2018 Baja Saildrone Cruise

Funding by The Schmidt Family Foundation, Saildrone, and NASA Physical Oceanography

11 April to 11 June 2018

Important information: For this cruise, all retrievals are unvalidated at this time. From initial analysis, all retrievals appear to be of high quality except the skin SSTs. Skin SSTs for this cruise are of limited utility due to the uncorrected reflected sky radiation. Please see USV description for more information.

Saildrone Unmanned Surface Vehicle returning from cruise on 11 June 2018. Image credit: Saildrone, Inc.

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Saildrone Baja 2018 Cruise Science Team

Table 1. Science Team

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Saildrone Baja 2018 Cruise Saildrone Team

Table 2. Saildrone team

Name	**Role**	**Focus**	**Email**
Richard Jenkins	Chief Executive Officer	Vehicle Design / Assembly / Operations	richard@saildrone.com

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Cruise Narrative

The Saildrone unmanned surface vehicle (USV) collected data on a 60-day cruise from San Francisco Bay, down along the US/Mexico coast to Guadalupe Island and back, during 11 April 2018 to 11 June 2018. The cruise track was selected to optimize both the science and validation objectives included in these projects. The scientific objectives include studies of upwelling dynamics, air-sea interactions including frontal regions, and diurnal warming regions, and ocean ecology. The validation objectives include establishing the utility of Saildrone measurements for inclusion into ocean models, validation of glider observations, and validation of satellite-derived fluxes, sea surface temperatures, ocean currents, and wind vectors.

The basic plan was to sail from San Francisco to Baja Mexico, with repeat surveys around NDBC moored buoys, and about one week at the end of the cruise sampling a targeted front, with sampling both along and across wind directions.

The Saildrone USV carried it's normal suite of instruments plus 4 additional temperature loggers supplied by Julian Schanze through NASA's Physical Oceanography Program (Table 3). These additional temperature loggers were added to provide information on thermal variability in the upper ocean.

During the cruise, the team collaborated via Google Hangouts to direct the USV's path. Near-real time VIIRS and GOES SSTs were used to identify interesting features that could be sampled without deviating significantly from the original cruise path and respond to changes in expected USV speeds (both faster and slower).

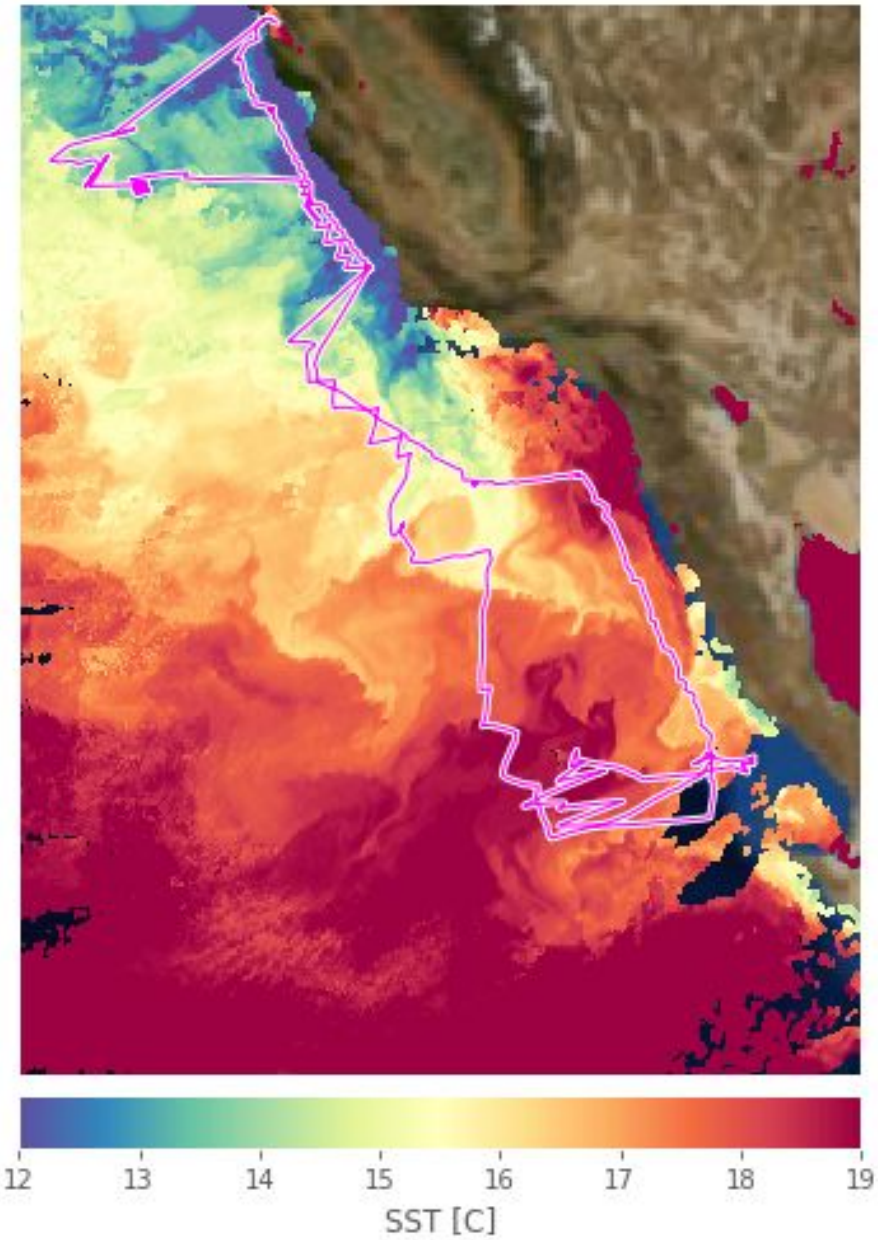

Figure 1. Overall cruise track for the 2018 Baja Saildrone cruise. VIIRS SSTs are in the background. The prevalent wind direction was to the South, as seen by the relatively straight lines on the downward portion of the cruise, and the zig-zags (tacks) back-and-forth on the return leg.

General Timeline for Saildrone SD-1002, 11 April - 11 June 2018

April 11 : Depart SF, sail to buoy 46042

April 13: arrive at 46042, circle location, sail to 46239

April : arrive 46239, circle location, sail to 46011

April : arrive 46011, circle location, sail to SIO glider line

April : follow glider line to 46047

April: arrive 46047, circle location, sail to 46086

April 20: arrive 46086, circle location

April 21-26: sail along Baja coast to 28.428094, -116.114588 to meet up with Prof. Gomez lagrangian drifters.

April 27 - May 11: sail in region near Guadalupe Island with strong fronts and diurnal warming.

May 12: sail northward to 46412

May 26: arrive 46412, sail to 46011

May 31: arrive 46011, sail to 36.296167, -125.334668 where strong front exists

June 4-9: sample frontal region

June 9: sail towards SF bay

June 11: recover vehicle

USV description

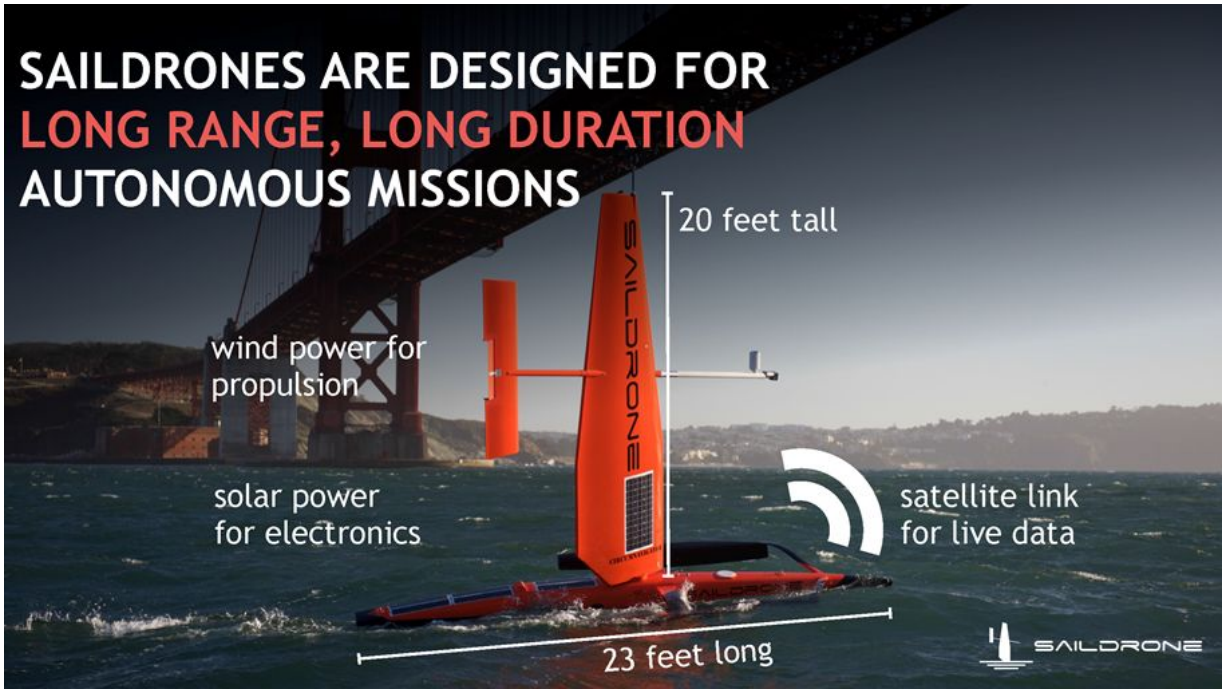

Figure 2. Dimensions of USV. Figure credit Saildrone, Inc.

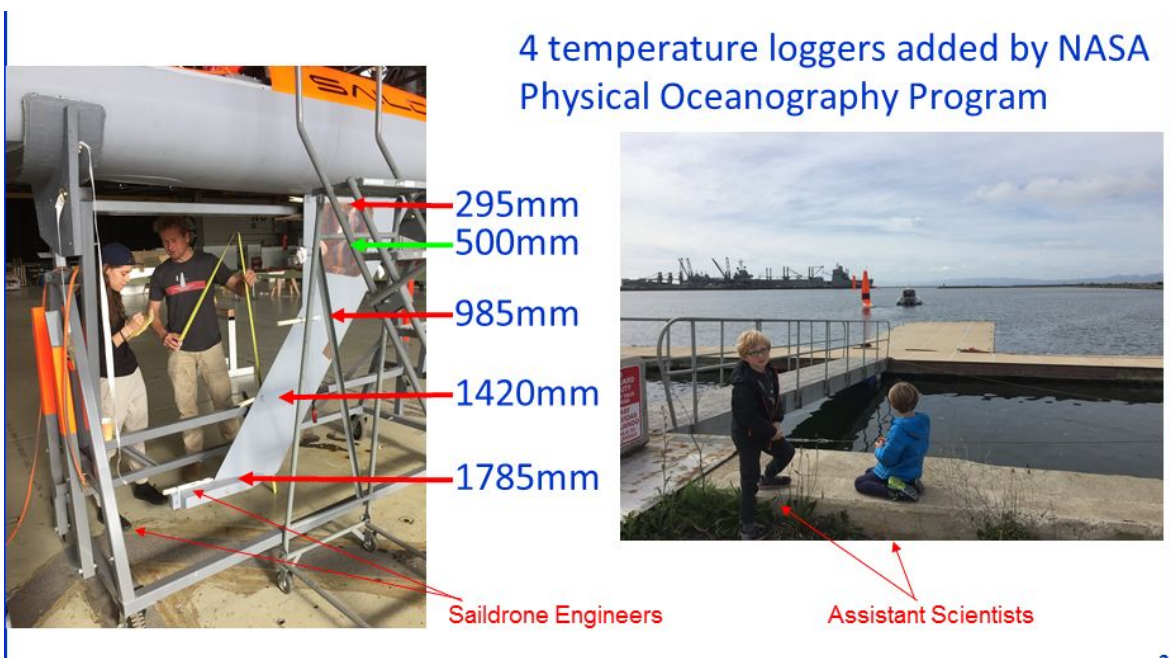

Figure 3. Installation of temperature loggers (left) and launch of USV (right).

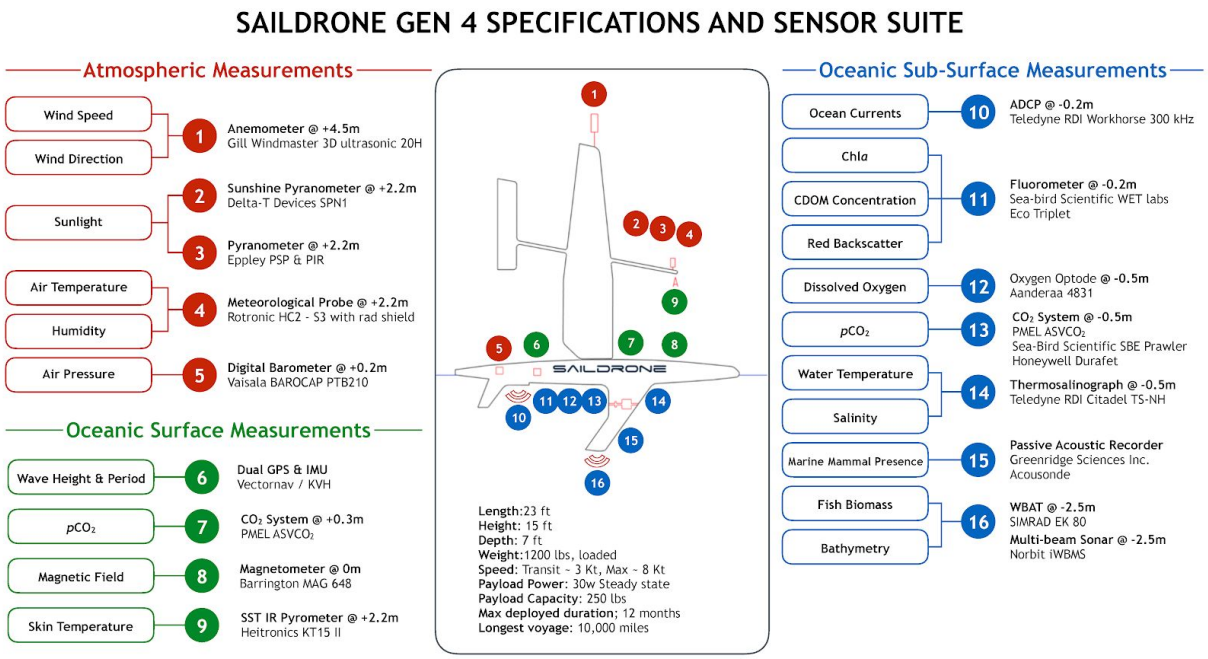

Figure 4. Saildrone USV instrumentation placement. Not all instruments in figure were installed for this cruise.

Table 1. Saildrone sensors

Instrument	Observations	Sampling Schedule Centered at :00	Height (m)
	WING		
Gill 1590-PK-020	3D Wind Dir, Speed & Gust	60s on, 240s off	5
Rotronic Hygroclip2	Air temperature, Relative Humidity	60s on, 240s off	2.4
Heitronics KT15.82.IIP	Skin sea surface temperature	30s on, 270s off	0
4 x USB cams	Visible Cameras		
	HULL		
Teledyne Citadel CTD-NH	Seawater temperature, seawater salinity	12s on, 48s off	-0.6
Aanderaa Oxygen Optode	Seawater oxygen fractional	10s on, 50s off	-0.6

	saturation		
WET Labs Eco Triplet-w	Chlorophyll concentration, colored dissolved organic matter concentration, Optical backscatter at 650 nm	10s on, 50s off	-0.25
Vaisala PTB 210 A1A1B	Air pressure	60s on, 240s off	
Teledyne Workhorse 300khz	3D surface velocities		
Seabird 56 (four)	Seawater temperature	2s on, 2 sec off	-0.295 -0.985 -1.420 -1.785

Table 2. Information on the Saildrone USV in situ dataset. This table is meant to accompany the Saildrone data description. See the report for more details on each dataset. This table describes the data from the standard vehicle payload.

Variable Name	Variable	Sensor Description	Model Name	Link to Product Webpage	Installed Height (m)	Sampling Schedule
BARO_PRES_MEAN	air_pressure	Vaisala Barometer	Vaisala : PTB210	http://www.vaisala.com/en/products/pressure/Pages/PTB210.aspx	0.3	60s on, 240s off, centered at :00
BARO_PRES_STDDEV	air_pressure	Vaisala Barometer	Vaisala : PTB210	http://www.vaisala.com/en/products/pressure/Pages/PTB210.aspx	0.3	60s on, 240s off, centered at :00
BKSCT_RED_MEAN		WET Labs Fluorometer	WET Labs : BBFL2W	http://wetlabs.com/eco-triplet-w	-0.25	10s on, 50s off, centered at :00
BKSCT_RED_STDDEV		WET Labs Fluorometer	WET Labs : BBFL2W	http://wetlabs.com/eco-triplet-w	-0.25	10s on, 50s off, centered at :00
CDOM_MEAN	concentration_of_colored_dissolved_organic_matter_in_sea_water_expressed_as_	WET Labs Fluorometer	WET Labs : BBFL2W	http://wetlabs.com/eco-triplet-w	-0.25	10s on, 50s off, centered at :00

	equivalent_mass_fraction_of_quinine_sulfate_dihydrate					
CDOM_STDDEV	concentration_of_colored_dissolved_organic_matter_in_sea_water_expressed_as_equivalent_mass_fraction_of_quinine_sulfate_dihydrate	WET Labs Fluorometer	WET Labs : BBFL2W	http://wetlabs.com/eco-triplet-w	-0.25	10s on, 50s off, centered at :00
CHLOR_MEAN	mass_concentration_of_chlorophyll_in_sea_water	WET Labs Fluorometer	WET Labs : BBFL2W	http://wetlabs.com/eco-triplet-w	-0.25	10s on, 50s off, centered at :00
CHLOR_STDDEV	mass_concentration_of_chlorophyll_in_sea_water	WET Labs Fluorometer	WET Labs : BBFL2W	http://wetlabs.com/eco-triplet-w	-0.25	10s on, 50s off, centered at :00
COG	platform_course					
COND_MEAN	sea_water_electrical_conductivity	Teledyne CTD	Teledyne : Citadel CTD-NH-0-000110-500-500-0	http://rdinstruments.com/product/ctd/citadel-ctd-nh	-0.6	12s on, 48s off, centered at :00
COND_STDDEV	sea_water_electrical_conductivity	Teledyne CTD	Teledyne : Citadel CTD-NH-0-000110-500-500-0	http://rdinstruments.com/product/ctd/citadel-ctd-nh	-0.6	12s on, 48s off, centered at :00
GUST_WND_MEAN	wind_speed_of_gust	Gill Anemometer	Gill : 1590-PK-020	http://gillinstruments.com/products/anemometer/windmaster.htm	5	60s on, 240s off, centered at :00
GUST_WND_STDDEV	wind_speed_of_gust	Gill Anemometer	Gill : 1590-PK-020	http://gillinstruments.com/products/anemometer/windmaster.htm	5	60s on, 240s off, centered at :00
HDG	platform_yaw_angle					
HDG_WING						
O2_CONC_UNCOR_MEAN	mole_concentration_of_dissolved_molecular_oxygen_in_sea_water	Aanderaa Dissolved Oxygen	Aanderaa : 4831	http://www.aanderaa.com/productsdetail.php?Oxygen-Optodes-2	-0.6	10s on, 50s off, centered at :00

O2_CONC_UNCOR_STDDEV	mole_concentration_of_dissolved_molecular_oxygen_in_sea_water	Aanderaa Dissolved Oxygen	Aanderaa : 4831	http://www.aanderaa.com/productsdetail.php?Oxygen-Optodes-2	-0.6	10s on, 50s off, centered at :00
O2_SAT_MEAN	fractional_saturation_of_oxygen_in_sea_water	Aanderaa Dissolved Oxygen	Aanderaa : 4831	http://www.aanderaa.com/productsdetail.php?Oxygen-Optodes-2	-0.6	10s on, 50s off, centered at :00
O2_SAT_STDDEV	fractional_saturation_of_oxygen_in_sea_water	Aanderaa Dissolved Oxygen	Aanderaa : 4831	http://www.aanderaa.com/productsdetail.php?Oxygen-Optodes-2	-0.6	10s on, 50s off, centered at :00
PITCH	platform_pitch_angle					
RH_MEAN	relative_humidity	Rotronic AT/RH	Rotronic : HC2-S3		2.4	60s on, 240s off, centered at :00
RH_STDDEV	relative_humidity	Rotronic AT/RH	Rotronic : HC2-S3		2.4	60s on, 240s off, centered at :00
ROLL	platform_roll_angle					
SAL_MEAN	sea_water_practical_salinity	Teledyne CTD	Teledyne : Citadel CTD-NH-0-000110-500-500-0	http://rdinstruments.com/product/ctd/citadel-ctd-nh	-0.6	12s on, 48s off, centered at :00
SAL_STDDEV	sea_water_practical_salinity	Teledyne CTD	Teledyne : Citadel CTD-NH-0-000110-500-500-0	http://rdinstruments.com/product/ctd/citadel-ctd-nh	-0.6	12s on, 48s off, centered at :00
SOG	platform_speed_wrt_ground					
TEMP_AIR_MEAN	air_temperature	Rotronic AT/RH	Rotronic : HC2-S3		2.4	60s on, 240s off, centered at :00
TEMP_AIR_STDDEV	air_temperature	Rotronic AT/RH	Rotronic : HC2-S3		2.4	60s on, 240s off, centered at :00
TEMP_CTD_MEAN	sea_water_temperature	Teledyne CTD	Teledyne : Citadel CTD-NH-0-000110-500-500-0	http://rdinstruments.com/product/ctd/citadel-ctd-nh	-0.6	12s on, 48s off, centered at :00

TEMP_CTD_STDDEV	sea_water_temperature	Teledyne CTD	Teledyne : Citadel CTD-NH-0-000110-500-500-0	http://rdinstruments.com/product/ctd/citadel-ctd-nh	-0.6	12s on, 48s off, centered at :00
TEMP_IR_UNCOR_MEAN	sea_surface_skin_temperature	Heitronics Wing IR Pyrometer	Heitronics : CT15.10		2.25	30s on, 270s off, centered at :00
TEMP_IR_UNCOR_STDDEV	sea_surface_skin_temperature	Heitronics Wing IR Pyrometer	Heitronics : CT15.10		2.25	30s on, 270s off, centered at :00
TEMP_O2_MEAN	sea_water_temperature	Aanderaa Dissolved Oxygen	Aanderaa : 4831	http://www.aanderaa.com/productsdetail.php?Oxygen-Optodes-2	-0.6	10s on, 50s off, centered at :00
TEMP_O2_STDDEV	sea_water_temperature	Aanderaa Dissolved Oxygen	Aanderaa : 4831	http://www.aanderaa.com/productsdetail.php?Oxygen-Optodes-2	-0.6	10s on, 50s off, centered at :00
UWND_MEAN	eastward_wind	Gill Anemometer	Gill : 1590-PK-020	http://gillinstruments.com/products/anemometer/windmaster.htm	5	60s on, 240s off, centered at :00
UWND_STDDEV	eastward_wind	Gill Anemometer	Gill : 1590-PK-020	http://gillinstruments.com/products/anemometer/windmaster.htm	5	60s on, 240s off, centered at :00
VWND_MEAN	northward_wind	Gill Anemometer	Gill : 1590-PK-020	http://gillinstruments.com/products/anemometer/windmaster.htm	5	60s on, 240s off, centered at :00
VWND_STDDEV	northward_wind	Gill Anemometer	Gill : 1590-PK-020	http://gillinstruments.com/products/anemometer/windmaster.htm	5	60s on, 240s off, centered at :00
WING_ANGLE						
WWND_MEAN	downward_air_velocity	Gill Anemometer	Gill : 1590-PK-020	http://gillinstruments.com/products/anemometer/windmaster.htm	5	60s on, 240s off, centered at :00
WWND_STDDEV	downward_air_velocity	Gill Anemometer	Gill : 1590-PK-020	http://gillinstruments.com/products/anemomete	5	60s on, 240s off, centered at :00

				r/windmaster.htm		
latitude	latitude	VectorNav IMU	VectorNav : VN-200 Wing	http://www.vectornav.com/products/vn200-smd		Always On
longitude	longitude	VectorNav IMU	VectorNav : VN-200 Wing	http://www.vectornav.com/products/vn200-smd		Always On
time	time					
trajectory						

Table 3. Information on the Saildrone ADCP in situ dataset. This table is meant to accompany the Saildrone data description. Instrument website: www.teledynemarine.com/workhorse-monitor-adcp

Variable Name	**Variable**
vel_east	east velocity
vel_north	north velocity
vel_up	vertical velocity
roll	platform roll angle
pitch	platform pitch angle
nav_start_time	navigation start time
nav_start_longitude	longitude of ensemble start
nav_start_latitude	latitude of ensemble start
nav_end_time	navigation end time
nav_end_longitude	longitude of ensemble end
nav_end_latitude	latitude of ensemble start
heading	vehicle heading
error_vel	error velocity

cell_depth	depth of bin center
bt_range	bottom track range
bt_amp	bottom track echo amplitude
bt_cor	bottom track correlation
bt_percent_good	percent of good bottom track pings
bt_vel_east	east velocity of bottom track
bt_vel_north	north velocity of bottom track
bt_vel_up	up velocity of bottom track
correlation	correlation
echo_intensity	echo amplitude
percent_good	percent good using 3 or 4 beam solutions
percent_good_3_beam	percent good using 3 beam solution
percent_good_4_beam	percent good using 4 beam solution
avg_true_vel_east	east velocity of the vehicle
avg_true_vel_north	north velocity of the vehicle
avg_true_vel_up	up velocity of the vehicle
latitude	latitude
longitude	longitude
time	time
trajectory	

Table 4. Information on the Saildrone SB56 temperature logger in situ dataset. This table is meant to accompany the Saildrone data description. See the report for more details on each dataset.

Variable Name	Variable	Sensor Description	Model Name	Link to Product Webpage	Installed Height (m)	Sampling Schedule
sea_water_temperature_1	temperature	temperature logger	SB56	http://www.seabird.com/sbe56-temperature-logger	-0.295	2 sec
sea_water_temperature_2	temperature	temperature logger	SB56	http://www.seabird.com/sbe56-temperature-logger	-0.985	2 sec
sea_water_temperature_3	temperature	temperature logger	SB56	http://www.seabird.com/sbe56-temperature-logger	-1.420	2 sec
sea_water_temperature_4	temperature	temperature logger	SB56	http://www.seabird.com/sbe56-temperature-logger	-1.785	2 sec
time	time					

Seawater Temperature

The Saildrone USV carries a Teledyne Citadel-NH CTD. This sensor measures temperature and conductivity, from which salinity is calculated. The instrument is mounted at 0.6m below sea level, and has a passive, flow-through intake. The intake has a mesh shield to reduce biofouling. Data are averaged into 1 minute means using 12 sec of 1Hz-sampled data centered at :00.

Dissolved Oxygen

The USV also carries a Aanderaa Dissolved Oxygen 3831 sensor that measures O2 concentration and temperature, installed at a depth of 0.6 m. Data are averaged into 1 minute means using 12 sec of 1Hz-sampled data centered at :00. Seawater flows through this sensor, there is no pumping. Saildrone designed the flow-thru so that "fresh" water would always be flowing past dissolved oxygen sensor due to motion of the USV, the drone's motion is essentially providing pumping

Figure 5. Dissolved Oxygen sensor installed on Saildrone USV.

A comparison of the CTD temperature and O2 temperature 1-minute averages is shown below. The mean bias is 10.02 K and standard deviation is 0.01 K. The two different sensors agree with each other and indicate both are working well. The small differences are largest during low wind speeds, with the CTD showing slightly lower values than the O2 temperature sensor. These values also occur during mid-day to late afternoon and are consistent with either diurnal heating of the upper ocean being measured slightly differently by the two sensors or heating of the USV.

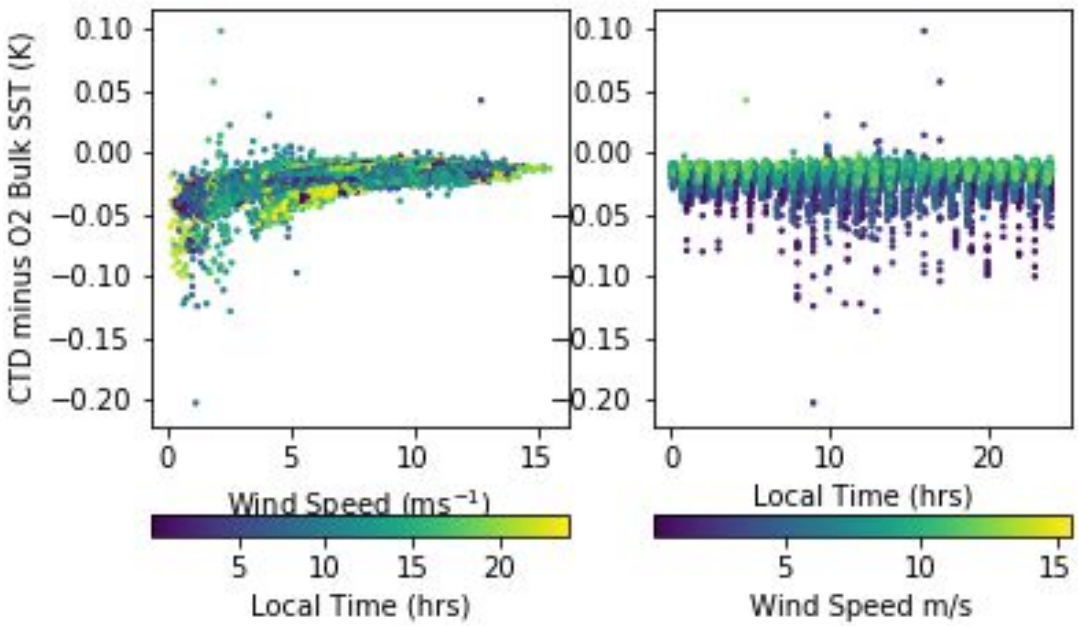

Figure 6. CTD minus O2 temperatures as a function of wind speed and local time.

Wind speeds

Three-dimensional wind vectors and gust values are collected by a Gill Anemometer 1590-PK-020. The anemometer is located at the top of the Saildrone mast at a height of 5 m. Data sampled at 10Hz are averaged into 1 minute values centered at :00 every 5 minutes. Wind measurements are transformed into worldspace and corrected with tangential and translational velocity every sample. During the cruise winds varied from 0.14 to 15.5 m/s.

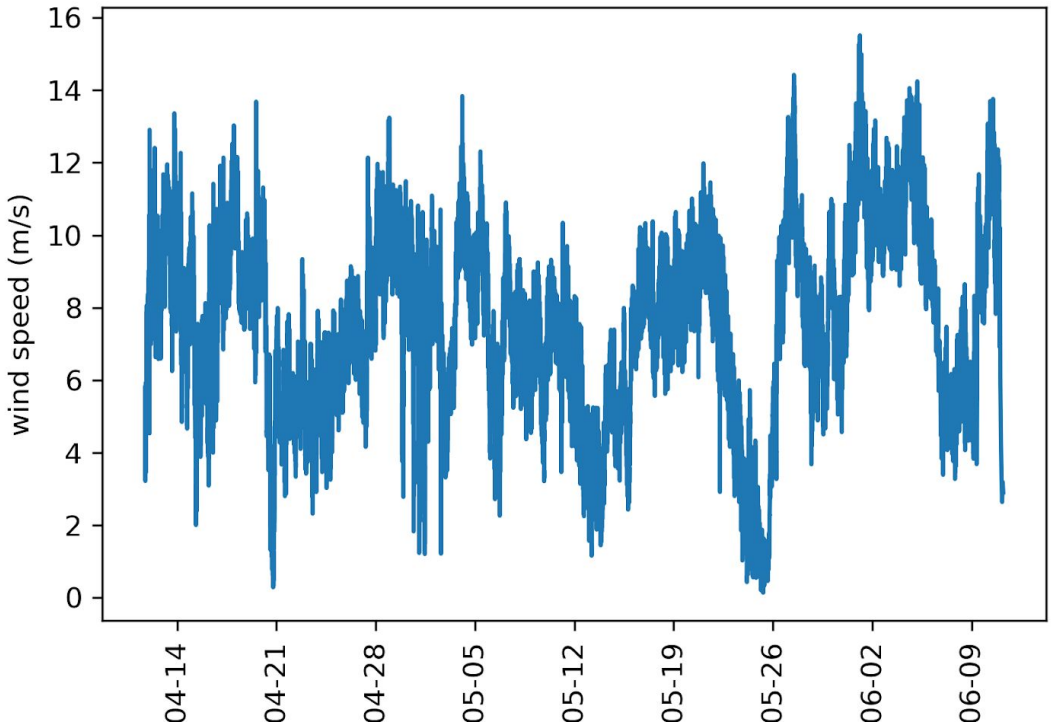

Figure 7. Wind speed during cruise.

Air pressure

Barometric pressure is measured by a Vaisala Barometer PTB210 installed at a height of 0.3 m. Data sampled at 1Hz are averaged into 1 minute values centered at :00 every 5 minutes.

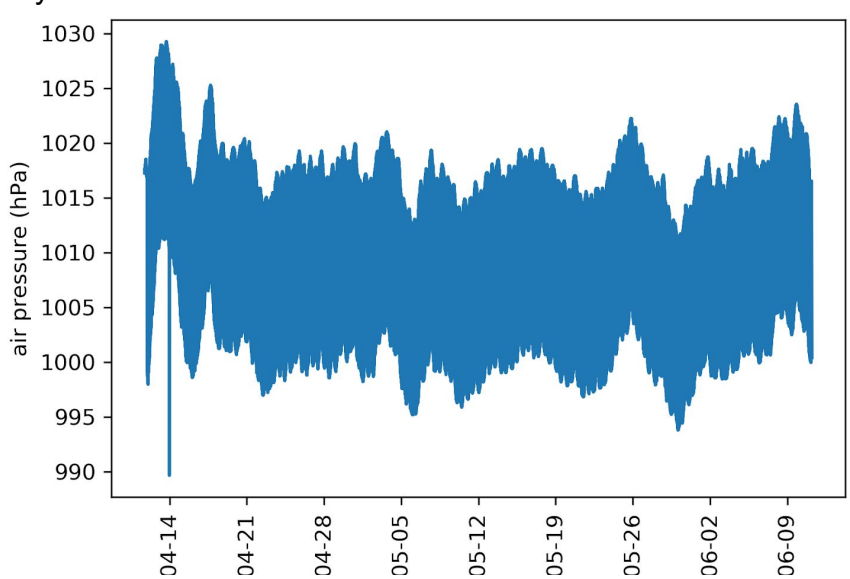

Figure 8. Time series of air pressure.

Air temperature and humidity -

Air temperature and humidity were measured by Rotronic AT/RH HC2-S3 installed at a height of 2.4 m. Data sampled at 1Hz are averaged into 1 minute values centered at :00 every 5 minutes.

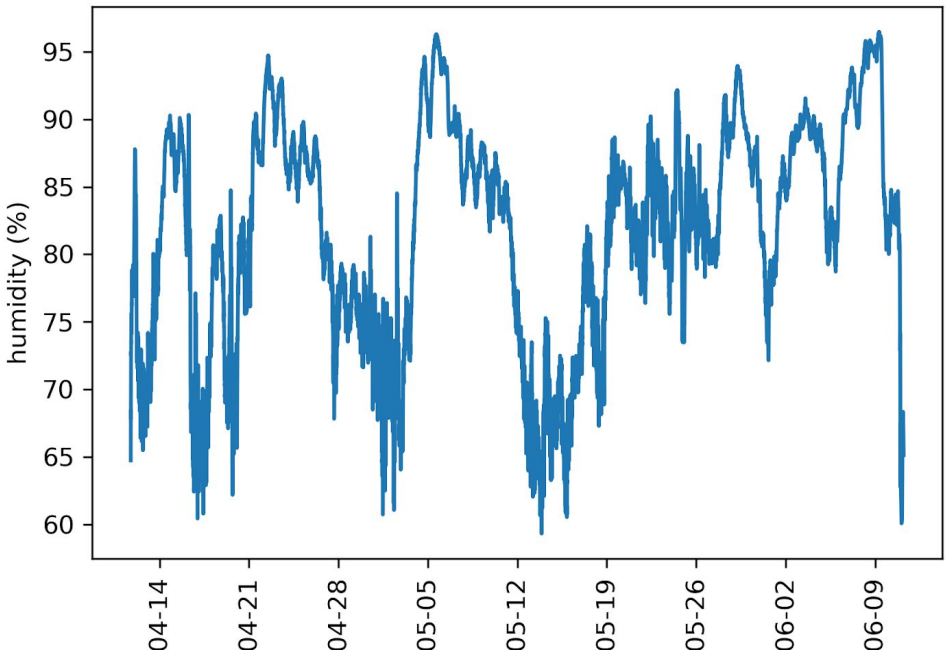

Figure 9. Relative humidity during the cruise.

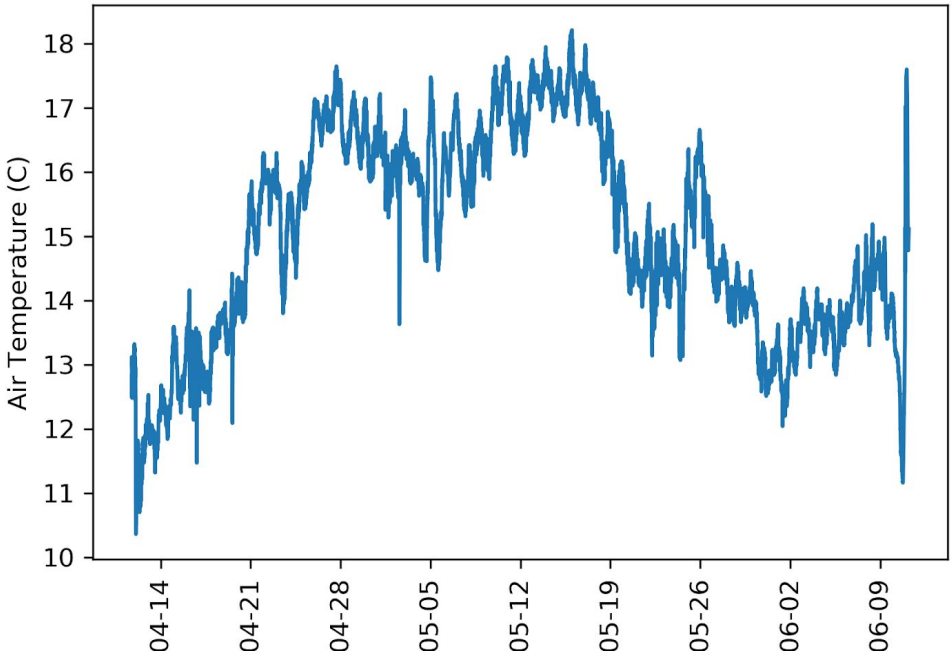

Figure 10. Air temperature during the cruise.

Ocean color

Optical backscatter at 650 nm, CDOM concentration, and Chlorophyll concentration were measured by a WET Labs Fluorometer BBFL2W installed at a depth of 0.25 m. The instrument is mounted behind at the base of the hull behind the keel. in the hull of the Saildrone USV. Data are averaged into 1 minute averages using 12 sec of data centered at :00.

Figure 11. ADCP installed on Saildrone USV.

Upper ocean velocities

The Saildrone ADCP is a 300kHz Teledyne Workhorse Monitor WHM300, configured with 2m bins, max depth of 93m, and 176cm blanking distance. The instrument is nominally sampled at 1Hz, 5 minutes out of 10, centered at :00. Per-ping radial beam data is transformed into world-space and corrected with vehicle velocity, and then averaged with a 5 minute period. The instrument that was used on this cruise has serial number 24428.

ADCP is located at the rear of the Saildrone USV, facing downwards (Figure X). It is at a depth of .25m. The ADCP data was processed to netCDF files by CISESE. The figures below show the horizontal and vertical velocities as a function of date and depth. Values with less than 60% good pings are not used in these figures and have a much higher rate of erroneous values and should be considered suspect.

Figure 12. ADCP installed on Saildrone USV (USV rotated 90 degrees).

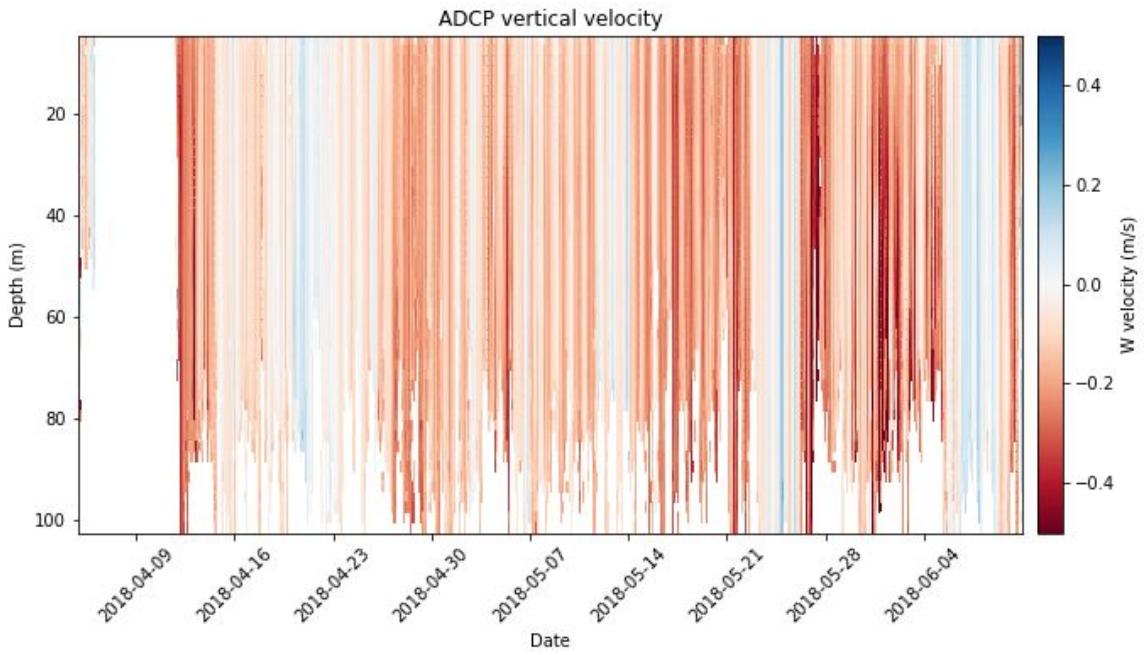

Figure 13. ADCP vertical velocity.

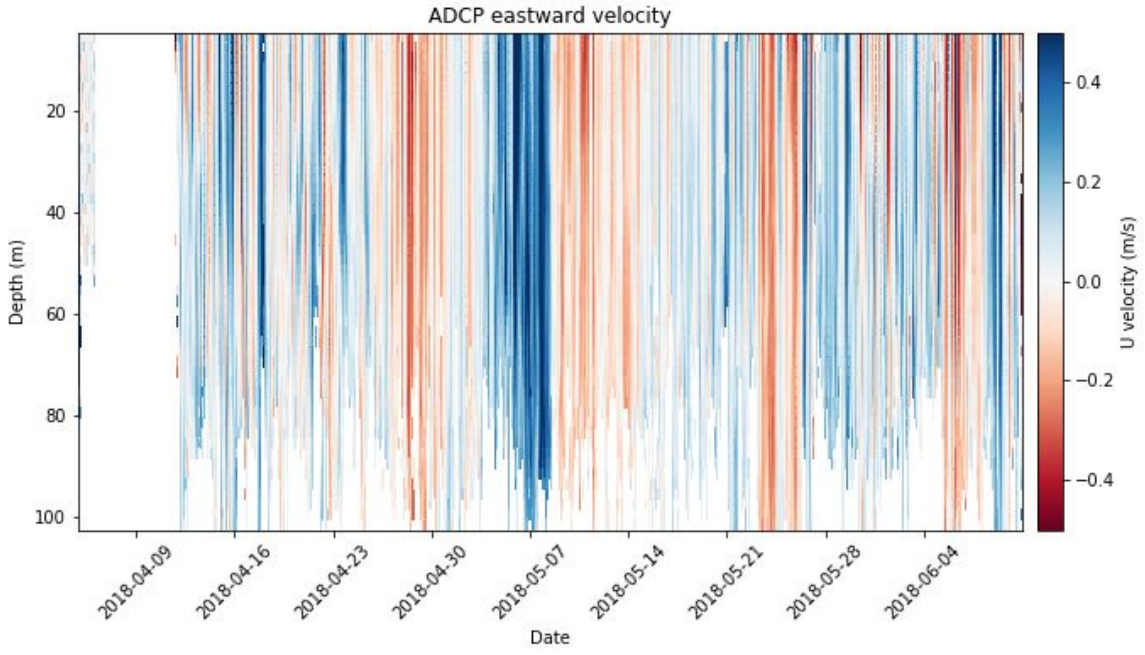

Figure 14. ADCP eastward velocity.

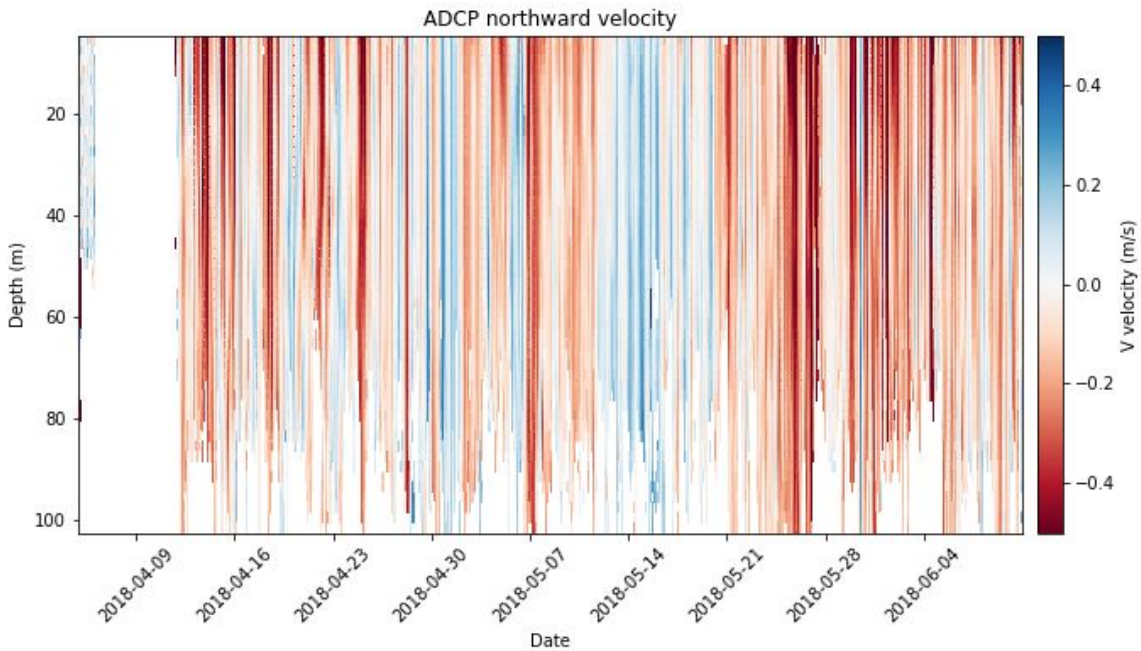

Figure 15. ADCP northward velocity.

Figure 16. Image of installed temperature loggers.

Temperature loggers

Four Seabird 56 Temperature Loggers were mounted to the keel at depths of -0.295, -0.985, -1.420, and -1.785 m. Sampling was set to 2 seconds on, 2 seconds off. At the end of the cruise, these data were resampled to the Saildrone 1 min sampling and integrated into the main file.

Salinity

Seawater salinity is derived from temperature and conductivity measured by a Teledyne CTD CTD-NH-0-000110-500-500-0 installed at a depth of 0.6 m. Data sampled at 1Hz are averaged into 1 minute averages using 12 sec of data centered at :00 seconds.

Skin SST

Infrared sea surface brightness temperature was measured by a Heitronics IR Pyrometer CT15.10 installed at a height of 2.25 m. Data sampled at 1Hz are averaged into 1 minute values using 30 sec of data centered at :00. The skin SST, when approximated by the measured brightness temperature, has a mean bias of -0.21 K and standard deviation of 0.24 K when compared to the CTD subsurface SST. These numbers are not indicative of the instruments performance, but instead result from errors in the approximation due to reflected sky radiation. The measurement of the CT15.10 radiometer includes a component that is the reflected sky radiation in addition to surface emitted radiation. Figure 6 shows the difference, skin minus bulk, as a function of wind speed and local time. When the sky is clear (cold), the mean bias is approximately -0.50 K and when the sky is warm (low clouds present), the mean bias is approximately -0.10 K (Figure 7). Figure 8 shows Saildrone onboard photos, with a clear sky, corresponding to the -0.50 K bias and Figure 9 shows a cloudy sky corresponding to the -0.10 K bias, indicative of the thermal skin effect at the ocean surface. For this cruise, the skin SSTs are of limited utility due to the uncorrected reflected sky radiation.

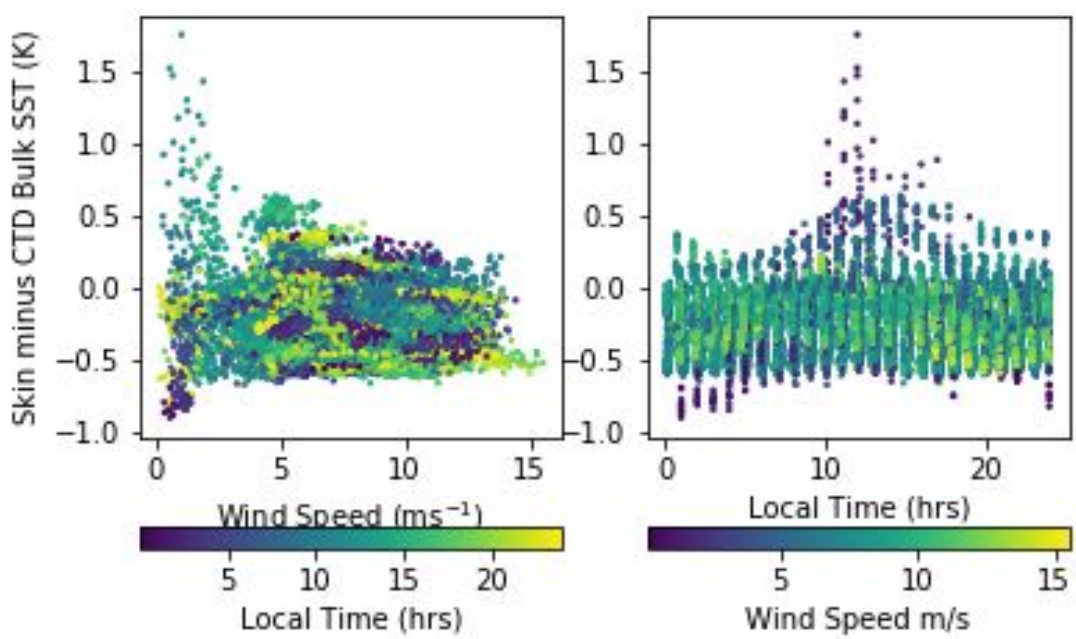

Figure 17. Skin SST minus CTD bulk SST as a function of (left) wind speed and (right) local time.

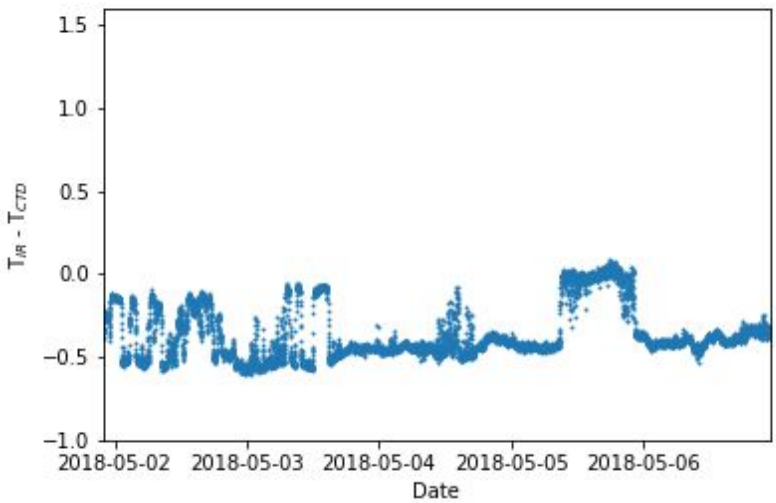

Figure 18. Skin SST minus CTD subsurface SST from 2 - 7 May 2018.

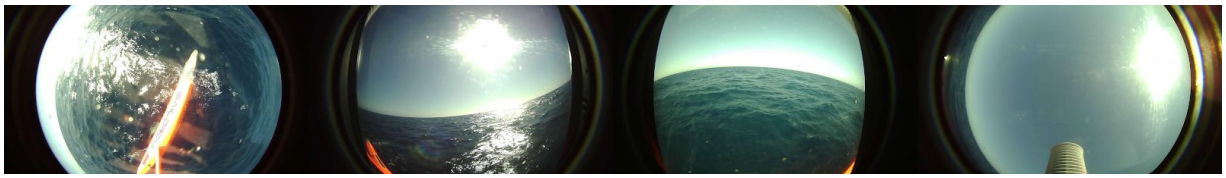

Figure 19. Clear-sky conditions on 4 May 2018 at 22:54 GMT.

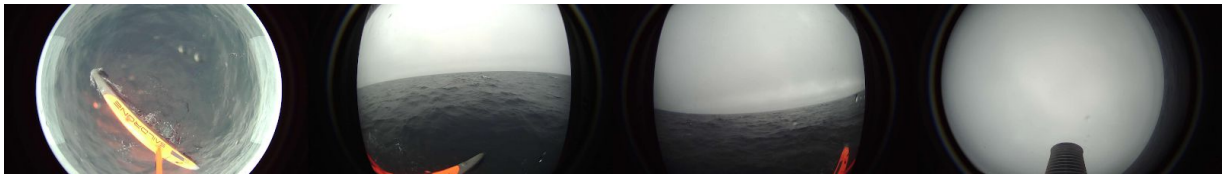

Figure 20. Cloudy conditions on 5 May 2018 18:55 GMT.