NOAA Pacific Marine Environmental Laboratory

Ocean Climate Stations Project

DATA ACQUISITION AND PROCESSING REPORT FOR PA008

Site Name:	Ocean Station Papa
Deployment Number:	**PA008**
Year Established:	2007
Nominal Location:	50.1°N 144.9°W
Anchor Position:	50.05°N 144.88°W
Deployment Date:	June 18, 2014
Recovery Date:	June 16, 2015
Project P.I.:	Dr. Meghan Cronin
Report Authors:	N.D. Anderson, J.A. Keene, and M.F. Cronin
Data Processors:	N.D. Anderson
Date of Report:	August 8, 2018
Revision History:	
Special Notes:	

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Data Acquisition and Processing Report for OCS Mooring PA008

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 support from the National Science Foundation (NSF) and 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. PA008 was the eighth deployment at this site.

The PA008 buoy was deployed on June 18th, 2014 by the CCGS JOHN P. TULLY, and was recovered by the same ship on June 16th, 2015. The captains and crews are gratefully acknowledged.

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.

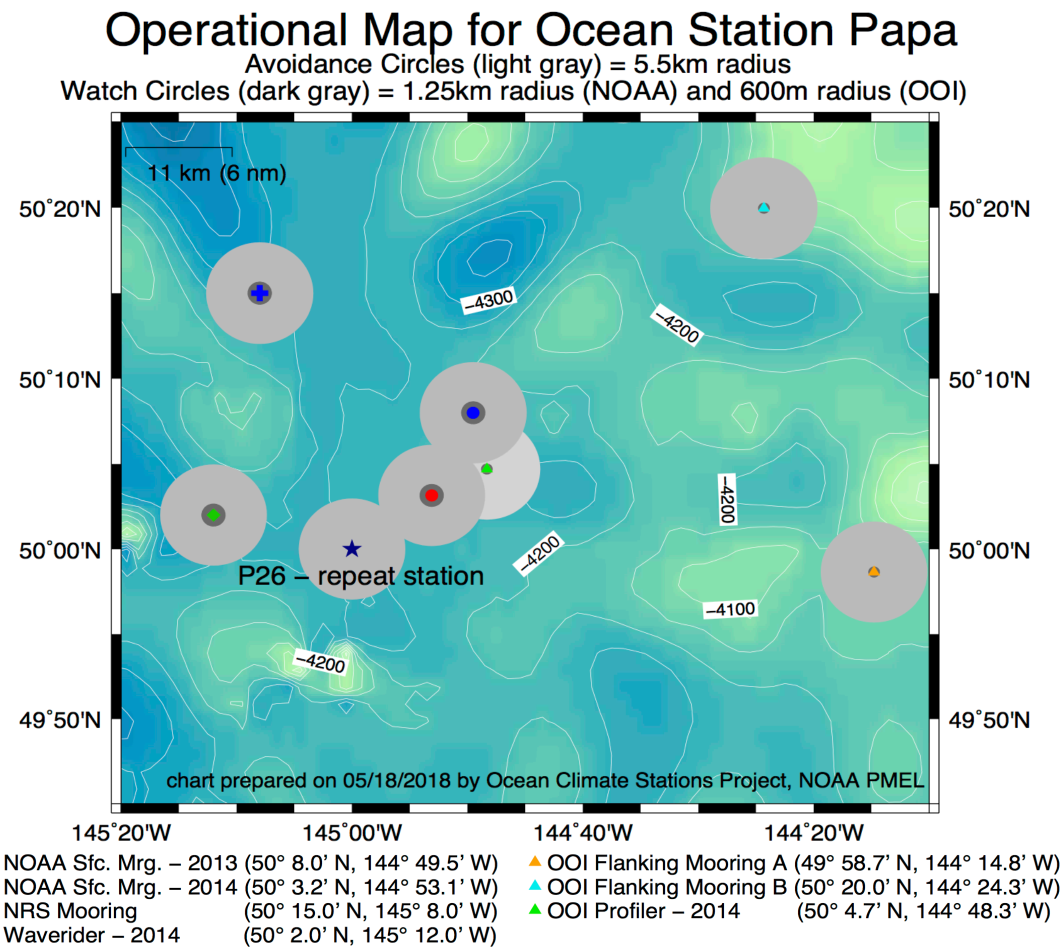

Figure 1: Operational map of OCS Station Papa. The red circle is PA008.

1.1 Mooring Description

The PA008 mooring was a taut-line mooring, with a nominal scope of 0.985. 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 of the mooring consisted of plaited 8-strand nylon line, to the acoustic release in line above the anchor. 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 CTD, gas tension device, and oxygen optode, all mounted on the bridle. A CO_2 flux monitoring system was also deployed on the PA008 mooring, in collaboration with the PMEL Carbon Group, whose instrumentation also 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.

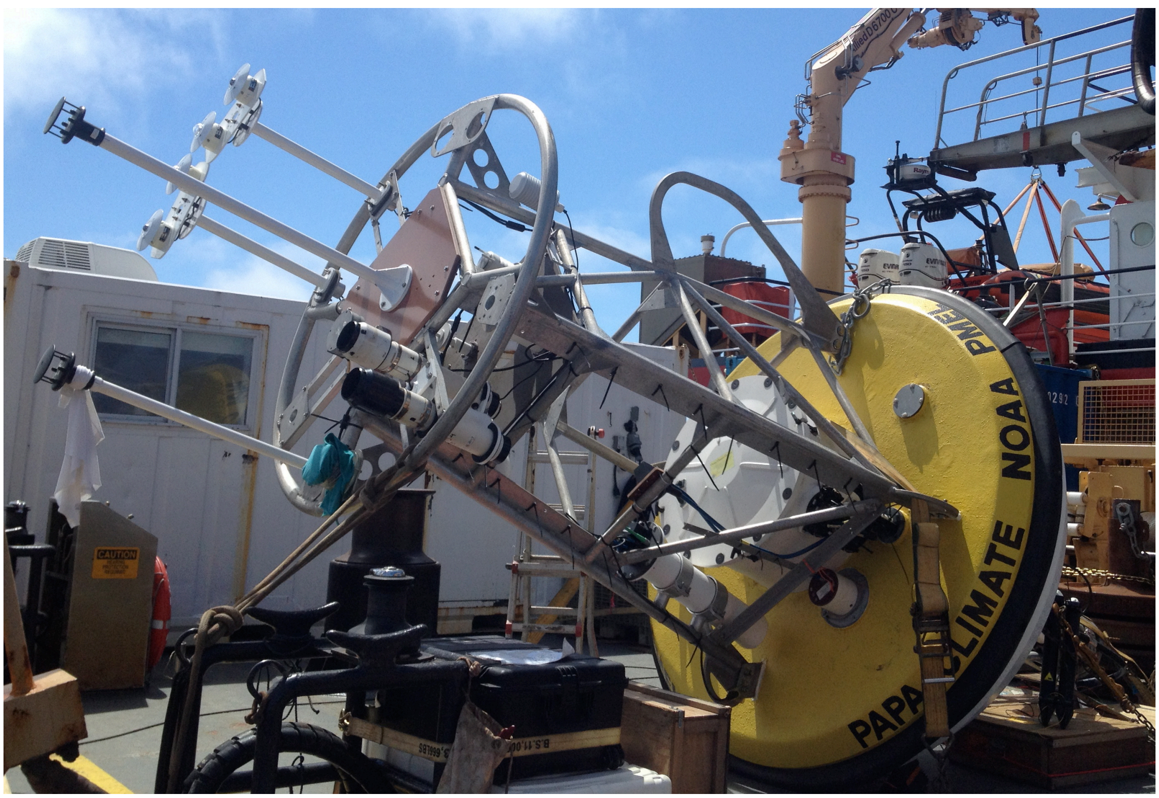

Figure 2: PA008 pre-deployment photo.

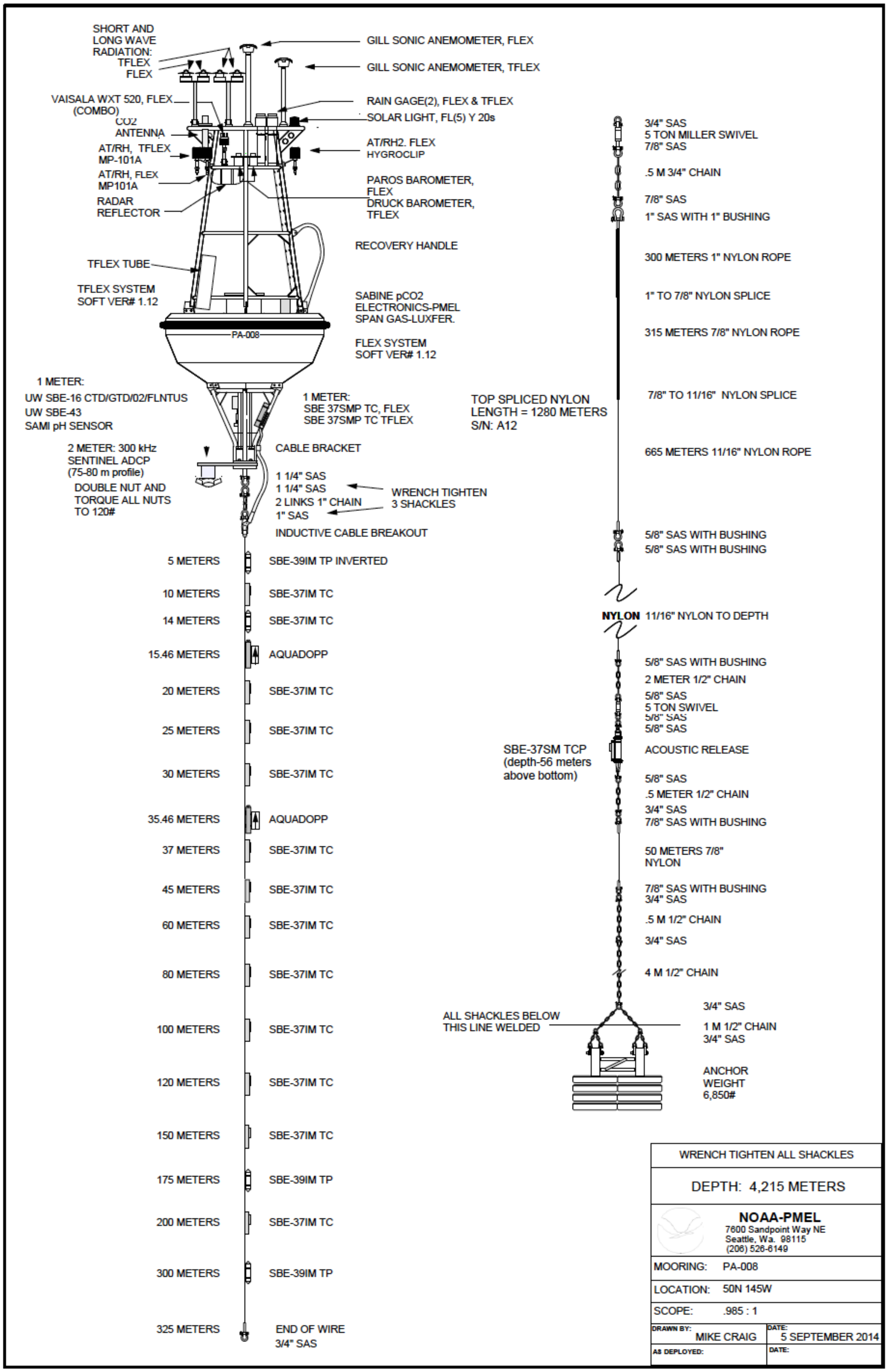

Figure 3: PA008 mooring diagram.

1.2 Instrumentation on PA008

The following instrumentation was deployed on PA008. 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:		**PAPA June 2014**			
		PA008 50°N, 145°W	As Deployed 6/18/2014		
Met Sensors		**Model**	**Serial #**		**Notes**
Height	Acquisition	**FLEX**	0005	FP3/1	
2.6m	ATRH	Rotronics MP-101A	118814		
2.6m	ATRH2	Rotronics HygroClip	61222482		
4.2m	Wind	Gill	070229		
2.5m	BP	Paros	81191		
2.5m	BP2	Vaisala WXT520	D3840028		
3.1m	Rain	RM Young	1545-4		
3.6m	SWR	Eppley PSP	35775		
3.6m	LWR	Eppley PIR	37083		
	Acquisition	**TFLEX**	2001		
2.6m	ATRH	Rotronics MP-101A	112220		
3.8m	Wind	Gill	044001		
2.4m	BP	Druck	1749053		
3.1m	Rain	RM Young	699		
3.6m	SWR	Eppley PSP	32284		
3.6m	LWR	Eppley PIR	35849		
CO2	Electronics	PMEL	0024		
	Span Gas	Luxfer	JB03404		
Subsurface Instrumentation					
Bridle		**Model**	**Serial #**		**Notes**
1m	SST/C	SBE37SMP - TC	7089		Flex
1m	SST/C	SBE37SMP - TC	11553		TFLEX (AA batteries)
1m	pH	SAMI	P003		Supplied by CO2
1m	SST/C	SBE16v2	6363		Supplied by UW
1m	Oxygen	Optode	488		Supplied by UW
1m	Oxygen	SBE43	430630		Supplied by UW
1m	Fluorescence	ECO FLNTUS	2646		Supplied by CO2
1m	Gas Tension	GTD	121901		Supplied by UW
2m	ADCP	Workhorse Sentinel	14607		
Depth		**Model**	**Serial #**	**ID**	**Notes**
5m	TP	SBE39IM - TP	4380	01	Inverted (Use TP for titanium housing)
10m	TC	SBE37IM - TC	6075	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	9819	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	4860	16	
200m	TC	SBE37IM - TC	7792	17	
300m	TP	SBE39IM - TP	4858	18	
325m	End of Wire				
Release	TCP	SBE37SM - TCP	2608	-	VENTS (v2)

Table 1: Instruments deployed on PA008.

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.

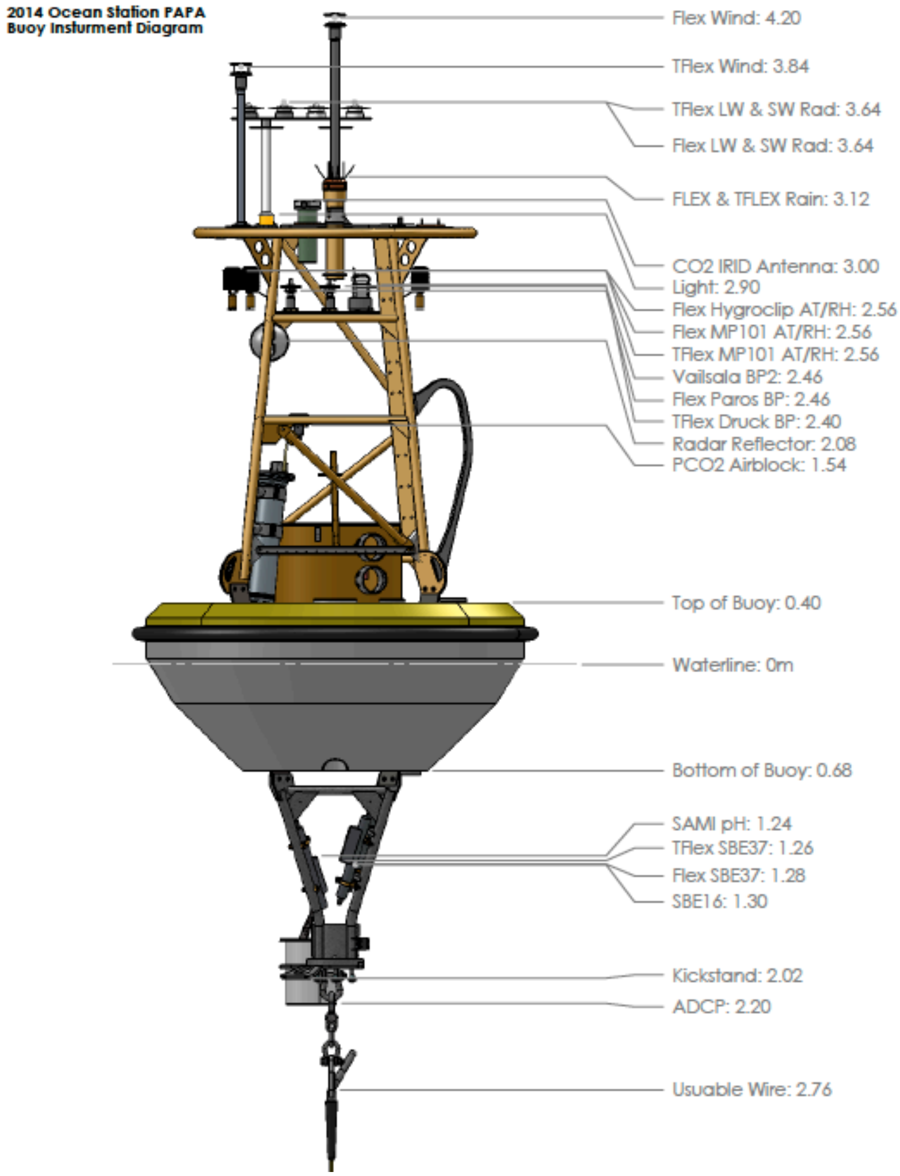

Figure 4: Buoy diagram showing bridle arrangement. The SBE16 package contains a suite of sensors.

2.0 Data Acquisition

Two independent data acquisition systems were deployed on PA008, 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. PA008 was the first Papa mooring to have phased out the ATLAS system and implemented the newer TFlex.

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	TFLEX/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 primary sensors on PA008.

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	FLEX
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 secondary sensors on PA008.

2.2 Data Return

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

Flex 0005:

```
Data Return Summary
2014-06-18 20:16:00 to 2015-06-16 15:15:00

Sensor      Deployed      Obs     Return
======================================
AT1            52242    52227     100.0%
AT2            52242    52227     100.0%
RH1            52242    52227     100.0%
RH2            52242    52227     100.0%
WIND1          52242    52207      99.9%
BP1            52242    52227     100.0%
BP2            52242    51755      99.1%
RAIN1         522429   516736      98.9%
SWR1          522429   516467      98.9%
LWR1          522429   501990      96.1%
```

Subsurface Temperature Profile			
1m	52242	52242	100.0%
5m	52242	52242	100.0%
10m	52242	52242	100.0%
14m	52242	52242	100.0%
15m	52242	52242	100.0%
20m	52242	52242	100.0%
25m	52242	52242	100.0%
30m	52242	52242	100.0%
35m	52242	52242	100.0%
37m	52242	52242	100.0%
45m	52242	40248	77.0%
60m	52242	52242	100.0%
80m	52242	52242	100.0%
100m	52242	52242	100.0%
120m	52242	52242	100.0%
150m	52242	52242	100.0%
175m	52242	52242	100.0%
200m	52242	52242	100.0%
300m	52242	52242	100.0%
4159m	52242	52242	100.0%
Total	1044840	1032846	98.9%

Subsurface Pressure Profile			
5m	52242	52242	100.0%
175m	52242	52242	100.0%
300m	52242	52242	100.0%
4159m	52242	52242	100.0%
Total	208968	208968	100.0%

Subsurface Salinity Profile			
1m	52242	52242	100.0%
10m	52242	52242	100.0%
14m	52242	3766	7.2%
20m	52242	52242	100.0%
25m	52242	52242	100.0%
30m	52242	52242	100.0%
37m	52242	52242	100.0%
45m	52242	12982	24.9%
60m	52242	52242	100.0%
80m	52242	52242	100.0%
100m	52242	52242	100.0%
120m	52242	52242	100.0%
150m	52242	52242	100.0%
200m	52242	52242	100.0%
4159m	52242	52242	100.0%
Total	783630	695894	88.8%

AQD Current Velocity			
15m	52242	52242	100.0%
35m	52242	52242	100.0%
Total	104484	104484	100.0%

TFlex 2001:

Data Return Summary
2014-06-18 20:16:00 to 2015-06-16 15:15:00

Sensor	Deployed	Obs	Return
AT1	52242	52242	100.0%
RH1	52242	46685	89.4%
WIND1	52242	52242	100.0%
BP1	52242	52242	100.0%
RAIN1	522429	518185	99.2%
SWR1	522429	518893	99.3%
LWR1	522429	500219	95.8%
SST1	52242	52242	100.0%
SSC1	52242	52242	100.0%
SSS1	52242	52242	100.0%

2.3 Known Sensor Issues

On July 15, 2014, conductivity values at 14m began diverging from adjacent sensors at 10m and 20m. By the deployment's end, salinity values differed by about 0.3 PSU, with a persistent density inversion of about 0.15 kg/m^3. These salinity data were removed from distribution with Q5 flags applied after July 15, 2014.

The 45m instrument's salinity, density, and conductivity data were flagged Q5 after September 17, 2014, due to values that produced density inversions. These data were not correctable with salinity adjustments due to noise that caused density inversions with both adjacent sensors. Batteries on the 45m instrument died March 27, 2015, ending the temperature and pressure time-series.

The Flex MP101 sensor reported relative humidity data well over 100% at times. Data quality was lowered to Q4 and the instrument was designated secondary. The TFlex relative humidity sensor was designated primary from the start of the deployment until the record ended on May 9, 2015. From this point forward, adjusted Flex data were spliced onto the TFlex data until the end of the deployment, in order to provide a full primary data record. Adjusted data are assigned Q3 flags.

TFlex temperatures were designated primary to match the relative humidity decision. Air temperature records diverged May 7, 2015, and both Flex and TFlex temperatures were assigned lower quality until recovery. The tertiary sensor suggested that the last months of Flex air temperature data might be superior to the TFlex data, so Flex air temperatures were spliced onto the TFlex record from May 7 until the end of the deployment to create a full primary record of the best available data.

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. Standard methods described below are applied whenever possible. The process includes assignment of quality flags for each observation, which are described in Appendix A.

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.

As part of post-processing, high resolution data are converted to other resolutions. If high-resolution data are finer than hourly, an n-point Hanning filter is used to calculate hourly values according to Table 4.

Highest Resolution Data	Value of n for Hanning filter
1 minute	120
2 minutes	60
10 minutes	13
20 minutes	7
30 minutes	5

Table 4: Hanning filter widths to create hourly data, based on highest resolution data.

Daily values are calculated using a boxcar filter. Both the Hanning and boxcar filters require 50% of data to exist in order to calculate a value at the lower resolution (85% in the case of SWR). The Hanning filter assigns higher weights to data in the middle of the filter (on the hour), and progressively lower weights toward the edges. If values are missing, filter weights are scaled according to the data present. The boxcar filter accounts for missing values by computing an average only when >50% of the high-resolution data is present on a given day.

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 PA008 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 PA008 buoy had secondary air temperature, relative humidity, wind, rain, air pressure, and radiation sensors. Tertiary test sensors included a Rotronic HygroClip measuring air temperature and relative humidity, and a Vaisala WXT520 measuring barometric pressure. These tertiary data from test sensors were not distributed in any format. More information about test sensors can be found in Technical Notes 3 and 5, which can be found here: https://www.pmel.noaa.gov/ocs/technical-notes

3.2.1 Winds

Several spikes were apparent in the wind data, mostly concentrated in the wind gust parameter. Since storms can produce high winds, a simple threshold is inappropriate for filtering this data.

On PA008, a few maximum 3-second gusts stood out as unrealistic. Data were flagged Q5 (removed) when ~20 m/s gusts were reported during low wind conditions (<5 m/s), and where gusts to ~45 m/s were not corroborated (in time or magnitude) by the other instrument.

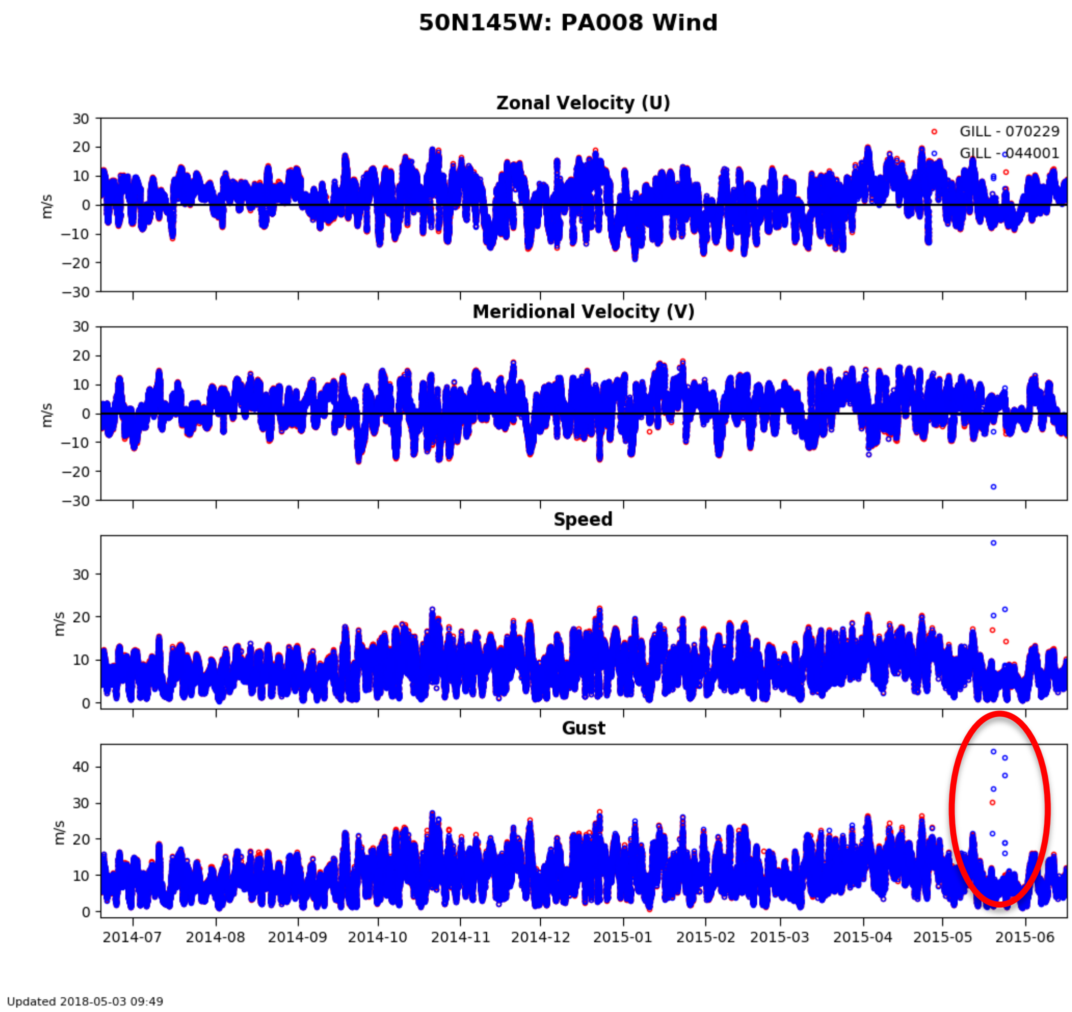

Figure 5: Delayed-mode wind data, before the application of flags, showing prominent outliers (circled), some of which were also detected in the U/V/Speed data. Winds were additionally checked against archived Ocean Prediction Center surface analyses for confirmation.

3.2.2 Air Temperature

Since the TFlex MP101 was chosen as primary for relative humidity throughout most of the deployment (see section 3.2.3), the TFlex sensor was chosen as the primary air temperature measurement as well. However, TFlex air temperatures diverged from both the Flex MP101 and HygroClip air temperature by over 0.2°C toward the end of May 6, 2015. By May 7, 2015 at 16:40 UTC, the difference was more than 1°C. From this point until the end of the record, the Flex MP101 air temperature is used as primary. The MP101s passed post-calibration procedures, but both data streams were flagged Q4 (lower quality) due to the unexplained differences.

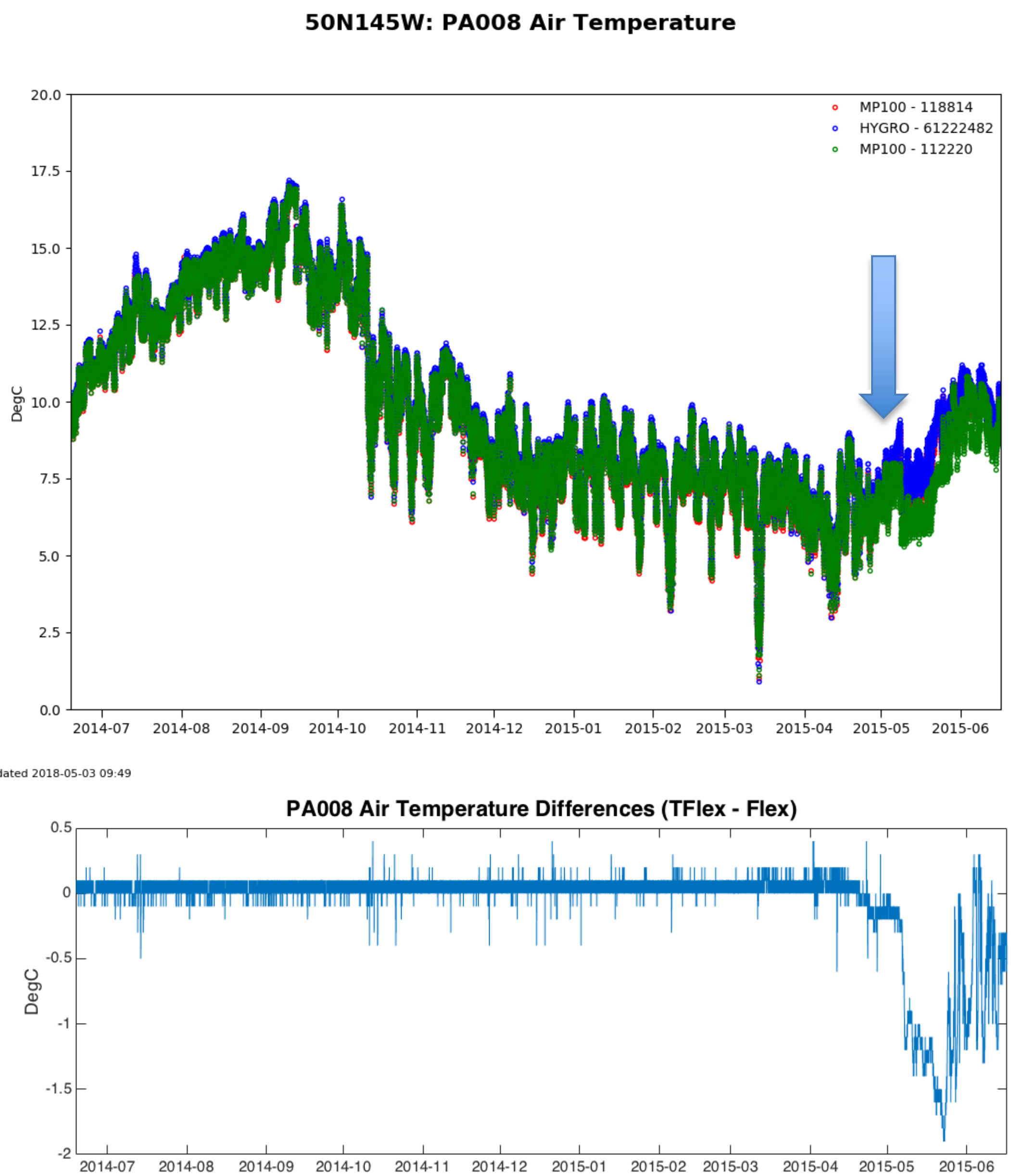

Figure 6: Air temperature time-series and difference plot from PA008. The TFlex drifts from the Flex and Hygroclip sensors in May (denoted by arrow), but occasionally returns to within 0.2°C.

3.2.3 Relative Humidity

Relative humidity from the MP101s differed throughout the deployment. The Flex sensor displayed a distinct high bias, with values approaching 107%. The instruments undergo a linear calibration at PMEL through a range of 45-95% relative humidity. Although relative humidity values greater than 100% are unrealistic, we leave it to the user to threshold values to 100%, since the calibrations theoretically make the instrument more accurate in the 45-95% range.

Flex data quality was lowered to Q4 throughout because the data did not agree with the primary, calibrated sensor. The TFlex sensor was designated primary until it failed on May 9, 2015. Figure 7 shows the time-series from each relative humidity sensor.

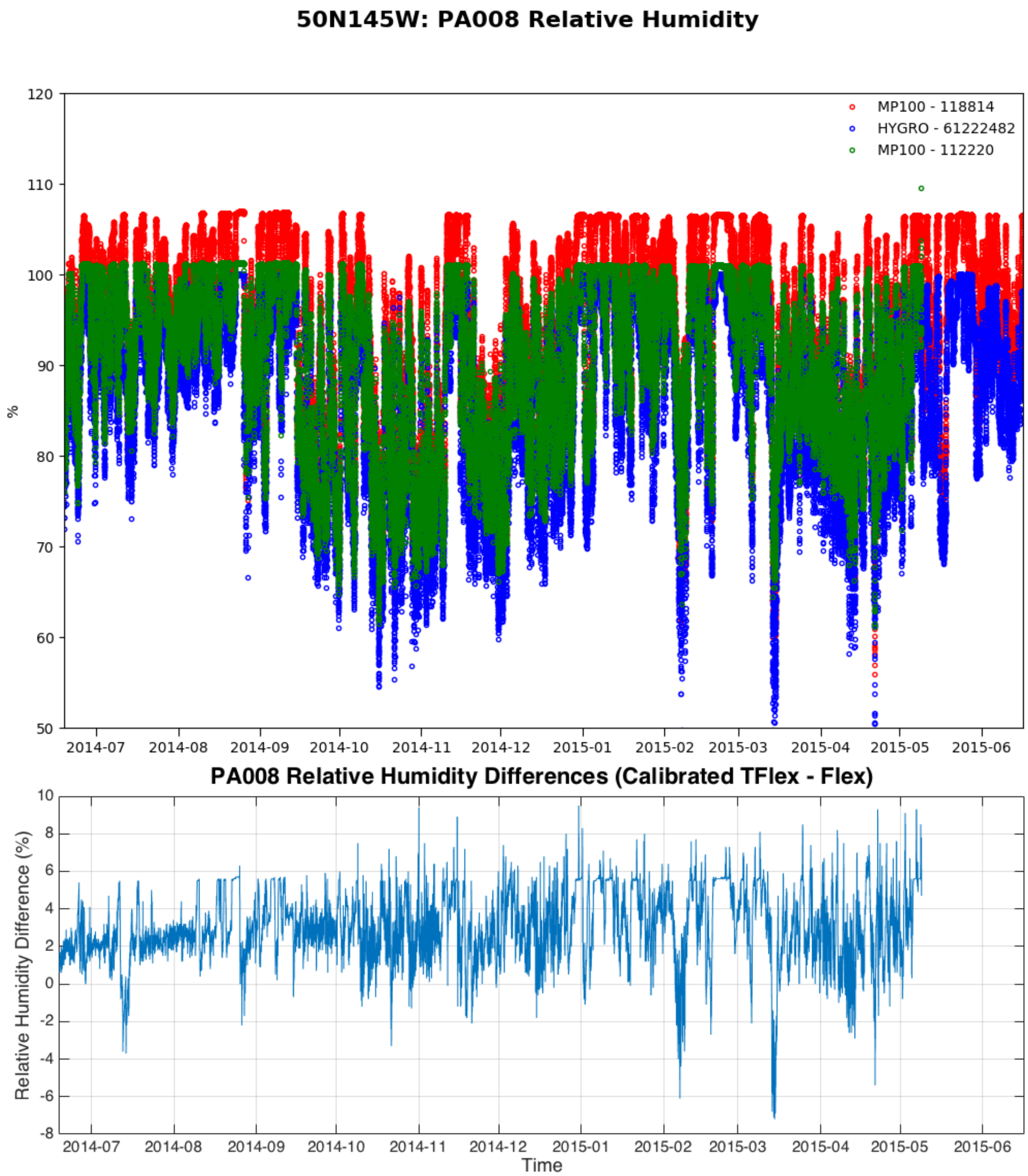

Figure 7: Relative humidity from the Flex (red) and TFlex (green) MP101s (upper), with difference plot (lower). The hygroclip (blue) is not considered a reliable field sensor, but is included for comparison.

Because the TFlex relative humidity record did not extend to the end of the deployment, this system was only used until May 9, 2015 at 00:20, right before it became noisy (Q=4) and failed (Q=5) at 1:00. The Hygroclip is considered a test sensor, so the Flex data were spliced to the TFlex data from 00:30 on May 9, 2015 to the deployment's end. In the spliced Flex data, values over 100% were set to 100% and given Q3 data quality flags.

Figure 8 shows the final distributed product spliced together. When distributed in OceanSITES format, TFlex is primary, Flex is secondary, and no adjustments are made.

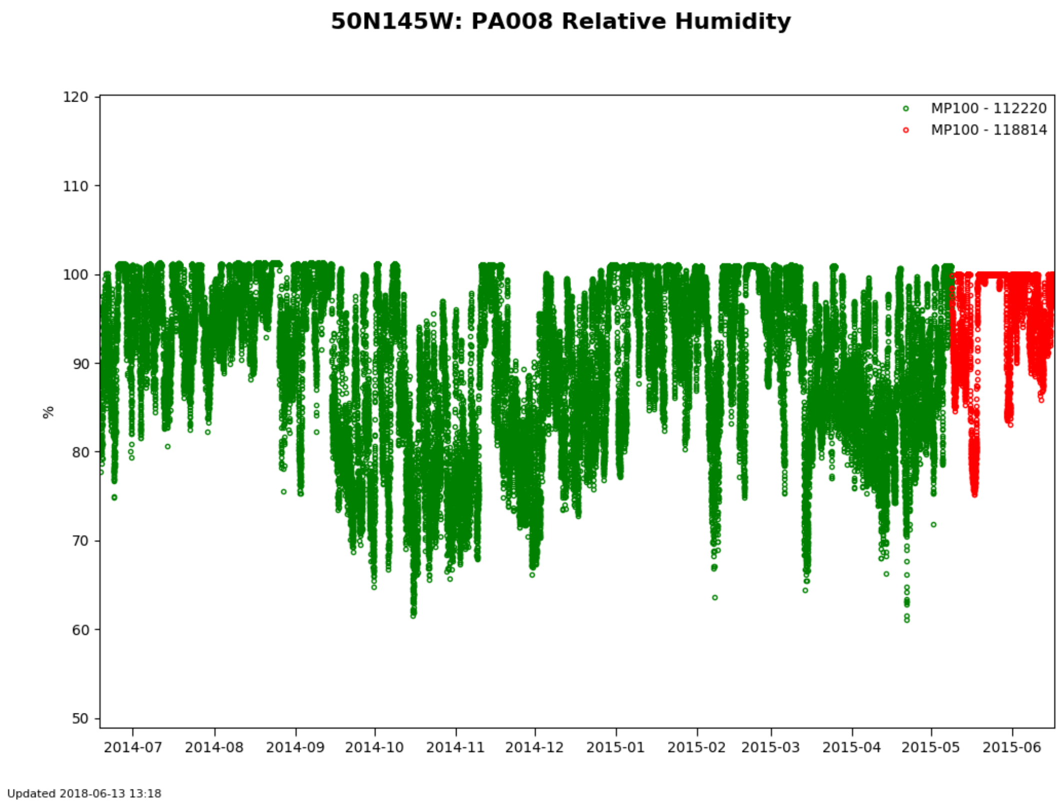

Figure 8: Relative humidity post-processing (spliced), with colors matching the previous figure.

The offset problem with the Flex MP101 data may have been introduced in the calibration process. Before and after this deployment, the instrument calibrations were performed with the temperature of the RH chamber held at 10°C, to replicate average conditions at Papa. However, it was later learned that this may have created a micro-climate within the RH chamber, causing invalid sensor calibration values. The practice of performing RH calibrations at 10°C was abandoned in 2016, reverting instead to maintaining the RH chamber temperature at 25°C, closer to room temperature.

3.2.4 Barometric Pressure

The barometric pressure time-series passed quality control standards and was considered a final product. When all else is equal, the standard procedure for selecting the primary instrument prioritizes the Flex data over TFlex data. With <0.1% difference in the returns from the Flex and TFlex barometric pressure sensors, the Flex sensor was designated primary. Test sensor data from the tertiary Vaisala were not distributed.

3.2.5 Rain

Rain data are acquired as accumulation values, and then converted to rain rates during processing. Rainfall data are collected using an 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. OCS does provide corrected precipitation data through the computed flux page: https://www.pmel.noaa.gov/ocs/data/fluxdisdel

The wind effect can be large. According to the Serra, et al. (2001) correction scheme, at wind speeds of 5 m/s the rain rates should be multiplied by a factor of 1.09, while at wind speeds of 10 m/s, the factor is 1.3. As winds are high at Papa, the user is strongly encouraged to apply an appropriate wind correction.

3.2.6 Shortwave Radiation

The primary shortwave radiation sensor was chosen based on a system developed by Hollings Scholar Kelly Balmes during the summer of 2014, using the following criteria:

- Use the sensor with the higher shortwave daily average (if difference is > 1%)
- Use the FLEX system if all else is similar
- Use the sensor that maximizes the time period of available data

Daily values from the Flex and TFlex instruments were compared, and found to be just over the 1% difference threshold. When the difference is over 1%, the higher of the two instruments is used. It is assumed that a radiation mast that reports low could be bent, and therefore not receiving the full solar insolation. Thus, the TFlex SWR was designated primary.

3.2.7 Longwave Radiation

Downwelling longwave radiation is computed from thermopile voltage, dome temperature, and instrument case temperature measurements, using the method described by Fairall et al. (1998). Kelly Balmes also developed a set of criteria for determining the primary LWR sensor:

- Use the LWR data from the sensor on the data system that was chosen for SWR
- If LWR data from the first criteria is not available, use the remaining instrument

Using this logic, the TFlex LWR was designated primary to match the SWR selection.

3.3 Subsurface Data

There were two sea surface temperature and conductivity (SSTC) instruments deployed on the bridle (Table 1). One was wired to the Flex system, and the other to the TFlex system. Both also logged data internally.

All subsurface instrumentation on the mooring wire 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 recovery log (Figure 9). 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-TC	7089	21:25:30	21:26:01	0:00:31	7089	6.71		
1	SBE37-TC	11553	21:30:15	21:30:18	0:00:03	11553	13.55		
2	SAMI pH	P003							
3	SBE 16v2	6363							
4	O2	488							
5	SBE43	430630							
6	FLNTUS	2646							
7	GTD	121901							
8	ADCP	14607	18:01:35	18:02:12	0:00:37	PA008000.000		PINGING ON DECK	
9	SBE39-TP	4380	20:32:00	20:33:15	0:01:15	PA008_SBE3	6.8		
10	SBE37-TC	6075	20:24:25	20:24:31	0:00:06	6075	6.51		
11	SBE37-TC	12229	20:16:40	20:16:09	-0:00:31	12229	13.77		
12	AquaDopp	8473	17:45:55	17:46:04	0:00:09	PA008_AQD_			
13	SBE37-TC	9412	20:09:45	20:10:11	0:00:26	9412	13.92		
14	SBE37-TC	6141	20:01:05	20:01:29	0:00:24	6141	7.01		
15	SBE37-TC	6142	19:50:30	19:50:56	0:00:26	6142	6.65		
16	AquaDopp	9819	21:12:35	21:13:30	0:00:55	PA008_AQD_			
17	SBE37-TC	6145	19:41:25	19:41:35	0:00:10	6145	6.75		
18	SBE37-TC	6146	19:34:10	19:52:15	0:18:05	6146	6.68	NOT LOGGING. LOW	
19	SBE37-TC	7786	18:26:30	18:26:48	0:00:18	7786	6.65		
20	SBE37-TC	7787	18:18:35	18:19:06	0:00:31	7787	6.61		
21	SBE37-TC	7789	21:17:30	21:17:57	0:00:27	7789	6.63		
22	SBE37-TC	7790	21:14:45	21:15:06	0:00:21	7790	6.66		
23	SBE37-TC	7791	21:07:35	21:07:53	0:00:18	7791	6.57		
24	SBE39-TP	4860	20:42:00	20:42:53	0:00:53	PA008_SBE3	6.8		
25	SBE37-TC	7792	21:11:45	21:12:11	0:00:26	7792	6.68		
26	SBE39-TP	4858	20:37:40	20:38:10	0:00:30	PA008_SBE3	6.9		
27	SBE37-	2608	16:15:00	16:17:15	0:02:15	PA008_SBE3			
28									
29									
30									
31									
32									
33									
34									
35									

Figure 9: Recovery log displaying instrument clock errors.

The 45m instrument had a clock error of 18:05, which, combined with low battery, resulted in occasional missing values toward the end of the instrument's record. The latter part of the salinity record (not T/P) was assigned Q5 due to values that produced density inversions when compared with both surrounding instruments (see Section 3.3.3).

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.

The two bridle instruments were evaluated for performance. The TFlex SSTC was more stable, and had fewer data spikes. Since both instruments had 100% data returns, the cleaner TFlex SSTC time-series was selected as primary.

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 four subsurface instruments, at 5m, 175m, and 300m, plus the deep instrument. 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-recovery 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.

The conductivity cells for both the 14m and 25m instruments were modified before the post-recovery calibration could be completed. Since these calibration coefficients did not reflect the state of the instrument at the time of recovery, they were not applied. No manual adjustments were required at those depths.

The instrument at 45m produced density inversions with adjacent instruments, so corrections through data adjustments were ineffective. Starting September 17, 2014, flags of Q5 were assigned to the salinity, density, and conductivity records.

Salinity Drifts in PSU (post-pre):

Depth:	Drift:	
1m (TFlex)	0.0079	
1m (Flex)	-0.0006	
10m	-0.0049	
14m	-0.5100	**
20m	-0.0003	
25m	-0.0809	**
30m	-0.0075	
37m	-0.0053	
45m	-0.0029	
60m	-0.0079	
80m	-0.0057	
100m	-0.0078	
120m	-0.0027	
150m	-0.0026	
200m	0.0016	

** Post-cals were 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:

Secondary 1m SSTC (Flex)

2014-06-17 01:52:35 to 2014-10-11 22:48:53 adjusted -0.0006 to 0.0142
2014-10-11 22:48:53 to 2015-04-27 11:33:19 adjusted 0.0142 to 0.0142
2015-04-27 11:33:19 to 2015-05-13 12:44:26 adjusted 0.0142 to 0.0051
2015-05-13 12:44:26 to 2015-06-18 07:59:59 adjusted 0.0051 to 0.0040

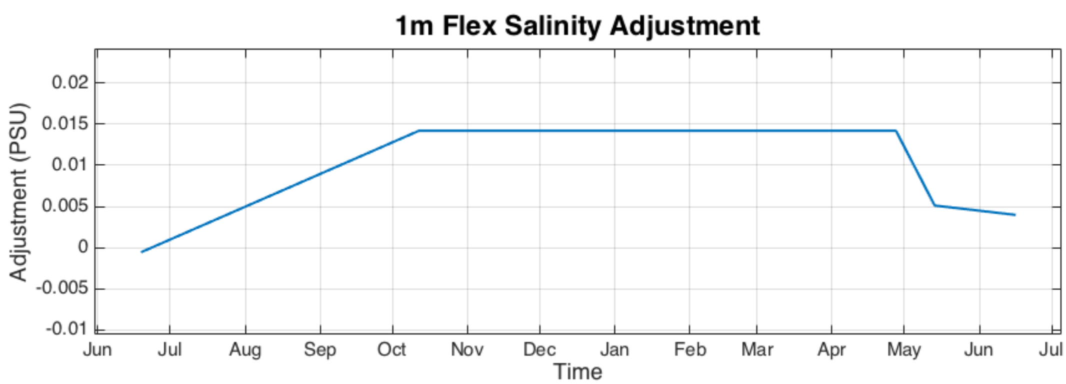

Figure 10: Flex SSTC Salinity Adjustments on PA008.

Several CTD casts were performed in the region during the time this mooring was in the water. After review, no changes were made to the data based on the CTD casts.

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. 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.

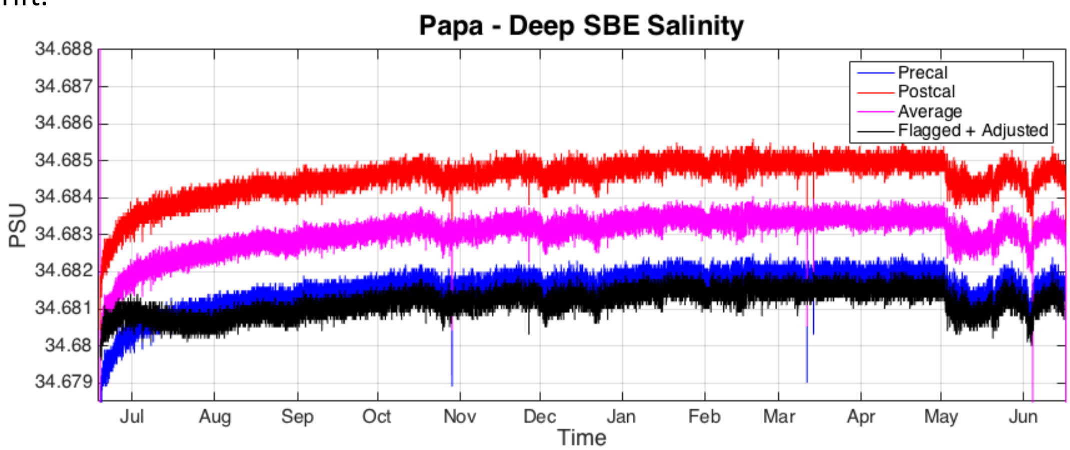

Figure 11: PA008 (2014 - 2015) deep Seabird salinity data with pre-deployment (blue) and post-recovery (red) calibration coefficients applied. Calibration variability, seen here as a vertical offset, and early deployment drift stand out against the signal, despite a compact y-axis. The average calibration (magenta) and final product after the offset continuity adjustment and flagging (black) are shown.

Early deployment drift can be seen as a curve in the first few months of the time-series. This anomaly is instrument-specific, and linked to S/N 2608. 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 = -0.0002138521
B = 0.0004722054
C = 34.6804384262
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.

Data from both the prior and following year's deployments (PA007 & PA009) were examined to address discontinuities between years. An offset of -0.0015 mS, or about half the conductivity cell's accuracy, was applied to the conductivity time-series to align PA008 data with adjacent deployments. The salinity that results is shown as the black line in Figure 11. The total salinity adjustment is the combined result of the conductivity offset and the detrend, and is shown in Figure 12.

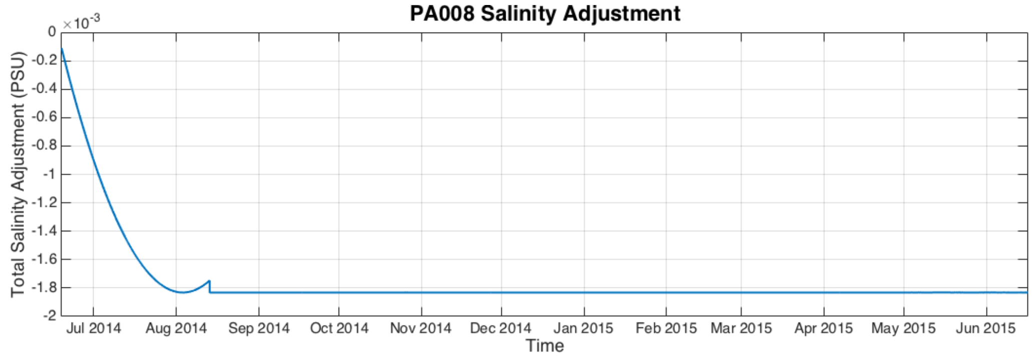

Figure 12: Cumulative salinity adjustment (curve detrend + conductivity offset), starting from the average calibration. This plot represents the black minus magenta line in Figure 11.

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 PA008 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 PA008 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 PA008 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 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 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 PA008. 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, and the internal magnetic declination for this ADCP was set at +17 degrees.

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.

Other instruments on the mooring line interfere with all four ADCP beams, despite a 20-degree beam angle (Figure 13). Manual flagging was performed to remove the bins with consistent contamination (Figure 14).

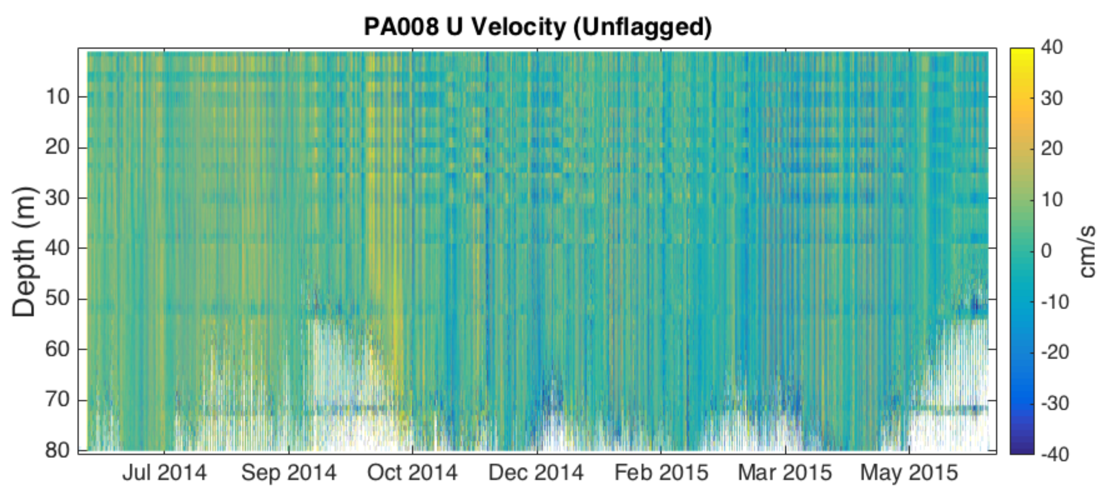

Figure 13: ADCP eastward velocities with autonomous flagging thresholds applied by the ADCP, but before manual flagging. All beams are affected by instruments on the line.

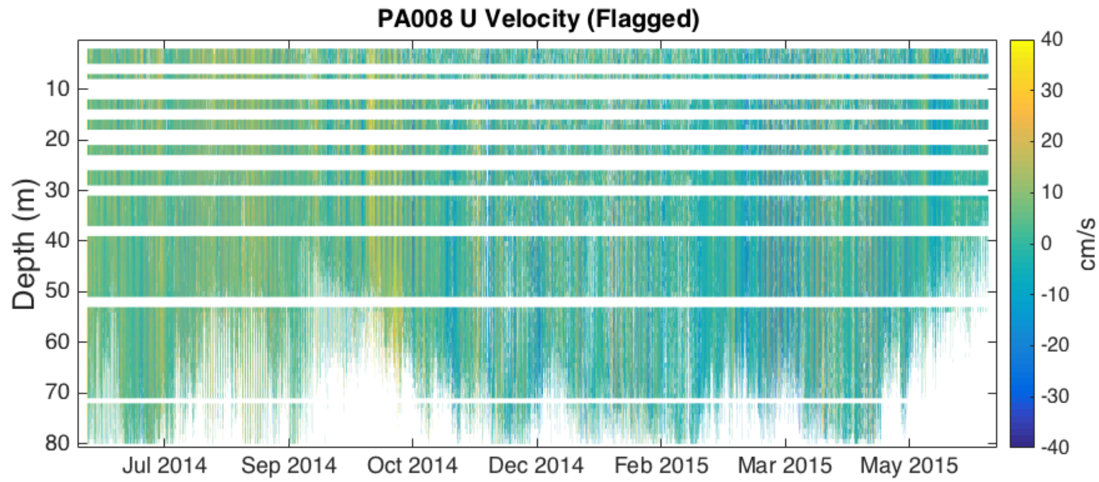

Figure 14: ADCP eastward velocities with manual flagging thresholds and bin-flagging applied, in addition to the autonomous flagging thresholds applied by the ADCP. All interference caused by instruments on the mooring line is removed.

4.0 References

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5.0 Acknowledgements

C. Fey and N. Anderson (both of UW JISAO) processed the Flex/TFlex data, and developed scripts to handle the new case of deployments without ATLAS systems. D. Dougherty (UW JISAO) is recognized for designing and generating the initial python files from which processing begins, and for the quality control of real-time data. S. Brown (UW JISAO) was consulted in the development of new salinity processing scripts.

The OCS project office is grateful to the captain and crew of the CCGS JOHN P. TULLY, who made the deployment and recovery operations possible. Collaboration with the Institute of Ocean Sciences (IOS) is greatly appreciated, and the project is thankful for the ship-time received through this partnership.

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 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

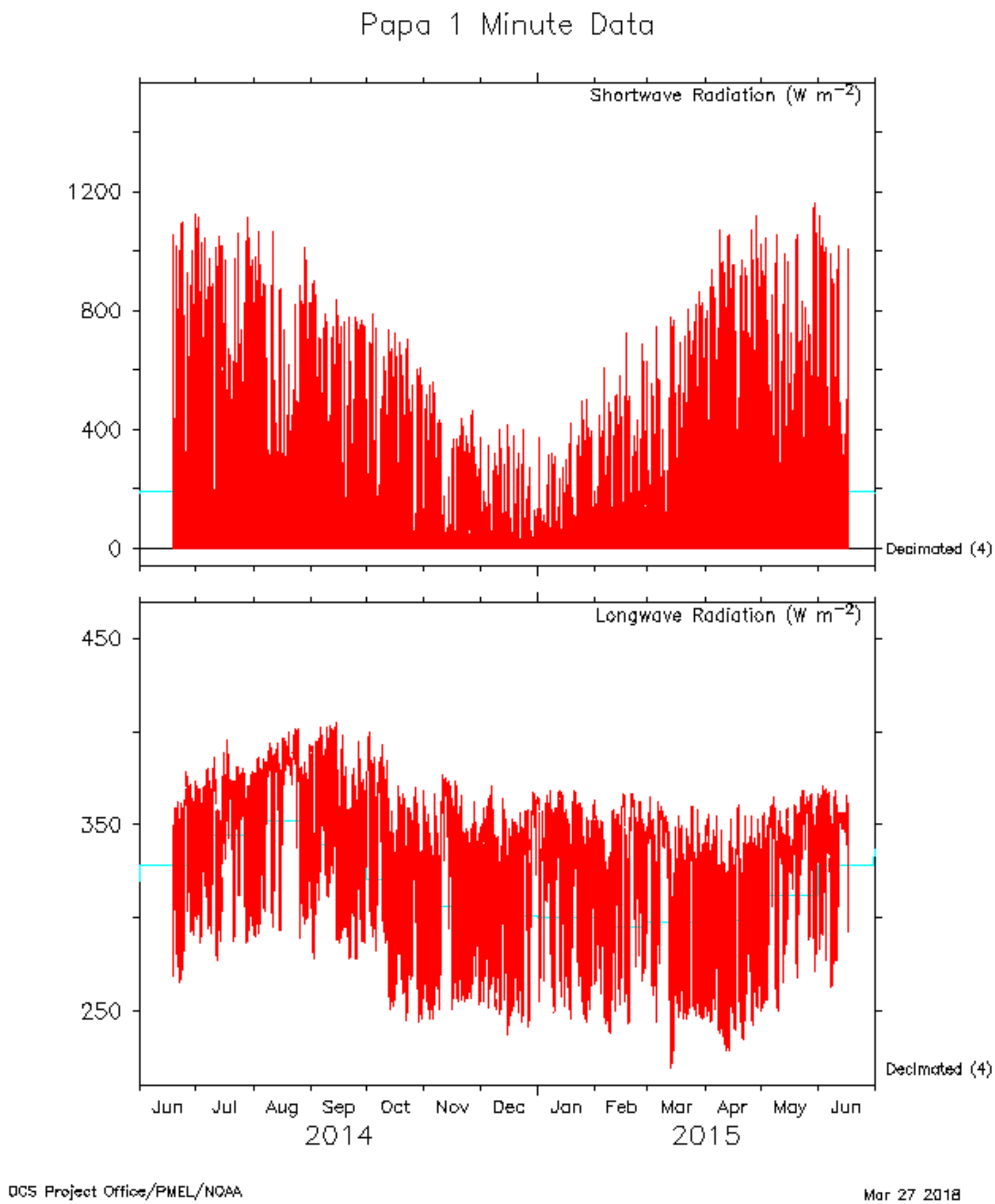

Figure B 1: PA008 primary shortwave and longwave radiation data at 1-min resolution (TFlex).

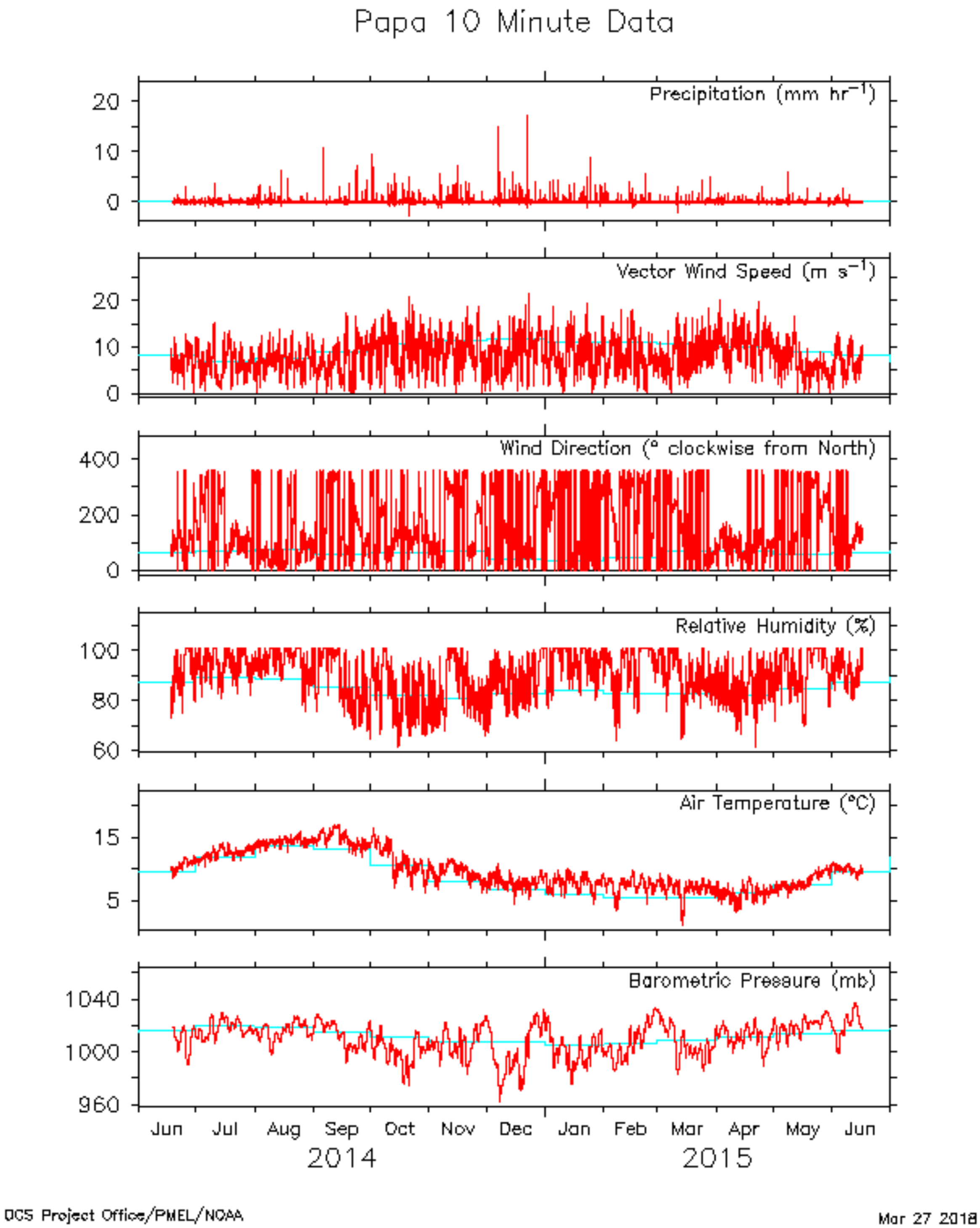

Figure B 2: PA008 meteorological data at 10-min resolution. Data are from the Flex system, except for the spliced TFlex/Flex ATRH record as described in the Air Temperature and Relative Humidity sections.

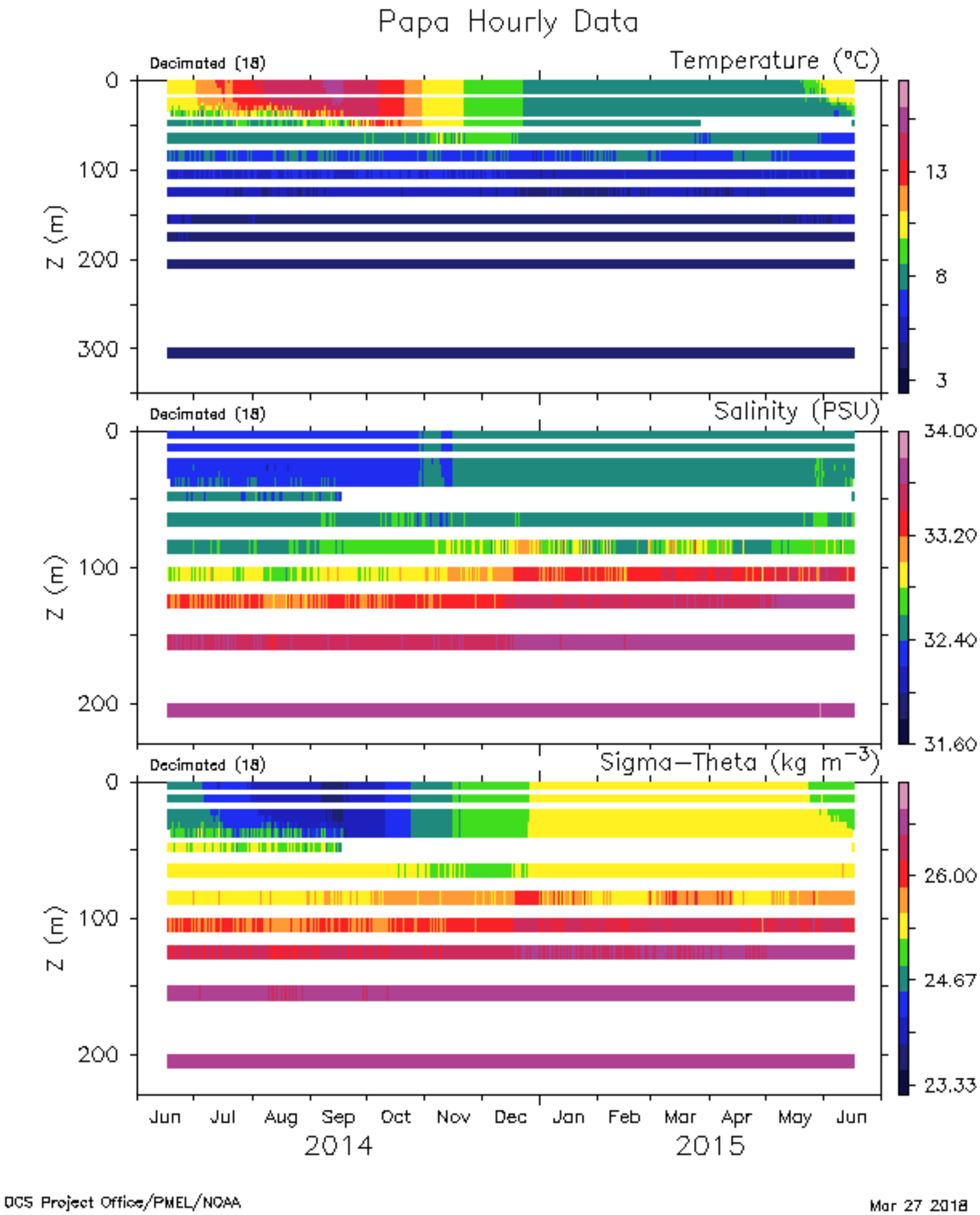

Figure B 3: PA008 subsurface temperature, salinity, and density at hourly resolution (decimated).

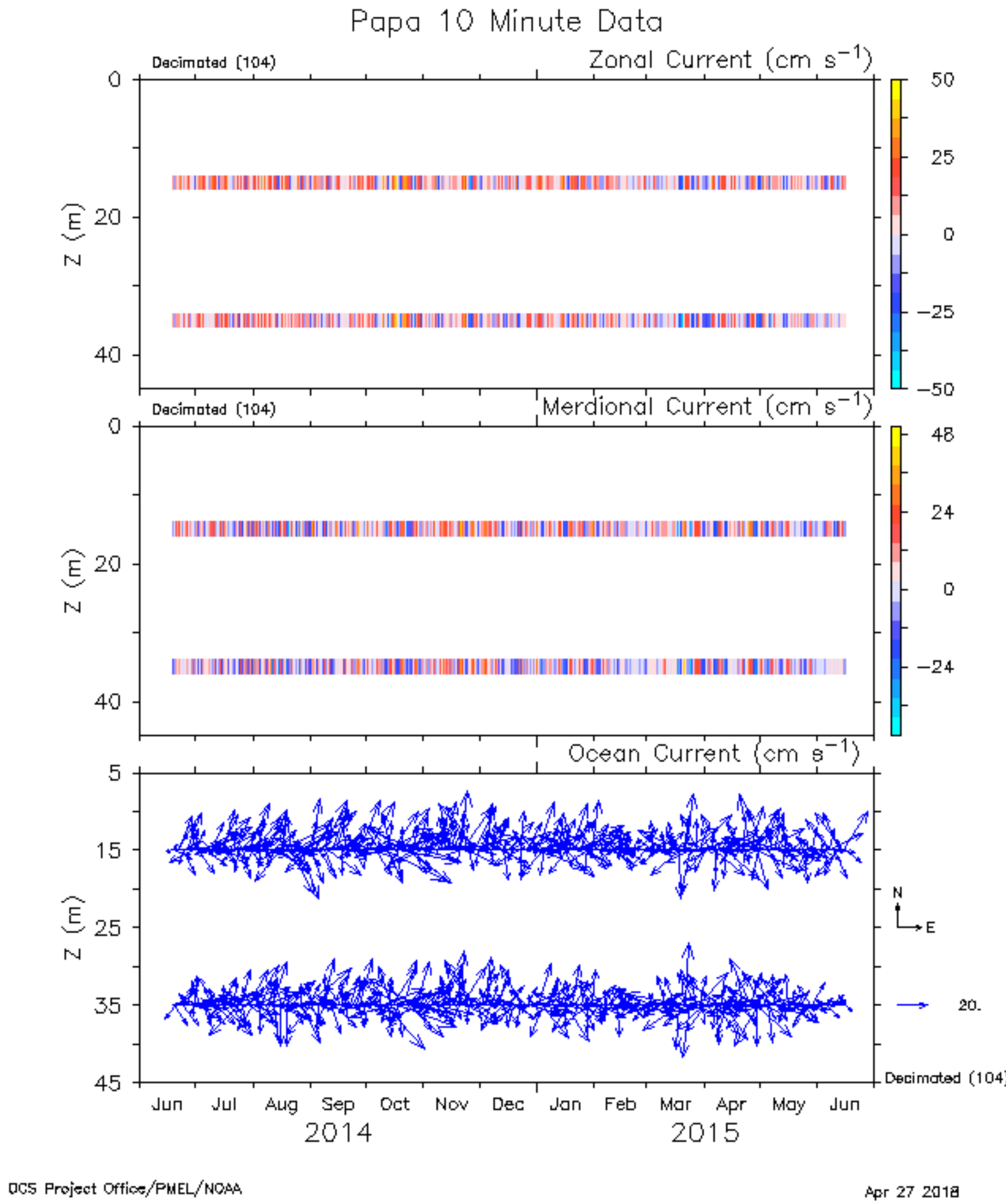

Figure B 4: Zonal and meridional current meter data from PA008.

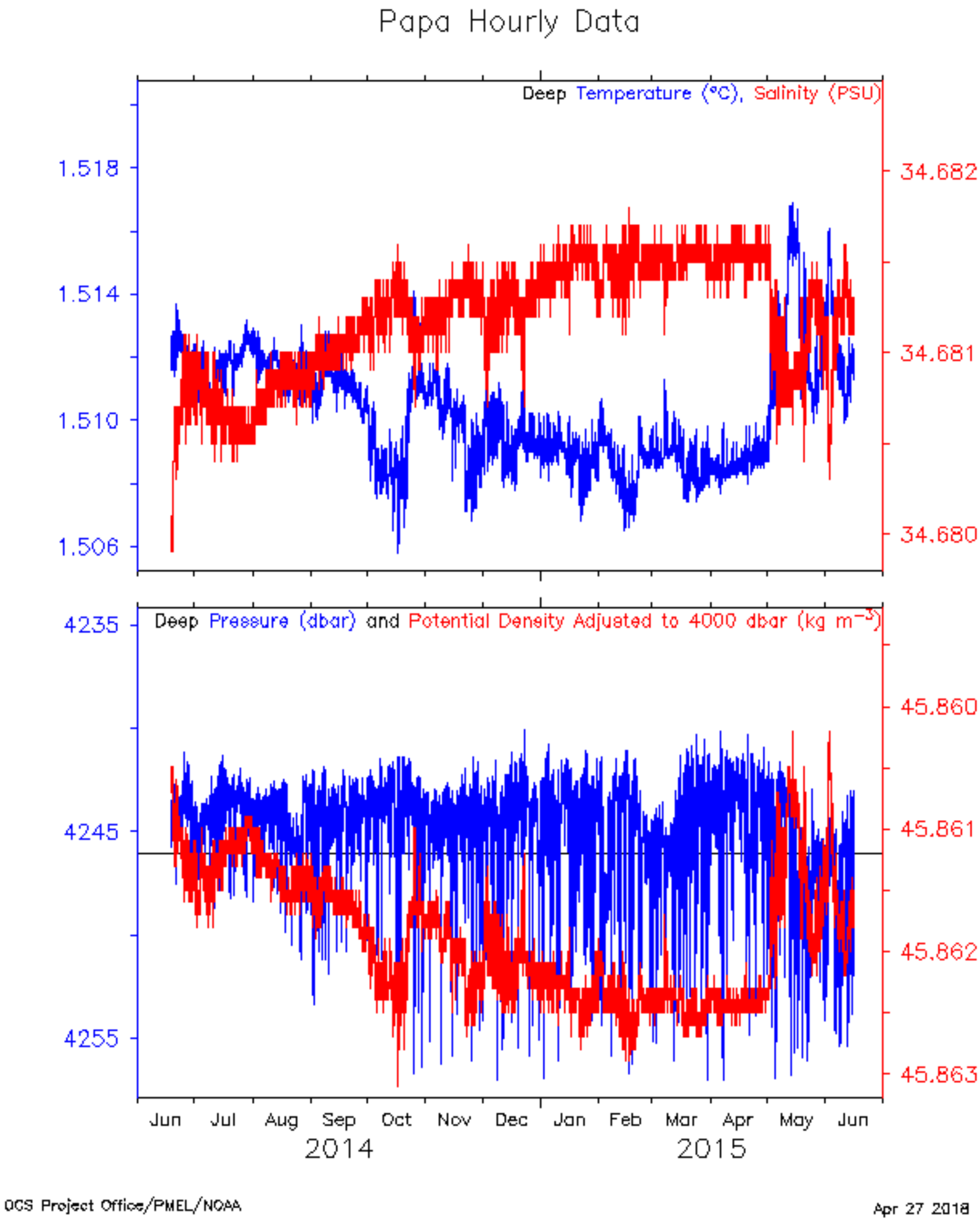

Figure B 5: Deep Seabird instrument temperature, pressure, salinity, and potential density.

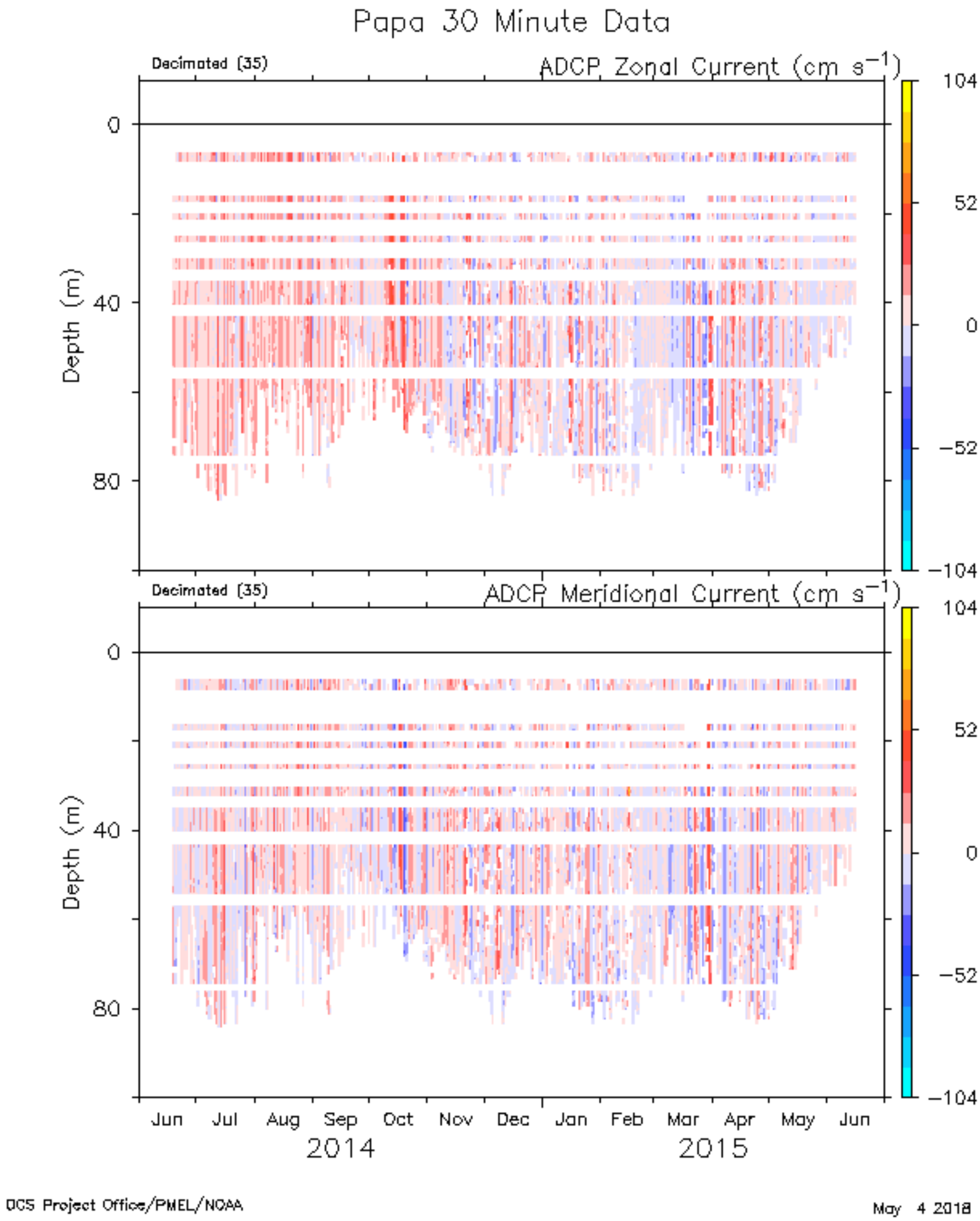

Figure B 6: Sentinel ADCP data, with striations due to bins influenced by hard-returns off of subsurface instruments.

APPENDIX C: Secondary Instrument High Resolution Data Plots

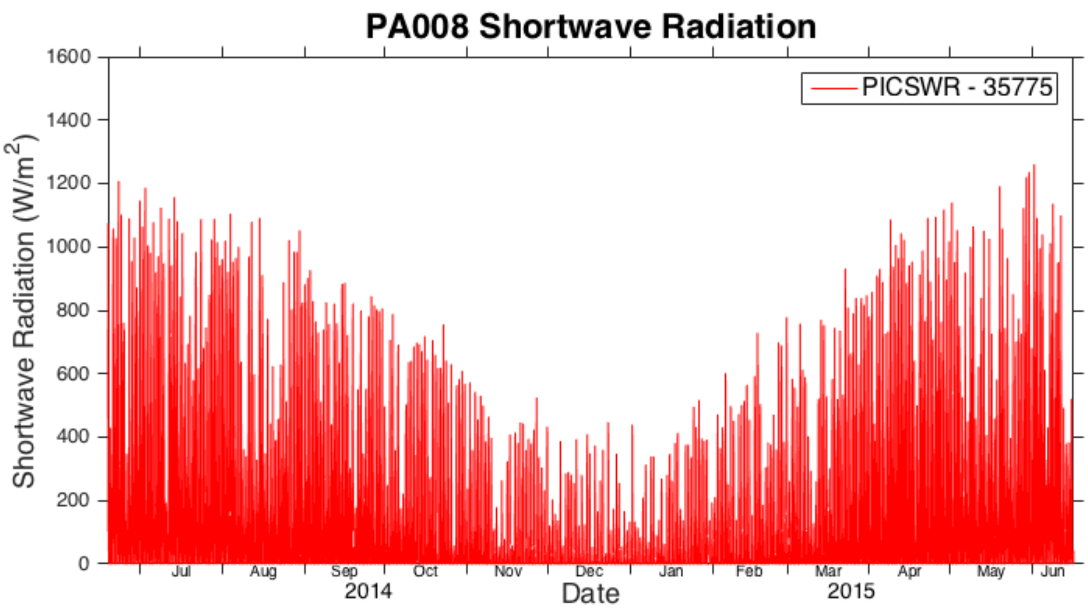

Figure C 1: Secondary (Flex Eppley PSP) shortwave radiation sensor.

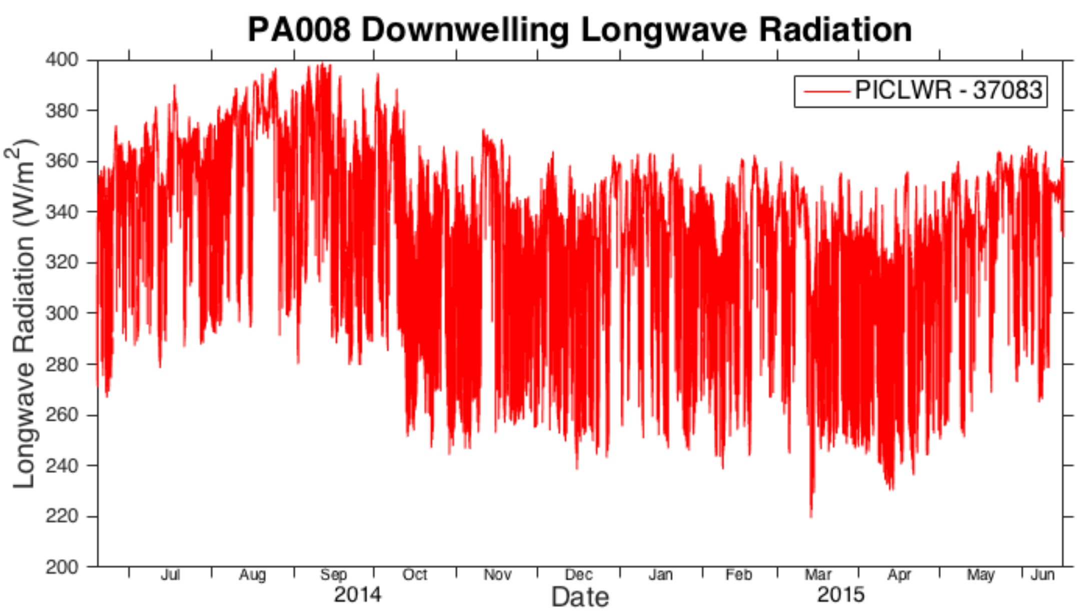

Figure C 2: Secondary (Flex Eppley PIR) longwave radiation sensor.

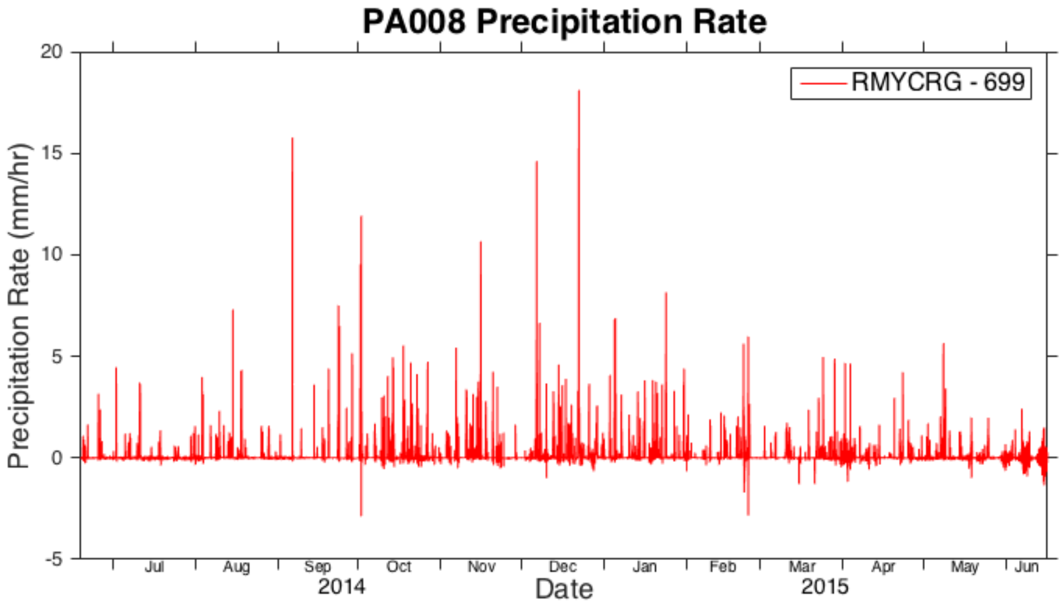

Figure C 3: Secondary (TFlex RM Young) rain sensor.

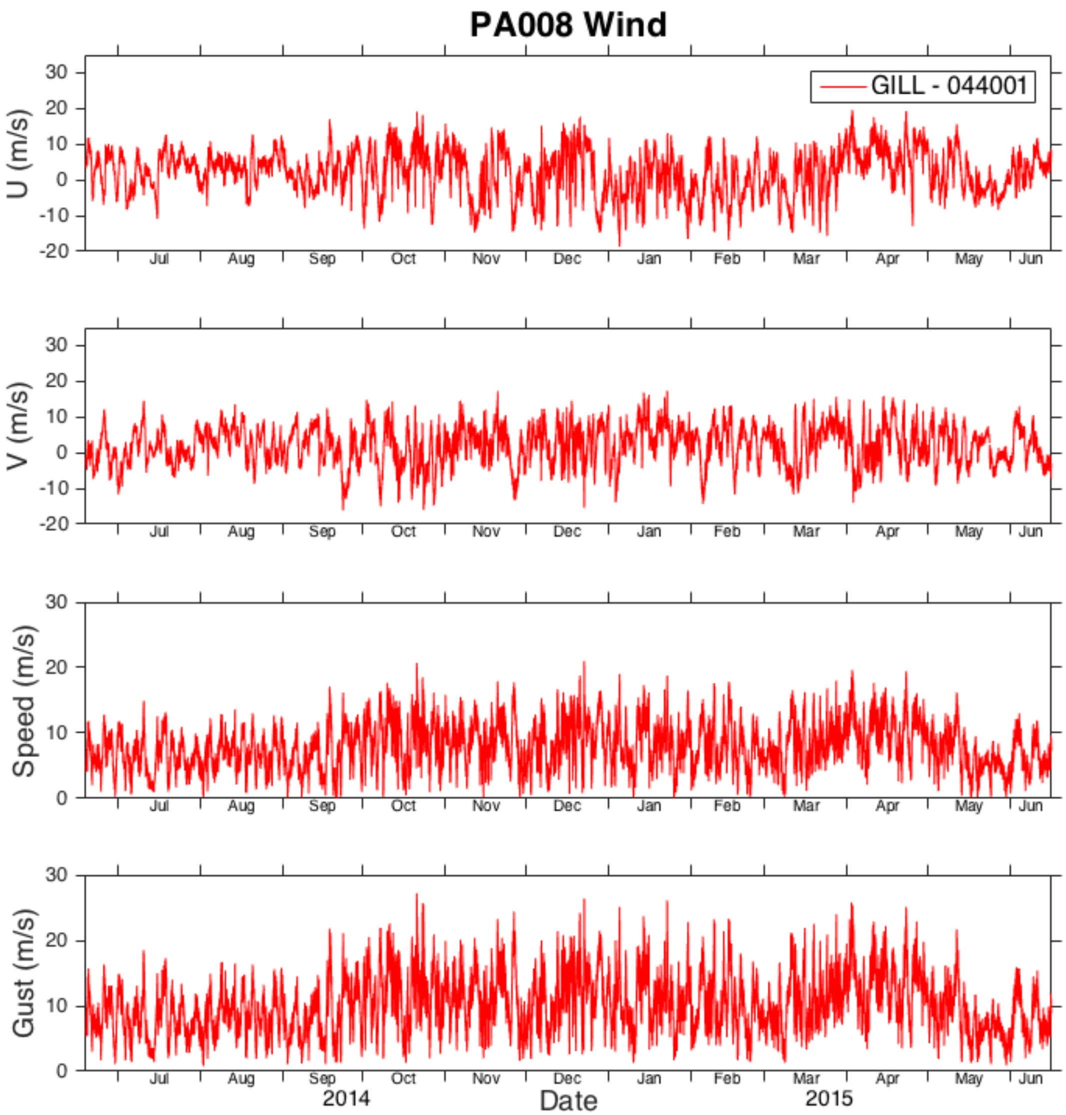

Figure C 4: Secondary (TFlex Gill) wind sensor.

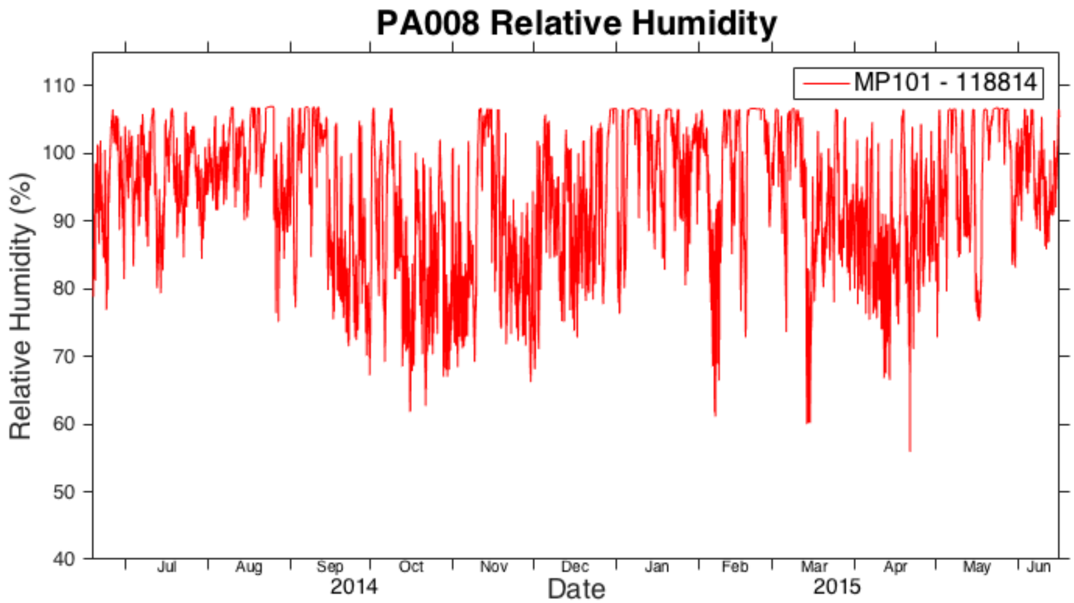

Figure C 5: Secondary (Flex MP101) relative humidity sensor. The entire record is flagged Q4 due to values over 100% in a time-series that was offset from the other ATRH sensors.

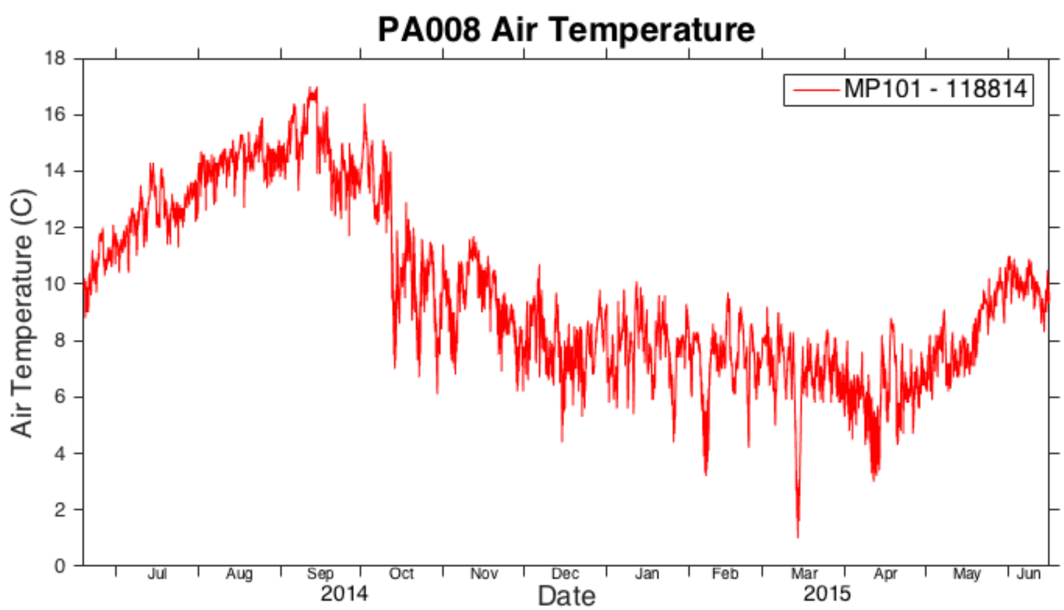

Figure C 6: Secondary (Flex MP101) air temperature sensor. Data were flagged Q4 from May 7th, 2015 to the end due to diverging temperature measurements.

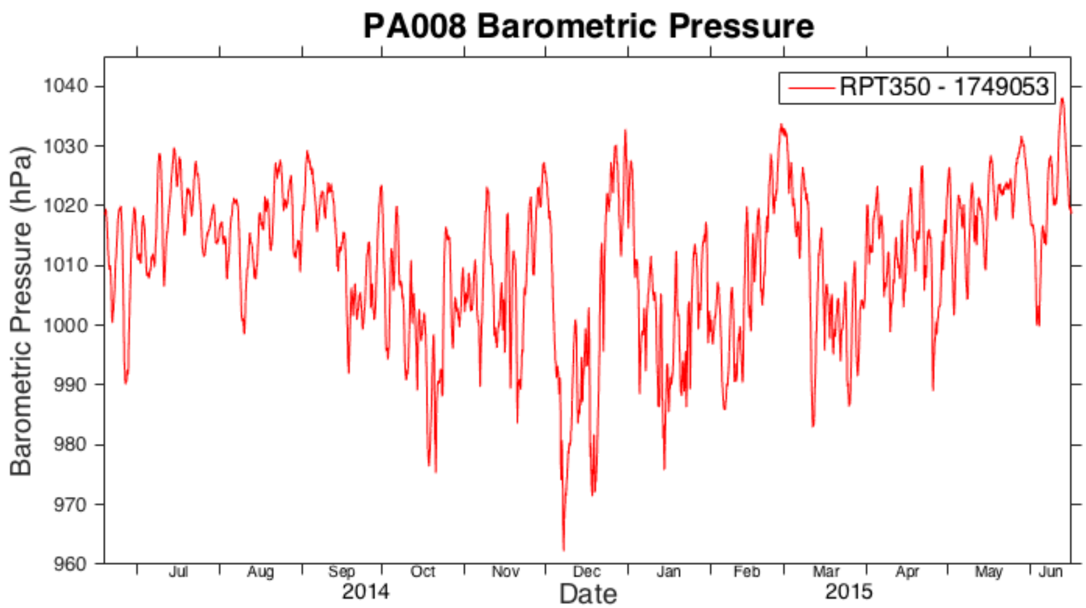

Figure C 7: Secondary (TFlex RPT350) barometric pressure sensor.

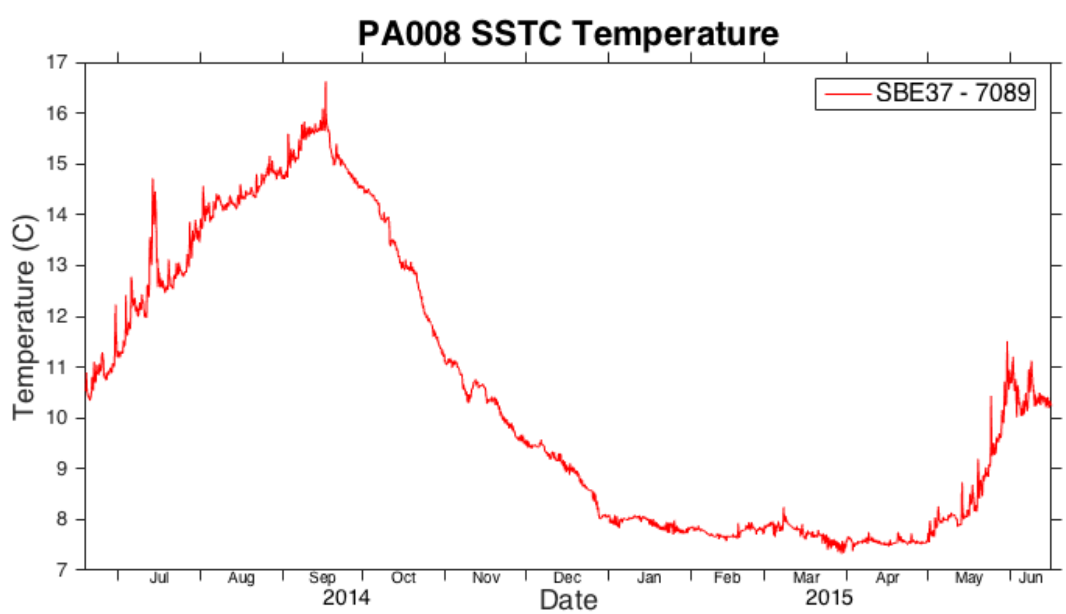

Figure C 8: Secondary (Flex) SSTC Temperature.

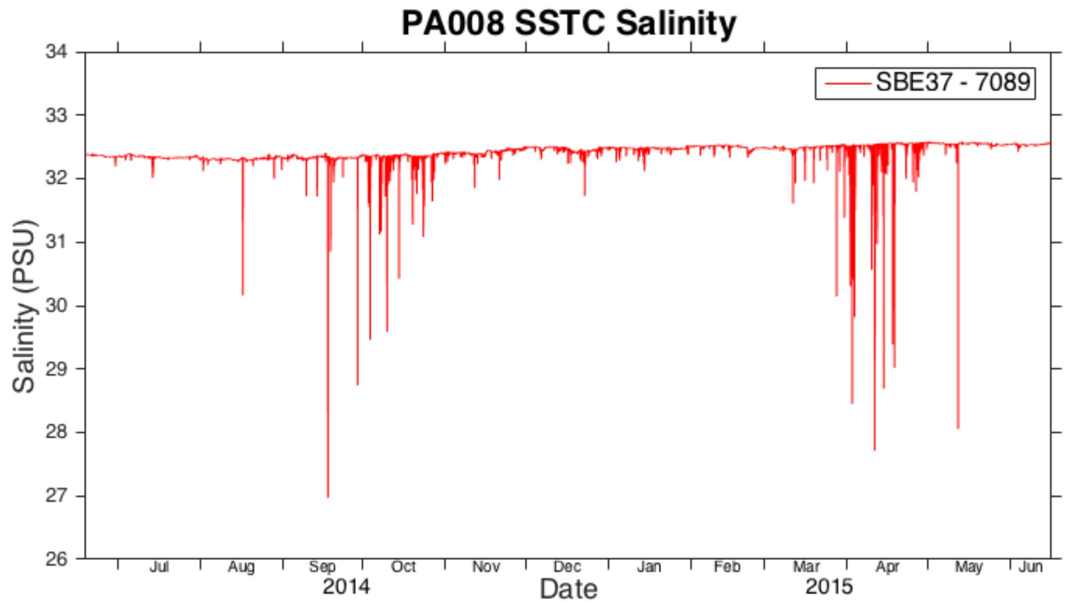

Figure C 9: Secondary (Flex) SSTC Salinity.

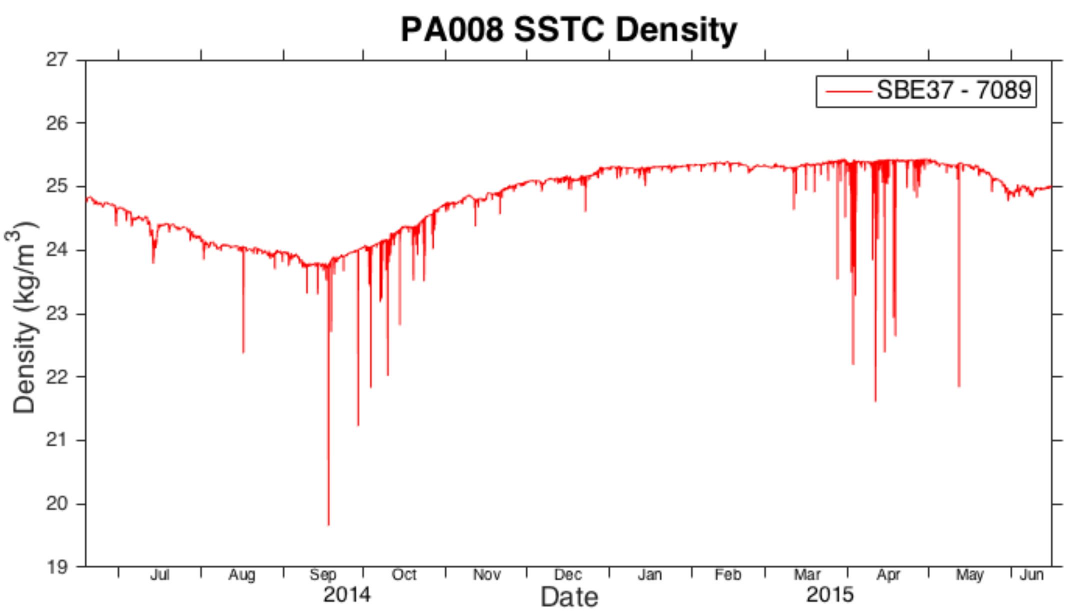

Figure C 10: Secondary (Flex) SSTC Density.