NOAA Pacific Marine Environmental Laboratory
Ocean Climate Stations Project

DATA ACQUISITION AND PROCESSING REPORT FOR PA009

Site Name:	Ocean Station Papa
Deployment Number:	**PA009**
Year Established:	2007
Nominal Location:	50.1°N 144.9°W
Anchor Position:	50.13°N 144.82°W (flyby buoy obs.)
Deployment Date:	June 15, 2015
Recovery Date:	July 5, 2016
Project P.I.:	Dr. Meghan F. Cronin
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Data Processors:	N.D. Anderson
Date of Report:	May 21, 2018
Revision History:	

Special Notes:

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Data Acquisition and Processing Report for OCS Mooring PA009

1.0 Mooring Summary

As the site of a former ocean weather ship, Station Papa (50.1°N, 144.9°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. PA009 was the ninth deployment at this site.

The PA009 mooring was deployed by the CCGS JOHN P. TULLY, and was recovered by NOAA's RON BROWN. The Ocean Climate Stations group is grateful to the captains and crews of the TULLY and BROWN for their efforts and mooring operation assistance. A June 2016 recovery was prevented by a combination of weather and small-boat limitations. During the period of overlap, data on the OCS webpage prioritize the newer deployment, but full records can be found on OceanSITES.

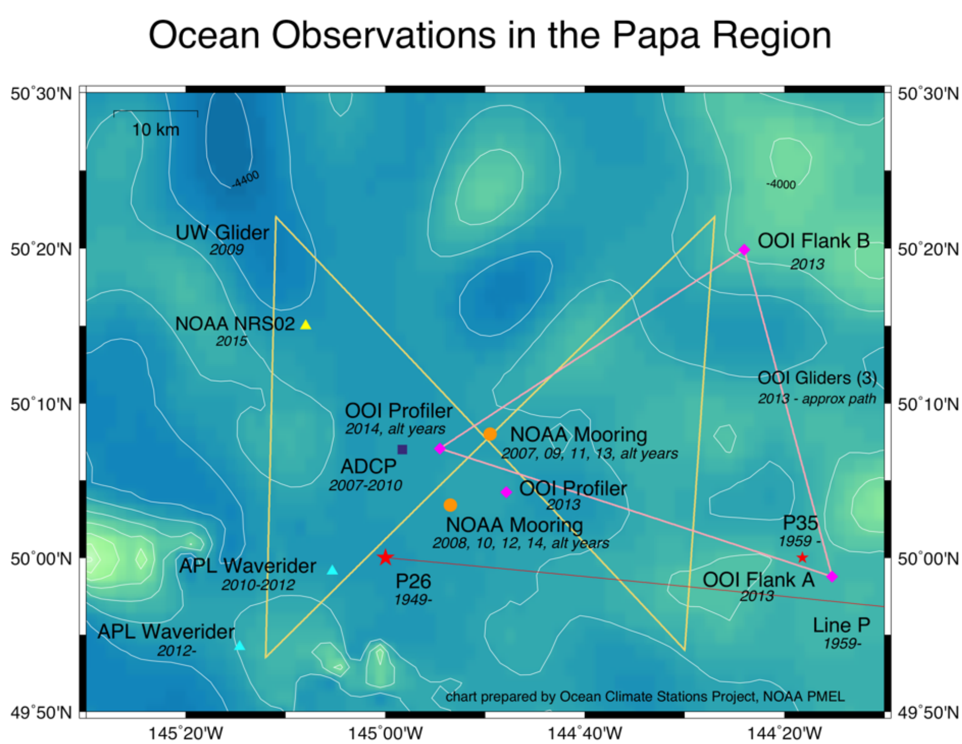


Figure 1: Ocean observations near OCS Station Papa mooring (labeled "NOAA Mooring").

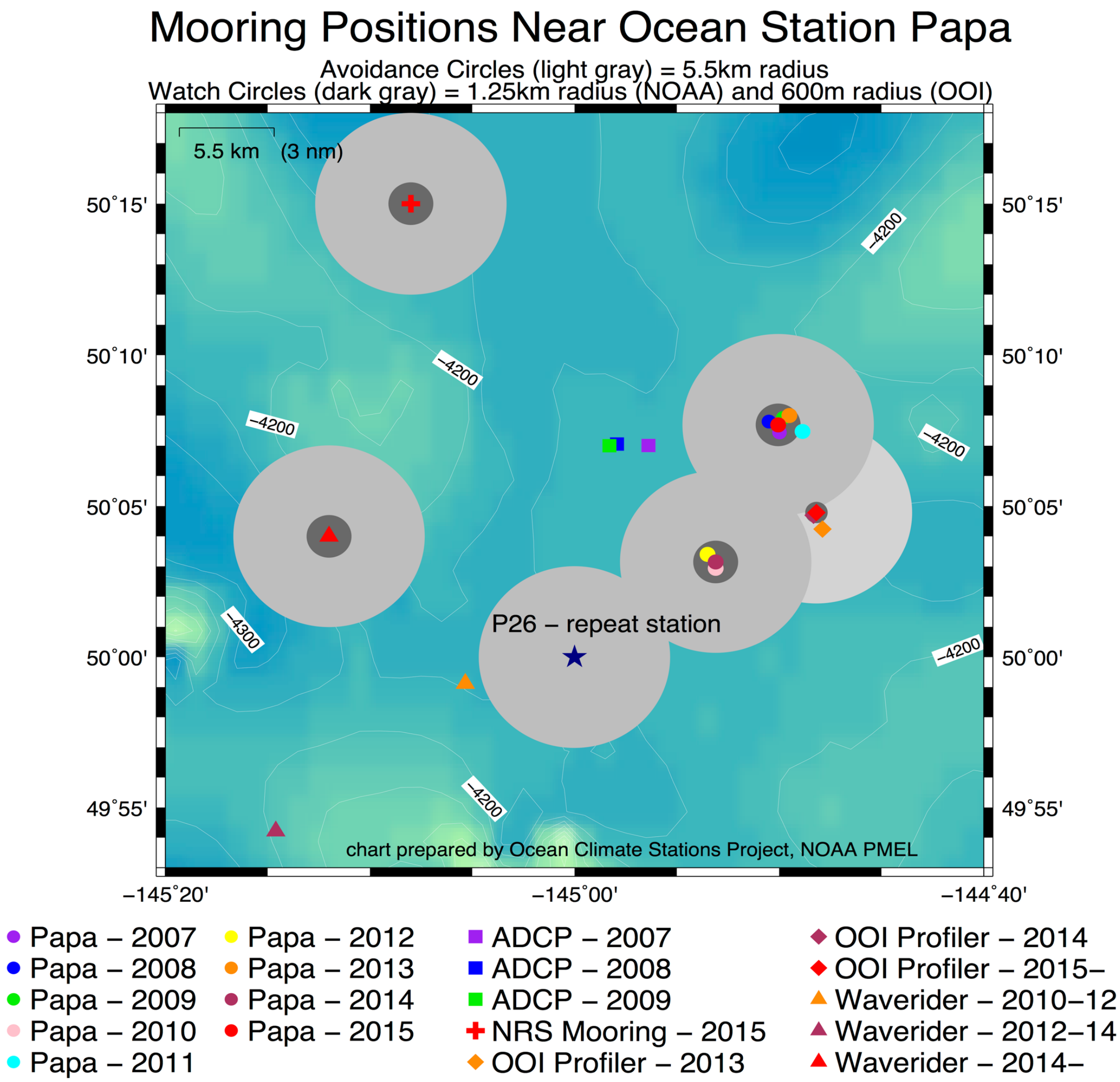


Figure 2: Overview of Station P deployments. This deployment is indicated by the red circle.

1.1 Mooring Description

The PA009 mooring was a taut-line mooring, with a shortened scope of 0.965. Previous deployments had shown pressure variation in the SBE-37SM TCP near the acoustic release, indicative of the line not remaining taut near the bottom. 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. A CO_2 flux monitoring system was also deployed on the PA009 mooring, in collaboration with the PMEL carbon group, whose instrumentation included a fluorometer and SAMI pH sensor. OCS is not responsible for the acquisition or processing of these data. No further discussion of these systems or instruments is included in this report.

Figure 3: PA009 as deployed.

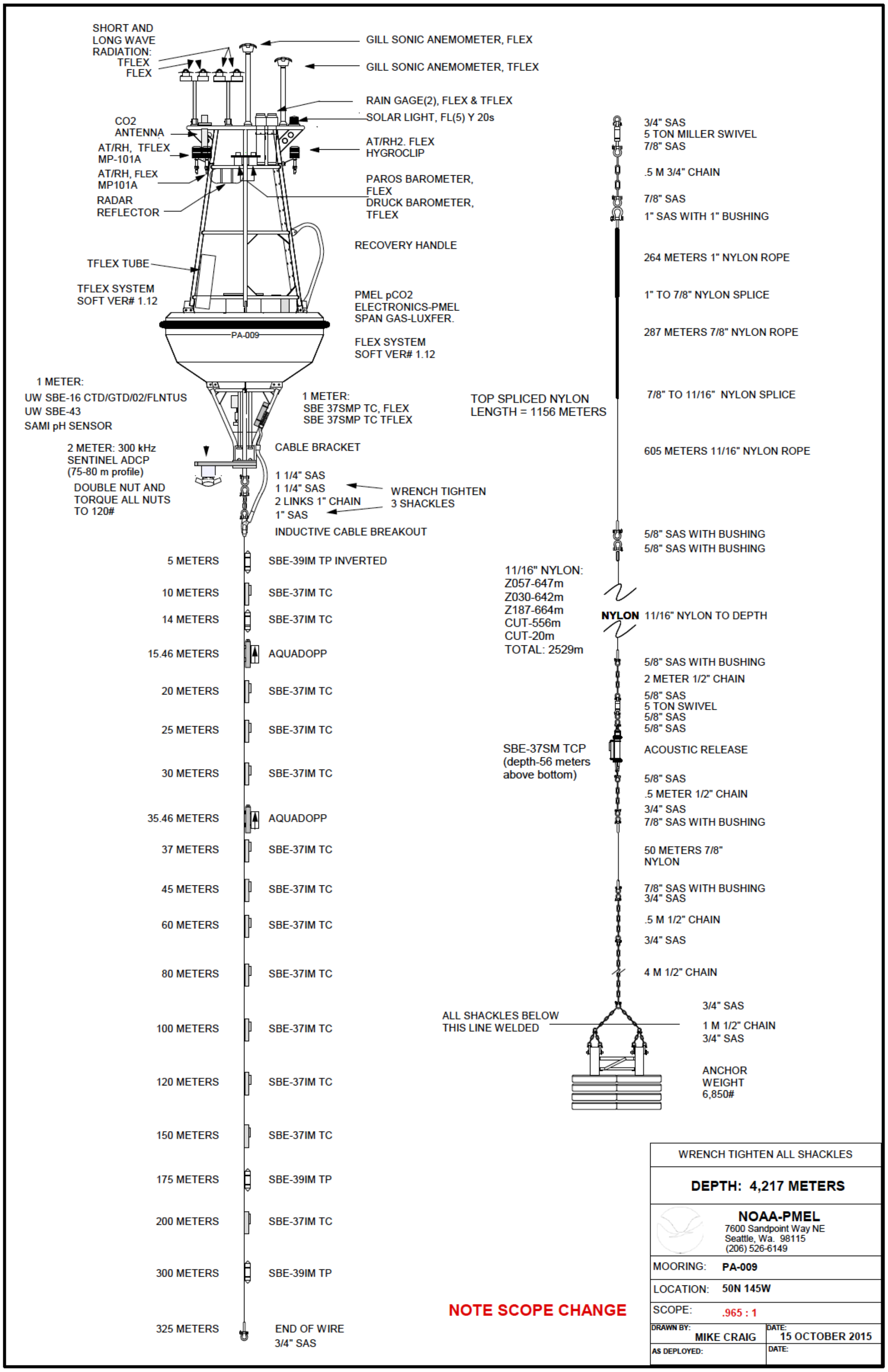


Figure 4: PA009 mooring diagram.

1.2 Instrumentation on PA009

The following instrumentation was deployed on PA009. 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:		**PA009**			
Met Sensors		**Model**	**Serial #**		**Notes**
Height	Acquisition	**FLEX**	0002	1/6	
2.6m	ATRH	Rotronics MP-101A	133375		
2.6m	ATRH2	Rotronics HygroClip	61334062		
4.2m	Wind	Gill	10510082		
2.5m	BP	Paros	106579		
3.1m	Rain	RM Young	968-4		
3.6m	SWR	Eppley PSP	35979		
3.6m	LWR	Eppley PIR	37086		
	Acquisition	**TFLEX**	2003		
2.6m	ATRH	Rotronics MP-101A	104889		
3.8m	Wind	Gill	11520107		
2.4m	BP	Druck	4253762		
3.1m	Rain	RM Young	1670		
3.6m	SWR	Eppley PSP	31621		
3.6m	LWR	Eppley PIR	37709		
CO2	Electronics	PMEL	0147		
	Span Gas	Luxfer	JB03815		
Subsurface Instrumentation					
Bridle		**Model**	**Serial #**		**Notes**
1m	SST/C	SBE37SMP - TC	7090		Flex
1m	SST/C	SBE37SMP - TC	11555		TFLEX, New AA
1m	pH	SAMI	59		Supplied by UW
1m	SST/C	SBE16	6618		Supplied by UW
1m	Oxygen	Optode	487		Supplied by UW
1m	Oxygen	SBE43	430333		Supplied by UW
1m	Fluorescence	ECO FLNTUS	2341		Supplied by CO2 - Self Powered
1m	Gas Tension	GTD	22018RD13		Supplied by UW
2m	ADCP	Workhorse Sentinel	14605		
Depth		**Model**	**Serial #**	**ID**	**Notes**
5m	TP	SBE39IM - TP	4862	01	Inverted (Use TP for titanium housing)
10m	TC	SBE37IM - TC	12517	02	New - AA
14m	TC	SBE37IM - TC	13248	03	New - AA. Replaces 39TP.
15.46m	ADCP	AquaDopp	6809	04	
20m	TC	SBE37IM - TC	12550	05	New - AA
25m	TC	SBE37IM - TC	8419	06	
30m	TC	SBE37IM - TC	8420	07	
35.46m	ADCP	AquaDopp	6810	08	
37m	TC	SBE37IM - TC	6140	09	
45m	TC	SBE37IM - TC	8422	10	
60m	TC	SBE37IM - TC	8423	11	
80m	TC	SBE37IM - TC	8424	12	
100m	TC	SBE37IM - TC	6072	13	
120m	TC	SBE37IM - TC	6073	14	
150m	TC	SBE37IM - TC	6074	15	
175m	TP	SBE39IM - TP	4863	16	
200m	TC	SBE37IM - TC	7788	17	
300m	TP	SBE39IM - TP	4864	18	
325m	End of Wire				
Release	TCP	SBE37SM - TCP	10503	-	Has AA batteries

Table 1: Instruments deployed on PA009.

Since 2007, the measurement point for bridle sensors, including the 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 all bridle sensors is stated as 1m.

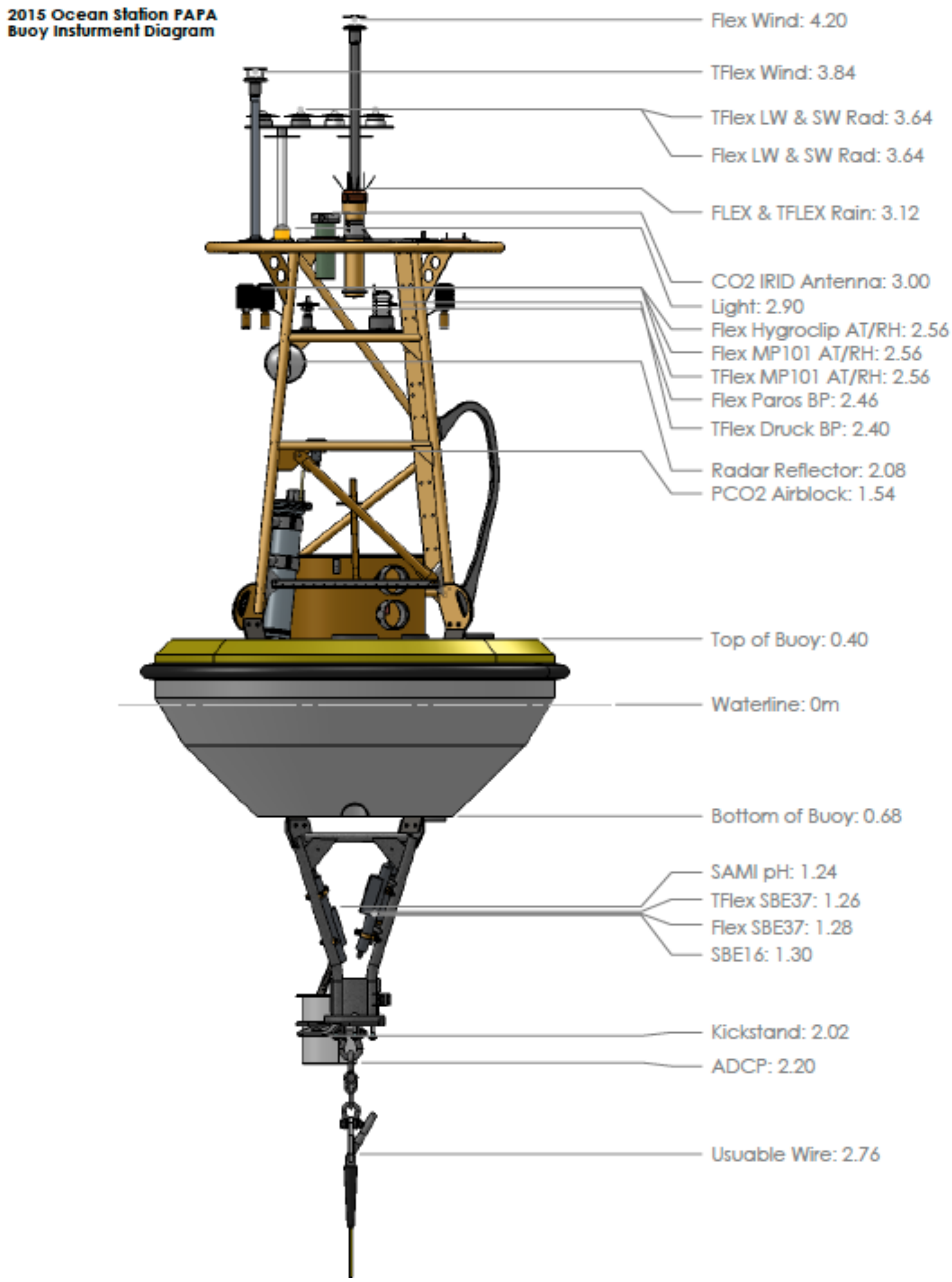


Figure 5: Buoy diagram showing bridle arrangement. The SBE16 package contains a suite of sensors.

2.0 Data Acquisition

Two independent data acquisition systems were deployed on PA009, 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	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 (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 PA009.

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 PA009.

2.2 Data Return

Delayed-mode data are returned to the lab post-recovery. These data are evaluated based on the amount of data available against the total amount of data possible for the period. The following list shows the data returns from the surface and subsurface measurements from both acquisition systems.

Flex 0002:

```
Data Return Summary
2015-06-15 23:18:00 to 2016-07-05 20:02:00

Sensor      Deployed      Obs    Return
=======================================
AT1            55564    55545    100.0%
AT2            55564    55545    100.0%
RH1            55564    55545    100.0%
RH2            55564    55545    100.0%
WIND1          55564    55414     99.7%
BP1            55564    55545    100.0%
RAIN1         555644   550244     99.0%
SWR1          555644   550290     99.0%
LWR1          555644   550347     99.0%

Subsurface Temperature Profile
     1m        55564    55564    100.0%
     1m(TFlex)55564     55564    100.0%
     5m        55564    55564    100.0%
    10m        55564    55564    100.0%
    14m        55564    55564    100.0%
    20m        55564    55564    100.0%
    25m        55564    55564    100.0%
    30m        55564    55563    100.0%
    37m        55564    22646     40.8%
    45m        55564    34526     62.1%
    60m        55564    55564    100.0%
    80m        55564    55564    100.0%
   100m        55564    55564    100.0%
   120m        55564    55564    100.0%
   150m        55564    55564    100.0%
   175m        55564    48932     88.1%
   200m        55564    55564    100.0%
   300m        55564    55564    100.0%
  4161m        55564    55564    100.0%

Subsurface Pressure Profile
     5m        55564    55564    100.0%
   175m        55564    48932     88.1%
   300m        55564    55564    100.0%
  4161m        55564    55564    100.0%
```

Subsurface Salinity Profile

1m	55564	55564	100.0%
1m(TFlex)	55564	55564	100.0%
10m	55564	9364	16.9%
14m	55564	55564	100.0%
20m	55564	55564	100.0%
25m	55564	55564	100.0%
30m	55564	55563	100.0%
37m	55564	0	0.0%
45m	55564	34526	62.1%
60m	55564	55564	100.0%
80m	55564	55564	100.0%
100m	55564	55564	100.0%
120m	55564	55564	100.0%
150m	55564	55564	100.0%
200m	55564	55564	100.0%
4161m	55564	55564	100.0%

AQD Current Velocity

15m	55564	0	0.0% **
35m	55564	55564	100.0%

** Flooded, only realtime data available.

TFlex 2003:

Data Return Summary

2015-06-15 23:18:00 to 2016-07-05 20:02:00

Sensor	Deployed	Obs	Return
AT1	55564	55546	100.0%
RH1	55564	55546	100.0%
WIND1	55564	55466	99.8%
BP1	55564	55546	100.0%
RAIN1	555644	536542	96.6%
SWR1	555644	552206	99.4%
LWR1	555644	552799	99.5%

2.3 Known Sensor Issues

The MP101 ATRH sensors often reported values of relative humidity over 100%. The issue is believed to originate from calibrations performed at cold temperatures (see Technical Note 7). For real-time data, the Hygroclip test sensor was designated as the primary ATRH on August 11, 2015. GTS distribution of all RH sensors stopped October 6, 2015 until the following deployment.

The salinity measurements taken at 10m diverged from adjacent sensors, and indicated a persistent density inversion. All real-time data at 10m were flagged Q5 from August 20, 2015 to the end of the deployment. Delayed-mode data showed a salinity drift of 0.1531 PSU. The calibration file indicated the manufacturer had made modifications prior to the post-calibration, so the post-calibration was discarded. The data with the pre-calibration coefficients applied aligned with surrounding instruments until August 20.

Salinity and density anomalies were observed in the 37m data, and real-time conductivity and salinity were flagged throughout the deployment. Temperature and conductivity became constant November 23, 2015. Temperatures were flagged from this point forward, but all conductivities (and calculated salinity and density) were flagged Q5 (sensor failed). The delayed-mode data were recovered, and showed extreme noise in the conductivities, and the real-time decision to withhold 37m conductivity/salinity/density data was upheld. Delayed-mode temperatures also ended November 23, 2015.

The 45m and 175m sensors reported constant data and all measurements were flagged in real-time data starting February 10 and May 20, 2016, respectively. This is indicative of battery failure, which was also confirmed in the returned logs.

The TFlex rain sensor was flagged Q5 from April 22, 2016 forward, with numerous spikes in the data.

Recovery notes indicate that the 300m TP instrument was dead upon recovery, with no established communications. However, the instrument produced a full set of delayed-mode data, indicating the data had been recoverable.

The 15m Aquadopp real-time data dropped out October 11, 2015. The instrument was flooded, and no delayed-mode data were recovered, so real-time data were left online as the best record available. The 35m instrument had 100% delayed-mode data returns.

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.

3.2 Meteorological Data

All primary meteorological sensors on PA009 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 PA009 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

Wind speed and direction data were assigned a standard quality of Q2, except in rare cases. A few measurements where the wind speed exceeded the wind gust values were flagged Q5, and were usually found around data gaps. Overall data return was over 99% for both TFlex and Flex. Although data returns were 0.1% less, the Flex wind sensor was primary because it was generally the more consistent instrument when the redundant sensors disagreed.

3.2.2 Air Temperature

Following the choice for relative humidity, the Flex MP101 was classified as primary. A list of timestamps was generated where the redundant sensors disagreed. These points were reviewed against difference plots and quality flags of Q4 were assigned to the secondary AT measurements when discrepancies were large. Manual data review revealed no further issues.

3.2.3 Relative Humidity

Relative humidity sensors are historically calibrated at 25°C. The mean temperature at Papa is around 7°C, which is near the lower limit of the calibration chamber. Calibrations were therefore done at 10°C. Gradients in the calibration chamber are thought to be the cause of RH values exceeding 100% during deployment. Subsequent deployments will be calibrated near room temperature at 25°C to avoid this issue in the future.

Relative humidity values from PA009 were backed out from the applied linear calibration, and the uncalibrated values were the distributed product. Figures 5 and 6 show the effect of the calibration on the MP101s and confirm the decision to distribute the uncalibrated values. The Flex MP101 was selected as the primary sensor, a choice confirmed by the failed relative humidity post-calibration on the TFlex MP101. Flex systems are regarded as primary unless a sensor failure occurs or data quality from TFlex is higher.

The same MP101 instruments that measure air temperature also measure relative humidity. The same procedure of generating a list of timestamps where redundant sensors disagreed was also used to locate regions of relative humidity differences. These points were reviewed against difference plots and quality flags of Q4 were assigned to the secondary RH measurements when discrepancies were large.

Calibrations in the RH chamber were done at 10°C to replicate average conditions at Papa. Deployments from PA010 forward go back to 25°C calibrations, which see better field performance, despite satisfactory lab testing at either temperature.

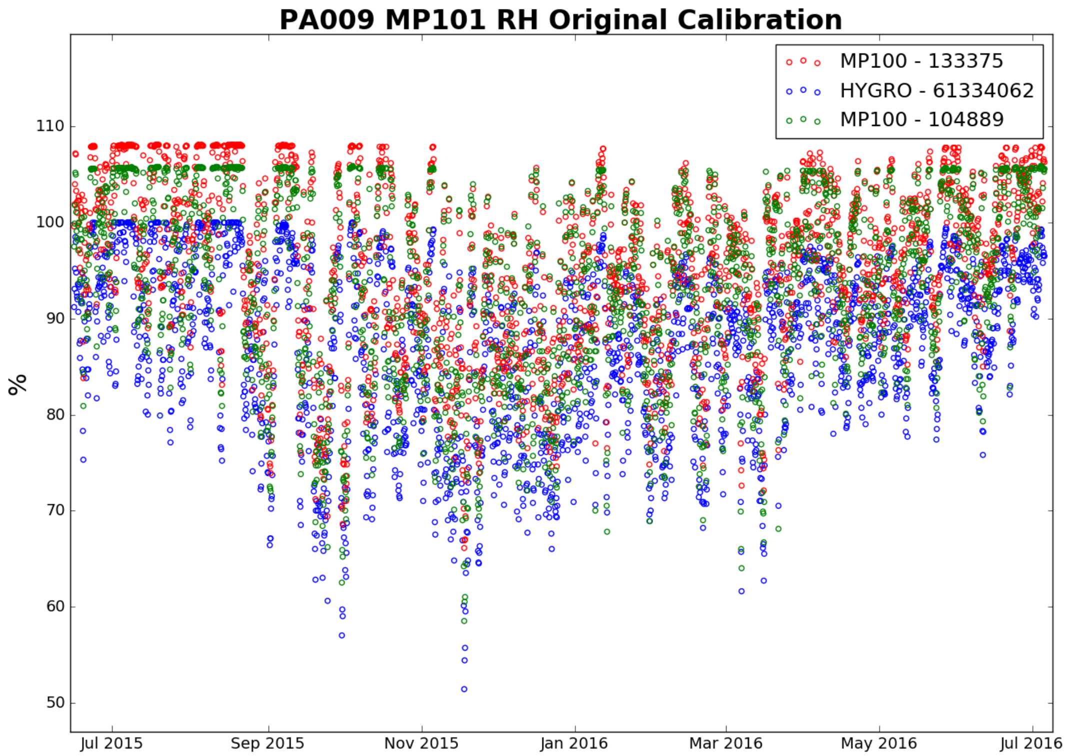


Figure 6: PA009 Relative Humidity with linear calibrations applied to all instruments.

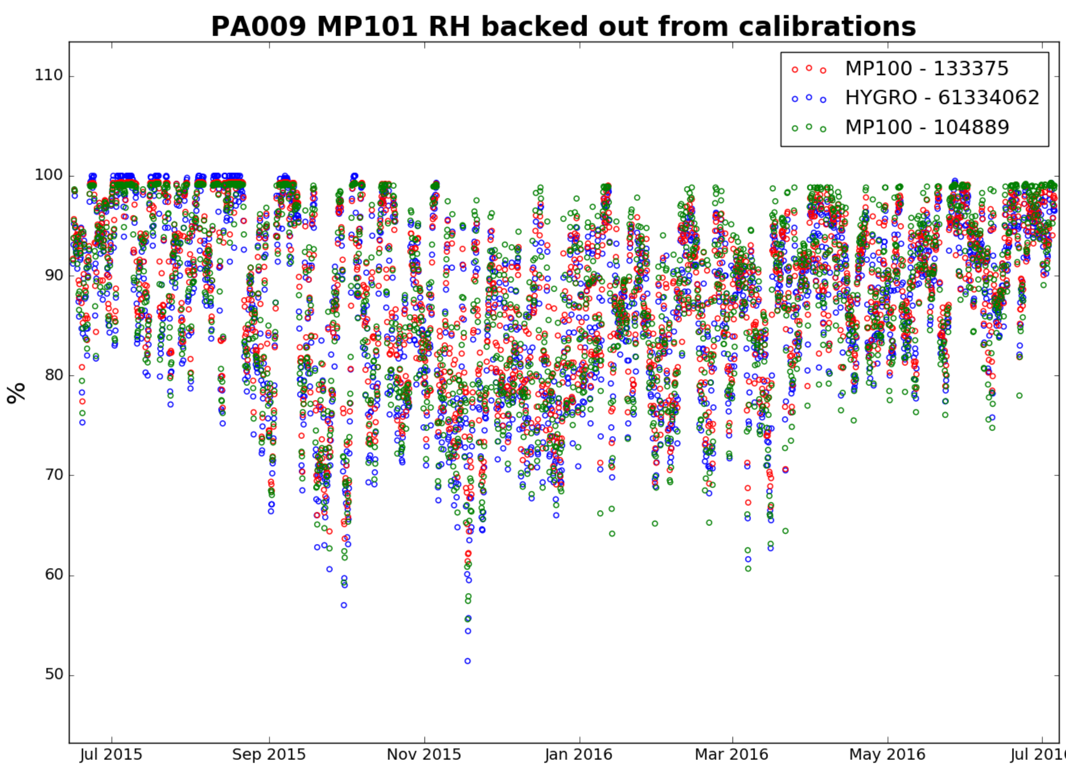


Figure 7: PA009 Relative Humidity with linear calibrations backed out on the MP101 sensors.

3.2.4 Barometric Pressure

There are no special processing notes for barometric pressure at PA009. Refer to section 3.0 for general remarks.

All else equal, Flex sensors are considered primary. Barometric pressure tracked well, so the Flex BP was distributed as primary.

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 Flex rain gauge on PA009 functioned through the entire deployment, but contained noisy sections of data. Due to the failure of the TFlex rain gauge, the Flex data was necessarily primary. Noise in the Flex rain gauge occurred at the 1 minute intervals surrounding each 10-minute interval (00:09:32, 00:10:32, …). The spikes had varying amplitude, and were removed with a filtering function during data processing. The underlying cause is unknown, but engineering input suggested that another instrument turning on during the rain gauge sample could have caused the spikes. Iridium logs were reviewed during the time of the worst and least noise, but no effect from the dial-in pattern was identified.

The TFlex rain gauge on PA009 failed December 22, 2015. After siphoning during a rain event, volumes became flat near 0mL. The top funnel was found to have broken off.

Figure 8: TFlex rain gauge with broken top funnel (right).

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

A single 1-minute spike in the Flex SWR data was flagged Q5 (removed) on November 29, 2015. The value was outside of seasonal ranges, and did not fit the surrounding data.

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 1.97%. 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 PA009 TFlex SWR, which also had the higher data return, was 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 on the same time base. Although LWR is less sensitive to orientation, a bent mast could impact the data. Based on these criteria, the PA009 TFlex LWR, which also had the higher data return, 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 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.

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-	7090	19:18:05	19:18:20	0:00:15	PA09_SBE37	6.78		
1	SBE37-	11555	19:24:45	19:24:44	-0:00:01	PA09_SBE37	13.48		
2	SAMI pH	59							
3	SBE16+	6618							
4	O2	487							
5	SBE43	430333							
6	ECO	2341							
7	GTD	22018RD1							
8	Sentinel	14605	19:30:00	19:27:01	-0:02:59				
9	SBE39-	4862	18:31:00	18:32:10	0:01:10	PA009_SBE3	7.0		
10	SBE37-	12517	19:01:35	19:01:20	-0:00:15	PA009_SBE3	14.07		
11	SBE37-	13248	19:05:15	19:04:52	-0:00:23	PA009_SBE3	13.97		
12	Aquadopp	6809							
13	SBE37-	12550	19:07:10	19:07:19	0:00:09	PA009_SBE3	13.94		
14	SBE37-	8419	18:14:20	18:14:31	0:00:11	PA009_SBE3	6.57		
15	SBE37-	8420	18:59:15	18:59:45	0:00:30	PA009_SBE3	6.55		
16	Aquadopp	6810							
17	SBE37-	6140	20:24:20	20:24:49	0:00:29	PA009_SBE3		NO IM COMMS- BAD	
18	SBE37-	8422	18:56:35	18:56:48	0:00:13	PA009_SBE3		NOT LOGGING- LOW	
19	SBE37-	8423	18:55:15	18:55:32	0:00:17	PA009_SBE3			
20	SBE37-	8424	18:53:25	18:53:58	0:00:33	PA009_SBE3	6.66		
21	SBE37-	6072	18:26:00	18:26:14	0:00:14	PA009_SBE3	6.68		
22	SBE37-	6073	18:27:45	18:27:57	0:00:12	PA009_SBE3	6.60		
23	SBE37-	6074	18:51:50	18:51:57	0:00:07	PA009_SBE3	6.57		
24	SBE39-	4863	18:34:25	18:35:07	0:00:42	PA009_SBE3	6.7	NOT LOGGING- LOW	
25	SBE37-	7788	18:49:15	18:49:52	0:00:37		6.61		
26	SBE39-	4864	18:21:30	18:22:37	0:01:07	PA009_SBE3	DEAD	NO IM COMMS	
27	SBE37-	10503	19:33:00	19:33:04	0:00:04	PA009_SBE3	6.93		
28									
29									
30									
31									
32									
33									
34									
35									

Figure 9: Filemaker log displaying all instrument clock errors.

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.

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.

During salinity processing, automated scripts detected out-of-range pre-to-post calibration salinity drift in the instrument at 10m (SN 12517). Calibration files revealed that the 10m sensor had been modified and recalibrated by Seabird. A note in the post-calibration paperwork said "Calibration after modification," meaning the instrument was not calibrated in the state it had been recovered. The post-calibration was discarded, bringing the data into alignment with the other instruments, and eliminating density inversions.

Salinity Drifts in PSU (post-pre):

Depth:	**Drift:**
1m (TFlex)	0.0020
1m (Flex)	-0.0129
10m	0.1531 **
14m	0.0135
20m	-0.0004
25m	-0.0073
30m	-0.0049
37m	-0.0330 *
45m	-0.0031
60m	-0.0045
80m	-0.0046
100m	-0.0018
120m	-0.0018
150m	-0.0010
200m	0.0018

* 37m C/S/D flagged Q5 (density inversions, noise)
** Post-cal was discarded.

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:

14m

2015-06-14 15:45:52 to 2016-07-07 09:10:35 adjusted 0.0080 to -0.0115

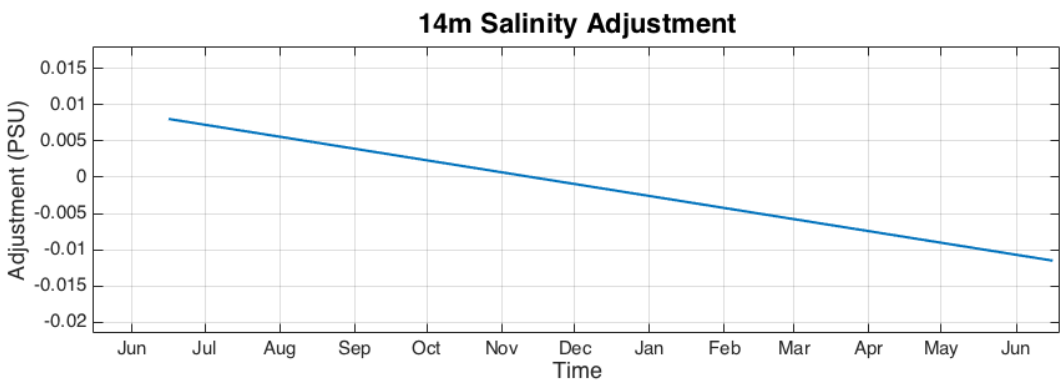


Figure 10: 14m Salinity Adjustments on PA009.

20m

2015-08-07 13:52:56 to 2016-02-27 00:14:07 adjusted 0.0040 to -0.0222
2016-02-27 00:14:07 to 2016-04-25 08:14:07 adjusted -0.0222 to -0.0426
2016-04-25 08:14:07 to 2016-07-05 10:07:03 adjusted -0.0426 to -0.0369

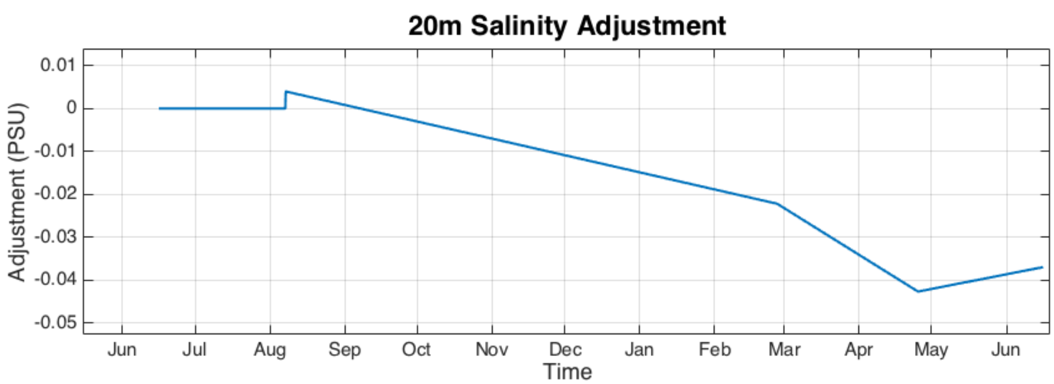
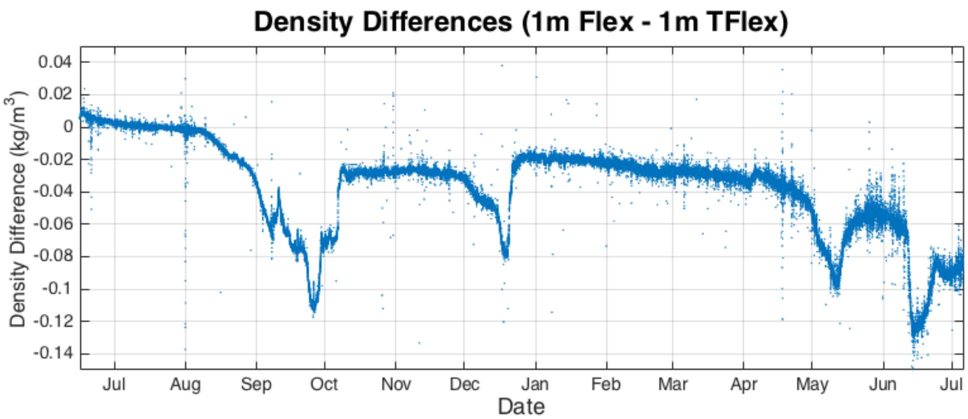


Figure 11: 20m Salinity Adjustments on PA009.

Nonlinear conductivity drift in the TFlex bridle instrument (SN 11555) produced unrealistic values of salinity and density. Two comparison plots are shown below, with density inversions when the TFlex SSTC is compared to either the Flex SSTC or 14m instrument. The TFlex instrument created density inversions when compared to every other instrument in the mixed layer, so the Flex instrument was considered primary.



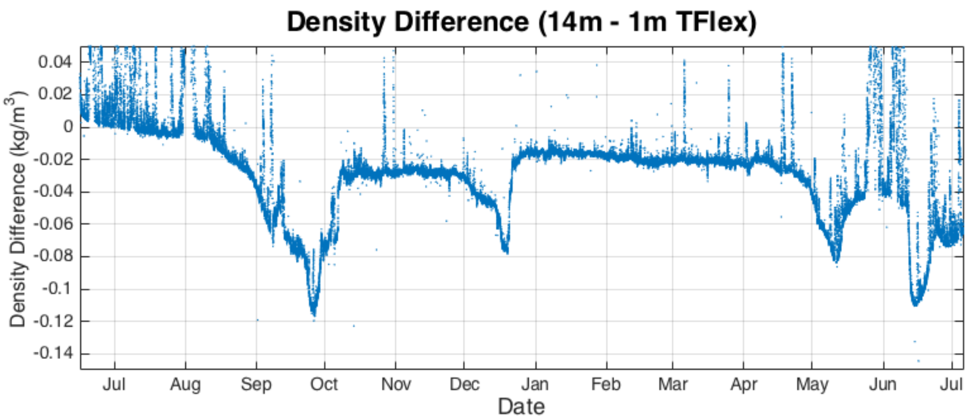


Figure 12: Pre-adjustment density differences showing nonlinear drift in the TFlex bridle SSTC. Note that the TFlex SSTC density issue overwhelms the adjustments on the order of 0.01kg/m^3 needed at 14m (virtually undetectable here).

The TFlex SSTC presented a borderline case between adjustments and flagging. Rather than applying numerous small-scale adjustments to align the TFlex SSTC with the Flex SSTC, the TFlex time-series was flagged Q4 (low quality), and should be used with caution.

Several CTD casts were performed in the region from deployment to recovery of PA009. 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 at the time of this report (2018).

At Papa, deep ocean measurements presented challenges, including calibration variability and small discontinuities between deployments. Calibration variability is the difference between data with pre-deployment calibrations applied and data with post-recovery calibrations applied. While calibration variability can indicate linear drift, interpolating between calibrations can also result in a false slope when the signal is small. Calibration variability was reduced by averaging conductivity and temperature calibrations. Many years of data were examined for continuity, to reduce the possibility of covering up real drift.

To address deployment-to-deployment discontinuities, adjacent deployments were examined. An offset of +0.0015 mS, or about half the instrument accuracy, was applied to the conductivity time-series to align PA009 data with surrounding deployments.

Temperature and pressure, along with calibration-averaged, adjusted 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 PA009 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 PA009 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 PA009 had a magnetic declination of +17 degrees applied. The delayed-mode data that later replaced the real-time data at 35m were reprocessed with a magnetic declination of +16 degrees instead, to reflect Earth's changing magnetic field, which had not been realized when the calibration files were made.

Real-time data was returned off the 15m Aquadopp until October 11, 2015, but the instrument flooded prior to recovery, so no delayed-mode data were available.

The 35m instrument had 100% delayed-mode data recovered, but slid down about 1.5m, and was found resting on the 37m instrument when the mooring was recovered. The movement was not detected in the current data, but evidence from the undistributed pressure data suggests a slide occurred September 20, 2015. Data after this point are flagged as lower quality. A segment of pressure data suggests the instrument was dragged up to 30m between Dec 18 and Dec 22, before finally resting closer to 37m. Some uncertainty exists as to when the instrument first came loose from its wire position, since mooring motions (or fishing activity) can also alter the vertical position of the instrument. The data were released without any alterations, aside from the magnetic declination correction of +16 degrees.

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 PA009. 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.

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. Single ping data may be collected in the future, to avoid 120-second averaging (during which there may be significant buoy motion) and to determine how individual pulses are affected by interference.

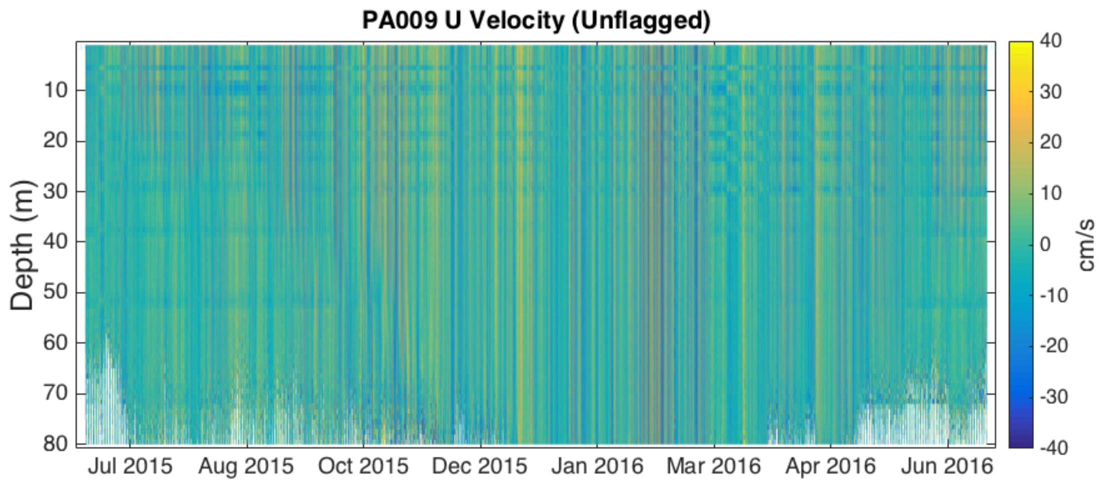


Figure 13: ADCP eastward velocities with autonomous flagging thresholds applied by the ADCP, but before manual flagging. All beams are affected by instruments on the line, as the beams sweep across the vertical in most of the 2-minute averages taken every 30 minutes.

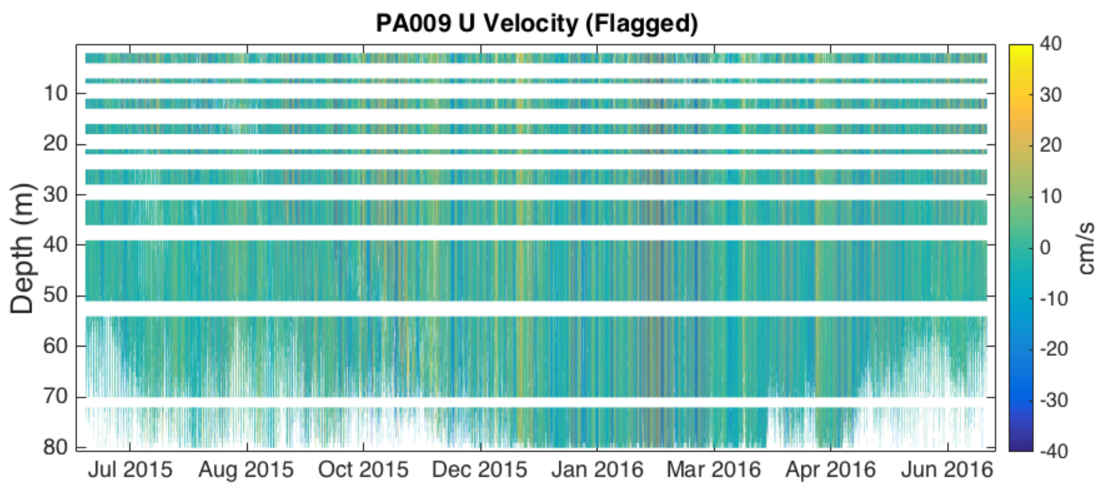


Figure 14: ADCP eastward velocities with manual flagging thresholds and bin-flagging applied, in addition to the autonomous flagging thresholds applied by the ADCP.

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.

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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. The scientists, captain and crews of the CCGS JOHN P. TULLY and RON BROWN are acknowledged for their efforts and operational assistance, which made the deployment and recovery of PA009 possible.

6.0 Contact Information

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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 format, the standard TAO 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

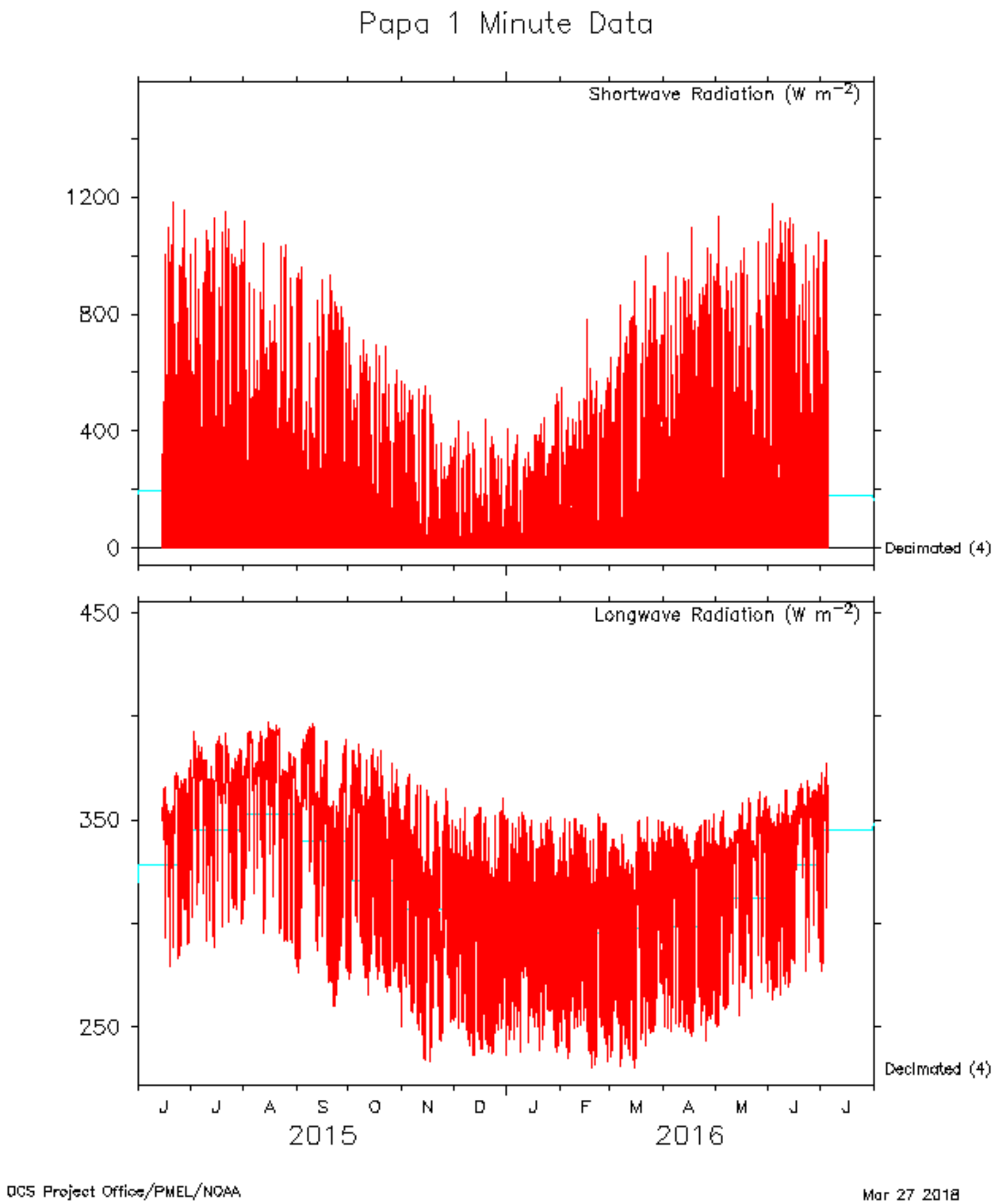

Figure B 1: PA009 primary shortwave and longwave radiation data at 1-min resolution (TFlex).

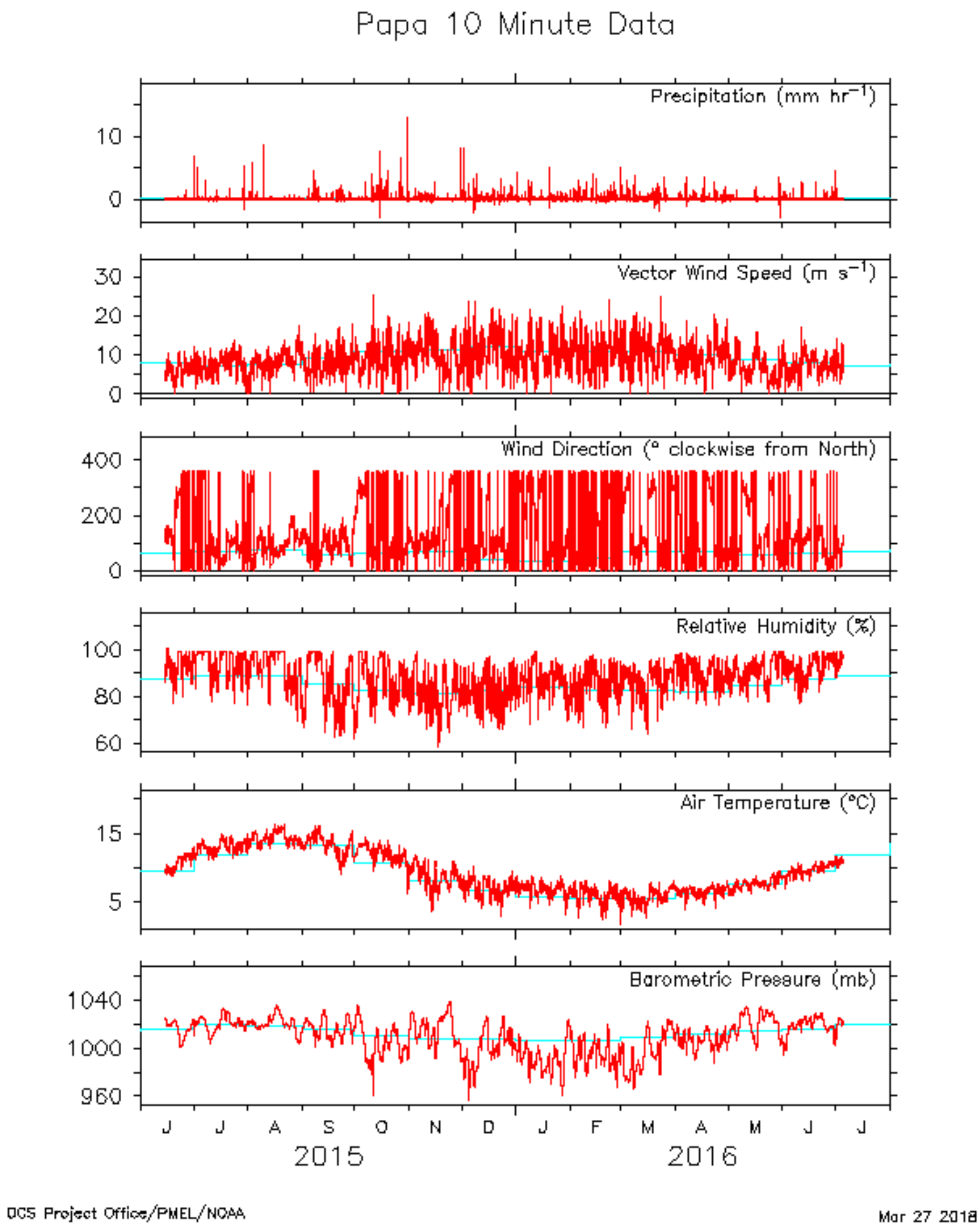

Figure B 2: PA009 meteorological data at 10-min resolution. All data are from the Flex system.

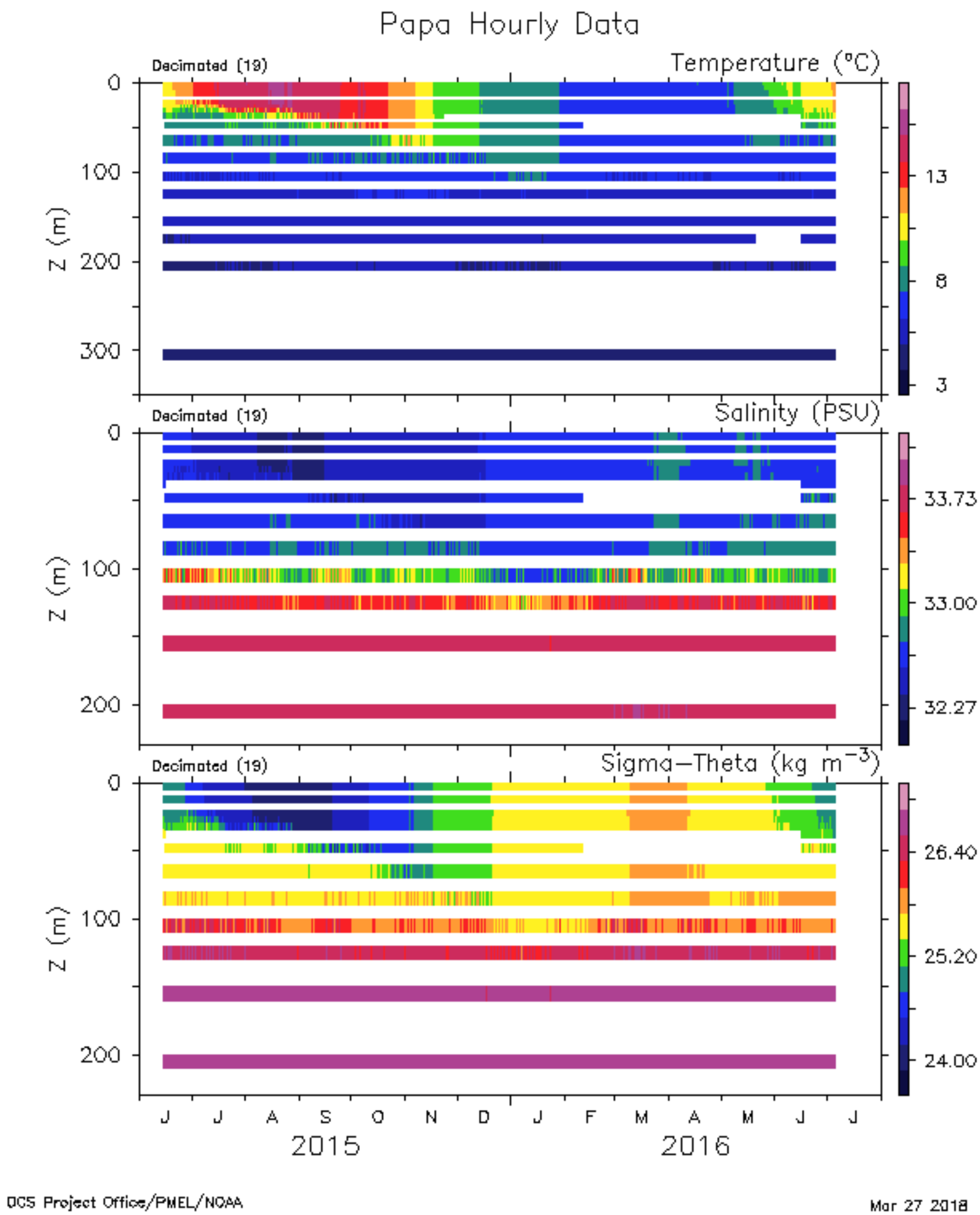

Figure B 3: PA009 subsurface temperature, salinity, and density at hourly resolution (decimated).

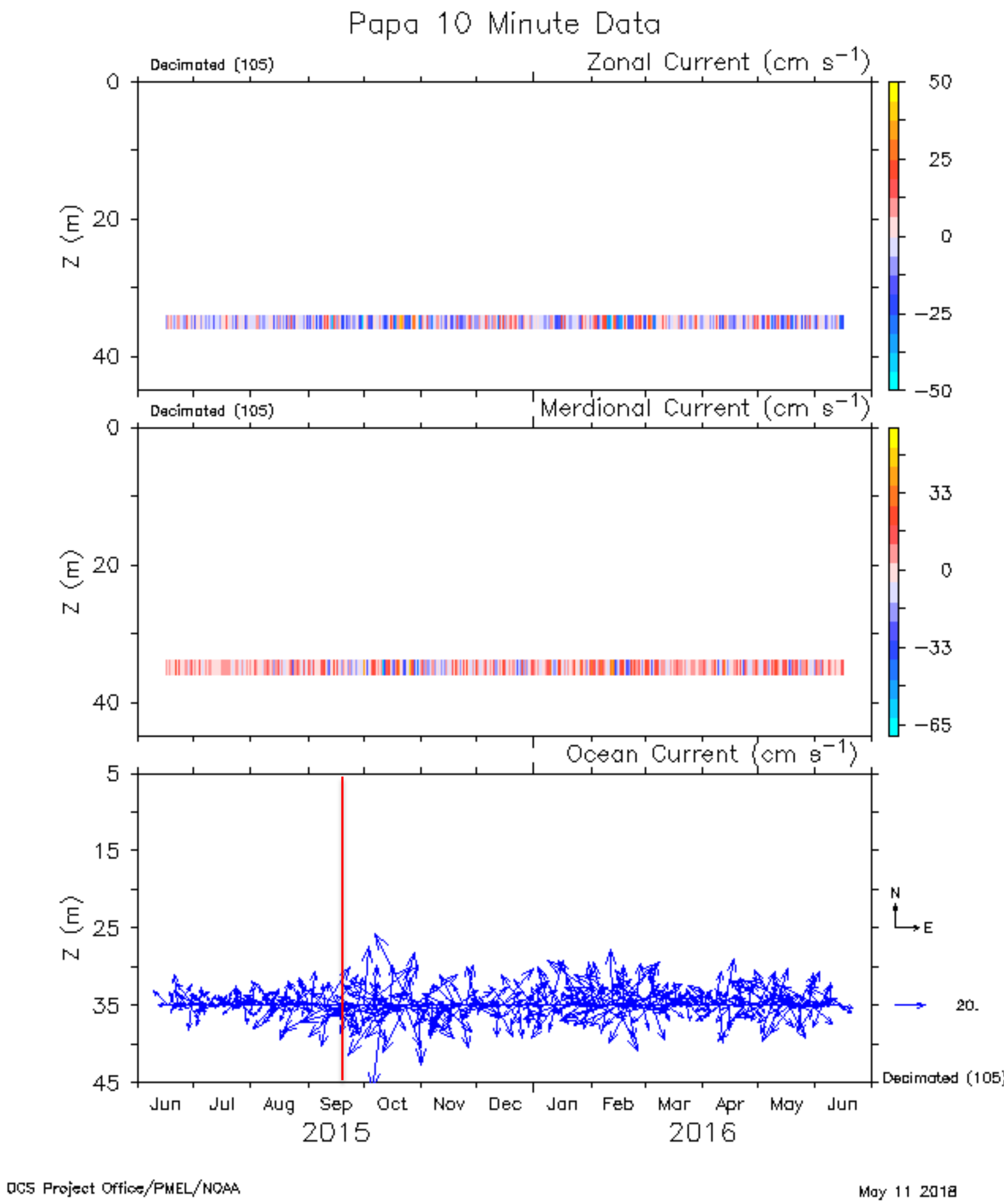

FIgure B 4: Zonal and meridional current meter data from PA009. Hourly realtime data are available through October 11, 2015, the best data available from the flooded 15m instrument. The 35m instrument was recovered at 37m, and data were flagged lower quality after September 20, 2015 (red line), when pressure records suggest the instrument dislodged from its nominal depth.

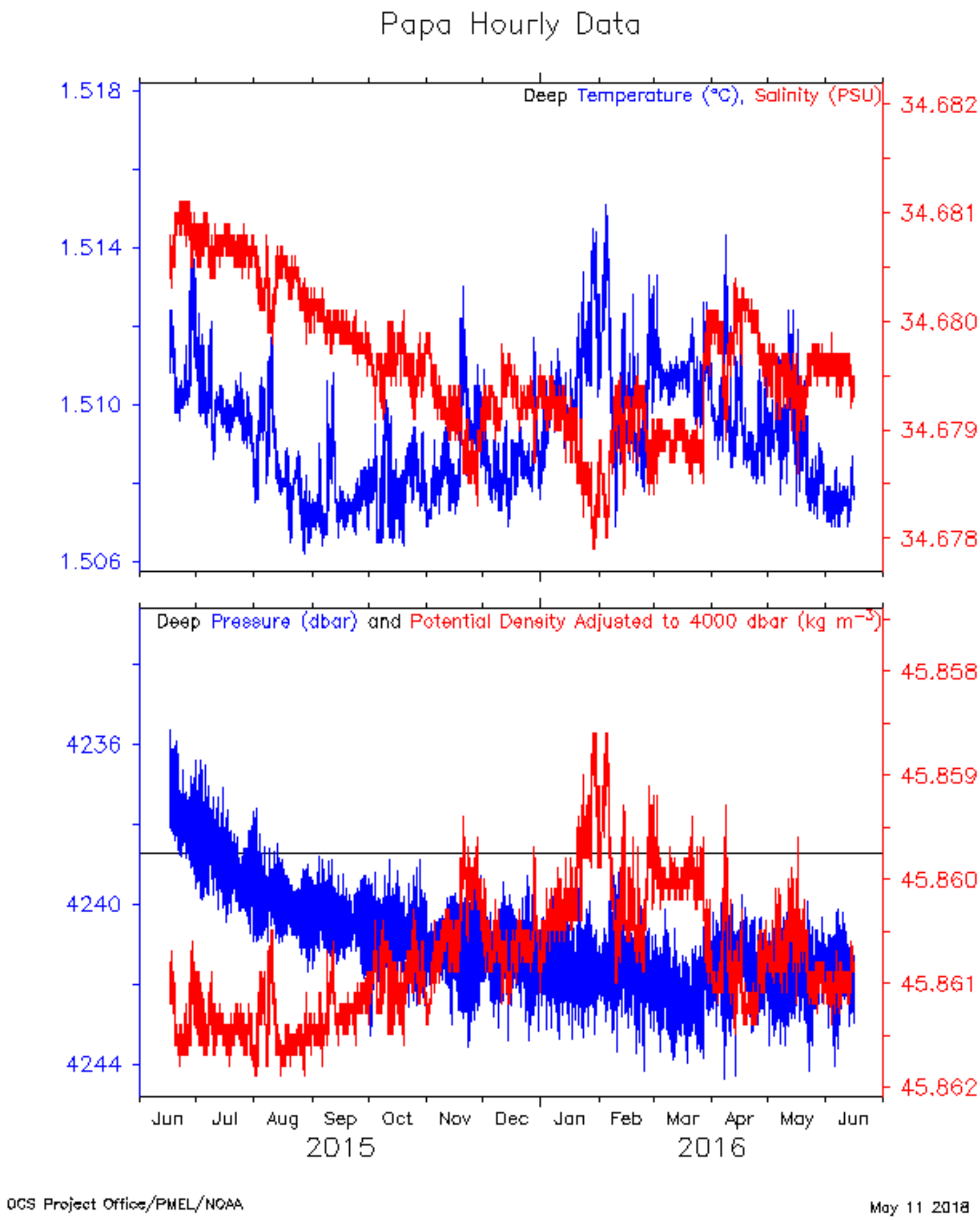

FIgure B 5: Deep Seabird instrument temperature, pressure, salinity, and potential density.

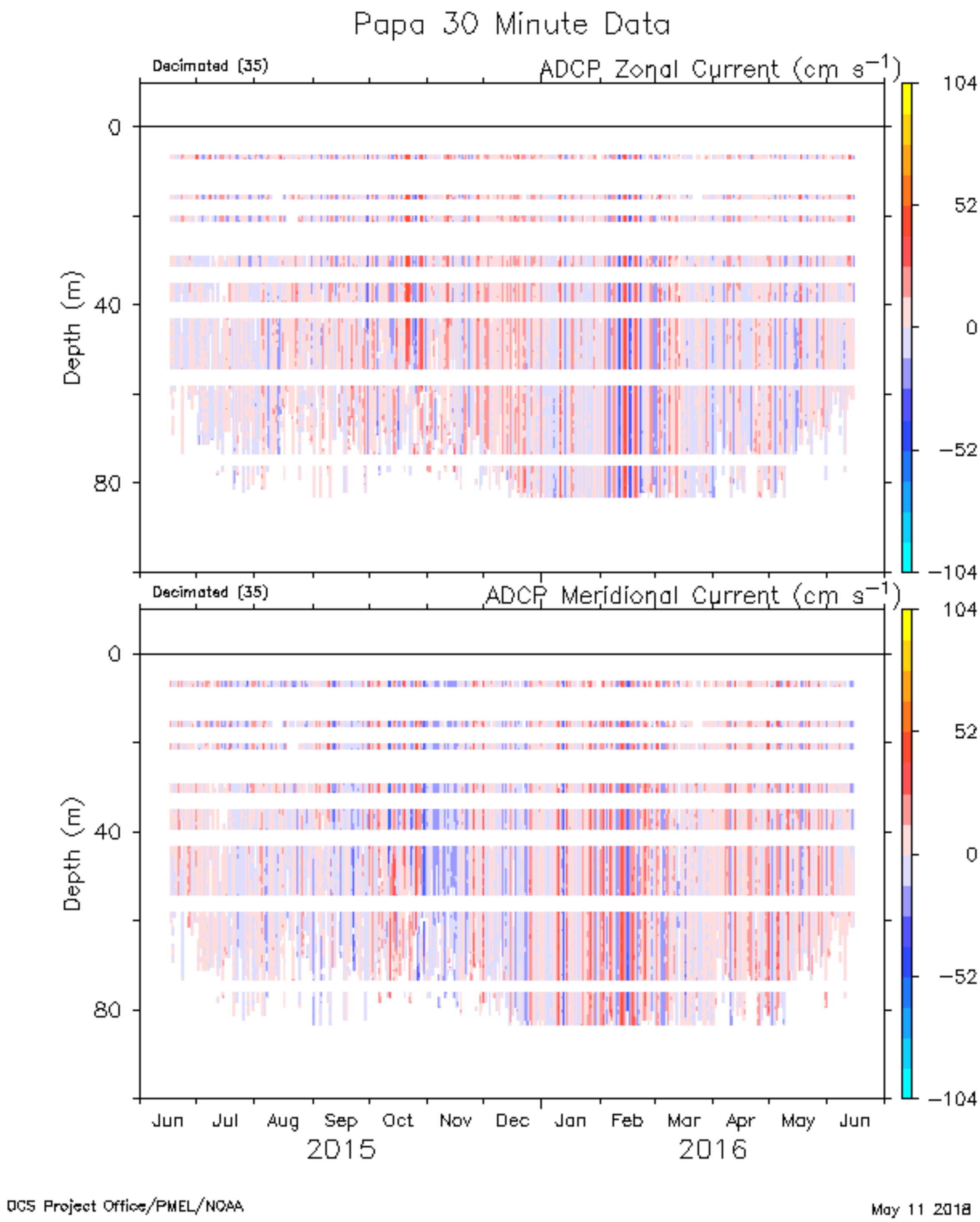

FIgure B 6: Sentinel ADCP data, with striations due to bins influenced by hard-returns off of subsurface instruments.

APPENDIX C: Secondary Instrument High Resolution Data Plots

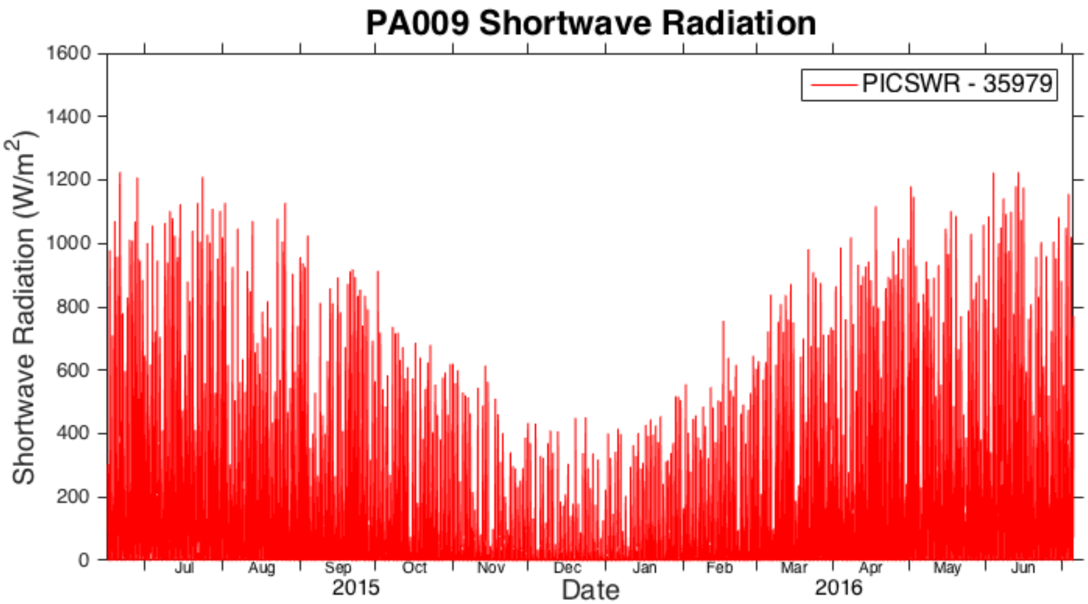

Figure C 1: Secondary (Flex Eppley PSP) shortwave radiation sensor.

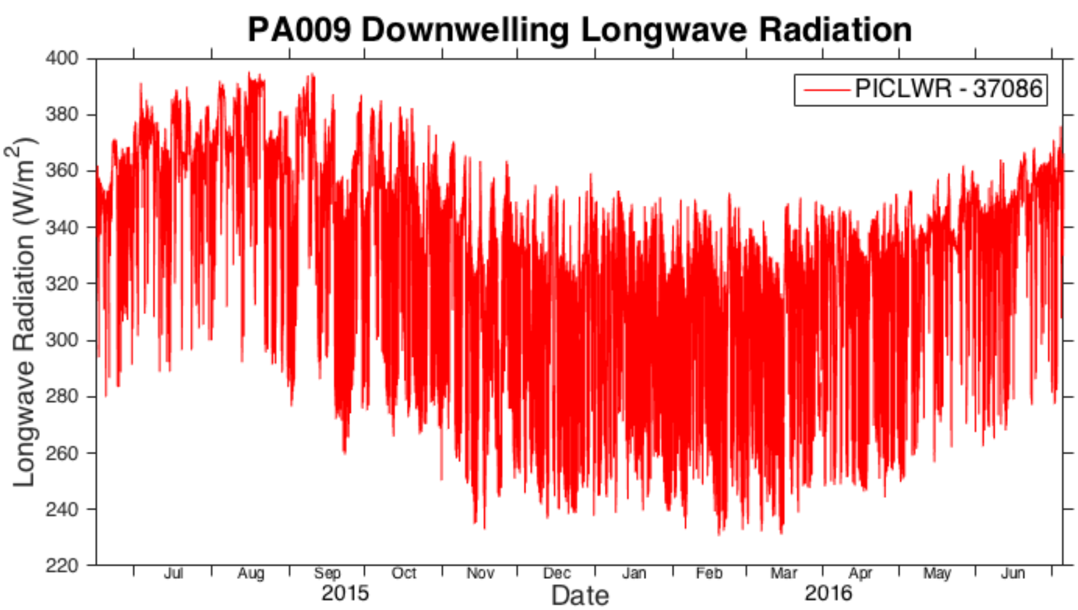

Figure C 2: Secondary (Flex Eppley PIR) longwave radiation sensor.

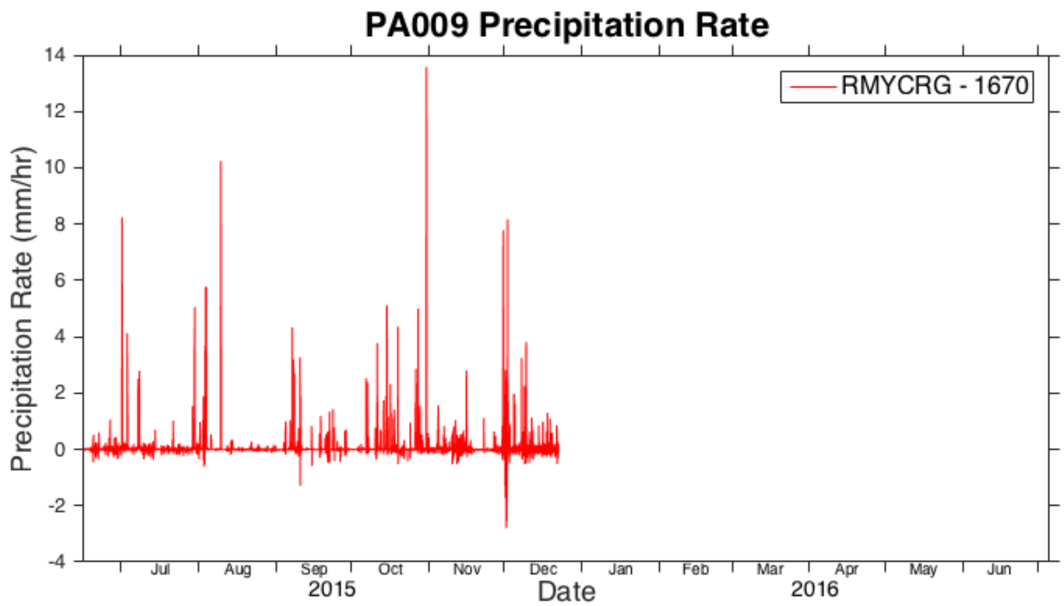

Figure C 3: Secondary (TFlex RM Young) rain sensor, which failed December 22, 2015. Accumulations were near or below 0mL thereafter, and the top funnel was missing upon recovery.

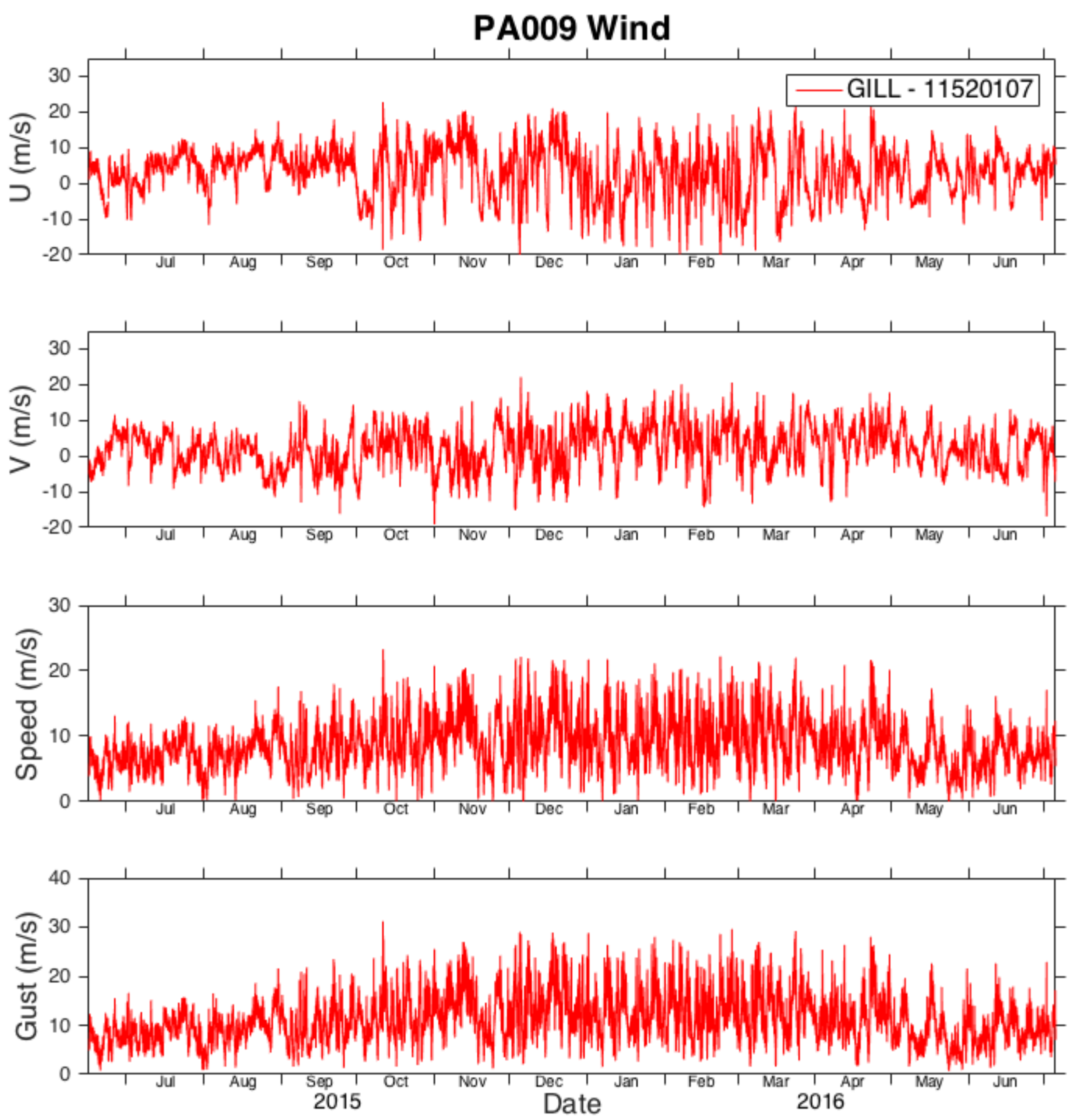

Figure C 4: Secondary (TFlex Gill) wind sensor.

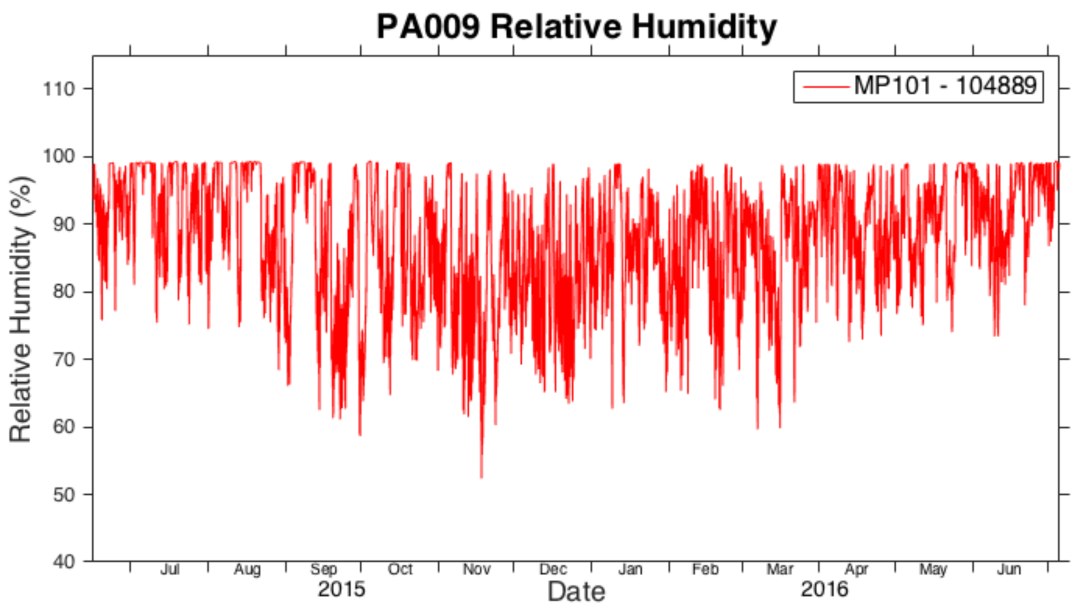

Figure C 5: Secondary (TFlex MP101) relative humidity sensor.

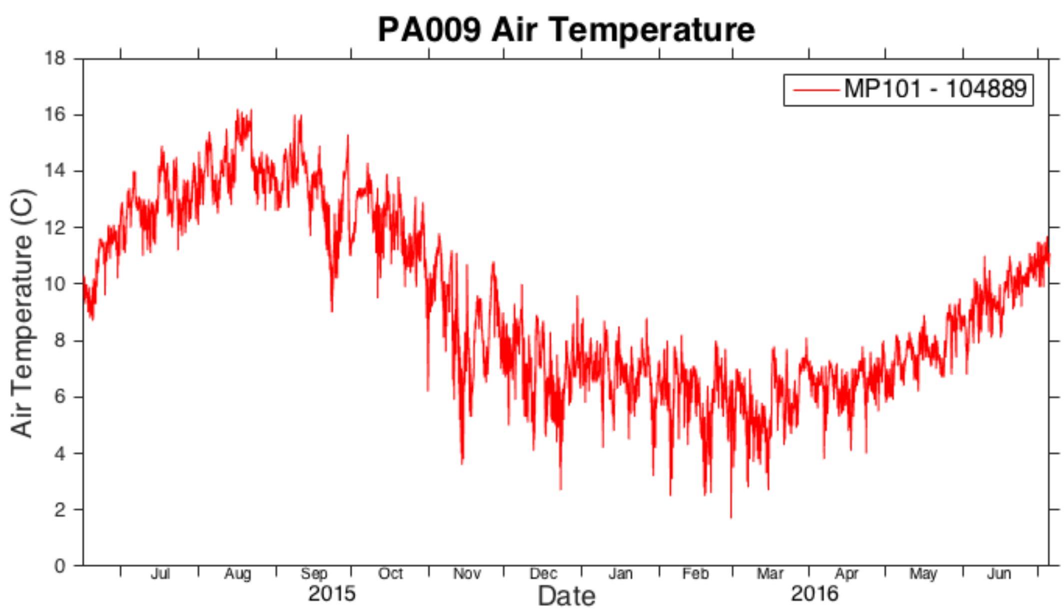

Figure C 6: Secondary (TFlex MP101) air temperature sensor.

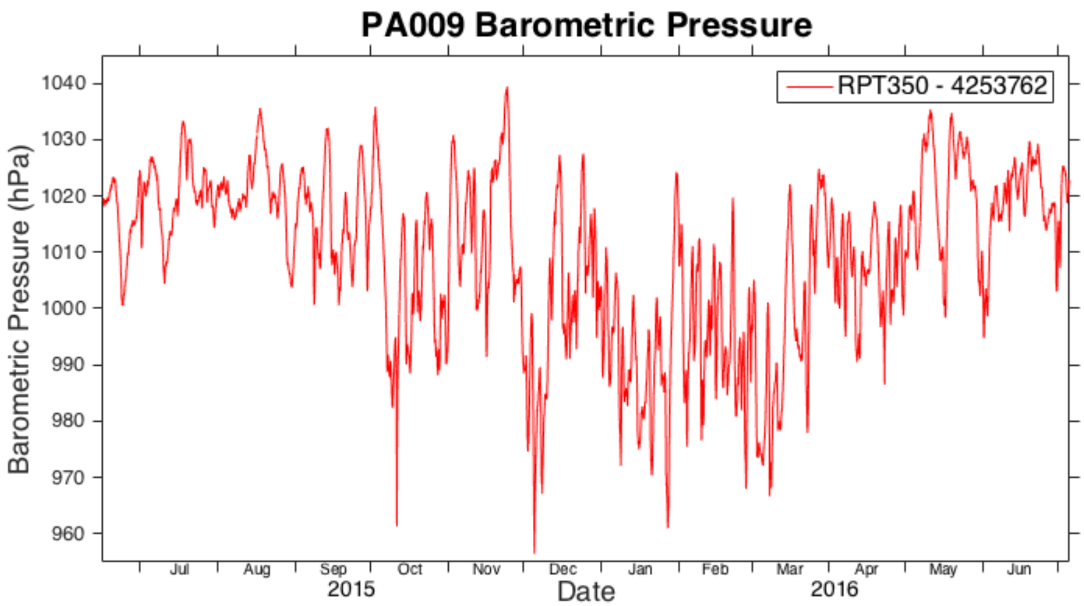

Figure C 7: Secondary (TFlex RPT350) barometric pressure sensor.

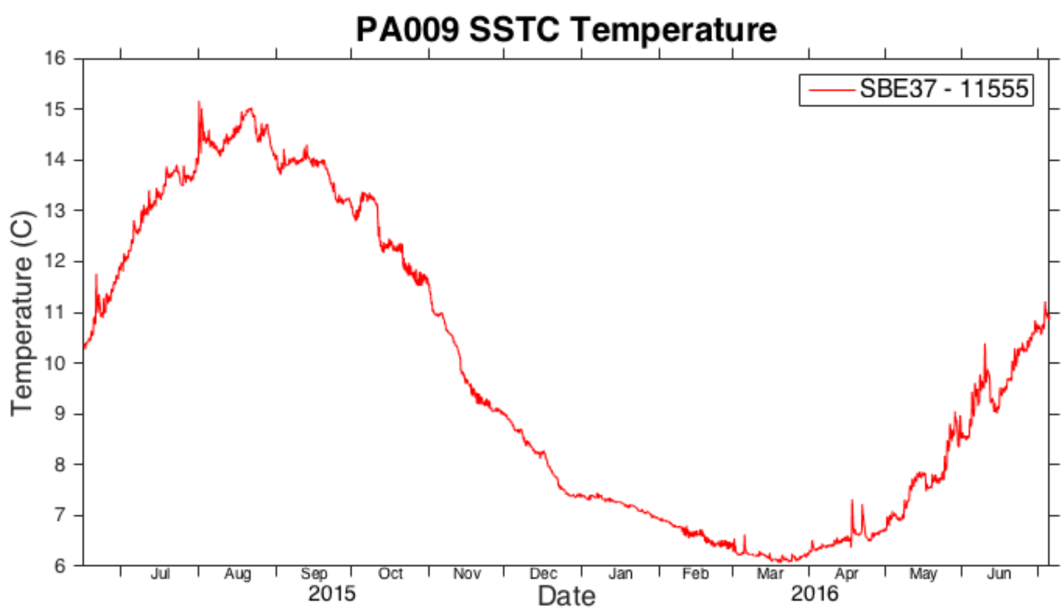

Figure C 8: Secondary (TFlex) SSTC Temperature.

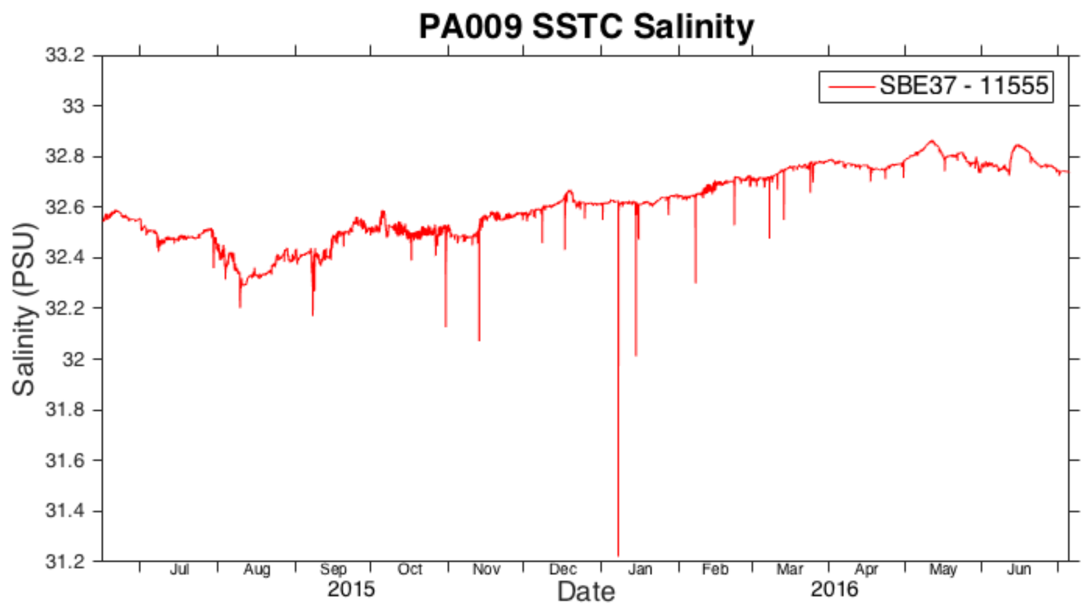

Figure C 9: Secondary (TFlex) SSTC Salinity.

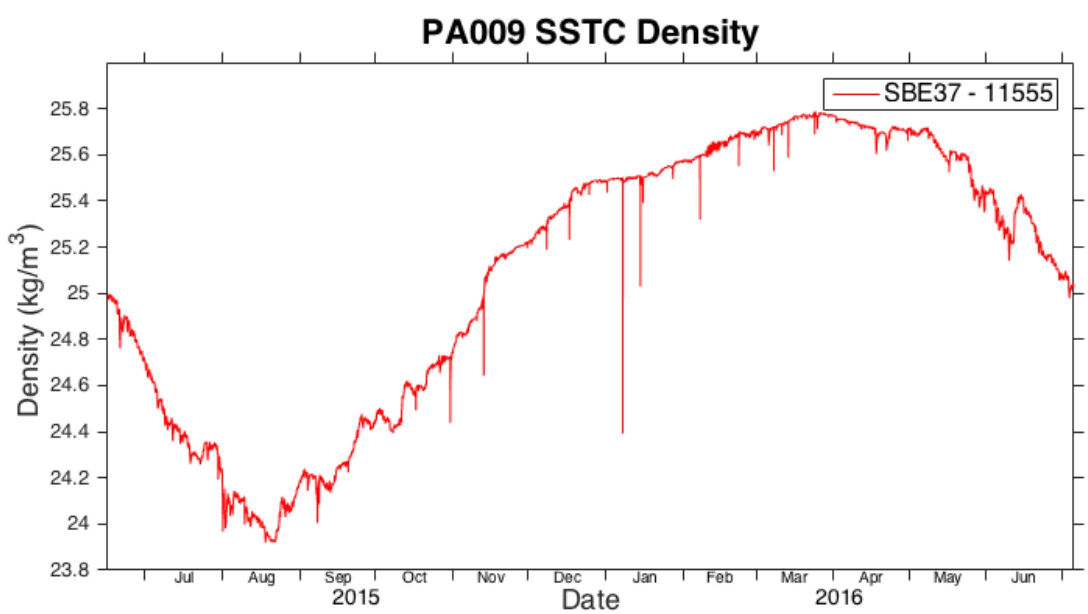

Figure C 10: Secondary (TFlex) SSTC Density.