2021 Arctic Saildrone Cruise

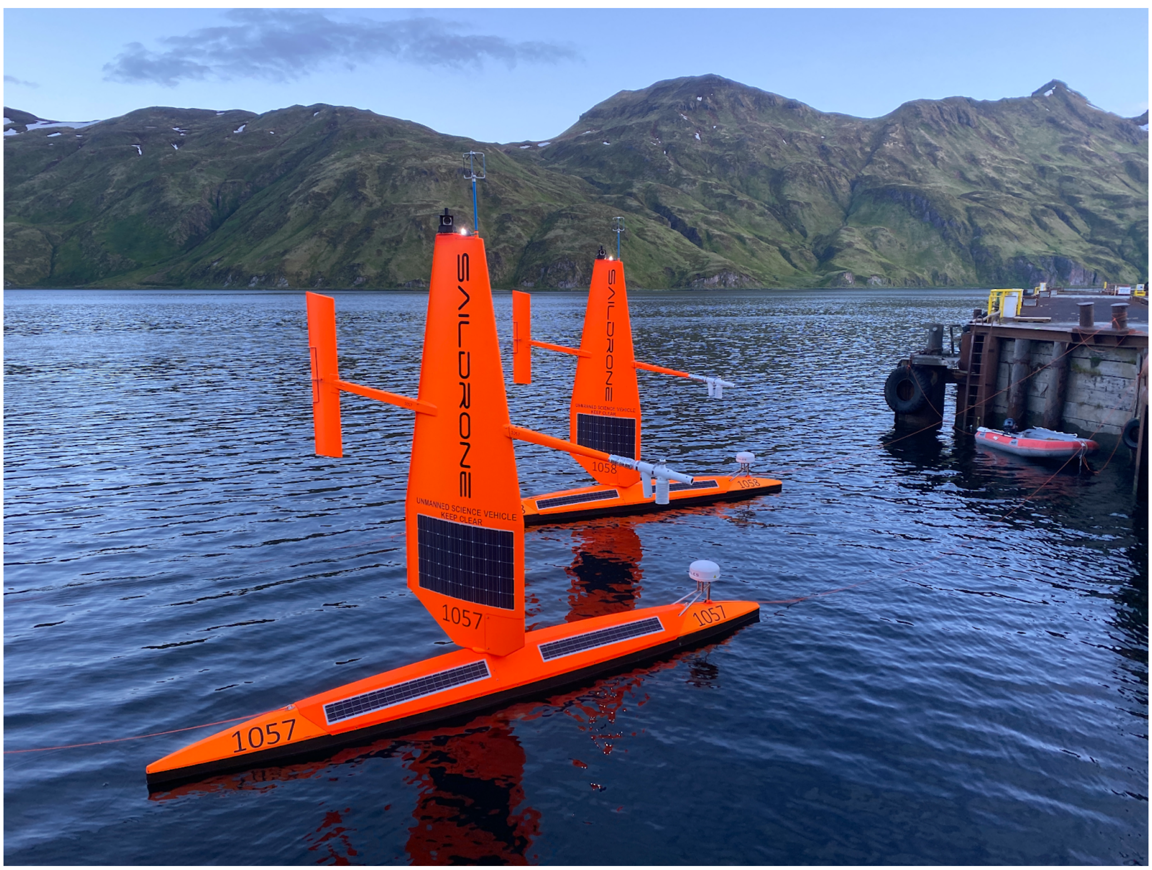
NASA Physical Oceanography, NOAA PMEL, and Saildrone

NASA grant #80NSSC18K0837

6 July to 20 October 2021

Important information: For this cruise, all measurements are unvalidated at this time. From initial analysis, all measurements appear to be of high quality, except oxygen data, which differ in variability between Saildrones. Please see the vehicle description for more information. Email the cruise PI: cgentemann@faralloninstitute.org for up-to-date information about any additional data flagging that might be necessary before use.

Saildrone vehicle deployment in Dutch Harbor, Alaska. Image credit: Saildrone, Inc.



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Saildrone Arctic 2021 Cruise Science Team

Table 1. Science Team

Name	**Role**	**Research Focus**	**Email**
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Saildrone Arctic 2021 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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Kimberly Sparling	VP Product Management	Data Management / Client Relations	kim@saildrone.com
Julia Paxton	Mission Manager	Vehicle Piloting and mission execution	julia.paxton@saildrone.com
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Cruise Narrative

The two Saildrone vehicles (SD-1057, SD-1058) in this cruise departed from Dutch Harbor, Alaska on a 90-day cruise per vehicle. Scientific data sampling occurred from 6 July to 20 September 2021, focused primarily on the Chukchi Sea. This means that science sampling was only started once the vehicles made it to the Bering Strait. Scientific objectives include collecting upper ocean temperature profiles with a full suite of ocean measurements, which could lead to significant improvements in the modeling of diurnal warming. Additionally, these new data will provide additional Arctic SST observations to benefit SST satellite remote sensing algorithm development and validation, and will collect additional data for studies of air- sea-ice interactions.

The overall mission objective was to measure atmospheric and oceanographic conditions in Alaskan arctic waters. The Saildrones transited the Bering Strait into the Chukchi Sea and ran transects in the Chukchi Sea, approaching the sea ice edge (up to 50 km away) to measure air-sea heat and momentum fluxes in the ocean near sea ice and to validate satellite sea-surface temperature measurements in the Arctic. Each Saildrone was equipped to measure air temperature and relative humidity, barometric pressure, surface skin temperature, wind speed and direction, wave height and period, seawater temperature and salinity, chlorophyll concentration, and dissolved oxygen. Both vehicles measured near surface currents with 300 kHz acoustic Doppler current profilers (ADCP).

A special emphasis during this year’s cruise was to better understand the spatial/temporal scales of air-sea covariance in the Chukchi Sea. This was addressed by running a series of parallel tracks using the two Saildrones at varying horizontal offsets during much of August and September, as shown in Figure 1.

Power constraints in August and September due to poor solar conditions severely limited the ability to recharge batteries, resulting in an early end to science measurements on September 20. The vehicles returned to Dutch Harbor on October 20.

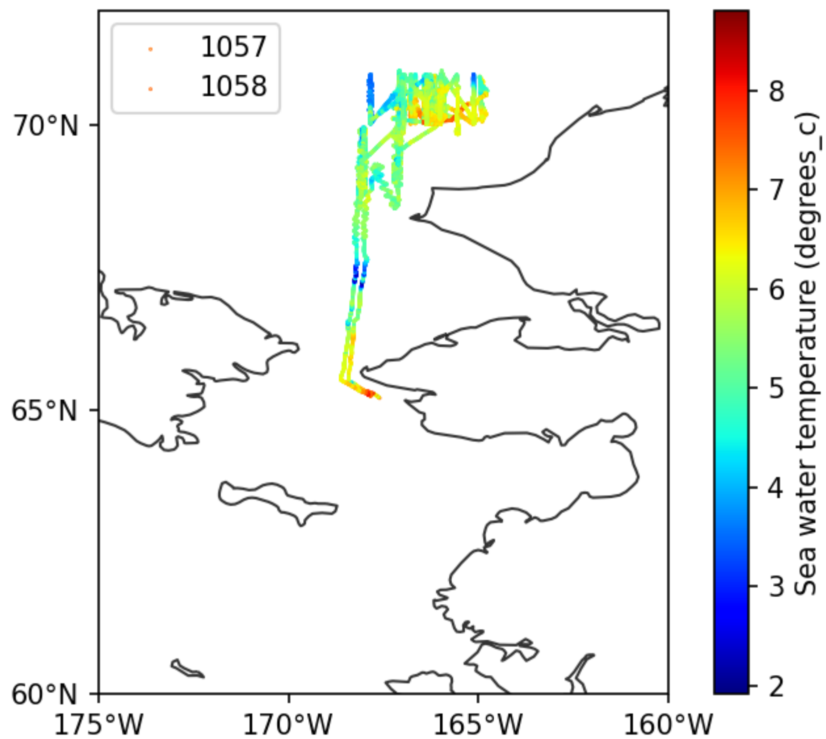

Figure 1. Cruise tracks for the 2021 Arctic Saildrone deployments, showing sea water temperature data from the SBE CT-ODO instrument.

General Timeline for Saildrone, 6 June 2021 to 20 October 2021

June 6 : Saildrone arrived Dutch Harbor
June 14: Departed Dutch Harbor for the Bering Strait
July 6: First waypoint reached, sampling started
August 12: Battery-saving actions started owing to low solar energy availability and weak winds
September 20: End of scientific sampling due to battery depletion
October 18: Arrived at Unalaska
October 20: Recovered at Dutch Harbor

Vehicle description

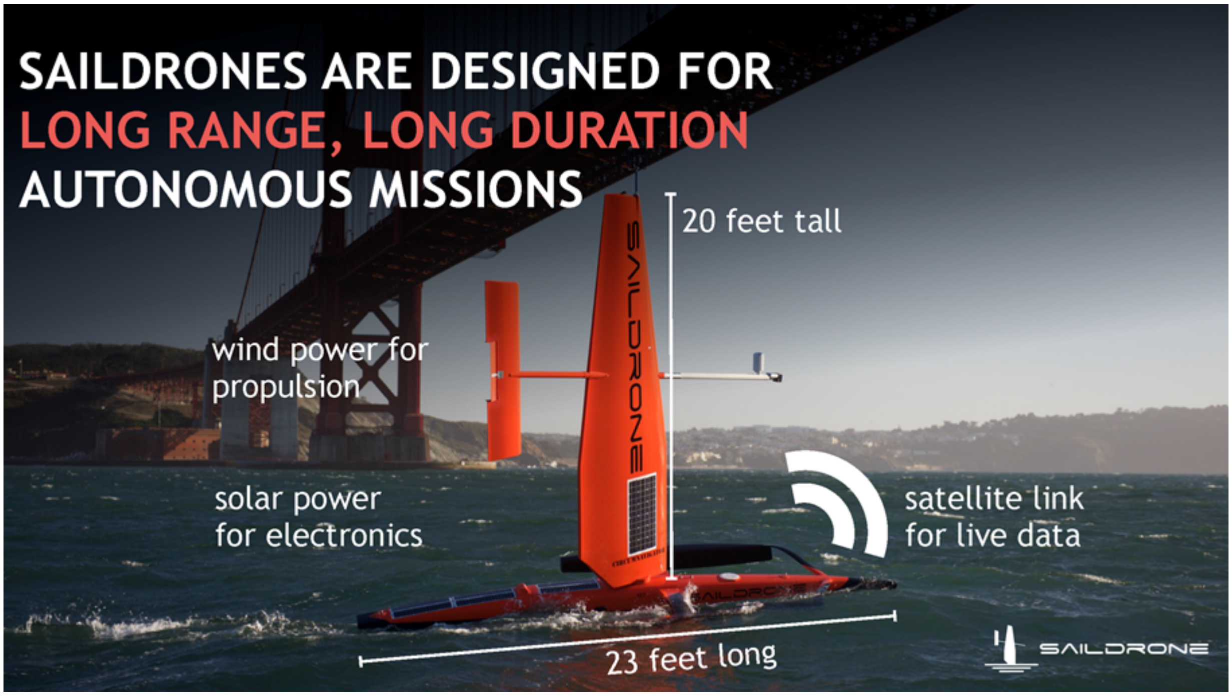

Figure 2. Dimensions of the vehicle. Figure credit Saildrone, Inc.

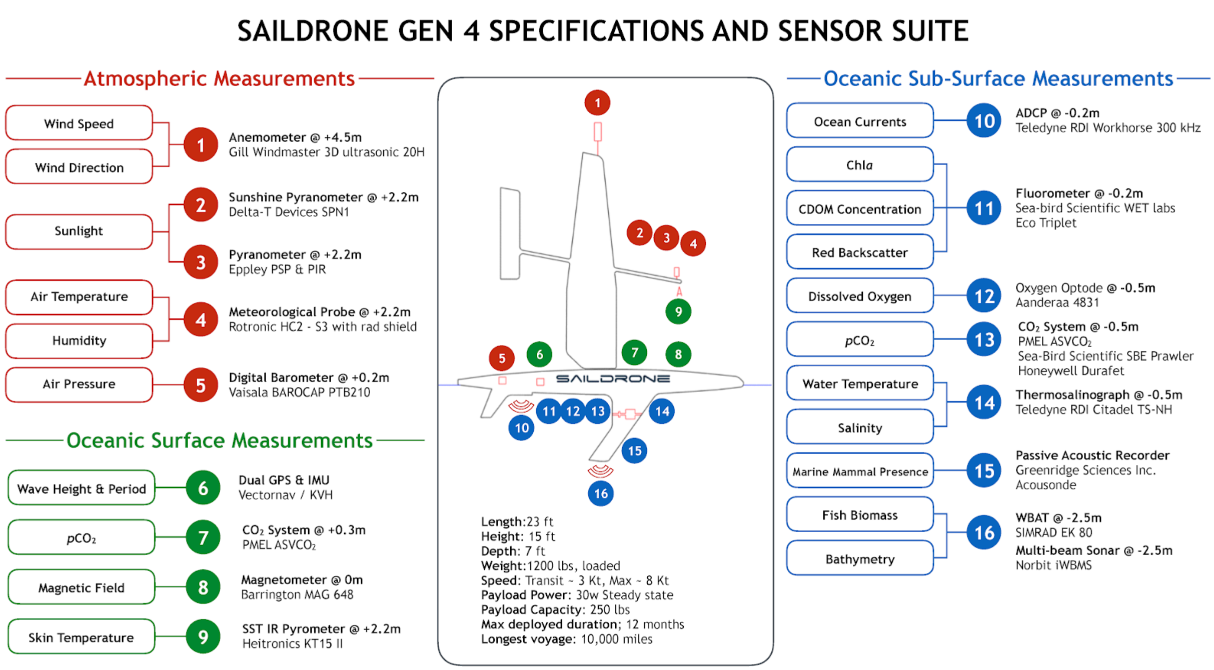

Figure 3. Saildrone vehicle instrumentation placement. Not all instruments in the figure were installed for these cruises; in addition, IR Heitronics radiometers were installed on the wings and Seabird CTD-ODO were installed.

Table 3. Information on the Saildrone vehicle 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 vehicle payload.

Variable Name	Variable	Sensor Description	Model Name	Installed Height (m)	Sampling Schedule
BARO_PRES_MEAN	air_pressure	Vaisala Barometer	Vaisala : PTB210	0.2	60s on, 240s off, centered at :00
BARO_PRES_STDDEV	air_pressure	Vaisala Barometer	Vaisala : PTB210	0.2	60s on, 240s off, centered at :00
CHLOR_WETLABS_MEAN	mass_concentration_of_chlorophyll_in_sea_water	WET Lab Fluorometers	WET Labs : FLS	-0.5	12s on, 48s off, centered at :00
CHLOR_WETLABS_STDDEV	mass_concentration_of_chlorophyll_in_sea_water	WET Lab Fluorometers	WET Labs : FLS	-0.5	12s on, 48s off, centered at :00
COG	platform_course				
COND_SBE37_MEAN	sea_water_electrical_conductivity	Sea-Bird Scientific CT-ODO	SBE37-SMP-ODO Microcat	-0.5	12s on, 588s off, centered at :00
COND_SBE37_STDDEV	sea_water_electrical_conductivity	Sea-Bird Scientific CT-ODO	SBE37-SMP-ODO Microcat	-0.5	12s on, 588s off, centered at :00
GUST_WND_MEAN	wind_speed_of_gust	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00
GUST_WND_STDDEV	wind_speed_of_gust	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00
HDG	platform_yaw_angle				
HDG_WING	Wing heading				
O2_CONC_SBE37_MEAN	mole_concentration_of_dissolved_molecular_oxygen_in_sea_water	Sea-Bird Scientific CT-ODO	SBE37-SMP-ODO Microcat	-0.5	12s on, 588s off, centered at :00
O2_CONC_SBE37_STDDEV	mole_concentration_of_dissolved_molecular_ox	Sea-Bird Scientific CT-ODO	SBE37-SMP-ODO Microcat	-0.5	12s on, 588s off, centered at :00

	ygen_in_sea_water				
O2_SAT_SBE37_MEAN	fractional_saturation_of_oxygen_in_sea_water	Sea-Bird Scientific CT-ODO	SBE37-SMP-ODO Microcat	-0.5	12s on, 588s off, centered at :00
O2_SAT_SBE37_STDDEV	fractional_saturation_of_oxygen_in_sea_water	Sea-Bird Scientific CT-ODO	SBE37-SMP-ODO Microcat	-0.5	12s on, 588s off, centered at :00
PITCH_FILTERED	platform_pitch_angle				
PAR_AIR_MEAN	surface_downwelling_photosynthetic_photon_flux_in_air	LI-COR PAR	LI-192SA	2.6	Always On
PAR_AIR_STD	surface_downwelling_photosynthetic_photon_flux_in_air	LI-COR PAR	LI-192SA	2.6	Always On
RH_MEAN	relative_humidity	Rotronic AT/RH	Rotronic : HC2-S3	2.3	60s on, 240s off, centered at :00
RH_STDDEV	relative_humidity	Rotronic AT/RH	Rotronic : HC2-S3	2.3	60s on, 240s off, centered at :00
ROLL_FILTERED	platform_roll_angle				
SAL_SBE37_MEAN	sea_water_practical_salinity	Sea-Bird Scientific CT-ODO	SBE37-SMP-ODO Microcat	-0.5	12s on, 588s off, centered at :00
SAL_SBE37_STDDEV	sea_water_practical_salinity	Sea-Bird Scientific CT-ODO	SSBE37-SMP-ODO Microcat	-0.5	12s on, 588s off, centered at :00
SOG	platform_speed_wrt_ground				
TEMP_AIR_MEAN	air_temperature	Rotronic AT/RH	Rotronic : HC2-S3	2.3	60s on, 240s off, centered at :00
TEMP_AIR_STDDEV	air_temperature	Rotronic AT/RH	Rotronic : HC2-S3	2.3	60s on, 240s off, centered at :00
TEMP_IR_SEA_WING_UNCOMP_MEAN	sea_surface_skin_temperature	Heitronics Wing IR Pyrometer	Heitronics : CT15.10	2.25	30s on, 270s off, centered at :00
TEMP_IR_SEA_WING_UNCOMP_STDDEV	sea_surface_skin_temperature	Heitronics Wing IR Pyrometer	Heitronics : CT15.10	2.25	30s on, 270s off, centered at :00

TEMP_SBE37_MEAN	sea_water_temperature	Sea-Bird Scientific CT-ODO	SBE37-SMP-ODO Microcat	-0.5	12s on, 588s off, centered at :00
TEMP_SBE37_STDDEV	sea_water_temperature	Sea-Bird Scientific CT-ODO	SBE37-SMP-ODO Microcat	-0.5	12s on, 588s off, centered at :00
UWND_MEAN	eastward_wind	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00
UWND_STDDEV	eastward_wind	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00
VWND_MEAN	northward_wind	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00
VWND_STDDEV	northward_wind	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00
WATER_CURRENT_SPEED_MEAN	Water Current Speed	Teledyne ADCP	Teledyne : Workhorse WHM300-I-UG1	-1.9	300s on, 300s off, centered at :00
WATER_CURRENT_DIRECTION_MEAN	Water Current Direction	Teledyne ADCP	Teledyne : Workhorse WHM300-I-UG1	-1.9	300s on, 300s off, centered at :00
WAVE_DOMINANT_PERIOD	sea_surface_wave_period_at_variance_spectral_density_maximum	VectorNav Hull IMU	VectorNav : VN-300	0.34	Always On
WAVE_SIGNIFICANT_HEIGHT	sea_surface_wave_significant_height	VectorNav Hull IMU	VectorNav : VN-300	0.34	Always On
WING_ANGLE	Wing angle				
WING_PITCH_FILTERED	Wing pitch one minute mean				
WING_ROLL_FILTERED	Wing roll one minute				
WIND_FROM_MEAN	wind_from_direction	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00
WIND_FROM_STDDEV	wind_from_direction	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00

WIND_MEASUREMENT_HEIGHT_MEAN	Wind measurement height	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00
WIND_MEASUREMENT_HEIGHT_STDDEV	Wind measurement height	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00
WIND_SPEED_MEAN	wind_speed	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00
WIND_SPEED_STDDEV	wind_spee	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00
WWND_MEAN	downward_air_velocity	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00
WWND_STDDEV	downward_air_velocity	Gill Anemometer	Gill : 1590-PK-020	5.2	60s on, 240s off, centered at :00
latitude	latitude	VectorNav Hull IMU	VectorNav : VN-300	0.34	Always On
longitude	longitude	VectorNav Hull IMU	VectorNav : VN-300	0.34	Always On
time	time				
trajectory	Saildrone Trajectory/Drone ID				

Table 4. 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	Saildrone vehicle identification number

Seawater Temperature

Saildrone carries several instruments for measuring seawater temperature. These include one CTD-ODO that measures sea water temperature at approximately 0.5 meters depth, and one pyrometer to measure infrared (IR) radiance from which the skin sea-surface temperatures can be derived. The pyrometer was mounted on the wing. The pyrometer was made by Heitronics with a model number of CT15.10. These measured temperatures should be considered as experimental and used with caution.

The Seabird SBE37 CT-ODO measures seawater temperature to high accuracy and with fast sampling. The highly stable instrument makes it possible to preserve the initial calibration in rapid sampling.

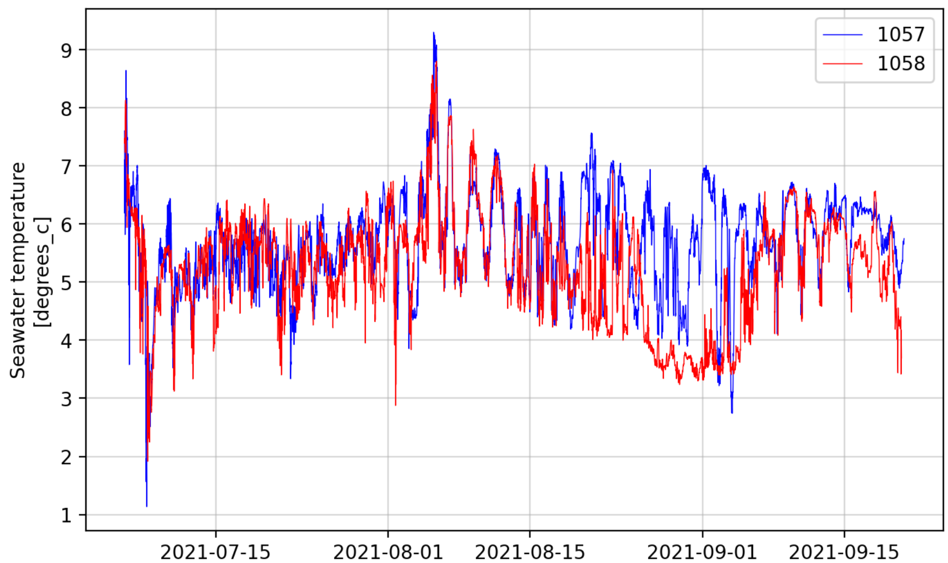

Figure 4. 0.5 m seawater temperatures measured by SBE37 instruments during the cruises.

Radiometric SST

Infrared (IR) sea surface brightness temperature, i.e. the temperature derived from a measurement of spectral radiance, was provided by a Heitronics IR Pyrometer CT15.10 installed on the wing at 2.25 m above the waterline. The measurement of the sea-surface brightness temperature by the CT15.10 pyrometer includes a component that is reflected by sky radiation. These measurements are not recommended for use as a skin SST without a sky correction.

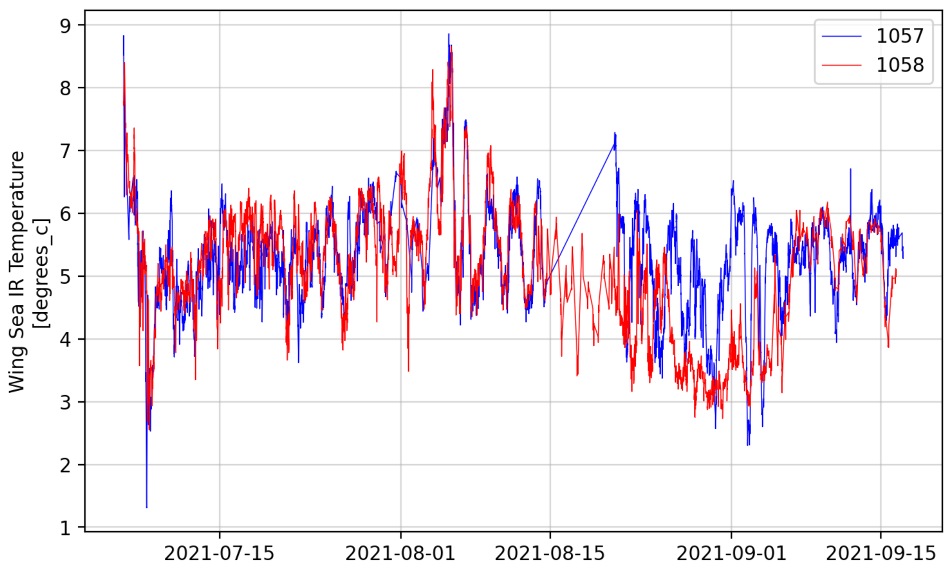

Figure 5. IR wing seawater temperature.

Dissolved Oxygen

The vehicles measure oxygen concentration and saturation using an unpumped Sea-Bird CTD-ODO. Data are averaged into 10 minute means using 12 sec of 1Hz-sampled data centered at :00.

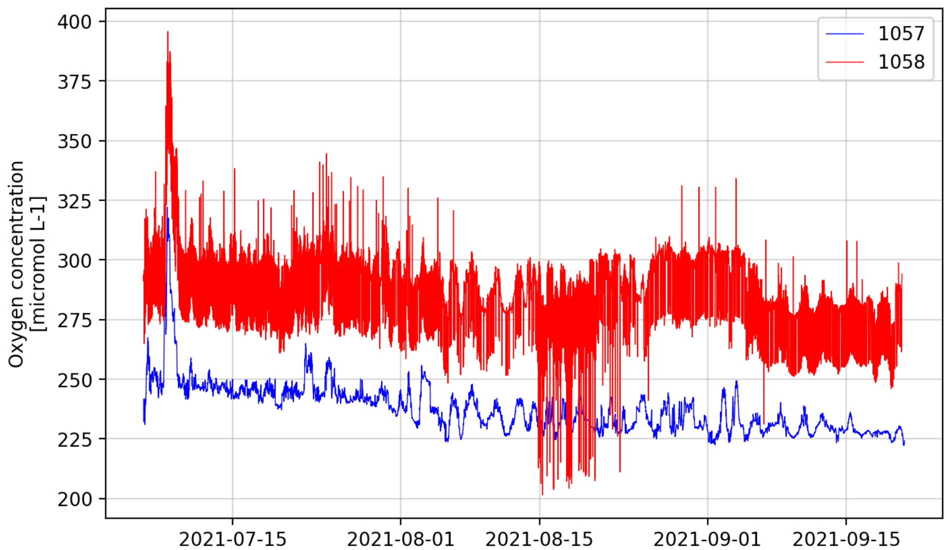

Figure 6. SBE37 O_2 concentrations measured during the cruises.

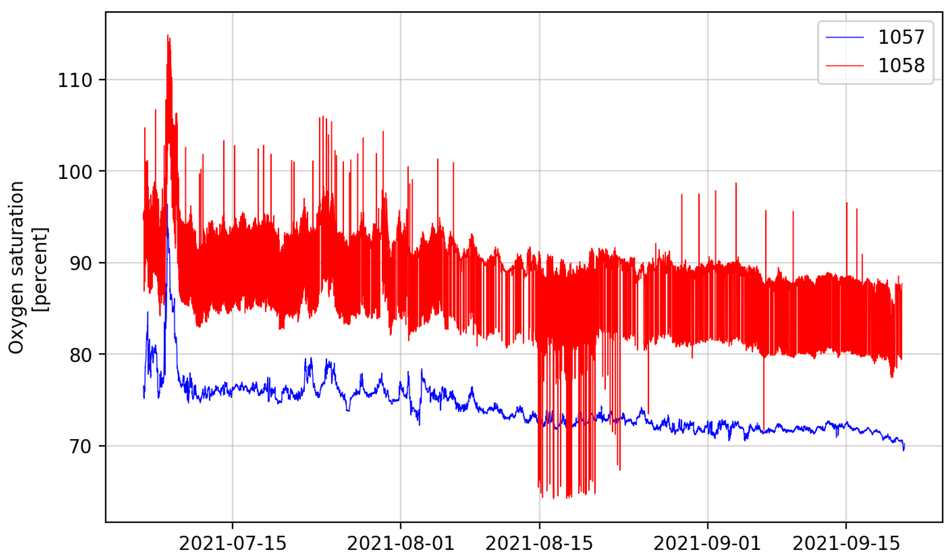

Figure 7. SBE37 O_2 Saturations measured during the cruises.

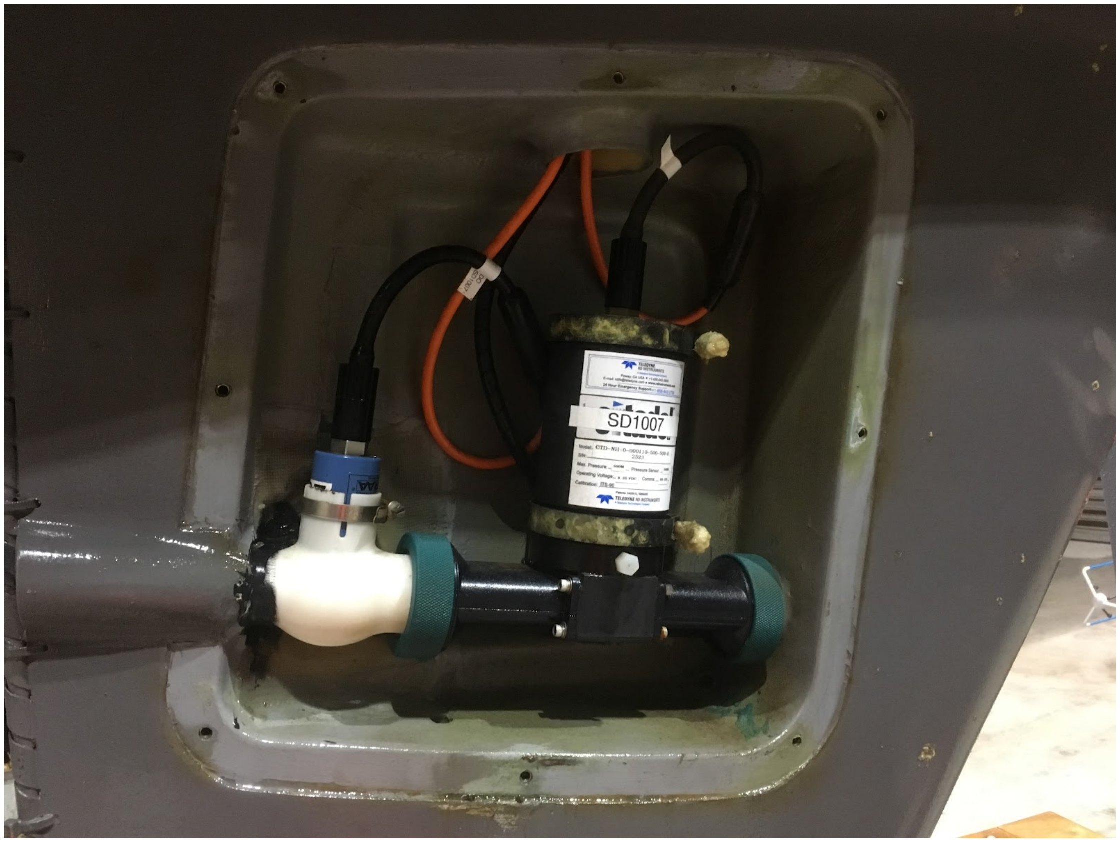

Figure 8. Dissolved Oxygen sensor installed on a Saildrone.

Wind speed

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 5.2 m. Data sampled at 20Hz are averaged into 1 minute values centered at :00 every 5 minutes. Wind measurements are transformed and corrected with tangential and translational velocity in every sample. During the cruise winds varied from 0.13 to 16.93 m/s.

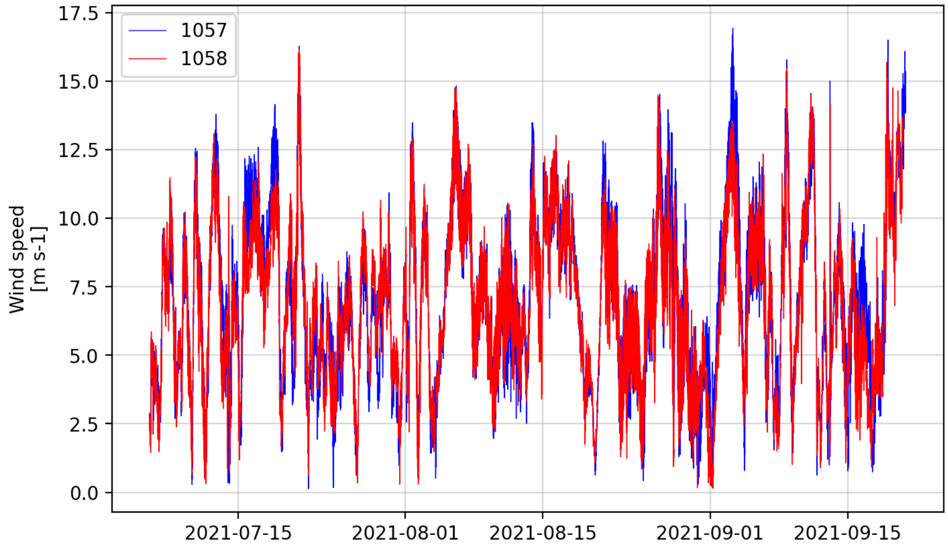

Figure 9. Wind speeds measured during the cruises (m/s).

Air pressure

Barometric pressure is measured by a Vaisala Barometer PTB210 installed at a height of 0.2 m. Data sampled at 1Hz are averaged into 1 minute values centered at :00 every 5 minutes.

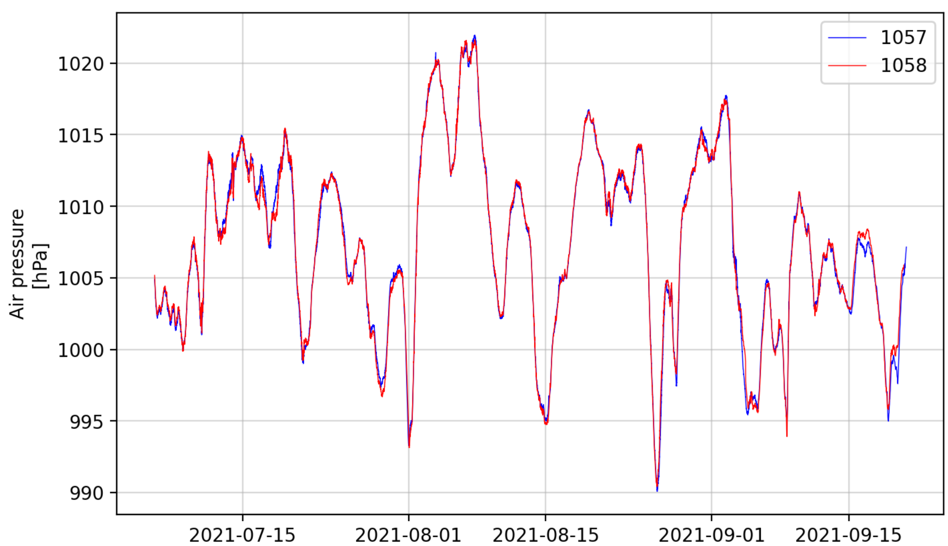

Figure 10. Time series of air pressures measured during the cruises.

Air temperature and humidity

Air temperature and humidity were measured by a Rotronic AT/RH HC2-S3 installed at a height of 2.3 m. Data sampled at 1Hz are averaged into 1 minute values centered at :00 every 5 minutes.

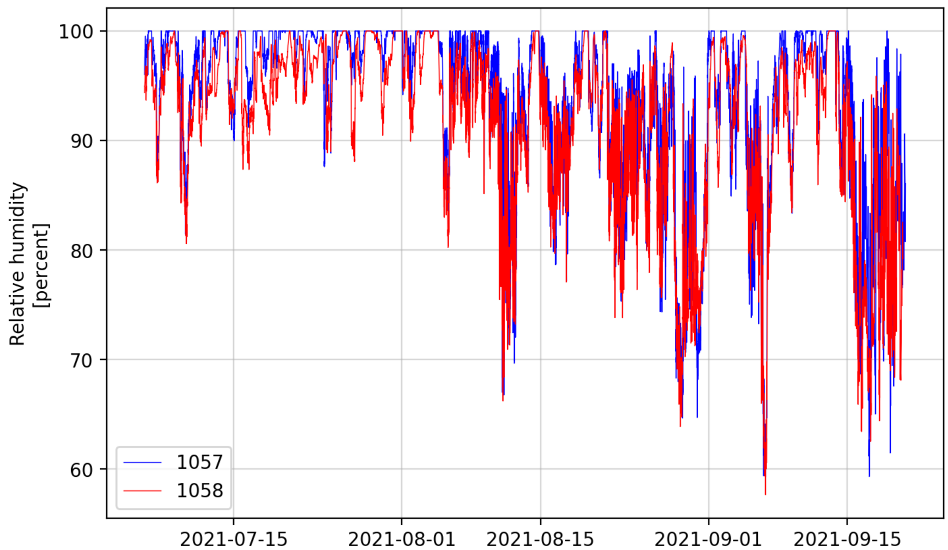

Figure 11. Relative humidity measured during the cruises.

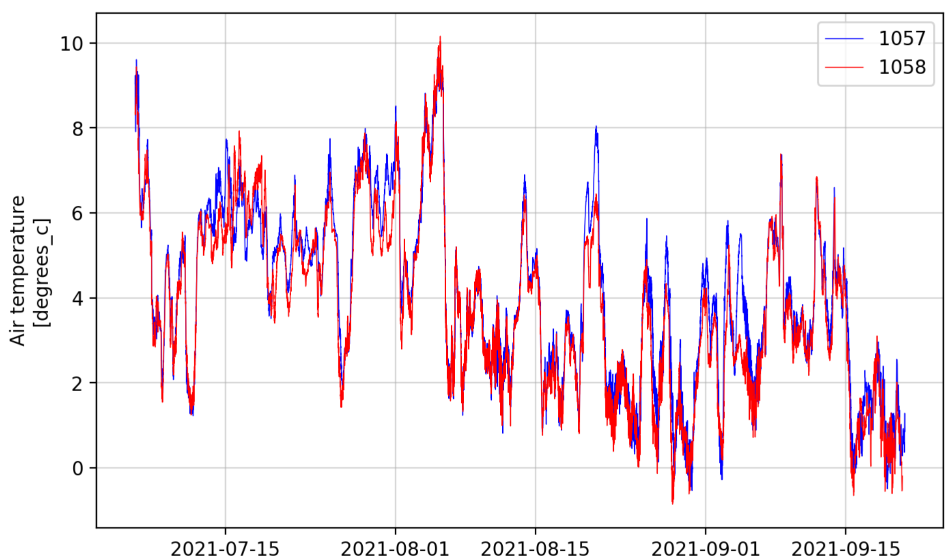

Figure 12. Air temperatures measured during the cruises.

Ocean color

Chlorophyll concentration was measured by a WET Labs Fluorometer FLS installed at a depth of 0.5 m. The instrument is mounted behind the base of the hull of the Saildrone vehicle, behind the keel. Data are averaged into 1 minute averages using 12 sec of data centered at :00.

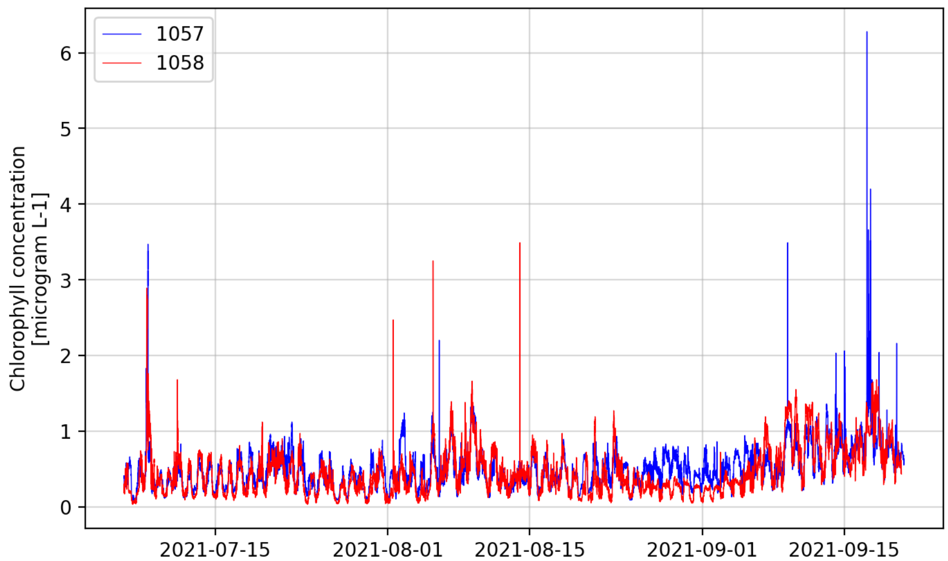

Figure 13. Chlorophyll concentrations measured by the Wetlabs instruments.

Upper ocean velocities

The Saildrone ADCP is a 300kHz Teledyne Workhorse Monitor WHM300, configured with 2 m bins, max depth of 93 m, and 176 cm 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. ADCP is located at the rear of the Saildrone vehicle, facing downwards (Figure 14) at a depth of 0.25 m. The ADCP data was processed to netCDF files by Saildrone.

Figure 14. ADCP installed on a Saildrone (vehicle rotated 90 degrees to present the bottom of the hull).

Figure 15. ADCP installed on a Saildrone vehicle.

Salinity

Seawater salinity is derived from temperature and conductivity measured by the SBE37 CT-ODO. Data sampled at 1Hz are averaged into 10 minute averages using 12 sec of data centered at :00 seconds. Differences can occur in regions with high stratification or if something blocks the intake.

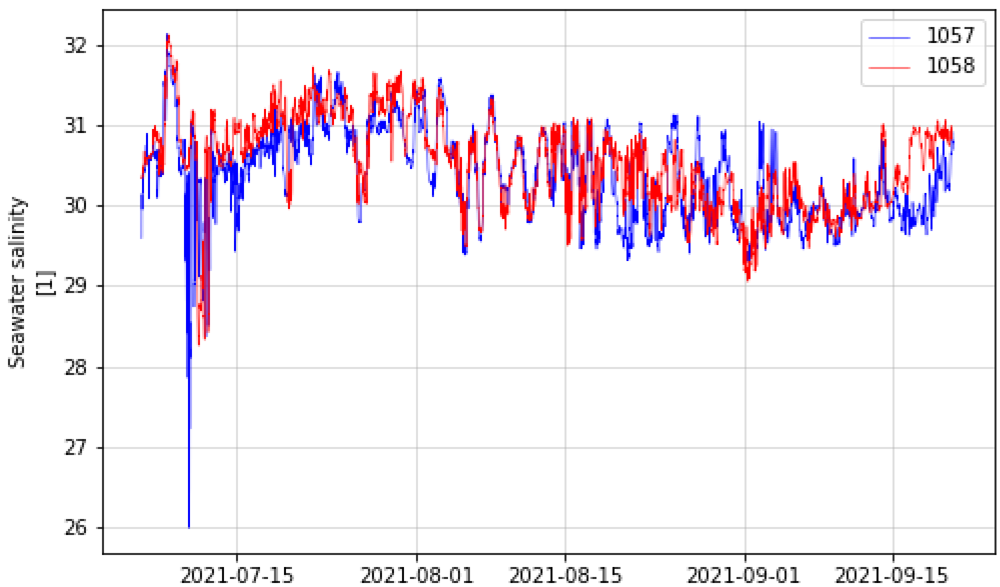

Figure 16. Salinity from SBE37 instrument.

Data Format and Access

All the data is in netcdf and CF/ACDD standards compliant and consistent with the NOAA/NCEI in-situ template. Data for deployments SD1057 and SD1058 may be accessed through the NASA Physical Oceanography Distributed Active Archive Center (PO.DAAC) via https://podaac.jpl.nasa.gov/dataset/SAILDRONE_ARCTIC.