NOAA Pacific Marine Environmental Laboratory
Ocean Climate Stations Project

DATA ACQUISITION AND PROCESSING REPORT FOR PA012

Site Name:	Ocean Station Papa
Deployment Number:	**PA012**
Year Established:	2007
Nominal Location:	50.1°N 144.9°W
Anchor Position:	50° 02.968’ N, 144° 52.402’ W (triangulated)
Deployment Date:	July 22, 2018
Recovery Date:	June 13, 2019
Project P.I.:	Dr. Meghan F. Cronin
Report Authors:	N.D. Anderson, P. Berk, and M.F. Cronin
Data Processors:	N.D. Anderson
Date of Report:	March 14, 2022
Revision History:	

Special Notes:

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Data Acquisition and Processing Report for OCS Mooring PA012

1.0 Mooring Summary

As the site of a former ocean weather ship, Station Papa (50°N, 145°W) is one of the oldest oceanic time series and a critical site in the global network of OceanSITES time series reference stations. Through initial 3-year support from the National Science Foundation (NSF) and sustained funding from NOAA, and in collaboration with the Canadian Department of Fisheries and Oceans (DFO) Line P Program, a surface mooring was deployed in June 2007 at Ocean Station Papa to monitor ocean-atmosphere interactions, carbon uptake, and ocean acidification. PA012 was the twelfth deployment at this site.

The PA012 mooring was deployed on July 22nd, 2018 from the Navy-owned UNOLS research vessel (R/V) SALLY RIDE, operated by the Scripps Institution of Oceanography. Recovery was performed on June 13th, 2019 by the Canadian Coast Guard Ship (CCGS) JOHN P. TULLY. The Ocean Climate Stations group would like to thank the captain and crew of both ships, as well as the scientists aboard, for their contributions to the success and maintenance of the Papa mooring.

The Papa mooring site is nominally at 50.1°N, 144.9°W. The actual anchor position is different for each year, but deployments alternate between two target locations.

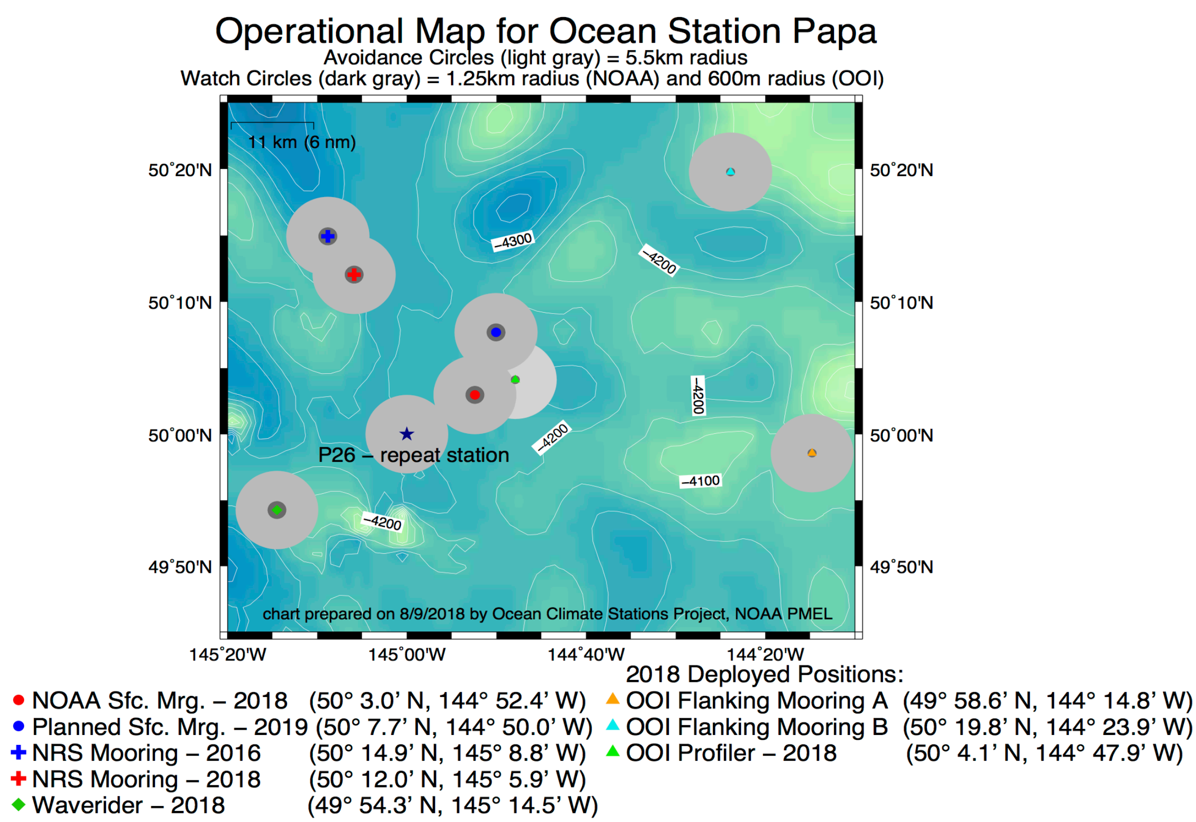

Figure 1: Overview of Station P deployments, at the time of PA012's deployment.

1.1 Mooring Description

The PA012 mooring was a taut-line mooring, with a scope of 0.965**. Non-rotating 7/16" (1.11cm) diameter wire rope, jacketed to 1/2" (1.27cm), was used in the upper 325m of the mooring line. The remainder consisted of plaited 8-strand nylon line to the acoustic release in line above the anchor, as shown in Figure 3. The 6,850lb (3,107kg) anchor was fabricated from scrap railroad wheels.

** PA012's scope was incorrect by ~200m due to an incorrect measurement of the tapered nylon. This increased the watch circle radius and caused the deep T/S to intermittently hit the seafloor.

The surface buoy was a 2.6m fiberglass-over-foam discus buoy, with a central instrument well. It had an aluminum tower and a stainless steel bridle.

OCS partner groups also provided mooring instrumentation. The University of Washington contributed a seabird, gas tension device, and oxygen level monitoring equipment, while the PMEL carbon group attached a fluorometer and a SAMI pH sensor, along with their primary CO_2 flux monitoring system housed in the well. OCS is not responsible for the acquisition or processing of these data, so no further discussion of these systems is included in this report.

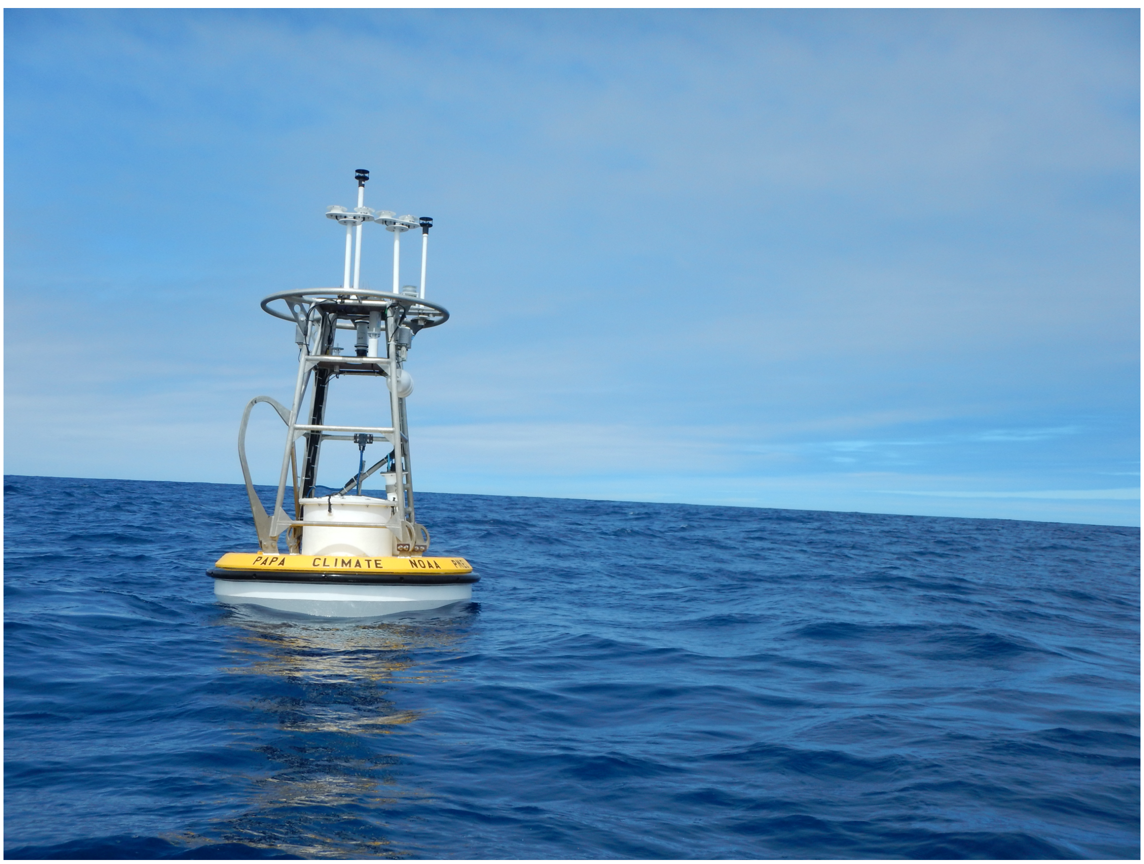

Figure 2: PA012 as deployed.

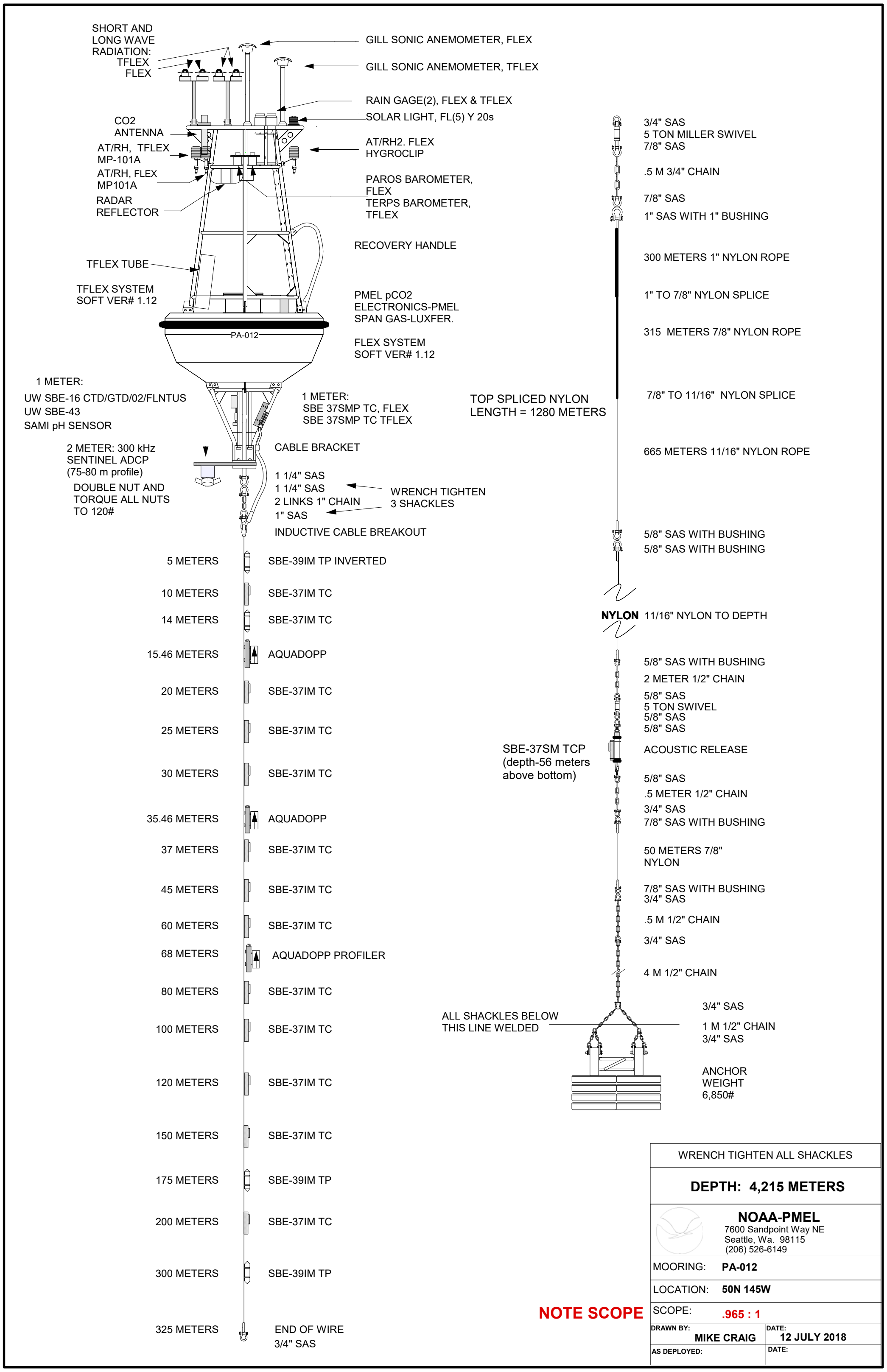

Figure 3: PA012 mooring diagram.

1.2 Instrumentation on PA012

The following instrumentation was deployed on PA012. Redundant data acquisition systems were used, Flex and TFlex. Flex meteorological sensors are generally considered primary. Any substitutions are noted in the relevant section of this report.

Deployment:		**PA012**			
Met Sensors		**Model**	**Serial #**		**Notes**
Height	Acquisition	**FLEX**	5	/	
2.6m	ATRH	Rotronics MP-101A	133375		
2.6m	ATRH2	Rotronics HygroClip	61334171		
4.2m	Wind	Gill	10510082		
2.5m	BP	Paros	114859		
3.1m	Rain	RM Young	1951		
3.6m	SWR	Eppley PSP	38430		
3.6m	LWR	Eppley PIR	38694		
	Acquisition	**TFLEX**	2003		
2.6m	ATRH	Rotronics MP-101A	500582		
3.8m	Wind	Gill	044001		
2.5m	BP	TERPS	10879093		
3.1m	Rain	RM Young	1807		
3.6m	SWR	Eppley PSP	38485		
3.6m	LWR	Eppley PIR	38440		
CO2	Electronics	PMEL	27		
	Span Gas	Luxfer	JJ12951		
Subsurface Instrumentation					
Bridle		**Model**	**Serial #**		**Notes**
1m	SST/C	SBE37SMP - TC	11553		Flex, AA batteries (2015)
1m	SST/C	SBE37SMP - TC	11555		TFLEX, AA batteries
1m	pH	SAMI	P210		
1m	SST/C	SBE16	6363		Supplied by UW
1m	Oxygen	Optode	488		Supplied by UW
1m	Oxygen	SBE43	430630		Supplied by UW
1m	Fluorescence	ECO FLNTUS	2844		Supplied by CO2 - Self Powered
1m	Gas Tension	GTD	32-131-15		Supplied by UW
2m	ADCP	Workhorse Sentinel	14607		
Depth		**Model**	**Serial #**	**ID**	**Notes**
5m	T	SBE39IM - T	3287	01	Inverted (Use TP for titanium housing)
10m	TC	SBE37IM - TC	16836	02	
14m	TC	SBE37IM - TC	12229	03	
15.46m	ADCP	AquaDopp	6810	04	
20m	TC	SBE37IM - TC	12517	05	
25m	TC	SBE37IM - TC	6141	06	
30m	TC	SBE37IM - TC	6142	07	
35.46m	ADCP	AquaDopp	8071	08	
37m	TC	SBE37IM - TC	6145	09	
45m	TC	SBE37IM - TC	6146	10	
60m	TC	SBE37IM - TC	7786	11	
68m	ADCP	AquaDopp Profiler	13317	-	Non-inductive; Upward Looking
80m	TC	SBE37IM - TC	7787	12	
100m	TC	SBE37IM - TC	7789	13	
120m	TC	SBE37IM - TC	7790	14	
150m	TC	SBE37IM - TC	7791	15	
175m	TP	SBE39IM - TP	4862	16	
200m	TC	SBE37IM - TC	7792	17	
300m	TP	SBE39IM - TP	4866	18	
325m	End of Wire				
Release	TCP	SBE37SM - TCP	12509	-	
Acoustic	Release		49323	-	

Table 1: Instruments deployed on PA012.

Since 2007, the measurement point for SST/C is known to have varied between 1.0 - 1.3m depth. Uncertainties in actual measurement depth are introduced by changes in buoy waterlines, variation between instrument mounting locations, and alteration of measurement points with different instrument versions. For these reasons, the nominal depth for the SST/C measurement is stated as 1m.

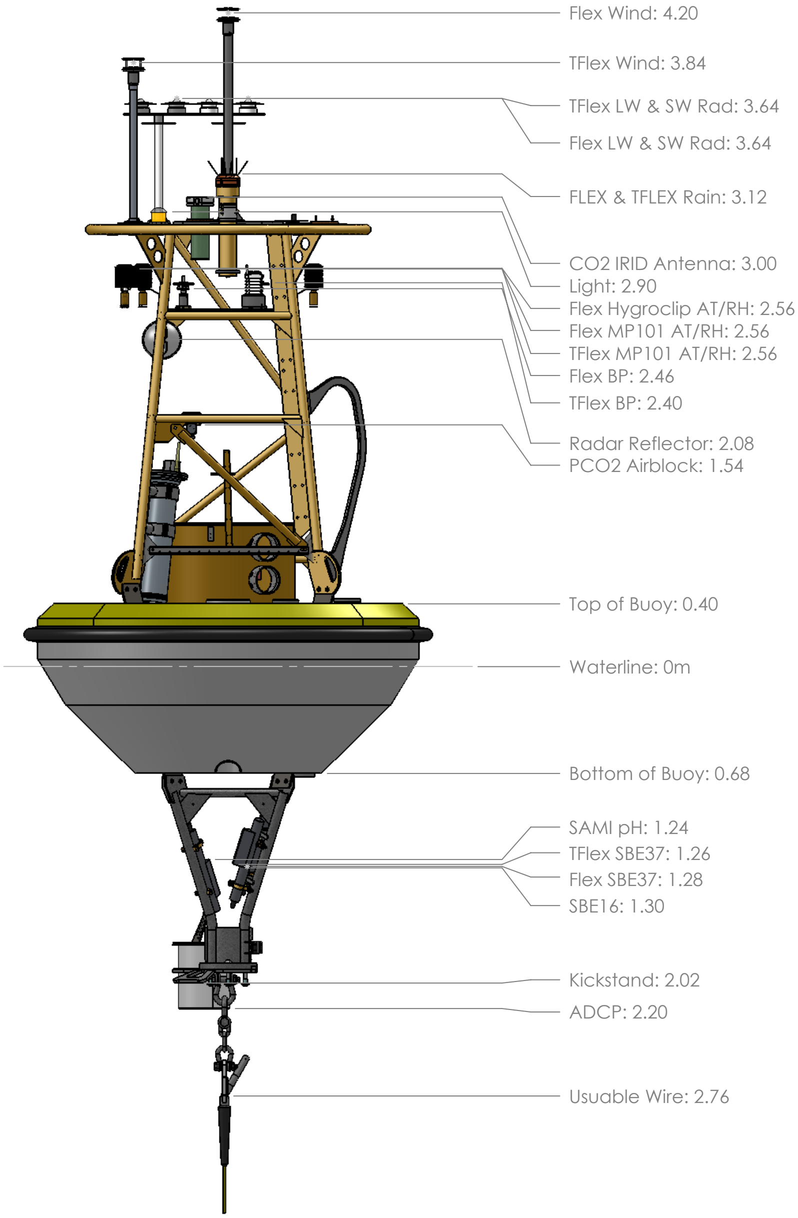

Figure 4: Buoy diagram showing bridle arrangement. The SBE16 package contains a suite of sensors.

2.0 Data Acquisition

Two independent data acquisition systems were deployed on PA012, Flex and TFlex. Both systems telemetered hourly averaged surface data via Iridium satellite, with Flex also transmitting hourly data from the subsurface instruments. High-resolution data are logged internally throughout the deployment in subsurface instruments, and downloaded upon recovery of the mooring.

Position information associated with real-time data comes through the Iridium satellite network. Buoy latitude and longitude are transmitted to shore via three GPS devices on the Flex, TFlex, and CO_2 systems. The Flex GPS measurements are hourly, and TFlex GPS measurements occur every six hours. Any positions outside the established watch circle are spotted and removed during quality control operations.

2.1 Sampling Specifications

The following tables describe the high-resolution sampling schemes for the PA012 mooring, for both the primary and secondary systems. Observation times in data files are assigned to the center of the averaging interval. Flex sensors are generally considered primary. Any substitutions are noted in the relevant section of this report.

PRIMARY SENSORS

Measurement	Sample Rate	Sample Period	Sample Times	Recorded Resolution	Acquisition System
Wind Speed/Direction	2 Hz	2 min	2359-0001, 0009-0011…	10 min	FLEX
Air Temperature + Relative Humidity	1 Hz	2 min	2359-0001, 0009-0011…	10 min	FLEX
Barometric Pressure	1 Hz	2 min	2359-0001, 0009-0011…	10 min	FLEX
Rain Rate	1 Hz	1 min	0000-0001, 0001-0002…	1 min	FLEX
Shortwave Radiation	1 Hz	1 min	0000-0001, 0001-0002…	1 min	TFLEX
Longwave Radiation (Thermopile, Case & Dome Temperatures)	1 Hz	1 min	0000-0001, 0001-0002…	1 min	TFLEX
Seawater Temperature, Pressure & Conductivity	1 per 10 min	Instant.	0000, 0010,…	10 min	Internal
Ocean Currents (Point)	1 Hz	2 min	2359-0001, 0009-0011…	10 min	Internal
Ocean Currents (Sentinel)	1 Hz	2 min	2359-0001, 0029-0031…	30 min	Internal
Ocean Currents (AQDPRO)	1 Hz	2 min	2354-2356, 0054-0056…	1 hr	Internal
GPS Positions	1 per hr	Instant.	~0000, 0100…	1 hr	FLEX

Table 2: Sampling parameters of the primary sensors on PA012.

SECONDARY SENSORS

Measurement	Sample Rate	Sample Period	Sample Times	Recorded Resolution	Acquisition System
Wind Speed/Direction	2 Hz	2 min	2359-0001, 0009-0011…	10 min	TFLEX
Air Temperature + Relative Humidity	1 Hz	2 min	2359-0001, 0009-0011…	10 min	TFLEX
Barometric Pressure	1 Hz	2 min	2359-0001, 0009-0011…	10 min	TFLEX
Rain Rate	1 Hz	1 min	0000-0001, 0001-0002…	1 min	TFLEX
Shortwave Radiation	1 Hz	1 min	0000-0001, 0001-0002…	1 min	FLEX
Longwave Radiation (Thermopile, Case & Dome Temperatures)	1 Hz	1 min	0000-0001, 0001-0002…	1 min	FLEX
SSTC	1 per 10 min	Instant.	0000, 0010,…	10 min	Internal
GPS Positions	1 per 6hrs	Instant.	~0000, 0600, …	6 hrs	TFLEX

Table 3: Sampling parameters of the secondary sensors on PA012.

2.2 Data Return

Data returns are calculated from the highest-resolution data, comparing the number of records available to the total amount of records expected for the period. The following list shows the data returns from the surface and subsurface measurements from both acquisition systems.

Flex 0005:

```
Data Return Summary
2018-07-22 01:28:00 to 2019-06-13 14:15:00

Sensor      Deployed      Obs    Return
=======================================
AT1            47020    46876     99.7%
AT2            47020    46876     99.7%
RH1            47020    46876     99.7%
RH2            47020    46876     99.7%
WIND1          47020    46738     99.4%
BP1            47020    46876     99.7%
RAIN1         470207   465171     98.9%
SWR1          470207   465173     98.9%
LWR1          470207   465161     98.9%
SST1           47020    47020    100.0%
SSC1           47020    47020    100.0%
SSS1           47020    47020    100.0%

Subsurface Temperature Profile
     1m        47020    47020    100.0%
     1m(TFlex)47020     47020    100.0%
     5m        47020    47020    100.0%
    10m        47020    47020    100.0%
    14m        47020    47020    100.0%
    20m        47020    47020    100.0%
    25m        47020    47020    100.0%
    30m        47020    47020    100.0%
    37m        47020    47020    100.0%
    45m        47020    47020    100.0%
    60m        47020    47020    100.0%
    80m        47020    47020    100.0%
   100m        47020    47020    100.0%
   120m        47020    47020    100.0%
   150m        47020    47020    100.0%
   175m        47020    47020    100.0%
   200m        47020    47020    100.0%
   300m        47020    47020    100.0%
  4171m        47020    47020    100.0%

Subsurface Pressure Profile
   175m        47020    47020    100.0%
   300m        47020    47020    100.0%
  4171m        47020    47020    100.0%
```

Subsurface Salinity Profile

1m	47020	47020	100.0%	
1m(TFlex)	47020	32352	68.8%	
10m	47020	47020	100.0%	
14m	47020	47020	100.0%	
20m	47020	47020	100.0%	
25m	47020	47020	100.0%	
30m	47020	47020	100.0%	
37m	47020	47020	100.0%	
45m	47020	47020	100.0%	(see Section 3.3)
60m	47020	47020	100.0%	
80m	47020	47020	100.0%	
100m	47020	47020	100.0%	
120m	47020	47020	100.0%	
150m	47020	47020	100.0%	
200m	47020	47020	100.0%	
4171m	47020	47020	100.0%	

AQD Current Velocity

15m	47020	47020	100.0%
35m	47020	47020	100.0%

TFlex 2003:

Data Return Summary
2018-07-22 01:28:00 to 2019-06-13 14:15:00

Sensor	Deployed	Obs	Return
AT1	47020	46942	99.8%
RH1	47020	46942	99.8%
WIND1	47020	46942	99.8%
BP1	47020	46942	99.8%
RAIN1	470207	467902	99.5%
SWR1	470207	468781	99.7%
LWR1	470207	469146	99.8%

2.3 Known Sensor Issues

Daily averaged SWR sensor data differed by 2.9%, so the higher TFlex data were used as primary. Flex LWR (S/N 38694) functioned throughout the deployment, but a few outlier datapoints were observed on November 29th and 30th of 2018 and were flagged Q5 (removed). Further discussion can be found in the SWR and LWR sections of this report.

The primary Flex RH sensor performed well, but read high after being brought aboard the ship, possibly having gotten wet during recovery. Data quality was not compromised during the deployment, and these data were eliminated when truncated to the deployment's start and end times. The TFlex RH failed its post-calibration, and was flagged as lower quality (Q4).

Recent testing revealed that Flex and TFlex systems were not applying calibration coefficients to non-Paros barometric pressure sensors. Calibration coefficients for the TFlex TERPS sensor were thus applied in post-processing and assigned Q3 (adjusted).

Any wind measurements that grossly differed between systems (>5 m/s) were flagged and removed in the secondary (TFlex) wind record, as well as any wind speed measurements that exceeded the measured gusts within a 2-minute burst sample, since the averaged wind speed across a burst sample should not exceed the average of the highest 3 samples.

All surface sensors on the Flex system failed to record data to memory between 3/21/2019 at 17:10 UTC and 3/22/2019 at 16:00, explaining the maximum Flex surface data returns being capped at 99.7% (see Section 2.2). This behavior has been observed before by GTMBA, but the cause is unknown.

Subsurface issues are discussed in Section 3.3, but relative to other mooring deployments, PA012 data returns were higher than average, and the dataset required relatively fewer quality control measures.

3.0 Data Processing

Processing of data from OCS moorings is performed with the assistance of the PMEL Global Tropical Moored Buoy Array (GTMBA) project group. There are some differences between OCS data and data from GTMBA moorings, but standard methods described below are applied whenever possible. The process includes assignment of quality flags for each observation, which are described in Appendix A. Any issues or deviations from standard methods are noted in processing logs, and in this report.

Raw data recovered from the internal memory of the data acquisition system are first processed using computer programs. Instrumentation recovered in working condition is returned to PMEL for post-recovery calibration before being reused on future deployments. These post-recovery calibration coefficients are compared to the pre-deployment coefficients. If the comparison indicates a drift larger than the expected instrumental accuracy, the quality flag is lowered for the measurement. If post-recovery calibrations indicate that sensor drift was within expected limits, the quality flag is raised. Post-recovery calibrations are not generally applied to the data, except for seawater salinity, or as otherwise noted in this report. Failed post-recovery calibrations are noted, along with mode of failure, and quality flags are left unchanged to indicate that pre-deployment calibrations were applied and sensor drift was not estimated.

The automated programs also search for missing data, and perform gross error checks for data that fall outside physically realistic ranges. A computer log of potential data problems is automatically generated as a result of these procedures.

Time series plots, difference plots, and comparison plots are generated for all data. Plots of differences between adjacent subsurface temperature measurements are also generated. Statistics, including the mean, median, standard deviation, variance, minimum and maximum are calculated for each time series.

Trained analysts examine individual time series and statistical summaries. Data that have passed gross error checks, but which are unusual relative to neighboring data in the time series, or which are statistical outliers, are examined on a case-by-case basis. Mooring deployment and recovery logs are searched for corroborating information such as battery failures, vandalism, damaged sensors, or incorrect clocks. Consistency with other variables is also checked. Data points that are ultimately judged to be erroneous are flagged, and in some cases, values are replaced with “out of range” markers. For a full description of quality flags, refer to Appendix A.

For some variables, additional post-processing after recovery is required to ensure maximum quality. These variable-specific procedures are described below.

3.1 Buoy Positions

Since Papa is a taut-line mooring with a short scope, the buoy has a watch circle radius of 1.25km. When using Papa data in scientific analyses, the nominal position is usually adequate. For users wanting additional accuracy, the more accurate positions from the GPS are also provided at their native resolution. Gross error checking was performed to eliminate values outside the watch circle, but no further processing was performed. Since the mooring remained anchored throughout the year, and positions outside of the PA012 watch circle were also uncorroborated by the other acquisition system, these few points indicated a bad GPS fix, justifying their removal.

At Papa, the acquired positions were used to determine buoy velocities. These velocities are not applied, but are provided alongside the current meter data at hourly and higher resolutions.

3.2 Meteorological Data

All primary meteorological sensors on PA012 remained functional at or near 100% throughout the deployment.

No data from secondary sensors are included in the final data files, except when included in OceanSITES files as secondary data. The OceanSITES data repository can be found here: https://dods.ndbc.noaa.gov/thredds/catalog/oceansites/DATA/PAPA/catalog.html

The PA012 buoy had secondary air temperature, relative humidity, wind, rain, air pressure, and radiation sensors. A Rotronic HygroClip measuring air temperature and relative humidity provided the mooring's only tertiary data, which were not distributed in any format.

3.2.1 Winds

PA012 winds performed well over the course of the deployment. Standard quality flags (Q2) were assigned, with infrequent hard-flagging (Q5) required where gross error thresholds were exceeded (e.g. large differences between Flex and TFlex on a given burst sample, or incompatible wind speed and gust measurements).

3.2.2 Air Temperature

The Flex air temperature sensor was selected as primary to align with the primary MP101 sensor selection for relative humidity. Air temperature sensors all performed well throughout this deployment, with mean and RMS differences of 0.1°C, below the accuracy specification of 0.2°C.

3.2.3 Relative Humidity

The TFlex relative humidity sensor failed its post-calibration upon return to the lab. The failed post-calibration, in addition to a relatively high mean difference between systems (1.7%), resulted in the decision to flag the TFlex data as lower quality (Q4), and leave the Flex sensor as primary.

Of note, the TFlex relative humidity sensor was more closely aligned with the Flex sensor data at higher relative humidity, showing a low bias of ~10% compared to the Flex sensor at the lowest observed RH. The right-hand plot of Figure 5 highlights the divergence at low RH values.

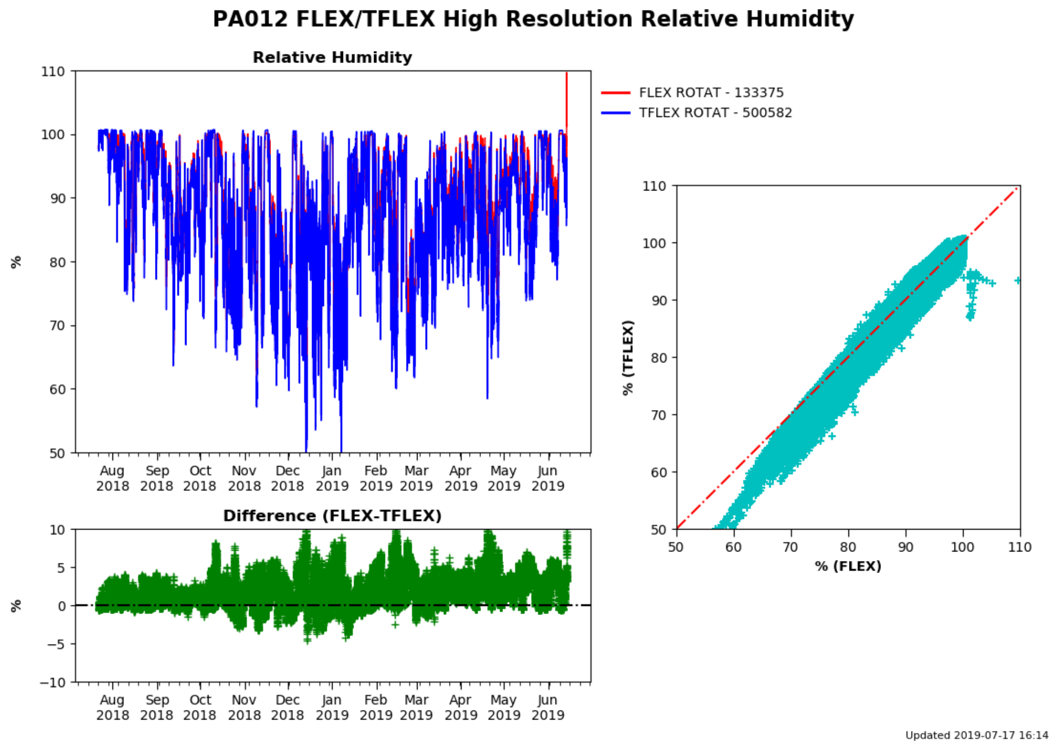

Figure 5: Raw relative humidity time-series, difference plot, and system comparison.

3.2.4 Barometric Pressure

Discovered in past years of testing, the aging mooring acquisition systems are known to fail at applying BP calibration coefficients to Druck sensors. This deployment had a Paros sensor connected to the Flex system and a TERPS sensor on the TFlex, but because the aging systems do not allow the addition of new instruments, the TERPS had to be registered internally as a Druck (the sensors have similar outputs). Calibration coefficients for the TFlex barometric pressure sensor therefore had to be applied in post-processing, and the data were flagged Q3 (adjusted compared to field measurements). The Paros Flex sensor was unaffected and had compared well against PMEL's reference sensor in pre-deployment testing, further supporting the decision to keep the Paros as the primary BP sensor. No other QC was required for this parameter.

3.2.5 Rain

Rain data are acquired as accumulation values, and then converted to rain rates during processing. Rainfall data are collected using a RM Young rain gauge, and recorded internally at a 1-min sample rate. The gauge consists of a 500mL catchment cylinder which, when full, empties automatically via a siphon tube. Data from a three-minute period centered near siphon events are ignored. Occasional random spikes in the accumulation data, which typically occur during periods of rapid rain accumulation, or immediately preceding or following siphon events, are eliminated manually.

To reduce instrumental noise, internally recorded 1-minute rain accumulation values are smoothed with a 16-minute Hanning filter upon recovery. These smoothed data are then differenced at 10-minute intervals and converted to rain rates in mm/hr. The resultant rain rate values are centered at times coincident with other 10-minute data (0000, 0010, 0020...).

Residual noise in the filtered data may include occasional false negative rain rates, but these rarely exceed a few mm/hr. No wind correction is applied, as this is expected to be done by the user. The wind effect can be large. According to the Serra, et al. (2001) correction scheme, at wind speeds of 5 m/s the rain rates should be multiplied by a factor of 1.09, while at wind speeds of 10 m/s, the factor is 1.3. As winds are high at Papa, the user is strongly encouraged to apply an appropriate wind correction.

3.2.6 Shortwave Radiation

Kelly Balmes established the selection criteria for primary and secondary radiation sensors. Mean daily Flex and TFlex SWR values were compared, and found to differ by 2.9%. When the difference is over 1%, the higher of the two instruments is considered primary, since lower values could indicate a bent radiation mast. If the difference is less than 1%, the sensor that maximizes the available data is primary, and if all else is equal, the Flex system is primary. Based on these criteria, the PA012 TFlex SWR was made primary.

3.2.7 Longwave Radiation

The downwelling longwave radiation is computed from thermopile voltage, dome temperature, and instrument case temperature measurements, using the method described by Fairall et al. (1998). Lower longwave radiation values are associated with clearer, colder skies, whereas larger values are associated with more water in the air column (e.g. cloudy, humid conditions).

The primary longwave sensor is chosen to be consistent (from the same acquisition system) with the SWR decision, unless the data are unavailable. This is based on the fact that SWR and LWR share a mast and the potential for mast tilt is determined by the SWR decision. Although LWR is less sensitive to orientation, a bent mast could still impact the data. Based on these criteria, the PA012 TFlex LWR was primary.

3.3 Subsurface Data

All OCS subsurface instrumentation was connected inductively to the Flex system, except for the instrument attached to the acoustic release. General comments and clock errors from each recovered subsurface instrument are summarized in a snapshot of the FileMaker log (Figure 6). Positive clock errors were most common, meaning the instrument drifted ahead of the actual time. Measurements were mapped to the nearest 10-minute time increment.

Clock Errors Are the clock dates all okay? (type yes/no or comment):

	Sensor Type	S/N	Actual Time (GMT)	Instr. Time	Clock Error	File Name	Bat. Voltage from Status	Comments	# of Records
0	SBE37-	11553	23:57:30	23:57:32	0:00:02		13.49/3.24		
1	SBE37-	11555	01:41:15	01:41:17	0:00:02		13.62/3.24		
2	SAMI pH	P210							
3	SBE16+	6363							
4	ECOFLNT	2844, 5T							
5	SBE43	430630							
6	Aanderaa	488							
7	GTD	32-131-15							
8	MapCO2	27							
9	Sentinel	14607							
10	SBE39-T	3287	21:06:45	21:07:56	0:01:11		N/A		
11	SBE37-	16836	20:13:50	20:13:11	-0:00:39		13.92/3.17		
12	SBE37-	12229	19:57:25	19:56:58	-0:00:27		13.89/3.18		
13	AquaDopp	6810					N/A		
14	SBE37-	12517	20:46:30	20:46:24	-0:00:06		13.93/3.07		
15	SBE37-	6141	19:27:00	19:27:23	0:00:23		6.95/3.05		
16	SBE37-	6142	19:48:30	19:48:55	0:00:25		6.98/3.07		
17	AquaDopp	8071					N/A		
18	SBE37-	6145	19:40:40	19:40:52	0:00:12		6.98/3.04		
19	SBE37-	6146	19:33:20	19:33:27	0:00:07		6.97/3.05		
20	SBE37-	7786	17:48:18	17:48:39	0:00:21		6.96/3.05		
21	AquaDopp	13317					N/A		
22	SBE37-	7787	18:01:10	18:01:40	0:00:30		6.95/3.11		
23	SBE37-	7789	18:48:35	18:49:00	0:00:25		6.97/3.05		
24	SBE37-	7790	18:24:10	18:24:27	0:00:17		7.00/3.13		
25	SBE37-	7791	18:38:30	18:38:45	0:00:15		6.98/3.13		
26	SBE39-	4862	21:17:35	21:18:36	0:01:01		N/A		
27	SBE37-	7792	18:16:20	18:16:42	0:00:22		6.92/3.05		
28	SBE39-	4866	21:26:00	21:26:43	0:00:43		N/A		
29									
30	SBE37-	12509	20:23:45	20:23:44	-0:00:01		6.97/3.07		
31									
32									
33									
34									
35									

Figure 6: Filemaker log displaying instrument clock errors.

3.3.1 Temperature

High-resolution temperatures are provided at the original 10-minute sampling increment of the Seabird sensors, as well as at hourly and daily resolutions. Temperatures are rarely corrected based on post-calibrations. On PA012, the 45m instrument drifted with respect to surrounding Seabird instruments. Although data were returned for the entire deployment, temperatures departed from neighboring sensors by over 1°C by mid-deployment.

The temperature record was flagged Q4 (low quality) until 9/27/2018, with Q3 (adjusted) assigned thereafter. This date was chosen by extrapolating back to zero along a difference plot to estimate the starting time of the drift, assuming an approximately linear temperature drift between the 37m and 45m instruments from mid-October to December, as the 45m sensor was gradually incorporated into the mixed layer. The plot below shows this transition from high variability (temperatures varied between ~7-14°C) to stabilization after introduction into the mixed layer. The 45m drift is apparent in the slope of the difference time-series (45m – 37m), and the continuing difference when temperatures from both instruments stabilize within the mixed layer.

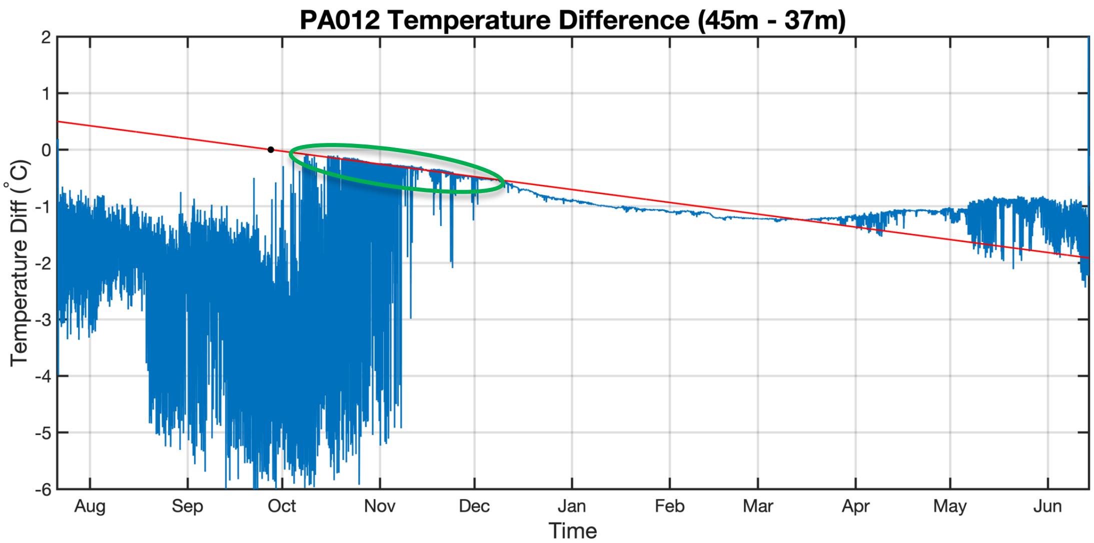

Figure 7: PA012 temperature difference between 45m and 37m. The red line is an estimated slope extracted from the data as 45m joined the mixed layer (i.e. the region circled in green). The black dot indicates an estimate of when the drift started, assuming linear drift.

From 9/27/2018 to 10/15/2018, the linear trend in the figure above was used to adjust the 45m data. From 10/15/2018 to 5/1/2019, when 45m was regularly in the mixed layer, the 45m – 37m difference was used to adjust the 45m temperature using 3-day windows (for example, on Nov 1, an adjustment of ~0.23°C was applied to the 45m temperatures, based on the minimum absolute temperature difference from 37m in the Oct 30 - Nov 2 window). In this way, 45m drift was removed while retaining measured small-scale variations. From 5/1/2019 to the end of the record, adjustments were again based on linear trends fit to the difference plot's slope. A summary of these adjustments applied to each segment of the data is shown below.

```
Start, end, depth, [°C correction at corresponding start and end]
  09/27/2018, 10/15/2018, 45, [0 0.13]
  10/15/2018, 05/01/2019, 45, [automated, in 3-day windows]
  05/01/2019, 05/23/2019, 45, [1.0168 0.8031]
  05/23/2019, 06/16/2019, 45, [0.8031 1.1712]
```

3.3.2 Pressure

Since this was a taut mooring, the sensors can be assumed to have been recording measurements at their nominal depths. Pressure measurements were recorded by two subsurface instruments. In processing for salinity, actual pressures were used where available, and nominal pressures were used elsewhere, including where an instrument's pressure sensor failed. In the case of complete instrument failure, where no temperature or conductivity data exists, nominal pressures are truncated to the time of failure.

3.3.3 Salinity

Salinity values were calculated from measured conductivity and temperature data using the method of Fofonoff and Millard (1983). Conductivity values from all depths were adjusted for sensor calibration drift by linearly interpolating over time between values calculated from the pre-deployment calibration coefficients and those derived from the post-deployment calibration coefficients. Salinities were calculated from both the pre and post conductivity values, to determine the drift in the salinity measurement.

The pre-deployment calibration coefficients were given a weight of one at the beginning of the deployment, and zero at the end, while the post-recovery calibration coefficients were weighted zero at the start of the deployment, and one at the end.

Salinity Drifts in PSU (post-pre):

Depth:	**Drift:**
1m (TFlex)	0.0448
1m (Flex)	-0.0025
10m	0.0048
14m	0.0030
20m	-0.0041
25m	-0.0034
30m	-0.0077
37m	-0.0077
45m	N/A (flooded in post-calibration)
60m	-0.0060
80m	0.0004
100m	-0.0032
120m	-0.0025
150m	-0.0002
200m	0.0003

The values above indicate the change in calculated salinity data values when post-recovery calibrations were applied to the conductivity measurements, versus when pre-deployment calibrations were applied. Negative differences suggest that the instrument drifted towards higher values while deployed, and indicate expansion of the conductivity cell effective cross-sectional area. This expansion is possibly due to scouring of the cell wall by abrasive material in the seawater. Positive values indicate decrease in the cell effective cross-sectional area, presumably due to fouling within the cell, and secondarily due to fouling or loss of material on the cell electrodes.

A thirteen point Hanning filter was applied to the high-resolution (ten-minute interval) conductivity and temperature data. A filtered value was calculated at any point for which seven of the thirteen input points were available. The missing points were handled by dropping their weights from the calculation, rather than by adjusting the length of the filter. Salinity values were then recalculated from the filtered data.

CTD casts from the regular visits to station Papa (by the R/V TULLY), as well as casts taken after deployment and before recovery, indicated no need for data adjustments beyond the adjustments required during density intercomparisons.

A few Q5 flags were applied to the PA012 dataset to remove gross salinity spikes in the SSTCs and 37m instrument. The 45m instrument did not have a postcal (flooded at Seabird), so only precal data were available at that depth. Unfortunately, both the 45m salinity and density frequently inverted against surrounding depths, so adjustments in either direction wouldn't correct the data. The salinity/density/conductivity record at 45m was flagged Q5 (bad data), as the record was too noisy to correct and became grossly offset from the surrounding sensors.

Manual Salinity Adjustments

The drift-corrected salinities were checked for continuity across deployments. Instrument ranges and magnitudes of variation matched well with prior and subsequent deployments. The instrument accuracy specifications were not strictly applied for cross-deployment comparisons, since Papa deployments are miles apart, and spatial differences can exceed instrument specifications (e.g. temperature accuracy is ±0.002°C–0.003°C, depending on instrument).

Additional linear corrections are applied to the salinity data in time segments based on density comparisons with surrounding instruments. These *in situ* calibration procedures are described by Freitag et al. (1999).

Based on manual review of the data against neighboring instruments, the following adjustments were made to the following data segments from 3 instruments:

2018-07-19 01:58:53 to 2019-06-15 17:10:27 at 14 m adjusted 0.0065 to -0.0151
2018-07-20 05:18:15 to 2019-06-15 23:05:38 at 10 m adjusted 0.0000 to -0.0045
2018-07-22 07:59:12 to 2018-08-17 21:59:29 at 1 m (TFlex) adjusted 0.0103 to 0.0023
2018-08-17 21:59:29 to 2018-08-23 00:04:43 at 1 m (TFlex) adjusted 0.0023 to -0.0169
2018-08-23 00:04:43 to 2018-08-30 09:18:08 at 1 m (TFlex) adjusted -0.0169 to -0.0280
2018-08-30 09:18:08 to 2018-09-27 14:41:23 at 1 m (TFlex) adjusted -0.0280 to -0.0068
2018-09-27 14:41:23 to 2018-10-11 13:26:43 at 1 m (TFlex) adjusted -0.0068 to -0.0048
2018-10-11 13:26:43 to 2018-10-27 11:27:37 at 1 m (TFlex) adjusted -0.0048 to -0.0179
2018-10-27 11:27:37 to 2018-12-21 06:51:09 at 1 m (TFlex) adjusted -0.0179 to -0.0250
2018-12-21 06:51:09 to 2019-01-04 13:29:05 at 1 m (TFlex) adjusted -0.0250 to -0.0210
2019-01-04 13:29:05 to 2019-01-18 04:21:49 at 1 m (TFlex) adjusted -0.0210 to -0.0270
2019-01-18 04:21:49 to 2019-02-09 08:02:02 at 1 m (TFlex) adjusted -0.0270 to -0.0472
2019-02-09 08:02:02 to 2019-02-23 18:36:16 at 1 m (TFlex) adjusted -0.0472 to -0.0543
2019-02-23 18:36:16 to 2019-03-07 06:17:07 at 1 m (TFlex) adjusted -0.0543 to -0.0573

Several adjustments were made to the secondary (TFlex) SSTC, which deviated from the surrounding instruments (Flex SSTC, 5m, and 10m). In early March, the remainder of the record was flagged Q5, when conductivities suddenly dropped to ~30, then later ~20 mS/cm, explaining the lack of adjustment from that point forward. The 10m and 14m instruments drifted linearly, becoming weakly inverted with respect to instruments below them, so minor corrections (below instrument accuracy) were made to each.

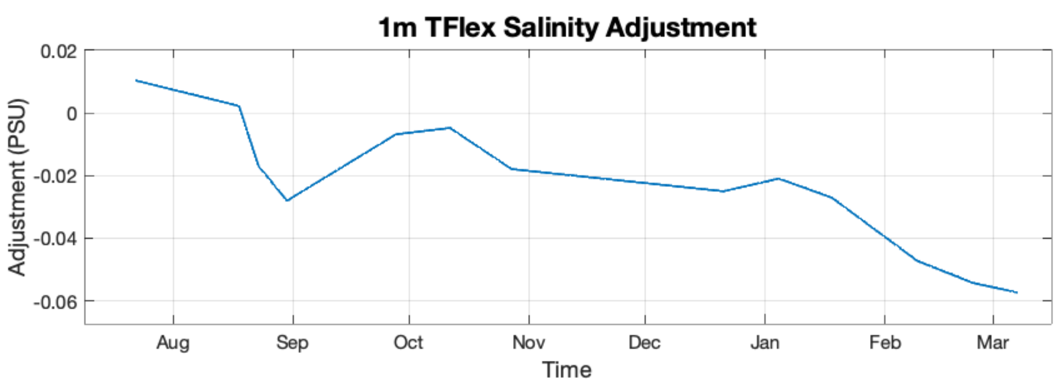

Figure 8: TFlex SSTC adjustments were based on differences against the Flex SSTC, 5m, and 10m sensors.

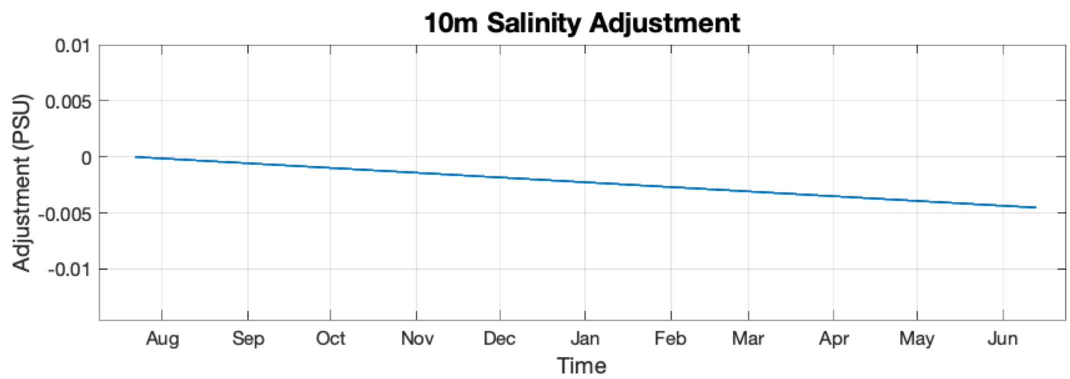

Figure 9: Minor adjustments performed to the 10m instrument.

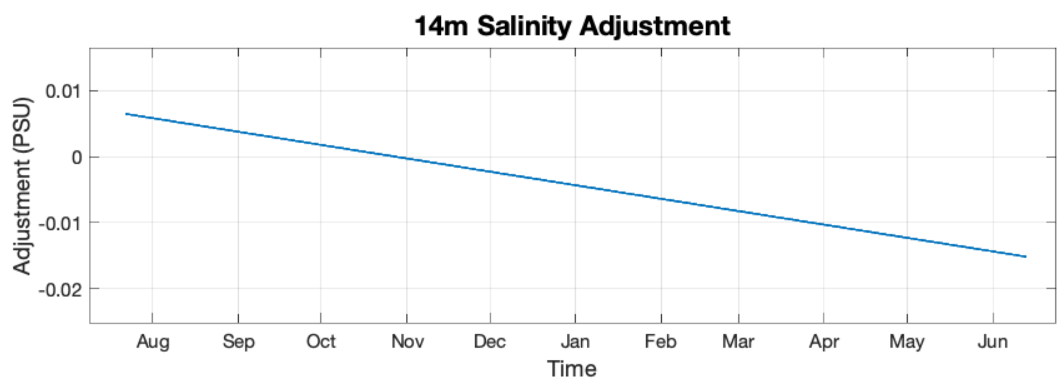

Figure 10: Minor adjustments on the 14m instrument.

3.3.4 Deep SBE Data

Since 2012, an SBE37SM-TCP has been mounted on the acoustic release near the anchor. Several years of data are available at the time of this report.

Temperature and pressure, along with conductivity, are used to calculate potential temperature (**θ**) and density (**ρ**) adjusted to the nearest 1000 dbar-reference pressure, which is 4000 dbar at Papa. Salinity is also calculated from these values, using the methods of Fofonoff and Millard, 1983. A standard 13-point Hanning filter was used to generate hourly data, and a boxcar filter created the daily averages.

Unfortunately, the PA012 mooring was deployed with ~200m of additional line due to an incorrectly measured piece of tapered nylon. The watch circle was enlarged, and the deep SBE instrument hit the seafloor intermittently when tides brought the surface mooring closer to the anchor position, slacking the line. A ~12 hr oscillatory tidal signal is seen in the pressure record, though not every cycle moves the instrument to the extrema. Temperature and pressure are distributed, but salinity, conductivity, and density were too noisy and discontinuous compared to previous records. Figures below show the pressure time series alongside the (undistributed) salinity record. The scoping issue is not a systemic problem, and will not affect future deployments.

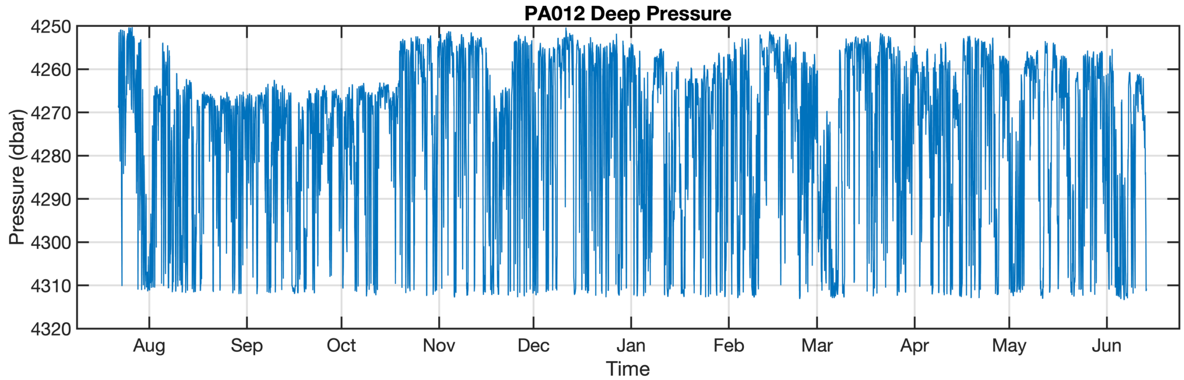

Figure 11: Deep SBE pressure data indicate oscillations between the seafloor and the nominal depth of 56m above the seafloor, similar to early deployments (scope was to be adjusted from 0.985 → 0.965).

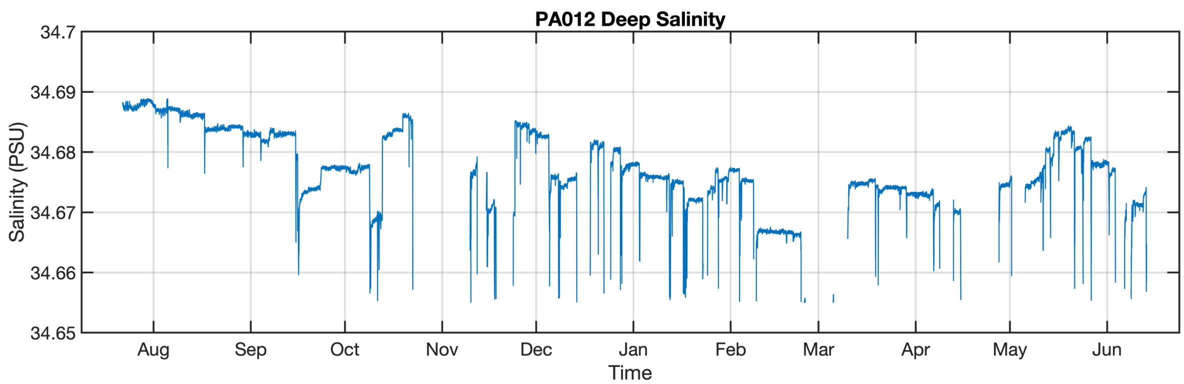

Figure 12: Undistributed deep SBE data were affected by seafloor impacts. Salinity excursions to ~29 PSU occurred, and were filtered out (as shown here), before deciding that the data were unusable.

3.3.5 Currents

The Nortek Aquadopp measures the speed of sound, and internally applies sound velocity corrections to current measurements. During post processing, a correction for magnetic declination is applied, and data are smoothed to hourly resolution using a thirteen-point Hanning filter.

Since PA012 was a taut-line mooring, Aquadopp current meter data were not corrected for the buoy's negligible horizontal movement. However, buoy motions are provided alongside Aquadopp data for users wanting to add buoy motion to measured velocities.

A magnetic declination correction of +15 degrees is added to the current meters in post-processing.

3.3.6 Acoustic Doppler Current Profiler (Aquadopp Profiler)

An upward-looking Aquadopp Profiler was deployed at 68m for the second time on the PA012 mooring. To process the data, 3 corrections were applied: declination (+15 degrees), tilt correction, and head depth adjustment. Aquadopps do not have an internal setting for declination, so this correction to true heading is applied first in post-processing. Tilt correction, also called "bin-mapping," is then computed using a conversion between Earth and Beam coordinates, taking samples along each beam where it most nearly pierces defined horizontal slices of the water column. Tilts over 20 degrees are eliminated (Q5), as the manufacturer considers data beyond this threshold unusable. A head depth adjustment is needed for the profiler, as its vertical position varies slightly, unlike the downward-looking Sentinel ADCP. The data are then regridded using linear interpolation. Buoy-motion, which can be optionally added to U/V currents, is provided in the NetCDF file.

From PA011 forward (from 2017), the Aquadopp profiler will be distributed as the primary ADCP, replacing the Sentinel ADCP, which saw interference as its beams swept across instruments on the mooring line. The profiler's highest resolution was hourly on PA011 and PA012, but will be set to 30-minutes from PA013 onward. The utility of the profiler as a replacement for the Sentinel ADCP was still being assessed on PA012, so the profiler was set to perform its 2-minute burst sample 5 minutes before the hour, to avoid interference with the Sentinel. Interpolation was performed to center the data and corresponding timestamps on the hourly grid.

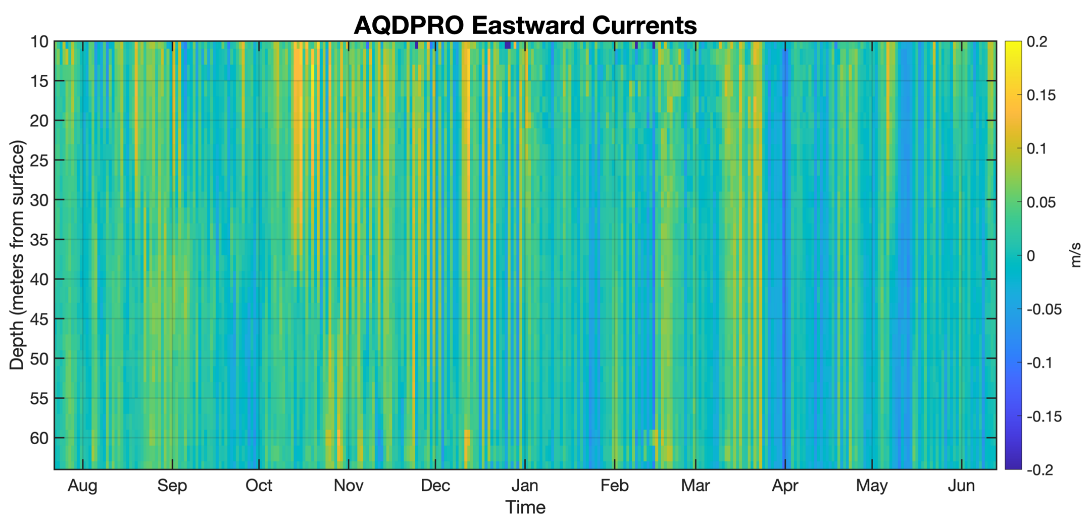

Figure 13: Aquadopp Profiler eastward velocities.

3.3.7 Acoustic Doppler Current Profiler (Sentinel ADCP)

A downward-looking ADCP was also deployed on PA012. Data were processed using established scripts that combine autonomous flagging with manual quality control. The ADCP collects various performance metrics that can be used to quality control recovered data. Standard thresholds are applied to echo amplitude ranges, percent good 3+ beam solutions, and error velocities. A clock check and orientation check are performed prior to releasing data.

The ADCP was set incorrectly, with a heading bias of +0.15 rather than +15 degrees. This occurred because the ADCP expects a heading bias in 1/100th degree increments. The remaining +14.85 degree declination correction was added in post-processing. The magnetic declination at Papa changes slowly, currently at a rate of roughly 1 degree every 5 years.

Plots are used to visualize echo amplitudes and three-dimensional velocities collected from the four ADCP beams. Shear between bins is also examined to help detect bias.

Despite a 20 degree beam angle, all four ADCP beams appear to interact with other subsurface instruments. Data inspection confirms that echo amplitudes increase and velocities are biased toward zero when the beams encounter the solid, stationary instruments on the mooring line. Manual flagging was performed to flag the bins that experience consistent contamination. Engineering solutions to beam interference are being examined. While the ADCP is too heavy to mount on the line, a lighter, upward-looking Aquadopp profiler was deployed on PA012. This configuration appears to reduce interference. The downward-looking ADCP is cantilevered off the bridle, and pitches with the buoy, sweeping all beams across the mooring line with time.

Similar to PA010, the PA012 ADCP collected 1-second data in beam coordinates, measured in 2-minute bursts every half hour. Binary files are converted to a readable format and into Earth coordinates using WinADCP, and each 2-minute burst was averaged to obtain the standard half-hour resolution data. Due to a file size near 4 GB, the data were split across memory cards, and into several files to be individually run through WinADCP, before being recombined as Matlab files. The ADCP returned 1.7 million timestamps, each spanning 80 bins, with an additional dimension for beam-specific variables (e.g. echo amplitudes, correlation coefficient, and percent good along each beam).

Several corrupt records (bad checksums, repeated timestamps + data) were present in this dataset. The outputs from WinADCP were trusted, but repeated timestamps and corresponding repeated data were found within the records, meaning not all data bursts contained 120 unique samples. Repeated timestamps were eliminated, and the unique data points within each burst sample were averaged. After the 2-minute ensemble averages were obtained, the data were run through the standard autonomous flagging and manual quality control procedures that GTMBA employs. The PA012 ADCP data ended about 1 month before recovery.

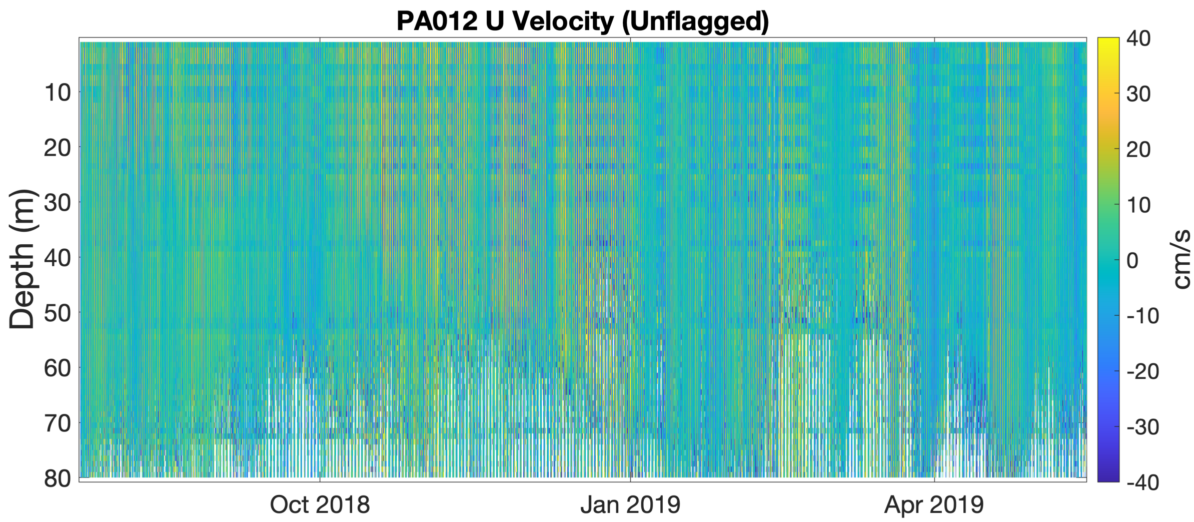

Figure 14: ADCP eastward velocities with autonomous flagging thresholds applied by the ADCP, but before manual flagging. All beams are affected by instruments on the line.

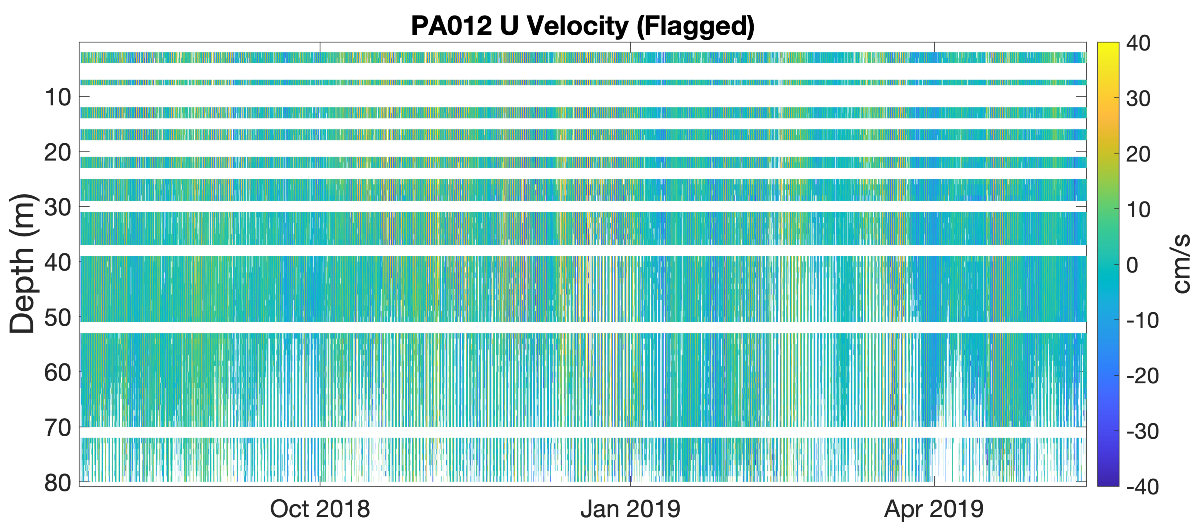

Figure 15: ADCP eastward velocities with manual flagging thresholds and bin-flagging applied, in addition to the autonomous flagging thresholds applied by the ADCP.

4.0 References

Freitag, H.P., M.E. McCarty, C. Nosse, R. Lukas, M.J. McPhaden, and M.F. Cronin, 1999: COARE Seacat data: Calibrations and quality control procedures. NOAA Tech. Memo. ERL PMEL-115, 89 pp.

Fairall, C.W., P.O.G. Persson, E.F. Bradley, R.E. Payne, and S.P. Anderson, 1998: A new look at calibration and use of Eppley Precision Infrared Radiometers. Part I: Theory and Application. J. Atmos. Ocean. Tech., 15, 1229-1242.

Fofonoff, P., and R. C. Millard Jr., 1983: Algorithms for computation of fundamental properties of seawater, Tech. Pap. Mar. Sci., 44, 53 pp., Unesco, Paris.

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5.0 Acknowledgements

The OCS project office is grateful to the Institute of Ocean Sciences (IOS) for granting ship time aboard the CCGS JOHN P. TULLY for recovery operations, and to the R/V Sally Ride for deployment operations. The scientists, captain and crew of the both vessels are acknowledged for their efforts and operational assistance, which made the PA012 mooring a success. Special thanks are extended to the WHOI science party aboard the R/V Sally Ride, who skillfully assisted with mooring operations, with long hours on deck.

This work was supported by NOAA's Global Ocean Monitoring and Observing Program (FundRef number 100018302).

6.0 Contact Information

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Seattle, WA 98115

APPENDIX A: Description of Data Quality Flags

Instrumentation recovered in working condition is returned to PMEL for post-recovery calibration before being reused on future deployments. The resultant calibration coefficients are compared to the pre-deployment coefficients, and measurements are assigned quality indices based on drift, using the following criteria:

Q0 - No Sensor, or Datum Missing.

Q1 - Highest Quality. Pre/post-deployment calibrations agree to within sensor specifications. In most cases, only pre-deployment calibrations have been applied.

Q2 - Default Quality. Pre-deployment calibrations only or post-recovery calibrations only applied. Default value for sensors presently deployed and for sensors which were not recovered or not calibratable when recovered, or for which pre-deployment calibrations have been determined to be invalid.

Q3 - Adjusted Data. Pre/post calibrations differ, or original data do not agree with other data sources (e.g., other in situ data or climatology), or original data are noisy. Data have been adjusted in an attempt to reduce the error.

Q4 - Lower Quality. Pre/post calibrations differ, or data do not agree with other data sources (e.g., other in situ data or climatology), or data are noisy. Data could not be confidently adjusted to correct for error.

Q5 - Sensor, Instrument or Data System Failed.

For data provided in OceanSITES format, the standard GTMBA quality flags described above are mapped to the different OceanSITES quality flags shown below:

Q0 -	No QC Performed.	
Q1 -	Good Data.	(GTMBA Q1, Q2)
Q2 -	Probably Good Data.	(GTMBA Q3, Q4)
Q3 -	Bad Data that are Potentially Correctable.	
Q4 -	Bad Data.	(GTMBA Q5)
Q5 -	Value Changed.	
Q6 -	Not Used.	
Q7 -	Nominal Value.	
Q8 -	Interpolated Value.	
Q9 -	Missing Value.	(GTMBA Q0)

APPENDIX B: Primary Instrument High Resolution Data Plots

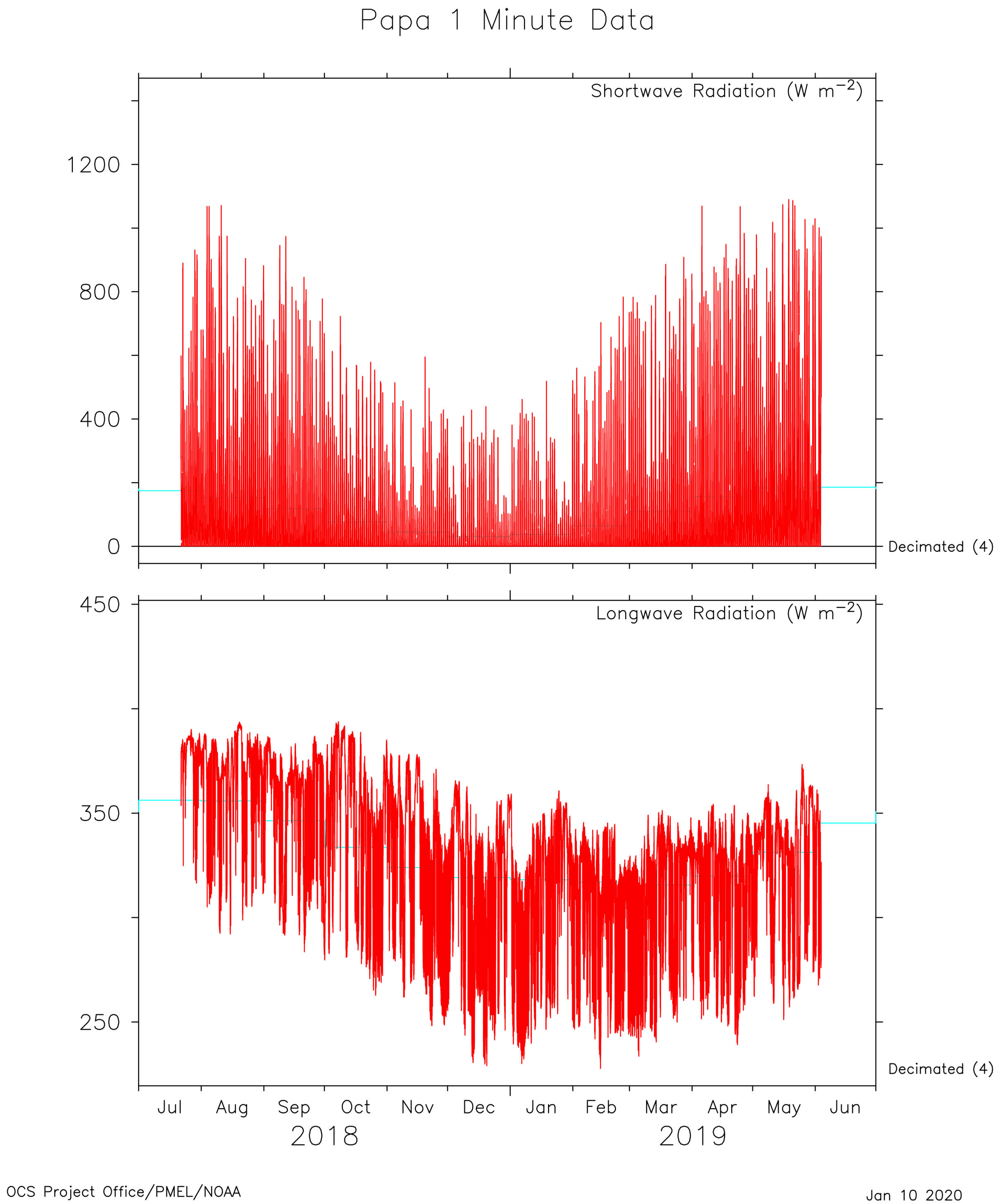

Figure B 1: PA012 primary shortwave and longwave radiation data at 1-min resolution (TFlex).

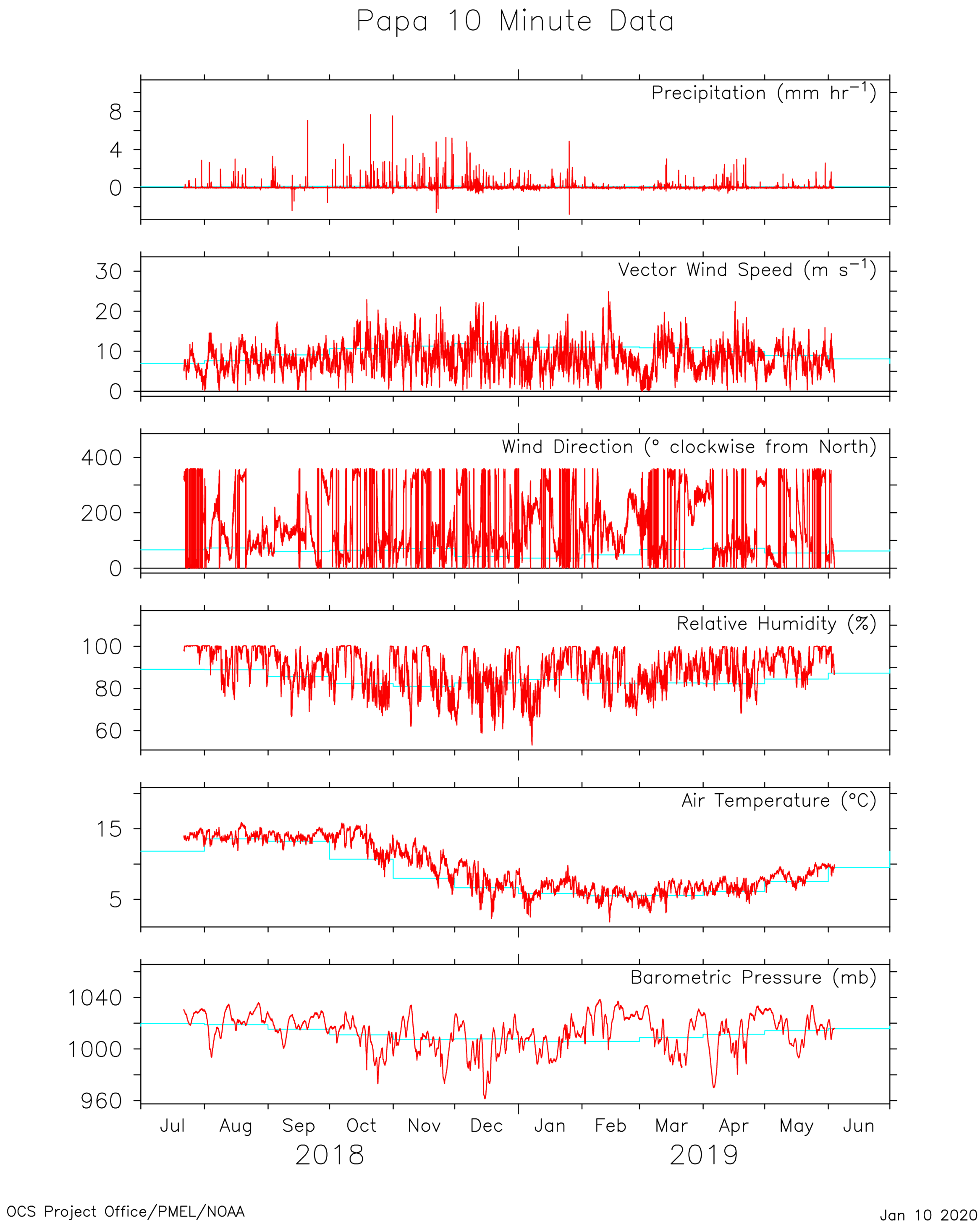

Figure B 2: PA012 meteorological data at 10-min resolution (all Flex).

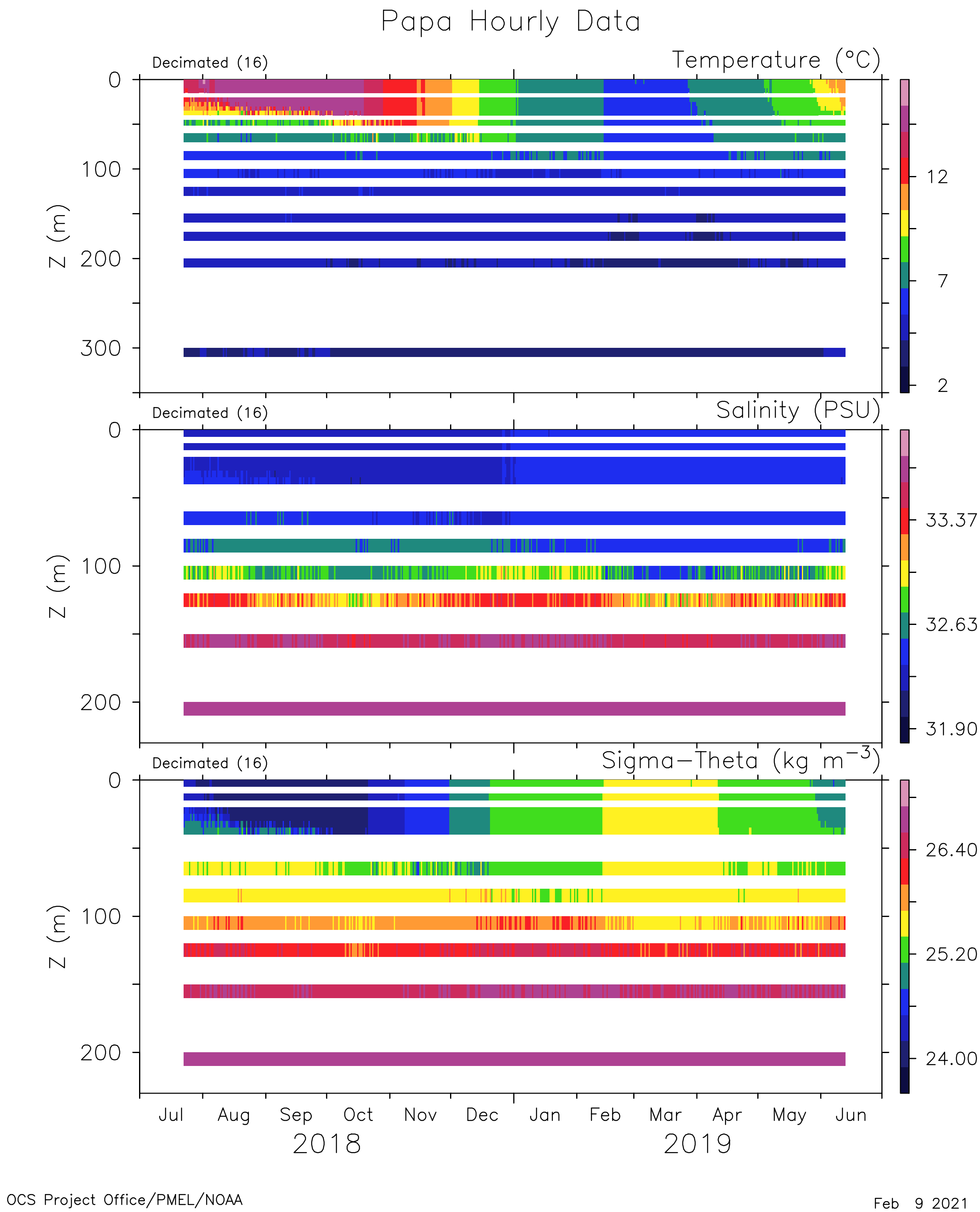

Figure B 3: PA012 subsurface temperature, salinity, and density at hourly resolution (decimated).

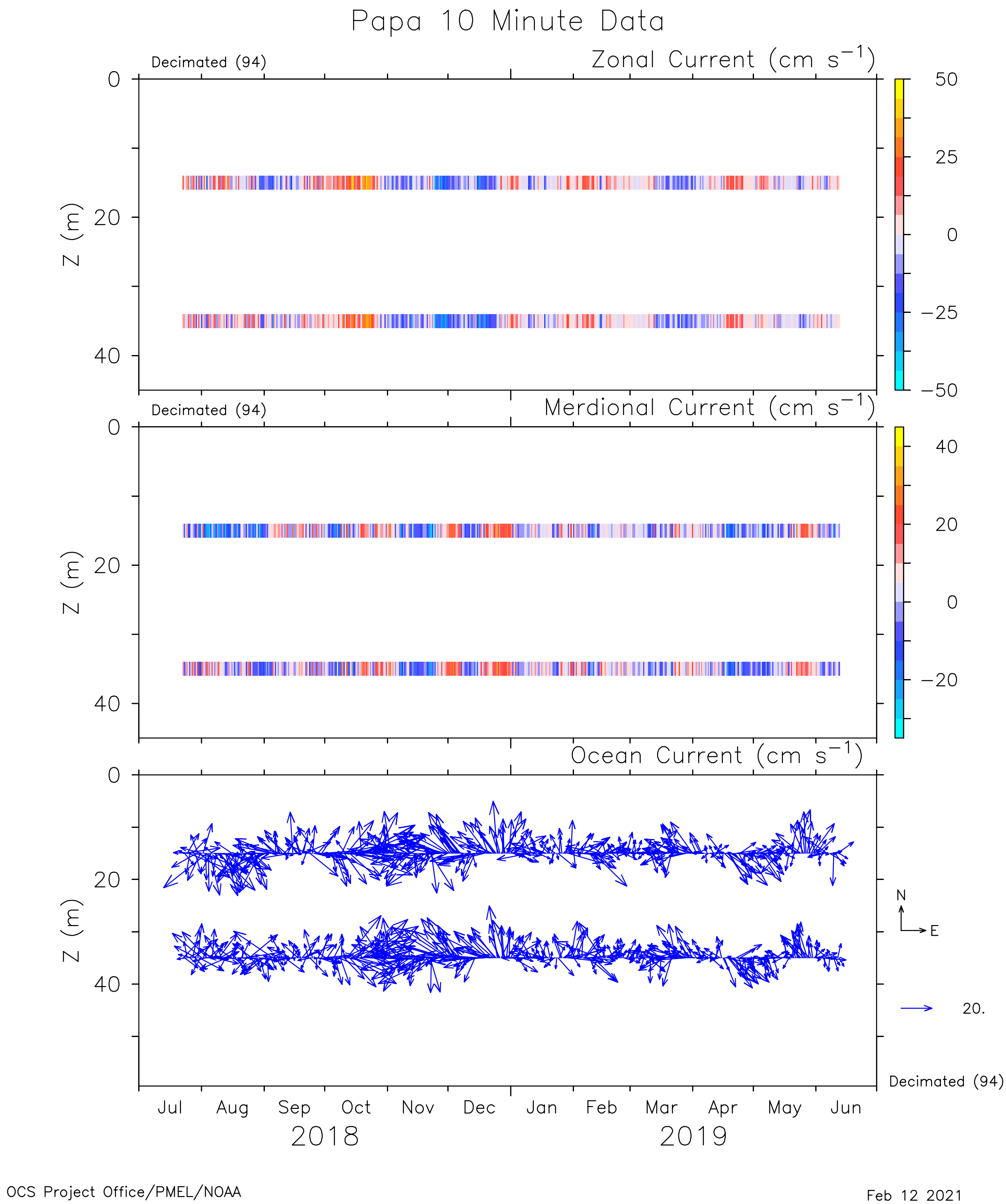

Figure B 4: PA012 Aquadopp current meter data.

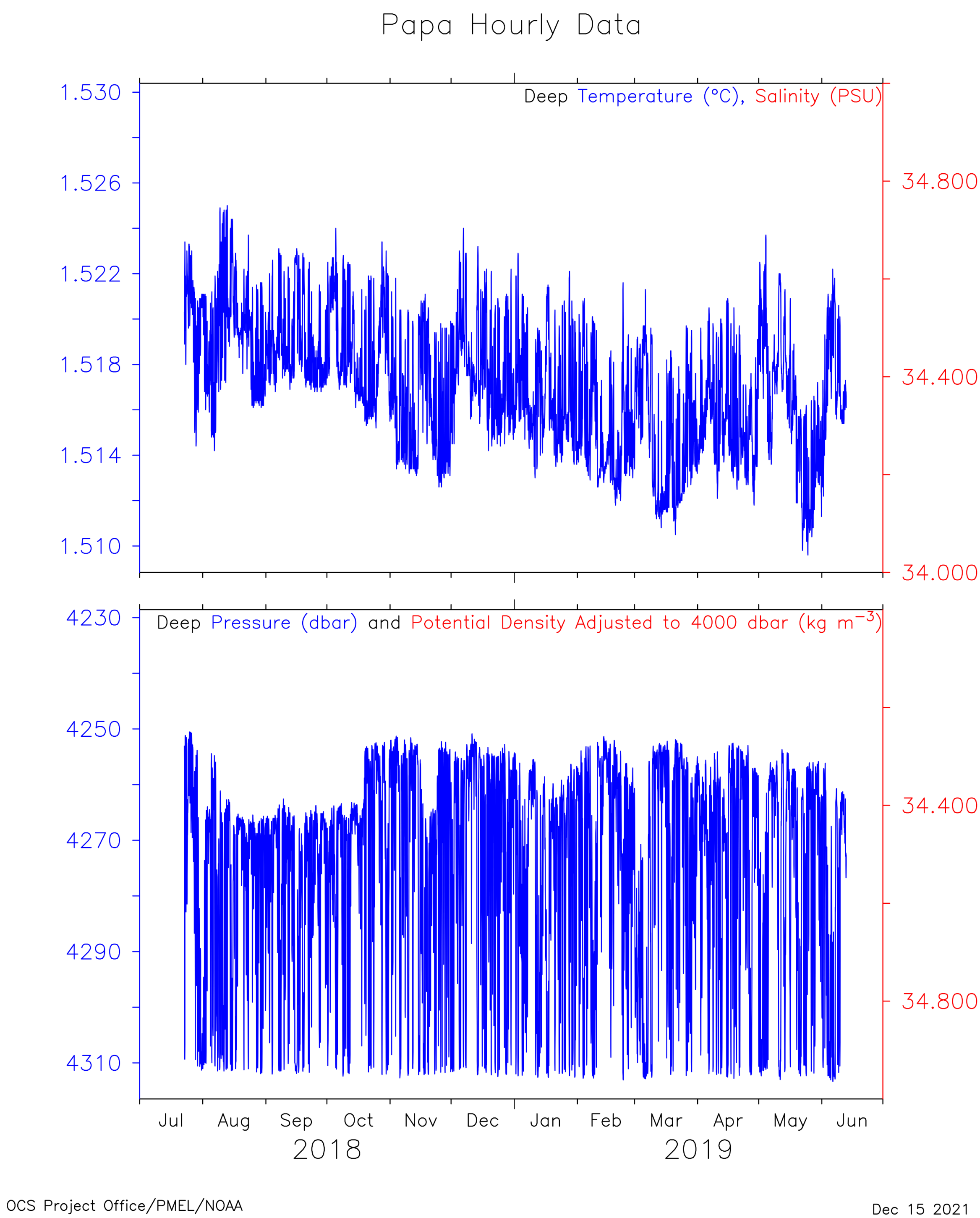

Figure B 5: Deep Seabird instrument temperature and pressure. Salinity and density were not distributed, because an incorrectly scoped line resulted in seafloor impacts and an incoherent conductivity time-series.

APPENDIX C: Secondary Instrument High Resolution Data Plots

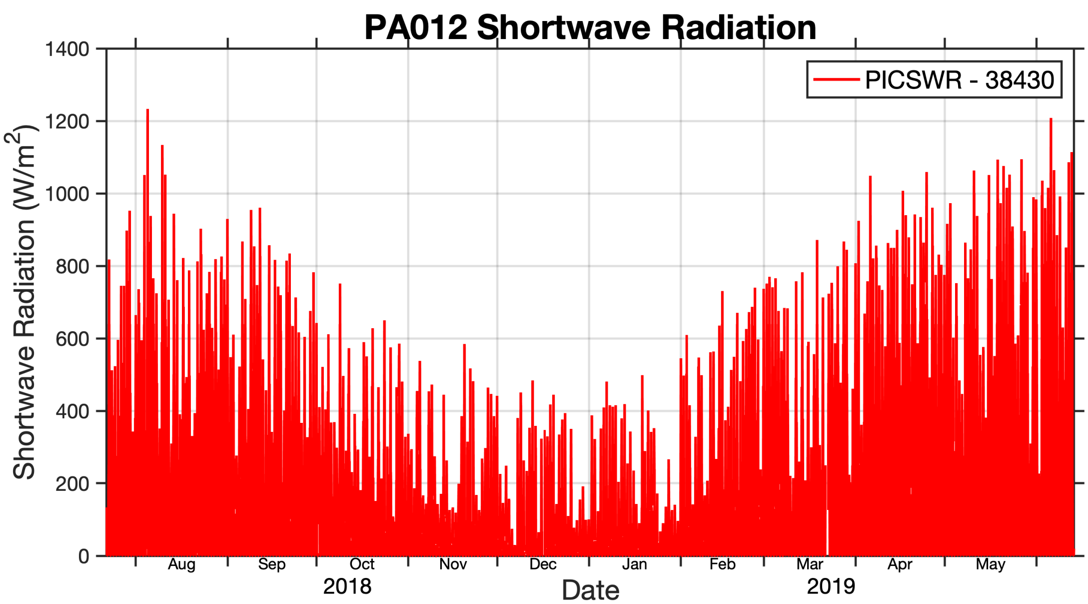

Figure C 1: Secondary (Flex Eppley PSP) shortwave radiation sensor.

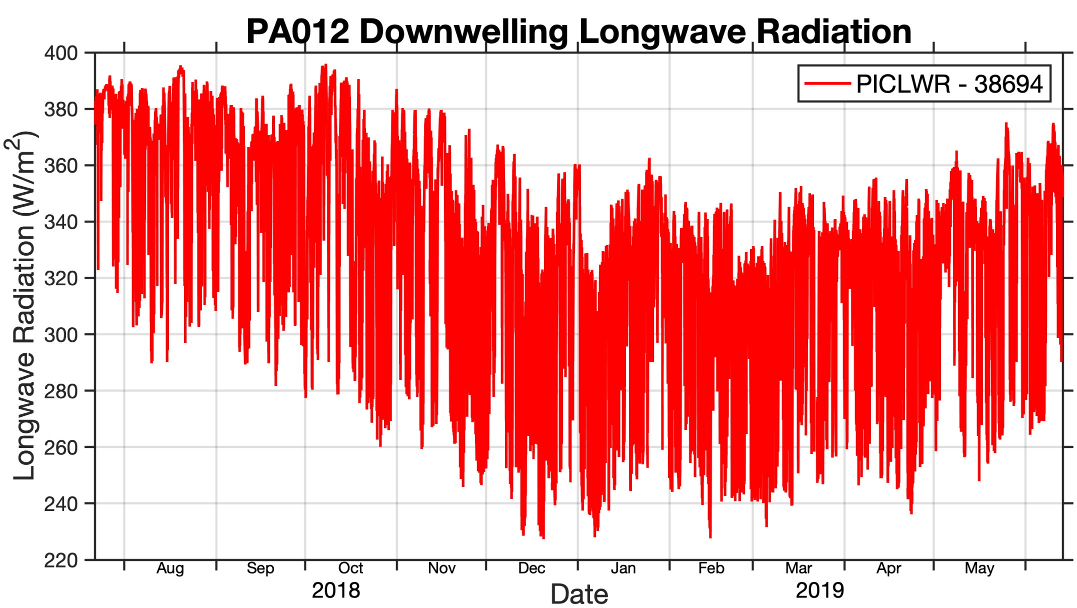

Figure C 2: Secondary (Flex Eppley PIR) longwave radiation sensor.

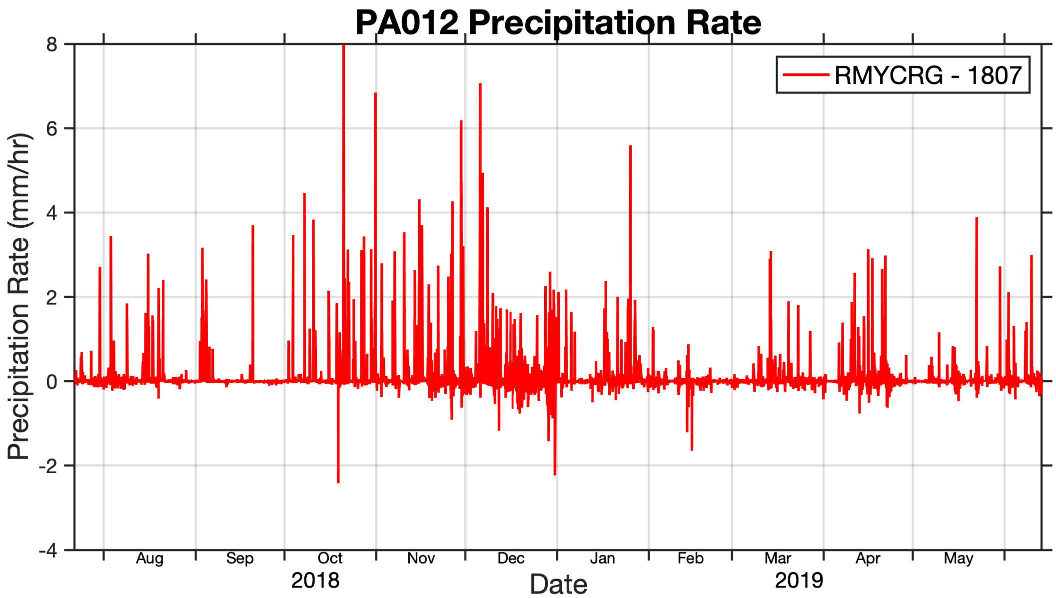

Figure C 3: Secondary (TFlex RM Young) rain sensor.

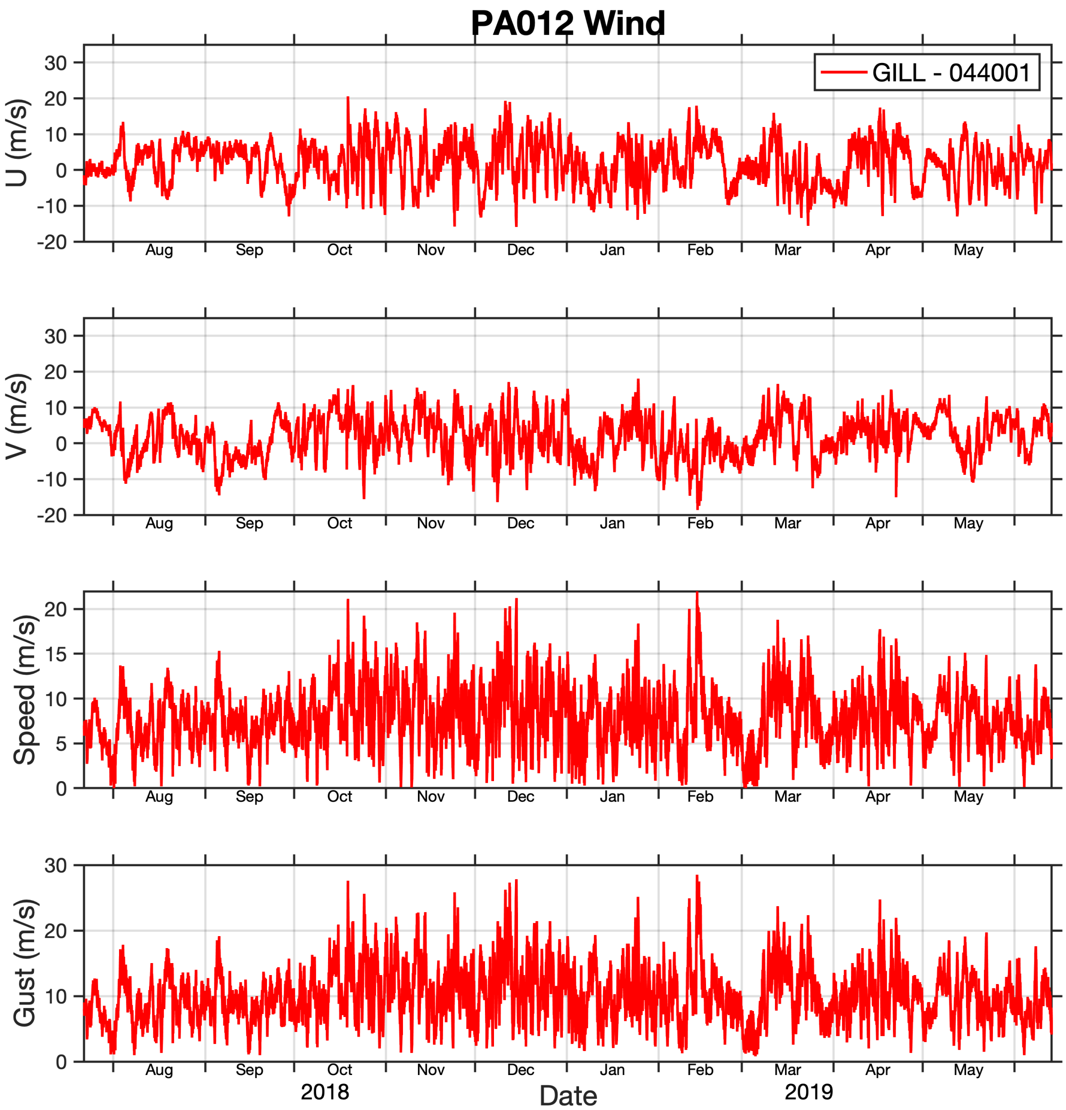

Figure C 4: Secondary (TFlex Gill) wind sensor.

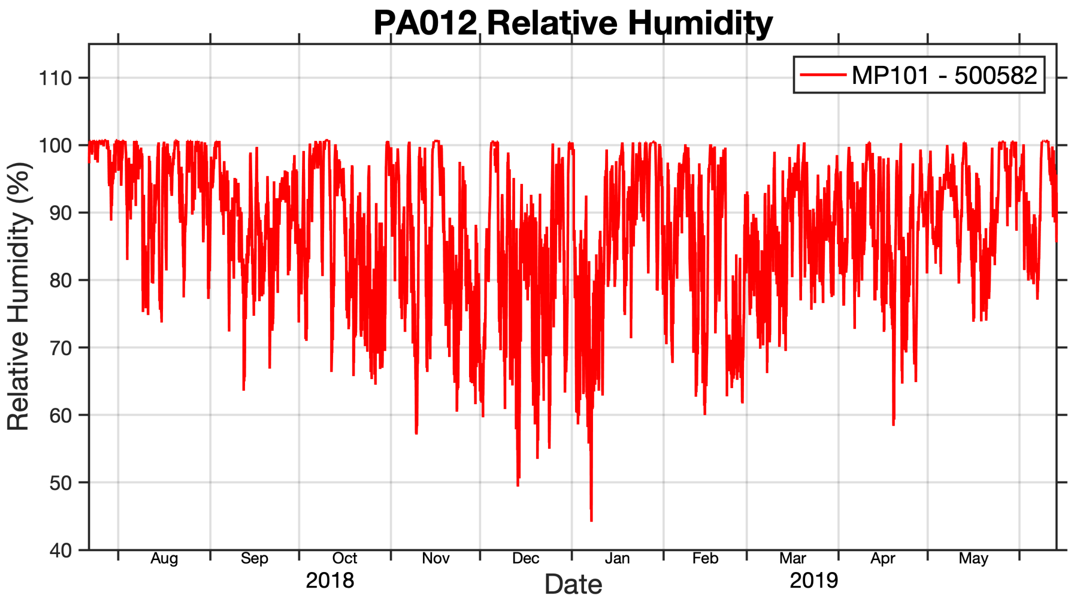

Figure C 5: Secondary (TFlex MP101) relative humidity sensor. The instrument failed its post-calibration, so data were flagged as lower quality (Q4).

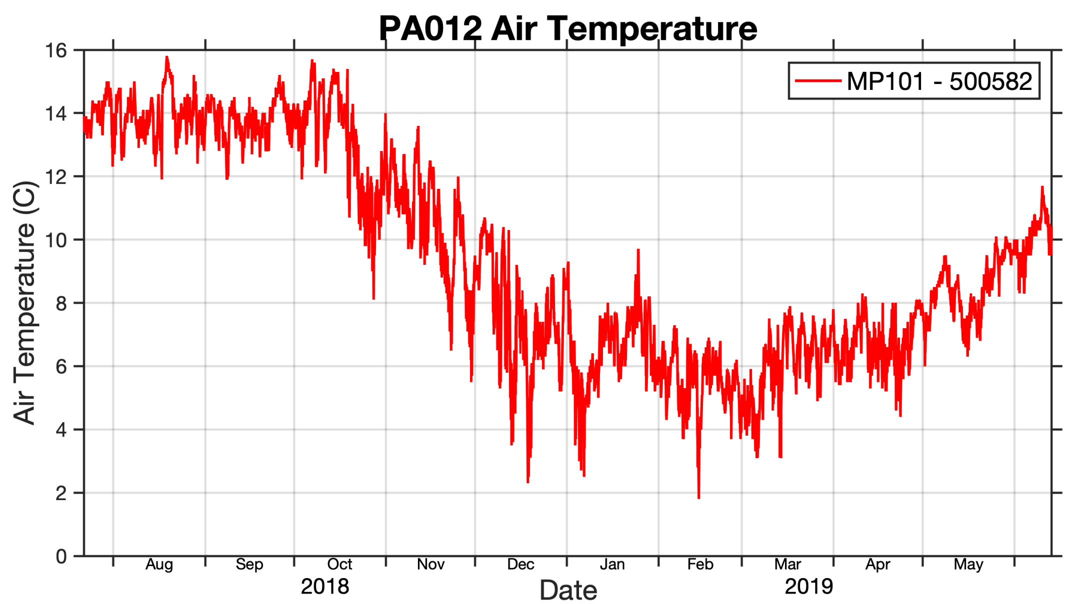

Figure C 6: Secondary (TFlex MP101) air temperature sensor.

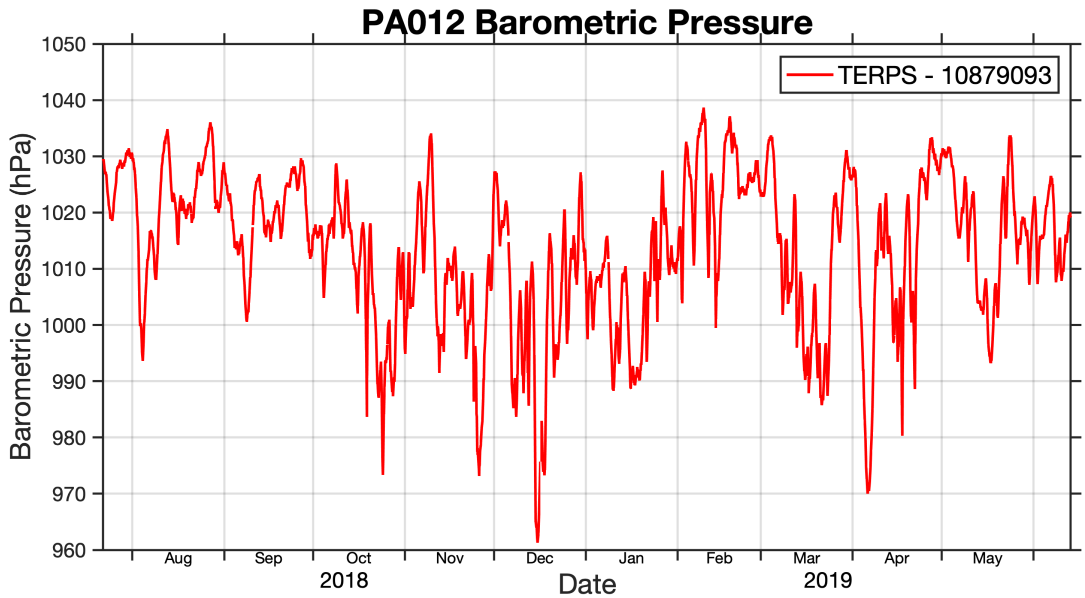

Figure C 7: Secondary (TFlex TERPS) barometric pressure sensor. Since TFlex is suspected of not applying calibrations, the calibrations loaded into the TFlex were applied in post-processing.

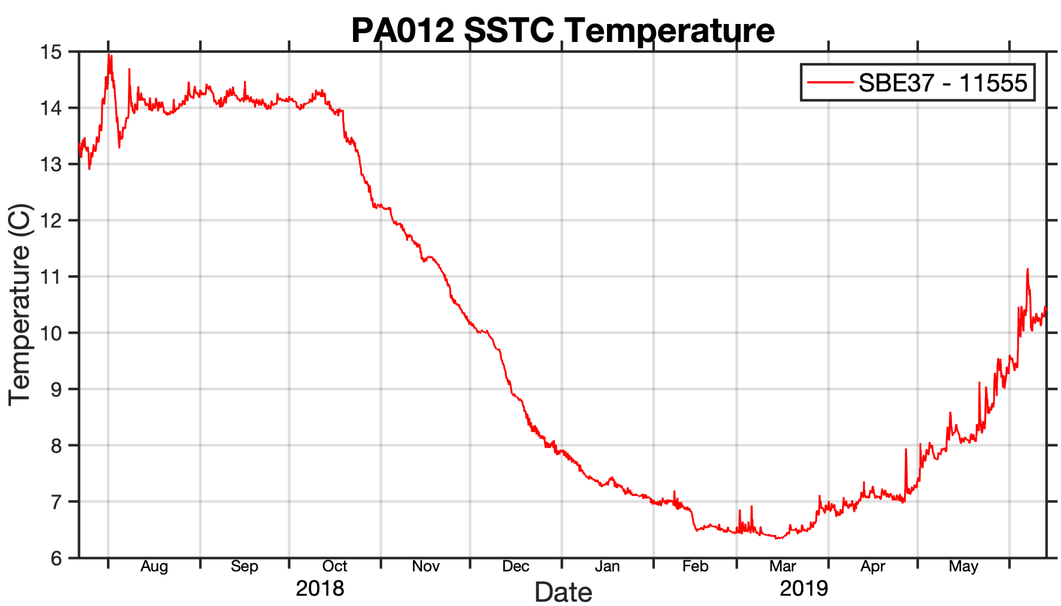

Figure C 8: Secondary (TFlex) SSTC Temperature.

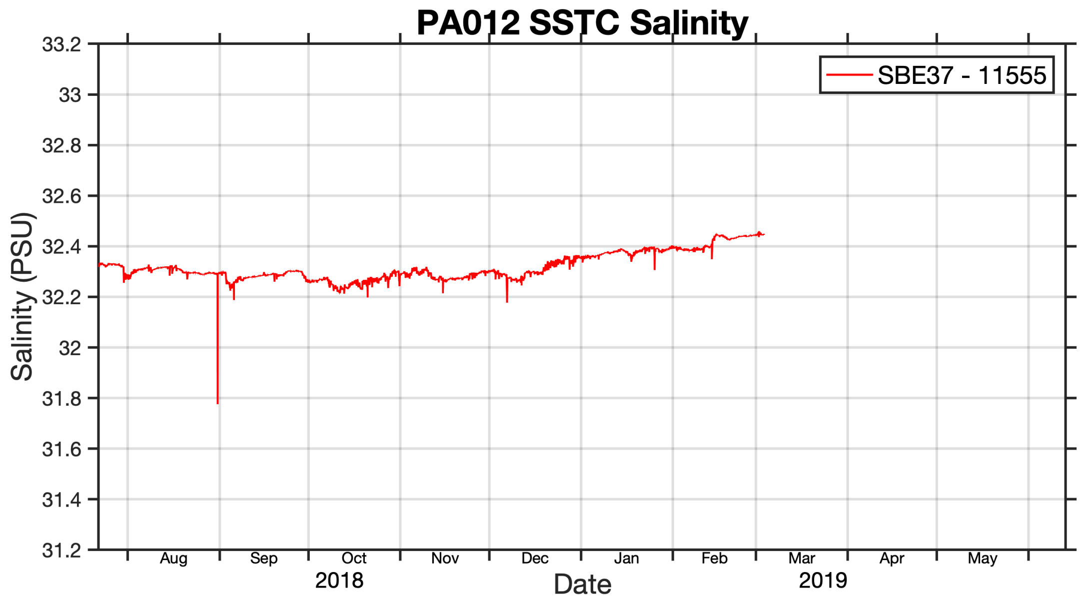

Figure C 9: Secondary (TFlex) SSTC Salinity. In early March, conductivities dropped precipitously out of climatological ranges, and the remainder of the record was flagged Q5. The low spike seen early in the record was allowed to pass QC, as transient fresh lenses are possible at the surface.

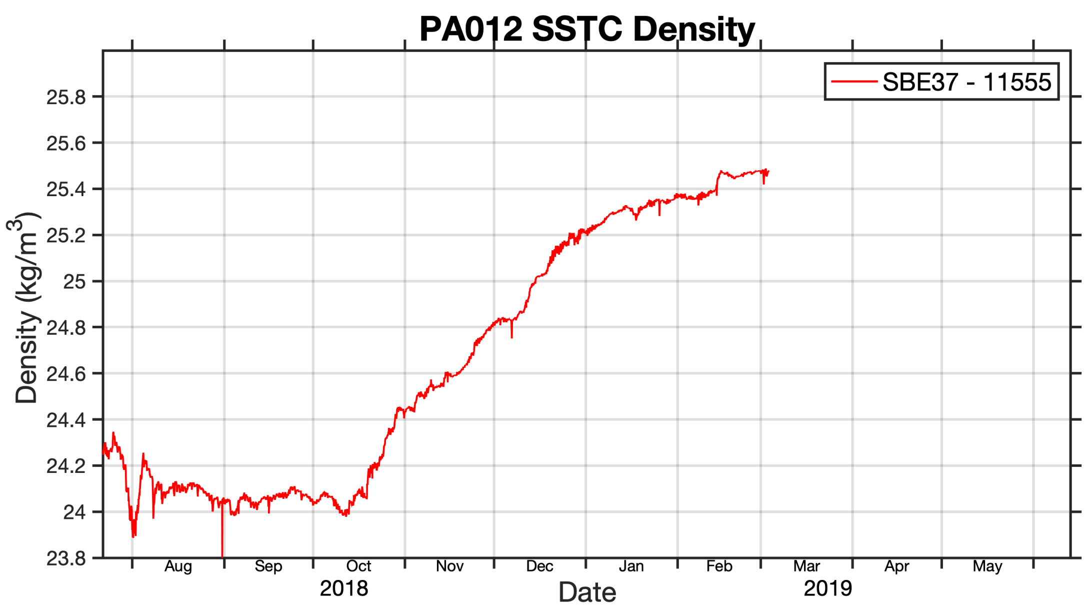

Figure C 10: Secondary (TFlex) SSTC Density.