NOAA Pacific Marine Environmental Laboratory
Ocean Climate Stations Project

DATA ACQUISITION AND PROCESSING REPORT FOR PA010

Site Name:	Ocean Station Papa
Deployment Number:	**PA010**
Year Established:	2007
Nominal Location:	50.1°N 144.9°W
Anchor Position:	50.05°N 144.89°W (flyby buoy obs.)
Deployment Date:	June 16, 2016
Recovery Date:	June 15, 2017
Project P.I.:	Dr. Meghan F. Cronin
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Data Processors:	N.D. Anderson
Date of Report:	October 5, 2020
Revision History:	August 30, 2018

Special Notes:

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Data Acquisition and Processing Report for OCS Mooring PA010

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. PA010 was the tenth deployment at this site.

The PA010 mooring was deployed and recovered by the CCGS JOHN P. TULLY. The Ocean Climate Stations group is grateful to the captain and crew of the TULLY for their efforts and mooring operation assistance.

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.

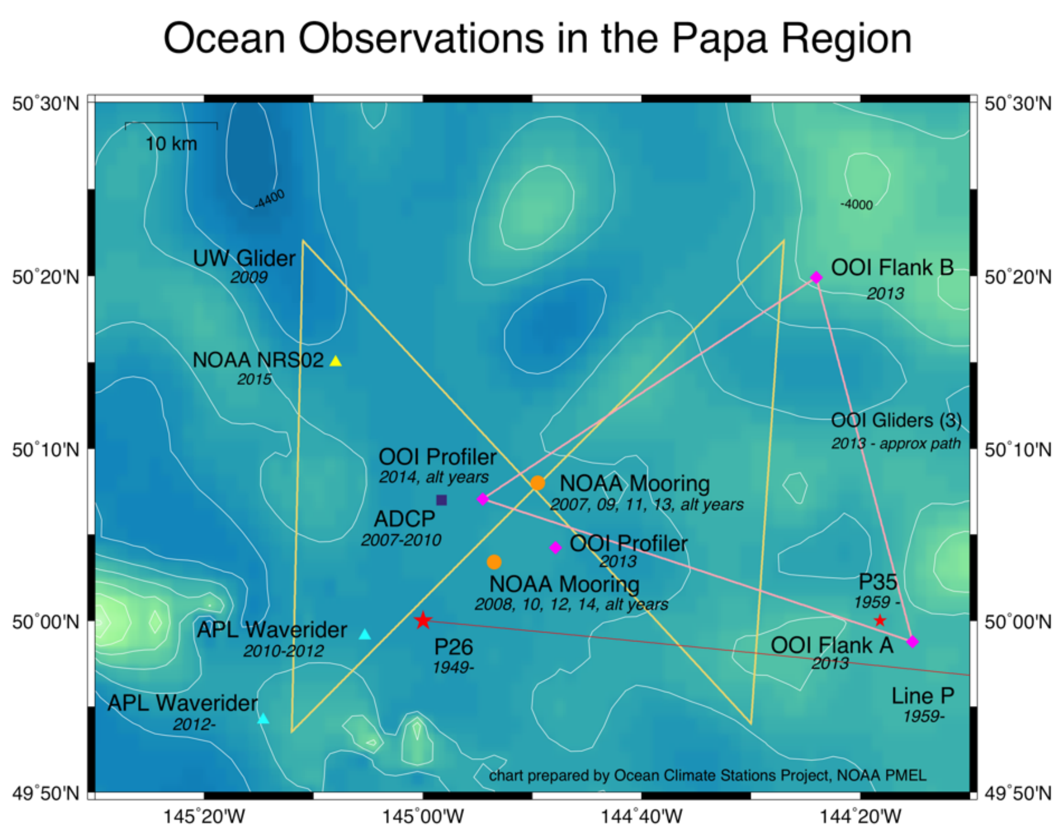

Figure 1: Ocean observations near OCS Station Papa mooring (labeled "NOAA Mooring").

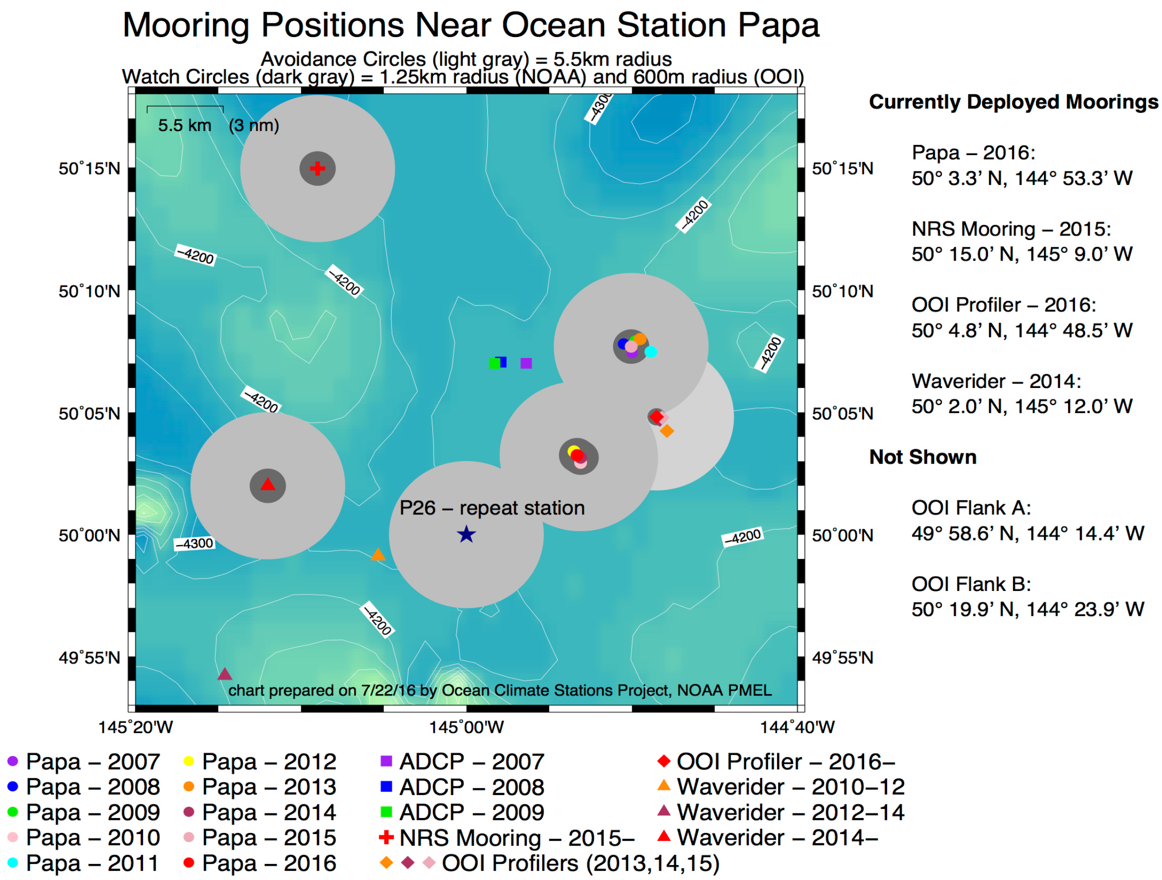

Figure 2: Overview of Station P deployments, at the time of PA010's deployment.

1.1 Mooring Description

The PA010 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 4. The 6,850lb (3,107kg) anchor was fabricated from scrap railroad wheels.

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. The SBE16 pump connector was found corroded upon recovery, but partner sensors otherwise appeared intact. OCS is not responsible for the acquisition or processing of these data. No further discussion of these systems is included in this report.

Figure 3: PA010 as deployed.

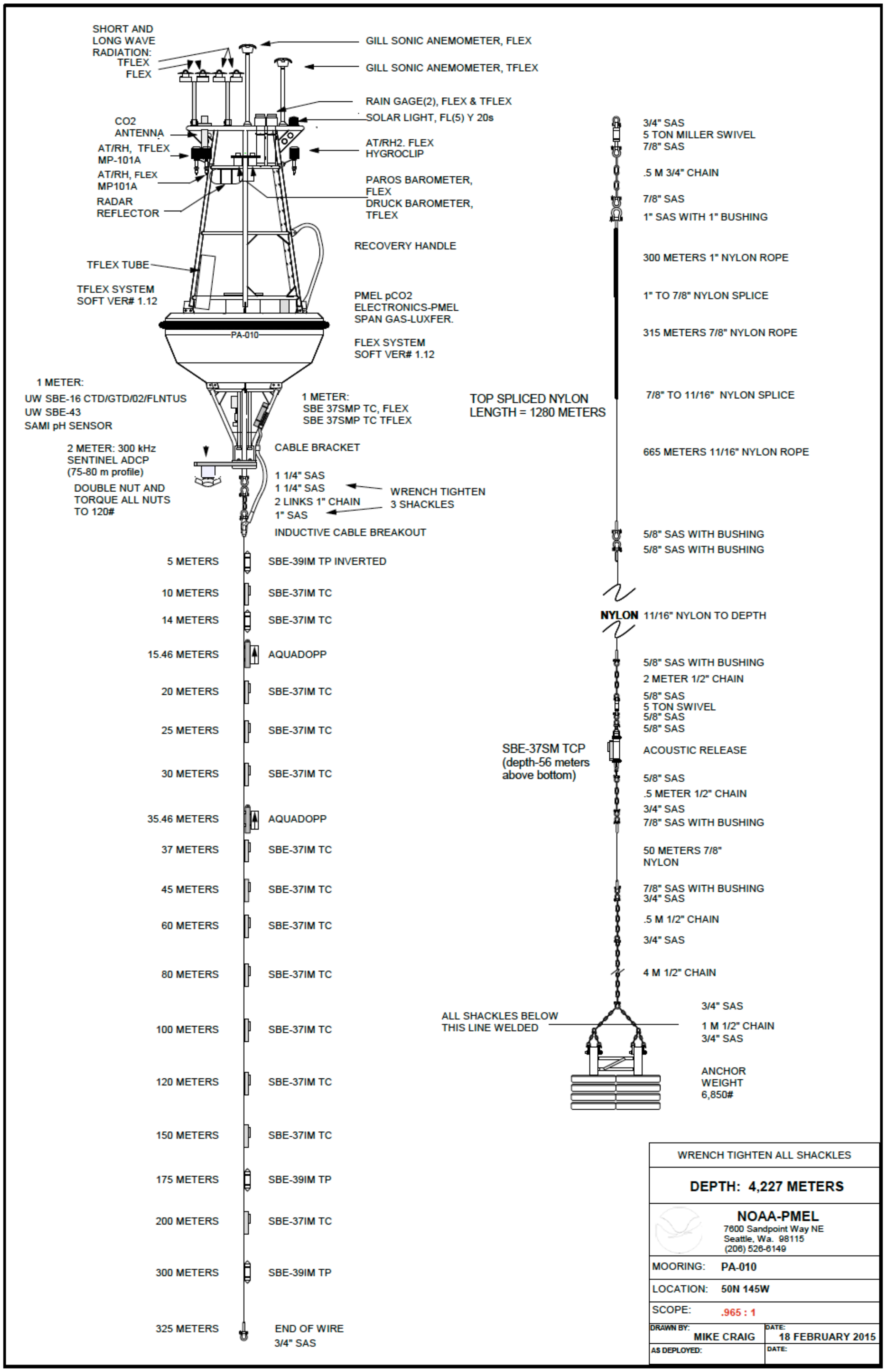

Figure 4: PA010 mooring diagram.

1.2 Instrumentation on PA010

The instrumentation shown in Table 1 was deployed on PA010. Flex and TFlex acquisition systems were attached to redundant surface instrumentation, with the Flex system powering the inductive modem for the subsurface instrumentation.

Deployment:		**PA010**			
Met Sensors		**Model**	**Serial #**		**Notes**
Height	Acquisition	**FLEX**	0004	6/3	
2.6m	ATRH	Rotronics MP-101A	500600		
2.6m	ATRH2	Rotronics HygroClip	61334171		
4.2m	Wind	Gill	10510081		
2.5m	BP	Paros	121220		
3.1m	Rain	RM Young	1554		
3.6m	SWR	Eppley PSP	29361		
3.6m	LWR	Eppley PIR	33340		
	Acquisition	**TFLEX**	2005		
2.6m	ATRH	Rotronics MP-101A	500582		
3.8m	Wind	Gill	044001		
2.4m	BP	Druck	4299622		
3.1m	Rain	RM Young	1553-4		
3.6m	SWR	Eppley PSP	30368		
3.6m	LWR	Eppley PIR	34944		
CO2	Electronics	PMEL	179		
	Span Gas	Luxfer	JB03817		
Subsurface Instrumentation					
Bridle		**Model**	**Serial #**		**Notes**
1m	SST/C	SBE37SMP - TC	12520		Flex, AA batteries (2015)
1m	SST/C	SBE37SMP - TC	11553		TFLEX, AA batteries
1m	pH	SAMI	P0036		Supplied by UW
1m	SST/C	SBE16			Supplied by UW
1m	Oxygen	Optode			Supplied by UW
1m	Oxygen	SBE43			Supplied by UW
1m	Fluorescence	ECO FLNTUS			Supplied by CO2 - Self Powered
1m	Gas Tension	GTD			Supplied by UW
2m	ADCP	Workhorse Sentinel	14607		
Wire Depth		**Model**	**Serial #**	**ID**	**Notes**
5m	TP	SBE39IM - TP	4860	01	Not Inverted
10m	TC	SBE37IM - TC	8421	02	
14m	TC	SBE37IM - TC	12229	03	AA batteries
15.46m	ADCP	AquaDopp	8473	04	
20m	TC	SBE37IM - TC	9412	05	AA batteries
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	
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	4865	16	
200m	TC	SBE37IM - TC	7792	17	
300m	TP	SBE39IM - TP	4866	18	
325m	End of Wire				
4170m	TCP	SBE37SM - TCP	12509	-	AA batteries (2015)

Table 1: Instruments deployed on PA010.

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.

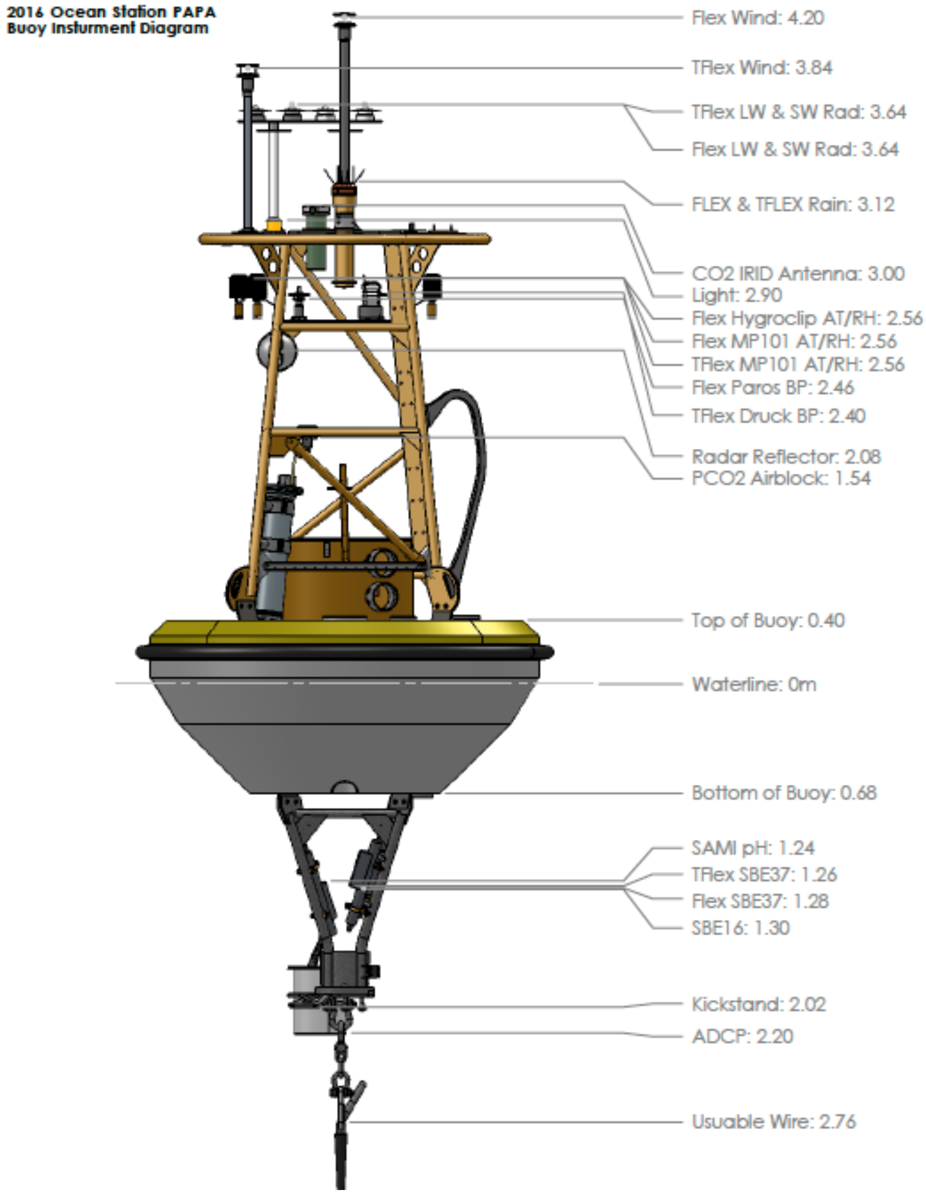

Figure 5: Buoy diagram showing bridle arrangement. The SBE16 package contains a suite of sensors.

2.0 Data Acquisition

Two independent data acquisition systems were deployed on PA010, 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. The CO_2 system positions are obtained at approximately 3 hour intervals. Occasional position errors were spotted and removed during quality control operations.

2.1 Sampling Specifications

The following tables describe the high-resolution sampling schemes for the PA008 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	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
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 (Profile)	1 Hz	2 min	2359-0001, 0029-0031…	30 min	Internal
GPS Positions	1 per hr	Instant.	~0000, 0100…	1 hr	FLEX

Table 2: Sampling parameters of the primary sensors on PA010.

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	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
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 PA010.

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 0004:

Data Return Summary
2016-06-16 00:21:00 to 2017-06-15 14:25:00

Sensor	Deployed	Obs	Return	
AT1	52500	52500	100.0%	
AT2	52500	52500	100.0%	
RH1	52500	52500	100.0%	
RH2	52500	52500	100.0%	
WIND1	52500	52130	99.3%	
BP1	52500	52500	100.0%	
RAIN1	525004	518984	98.9%	
SWR1	525004	519903	99.0%	
LWR1	525004	519970	99.0%	
Subsurface Temperature Profile				
1m	52500	52500	100.0%	
1m(TFlex)	52500	50975	97.1%	
5m	52500	52500	100.0%	
10m	52500	0	0.0%	Realtime Only.
14m	52500	52500	100.0%	
20m	52500	52500	100.0%	
25m	52500	2719	5.2%	Bad recovered data/times.
30m	52500	52500	100.0%	
37m	52500	52500	100.0%	
45m	52500	25514	48.6%	
60m	52500	52500	100.0%	
80m	52500	52500	100.0%	
100m	52500	52500	100.0%	
120m	52500	52500	100.0%	
150m	52500	52500	100.0%	
175m	52500	52500	100.0%	
200m	52500	52500	100.0%	
300m	52500	52500	100.0%	
4171m	52500	52500	100.0%	
Subsurface Pressure Profile				
5m	52500	52500	100.0%	
175m	52500	52500	100.0%	
300m	52500	52500	100.0%	
4171m	52500	52500	100.0%	

Subsurface Salinity Profile				
1m	52500	19581	37.3%	
1m(TFlex)	52500	50975	97.1%	
10m	52500	0	0.0%	Realtime Only.
14m	52500	52500	100.0%	
20m	52500	52500	100.0%	
25m	52500	2719	5.2%	Bad recovered data/times.
30m	52500	52500	100.0%	
37m	52500	52500	100.0%	
45m	52500	25514	48.6%	
60m	52500	52500	100.0%	
80m	52500	52500	100.0%	
100m	52500	52500	100.0%	
120m	52500	52500	100.0%	
150m	52500	52500	100.0%	
200m	52500	52500	100.0%	
4171m	52500	52500	100.0%	

AQD Current Velocity			
15m	52500	52500	100.0%
35m	52500	52500	100.0%
Total	105000	105000	100.0%

TFlex 2005:

Data Return Summary
2016-06-16 00:21:00 to 2017-06-15 14:25:00

Sensor	Deployed	Obs	Return
AT1	52500	52439	99.9%
RH1	52500	52439	99.9%
WIND1	52500	52430	99.9%
BP1	52500	52439	99.9%
RAIN1	525004	520693	99.2%
SWR1	525004	521544	99.3%
LWR1	525004	521985	99.4%

2.3 Known Sensor Issues

The TFlex system reset once in early September 2016, followed by 6 additional resets in the months leading up to recovery. The cause is unknown and data returns do not appear to have been affected.

The Flex ATRH sensor performed slightly better than the TFlex ATRH based on visual inspection. Both mounts were bent, and the TFlex RH ceiling was slightly over 100%, but both instruments passed their post-calibrations. Instruments attached to the Flex system default to being primary, with all else equal.

Wind sensor plots showed several early-deployment spikes to 20 – 50 m/s in the TFlex wind speed and gust, which were not corroborated by the Flex anemometer. With no known storms and side-by-side sensors, the TFlex spikes were flagged Q5 (removed).

BP sensors compared well with the standard, a factory-calibrated instrument. However, field data show the TFlex Druck reporting higher mean values by 0.196 mb. The Flex (Paros) sensor was considered primary.

Rain sensors had occasional noise near the siphoning level. A standard number of corrections were detected by automated scripts, and corrected with manual flagging. The Flex rain gauge had an unexplained region of missing accumulation from 8/27/16 23:57:32 to 8/28/16 13:47:32. Similar issues have been reported in the lab, where the sensor performs well, yet has periods of unrecorded or missing data. The TFlex rain gauge was considered primary to achieve the most complete record.

The Flex SSTC (SN 12520) conductivities slowly drifted from the TFlex SSTC (SN 11553) starting October 30, 2016. In February 2017, conductivity values dropped below 2.5 S/m, well beneath annual climatological values, in an abrupt discontinuity. The instrument reported a full record of data, but the drift and discontinuity do not reflect actual conditions. The persistence of values well outside the climatological range eliminated the possibility of a transient freshwater lens. The TFlex instrument did not corroborate the anomaly, so Flex conductivity data were flagged Q5 starting October 30, 2016. When returned, the Flex SSTC post-recovery calibration was performed after modifications. This calibration was not applied, because it did not reflect the instrument as deployed. The TFlex SSTC was considered primary, but also had a questionable post-calibration that caused substantial drift compared to other sensors on the line. Only pre-calibration coefficients were applied to the SSTCs.

The deep SBE instrument (S/N 12509) had a calibration done after cleaning and replatinizing the conductivity cell, so the calibration was discarded. Several iterations of calibrations were applied, but it was unclear if the manufacturer performed a calibration prior to replatinizing the conductivity cell, and whether it was valid after plotting up the effect of several calibrations on salinity. Typically, deep Seabird pre- and post-deployment calibrations are averaged at Papa, but since the post-calibration was not done, only data with the pre-deployment calibrations applied were distributed for this instrument.

The 10m instrument produced corrupt records shortly after entering the water, and before the deployment start time. Both clock and data values were incorrect. Realtime data were placed into the distributed files at this depth.

The 25m instrument had a significant clock error, likely due to depleted batteries. Summary notes indicate the data were corrupt from 2016-07-04 21:30:00 until logging stopped. Real-time data were distributed at the cessation of delayed-mode data, to achieve the most complete record with reliable timestamps. When the instrument was sent for post-calibrations, Seabird also discovered the pump was broken (sheared shaft).

The 45m instrument had reasonable conductivity and temperature values compared to surrounding instruments, but produced noisy salinity and density records during the summer months. This is likely due to nonlinearities in the salinity equation. The instrument stabilized and performed well after the 45m water rejoined the mixed layer. The instrument produced intermittent records starting 2016-11-14 08:30:00 until logging stopped on 2016-12-10.

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, spectral plots, and histograms 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.

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 PA010 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 PA010 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

Unrealistic spikes to 20 - 50 m/s were observed in the TFlex wind data. While the lower part of the range is possible during stormy conditions, the spikes did not appear in the Flex records. Wind gust spikes were most common, with fewer occurrences in U, V, speed, and direction. A gross error threshold was used on the differences between Flex and TFlex winds to locate data spikes, which were flagged Q5 (removed) when the absolute value of Flex – TFlex wind speeds exceeded 5 m/s. The Q5 flag was also assigned in rare cases where wind speeds exceeded recorded gusts in a given 2-minute sample window. Utilizing the manufacturer's accuracy threshold of 2% of the measured speed when comparing redundant wind sensors would result in over-flagging the data from a moving platform.

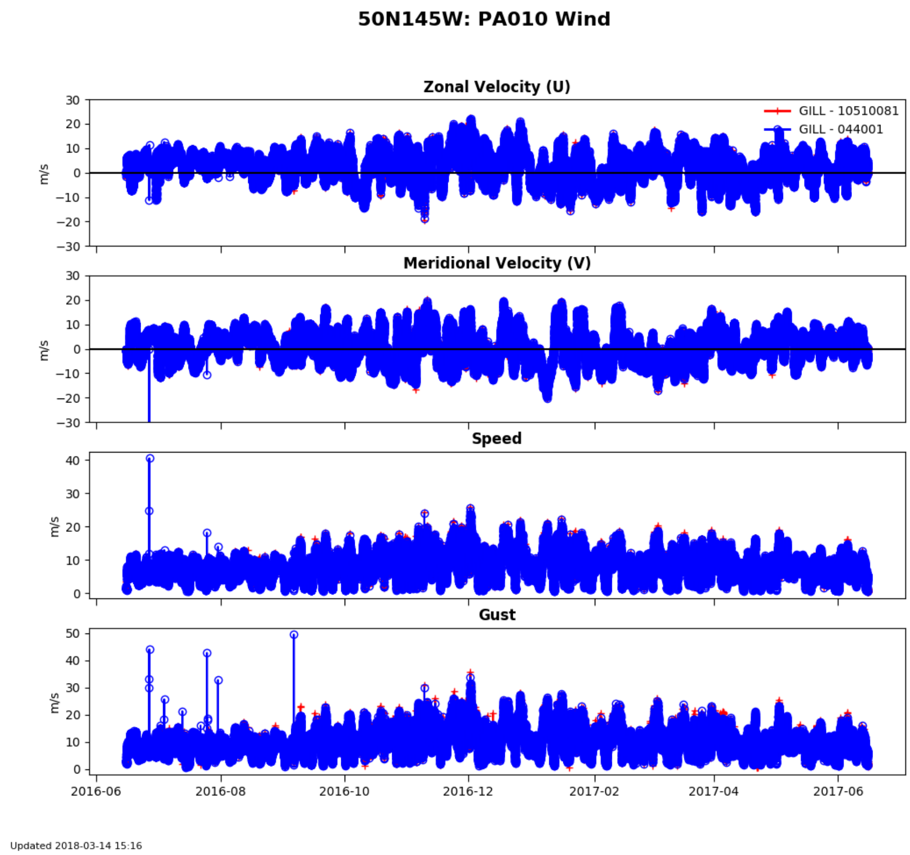

Figure 6: Wind data showing TFlex Gill spikes before flagging was applied. Most spikes were confined to the wind gust variable, but a few influenced other wind variables.

3.2.2 Air Temperature

Both MP101 sensors performed well. No processing issues arose with air temperature, and the sensor attached to the Flex system was primary.

3.2.3 Relative Humidity

PA010 RH sensors were calibrated at PMEL. The calibration chamber was historically set to 25°C with various relative humidity set points. PA008 and PA009 were calibrated at 10°C, but data exceeding 100% humidity under field conditions resulted in a reversion to the 25°C calibration temperature for PA010. No further issues were noted while processing relative humidity, and by default, the Flex RH was primary.

3.2.4 Barometric Pressure

All else equal, Flex sensors are considered primary. Barometric pressure data from the two sensors tracked well, although the TFlex Druck was often 0.1 – 0.2 mb higher. By default, the Paroscientific instrument attached to the Flex system is considered primary, and the handoff from the previous deployment better matched the Flex sensor. The offset was not considered out of range, as the accuracy of each instrument is 0.1mb, and the mean difference of 0.196 mb falls just under the combined accuracy specification of two sensors. Standard Q2 quality flags were given to both instruments.

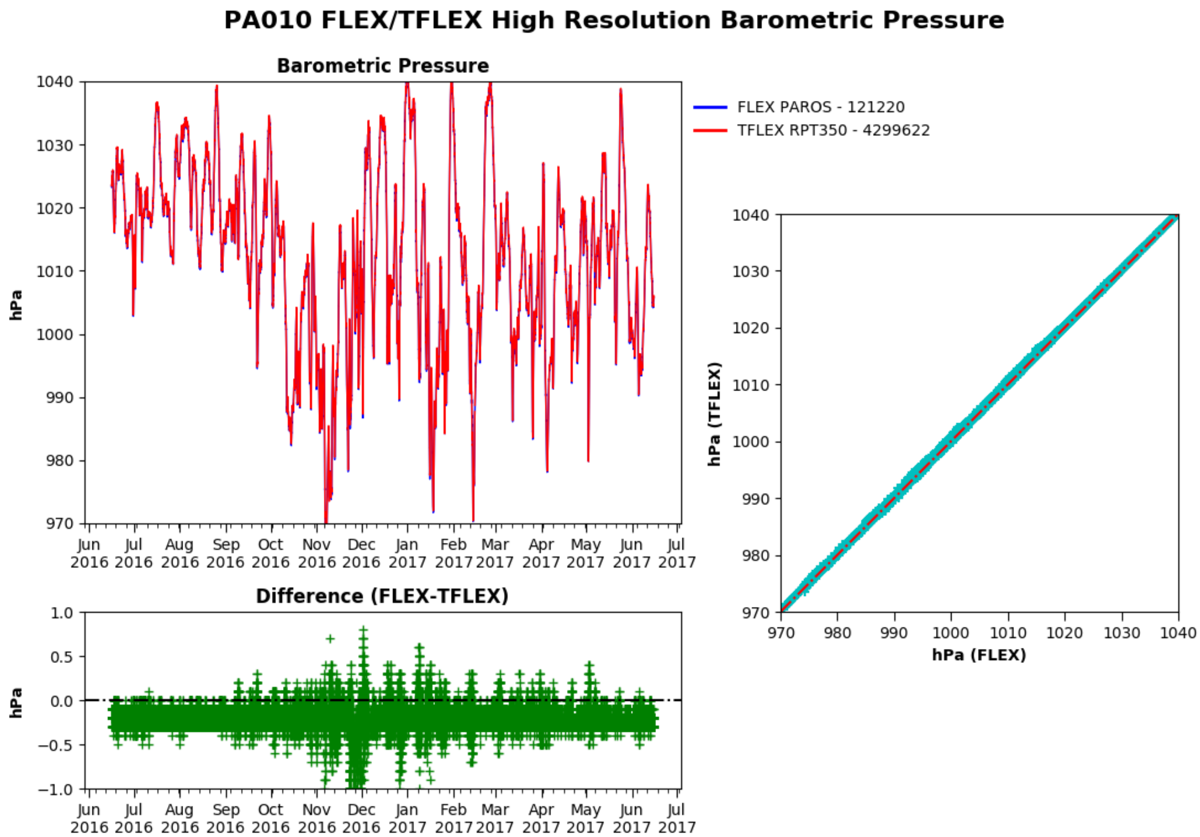

Figure 7: Barometric Pressure, showing higher TFlex values.

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.

The TFlex rain gauge on PA010 was considered primary, partially because the Flex rain gauge failed a calibration upon return to the lab. The Flex rain data also contained gaps in raw accumulations, affirming the decision. Linear interpolation was performed over short gaps or noisy accumulations, and over a single, longer 13-hour gap where no accumulations occurred. Both sensors showed zero accumulation during this period, confirming the rain gauge volume was not aliased by a siphon and additional accumulation. This cross-validation allowed missing values to be replaced by rain rates of 0 during verified dry periods. When accumulations did occur, volumes differed slightly. A total of 1,164.6 mL of additional accumulation was reported from the Flex instrument. Over an entire year, the impact on rain rate was minimal.

Rain data processing uses scripts to detect siphons and other events. A standard amount of interpolation, adjustment and flagging near siphons was required to extract true rain rates.

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 2.05%. 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 PA010 Flex 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 with the SWR decision, unless the data are unavailable. This is based on the fact that SWR and LWR are on the same mast and mast tilt is determined by the SWR decision. Using the same acquisition system also keeps the high-resolution radiation data more consistent if system clocks were to drift. Although LWR is less sensitive to orientation, a bent mast could impact the data, bringing more ocean into the sensor's hemispheric view. Based on these criteria, the PA010 Flex LWR was primary.

LWR and SWR measurements were occasionally interrupted by realtime transmissions. At around 6 hour intervals, a single minute of radiation data typically came back as a missing value in the delayed-mode data. The firmware issue has been observed before in the Flex system, and has minor impacts on data return.

3.3 Subsurface Data

All OCS subsurface instrumentation was connected inductively to the Flex system, except for the instrument attached to the acoustic release and the ADCP. General comments and clock errors from each recovered subsurface instrument are summarized in a snapshot of the FileMaker log (Figure 8). 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.

The 25m instrument experienced nearly 4 hours of time drift. It was not logging upon recovery due to low batteries, and standard timestamp mapping was applied.

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

	Sensor Type	S/N	Actual Time (GMT)	Instr. Time	Clock Error	File Name	Bat. Voltage from Status	Comments	# of Records
0	SBE37-	15520	21:57:11	21:57:15	0:00:04	PA010A_SBE			
1	SBE37-	11553	22:11:31	22:11:30	-0:00:01	PA010A_SBE			
2	SAMI pH	P0036							
3	SBE16+	6363							
4	O2								
5	SBE43								
6	ECO								
7	GTD								
8	ADCP	14607				PA0101			
9	SBE39-TP	4860	16:29:12	16:30:22	0:01:10	PA010A_SBE	6.9	Trouble downloading	
10	SBE37-TC	8421	16:31:45	16:32:02	0:00:17	PA010A_SBE	6.7		
11	SBE37-TC	12229	16:32:06	16:31:39	-0:00:27	PA010A_SBE	13.69		
12	AquaDopp	8473	14:50:15	14:50:58	0:00:43				
13	SBE37-TC	9412	16:32:24	16:32:57	0:00:33	PA010A_SBE	13.83		
14	SBE37-TC	6141	16:34:21	20:31:06	3:56:45	PA010A_SBE	7.05/2.89	Not Logging Low	
15	SBE37-TC	6142	16:34:49	16:35:23	0:00:34	PA010A_SBE	6.52		
16	AquaDopp	8071	14:51:15	14:50:58	-0:00:17				
17	SBE37-TC	6145	16:35:33	16:35:52	0:00:19	PA010A_SBE	6.57		
18	SBE37-TC	6146	16:35:59	16:36:12	0:00:13	PA010A_SBE	6.61		
19	SBE37-TC	7786	16:36:52	16:37:18	0:00:26	PA010A_SBE	6.59		
20	SBE37-TC	7787	16:37:13	16:37:54	0:00:41	PA010A_SBE	6.57		
21	SBE37-TC	7789	16:37:34	16:38:10	0:00:36	PA010A_SBE	6.59		
22	SBE37-TC	7790	16:38:36	16:39:04	0:00:28	PA010A_SBE	6.56		
23	SBE37-TC	7791	16:38:57	16:39:23	0:00:26	PA010A_SBE	6.50		
24	SBE39-TP	4865	22:15:25	22:16:44	0:01:19	PA010A_SBE	6.4		
25	SBE37-TC	7792	16:39:41	16:40:14	0:00:33	PA010A_SBE	:6.53		
26	SBE39-TP	4866	16:40:05	16:40:14	0:00:09	PA010A_SBE	6.7		
27	SBE37-	12509	22:21:10	22:21:17	0:00:07	PA010A_SBE			
28									
29									
30									
31									
32									
33									
34									
35									

Figure 8: Filemaker log displaying all 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, and there was no evidence of drifting temperature measurements.

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 three 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 were 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)	0.0000 **
1m (Flex)	0.0000 **
10m	-0.0000 (rounds to zero)
14m	-0.0026
20m	-0.0119
25m	-0.0003
30m	-0.0111
37m	-0.0029
45m	-0.0039
60m	-0.0046
80m	-0.0051
100m	-0.0033
120m	0.0001
150m	-0.0007
200m	-0.0002

** Post-cal was discarded. See section 2.3: "Known Sensor Issues"

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.

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 this comparison, 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 were also applied to the salinity data in time segments, as noted below. These corrections were based on comparisons with neighboring sensors on the mooring line. If an unrealistic, prolonged density inversion was found, an attempt was made to identify the sensor at fault and adjust its data based on differences with data from adjacent depths during unstratified conditions (e.g. within the mixed layer during nighttime). 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:

Primary 1m SSTC (TFlex)
2016-06-14 14:26:40 to 2016-09-02 05:33:20 adjusted 0.0059 to 0.0037
2016-09-02 05:33:20 to 2017-02-02 11:20:00 adjusted 0.0037 to -0.0112
2017-02-02 11:20:00 to 2017-06-07 00:13:20 adjusted -0.0112 to -0.0069

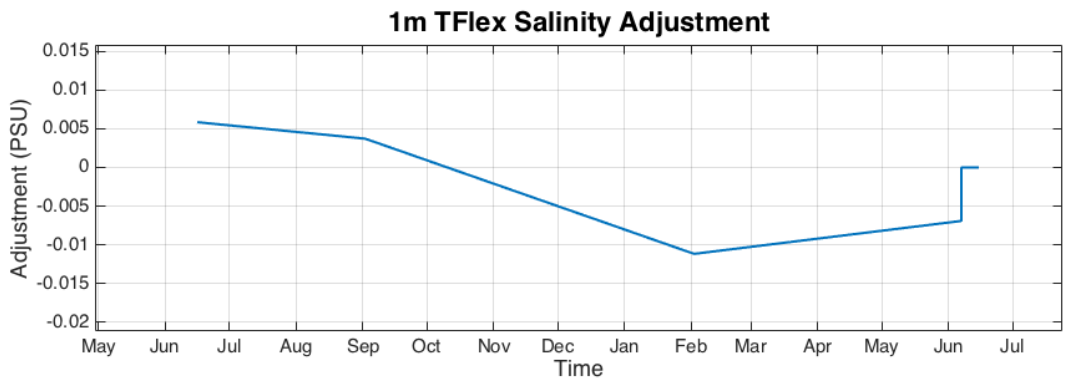

Figure 9: TFlex SSTC Salinity Adjustments on PA010. Time-series ended just prior to recovery, so zero adjustment is applied to the region of missing values.

Secondary 1m SSTC (Flex)
2016-06-15 15:08:49 to 2016-07-02 00:09:12 adjusted 0.0183 to 0.0050
2016-07-02 00:09:12 to 2016-09-27 08:11:15 adjusted 0.0050 to -0.0072
2016-09-27 08:11:15 to 2016-10-30 14:28:54 adjusted -0.0072 to -0.0250

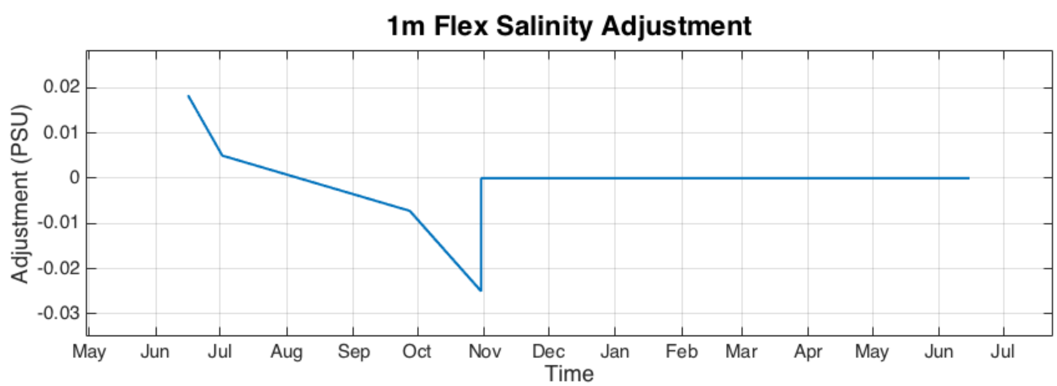

Figure 10: Flex SSTC Salinity Adjustments on PA010. The time-series went outside seasonal bounds in late October. As data afterward are not distributed, zero adjustments are applied after this point.

Several CTD casts were performed in the region from deployment to recovery of PA010. No changes were made to the data based on the CTD casts, because the small differences were within the natural variability of the moored time-series and due to the neighboring instrument comparisons described above.

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 (2018).

At Papa, deep ocean measurements presented challenges, including calibration variability, early-deployment drift, and small discontinuities between deployments. Calibration variability is the difference between data with pre-deployment calibrations applied and data with post-recovery calibrations applied (the offset between lines in Figure 11). While calibration variability can indicate linear drift, interpolating between calibrations can also result in a false slope when the signal is small. Many years of data were examined for continuity, to reduce the possibility of covering up real drift. Because previous deployments matched the data with pre-deployment calibration coefficients applied, PA010 data were released without the application of post-recovery calibrations.

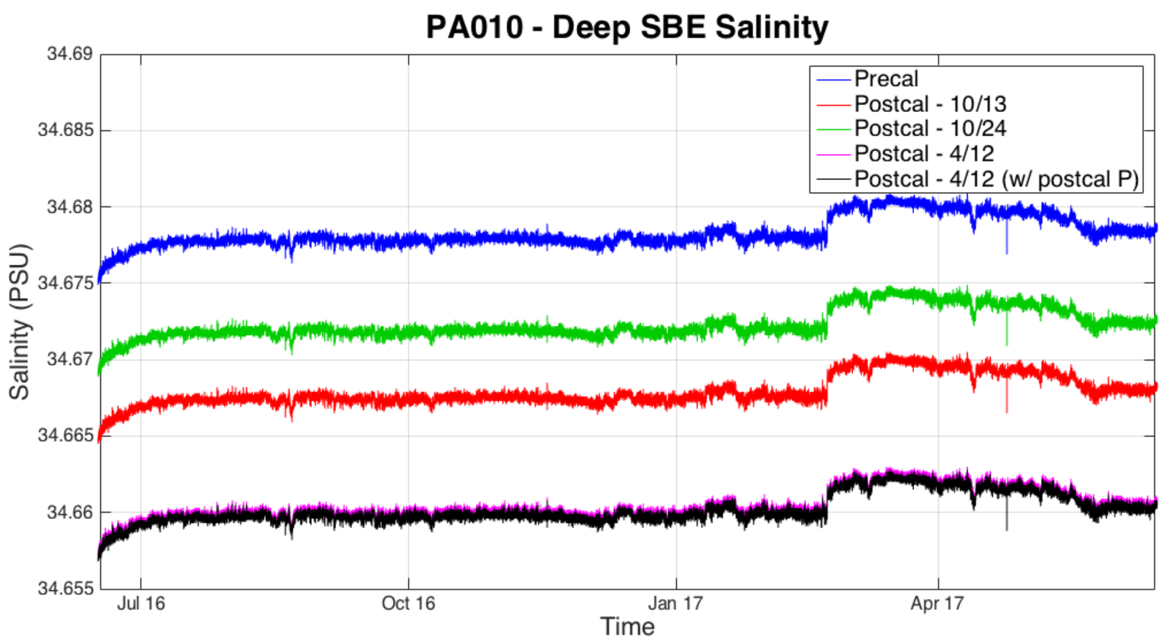

Figure 11: A mix-up resulted in low confidence in any calibration performed after recovery. The spread of calibrations, most of which were done after cell replatinization (except, perhaps 10/13) reveal that consecutive calibrations can differ slightly. These differences can overwhelm the small signal in the deep ocean.

Early deployment drift can be seen as a curve in the first few months of the time-series. This anomaly has been seen in one other instrument (S/N 2608), with a similar magnitude. To correct the data, a quadratic curve is fit and detrended from the first ~2 months of salinity data. Conductivities are then backed out, and Q3 (adjusted) flags are assigned to C/S/D in the adjusted region. A decaying film of biocide in the conductivity cell (Wong et al. 2003), or accumulating sediment could explain this drift.

The best-fit quadratic used for the detrend is given by the equation $Ax^2 + Bx + C$, where:
A = -0.0003236408
B = 0.0004839653
C = 34.6777351579
X = Time

More technically, X is $\frac{t-\bar{t}}{t_\sigma}$, where t is time, $\bar{t}$ is the average time, and t_σ is the standard deviation of time. This is necessary for curve-fitting with Matlab timestamps.

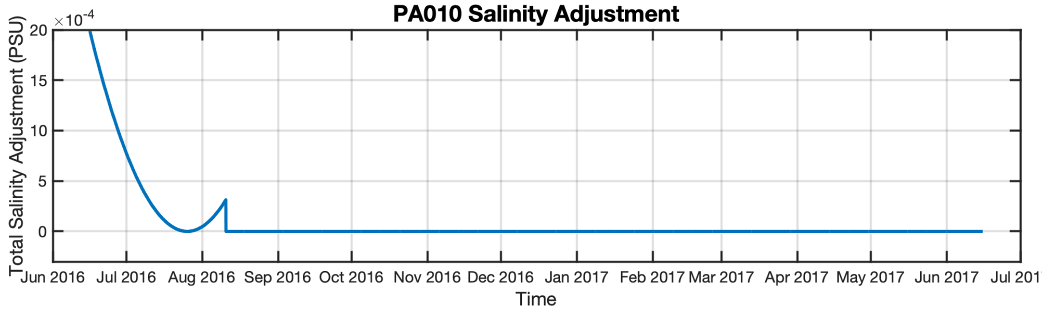

Figure 12: Salinity adjustment (logarithmic detrend) to correct the early data's salinity drift.

Data from previous years were examined to address any discontinuities, but no offset was needed to align the data to previous years. Appendix figure B5 shows the final data, combining the precal line from Figure 11 with the salinity adjustment in Figure 12.

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.

3.3.5 Currents

Point current meters were deployed at two depths on the PA010 mooring. The stated head depth differs from the actual current measurement depth, because the instruments require a blanking distance. Currents from the instruments deployed at 15.46m and 35.46m measured velocities at 15m and 35m, respectively. Both current meters deployed on PA010 were upward-facing Nortek Aquadopps.

The current meters calculate the speed of sound, and internally apply sound velocity corrections to current measurements. A thirteen-point Hanning filter is applied to the 10-minute resolution data to get hourly data, and a boxcar filter produces daily averaged values.

Real-time data from PA010 had a magnetic declination of +17 degrees applied. The delayed-mode data that later replaced the real-time data were reprocessed with a magnetic declination correction of +16 degrees instead, to reflect Earth's changing magnetic field.

Buoy motion corrections were not applied to the Aquadopps because Papa is a taut-line mooring. While the buoy's horizontal motion is often negligible, velocities interpolated from aggregated Flex + TFlex GPS data are provided alongside the current meter data at 10-minute and hourly resolutions. GPS data should not be averaged, or applied to averaged current meter data. If corrected currents are desired at lower resolutions, apply the correction to the high-resolution data, and then perform averaging to the desired resolution.

3.3.6 Acoustic Doppler Current Profiler (ADCP)

A downward looking ADCP was deployed on PA010. 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 with a heading bias of +17. This will be changed on future deployments to match the time-variant declination correction. 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 ADCP is being tested on more recent deployments. 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.

For the first time on PA010, the ADCP collected 1-second data in beam coordinates, measured in 2-minute bursts every half hour. Binary files are converted to readable format and 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 into several files and 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).

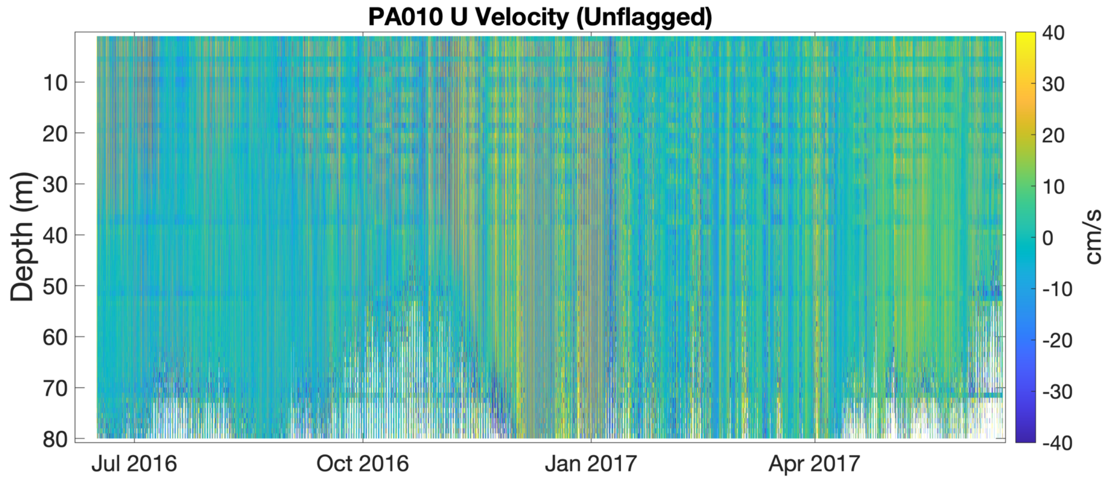

Figure 13: ADCP eastward velocities with autonomous flagging thresholds applied by the ADCP, but before manual flagging. All beams are affected by instruments on the line.

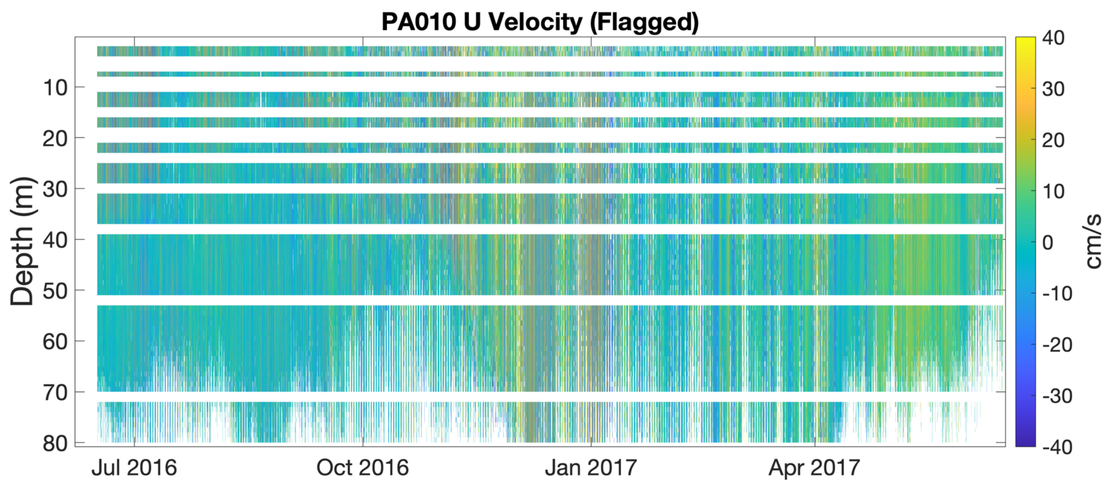

Figure 14: ADCP eastward velocities with manual flagging thresholds and bin-flagging applied, in addition to the autonomous flagging thresholds applied by the ADCP.

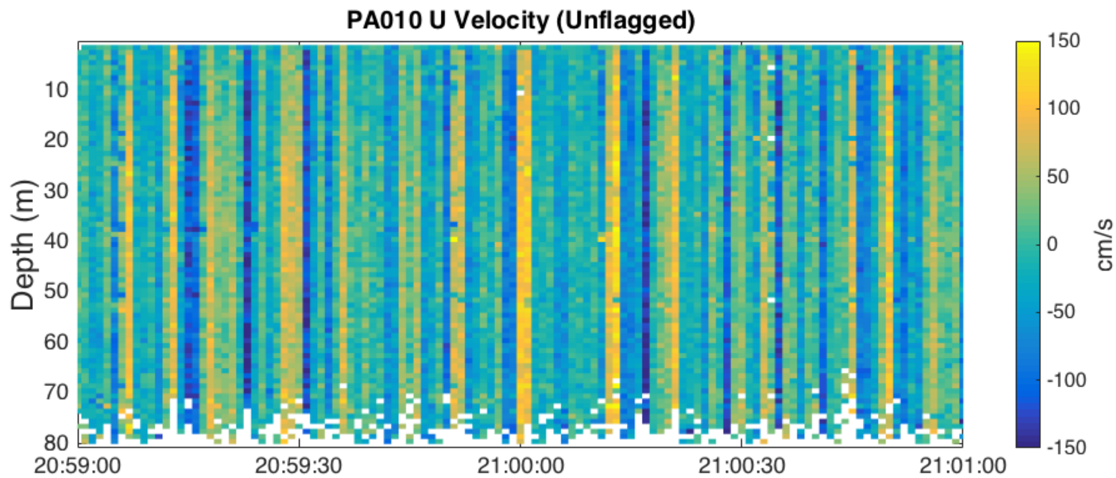

Figure 15: Zoom-in on a burst sample (120 x 1-second profiles), showing individual wave motion on 6/25/2016.

Figure 15 shows an example of raw data from one burst sample. The 120 profiles average into a single 2-minute average profile (a vertical slice in Figures 13 and 14). Instrument interference is less apparent in the unaveraged (1-second) profiles, but the buoy motion sweeps each beam across the vertical in the mean. Wave action is pronounced in 1-second data, as the buoy rides up and down each wave, at speeds greater than the measured seawater velocities, and occasionally exceeding 1 m/s. This highlights the difficulty of making current measurements from a moving platform, and the need for a wide enough averaging interval so that wave motion is averaged out.

4.0 References

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5.0 Acknowledgements

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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 v1.2 or v1.3 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

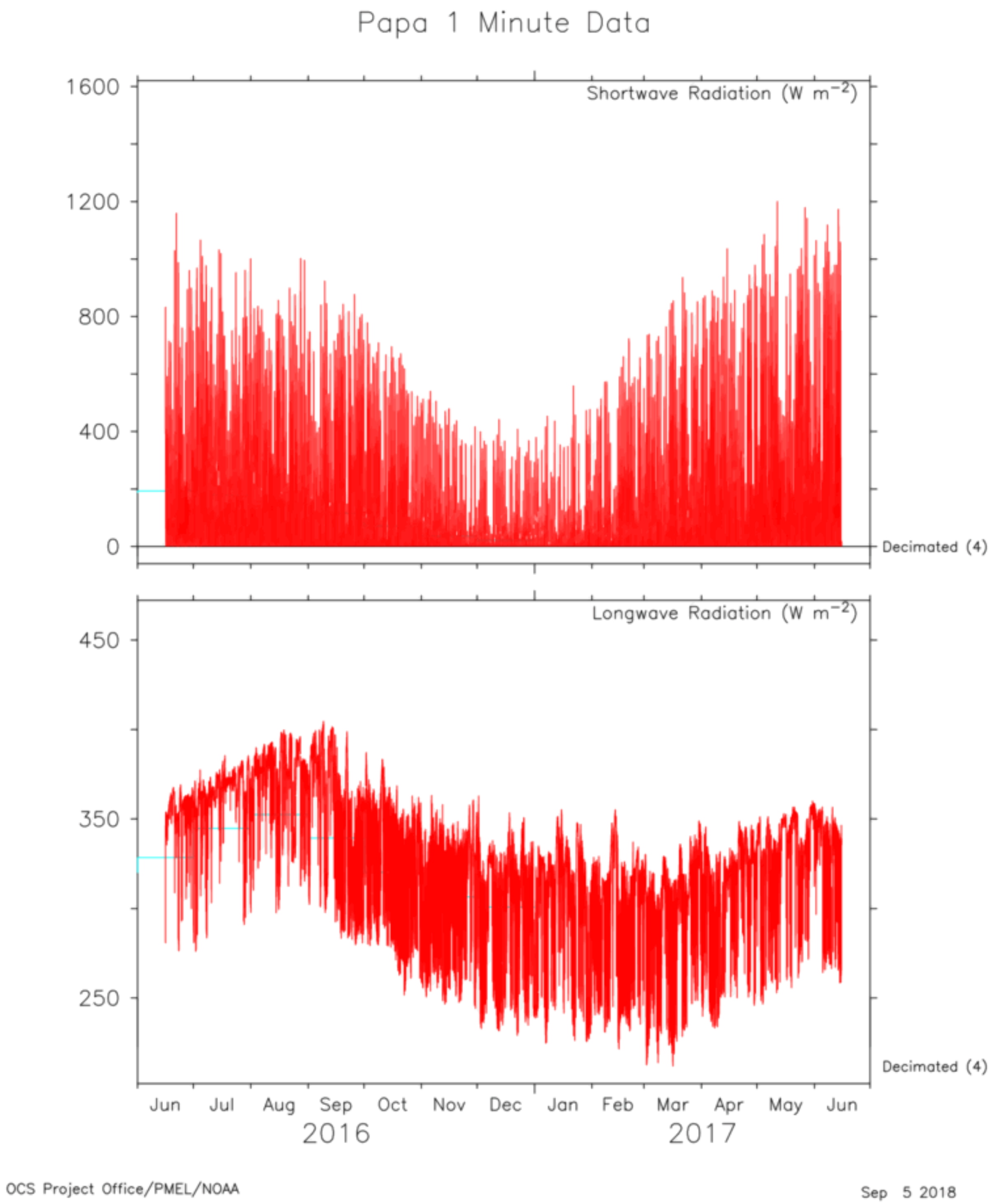

Figure B 1: PA010 primary shortwave and longwave radiation data at 1-min resolution (Flex).

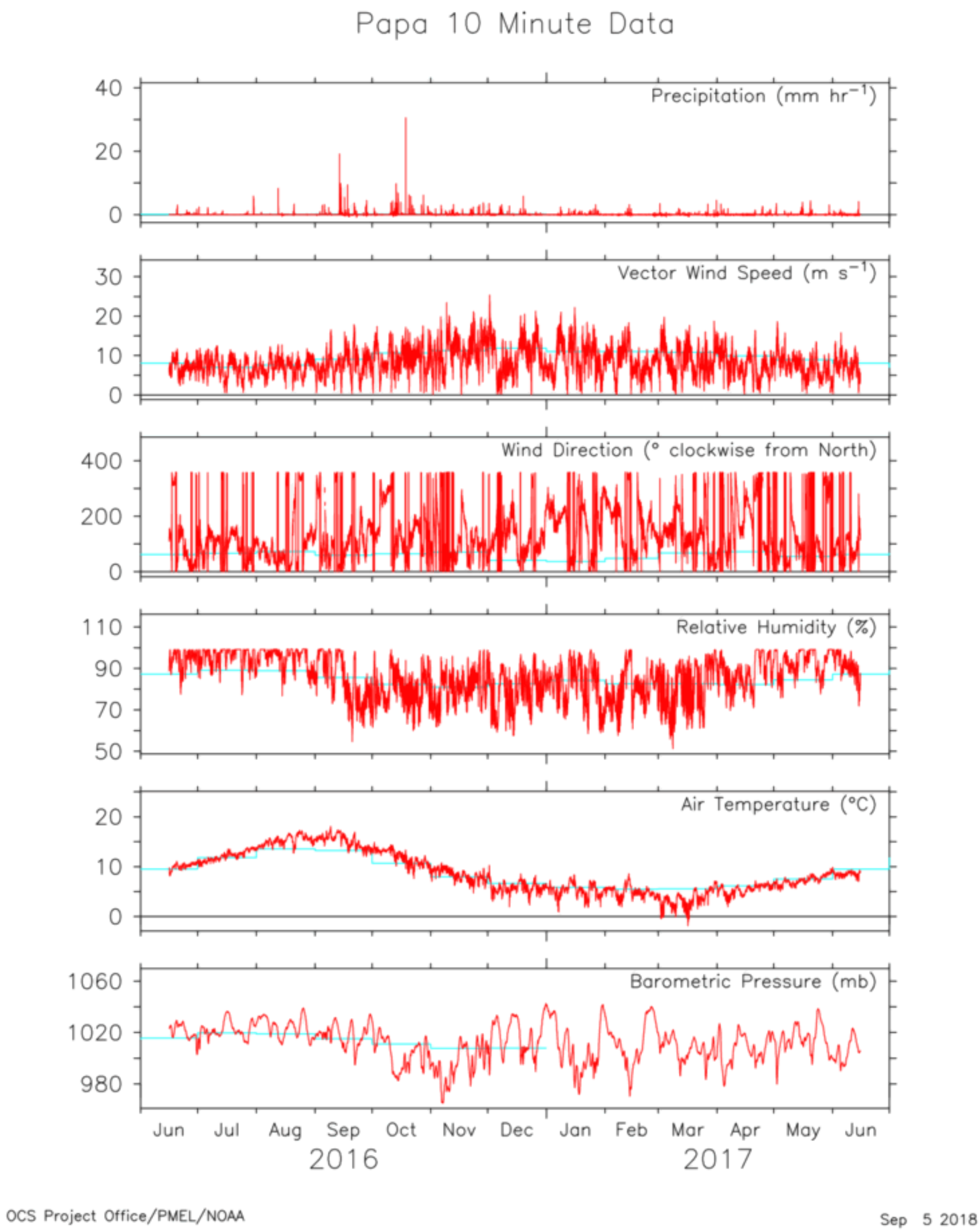

Figure B 2: PA010 meteorological data at 10-min resolution. Data are from the Flex system, except for the rain data, which is from the TFlex. The Flex rain record had short, unexplained gaps, and a failed initial post-calibration.

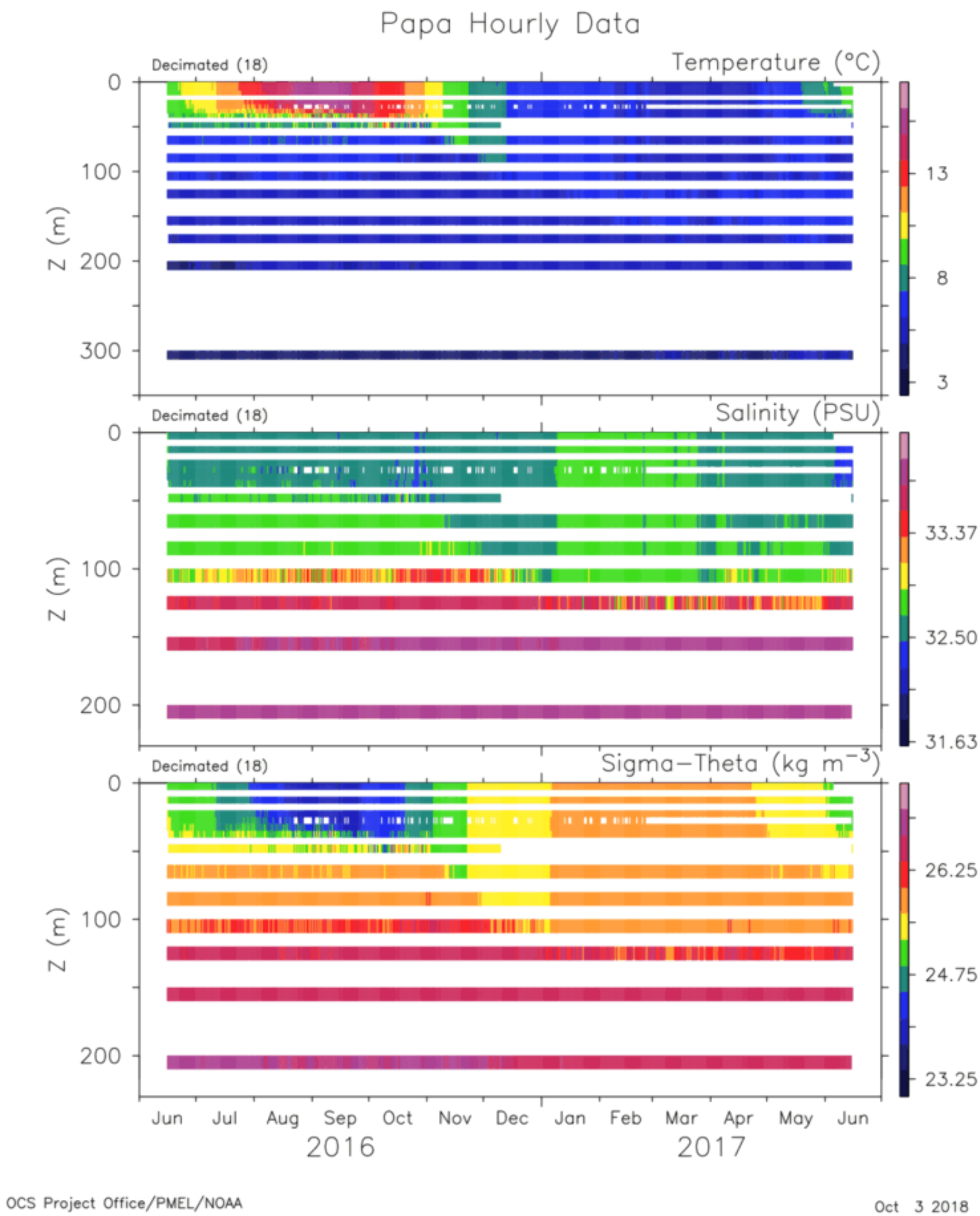

Figure B 3: PA010 subsurface temperature, salinity, and density at hourly resolution (decimated).

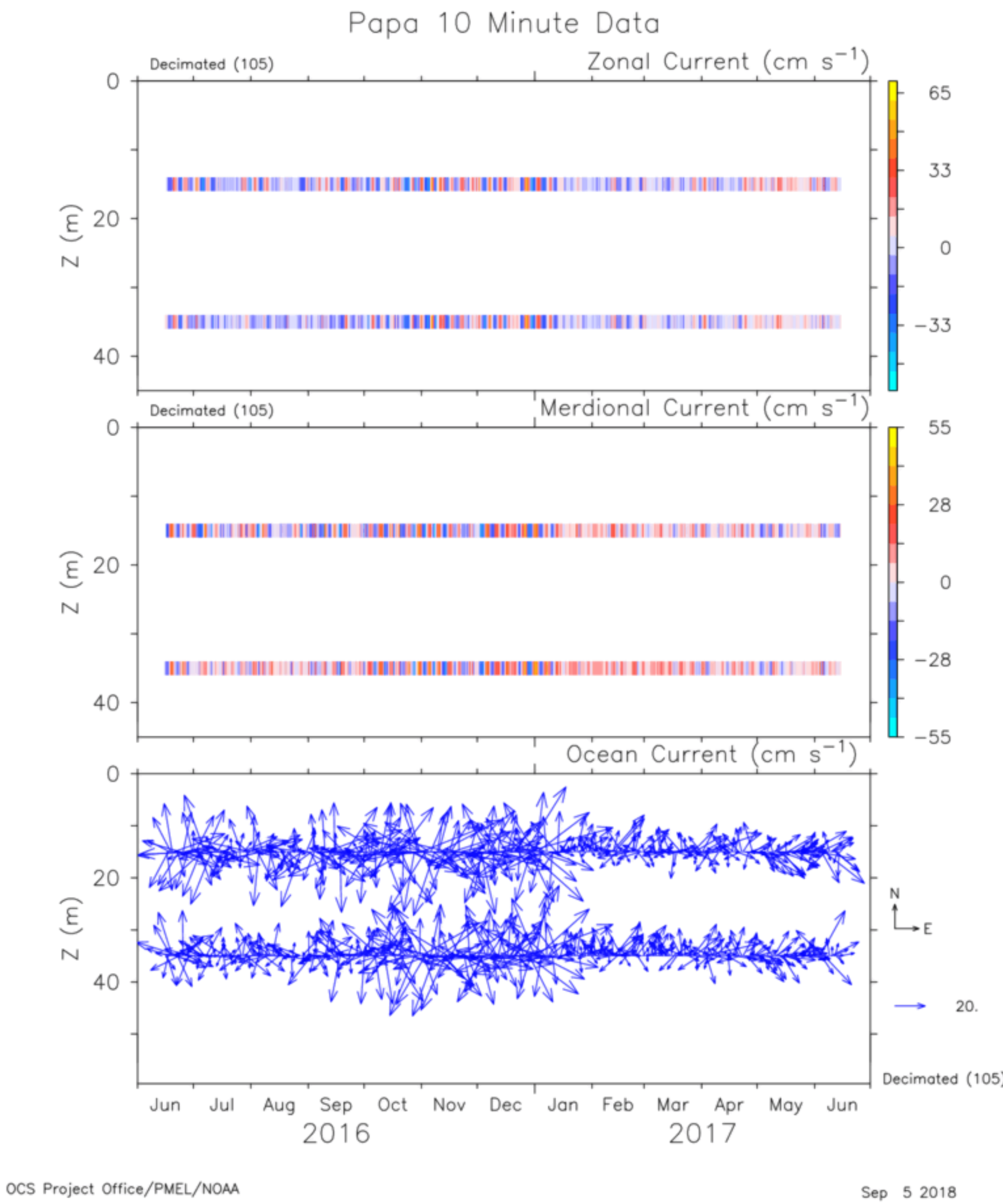

Figure B 4: Zonal and meridional current meter data from PA010.

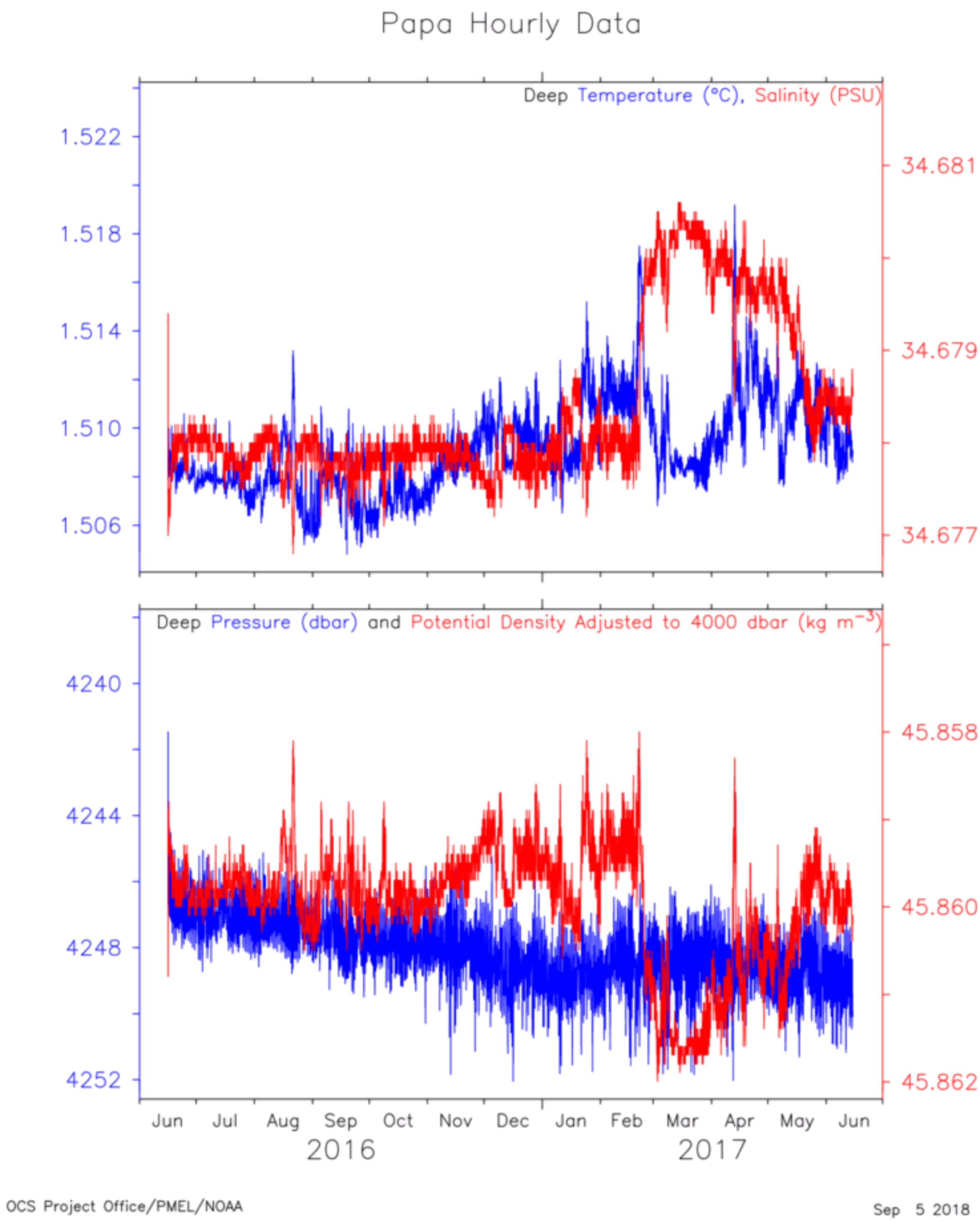

Figure B 5: Deep Seabird instrument temperature, pressure, salinity, and potential density. Only pre-calibration coefficients were applied (see Deep SBE section 3.3.4).

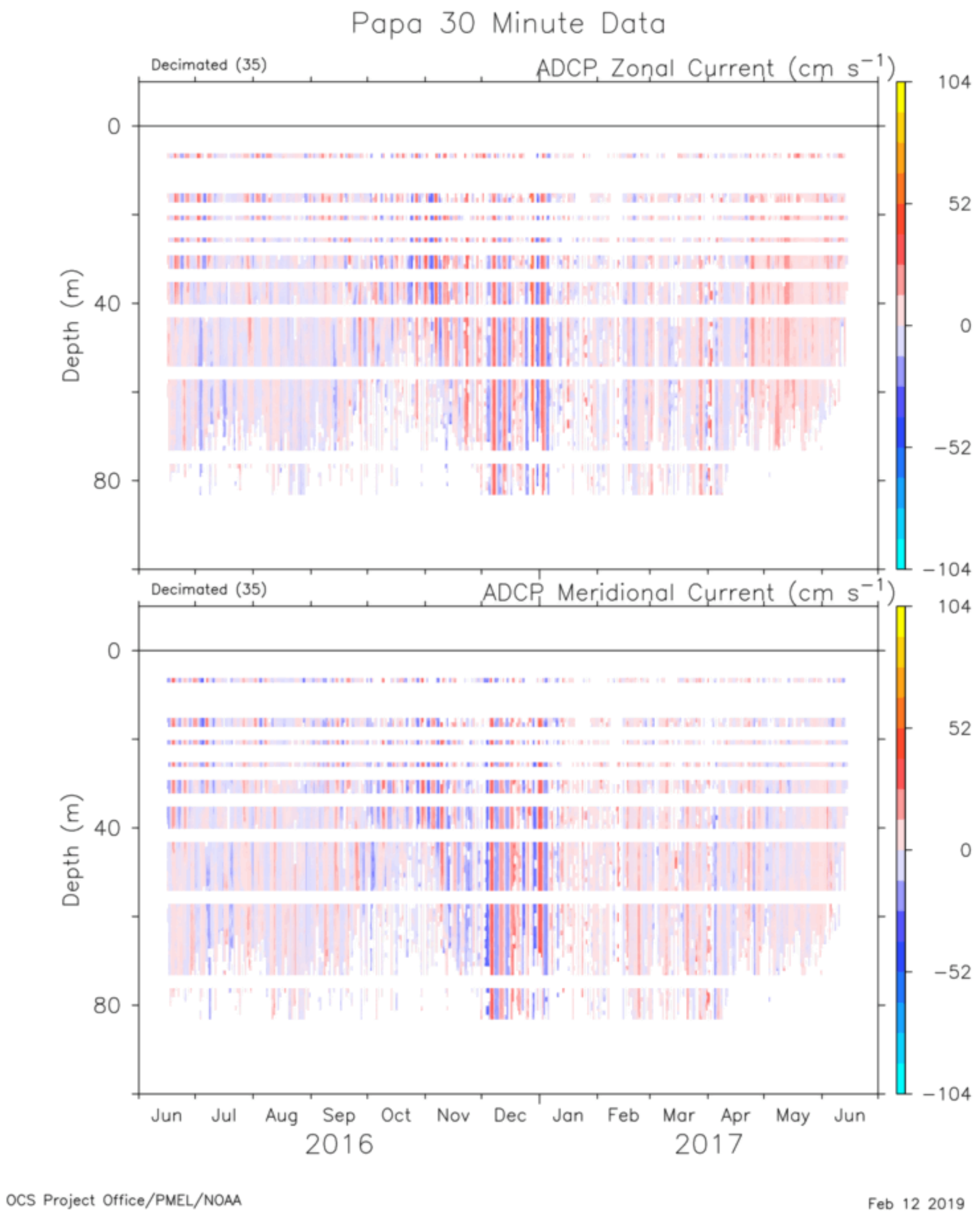

Figure B 6: Sentinel ADCP data, with striations due to bins influenced by hard-returns off of subsurface instruments. On PA010, single-ping ADCP data were collected (120 pings in 2 minutes, taken every half hour). Each burst sample was averaged for a single value every half hour, to match previous deployments.

APPENDIX C: Secondary Instrument High Resolution Data Plots

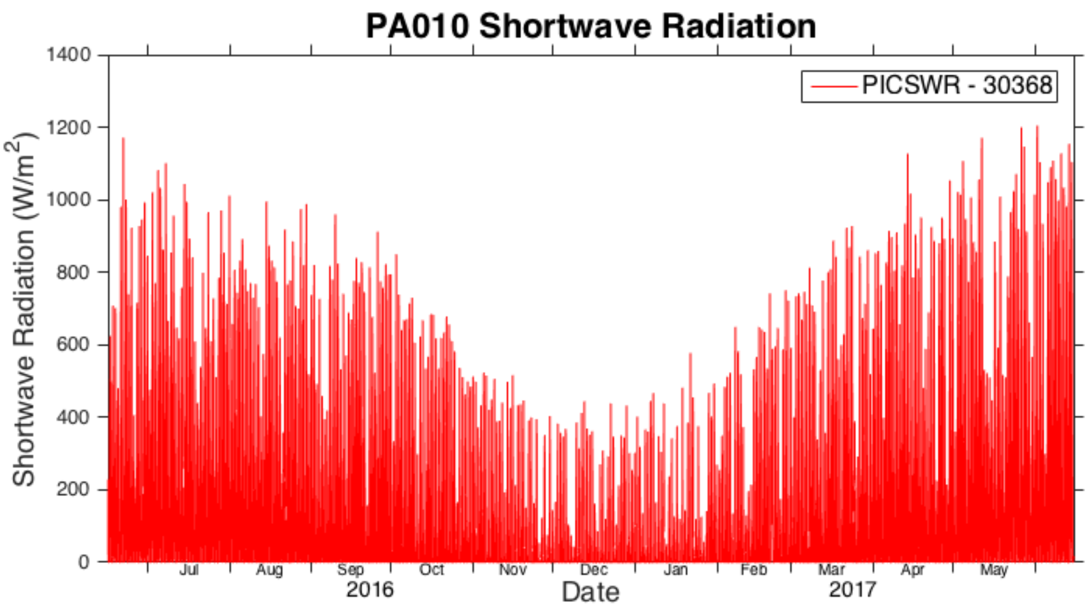

Figure C 1: Secondary (TFlex Eppley PSP) shortwave radiation sensor.

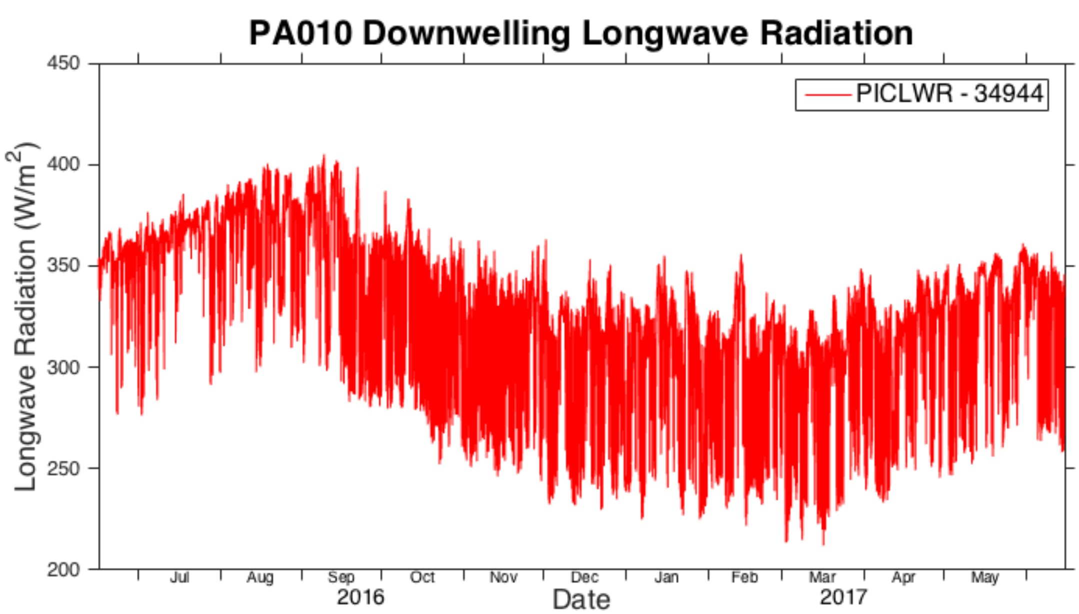

Figure C 2: Secondary (TFlex Eppley PIR) longwave radiation sensor.

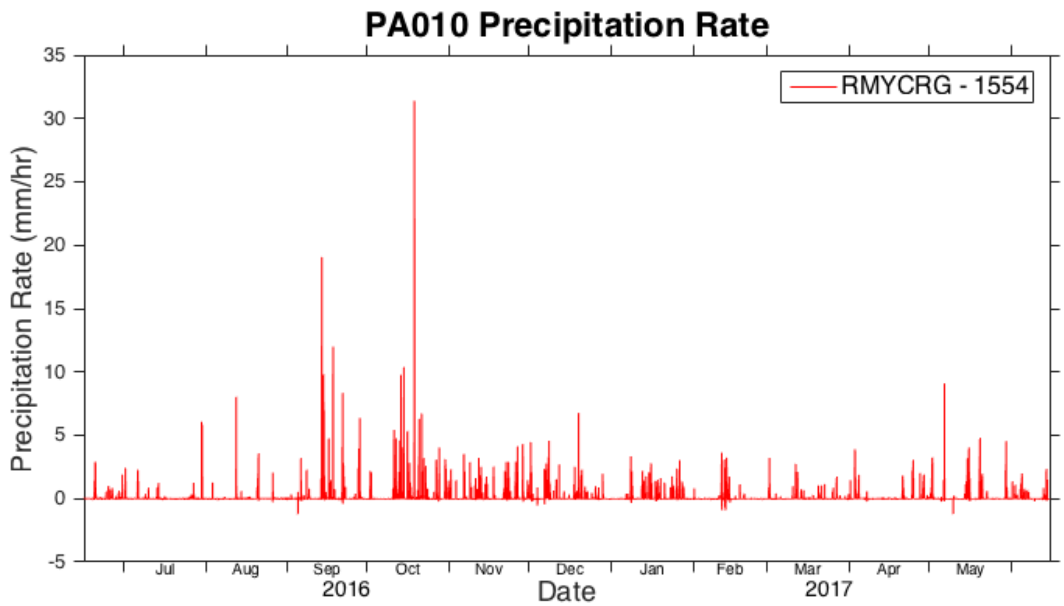

Figure C 3: Secondary (Flex RM Young) rain sensor. Failed a post-calibration, and contained short gaps.

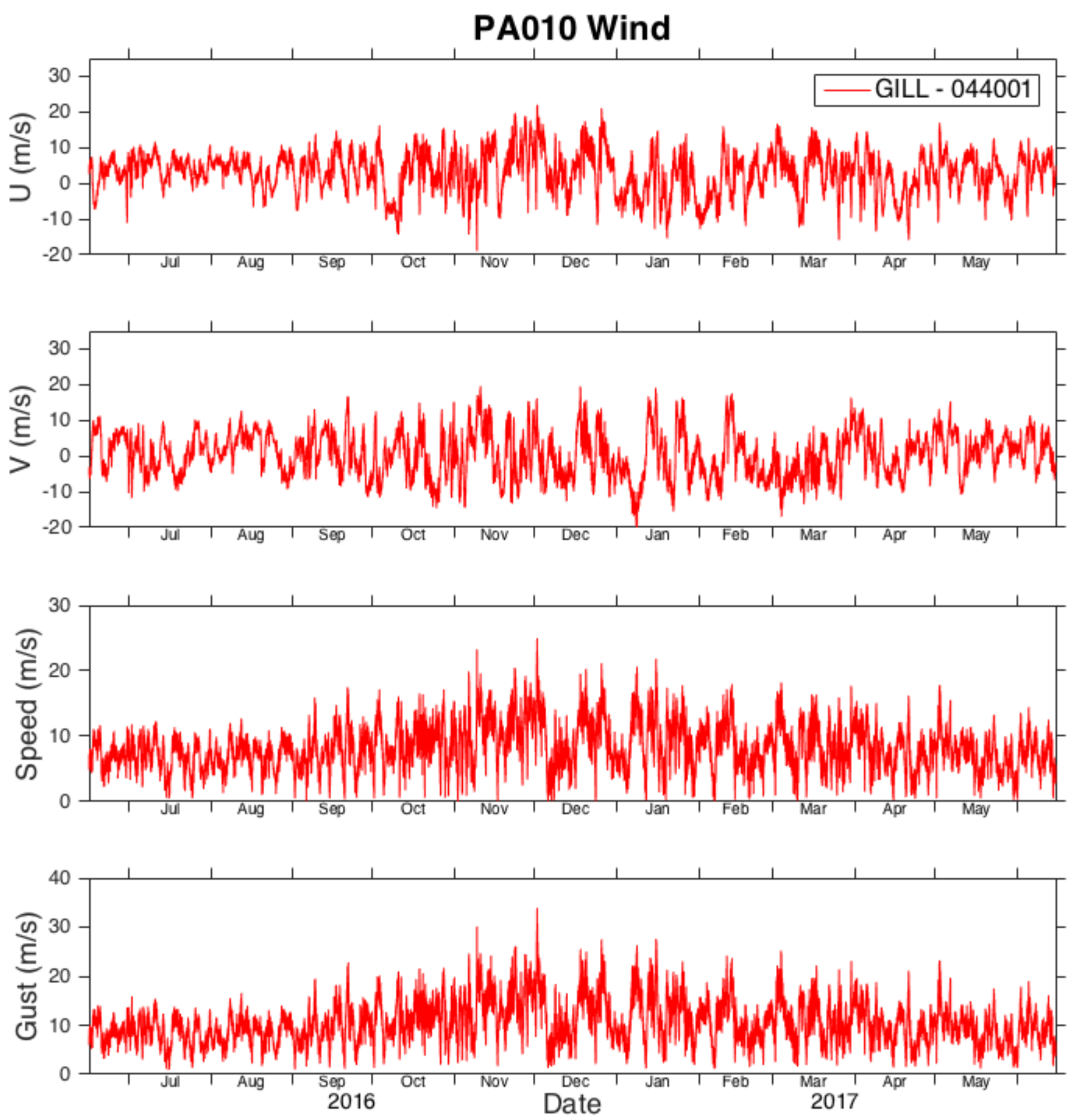

Figure C 4: Secondary (TFlex Gill) wind sensor.

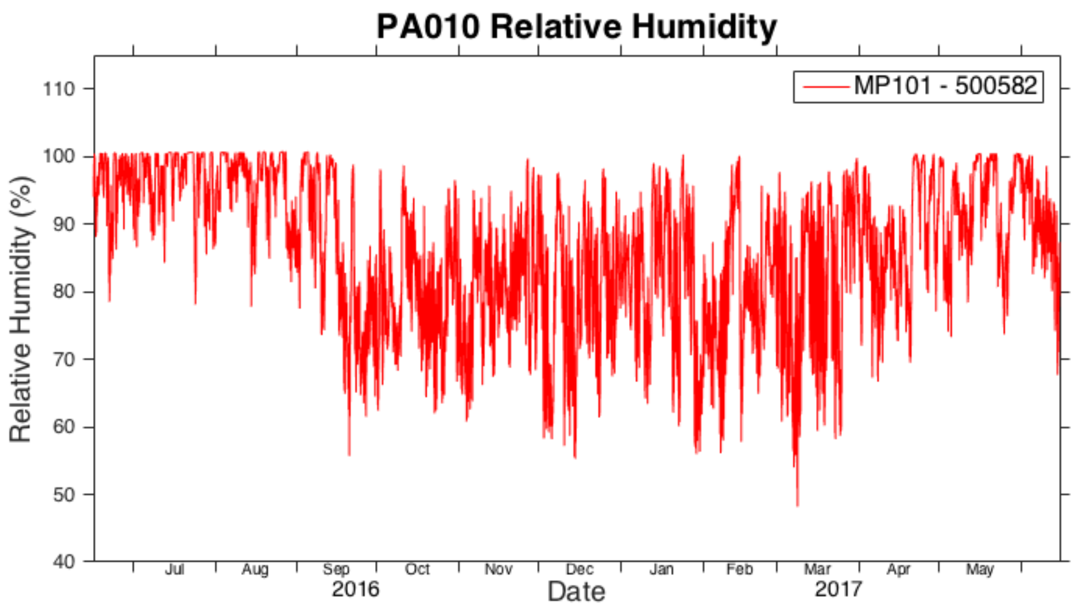

Figure C 5: Secondary (TFlex MP101) relative humidity sensor.

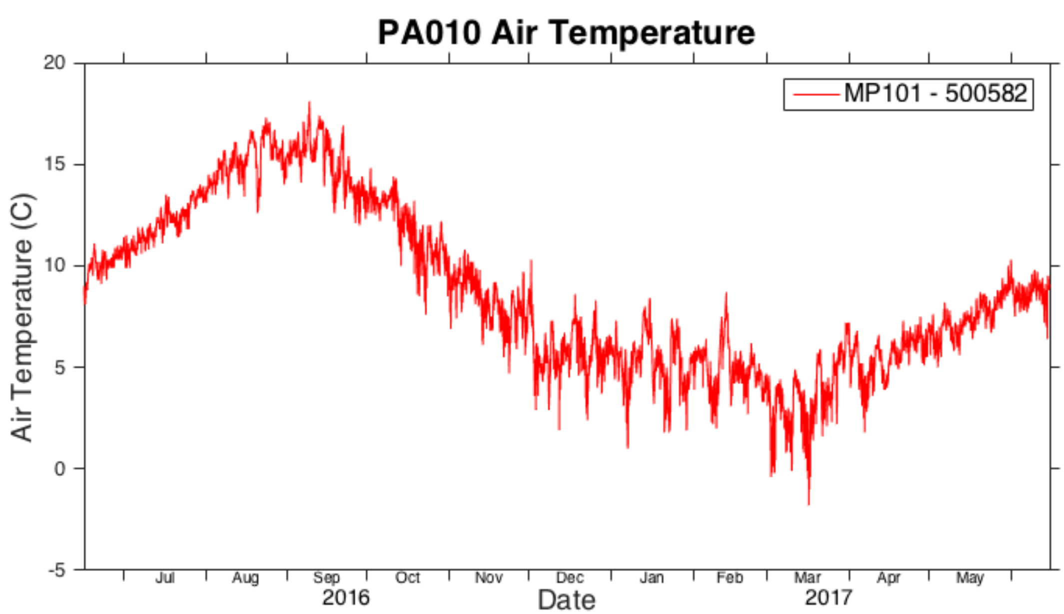

Figure C 6: Secondary (TFlex MP101) air temperature sensor.

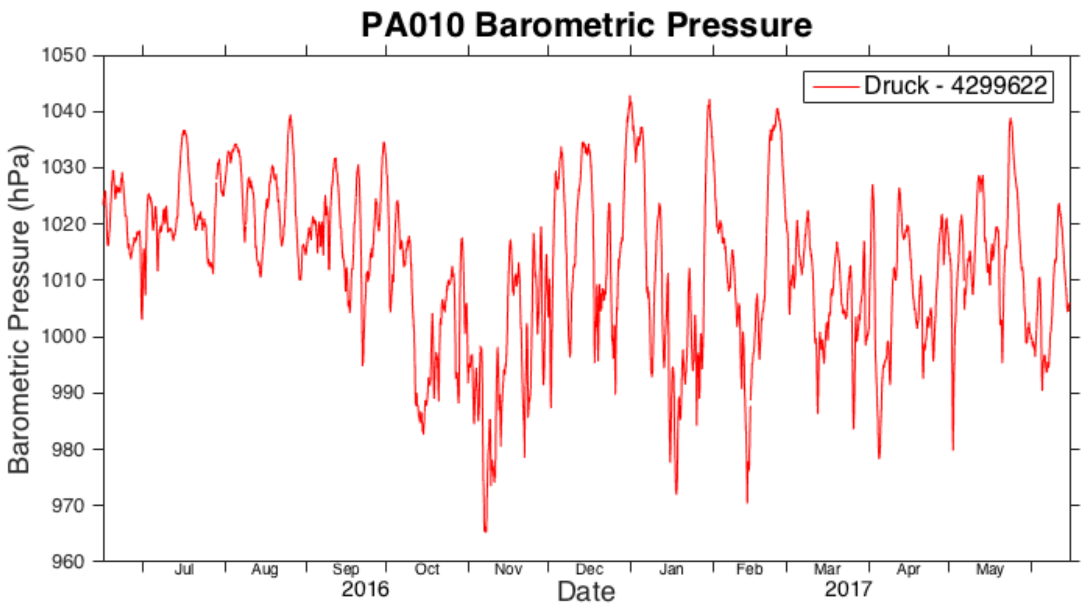

Figure C 7: Secondary (TFlex Druck) barometric pressure sensor.

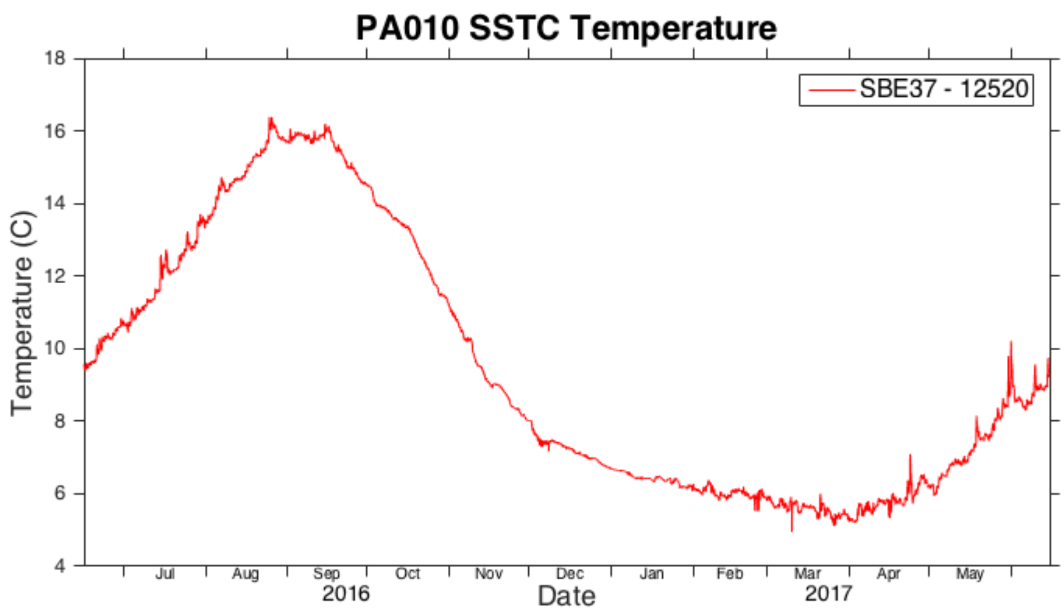

Figure C 8: Secondary (Flex) SSTC Temperature.

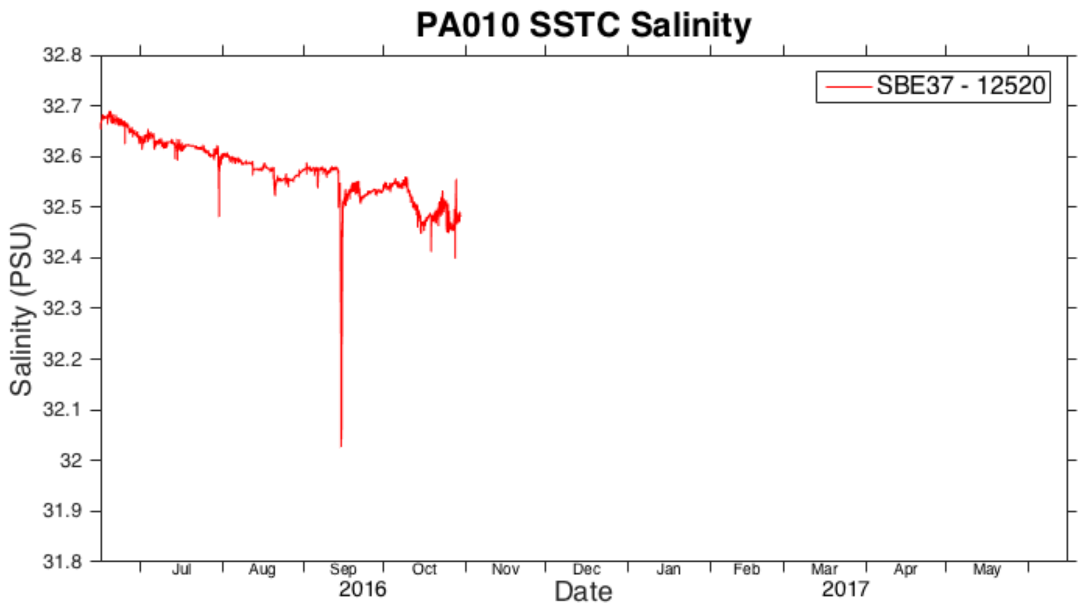

Figure C 9: Secondary (Flex) SSTC Salinity. The instrument's conductivity drifted and became clearly offset from the other SSTC and adjacent sensors. This affected salinity and density, which were flagged Q5 after October 30, 2016.

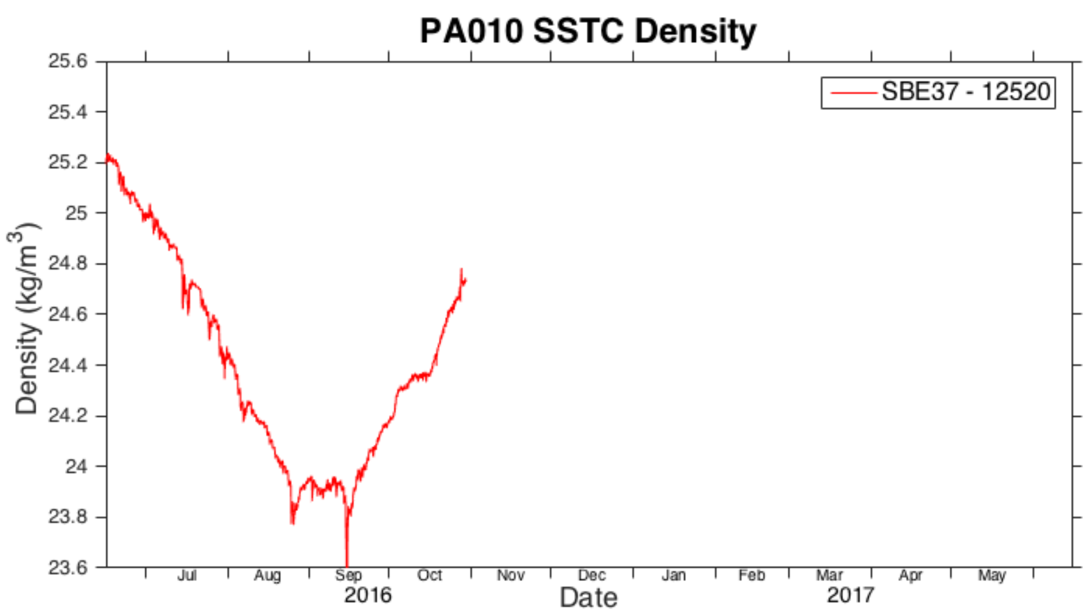

Figure C 10: Secondary (Flex) SSTC Density.