used. We will not correct for spatial variability in speed of sound in this project because 1) for the range of expected salinity (25-35 ppt) and temperate (28°) at the deployment depths (10-13 m), the most the ratio would change the measurements is 0.8%; and 2) this would require a vertical array of salinity measurements (e.g., CTDs), which is outside the project scope.

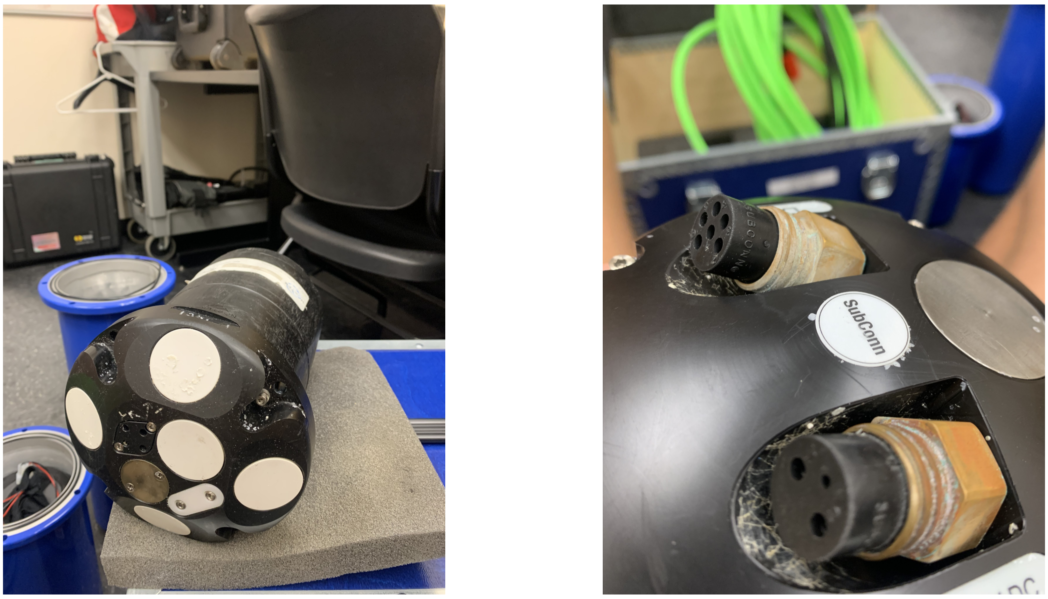
- **Large concentration of reflectors**: In the case where there are too many reflectors in the water column – for example, a fish passing overhead, turbulence causing large amounts of bubbles, or high concentrations of sediment – the ADCP has a hard time differentiating the speed of individual reflectors, leading to low correlations. This is one of the most common forms of error in ADCP data collection. As discussed in more detail in Section 4.2, data is omitted if correlation values recorded by the ADCP are below a threshold.

2.2 Equipment maintenance

The following equipment is required for data collection:

1. Signature 1000 HR ADCP
2. Bottom mount or "lander"
3. Internal and external batteries
4. External battery canister
5. Marker buoy and anchor

Proper maintenance of the instrument is crucial, with a particular focus on O-ring care and corrosion prevention. Before each deployment, O-rings on the Signature 1000 and the external battery canister will confirmed to be in good condition and well-lubricated. To prevent corrosion during the deployment (e.g., Figure 4b), we will ensure that any unused connection ports are capped with dummy plugs. After each deployment, we will thoroughly rinse the entire instrument with fresh water to remove salt and debris (e.g., Figure 4a). For any exposed electrical components, we will additionally apply electronics cleaner and silicone lubricant.



(a) Salt buildup and damage to film

(b) Corrosion

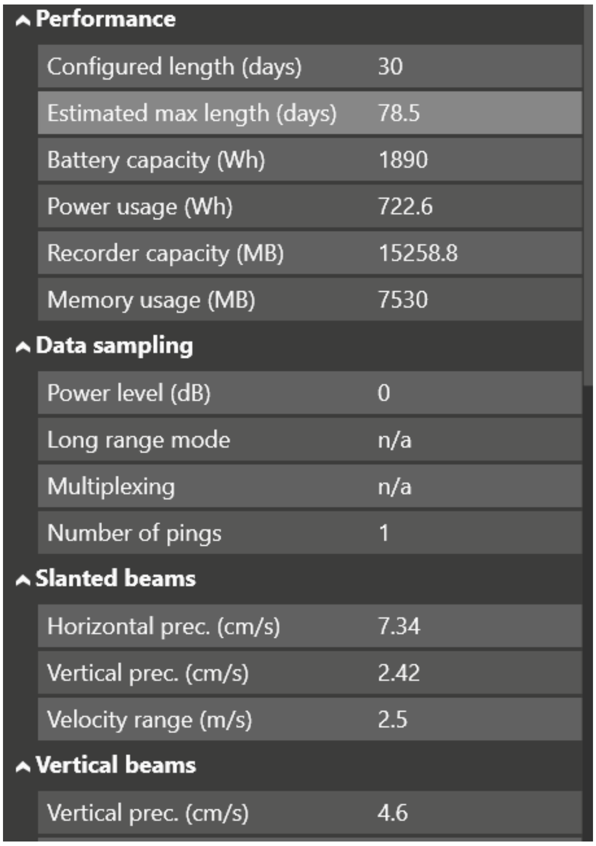
Figure 4: Examples of wear and tear a Signature 1000 can undergo during deployment, including salt buildup, damage to anti-fouling films, scratches, and corrosion on bottom ports.

3 Deployment methodology

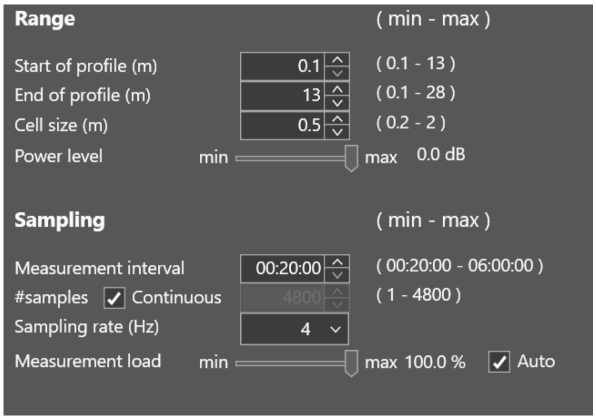
This section provides a checklist of the steps that will be completed prior to and post-deployment to ensure successful data collection.

3.1 Deployment Software Settings

The NCSU Signature 1000 will sample for waves and currents using the 5 beams mode. So far, we have conducted tests sampling at 2 Hz and using an echosounder. However, for the deployment we have chosen to not use the echosounder in order to increase the sampling frequency from 2 Hz to 4 Hz to better characterize wave velocities.



(a) Performance details



(b) Cell information, sampling rate

Figure 5: Screenshots of the Signature 1000 settings selected for the BOEM deployments. The left window displays the chosen ambiguity velocity (horizontal and vertical precision) and battery usage, memory usage, and number of pings. The righ window displays info about the depth range, cell size, and sample rate of the instrument.

3.2 Pre-deployment checklist (1 week before deployment)

- Ensure external batteries have sufficient charge for the 20-day deployment.
- Insert a new desiccant bag into the Signature 1000 housing and external battery casing.
- Check internal battery charge (14V is full, 12V is dead); deployment software will provide a good estimate of watt-hours used. Record values in deployment spreadsheet.
- Disassemble the Signature 1000 and then reassemble it by tightening each screw evenly, similar to tuning a drum. Ensure the cable ports face the -X direction, as indicated by the guide on the top piece. Do not overtighten; use two-finger torque.
- Ensure that the Signature 1000 software is up-to-date.

- Create a .deploy file using the Signature 1000 software and conduct a functionality test using this same file. See the deployment settings for more information on the sampling performed by the instrument.

- Check temperature, tilt, compass, and pressure readings in "online measurement" mode. Compare them to values you would expect. If you are inside a building, the temperature should read room temperature. If you are facing north, the compass should be approximately 0°. Move the instrument around while looking at the tilt values and make sure they make sense. The pressure should be approximately 1 atm.

- Test amplitude and correlations using a Ziploc bag of water or similar item. To do this, fill up a Ziploc with water. Pass it over the sensors while they are reading in online mode. Correlation and amplitude values should be low until you pass the water over them, after which measurements should jump to higher values. You can also use your hand for similar results assuming they are clean.

- Verify that the recorder memory is working and the settings function as desired by starting a recorder deployment. Let the deployment run for a minute or two and then stop it. Make sure the instrument successfully recorded data during this test.

- Check the mount, ensuring the Signature 1000 clasp, bolts, and weights are present. Secure the Signature 1000 within the mount (with all hardware) and rotate for compass calibration. In order to start a compass calibration, navigate to the instrument tab in the Nortek deployment software and select compass calibration.

- Set the pressure offset. This is done in the same tab as the compass calibration. The ADCP will autoset the pressure if it detects in air as 0 atm. This is important for the ADCP to be able to accurately measure the pressure at depth without atmospheric pressure.

- Apply anti-biofouling stickers to the beams and powder to the ADCP body.

Figure 6: Bottom mount for the Signature 1000.

3.3 Deployment checklist (1 day before deployment)

- Update the computer clock to match internet time. Computer must be within one second of time.is. Record time difference between internet time and the comupter in the deployment spreadsheet.
- The ADCP will begin sampling the moment it's programmed; ensure the blue LED is blinking before deploying the instrument.
- Balance the mount with weights on each foot to prevent tilting or landing sideways during deployment.
- Secure any additional instruments, such as a CTD or sand trap, onto the mount.
- Ensure you have the Signature 1000, loaded external battery canister, marker buoy, line, and anchor on the boat before departure.
- Deploy the instrument.
- Record the latitude and longitude of the deployment location.

3.4 Post-deployment checklist (immediately after instrument retrieval)

- Thoroughly rinse all equipment with freshwater.

- Spray electronic components with cleaner and silicone lubricant.
- Update the computer clock so it is within 1 sec of time.is. Record time difference between internet time and the computer in the deployment spreadsheet.
- Connect to the Signature 1000 to stop measurements.
- Record the deployment duration and estimated battery usage in the deployment spreadsheet.
- Export the Signature data as a .mat file.

3.5 Field Kit and Safety Supplies

When on a deployment, a field kit must always be brought in order to ensure safety in the case of emergency. Some supplies such as closed toes shoes and sunglasses should be brought by each person. Other supplies such as hard hats, wrenches, and the first aid kit should always be present in the field kit. The field kit should contain:

- Hard hats
- Pfds
- First aid kit
- Dramamine
- Hat
- Sunglasses
- Sunblock
- Closed toed shoes (sneakers plus hiking boots)
- iPad and charger (for notes)
- Wipes
- Towel
- Wrenches
- Hardware
- Electrical tape
- Pipe tape

- Hose clamps
- Zip ties

4 Post-processing workflow and quality control

All scripts and algorithms associate with this workflow are housed in the NCSU Hydrographic RV GitHub. The workflow is organized into a read script (data import), a processing script (quality control and data corrections), and a plotting script.

4.1 Read

We export raw data from the Signature 1000 as a MATLAB-compatible .mat file. Although our quality control workflow is based in Python, the .mat file provides access to more detailed information than the CSV file option. The read script includes a function to convert the .mat file into usable data formats such as Pandas DataFrames and NumPy arrays. The Signature 1000 software indicates that long deployments may result in data fields being segmented into smaller structures, and a function is available to recombine these structures into a single dataset.

4.2 Process

The process script includes a function to convert MATLAB's datenum format into UTC datetime structures. It also performs quality control of the data.

- The first step in data quality control is to remove any low-correlation data points across all depths. This is accomplished using the equation $Threshold = .3 + .4\sqrt{\frac{s_f}{25}}$ from (Steve Elgar, 2001), which incorporates the instrument sample rate. For our 4 Hz measurements, the threshold is approximately 0.46, so data points with correlation values lower than 0.46 will be flagged and converted to NaNs.
- Next, data collected beyond the water surface is removed. We set a water depth limit based on the highest tide, but at lower tides, data collected above the surface must be discarded. This is done using pressure readings directly from the instrument. We will also evaluate the utility of the 5th beam for identifying the water surface.

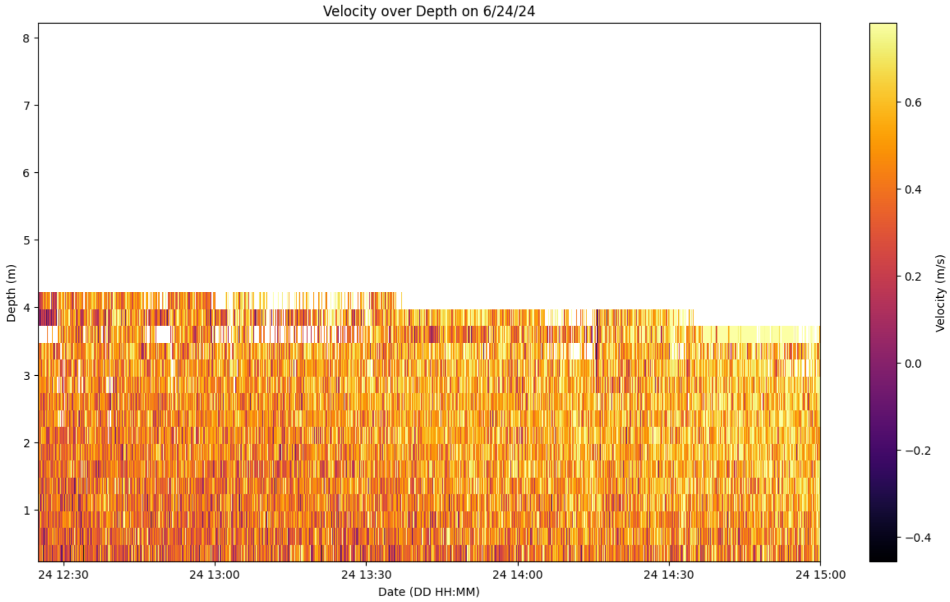


Figure 7: Illustration of data collected at approximately 8-m water depth within the Intracoastal Waterway at the Center for Marine Science in Wilmington. The "process" algorithm removes data above the surface and data in individual depth bins that do not meet the correlation threshold.

- Data is then converted from beam coordinates to ENUD (East, North, Up, Difference) using the transformation matrix provided in the exported .mat file. The matrix incorporates beam angles and directions, and is combined with heading, roll, and pitch data for the transformation.

- Each angled beam measures a cardinal direction, while the fourth beam remeasures one direction to check the instrument's accuracy and consistency. This creates a "difference beam", serving as a rough error estimate (in m/s) that will be provided as a metric of data quality. In cases of beam failure during deployment, a three-beam solution can be used to continue data collection by using this fourth beam.

- Speed of sound changes with depth are not currently corrected in the process script, although we plan to implement it in the future using a co-located CTD.

4.3 Plotter

The plotter script contains functions for plotting post-processed velocity components and velocity as a function of depth.

References

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