NOAA Pacific Marine Environmental Laboratory

Ocean Climate Stations Project

DATA ACQUISITION AND PROCESSING REPORT FOR PA014

Site Name:	Ocean Station Papa
Deployment Number:	**PA014**
Year Established:	2007
Nominal Location:	50.1°N 144.9°W
Anchor Position:	50° 02.448' N, 144° 51.876' W (estimated from watch circle)
Deployment Date:	August 15, 2020
Recovery Date:	April 25, 2021
Project P.I.:	Dr. Meghan F. Cronin
Report Authors:	N.D. Anderson, P. Berk, and M.F. Cronin
Data Processors:	N.D. Anderson
Date of Report:	October 27, 2022
Revision History:	

Special Notes:

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Data Acquisition and Processing Report for OCS Mooring PA014

1.0 Mooring Summary

As the site of a former ocean weather ship, Station Papa (50°N, 145°W) is one of the oldest oceanic time series and a critical site in the global network of OceanSITES time series reference stations. Through initial 3-year support from the National Science Foundation (NSF) and sustained funding from NOAA, and in collaboration with the Canadian Department of Fisheries and Oceans (DFO) Line P Program, a surface mooring was deployed in June 2007 at Ocean Station Papa to monitor ocean-atmosphere interactions, carbon uptake, and ocean acidification. PA014 was the fourteenth deployment at this site.

The PA014 mooring was deployed on August 15th, 2020 by the NOAA ship OSCAR DYSON. Due to the COVID-19 pandemic, OCS personnel assisted with dockside staging, but the DYSON crew completed the first crew-only deployment in Station Papa history. Recovery was performed by OCS personnel and DYSON crew members on April 25th, 2021. The Ocean Climate Stations group would like to thank the captain and crew of the DYSON for their outstanding contributions toward successfully maintaining this important time series during a worldwide pandemic.

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

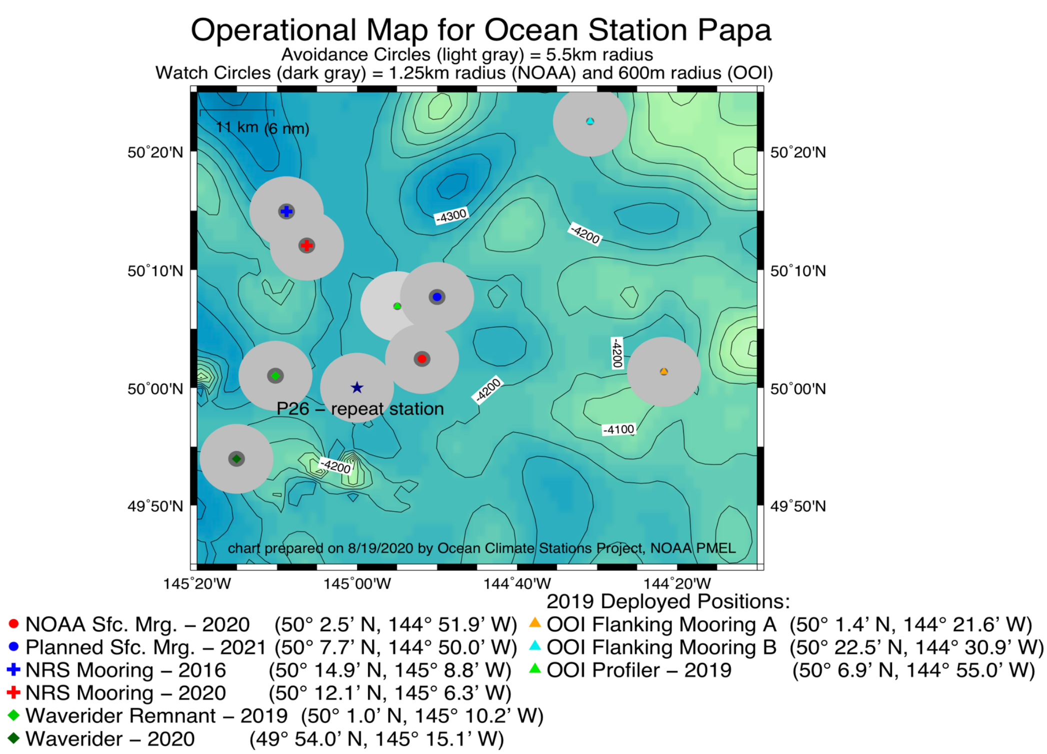

Figure 1: Overview of Station P deployments, including PA014.

1.1 Mooring Description

The PA014 mooring was a taut-line mooring, with a scope of 0.965. Non-rotating 7/16" (1.11cm) diameter wire rope, jacketed to 1/2" (1.27cm), was used in the upper 325m of the mooring line. The remainder consisted of plaited 8-strand nylon line to the acoustic release in line above the anchor, as shown in Figure 3. The 6,850lb (3,107kg) anchor was fabricated from scrap railroad wheels.

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 PMEL carbon group contributed an SBE16 package (with attached oxygen sensor and fluorometer) and SAMI pH sensor to the buoy bridle, along with their primary CO_2 flux monitoring system housed in the well. OCS is not responsible for the acquisition or processing of these data, and no further discussion of these systems is included in this report. All OCS and partner systems with corresponding instrumentation are shown in the mooring diagram (Figure 3).

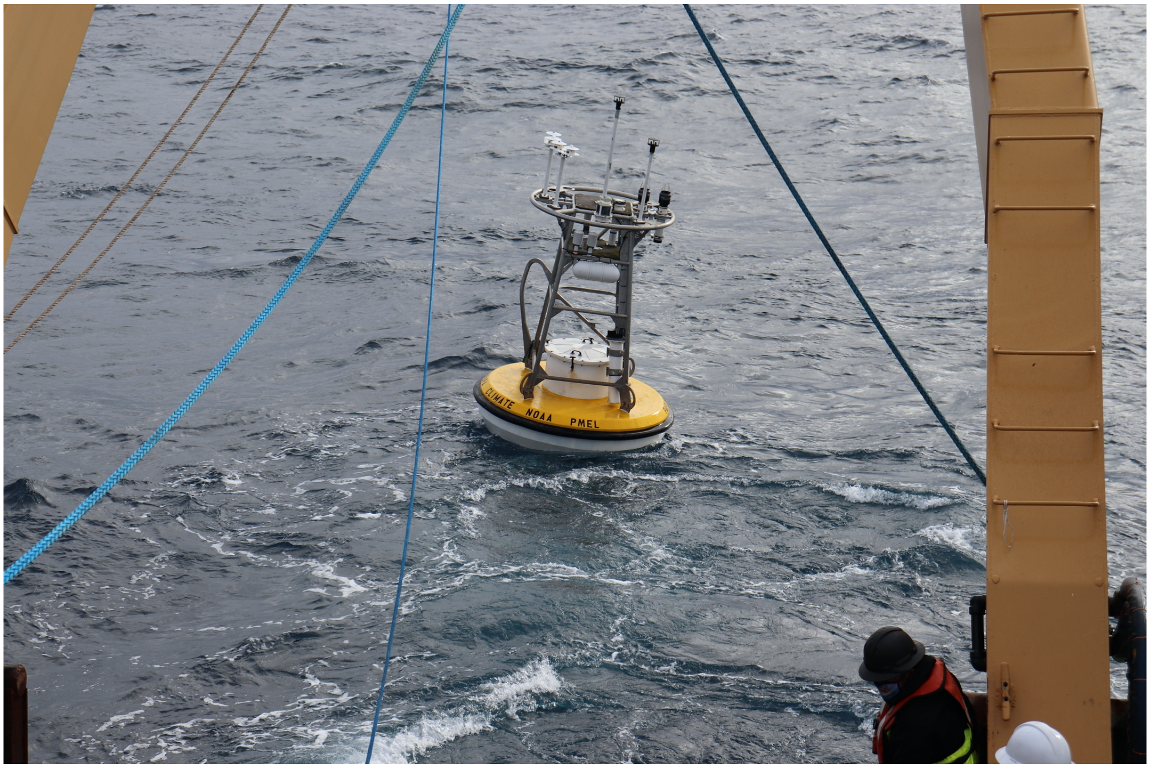

Figure 2: PA014 mooring as deployed (photo credit: Laura Dwyer).

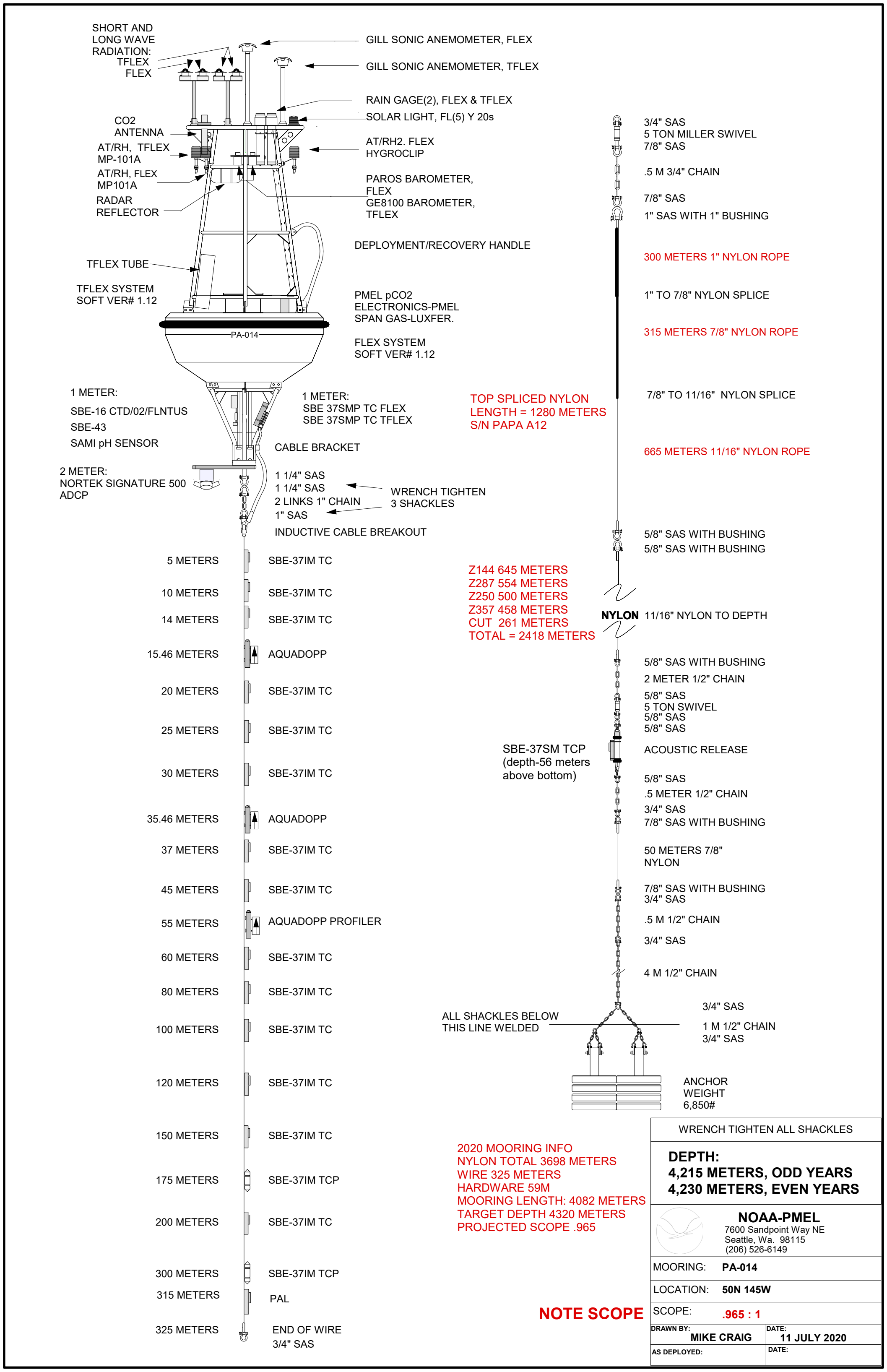

Figure 3: PA014 mooring diagram.

1.2 Instrumentation on PA014

The following instrumentation was deployed on PA014. 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:		PA014			PA1-20-DY
Met Sensors		**Model**	**Serial #**		**Notes**
Height	Acquisition	**FLEX**	0006		
2.6m	ATRH	Rotronics MP-101A	461007		
2.6m	ATRH2	Rotronics HygroClip	61334171		
4.2m	Wind	Gill	073805		
2.5m	BP	PAROS	114864		
3.1m	Rain	RM Young	1549		
3.6m	SWR	Eppley PSP	38432		
3.6m	LWR	Eppley PIR	38440		
	Acquisition	**TFLEX**	2001		
2.6m	ATRH	Rotronics MP-101A	133390		
3.8m	Wind	Gill	044001		
2.5m	BP	GE8100	11335024		
3.1m	Rain	RM Young	1343		
3.6m	SWR	Eppley PSP	38431		
3.6m	LWR	Eppley PIR	38487		
CO2		**CO2**			
	Electronics	PMEL	169		
	Span Gas	Luxfer	JJ13515		
1m	pH	Sami	P33		CO2
1m	SST/C	SBE16+V2	50314		CO2
1m	Oxygen	SBE63 Optode	2465		Attached to CO2 SBE16+
1m	Fluorescence	ECO FLNTUS	5974		Attached to CO2 SBE16+
Subsurface Instrumentation					
Bridle	**Type**	**Model**	**Serial #**	**IM**	**Notes**
1m	SST/C	SBE37SMP-TC	12520	-	Flex
1m	SST/C	SBE37SMP-TC	11552	-	TFLEX
Depth		**Model**	**Serial #**	**IM ID**	**Notes**
5m	TC	SBE37IM-TC	21431	01	
10m	TC	SBE37IM-TC	21429	02	
14m	TC	SBE37IM-TC	21428	03	
15.46m	ADCM	AquaDopp	8071	04	
20m	TC	SBE37IM-TC	16836	05	
25m	TC	SBE37IM-TC	7793	06	
30m	TC	SBE37IM-TC	7791	07	
35.46m	ADCM	AquaDopp	6810	08	
37m	TC	SBE37IM-TC	7790	09	
45m	TC	SBE37IM-TC	7789	10	
55m	ADCP	AquaDopp Profiler	13317	NO-IM	Non-inductive; Upward Looking
60m	TC	SBE37IM-TC	7787	11	
80m	TC	SBE37IM-TC	7786	12	
100m	TC	SBE37IM-TC	6145	13	
120m	TC	SBE37IM-TC	6142	14	
150m	TC	SBE37IM-TC	6141	15	
175m	TCP	SBE37IM-TCP	7107	16	
200m	TC	SBE37IM-TC	7792	17	
300m	TCP	SBE37IM-TCP	7092	18	
Release	TCP	SBE37SM-TCP	11926	Release	Non-pumped; w/ pressure

Table 1: Instruments deployed on PA014.

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

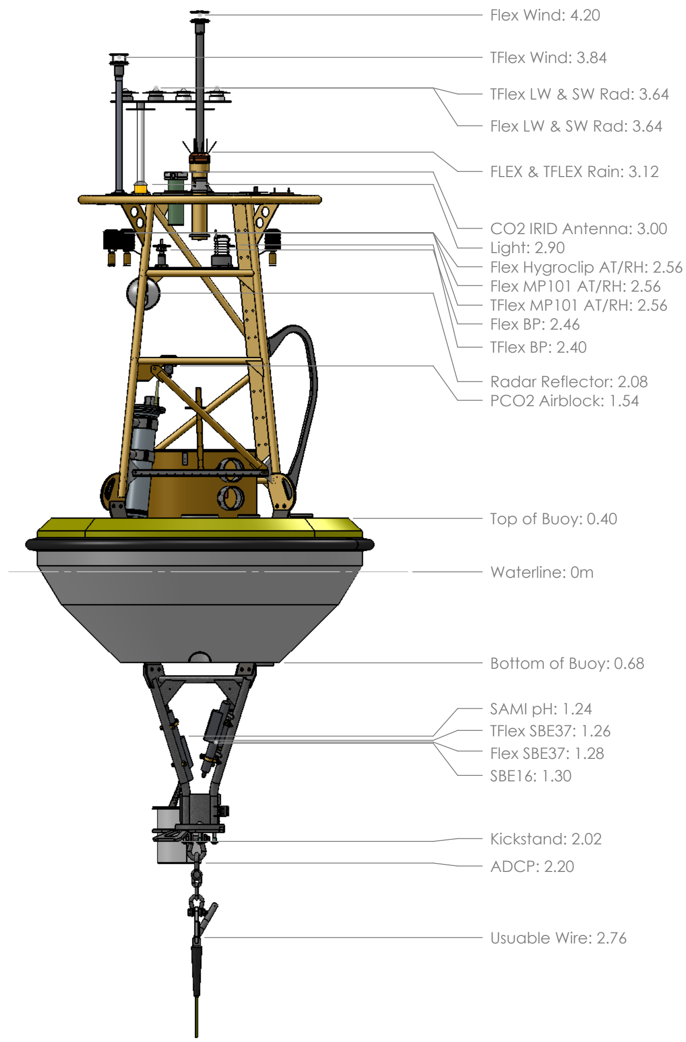

Figure 4: Buoy diagram showing bridle arrangement. The SBE16 package contains a suite of sensors. The ADCP on PA014 was a new test instrument (Nortek Signature 500).

2.0 Data Acquisition

Two independent data acquisition systems were deployed on PA014, 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. 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 PA014 mooring, for both the primary and secondary systems. Observation times in data files are assigned to the center of the averaging interval. While Flex sensors are generally considered primary, a combination of failures resulted in all TFlex sensors being primary.

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	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	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 (Signature 500)	1 Hz	25 min	00:02:30-00:27:30,…	30 min	Internal
Ocean Currents (AQDPRO)	1 Hz	2 min	2359-0001, 0059-0101…	30 min	Internal
GPS Positions	1 / 6 hr	Instant.	~0000, 0600…	6 hr	TFLEX

Table 2: Sampling parameters of the primary sensors on PA014.

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	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	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 hr	Instant.	~0000, 0100, …	1 hr	FLEX

Table 3: Sampling parameters of the secondary sensors on PA014.

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 0006:

```
Data Return Summary
2020-08-15 23:27:00 to 2021-04-25 19:36:00

Sensor      Deployed      Obs    Return
=======================================
AT1            36409     3084      8.5%
AT2            36409    18287     50.2%
RH1            36409     3079      8.5%
RH2            36409    18298     50.3%
WIND1          36409    18001     49.4%
BP1            36409    18582     51.0%
RAIN1         364090   166357     45.7%
SWR1          364090   180008     49.4%
LWR1          364090   158219     43.5%

Subsurface Temperature Profile
     1m        36409    27575     75.7%
     5m        36409    36409    100.0%
    10m        36409    36409    100.0%
    14m        36409    36409    100.0%
    20m        36409    36409    100.0%
    25m        36409     1061      2.9%
    30m        36409    36409    100.0%
    37m        36409    36409    100.0%
    45m        36409    36409    100.0%
    60m        36409    36409    100.0%
    80m        36409    36409    100.0%
   100m        36409    36409    100.0%
   120m        36409    36409    100.0%
   150m        36409    36409    100.0%
   175m        36409    36409    100.0%
   200m        36409    36409    100.0%
   300m        36409    36409    100.0%
  4174m        36409    36409    100.0%
  Total       655362   611180     93.3%

Subsurface Pressure Profile
   175m        36409    36409    100.0%
   300m        36409    36409    100.0%
  4174m        36409    36409    100.0%
  Total       109227   109227    100.0%

Subsurface Conductivity Profile
     1m        36409    21941     60.3%
```

5m	36409	36409	100.0%
10m	36409	36409	100.0%
14m	36409	36409	100.0%
20m	36409	36409	100.0%
25m	36409	0	0.0%
30m	36409	36409	100.0%
37m	36409	36409	100.0%
45m	36409	36409	100.0%
60m	36409	36409	100.0%
80m	36409	36409	100.0%
100m	36409	36409	100.0%
120m	36409	36409	100.0%
150m	36409	36409	100.0%
175m	36409	36409	100.0%
200m	36409	36409	100.0%
300m	36409	36409	100.0%
4174m	36409	36409	100.0%
Total	655362	604485	92.2%

Subsurface Salinity Profile

1m	36409	21941	60.3%
5m	36409	36409	100.0%
10m	36409	36409	100.0%
14m	36409	36409	100.0%
20m	36409	36409	100.0%
25m	36409	0	0.0%
30m	36409	36409	100.0%
37m	36409	36409	100.0%
45m	36409	36409	100.0%
60m	36409	36409	100.0%
80m	36409	36409	100.0%
100m	36409	36409	100.0%
120m	36409	36409	100.0%
150m	36409	36409	100.0%
175m	36409	36409	100.0%
200m	36409	36409	100.0%
300m	36409	36409	100.0%
4174m	36409	36409	100.0%
Total	655362	604485	92.2%

AQD Current Velocity

15m	36409	36409	100.0%
35m	36409	36409	100.0%
Total	72818	72818	100.0%

TFlex 2001:

Data Return Summary
2020-08-15 23:27:00 to 2021-04-25 19:36:00

Sensor	Deployed	Obs	Return
AT1	36409	25907	71.2%
RH1	36409	25907	71.2%
WIND1	36409	18943	52.0%
BP1	36409	29677	81.5%
RAIN1	364090	293117	80.5%
SWR1	364090	294088	80.8%
LWR1	364090	294744	81.0%
SST1	36409	34361	94.4%
SSC1	36409	34361	94.4%
SSS1	36409	34361	94.4%

2.3 Known Sensor Issues

PA014 surface data contained more gaps, spikes, and noise than most previous deployments, requiring additional quality control. The Flex system failed early due to water intrusion into the buoy well, with the water approximately 1 ft in depth upon recovery. Surprisingly, all batteries and the Flex system itself were in working condition upon recovery, but condensation on the walls of the buoy well had corroded the faceplate connector, severing the connection between the sensors and the Flex system. Most of these failures were staggered, occurring 1-2 sensors at a time between 12/15/2020 and 1/20/2021. The TFlex system lasted throughout the deployment, but was plagued by resets, resulting in gaps in the latter half of the record. The combined failures prompted an early-season turnaround in 2021, and explain the reduced surface data returns.

Abrasive marks on the buoy's aluminum tower were noted during recovery, indicative of a ship having tied up to the mooring. Some rope-caused wear on the tower leg that holds the TFlex cables could have contributed to lower data returns. The wind and radiation cables within the tower leg had worn to the point of exposing the individual, internal wires, but only the data returns from the wind sensor were noticeably shorter. Since the TFlex system resets tended to impact data returns with relative uniformity across all variables, it's suspected that the physical cable damage contributed more to the reduced wind returns. Overall, the wind sensors performed well within the context of the system failures, with Flex winds ending 12/29/20 and TFlex winds ending 12/27/20. With slightly higher data return statistics, the TFlex winds were designated primary. Standard intercomparison procedures eliminated gross errors, and a moderate amount of flagging was required.

The most visible evidence of human interference was a missing radar reflector and 2 missing ATRH sensors (a Flex MP101 and a Hygroclip, on opposing sides of the buoy). Substantial force would have been required to break the newly-strengthened ATRH mounts and nearby welds. The sole remaining TFlex ATRH passed its post-calibrations and was considered primary, although a repair was required prior to the post-calibration, as the calibration report noted a hygrometer lead had separated from a solder joint.

The Flex relative humidity sensor was biased slightly high (but within accuracy specifications) from the start of the deployment until it spiked to ~110% and became unreliable in early September 2020. The Flex air temperature was ~0.2 degrees higher than the TFlex air temperatures at the time, and was also flagged Q5 after early September. Large spikes in temperature to 59.1°C, an apparent electronic output maximum for this sensor, were flagged in November and December 2020, and additional flagging details can be found in the air temperature and relative humidity sections below.

Barometric pressure was measured by a Flex Paros and TFlex GE8100 TERPS sensor. Few issues presented in the pressure records, aside from gaps aligning with the respective acquisition system failures (Flex ended 12/25/2020; TFlex persisted through recovery, with some missing data attributed to system resets).

Rain accumulation data were particularly noisy on PA014. Interpolation was performed over regions where confidence was high that accumulations were flat between gaps in the record, with corresponding Q3 (adjusted) flags assigned. Minor manual adjustments (also flagged Q3) were required where accumulations were starkly discontinuous, possibly due to waves splashing into the catchment or pre-mature siphoning. Most of the primary TFlex rain rate record was recovered from intermittent accumulation data, but some accumulations in the final months could not be confidently corrected, as interpolation over gaps where accumulation occurs would artificially smooth rain rates, degrading data quality. The secondary rain data ended 12/15/2020, and both rain sensors failed their post-calibration in their as-received conditions at the lab, but were later returned to service after cleanup, re-calibration, and bench testing. The calibration report also stated that instability in the accumulation output of the Flex rain gauge was resolved after a new sensor tube was installed.

Both radiation records showed more spikes than typical. Gross error thresholds filtered out unrealistic data, and manual quality control measures located isolated spikes outside of their seasonal context. Though missing data points were scattered throughout the TFlex radiation records due to system resets, data extended to the end of the deployment. The Flex longwave records ended 12/15/2020 and shortwave records terminated about a month later, on 1/20/2021.

3.0 Data Processing

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

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

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

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

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

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

3.1 Buoy Positions

Since Papa is a taut-line mooring with a short scope, the buoy has a watch circle radius of 1.25km. When using Papa data in scientific analyses, the nominal position is usually adequate. For users wanting additional accuracy, the more accurate positions from the GPS are also provided at their native resolution. Gross error checking was performed to eliminate values outside the watch circle, but no further processing was performed.

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

3.2 Meteorological Data

The flooding of the buoy well and TFlex resets limited surface meteorological data returns on PA014. Downloaded data returns were comparable to those observed in realtime.

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 PA014 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

The acquisition of wind data was limited by the flooding and faceplate corrosion within the buoy well and the TFlex issue with constant resets. Heavier flagging became necessary starting in December 2020, as the systems deteriorated and automated thresholds were triggered with increasing frequency. Most notably, averaged speeds began exceeding the reported 3-second gust more often within a given burst sample, indicating that one of the two values was incorrect. A few scattered TFlex wind data points were recorded later on (e.g. March 2021), but were flagged and removed, being both lower values than climatology would suggest and out of context with the consistent records earlier in the deployment.

3.2.2 Air Temperature

The air temperature records had several issues shown in the plot below. With a high bias of ~0.2°C in the Flex air temperature measurement along with the Flex relative humidity spiking to unrealistic values >105% after 9/6/20, the Flex MP101 was designated the secondary sensor and Q5 flags were applied when the sensor began failing. Gross high spikes in the Flex air temperature data were observed later in the record (particularly in December 2020), and were flagged Q5 and removed accordingly.

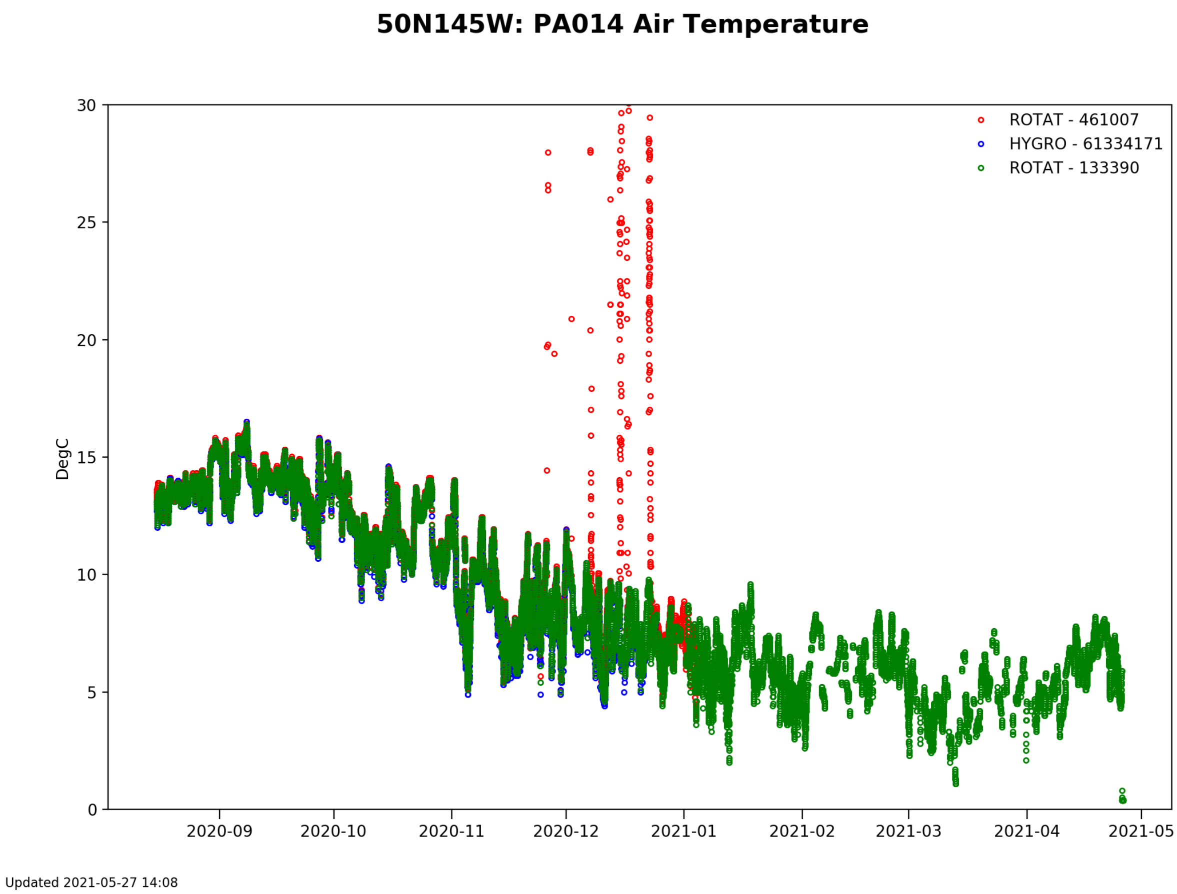

Figure 5: High-resolution air temperature time series (pre-flagging).

The primary TFlex sensor was assigned standard Q2 quality flags, but Q5 flags were applied as needed in the latter part of the record. A large percentage of data points were missing starting in February 2021 due to TFlex resets, and values outside of climatological norms were flagged Q5, including the particularly unrealistic air temperature drop to ~0.5°C in late April on the right side of Figure 5.

3.2.3 Relative Humidity

The MP101 instrument measures both air temperature and relative humidity from within the same housing, so issues often present simultaneously in both time series. As an example, the high Flex air temperature spikes shown above were aligned with the low relative humidity spikes shown below in December 2020, both of which are flagged Q5. Other features flagged Q5 in the distributed record include the high relative humidity spikes (exceeding 100%) early in the Flex time series, and the region of TFlex relative humidity that plummeted below seasonally plausible values <50% in March 2021. The subplots below show the time series, difference plot, and a Flex/TFlex scatterplot prior to flagging.

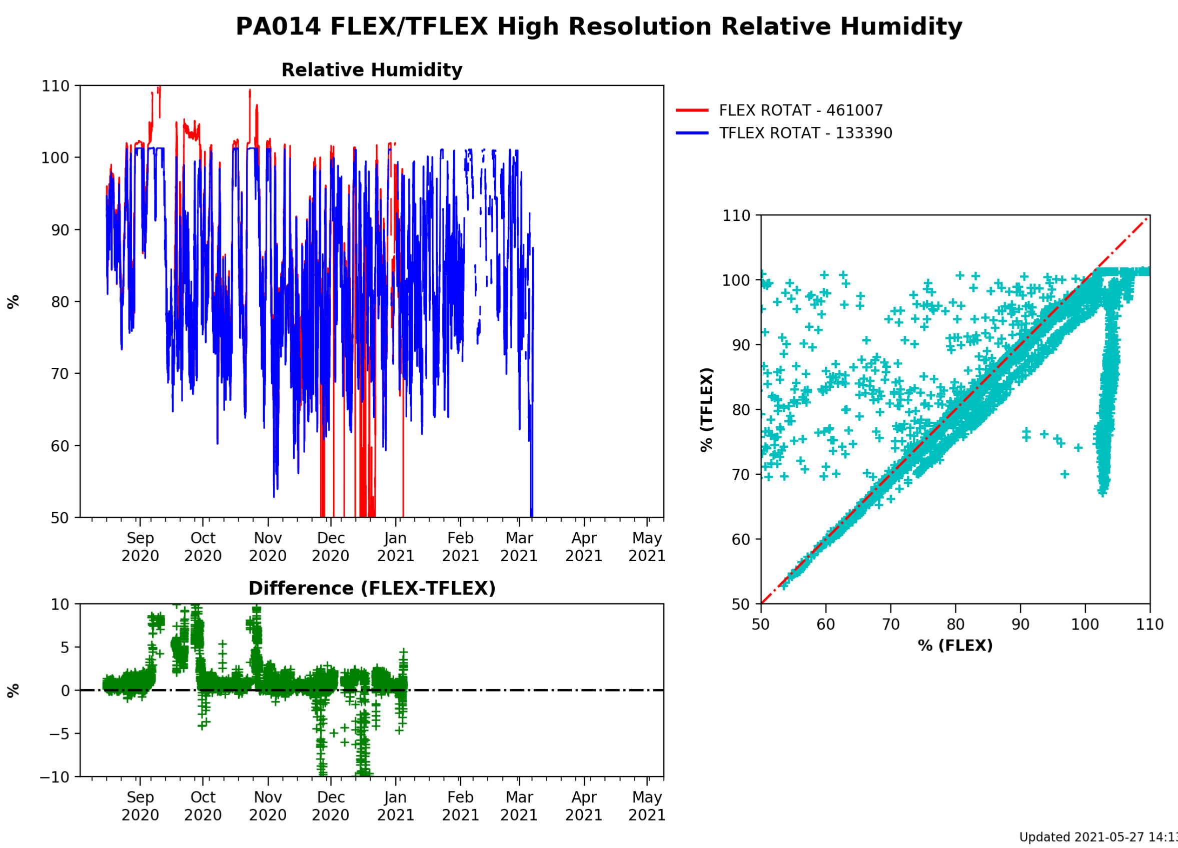

Figure 6: High-resolution relative humidity time series (pre-flagging).

3.2.4 Barometric Pressure

Barometric pressure was measured by a Paros (Flex) and a GE8100 TERPS (TFlex) sensor, which both performed well during the operation of their parent acquisition systems. The mode of the difference between the measured Flex and TFlex pressures was 0.1°C, right at the accuracy specification of the two sensors, and standard Q2 flags were applied to the primary and secondary sensors.

While the Paros is typically the superior sensor, the TERPS sensor was a) more continuous with data in the surrounding deployments, and b) had a longer record, so was considered primary. The Flex Paros failed 12/25/2020, with automated thresholds applying Q4 flags to questionable data, and Q5 flags where gross error thresholds were exceeded in the months leading up to the failure. This trend toward lower quality data can be seen in the difference plot below, with Flex-TFlex differences falling into a relatively tight ~0.4hPa vertical range at the start of the deployment and becoming noisier and ending in December 2020 with Flex-TFlex differences in a ~1.5hPa vertical range.

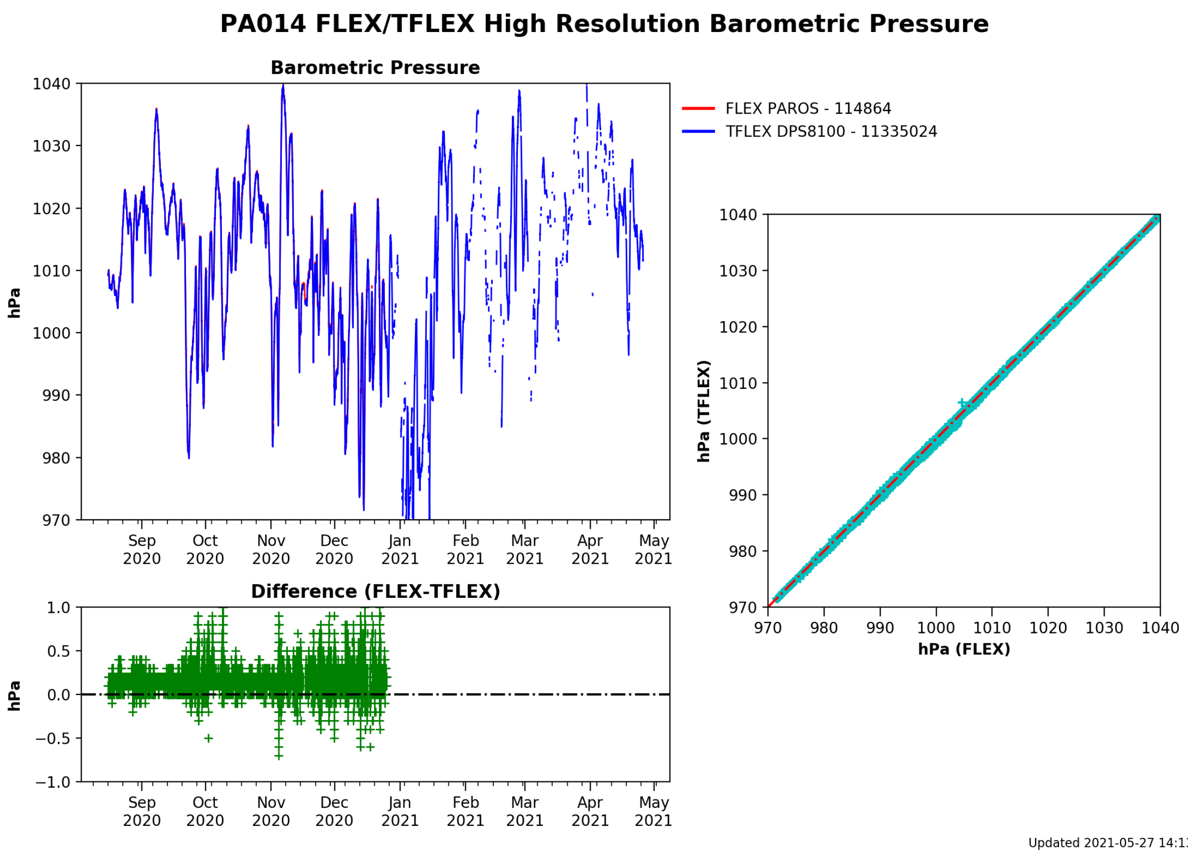

Figure 7: High-resolution barometric pressure time series (pre-flagging).

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.

Rain data processing uses scripts to detect siphons and other events. The TFlex rain gauge accumulations were noisier than usual, requiring occasional interpolation, adjustments, and flagging near siphons to extract true rain rates. The noise may be electronic in nature, as spikes in accumulation occurred semi-regularly at HH:M6:32.

3.2.6 Shortwave Radiation

Kelly Balmes established the selection criteria for primary and secondary radiation sensors. Mean daily Flex and TFlex SWR values were compared, and found to differ by <0.1%. 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 PA014 TFlex SWR was made primary on account of its longer record.

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 PA014 TFlex LWR was primary.

3.3 Subsurface Data

All OCS subsurface instrumentation was connected inductively to the Flex system, except for the instrument attached to the acoustic release. General comments and clock errors from each recovered subsurface instrument are summarized in a snapshot of the FileMaker log (Figure 8). Positive clock errors were most common, meaning the instrument drifted ahead of the actual time. Measurements were mapped to the nearest 10-minute time increment.

The most notable clock errors were from two instruments (SN 11552 and SN 7789 – the Flex SSTC and the 45m TC) which had 1-hour offsets, indicative of a timezone issue during setup. The timestamps for these instruments were shifted during post-processing to correctly align all records in the distributed files.

Type	Serial	Real Time	Inst Time	Clock Error
SBE37-TC-SMP	12520	20:51:00	20:51:00	0:00:00
SBE37-TC-SMP	11552	17:45:20	18:45:20	1:00:00
SBE37-TC-IMP	21431	6:07:55	6:07:38	-0:00:17
SBE37-TC-IMP	21429	6:14:30	6:14:21	-0:00:09
SBE37-TC-IMP	21428	5:55:55	5:55:48	-0:00:07
SBE37-TC-IMP	16836	5:51:00	5:50:33	-0:00:27
SBE37-TC-IMP	7793	4:40:50	4:41:20	0:00:30
SBE37-TC-IMP	7791	5:03:30	5:03:48	0:00:18
SBE37-TC-IMP	7790	4:26:05	4:26:23	0:00:18
SBE37-TC-IMP	7789	4:47:00	5:47:23	1:00:23
SBE37-TC-IMP	7787	3:28:30	3:28:59	0:00:29
SBE37-TC-IMP	7786	3:23:25	3:23:42	0:00:17
SBE37-TC-IMP	6145	3:08:45	3:08:59	0:00:14
SBE37-TC-IMP	6142	5:32:20	5:32:42	0:00:22
SBE37-TC-IMP	6141	4:58:50	4:59:11	0:00:21
SBE37-TCP	7107	4:02:15	4:02:34	0:00:19
SBE37-TC-IMP	7792	5:07:20	5:07:42	0:00:22
SBE37-TCP	7092	4:50:00	4:50:29	0:00:29
SBE37-TCP	11926	2:34:20	2:34:24	0:00:04

Figure 8: Filemaker log displaying all instrument clock errors.

3.3.1 Temperature

High-resolution temperatures are provided at the original 10-minute sampling increment of the Seabird sensors, as well as at hourly and daily resolutions. Temperatures are rarely corrected based on post-calibrations, and no corrections were required for this deployment.

3.3.2 Pressure

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

<u>Salinity Drifts in PSU (post-pre):</u>

Depth:	**Drift:**
1m (TFlex)	0.0029
1m (Flex)	0.0007
5m	0.0026**
10m	-0.0037
14m	0.0016
20m	-0.0099
25m	N/A (instrument reported incorrect salinity shortly after deployment)
30m	-0.0001
37m	-0.0039
45m	N/A (no post-cal)
60m	-0.0101
80m	-0.0054
100m	-0.0026
120m	-0.0029
150m	-0.0054
175m	0.0077**
200m	-0.0041
300m	0.0082**

** Upgraded on PA014 from SBE39 TP to SBE37 TCP, newly adding salinity at these depths.

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

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

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

While the PA014 subsurface data returns were fairly high, a few issues were noted during post-processing:

- TFlex SSTC records ended 4/12/2021 (low batt), ~2 weeks prior to recovery, but were considered primary, as the record length exceeds that of the Flex SSTC.

- Flex SSTC reported extremely low conductivity values from deployment until data returned to climatological values from 9/24/2020 at 2:30 UTC until batteries failed after a final data point on 2/24/2021 at 2:20 UTC. This failure mode has been witnessed before, and is usually attributed to bubbles getting trapped in the conductivity cell.

- 25m failed just 1 week into the deployment, with the final recorded temperature value taken on 8/23/2020 at 12:40 UTC. This instrument also reported out of range conductivity starting in the middle of the deployment day (8/15/2020 at 19:10 UTC), so all conductivity data were flagged Q5 (unusable).

- 45m had complete records, but no post-cal was available, as the instrument was sent as a spare on a subsequent mission. Assigned Q2 (standard, no post-cal) quality flags.

Manual Salinity Adjustments

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

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

However, based on manual review of the data against neighboring instruments, no adjustments from the density-intercomparison were needed on PA014, as water at each depth remained stable or neutrally stratified throughout the year.

3.3.4 Deep SBE Data

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

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

The deep T/S data are shown in appendix plot B5. For the deep T/S instrument, calibration differences can overwhelm the natural variability throughout the year, so calibrations are averaged to avoid falsely inducing a slope across the year. This approach has also shown promise in making deployment-to-deployment transitions smoother, although some small differences are expected between the two Papa deployment sites and the depth at which the instrument ultimately settles.

3.3.5 Currents (Nortek Aquadopp)

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

Since PA014 was a taut-line mooring, Aquadopp current meter data were not corrected for the buoy's negligible horizontal movement. However, buoy motions are provided alongside Aquadopp data for users wanting to add buoy motion to measured velocities.

A magnetic declination correction of +15 degrees is added to the current meters in post-processing. Both current meters on PA014 had 100% data returns, and were processed using new routines that allow data processing directly from the instrument output files.

3.3.6 Acoustic Doppler Current Profiler (Aquadopp Profiler)

An upward-looking Aquadopp Profiler was deployed for the fourth time on the PA014 mooring, at a depth of 55m. To process the data, 3 corrections were applied: declination (+15 degrees), tilt correction, and head depth adjustment. Aquadopps do not have an internal setting for declination, so this correction to true heading is applied first in post-processing. Tilt correction, also called "bin-mapping," is then computed using a conversion between Earth and Beam coordinates, taking samples along each beam where it most nearly pierces defined horizontal slices of the water column. Tilts over 20 degrees are eliminated (Q5), as the manufacturer considers data beyond this threshold unusable. A head depth adjustment is needed for the profiler, as its vertical position varies slightly, unlike a bridle-mounted ADCP. The data are then regridded using linear interpolation. Buoy-motion, which can be optionally added to U/V currents, is provided in the NetCDF file.

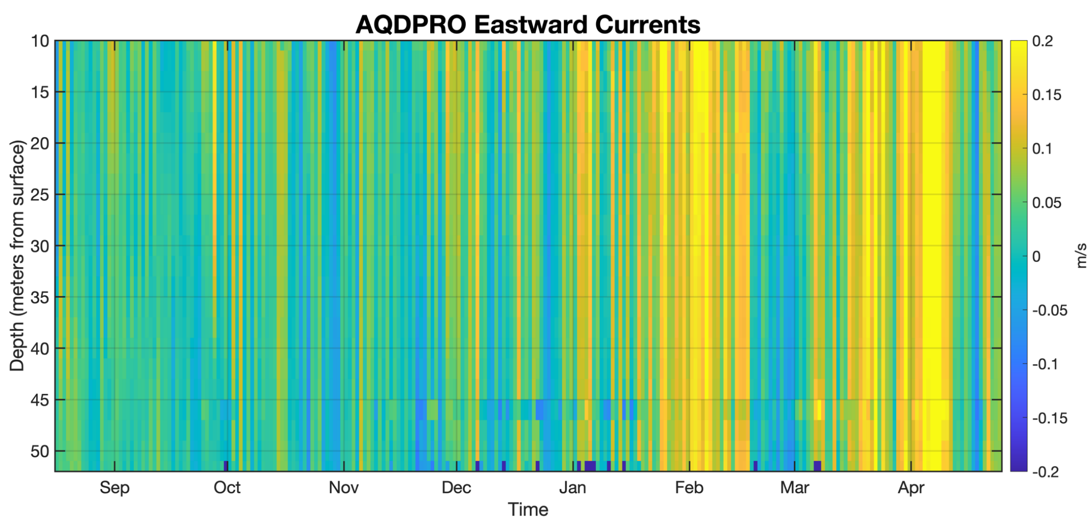

Figure 9: Aquadopp Profiler eastward velocities.

3.3.7 Test Sensor (Signature 500 ADCP)

PA014 was the first deployment to have phased out the Sentinel ADCP, and another downward-looking ADCP was deployed in its place. The new instrument, a Nortek Signature 500 on loan from the manufacturer (Nortek), is currently considered a test sensor, and an OCS outlier in terms of sampling rates (1Hz pings for 25 minutes every half hour), data handling (performed using Nortek's Ocean Contour software to date), data quantity (~50 GB for a few months of data), and scientific aims (looking at ocean bubbles in the surface layer caused by wind and wave action).

Minimally processed netCDF files from the Signature 500 are handed off to OCS partners, who are responsible for any further processing or distribution. The Applied Physics Lab at the University of Washington (UW/APL) is primarily interested in this data for studying water column bubbles and diel vertical migration. On future deployments, a combination of OCS-owned and UW/APL-owned Signature 500s will be utilized.

If the sensor is proven in the field and its data can be averaged to match standard OCS sampling, we reserve the possibility of serving Signature 500 data as a backup, should the primary Nortek Aquadopp Profiler fail.

4.0 References

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

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

Serra, Y.L., P.A'Hearn, H.P. Freitag, and M.J. McPhaden, 2001: ATLAS self-siphoning rain gauge error estimates. J. Atmos. Ocean. Tech., 18, 1989-2002.

5.0 Acknowledgements

The OCS project office is grateful for the flexibility and expertise demonstrated aboard the NOAA ship OSCAR DYSON, which allowed for the deployment of the PA014 mooring without OCS personnel aboard at the start of the COVID pandemic. The captain and crew of the DYSON are acknowledged for their successful execution of the mission and ability to adapt to ever-changing conditions. P. Berk and N. Anderson (both of UW CICOES) joined the PA014 recovery cruise, which was also conducted aboard the OSCAR DYSON, and all members aboard the ship are recognized for their teamwork in conducting 5 different mooring operations during a short 30 hours on station.

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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

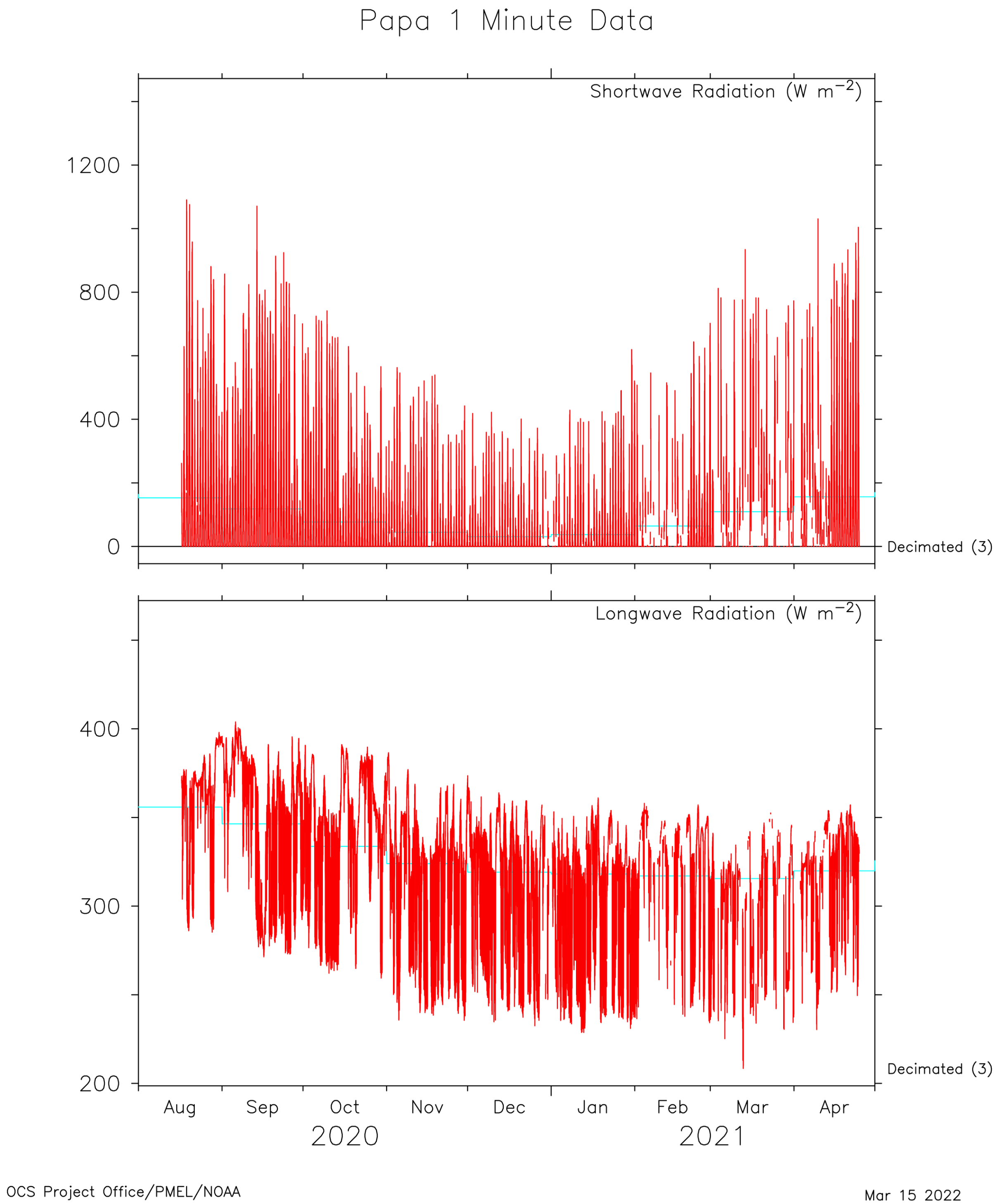

Figure B 1: PA014 primary shortwave and longwave radiation data at 1-min resolution (TFlex).

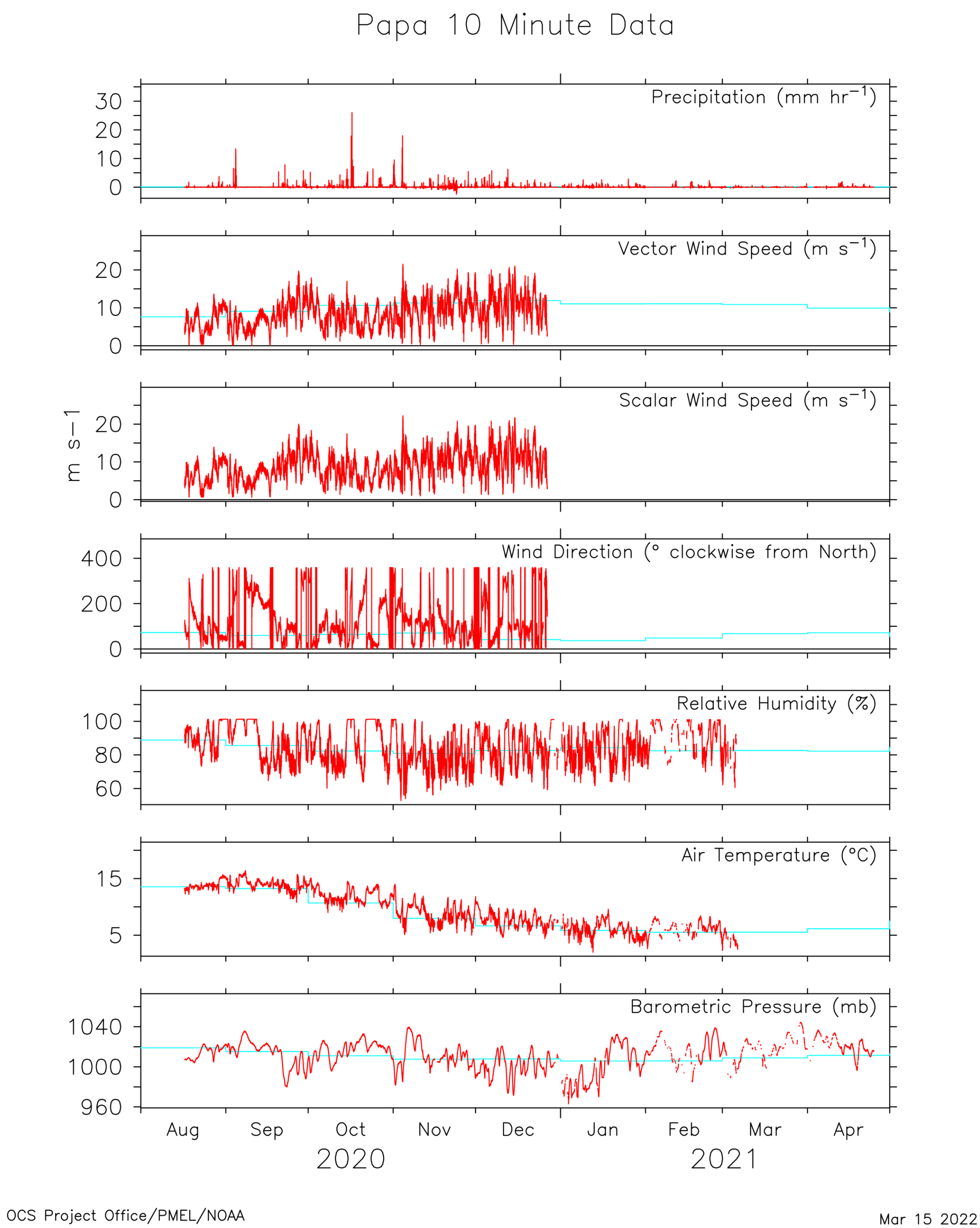

Figure B 2: PA014 meteorological data at 10-min resolution (all TFlex).

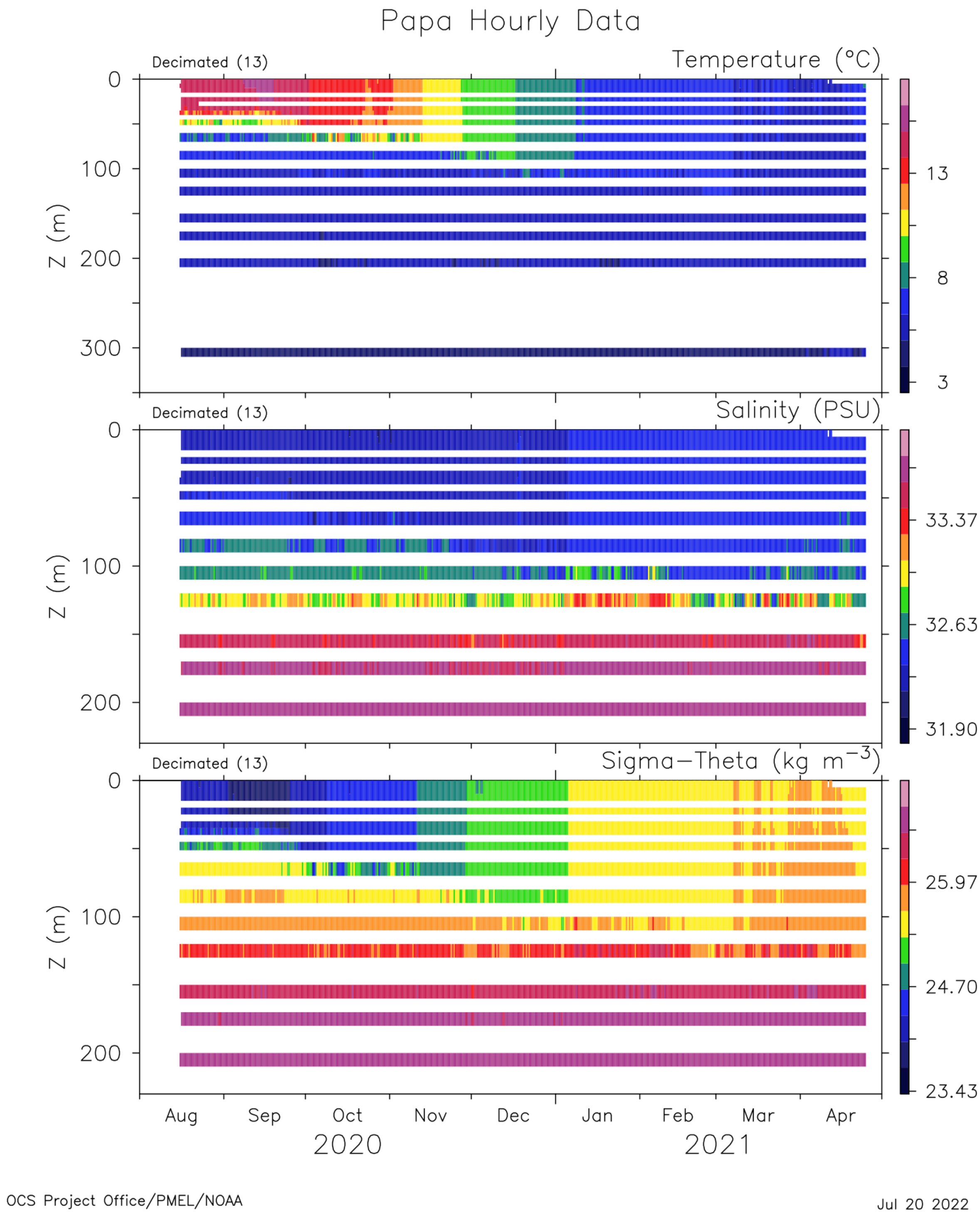

Figure B 3: PA014 subsurface temperature, salinity, and density at hourly resolution (decimated).

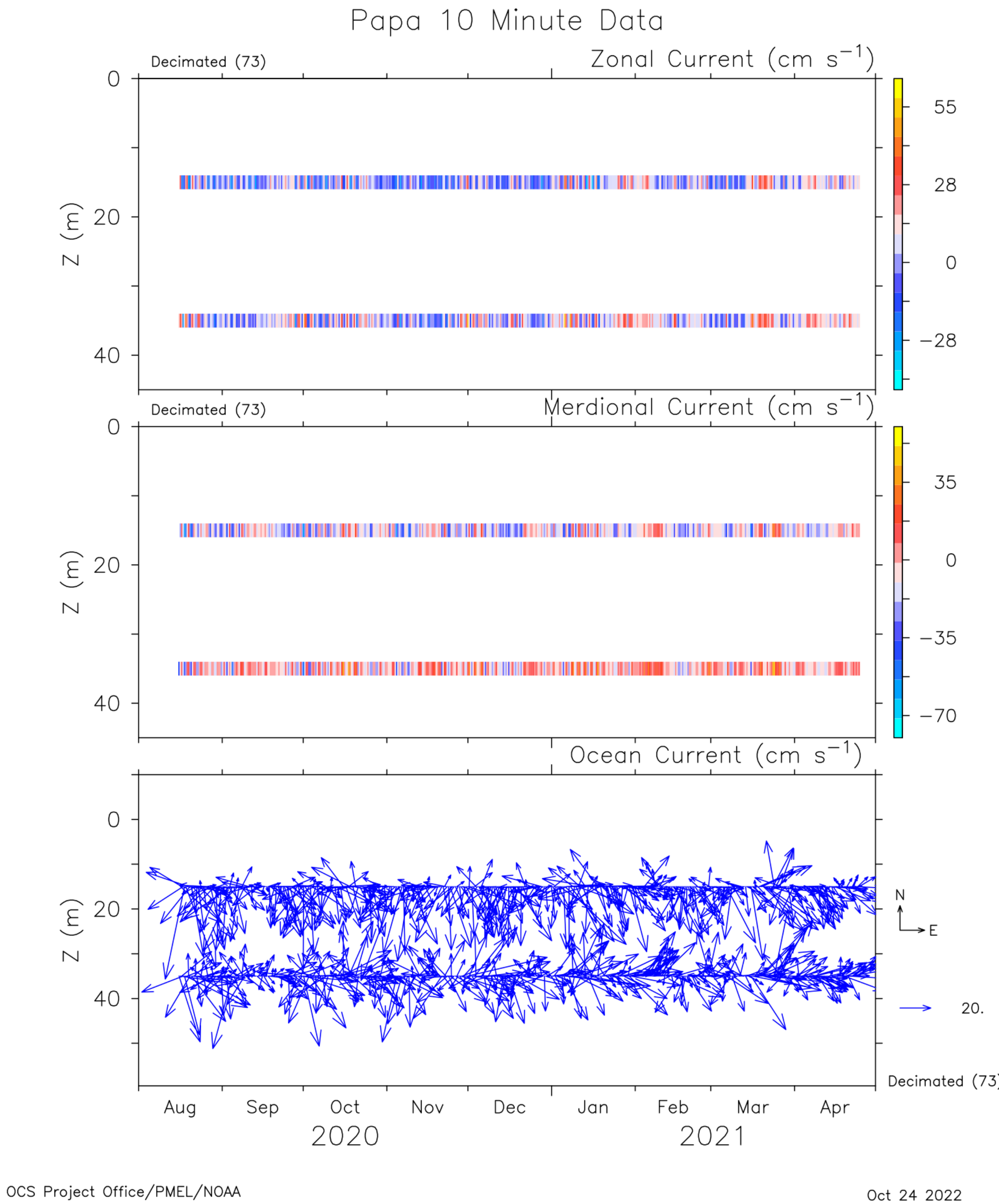

Figure B 4: PA014 Aquadopp current meter data.

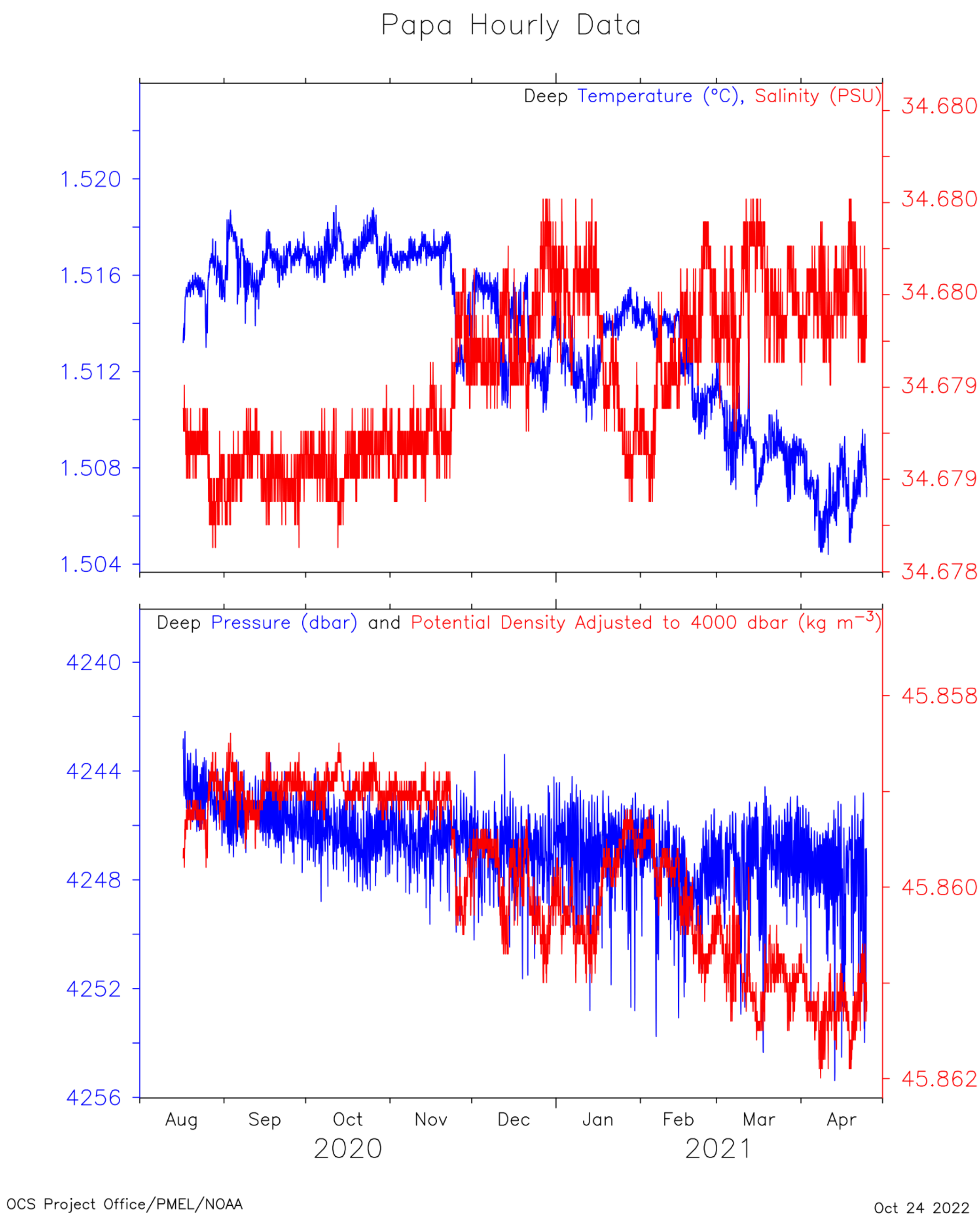

Figure B 5: Deep Seabird temperature, salinity, pressure, and density.

APPENDIX C: Secondary Instrument High Resolution Data Plots

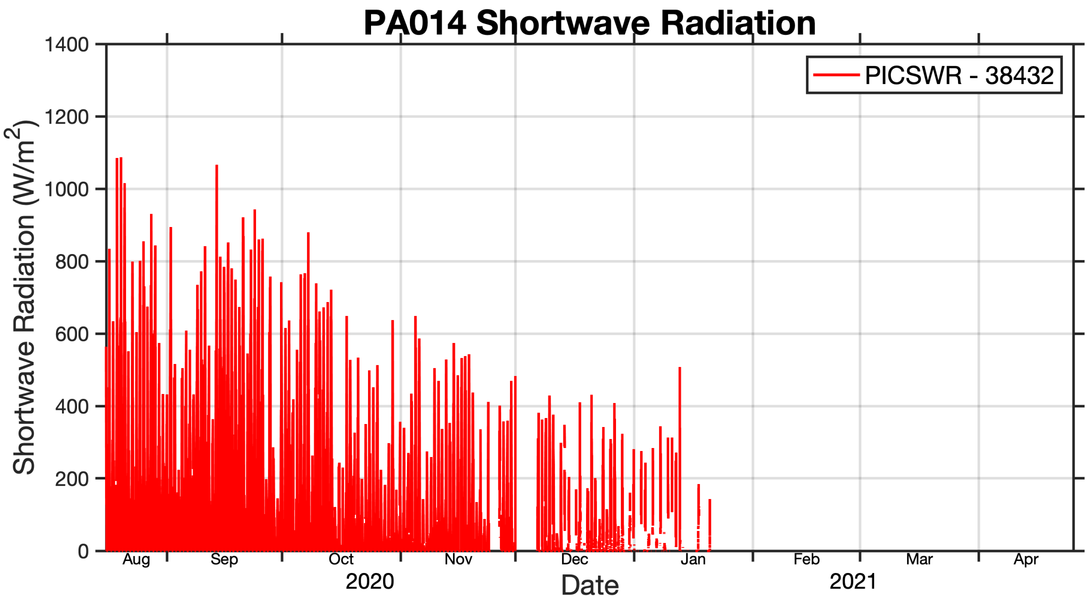

Figure C 1: Secondary (Flex Eppley PSP) shortwave radiation sensor.

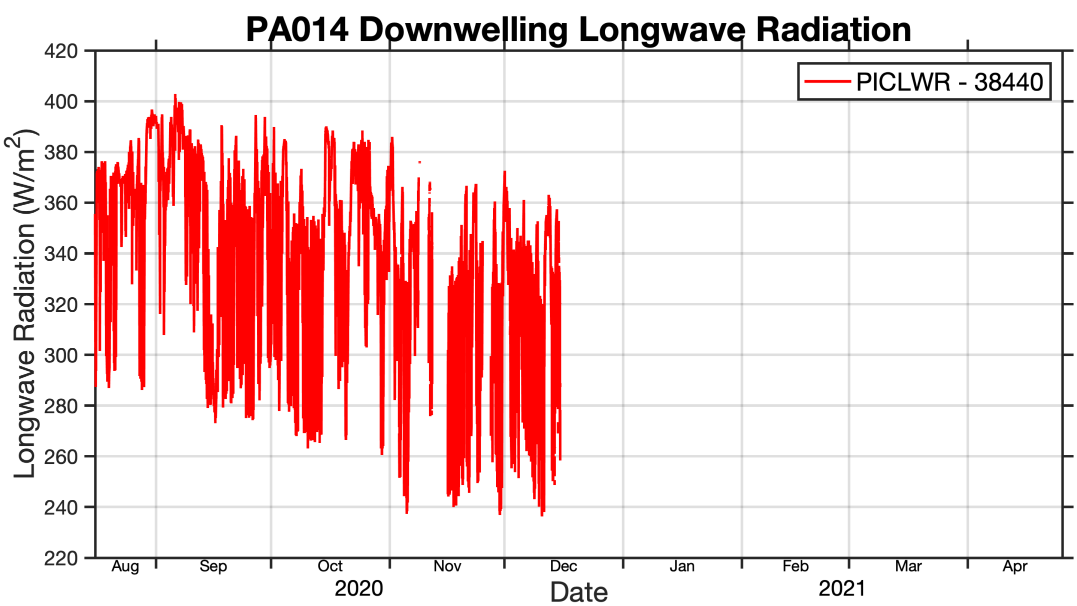

Figure C 2: Secondary (Flex Eppley PIR) longwave radiation sensor.

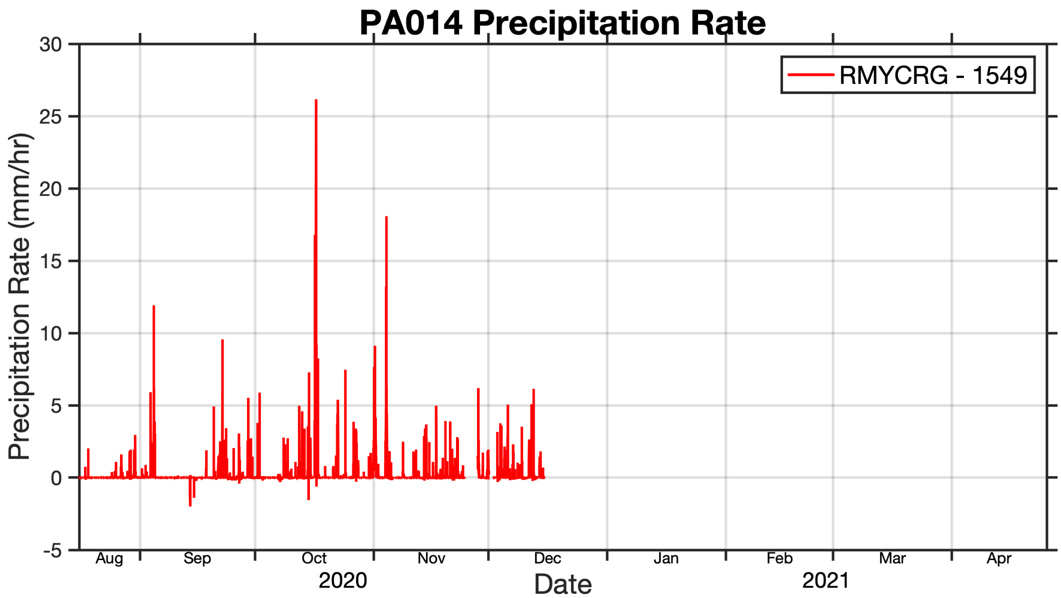

Figure C 3: Secondary (Flex RM Young) rain sensor.

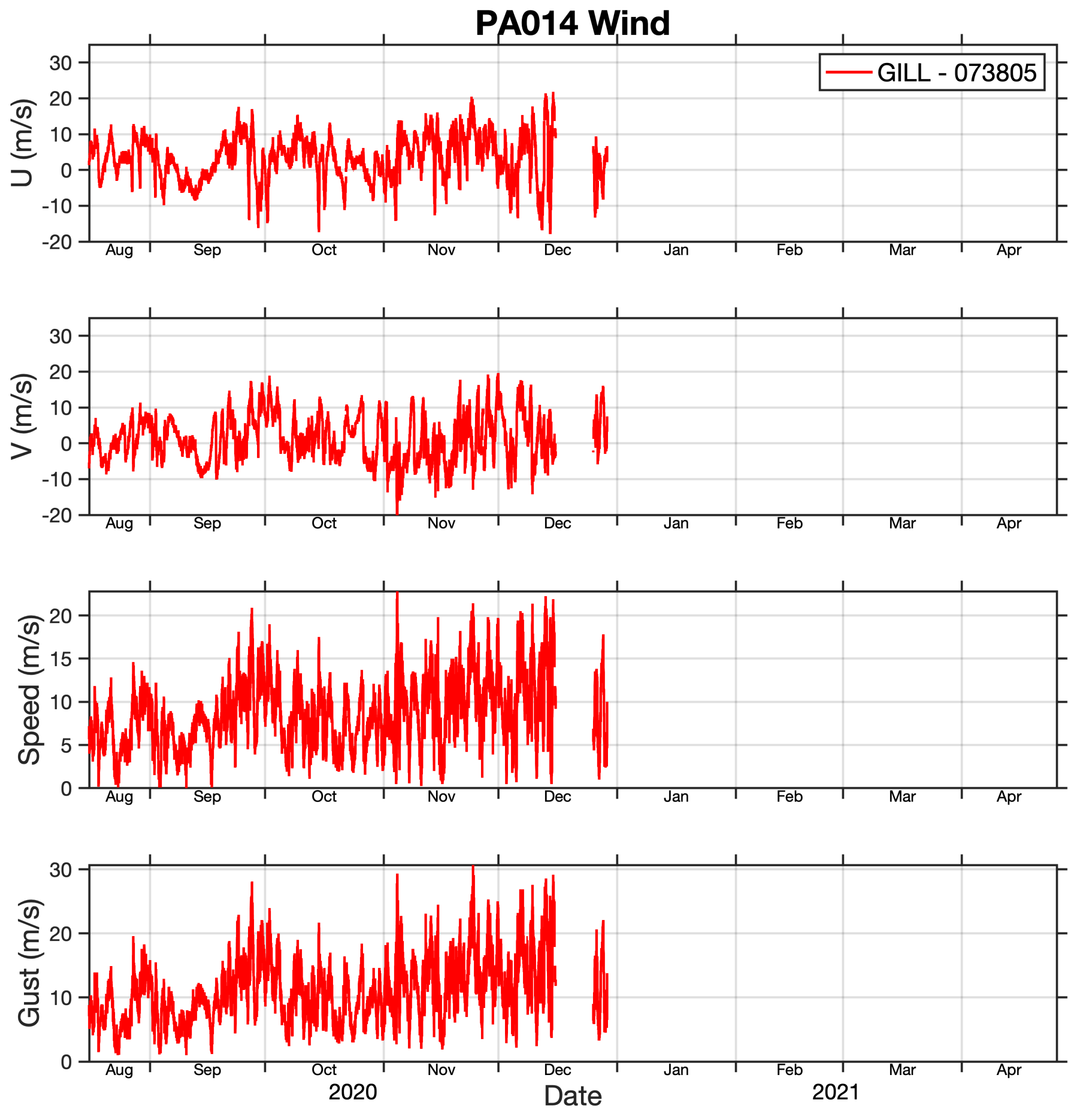

Figure C 4: Secondary (Flex Gill) wind sensor.

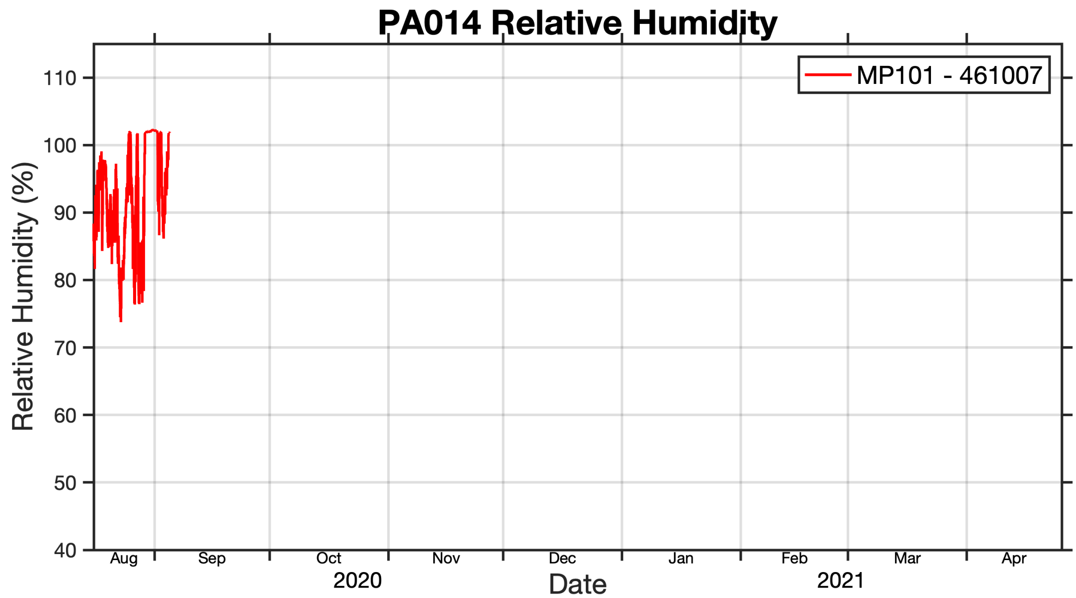

Figure C 5: Secondary (Flex MP101) relative humidity sensor.

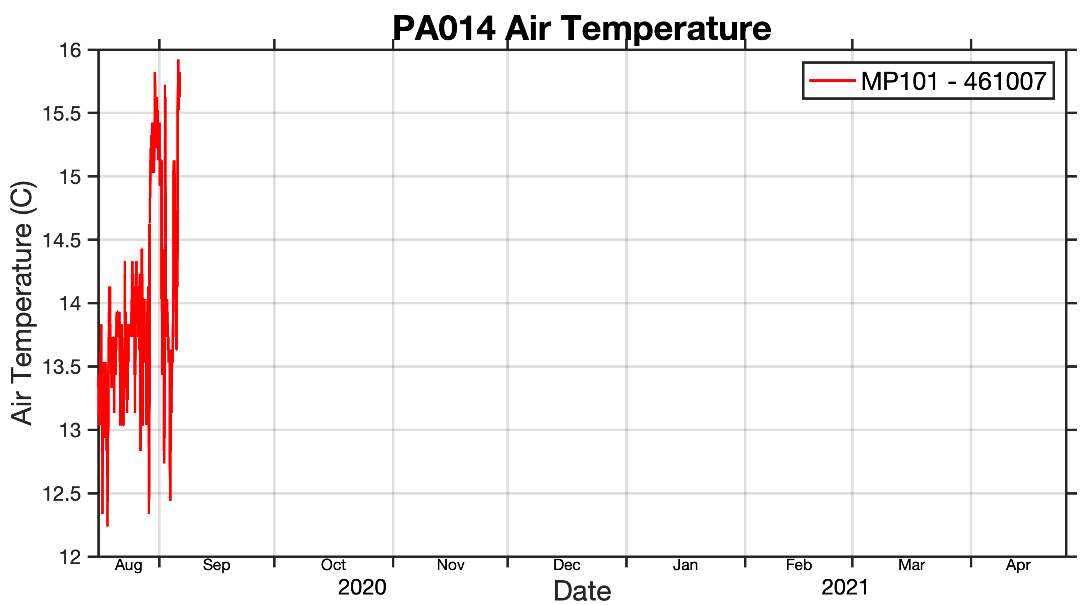

Figure C 6: Secondary (Flex MP101) air temperature sensor.

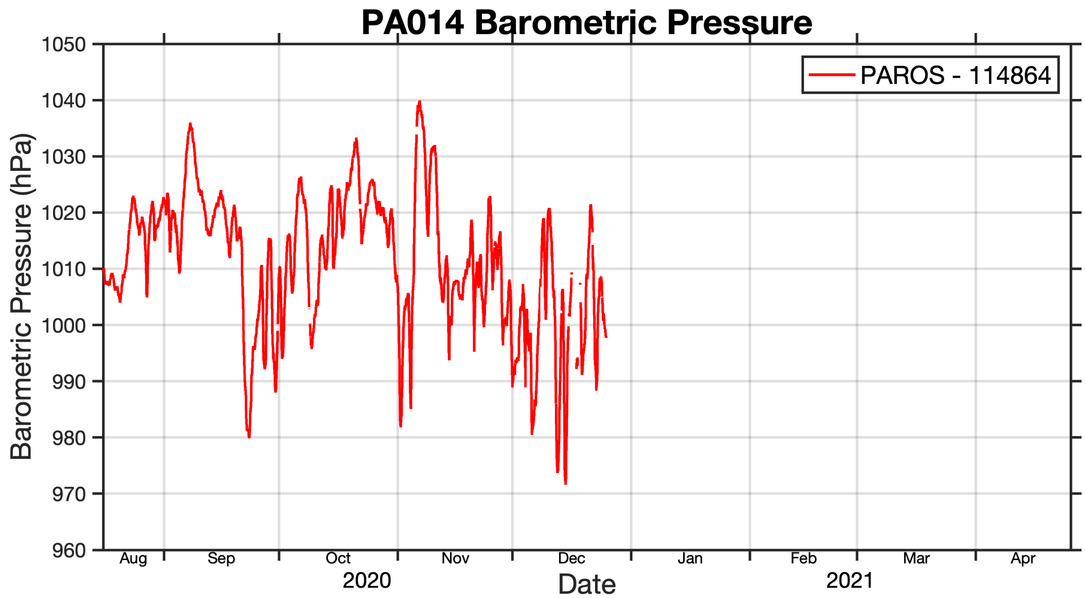

Figure C 7: Secondary (TFlex Paros) barometric pressure sensor.

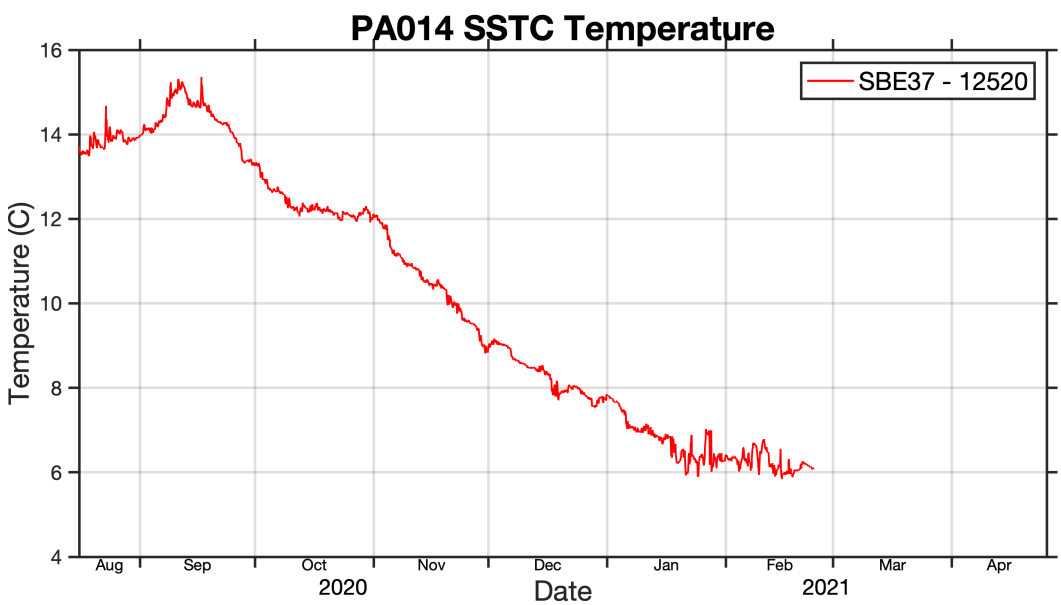

Figure C 8: Secondary (Flex) SSTC Temperature.

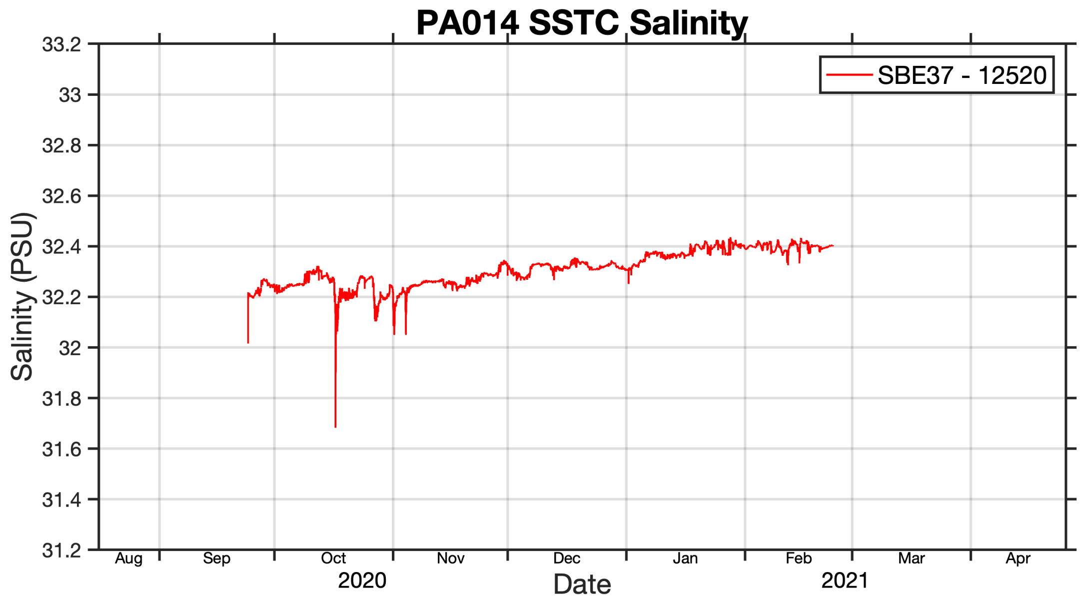

Figure C 9: Secondary (Flex) SSTC Salinity. Conductivity, salinity, and density data in the first month were flagged Q5, as values were outside of climatological norms (~15 PSU). The SSTC's batteries failed in February. The low spikes that remain in the record here are corroborated by the primary SSTC, so are believed to reflect the actual surface state, with the largest spike coinciding with the mid-October rain maximum.

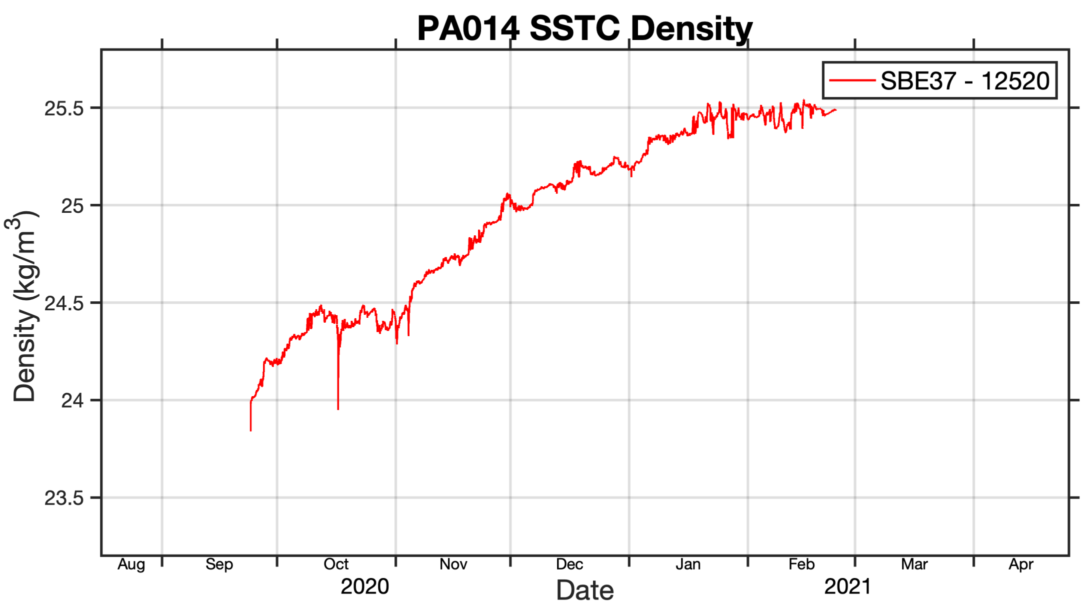

Figure C 10: Secondary (Flex) SSTC Density.