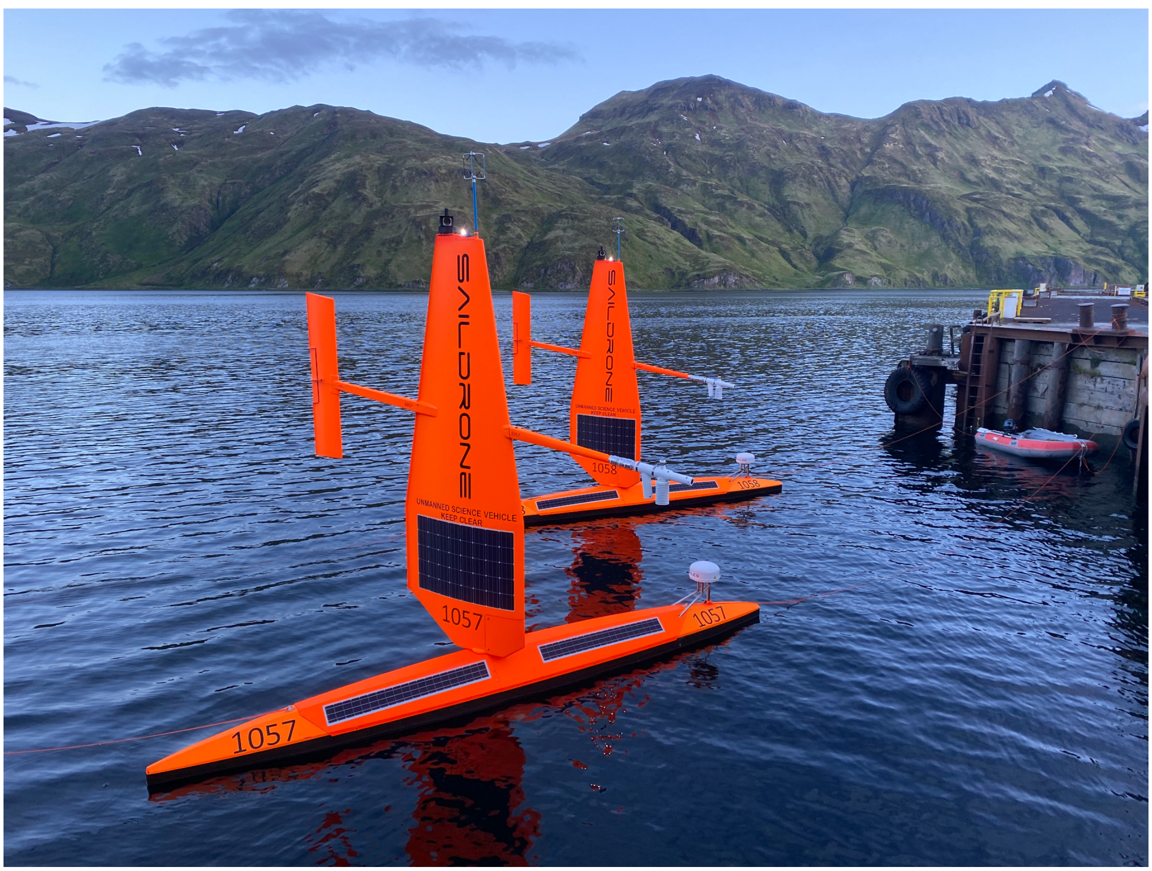
2021 Arctic Saildrone Cruise

NASA Physical Oceanography and Saildrone

NASA grant #80NSSC20K0768

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 or marisolgr@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**
Chelle Gentemann	Chief Scientist	Air-sea interactions, diurnal warming, validation of obs	cgentemann@faralloninstitute.org
Peter Minnett	Co-Investigator	Diurnal warming, satellite comparisons	pminnett@rsmas.miami.edu
Michael Steele	Co-Investigator	Arctic Oceanography	mas@apl.washington.edu
Sandra Castro	Partner	SST validation and uncertainties, diurnal warming	sandrac@colorado.edu
Peter Cornillon	Partner	Fronts, small scale variability in the upper ocean	pcornillon@me.com
Ed Armstrong	Partner	Data distribution	edward.armstrong@jpl.nasa.gov
Jorge Vazquez-Cuervo	Partner	Application of salinity and SST to coastal upwelling/validation	jvazquez@jpl.caltech.edu
Vardis Tsontos	Partner	Data archival / distribution	vtsontos@jpl.nasa.gov
Edward Cokelet	Partner	Data validation / distribution	edward.d.cokelet@noaa.gov
Marisol García-Reyes	Partner	Report, data distribution	marisolgr@faralloninstitute.org

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
Dave Peacock	Director of Robotics	Vehicle Software	dave@saildrone.com
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
Charles Hamel	Mission Manager	Vehicle Piloting and mission execution	charles.hamel@saildrone.com

Cruise Narrative

The two Saildrone vehicles (SD-1057, SD-1058) in this cruise departed from Dutch Harbor, Alaska for a 90-day cruise in the Chukchi Sea. Scientific data sampling occurred from 6 July to 20 September 2021, once the vehicles made it to the Bering Strait. Scientific objectives included 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 the recording of science measurements on September 20. The vehicles returned to Dutch Harbor on October 20.

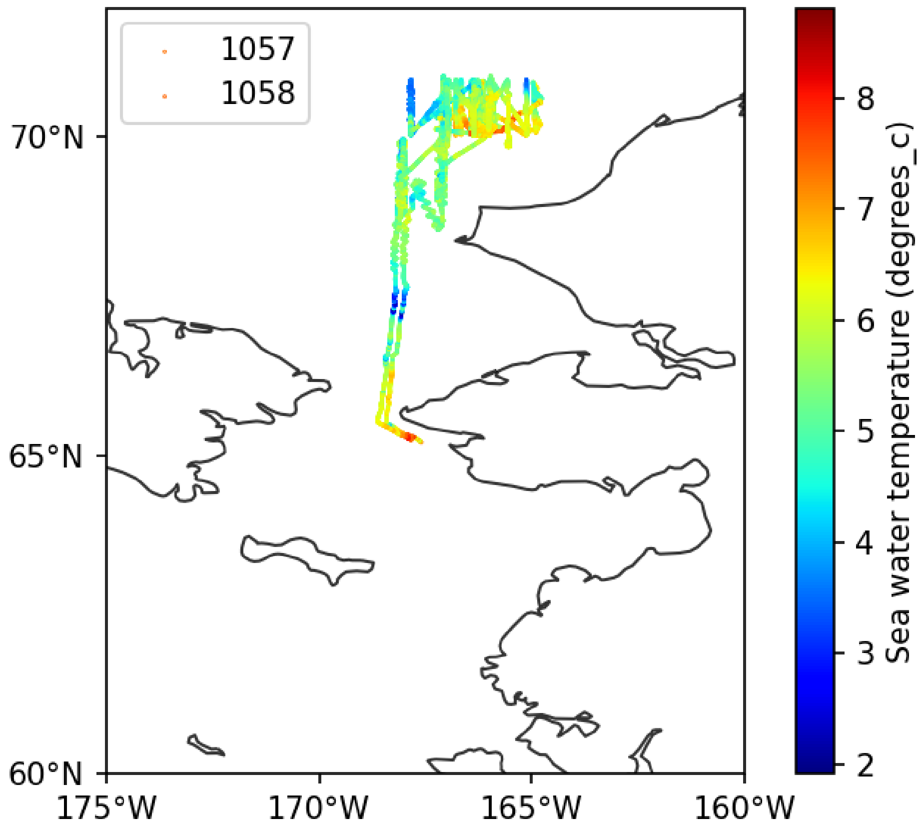


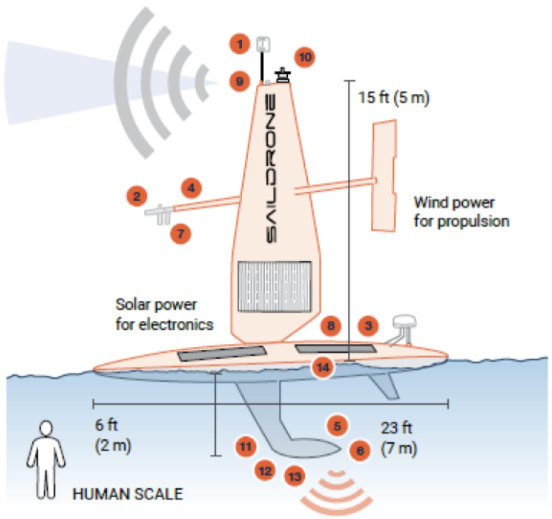
Figure 1. Cruise tracks for the 2021 Arctic Saildrone deployment, showing sea water temperature data from the SBE37 CT-ODO instrument.

General Timeline for Saildrones, 14 June 2021 to 20 October 2021

June 14: Saildrone vehicles departed from Dutch Harbor f
July 6: First waypoint reached near the Bering Strait, 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

The following diagram shows the standard configuration of Saildrone vehicles. For this campaign, some instrumentation is different, some in depth/height, and others instruments that are replaced for the particular purposes of this cruise. Details in the next tables and the figures of the Data section.



PAYLOAD OPTIONS

No.	Variable	Sensor	
1	Wind speed & direction	Gill Windmaster 3D Ultrasonic 20Hz @ + 5.2 m	ATMOSPHERIC
2	Air temp & humidity	Rotronic HC2 - S3 with rad shield @ + 2.3 m	ATMOSPHERIC
3	Barometric pressure	Vaisala Barocap PTB210 @ +0.2 m	ATMOSPHERIC
4	Photosynthetically active radiation	LI-COR LI-192SA @ +2.6 m	ATMOSPHERIC
5	Salinity, temperature & dissolved oxygen	Seabird SBE 37 SMP ODO @ -1.7 m	OCEAN
6	Chlorophyll-a	Wetlabs ECO-FL-S G4 @ -1.9 m	OCEAN
7	Skin temperature	Heitronics CT 15.10 @ +2.3	OCEAN
8	Wave height & period	Dual GPS aided IMU	OCEAN
14	Carbon	NOAA PMEL ASVCO2 (pCO2) Atmospheric & dissolved pCO2	OCEAN
9	AIS transceiver		MDA
10	Smart camera array	360° High-resolution optical cameras with ML target detection	MDA
11	Ocean currents	Teledyne RDI Workhorse ADCP 300 kHz @ -1.9 m	ACOUSTIC
12	Fish biomass	Simrad WBT Mini (EK80) @ -1.9 m	ACOUSTIC
13	Bathymetry	Shallow-water single-beam: Airmar DT800	ACOUSTIC
		Deep-water single-beam: Teledyne Echotrac E20	ACOUSTIC
		Deep-water single-beam: Simrad WBT Mini	ACOUSTIC

VEHICLE SPECIFICATIONS

Hull length:	23 ft (7 m)
Wing height:	15 ft (5 m)
Draft:	6 ft (2 m)
Propulsion:	Wind (Saildrone wing)
Average speed:	2 – 3 knots
Endurance:	12+ months
Range:	Unlimited

SAILDRONE EXPLORER

Figure 2. Saildrone vehicle specifications and instrumentation placements.Saildrone vehicle specifications and instrumentation placements. Not all instruments in the figure were installed for this cruise, and some are at different depth/height. In addition, IR Heitronics radiometers were installed on the wings and Seabird CTD-ODO were installed in each vehicle. See table 3 for more details. Image credit: Saildrone, Inc.

Table 3. Information on the main variables of the Saildrone vehicle *in situ* dataset from the standard vehicle payload. This table is meant to accompany the Saildrone data description. See the text for more details on each dataset.

Variable Name	Variable	Sensor	Model Name	Installed Height (m)	Sampling Schedule
BKSCT_RED_MEAN	Optical backscatter at 650 nm	Fluorometer	WET Labs FLS	-1.9	12s on, 48s off
BARO_PRES_MEAN	Air pressure	Barometer	Vaisala: PTB210	0.2	60s on, 240s off
CDOM_MEAN	CDOM concentration	Fluorometer	WET Labs FLS	-1.9	12s on, 48s off
CHLOR_WETLABS_MEAN	Chlorophyll concentration	Fluorometer	WET Labs FLS	-1.9	12s on, 48s off
COND_SBE37_MEAN	Seawater conductivity	Sea-Bird CT-ODO	SBE37-SMP-ODO Microcat	-1.7	12s on, 588s off
GUST_WND_MEAN	Wind gust speed	Anemometer	Gill: 1590-PK-020	5.2	60s on, 240s off
O2_CONC_SBE37_MEAN	Oxygen concentration	Sea-Bird CT-ODO	SBE37-SMP-ODO Microcat	-1.7	12s on, 588s off
O2_SAT_SBE37_MEAN	Oxygen saturation	Sea-Bird CT-ODO	SBE37-SMP-ODO Microcat	-1.7	12s on, 588s off
PAR_AIR_MEAN	Photosynthetically active radiation in air	LI-COR PAR	LI-COR: LI-192SA	2.6	Always On
RH_MEAN	Relative humidity	AT/RH	Rotronic: HC2-S3	2.3	60s on, 240s off
SAL_SBE37_MEAN	Seawater salinity	Sea-Bird CT-ODO	SBE37-SMP-ODO Microcat	-1.7	12s on, 588s off
TEMP_AIR_MEAN	Air temperature	AT/RH	Rotronic: HC2-S3	2.3	60s on, 240s off
TEMP_IR_SEA_WING_UNCOMP_MEAN	Wing Sea IR Temperature	Wing IR Pyrometer	Heitronics: CT15.10	2.25	30s on, 270s off
TEMP_SBE37_MEAN	Seawater temperature	Sea-Bird CT-ODO	SBE37-SMP-ODO Microcat	-1.7	12s on, 588s off
UWND_MEAN	Eastward wind speed	Anemometer	Gill: 1590-PK-020	5.2	60s on, 240s off
VWND_MEAN	Northward wind speed	Anemometer	Gill: 1590-PK-020	5.2	60s on, 240s off
WWND_MEAN	Downward wind speed	Anemometer	Gill: 1590-PK-020	5.2	60s on, 240s off
WATER_CURRENT_SPEED_MEAN	Water Current Speed	ADCP	Teledyne: Workhorse WHM300-I-U	-1.9	300s on, 300s off

			G1		
WATER_CURRENT_DIRECTION_MEAN	Water Current Direction	ADCP	Teledyne: Workhorse WHM300-I-UG1	-1.9	300s on, 300s off
WAVE_DOMINANT_PERIOD	Dominant wave period	Hull IMU	VectorNav: VN-300	0.34	Always On
WAVE_SIGNIFICANT_HEIGHT	Significant wave height	Hull IMU	VectorNav: VN-300	0.34	Always On
WIND_HEIGHT_MEAN	Wind measurement height	Anemometer	Gill: 1590-PK-020	5.2	60s on, 240s off
latitude	Latitude	Hull IMU	VectorNav: VN-300	0.34	Always On
longitude	Longitude	Hull IMU	VectorNav: VN-300	0.34	Always On
time	time UTC				
trajectory	Vehicle identification number				

Table 4. Information on the ocean current *in situ* Saildrone instrument: 300kHz Teledyne RDI ADCP Workhorse Monitor WHM300. The ADCP is installed at a depth of 1.9m and configured with 2m bins, with a max depth of 102m. ADCP data is provided at 5min resolution (sampling schedule 300s on, 300s off) and corrected with the vehicle velocity. The ADCP data was processed to netCDF files by Saildrone. 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 up
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 of 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	Bottom track percent good
bt_vel_east	Bottom track velocity east
bt_vel_north	Bottom track velocity north
bt_vel_up	Bottom track velocity up
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
latitude	Latitude
longitude	Longitude
time	time UTC
trajectory	Saildrone vehicle identification number

Data

Seawater Temperature

Saildrone carries two instruments for measuring seawater temperature. These include one CTD-ODO that measures sea water temperature at 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.

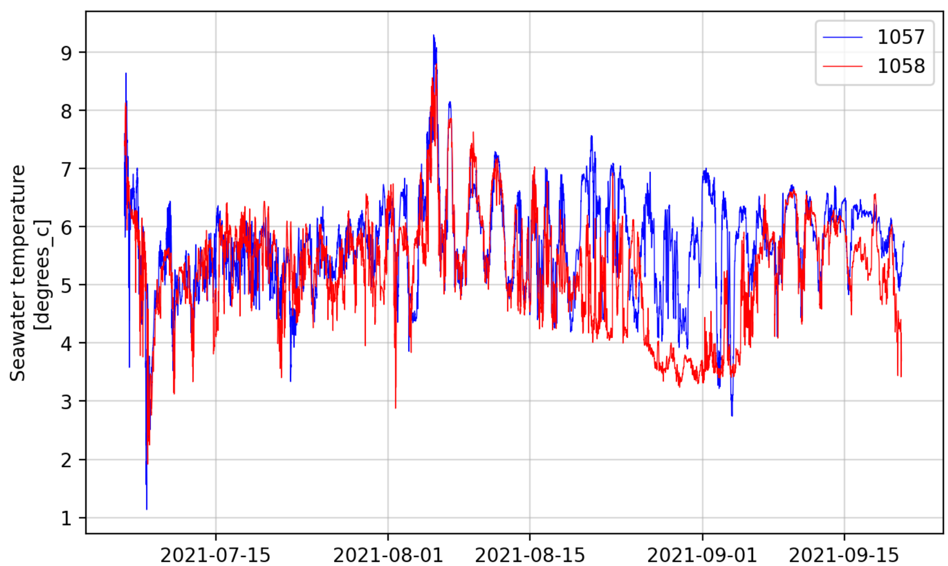


Figure 3. Seawater temperatures measured by SBE37 instruments at 0.5m depth during the cruises.

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.

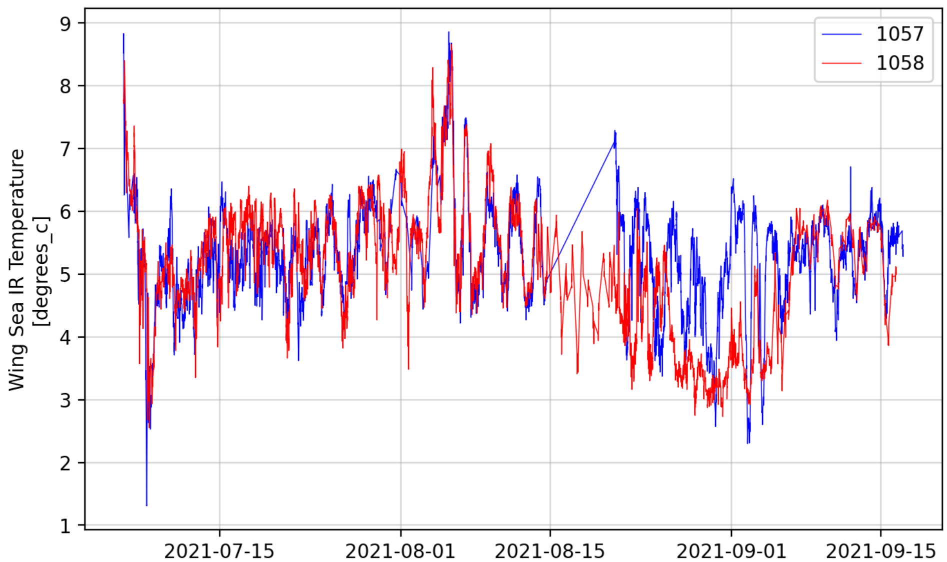


Figure 4. IR wing seawater temperature measured during the cruises.

Dissolved Oxygen

The vehicles measure oxygen concentration and saturation using an unpumped SBE37 CTD-ODO. Data are averaged into 1 minute means using 12 sec of 1Hz-sampled data. Saildrone designed the flow-thru so that "fresh" water would always be flowing past dissolved oxygen sensor due to motion of the vehicle, the drone's motion is essentially providing pumping. The instruments are installed at 0.5m depth.

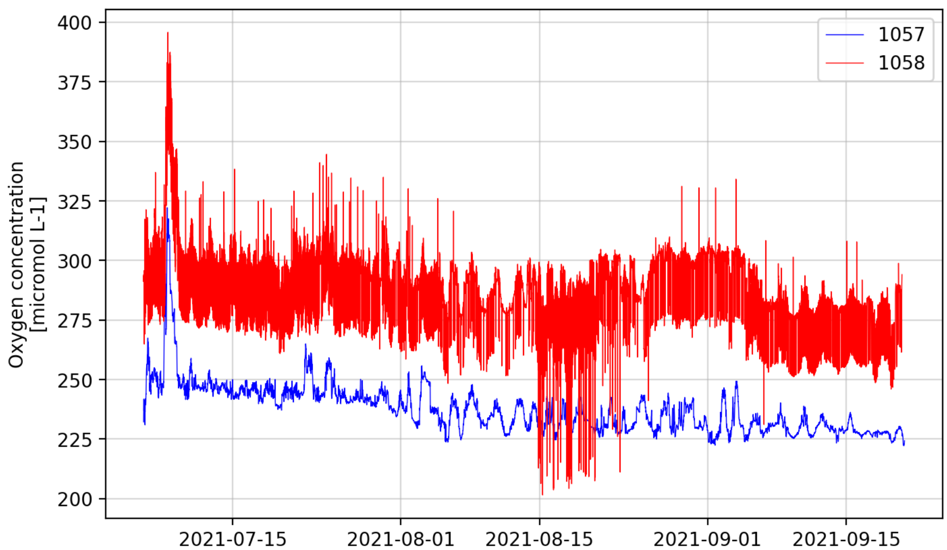


Figure 5. SBE37 O_2 concentrations measured during the cruises.

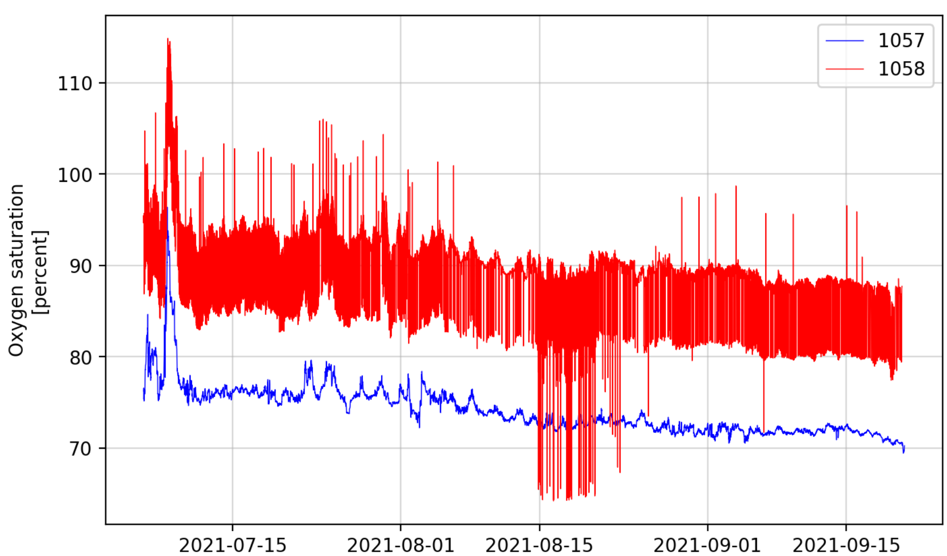


Figure 6. SBE37 O_2 saturations measured during the cruises.

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 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.

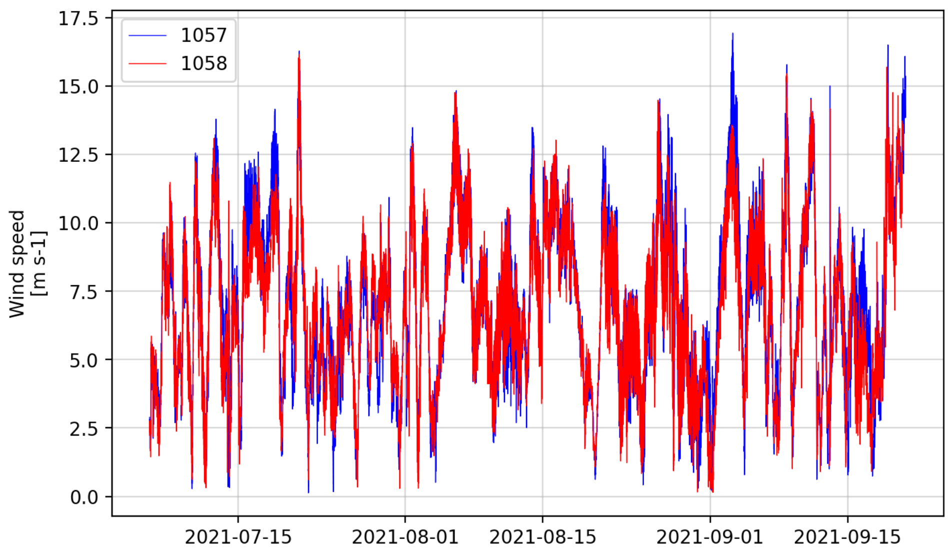


Figure 7. Wind speeds measured during the cruises.

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 every 5 minutes.

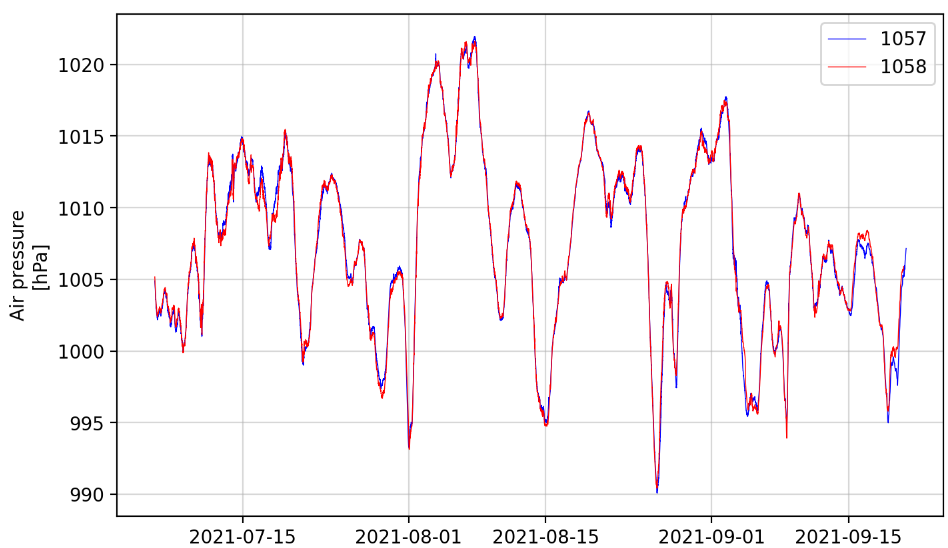


Figure 8. Air pressures measured during the cruises.

Air Temperature and Humidity

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

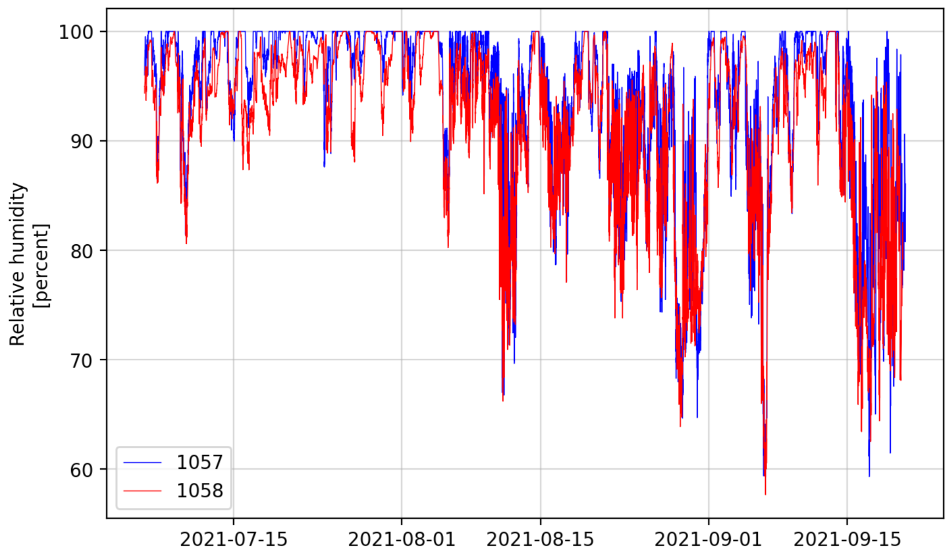


Figure 9. Relative humidity measured during the cruises.

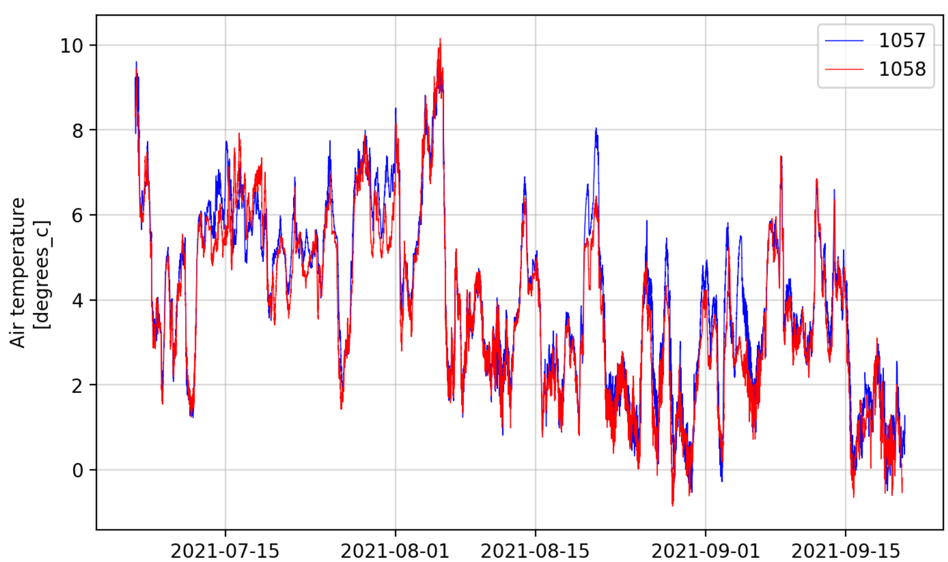


Figure 10. Air temperatures measured during the cruises.

Ocean Color

Chlorophyll concentration, CDOM concentration, and optical backscatter at 650 nm were 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.

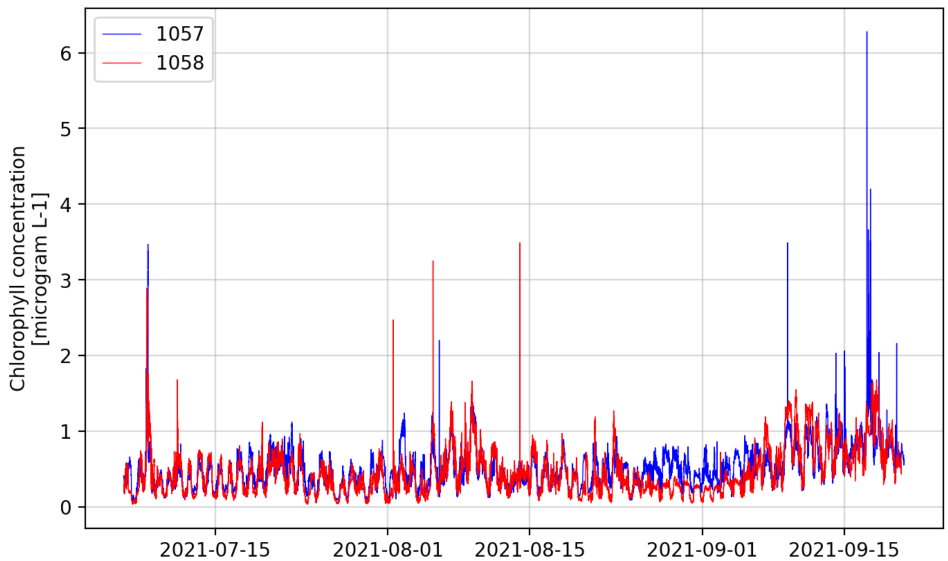


Figure 11. Chlorophyll concentrations measured by the Wetlabs instruments.

Salinity

Seawater salinity is derived from temperature and conductivity measured by the SBE37 CT-ODO. Data sampled at 1Hz are averaged into 1 minute averages using 12s of data.

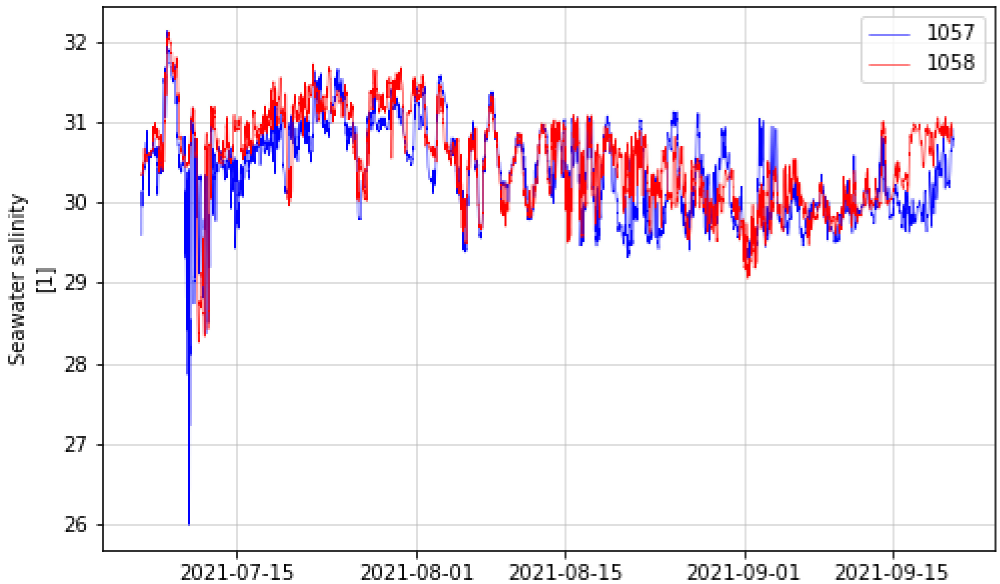


Figure 12. Salinity from SBE37 CT-ODO instrument.

Data Format and Access

All the data are in netcdf files, which are CF/ACDD standards compliant and consistent with the NOAA/NCEI *in situ* template v2.0. Data for deployments SD-1057 and SD1-058 may be accessed through the NASA Physical Oceanography Distributed Active Archive Center (PO.DAAC) via https://podaac.jpl.nasa.gov/dataset/SAILDRONE_ARCTIC_2021.