2017 Western Passage Tidal Energy Resource Characterization Measurements

These data are from tidal resource characterization measurements collected between April and July 2017 in Western Passage near Eastport, Maine, USA.

The dataset contains the following four sub-datasets, each of which is described in more detail below:

1. A bottom-mounted Teledyne RDI Workhorse 600 kHz acoustic Doppler current profiler (ADCP) was deployed at 44.92015°N, 66.98915°W in ~50 m of water from 3 April – 18 July (106 days). Data were recorded in 6-minute increments in the ENU (East, magnetic North, Up)coordinate system with bin-mapping enabled.

2. A bottom-mounted Nortek Signature 500 kHz ADCP was deployed at 44.92192°N, 66.98913°W in ~50 m of water from 4 April – 18 July (105 days). Data were sampled and recorded at 2 Hz and recorded in the ENU (East, magnetic North, Up) coordinate system.

3. Between those stations along a cross-channel transect, a Stable Tidal Turbulence Mooring (STTM) positioned ~10 m above the seabed was deployed for one week during a spring tide. The STTM was outfitted with two Nortek Vector acoustic Doppler velocimeters equipped with inertial motion units (ADVs), a bottom-tracking downward-looking Teledyne RDI Workhorse 600 kHz ADCP to provide motion-corrected flow and turbulence characteristics at high temporal resolution, and an upward-looking Teledyne RDI Sentinel V20 ADCP. The STTM was deployed at 44.92098°N, 66.98922°W from 24-31 May.

4. A vessel-mounted Teledyne RDI Workhorse 300 kHz ADCP collected current data along three transects over two days, 4-5 April.

The data processing used DOLfYN version 0.11.2. All hdf5 files (i.e., files ending in `.h5`) contained here can be opened using that version of DOLfYN (e.g., `dat = dolfyn.load('<filename.h5>')`).

All distances are in meters (e.g., depth, range, MLLW, hab, eta, z__), and all velocities in m/s. See the DOLfYN documentation, and/or the Nortek and Teledyne RDI documentation for additional details.

Reproducing the data processing

The scripts that were used to process the data from the source files to the processed files are included in the `wp2017_processing.zip` file. This is included for several reasons:

- in case users of the data need to modify the data processing
- as a complete log of what was done to generate the data

- as an example guide for using DOLfYN to process this or similar datasets.

If you wish to reproduce the data processing, follow these steps:

1. Unzip the files in `wp2017_processing.zip` into the same folder that contains all of the data files (all files should be in one folder).
2. Install DOLfYN and its dependencies:

   ```
   pip install -f requirements.txt
   ```

3. From here you have two options:
   - Run the `process_<sub dataset>.py` scripts individually, or
   - Run the `run_tests.py` script to run all of the scripts in sequence, write the data out to a `tmp/` folder, and compare the data to the original data files (i.e., confirm that running the processing on your machine generates the same data as contained in the public dataset).

Bottom-Mounted RDI Workhorse 600

The bottom-mounted upward looking Teledyne RDI Workhorse 600 kHz ADCP data from a stationary survey in the Western Passage, on the border of Maine, USA, and New Brunswick, Canada. The data was collected continuously from April 3, 2017 to July 18, 2017. The station location is 44.92015°N, 66.98915°W.

Data were recorded in 6-minute increments in the ENU (East, magnetic North, Up) coordinate system with internal bin mapping enabled. Each velocity data point is the average of 60 pings where the sampling frequency of each ping was 1 sample/6 seconds (0.166 Hz). The data was collected in Maine local time (UTC-4) and so the source data file (ending `.000`) are in that timezone, but all other files have been adjusted to UTC.

Workhorse 600 Data File Description

The following files are from this instrument:

Source Data File

- `WP2017_Bottom_RDI600.000` is the raw/source RDI ADCP file. See the RDI documentation for details on this file format.

DOLfYN/HDF5 Files

- `WP2017_Bottom_RDI600_raw_ETU_d112.h5` contains all data in the `.000` file, is corrected for magnetic declination, and the timestamps are adjusted from UTC-4 to UTC.

- `WP2017_Bottom_RDI600_cln_ETU_d112.h5` contains the data after cleaning, calculating mean lower low water (MLLW), depth relative to MLLW, and sea surface height relative to MLLW.

Zipped CSV Files

- The `.csv.zip` file is the processed data in a set of csv files that have been zipped together into a single file. The `.csv.zip` file contains:
  - `WP2017_Bottom_RDI600.EAST.csv`, true eastward velocity component, units: m/s. Columns are depth bins relative to observed MLLW, with the headers indicating the depth in m. Rows are timesteps.
  - `WP2017_Bottom_RDI600.NORTH.csv`, true northward velocity component. Format the same as `.EAST.csv`
  - `WP2017_Bottom_RDI600.UP.csv`, up velocity component, units: m/s. Format the same as `.EAST.csv`
  - `WP2017_Bottom_RDI600.ERROR.csv`: RDI-defined error velocity, units: m/s. Format the same as `.EAST.csv`
  - `WP2017_Bottom_RDI600.INFO.csv`: Distance to the center of each bin from the RDI face (`range_m`), water depth above the seabed (`depth_m`), temperature measured at the RDI head in degrees C (`temp_C`).

Workhorse 600 Data Processing

The `.csv.zip` file and `.h5` files were created using the `process_btmWkhs.py` script. See that script for a complete description of what has been done, but a summary is:

- Timestamp has been modified from UTC-4 to UTC
- Orientation of the instrument has been updated to include magnetic declination
- DOLfYN-defined heading, pitch, and roll values have been added to dat.orient, while instrument-defined heading, pitch, and roll can be found in dat.orient.raw
- Data has been cropped to eliminate samples collected before and after the instrument was on the seabed
- Data has been cleared (i.e., "NaN'd") where signal correlation < 64 and the sum of the percent of good 3-beam and 4-beam solutions < 90
- MLLW has been calculated from the observed timeframe
- Sea surface height relative to observed MLLW has been calculated
- Data has been cleared (i.e., "NaN'd") below 90% of the water depth
- Velocity data has been cleared (i.e., "NaN'd") for the duration of the observed timeframe for any range bin without *good* data (i.e., not "NaN'd") in at least 95% of the time events

Bottom-Mounted Nortek Signature 500

The bottom-mounted upward looking Nortek Signature 500 kHz AD2CP data was collected in the Western Passage, on the border of Maine, USA, and New Brunswick, Canada. The data was collected continuously from April 4, 2017 to July 18, 2017. The station location is 44.92192°N, 66.98913°W

Data were sampled and recorded at 2 Hz and recorded in the ENU (East, magnetic North, Up) coordinate system. The timestamps are in UTC.

DOLfYN (as of version 0.11.2) does not have a bin mapping function, therefore Nortek's Ocean Contour software has been used to import the raw `WP2017_Bottom_Sig500.ad2cp`, process it into 5-minute means, and output the MATLAB files described in the next section.

The following selections have been made in the Processing Wizard of the Ocean Contour software:

- "Transforms/Corrections":ENU velocity, bin mapping, magnetic declination = -16.74, surface pressure offset (dbar) = 0
- "Data Selection": Side Lobe Interference (%) = 90, Min. Amplitude (dB) = 30, Min. Correlation (%) = 50.
- "Averaging Parameters": 5-minute means created by setting the averaging window to 600 (samples), percent good threshold to 50% (meaning a 5-minute mean has only been made if at least 300 of the 600 samples are "good").

The slanted and 5th beam 5-minutes means generated by Ocean Contour have been exported as MATLAB .mat files. When the data was examined in Ocean Contour, two chunks of time when the quality of the velocities was good (i.e., the data range in the water column was good) and the instrument attitude were fairly steady were identified:

1. The first chunk ranges from May 1 00:00:00 to May 26 00:00:00 with heading ~105, pitch 12-15, roll -10 degrees.
2. The second chunk ranges from June 3 12:00:00 - June 23 00:00:00 with heading ~96, pitch 11, roll -6.7 degrees.

Signature 500 Data Files

Source File

- `WP2017_Bottom_Sig500.ad2cp` is the source data file for the bottom-mounted signature.

MATLAB Files

- `WP2017_Bottom_Sig500_OceanContour_Burst.VTC.DSEL_binmap.AVER.mat` is the MATLAB file of 5-minute means of data from the 4 slanted beams on the bottom-mounted Nortek Signature 500 kHz ADCP generated in Nortek's Ocean Contour software. Data are in the ETU coordinate system (East, True North, Up).

- `WP2017_Bottom_Sig500_OceanContour_IBurst.DSEL.AVER.mat` is the MATLAB file of 5-minute means of data from the vertical beam on the bottom-mounted Nortek Signature 500 kHz ADCP generated in Nortek's Ocean Contour software.

DOLfYN/HDF5 Files

- `WP2017_Bottom_Sig500_OceanContour_masked_d112_ETU.5min.h5` contains 5-minute means of the bottom-mounted Nortek Signature 500 kHz ADCP data exported from Ocean Contour software and the air pressure from the NDBC `.mat` file after being imported into DOLfYN, where NaNs replaced the "bad" Nortek Signature 500 data and water depth was calculated from the air pressure and the pressure measurement at the ADCP.
- `WP2017_Bottom_Sig500_OceanContour_May_d112_ETU.5min.h5` is the May 1-26 subset of `Sig500_5min_means_OceanContour_masked_d112_ETU.h5`, with velocity bins cropped to include only bins with good data 95% of the time, and the calculation of MLLW, depth relative to MLLW, and sea surface height relative to MLLW.
- `WP2017_Bottom_Sig500_OceanContour_June_d112_ETU.5min.h5` is the June 3-23 subset of `Sig500_5min_means_OceanContour_masked_d112_ETU.h5`, with velocity bins cropped to include only bins with good data 95% of the time, and the calculation of MLLW, depth relative to MLLW, and sea surface height relative to MLLW.

Zipped CSV Files

- The `.csv.zip` file is the processed data in a set of csv files that have been zipped together into a single file. The `.csv.zip` file contains:
  - `WP2017_Bottom_Sig500.EAST.csv`, true eastward velocity component, units: m/s. Columns are depth bins relative to observed MLLW, with the headers indicating the depth in m. Rows are timesteps.
  - `WP2017_Bottom_Sig500.NORTH.csv`, true northward velocity component. Format the same as `.EAST.csv`
  - `WP2017_Bottom_Sig500.UP1.csv`, up velocity component calculated from one pair of slanted beams, units: m/s. Format the same as `.EAST.csv`
  - `WP2017_Bottom_Sig500.UP2.csv`: up velocity component calculated from the other pair of slanted beams. Format the same as `.EAST.csv`

- WP2017_Bottom_Sig500.INFO.csv: Distance in meters to the center of each bin from the Signature face (range_m), water depth above the seabed (depth_m)

Signature 500 Data Processing

The .csv.zip files and .h5 files were created using the process_btmSig500.py script. See that script for a complete description of what has been done. A summary is:

- The .mat files of 5-minute means Ocean Contour software have been loaded and select variables have been added to a DOLfYN data structure
- Water depth above the Signature has been calculated using the Signature's pressure data and atmospheric pressure measured at a nearby NDBC station
- DOLfYN-defined heading, pitch, and roll values have been added to dat.orient, while instrument-defined heading, pitch, and roll can be found in dat.orient.raw
- Data has been cleared (i.e., "NaN'd") with the mask Ocean Contour processing steps identified as "bad"
- May and June data subsets have been created. Within each subset
  - Data has been cleared (i.e., "NaN'd") for the duration of the observed timeframe for any range bin without "good" data (i.e., not "NaN'd")in at least 95% of the time events
  - MLLW has been calculated from the observed timeframe
  - Sea surface height relative to observed MLLW has been calculated

Stable Tidal Turbulence Mooring

The Stable Tidal Turbulence Mooring (STTM) was deployed in the Western Passage, on the border of Maine, USA, and New Brunswick, Canada. The data was collected continuously from May 24, 2017 to May 31, 2017. The station location is 44.92098°N, 66.98922°W .

The STTM is broadly described in Kilcher et.al. 2016 and Harding et.al. 2017. The StableMoor buoy for this project is approximately 3.5 m long with a main body diameter of 0.5 m, tail ring maximum diameter of 0.75 m, wingspan of 1.5 m, a nominal weight in air of 650 kg, and seawater buoyancy of 185 kg and was produced by DeepWater Buoyancy, Biddeford, Maine, USA.

The STTM was outfitted with two Nortek Vector acoustic Doppler velocimeters equipped with inertial motion units, a bottom-tracking downward-looking Teledyne RDI Workhorse 600 kHz ADCP to provide motion-corrected flow and turbulence characteristics at high temporal resolution, and an upward-looking Teledyne RDI Sentinel V20 ADCP.

- A Nortek Vector sensor head was mounted to the end of each ‘wing’ in an upward facing direction and the Vector bodies were mounted vertically in wells in the StableMoor. Vectors sampled continuously at 16 Hz.
- One downward-looking Teledyne RDI Workhorse 600 kHz ADCP. Data were sampled at 2 Hz and recorded the mean of 3 samples in 1.5-second increments (for an effective sampling rate of 0.66 Hz) in the ENU (East, magnetic North, Up) coordinate system with bin mapping enabled.
- One upward-looking Teledyne RDI Sentinel V20 1000 kHz ADCP. Data were recorded at 0.4 Hz and collected in beam coordinates.

The timestamps are in UTC.

STTM Data Files

Source Data Files

- `WP2017_STTM_ADVport.VEC` is the source file from the STTM’s port Nortek Vector.
- `WP2017_STTM_ADVstbd.VEC` is the source file from the STTM’s starboard Nortek Vector.
- `WP2017_STTM_RDI.000` is the source file from the STTM’s downward-looking RDI Workhorse 600 kHz ADCP. See the RDI documentation for details on this file format.
- `WP2017_STTM_V20.pd0` is the source file from the STTM’S upward-looking Teledyne RDI Sentinel V20 ADCP.

MATLAB Files

- `WP2017_STTM_v20.mat` is the MATLAB .mat file saved after reading in `WP_SMB02_V20_May2017.pd0` using the `rdradcp` function from RDADCP_Jan18v0 at https://www.eoas.ubc.ca/~rich/#RDADCP. Data are in beam coordinates. The velocity data need bin mapping and motion correction, neither of which has been done. Here, the only data used is the depth data; it is used to calculate the STTM’s height above the bottom.

DOLfYN/HDF5 Files

- `WP2017_STTM_ADVport_read_from_VEC_INST_d112.h5` is the port ADV data from file `WP2017_STTM_ADVport.VEC`, plus: defining parameters needed for motion correction, and updating the orientation matrix for magnetic declination. Data are in the instrument coordinate system.

- WP2017_STTM_ADVstbd_read_from_VEC_INST_d112.h5 is the starboard ADV data from file WP2017_STTM_ADVstbd.VEC, defining parameters needed for motion correction, and updating the orientation matrix for magnetic declination. Data are in the instrument coordinate system.
- WP2017_STTM_ADVstbd_clnETU_d112.h5 contains the starboard ADV data after cropping and cleaning the data following the Goring and Nikora

(2002) despiking method, with Wahl (2003) correction.

- WP2017_STTM_ADVstbd_d112_w_ulow_waterdepth_ETU.h5 contains the starboard ADV data after motion correcting and calculating the low frequency translational motion of the STTM recorded by the STTM's downward-looking RDI Workhorse 600 kHz ADCP in order to fully motion correct the STTM's starboard Nortek Vector velocity data, and calculating MLLW.
- WP2017_STTM_ADVstbd_d112_ETU_5min.h5 is the starboard ADV data after calculating 5-minute means and turbulence statistics.
- WP2017_STTM_RDI_read_from_000_ETU_d112.h5 contains the data in WP2017_STTM_RDI.000 and corrected for magnetic declination.
- WP2017_STTM_RDI_timesynced2ADVs_clnETU_d112.h5 contains the STTM's downward-looking Teledyne RDI Workhorse 600 kHz ADCP data saved after syncing the Workhorse time stamp to the starboard Nortek Vector time stamp.
- WP2017_STTM_RDI_d112_5min_ETU.h5 contains the 5-minute means of the vertically binned velocity data from the STTM's downward-looking Teledyne RDI Workhorse 600 kHz ADCP.

CSV Files

- WP2017_STTM_ADVstbd_corrected_RDI_time_1H_Bins.csv This is the time correlation data between the Starboard ADV and the down-looking ADCP on the STTM.
- WP2017_STTM_ADVstbd_d112_ETU_5min.csv This is the 5-minute averaged starboard ADV data. Rows are timesteps, columns are:
  - East vel [m/s]: true eastward velocity component
  - North vel [m/s]: true northward velocity component
  - Up vel [m/s]: upward velocity component
  - Horizontal Velocity Mag. [m/s]: horizontal velocity magnitude
  - water depth [m]: full water column depth at the STTM station
  - height above bottom [m]: height of the STTM above the seabed
  - depth below surface [m]: depth of the STTM below the water surface

- `Turbulence Intensity [-]`: turbulence intensity calculated using horizontal velocity magnitude and with Doppler noise removed, units: nondimensional
- `u'u' [m^2/s^2]`: East component of TKE
- `v'v' [m^2/s^2]`: North component of TKE
- `w'w' [m^2/s^2]`: Up component of TKE
- `Temperature [C]`: water temperature measured at the end bell of the Vector

STTM Data Processing

See the `process_STTM.py` script for a complete description of the data processing that generated the `.csv` and '.h5 files. A summary is:

- Raw files have been imported from the starboard Vector and the STTM's downward-looking RDI Workhorse
- Raw files have been read, cropped, cleaned, and .h5 files have been saved in ETU coordinates
- The starboard Vector and STTM's downward-looking RDI Workhorse timestamps have been time synced. Done externally then imported here.
- The starboard Vector data has been motion corrected following the method described in Kilcher et.al. 2017
- The 'rotational' motion of STTM's downward-looking RDI Workhorse's head has been calculated and added to datADVs.orient as 'ulow_rot'
- The 0.66 Hz RDI bt_vel and bt_range have been interpolated up to 16 Hz to match the datADVs data and named `datADVs.orient['ulow_bt']` and `datADVs.orient['ulow_bt_range']`. The low frequency motion of the STTM has been calculated as `datADVs.orient['ulow'] = low pass filter (datADVs.orient['ulow_bt'] + datADVs.orient['ulow_rot'])`. `datADVs.props['rotate vars']` have been updated to include ulow and ulow_rot.
- Water depth at the STTM has been calculated using the depth data from the upward-looking Teledyne RDI V20 Sentinel ADCP. The V20 was upward-looking on the STTM, but the data is only being used to calculate depth of the STTM
- `dat['vel']` has been updated to be: `vel = velraw + velrot + velacc - ulow_bt + ulow_rot`
- TurbBinner has been used to calculate 5-minute means for ADV in ETU (East, True North, Up)
- TurbBinner has been used to calculate 5-minute means for SMBworkhorse in ETU (East, True North, Up)

- Raw file has been imported from the port Vector. No additional processing to these data have been performed.
- Some of the the Starboard Vector variables have been exported to .csv

Mobile Transects

A ship-mounted, downward looking 300kHz ADCP data was used to conduct the mobile transect survey in the Western Passage, on the border of Maine, USA, and New Brunswick, Canada. The data was collected April 5 and 6, 2017. The transects target three lines, defined by the following points (A to B):

- Line 1: `66° 59.561 W', 44° 55.268' N` to `66° 59.267 W', 44° 55.477' N`
- Line 2: `66° 59.422 W', 44° 55.185' N` to `66° 59.125 W', 44° 55.395' N`
- Line 3: `66° 59.281 W', 44° 55.101' N` to `66° 59.984 W', 44° 55.309' N`

There are a total of 86 transects in this folder. 42 transects were made on April 5, and 44 on April 6. The `WP2017_MobileTransect_LOG.xlsx` file catalogues the time and target-transect of each file (including direction denoted by "B-A" or "A-B"). All timestamps (in the log and in the data files) are in Maine local time (UTC-4).

Mobile Transects Data Files

All mobile transect data is contained in the `WP2017_MobileTransect_RDI300_ALLDATA.zip` file. Within that file, the data is organized as described below.

The transect data files have the following naming convention:

`WP2017_MobileTransect_RDI300_###.<ext>`

Where `###` indicates the transect number, and `.<ext>` is one of the following file extensions:

- `.PD0` files are the source RDI ADCP files. See the RDI documentation for details on this file format.
- `.h5` contain all of the data after processing.
- `.csv.zip` files are the processed data in a set of csv files that have been zipped together into a single zip file. The zip files contain the following files:
  - `WP2017_MobileTransect_RDI300_###.EAST.csv`, magnetic eastward velocity component, units: m/s. Columns are depth bins, with the headers indicating the depth in m. Rows are timesteps.
  - `WP2017_MobileTransect_RDI300_###.NORTH.csv`, magnetic northward velocity component. Format the same as `.EAST.csv`

– WP2017_MobileTransect_RDI300_###.UP.csv, upward velocity component, units: m/s. Format the same as .EAST.csv

– WP2017_MobileTransect_RDI300_###.ERROR.csv: RDI-defined error velocity, units: m/s. Format the same as .EAST.csv

– WP2017_MobileTransect_RDI300_###.INFO.csv: Latitude (Lat), Longitude (Long), bottom depth in meters (bottom_m), temperature measured at the instrument head in degrees C (temp_C).

Mobile Transects Data Processing

A complete description of data processing can be found in process_transects.py. A summary is:

- Ship motion velocity subtracted from measurements
- Data has been cleared (i.e., "NaN'd") below 90% of the water depth
- Apply an 11-timestep by 11-depth bin median filter to the data. This heavy filtering was applied because the data is very noisy in many transects, especially below ~30 m
- Set bottom velocity to zero
- Fill gaps in the data both vertically and temporally

Additional Data

- WP2017_TideMet_NDBC_PSBM1.mat is a MATLAB file of tidal height and meteorological measurements created using data from NDBC Station PSBM1 - 8410140 - Eastport, ME.
- wp2017_processing.zip contains the Python scripts that were used to process the data.
- Link to DOLfYN 0.11.2 is the version of dolfyn used for processing this data.