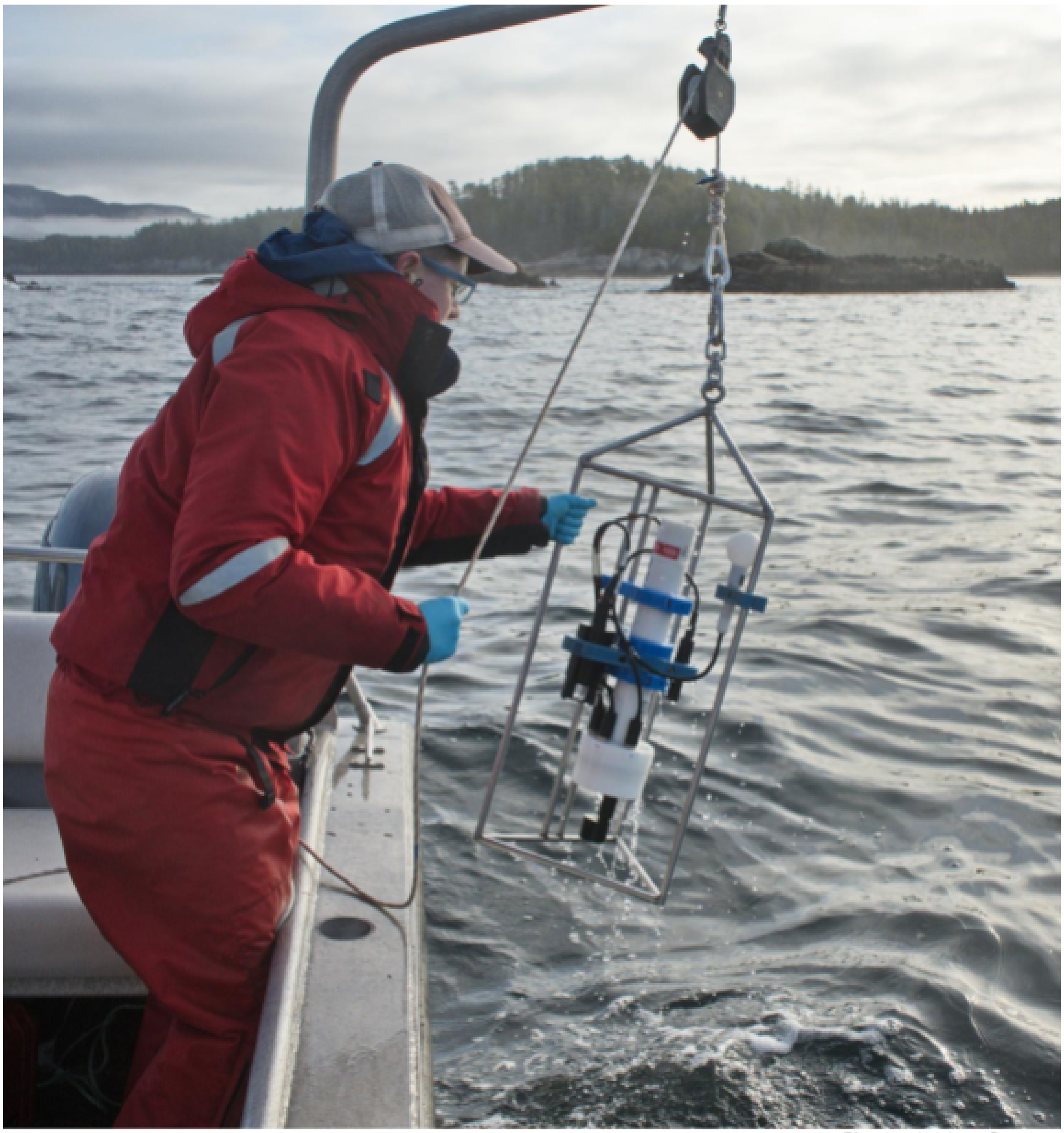
Hakai Water Properties Profile Processing and QA/QC Procedure Manual

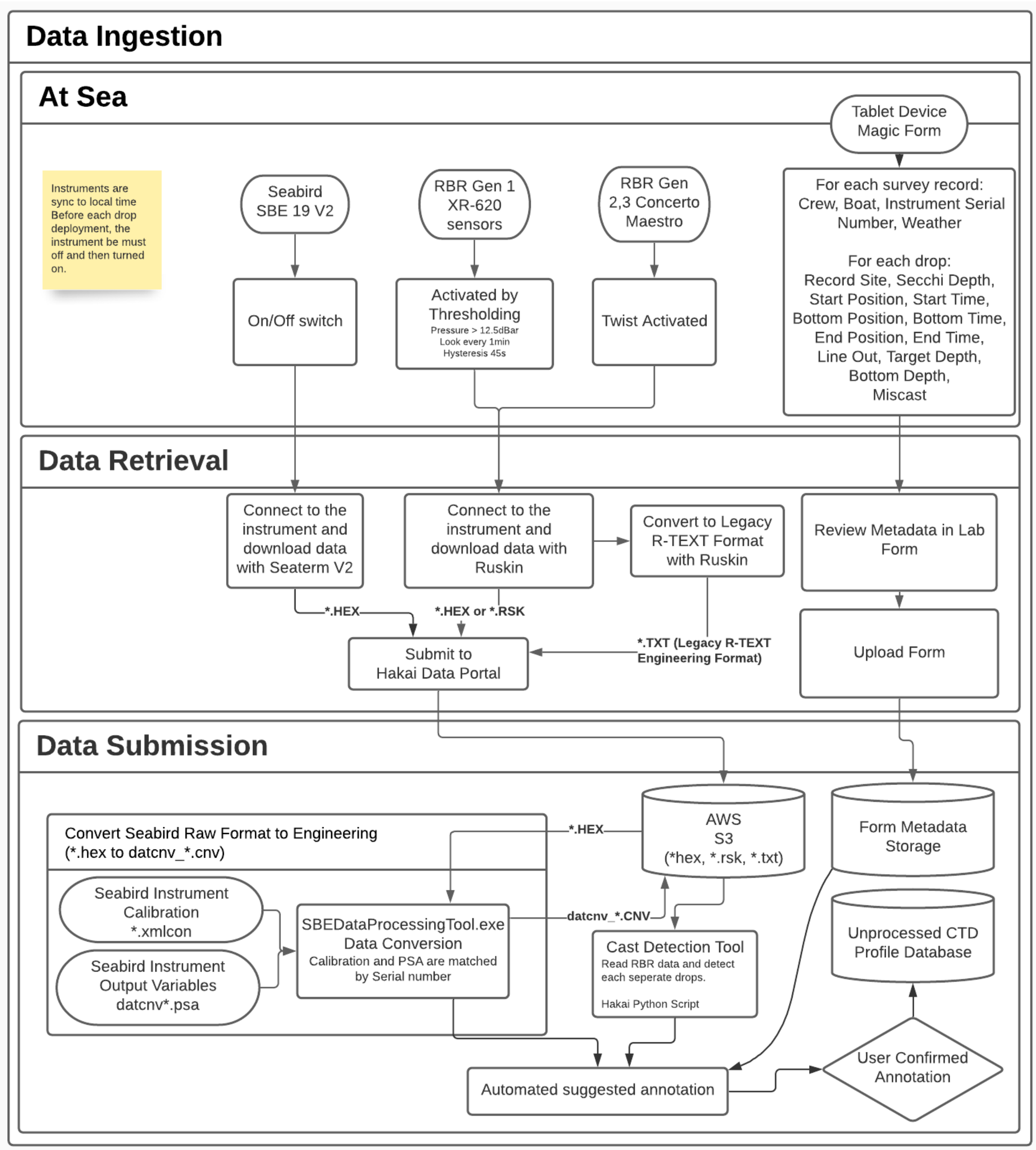


Photography: Jessy Barrette

Table Of Contents

General Field Workflow Procedure

The Hakai Institute Oceanographic Profiler Deployment Protocole follow the different points described below:



Instrument Internal Clock Time Zone Sync

Instrument internal clock is synchronized to the local Pacific time zone, which alternates between Pacific Standard Time (PST) and Pacific Daylight Time (PDT), with daylight savings. The time is labeled accordingly as PST or PDT.

Field Procedure

- Instrument is soaked at a target depth of 2 meters for 2 minutes prior to collecting the profile.
- Instrument is brought back near surface:
    a. RBR XR-620 instruments are brought out of the water for a brief inspection to confirm the instrument is running properly, due to the thresholding method used to activate the instrument.
    b. Other instruments (RBR twist-activated units or Seabird SBE19plus v2 units) are brought to just below the surface.
- Record start time and location.
- Instruments are lowered through the water column at a target speed of 1 m/s:
    a. RBR Instruments are free falled
    b. Seabird Instruments are lowered.
- Instrument is lowered to target depth which is based on the depth sounder and rope length and generally few meters above bottom.
- Record bottom time and location.
- Once at the bottom depth, the instrument is retrieved by using a winch or a crab pot hauler style system at a speed of 1-2 m/s.
- Once near the surface, the instrument is brought back on deck
- Record end time and location.
- Turn instrument off.
- Metadata related to the instrument used, location and time are recorded through an electronic form on a tablet.

Laboratory Procedure

Instrument data

Back from the field, the instrument raw data are downloaded by using the manufacturer software (Seaterm v2, RBR Ruskin). RBR instruments raw data are converted to the Legacy R-Text Engineering format within Ruskin. All raw files retrieved are then uploaded to the Hakai servers through the Hakai Portal website.

- Seabird Instruments
    - Produce one .hex file per profile.
- RBR
    - XR-620 instruments produce one *.hex file per survey.
    - Concerto and Maestro units produce one *.rsk file per survey.
    - Both *.hex and *.rsk are converted to the Ruskin Legacy R-Eng format.

Hakai servers retrieve RBR Instrument data and detect each profile available within the initial time series with a Hakai proprietary Cast Detection algorithm.

Metadata

Metadata forms are reviewed in the lab by field technicians before being submitted to the Hakai Servers.

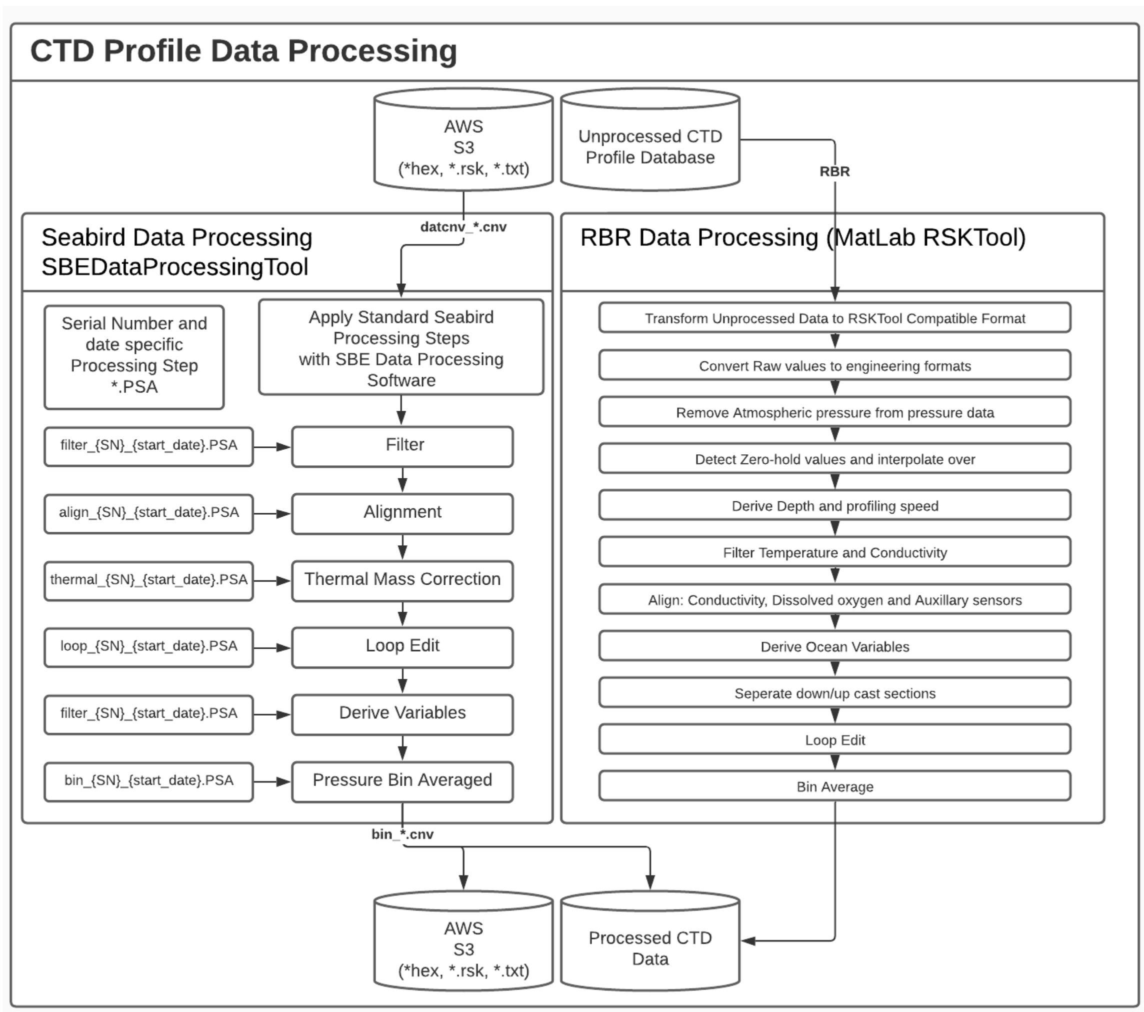
Data Annotation

Once metadata and data are submitted, field technicians can annotate each instrument deployment and link the field form metadata with the associated instrument profile.

Following data annotation, processed data are stored within the Hakai database alongside the original raw data, which is also transferred to the Hakai Vertical Water Properties Processing algorithm.

Automated Data Processing

Each instrument's raw data are processed by following the guidelines enumerated within the [RBR Data Processing Guidelines Document] and the [Seabird Data Processing Manual] (see SBE19v2 instrument). Each section below represents an individual step and associated parameters applied to each sensor type.
The objective of this step is to obtain a uniform 1 decibar bin averaged data product with resulting data comparable between each manufacturer.



RBR Instruments (XR-620, Concerto, Maestro)

1. Convert Ruskin R-Eng Text format to RSKTool compatible format
2. Correct Sea Pressure for atmospheric pressure:
    a. Use post deployment deck pressure
    b. Use a constant of 10.1325 dbar
3. Correct Zero-order hold values (Maestro units): Pressure, Temperature and Conductivity
4. Derive Depth and Profiling Velocity
    a. Derive Depth based on the deployed station latitude.
    b. Derive Profiling velocity from depth filtered with a window length of 3 samples.
5. Filter Correction
    a. Apply a 0.5s triangle filter on: Temperature and Conductivity
    b. Apply a 1s triangle filter on
6. Alignment Correction
    a. Conductivity Alignment
        i. 1st Generation Conductivity Cell (black cell): +0.333s
        ii. 2nd Generation Conductivity Cell (red cell): +0.04s[1]
    b. Dissolved Oxygen
        i. JFE Rinko Sensor: -3.0s
        ii. RBR CodaL: Unknown
    c. Turbidity: -0.25s
    d. Fluorescence: -0.25s
7. Derive Variables
    a. [TEOS-10] Practical Salinity
    b. Dissolved Oxygen Concentration (mL/L) derived from Rinko saturation percentage value by following the conversion equations from *Bittig et al. (2018)*[2] and 4.175s triangle filtered Temperature, Salinity and Pressure values.
8. Separate up and down cast
9. Loop Edit Correction:
    a. Minimum Speed: 0.25 m/s
    b. Maximum Deceleration: -0.5m/s^2
10. Vertical Bin Average
    a. Bin type: decibar
    b. Bin size: 1

[1] Dever et al. (2020) https://doi.org/10.1175/JTECH-D-19-0145.1

[2] Bittig et al. (2018): SCOR WG 142 Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders. Recommendations on the conversion between oxygen quantities for Bio-Argo floats and other autonomous sensor platforms, DOI (10.13155/45915)

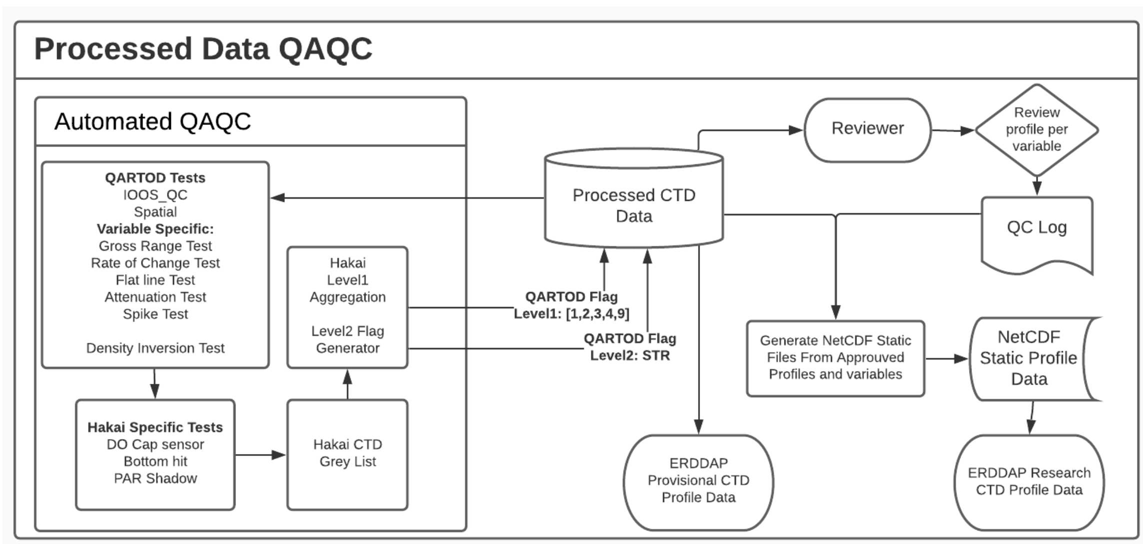
Seabird (SBE 19plus v2)

Every step described here is executed within the Seabird Data Processing Software.

1. Ignore the first minute of data (240 records at 4Hz) which includes data recorded while the instrument is lowered to the soak depth.
2. Low-Pass Filter Correction:
    a. Low pass filter = 0.5: Temperature, Conductivity, Transmissivity, Absorbance, Rinko Oxygen Sensor
    b. Low pass filter = 1: Pressure
3. Alignment Correction
    a. Temperature: 0.50s
    b. Seabird Oxygen (SBE43) Voltage: 3.00s
    c. Fluorescence: 0.25s
    d. Transmissometry (CStar): 0.35s
    e. Rinko Oxygen Voltages: 2.00s
4. Thermal Mass Correction
    a. alpha = 0.0400
    b. beta = 8.0000
5. Loop Edit Correction
    a. Minimum Speed: 0.25m/s
    b. Soak Detection
        i. Minimum Depth: 1 m
        ii. Maximum Depth: 5 m
        iii. Use Deck Pressure: Yes
6. Derive Practical Salinity [Constant Geographic Position: 50N, 125W]
7. Derive Oxygen Concentration from raw voltage
    a. docdt = 2s
    b. tau correction = Yes
8. Vertical Bin Average
    a. Bin type = decibars
    b. Bin Size = 1
    c. Exclude bad scans = Yes
    d. Skip over = 20
    e. No surface bin

Water Properties Vertical Profile QA/QC

Once Hakai Water Properties Profile data are processed, a series of tests is applied to detect any suspicious, abnormal or bad values within the dataset. The different tests applied are presented below. Hakai uses an implementation of the ioos_qc python package.



Flag Convention

Hakai uses the QARTOD flag convention which is based on UNESCO 2013[3]. For each variable two flag level are used:

- Level 1 Flag is a single flag value [1, 2, 3, 4, 9] which is the aggregation of the different flags resulting from every test for this record with prevalence to flag values in that specific order [9, 2, 1, 3,4].
- Level 2 Flag is a text description per record that provides the complete list of flags for which the test result was reported as Suspect(3) or Fail(4).

[3] U.S. Integrated Ocean Observing System, 2017. Manual for the Use of Real-Time Oceanographic Data Quality Control Flags, Version 1.1. 43 pp.

Flag	Description
Pass=1	Data have passed critical real-time quality control tests and are deemed adequate for use as preliminary data.
Not evaluated=2	Data have not been QC-tested, or the information on quality is not available.
Suspect or Of High Interest=3	Data are considered to be either suspect or of high interest to data providers and users. They are flagged suspect to draw further attention to them by operators.
Fail=4	Data are considered to have failed one or more critical real-time QC checks. If they are disseminated at all, it should be readily apparent that they are not of acceptable quality.
Missing data=9	Data are missing; used as a placeholder.

QARTOD Tests

Below is the list of tests and thresholds applied for each variable, please refer to the [Hakai Institute Profile QC Tests List](#) for a more up to date test list:

Variable	Test	Parameters
position	location_test	{bbox: [-180, -90, 180, 90] target_range: 3000}
pressure	gross_range_test	{suspect_span: [0, 12000] fail_span: [0, 12000] maximum_suspect_depth_ratio: 1.05 maximum_fail_depth_ratio: 1.1}
depth	gross_range_test	{suspect_span: [0, 12000] fail_span: [0, 12000] maximum_suspect_depth_ratio: 1.05 maximum_fail_depth_ratio: 1.1}
dissolved_oxygen_ml_l	attenuated_signal_test	{suspect_threshold: 0.1 fail_threshold: 0.01 check_type: 'range'}
dissolved_oxygen_ml_l	gross_range_test	{fail_span: [0, 20] suspect_span: [1, 15]}
dissolved_oxygen_ml_l	rate_of_change_test	{threshold: 3}
dissolved_oxygen_percent	attenuated_signal_test	{suspect_threshold: 0.1 fail_threshold: 0.01 check_type: 'range'}
dissolved_oxygen_percent	gross_range_test	{fail_span: [-1, 150] suspect_span: [0, 140]}
dissolved_oxygen_percent	rate_of_change_test	{threshold: 30}
rinko_do_ml_l	attenuated_signal_test	{suspect_threshold: 0.1 fail_threshold: 0.01 check_type: 'range'}
rinko_do_ml_l	gross_range_test	{fail_span: [0, 20] suspect_span: [1, 15]}
rinko_do_ml_l	rate_of_change_test	{threshold: 3}
turbidity	attenuated_signal_test	{suspect_threshold: 0.01 fail_threshold: 0.001 check_type: 'range'}
turbidity	gross_range_test	{fail_span: [-0.1, 10000] suspect_span: [0, 1000]}
c_star_at	attenuated_signal_test	{suspect_threshold: 0.002 fail_threshold: 0.0001 check_type: 'range'}
par	attenuated_signal_test	{suspect_threshold: 0.05 fail_threshold: 0.02 check_type: 'std' min_obs: 5}
par	gross_range_test	{fail_span: [-2, 100000] suspect_span: [-1, 50000]}
salinity	gross_range_test	{fail_span: [0, 45] suspect_span: [2, 42]}
salinity	rate_of_change_test	{threshold: 5}
temperature	gross_range_test	{fail_span: [-2, 100] suspect_span: [-2, 40]}

temperature	rate_of_change_test	{threshold: 5}
conductivity	gross_range_test	{fail_span: [-0.1, 100] suspect_span: [0, 100]}
sigma0	density_inversion_test	{suspect_threshold: -0.005 fail_threshold: -0.03}
flc	gross_range_test	{fail_span: [-0.5, 150] suspect_span: [-0.1, 80]}

To execute the density inversion test, Hakai derives the potential density at the surface (0dbar) by using the TEOS-10 equations and deriving in the order of absolute salinity, conservative temperature, and potential density at the surface (sigma0).

Hakai Specific Tests

Hakai has developed a series of tests to detect known issues related to its dataset and sensors. A brief description of each of the tests follows below:

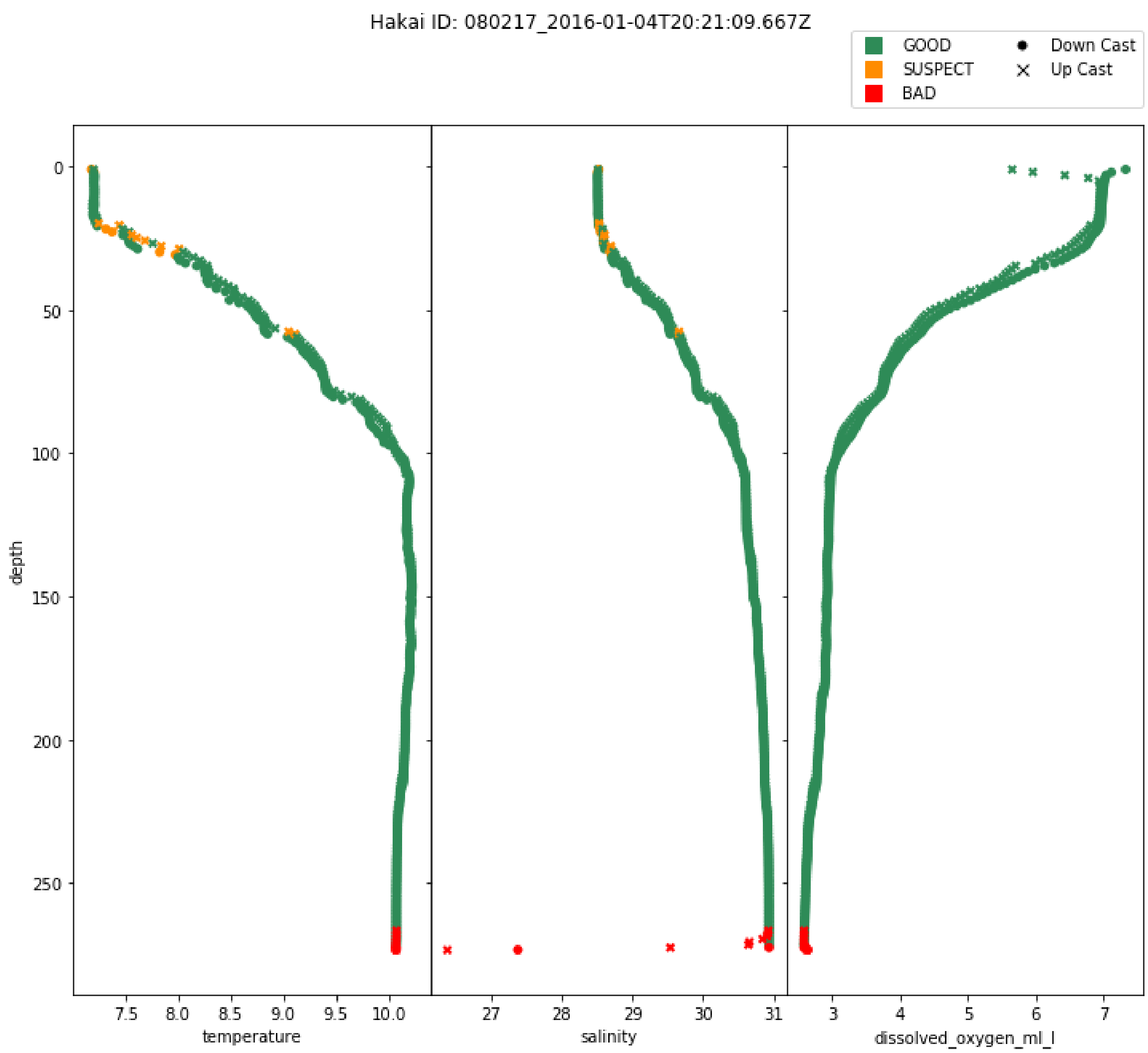
Bad Value Test

Seabird instrument data within the Hakai Water Properties Profile dataset contains occasional flag values (-9.99E-29) generated by the Seabird Processing Software. Hakai reviews available data and assigns a FAIL (4) flag to associated records.

Bottom Hit Detection Test

Infrequently, Hakai instrumentation hits the sea floor which can have a major impact on data recorded by all sensors. Hakai uses the QARTOD density inversion test if an instrument hits bottom. A bottom hit has a great impact on the conductivity sensor which gets covered by bottom sediments and greatly reduces the conductivity value recorded by the sensor. Reduced conductivity impacts and reduces the derived density, triggering the density inversion test if the inversion is higher than the set thresholds for *suspect* or *fail*.

Any successive records starting from the bottom of a profile associated with a density inversion is applied a FAIL flag. This flag is applied to every variable.



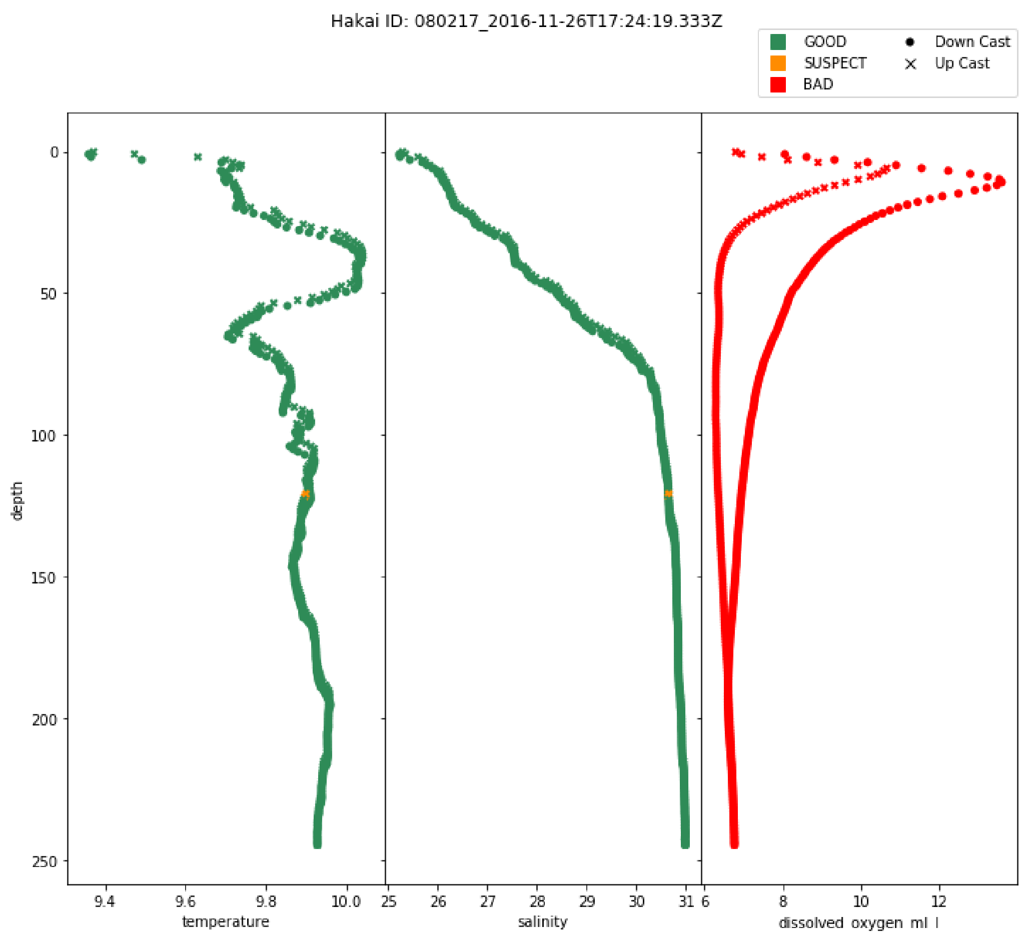
Dissolved Oxygen Sensor Cap Detection Test

Occasionally, Hakai's field technicians omit to remove the protective cap over the JFE Rinko dissolved oxygen sensor which makes any associated data unusable. In such cases, the oxygen value recorded is obviously bad and needs to be flagged. Generally, the dissolved oxygen signal recorded by the sensor presents a slow negative trend over time during the deployment which is depth independent. To detect this issue, we compare both the up and down cast associated with a profile and compute the difference in dissolved oxygen concentration recorded by each profile for the same pressure bin.

If the dissolved oxygen concentration difference between the up and down cast exceed for more than 50% of the profile:

- ΔDO > 0.2 mL/L: flag as SUSPECT
- ΔDO > 0.5 mL/L: flag as FAIL

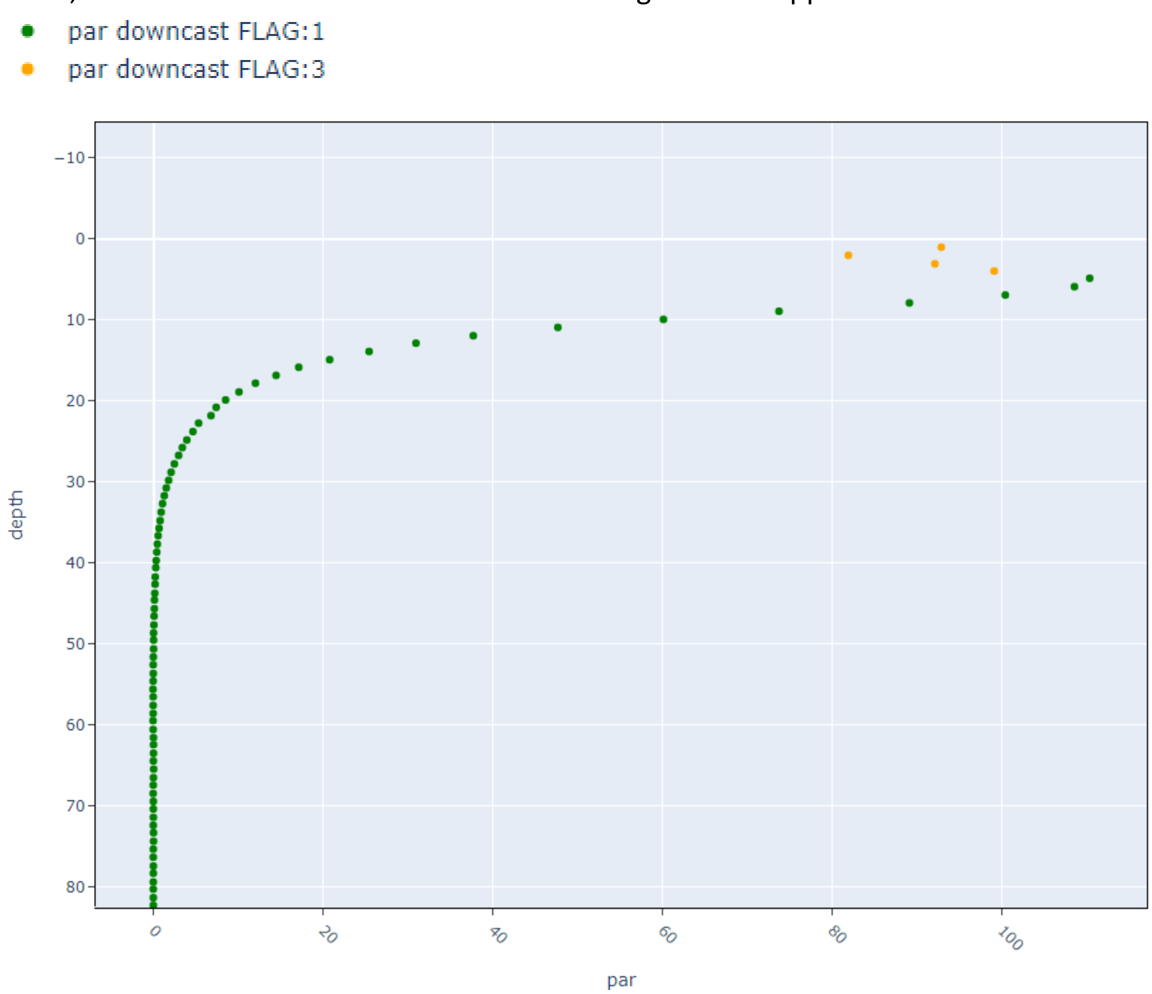
A minimum of 10m of comparable data (up vs down cast) is necessary to apply the test.



Boat PAR Shadow Test

Photosynthetically Active Radiation data are highly sensitive to the position on the ship where the instrument is deployed compared to the sun. If deployed along the opposite side of the ship to the sun, boat shadow affects measurements for the first few meters near the surface. This will be represented in a PAR profile by a sudden increase in PAR values once the instrument gets away from the ship shadow. To detect this issue, we analyse the PAR profile from the bottom going to the surface and flag any data which are lower than the maximum value recorded up until this depth in the vertical profile.

In normal conditions, we should expect PAR to follow an exponential decay with depth, going from the bottom to the surface; this means that a PAR profile should always be increasing as it goes closer to the surface. To ignore any noise effect related to lower value, we set a minimum value from which the algorithm is applied.



Provisional and Research Datasets

Hakai provides two version of the same dataset:

- The provisional dataset corresponds to all the data collected including the data which have not been manually reviewed and quality controlled. QARTOD flag values are associated with each variable and record that can be used to filter data considered GOOD, SUSPECT or FAIl.
- The Research Dataset corresponds exclusively to the data which were manually reviewed and considered as good. Any data which failed the automated tests or the manual QC are automatically rejected from this dataset.