NOAA Pacific Marine Environmental Laboratory
Ocean Climate Stations Project

DATA ACQUISITION AND PROCESSING REPORT FOR PA015

Site Name:	Ocean Station Papa
Deployment Number:	**PA015**
Year Established:	2007
Nominal Location:	50.1°N 144.9°W
Anchor Position:	50° 7.98’ N, 144° 49.56’ W (anchor drop)
Deployment Date:	April 25th, 2021
Recovery Date:	May 24th, 2022
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:	5/16/2023
Revision History:	Started 4/19/2021

Special Notes: Delayed-mode meteorological data were unrecoverable due to acquisition system damage, but realtime hourly data are available. Secondary rain and wind instruments were damaged during deployment, and were swapped out for spares April 25, 2021.

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Data Acquisition and Processing Report for OCS Mooring PA015

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. PA015 was the fifteenth deployment at this site.

The PA015 mooring was deployed on April 25th, 2021 from the NOAA ship R/V OSCAR DYSON. Recovery was performed on May 25th, 2022 by the R/V SIKULIAQ. The Ocean Climate Stations group would like to thank the captain and crew of both ships, as well as the supporting scientists, for their contributions to the success and maintenance of the Papa mooring.

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

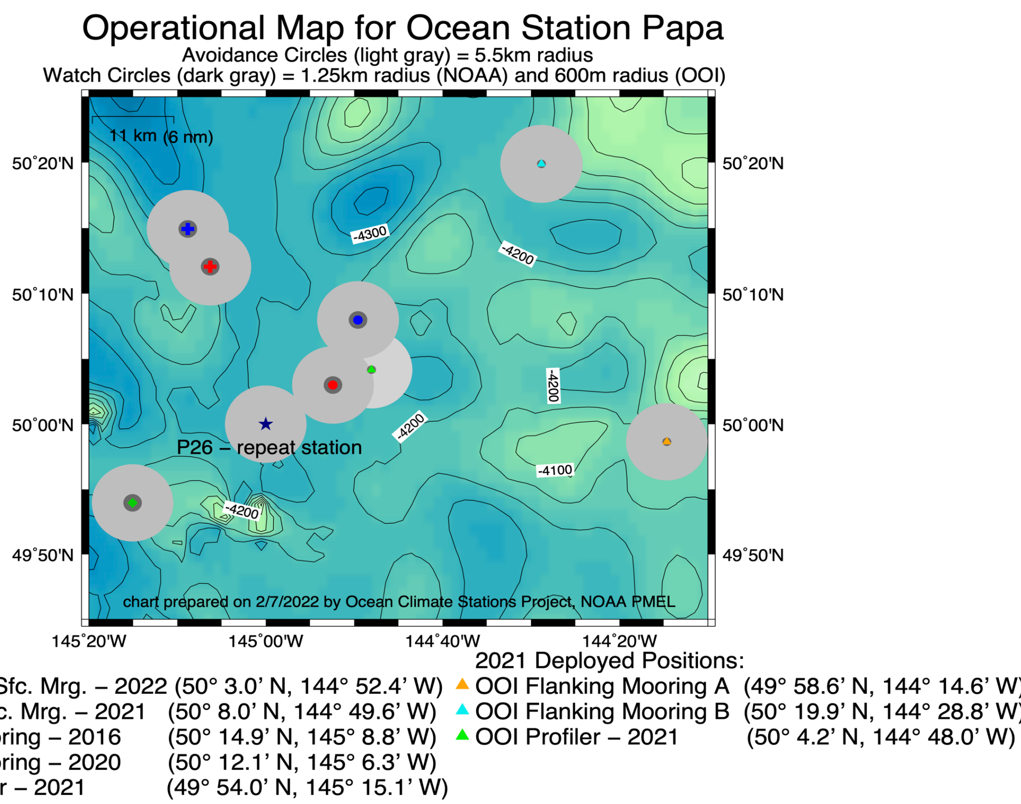

Figure 1: Overview of Station P moorings while PA015 was deployed.

1.1 Mooring Description

The PA015 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. 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 (PI: Dr. Adrienne Sutton) contributed an SBE16 package (with attached oxygen sensor and fluorometer) and a SAMI pH sensor mounted on the buoy bridle, along with their primary CO_2 flux monitoring system housed in the buoy 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).

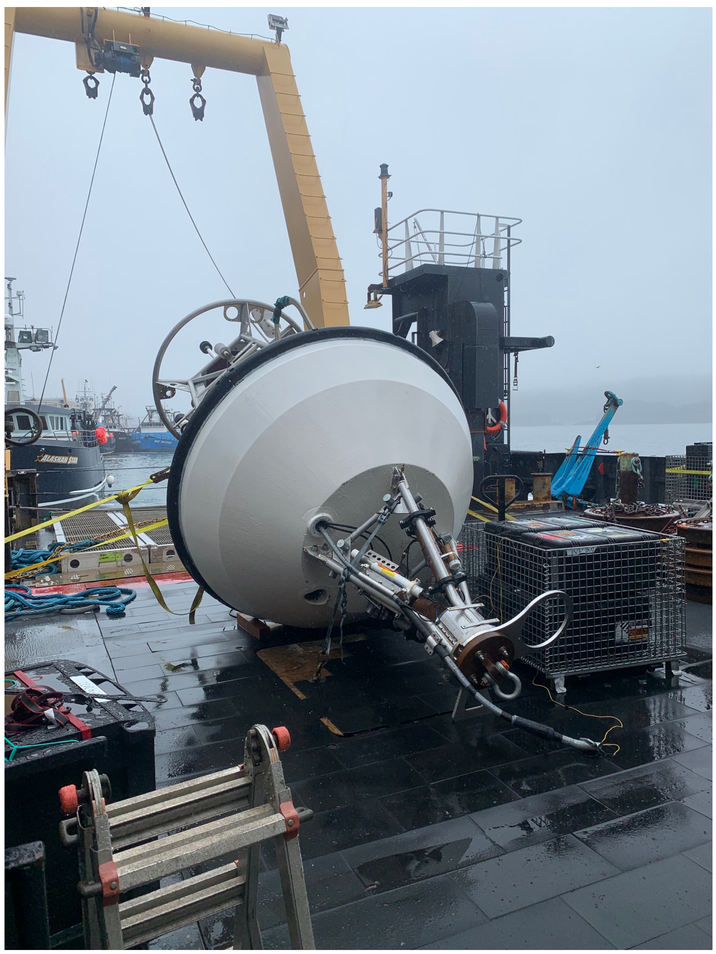

Figure 2: Preparing the PA015 buoy for deployment in Kodiak, AK.

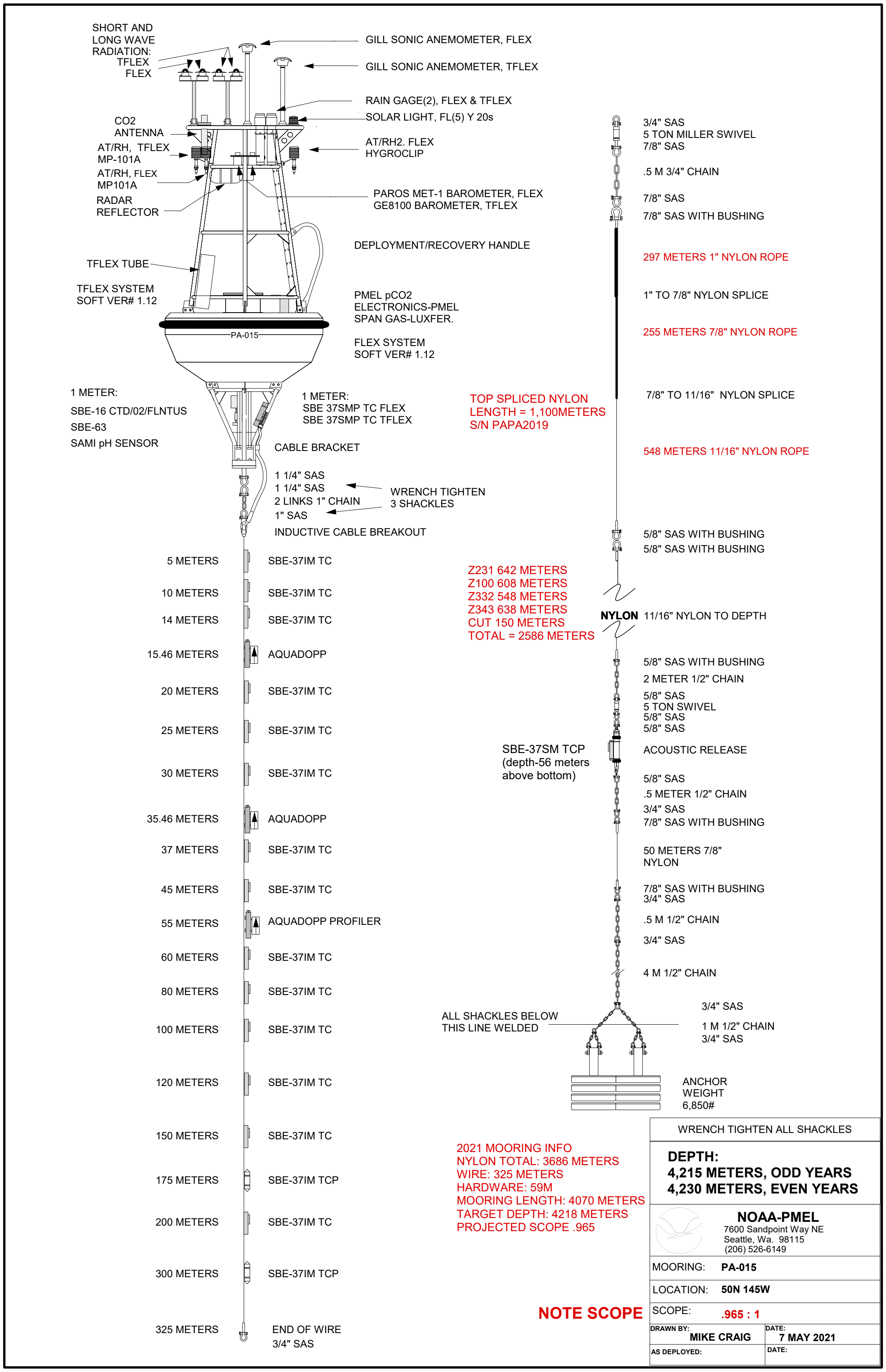

Figure 3: PA015 mooring diagram.

1.2 Instrumentation on PA015

The following instrumentation was deployed on PA015. 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:		**PA015**		
Met Sensors			**Serial #**	
			FLEX	**TFLEX**
Height		**Model**	**0004**	**2002**
2.6m	ATRH	Rotronics MP-101A	104893	133385
2.6m	ATRH2	Rotronics HygroClip	20086871	-----
4.2m	Wind	Gill	14180060	051415/070229
2.5m	BP	Paros	135469	-----
2.5m	BP	GE8100	------	10975354
3.1m	Rain	RM Young	1630	1806 / 1691
3.6m	SWR	Eppley PSP	38429	38433
3.6m	LWR	Eppley PIR	38437	38488
CO2		**Model**	**Primary**	**Comment**
	Electronics	PMEL	8	
	Span Gas	Luxfer	JB03228	
1m	pH	SAMI	P202	CO2
1m	SST/C	SBE16	7410	CO2
1m	Fluorescence	ECO FLNTUS	1818	Attached to SBE16
1m	Oxygen	SBE63 Optode	630481	Attached to SBE16
Subsurface Instrumentation				
Bridle		**Model**	**Serial #**	
1m	SST/C	SBE37SMP - TC	11555	FLEX
1m	SST/C	SBE37SMP - TC	7090	TFLEX
Wire		**Model**	**Serial #**	**IM ID**
5m	TC	SBE37IM - TC	6073	01
10m	TC	SBE37IM - TC	8422	02
14m	TC	SBE37IM - TC	8423	03
15.46m	ADCP	AquaDopp	16108	04
20m	TC	SBE37IM - TC	8424	05
25m	TC	SBE37IM - TC	12517	06
30m	TC	SBE37IM - TC	13248	07
35.46m	ADCP	AquaDopp	13499	08
37m	TC	SBE37IM - TC	21426	09
45m	TC	SBE37IM - TC	20087	10
55m	ADCP	AquaDopp Profiler	13890	
60m	TC	SBE37IM - TC	21444	11
80m	TC	SBE37IM - TC	6074	12
100m	TC	SBE37IM - TC	7788	13
120m	TC	SBE37IM - TC	6075	14
150m	TC	SBE37IM - TC	6072	15
175m	TCP	SBE37IM - TCP	9413	16
200m	TC	SBE37IM - TC	12229	17
300m	TCP	SBE37IM - TCP	7780	18
325m	End of Wire			
Release	TCP	SBE37SM - TCP	10503	-
Acoustic	Release	EdgeTech	51686	-

Table 1: Instruments deployed on PA015.

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

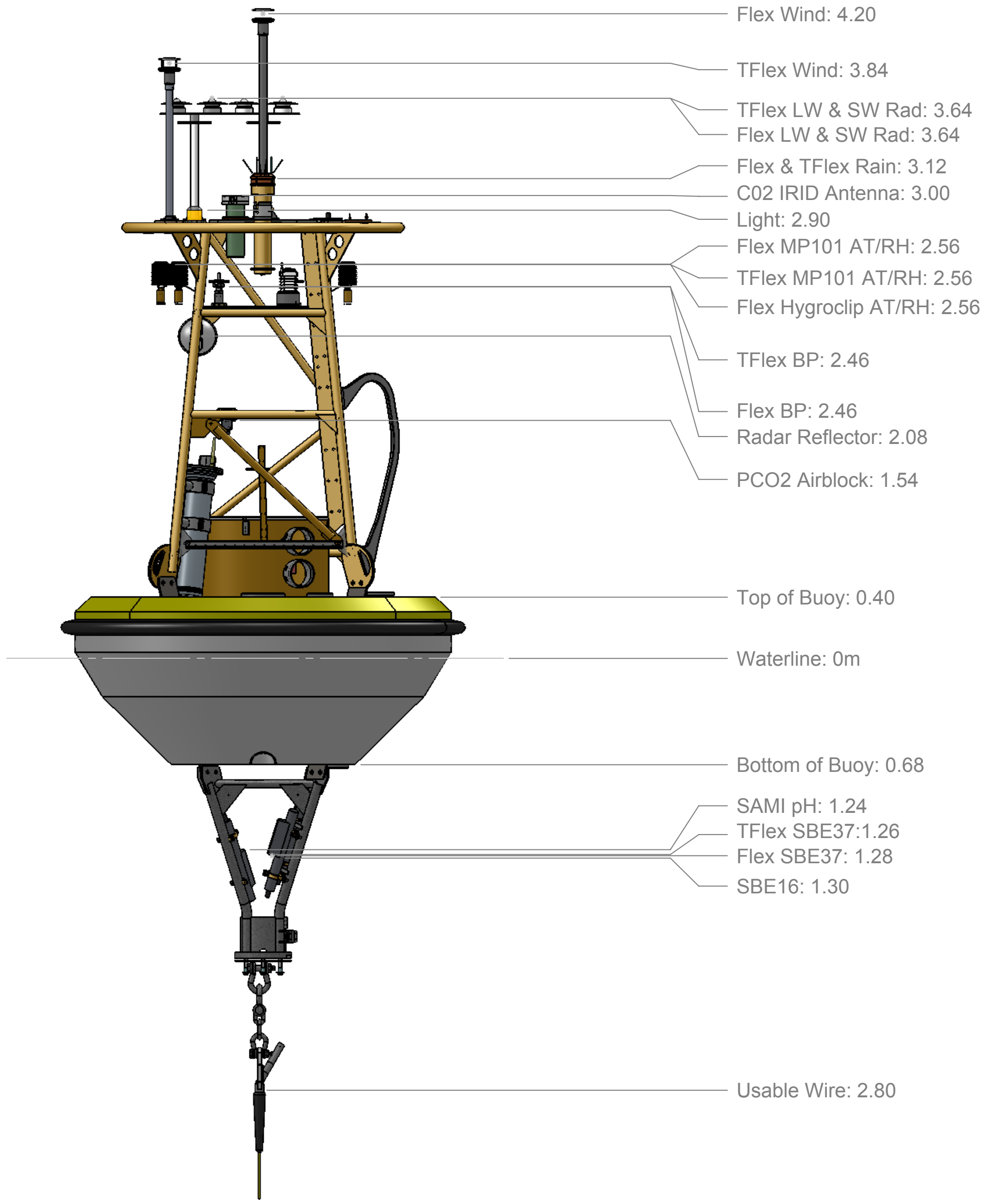

Figure 4: Buoy diagram showing bridle arrangement. The SBE16 package contains a suite of sensors.

2.0 Data Acquisition

Two independent data acquisition systems were deployed on PA015, 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 PA015 mooring, for both the primary and secondary systems. Observation times in data files are assigned to the center of the averaging interval. Flex sensors are generally considered primary. Any substitutions are noted in the relevant section of this report.

PRIMARY SENSORS

Measurement	Sample Rate	Sample Period	Sample Times	Recorded Resolution	Acquisition System
Wind Speed/Direction	2 Hz	2 min	2359-0001, 0009-0011…	10 min	FLEX
Air Temperature + Relative Humidity	1 Hz	2 min	2359-0001, 0009-0011…	10 min	FLEX
Barometric Pressure	1 Hz	2 min	2359-0001, 0009-0011…	10 min	FLEX
Rain Rate	1 Hz	1 min	0000-0001, 0001-0002…	1 min	FLEX
Shortwave Radiation	1 Hz	1 min	0000-0001, 0001-0002…	1 min	FLEX
Longwave Radiation (Thermopile, Case & Dome Temperatures)	1 Hz	1 min	0000-0001, 0001-0002…	1 min	FLEX
Seawater Temperature, Pressure & Conductivity	1 per 10 min	Instant.	0000, 0010,…	10 min	Internal
Ocean Currents (Point)	1 Hz	2 min	2359-0001, 0009-0011…	10 min	Internal
Ocean Currents (Sentinel)	1 Hz	2 min	2359-0001, 0029-0031…	30 min	Internal
Ocean Currents (AQDPRO)	1 Hz	2 min	2359-0001, 0059-0101…	1 hr	Internal
GPS Positions	1 per hr	Instant.	~0000, 0100…	1 hr	FLEX

Table 2: Sampling parameters of the primary sensors on PA015.

SECONDARY SENSORS

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

Table 3: Sampling parameters of the secondary sensors on PA015.

Sampling and Data Return Notes:

- The tables above show the resolutions recorded by the acquisition systems. Due to system failures on PA015, only hourly realtime meteorological data are available. Realtime statistics were computed by assessing the number of non-missing realtime records present divided by the number of hours deployed.
- Stemming from the system failures, the upper bound of the Flex (TFlex) data return was 77.4% (35.6%). Given the longer records from the Flex system, all Flex sensors are designated primary.
- Subsurface sensors record data internally, so these data returns were relatively high in the post-mission statistics shown below.
- Although the raw data returns from the 20m instrument was 96.9%, the instrument began irregularly sampling after 7/12/2021 at 16:00 UTC. GTMBA data processors pre-processed this record, truncating it at this timestamp and indicating that data beyond this point were unusable. This instrument (S/N 8424) will be decommissioned or held in reserve as a spare for future deployments.

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. Note that due to acquisition system failures, only realtime hourly data are available for the meteorological variables.

Flex 0004:

```
Data Return Summary
2021-04-25 06:00:00 to 2022-05-24 23:00:00 (realtime, hourly)

Sensor      Deployed        Obs     Return
==========================================
AT1             9474       7334      77.4%
AT2             9474       7334      77.4%
RH1             9474       7334      77.4%
RH2             9474       7334      77.4%
WIND1           9474       7334      77.4%
BP1             9474       7334      77.4%
RAIN1           9474       7334      77.4%
SWR1            9474       7334      77.4%
LWR1            9474       7334      77.4%

Data Return Summary
2021-04-25 03:28:00 to 2022-05-24 23:11:00 (delay-mode, 10-min)

Subsurface Temperature Profile
     1m        56855      56711      99.7%
     5m        56855      56855     100.0%
    10m        56855      56855     100.0%
    14m        56855      56855     100.0%
    20m        56855      55079      96.9% * Irregular sampling
    25m        56855      56855     100.0%
    30m        56855      56855     100.0%
    37m        56855      56855     100.0%
    45m        56855      56855     100.0%
    60m        56855      56855     100.0%
    80m        56855      56855     100.0%
   100m        56855      56855     100.0%
   120m        56855      56855     100.0%
   150m        56855      56855     100.0%
   175m        56855      56855     100.0%
   200m        56855      56855     100.0%
   300m        56855      56855     100.0%
  4154m        56855      56855     100.0%

Subsurface Pressure Profile
   175m        56855      56855     100.0%
   300m        56855      56855     100.0%
  4154m        56855      56855     100.0%
```

Subsurface Salinity Profile

1m	56855	56711	99.7%	
5m	56855	56855	100.0%	
10m	56855	56855	100.0%	
14m	56855	56855	100.0%	
20m	56855	55079	96.9%	* Irregular sampling
25m	56855	56855	100.0%	
30m	56855	56855	100.0%	
37m	56855	56855	100.0%	
45m	56855	56855	100.0%	
60m	56855	56855	100.0%	
80m	56855	56855	100.0%	
100m	56855	56855	100.0%	
120m	56855	56855	100.0%	
150m	56855	56855	100.0%	
175m	56855	56855	100.0%	
200m	56855	56855	100.0%	
300m	56855	56855	100.0%	
4154m	56855	56855	100.0%	

AQD Current Velocity

15m	56855	38215	67.2%
35m	56855	56855	100.0%

TFlex 2002:

Data Return Summary
2021-04-25 06:00:00 to 2022-05-24 23:00:00 (realtime, hourly)

Sensor	Deployed	Obs	Return
AT1	9474	1439	15.2%
RH1	9474	1439	15.2%
WIND1	9474	3353	35.4%
BP1	9474	3371	35.6%
RAIN1	9474	3115	32.9%
SWR1	9474	3371	35.6%
LWR1	9474	3371	35.6%

Data Return Summary
2021-04-25 03:28:00 to 2022-05-24 23:11:00 (delay-mode, 10-min)

SST1	56855	56711	99.7%
SSC1	56855	56711	99.7%
SSS1	56855	56711	99.7%

2.3 Known Sensor Issues

During deployment of PA015, the buoy sustained minor damage from impacts against the A-frame. The TFlex wind (S/N 051415) and rain (S/N 1806) sensors were damaged, and a buoy ride was performed the following day (in the late UTC hours of April 25th, 2021) to install spare sensors. After installing the new wind (S/N 070229) and rain (S/N 1691), realtime data transmissions were restored. During the buoy ride, all instruments were queried through the Flex and TFlex systems, and the bridle-mounted SSTCs did not respond. All cables were checked and the 2x bridle-mounted instruments were reset and confirmed to be reporting data.

No delayed-mode data was recovered from the Flex and TFlex systems aboard PA015. The Flex system reported realtime data until 2/25/2022, with the immediate cause of failure being battery depletion to less than 7 volts and a high reset count of ~1500. Unfortunately, a near-zero number of records were found in memory when it was repowered on the transit home. The internal storage media were examined extensively at PMEL but ultimately did not produce usable data. It remains unclear why 1) the memory card didn't retain data prior to battery depletion, even after being returned and examined back at PMEL, and 2) why the battery voltage dropped more rapidly than in previous deployments. All systems tested and functioned correctly during pre-deployment testing.

The TFlex system reported realtime data until 9/16/2021, with the tube having been inundated with approximately 5 gallons of water. Upon recovery, a small (<1mm) breach was discovered in the waterproof seal/gasket holding the system's faceplate, which slowly but cumulatively introduced water. The tip of a small wire protruding from the back of the faceplate (but invisible to the outside) had pinched against the seal, resulting in a route for water entry. The memory card was submerged and no data was recovered.

This unprecedented dual failure resulted in no delayed-mode meteorological data being recovered, but realtime hourly meteorological data were made available on the OCS webpage and in OceanSITES format, with Flex transmissions considered primary due to the earlier TFlex failure. While surface data returns were heavily affected by the system failures, 100% of the subsurface instruments downloaded their data from internal memory, so a full delayed-mode record of subsurface data is available, with the exception of a single battery failure in the 15m Aquadopp on 1/15/2022 and the 20m instrument that began sampling irregularly on 7/12/2021.

Flex realtime meteorological data were considered primary on account of their longer records, and the secondary TFlex data were included alongside the Flex data in realtime files created for OceanSITES. Flex realtime meteorological data remains posted as the best available data on the OCS display and delivery page.

3.0 Data Processing

Processing of data from OCS moorings is performed after the data are returned to PMEL. 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 instrument accuracy, the quality flag is lowered for the measurement. If post-recovery calibrations indicate that sensor drift was within expected limits, the quality flag is raised. Post-recovery calibrations are not generally applied to the data, except for seawater salinity, or as otherwise noted in this report. Failed post-recovery calibrations are noted, along with mode of failure, and quality flags are left unchanged to indicate that pre-deployment calibrations were applied and sensor drift was not estimated.

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

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

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

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

3.1 Buoy Positions

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

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 PA015 remained functional in realtime (at hourly and daily resolutions) until the Flex system failure on 2/25/2022. Because no delayed-mode data were available for this deployment, meteorological data plots below appear slightly different from previous reports, as standard data plotting routines had to be reconfigured for the realtime data files.

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 PA015 buoy had secondary air temperature, relative humidity, wind, rain, air pressure, and radiation sensors. A Rotronic HygroClip measuring air temperature and relative humidity provided the mooring's only tertiary data, which were not distributed in any format.

3.2.1 Winds

Wind sensors performed well, with records cut short due to system failures on 9/16/2021 (TFlex) and 2/25/2022 (Flex). The Flex sensor passed its post-calibration, but no calibration was available from the TFlex sensor due to a missing top plate upon recovery. The top plate almost certainly broken off after 9/16/2021 and before recovery, since complete data strings were transmitted with the realtime wind data, and a broken top plate would cause only the internal compass to report values.

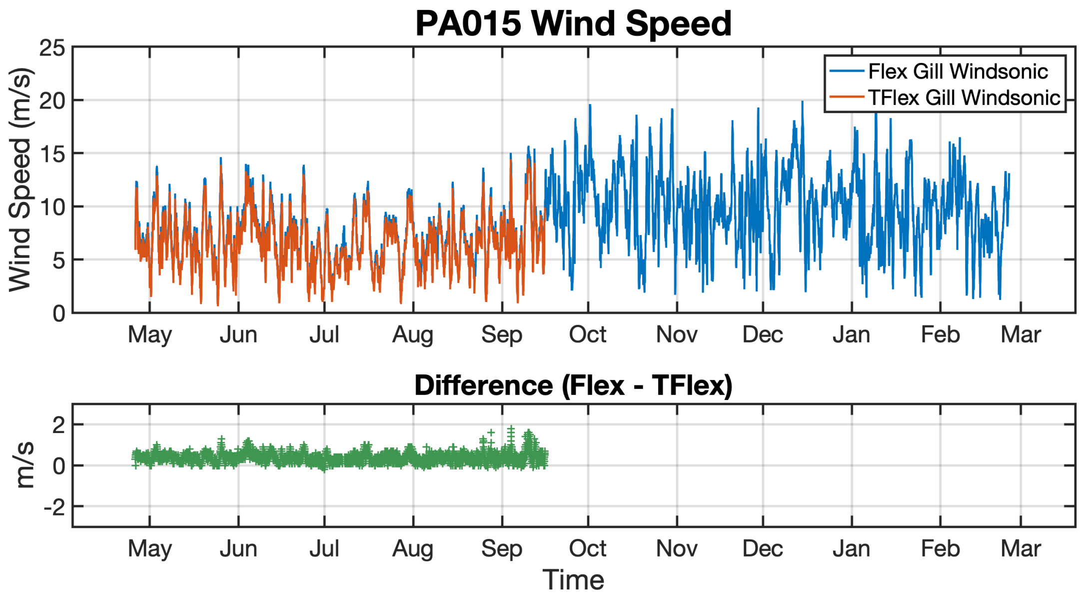

Figure 5: PA015 realtime hourly wind speed time series.

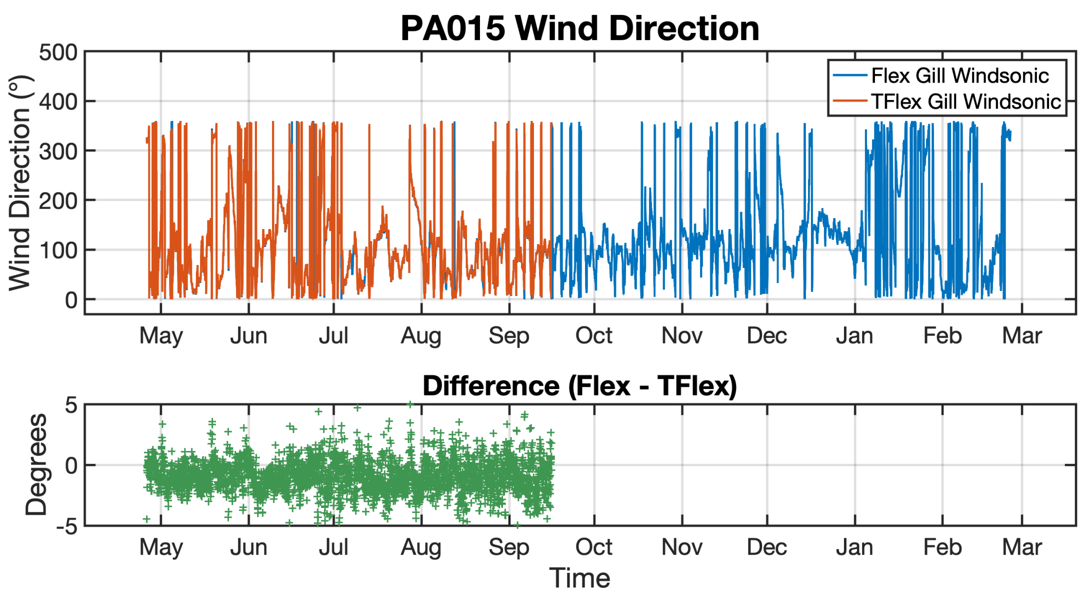

Figure 6: PA015 realtime hourly wind direction time series.

3.2.2 Air Temperature

Both air temperature sensors passed their post-calibration procedures, but the TFlex temperature sensor malfunctioned and began reporting unrealistic values near 60°C on 6/24/2021, and data were hard flagged Q5 thereafter (not shown in Figure 7). The mean difference between Flex and TFlex had been 0.07°C (RMSE = 0.09°C), indicating reasonable agreement to within accuracy specifications prior to the failure. The Flex air temperature sensor was therefore considered primary, with a longer record and no reported sensor damage (discussed in the relative humidity section below).

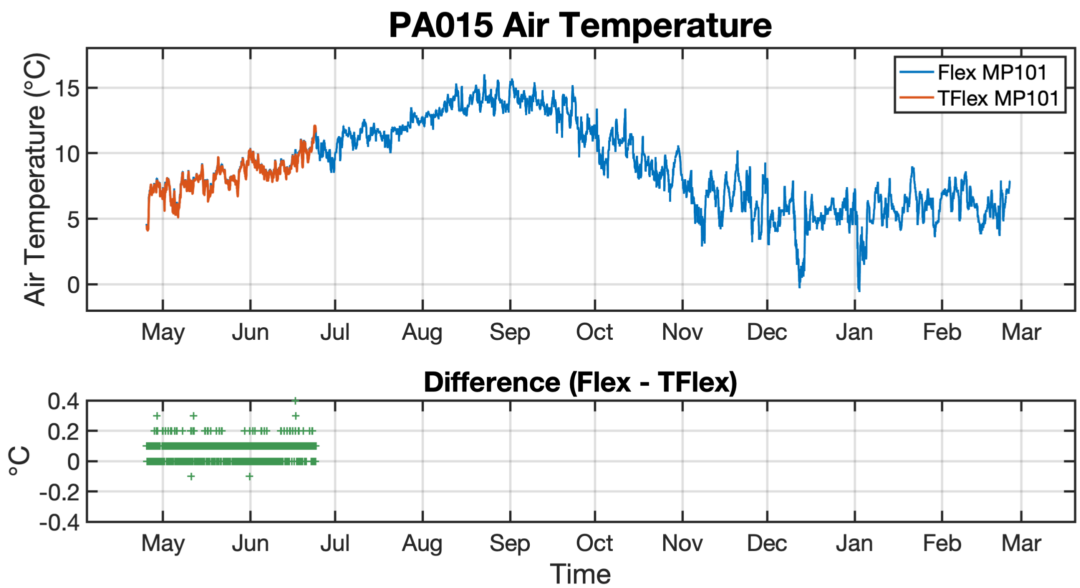

Figure 7: PA015 realtime hourly air temperature time series.

3.2.3 Relative Humidity

The TFlex relative humidity sensor failed its post-calibration upon return to PMEL, with a high standard error and max residual noted in the calibration report. This instrument (S/N 133385) was also noted as having corroded terminals, and is slated to be retired from service. The shorter record length, combined with the failed postcal and observed corrosion, confirmed the decision to classify the TFlex sensor as secondary to the Flex sensor.

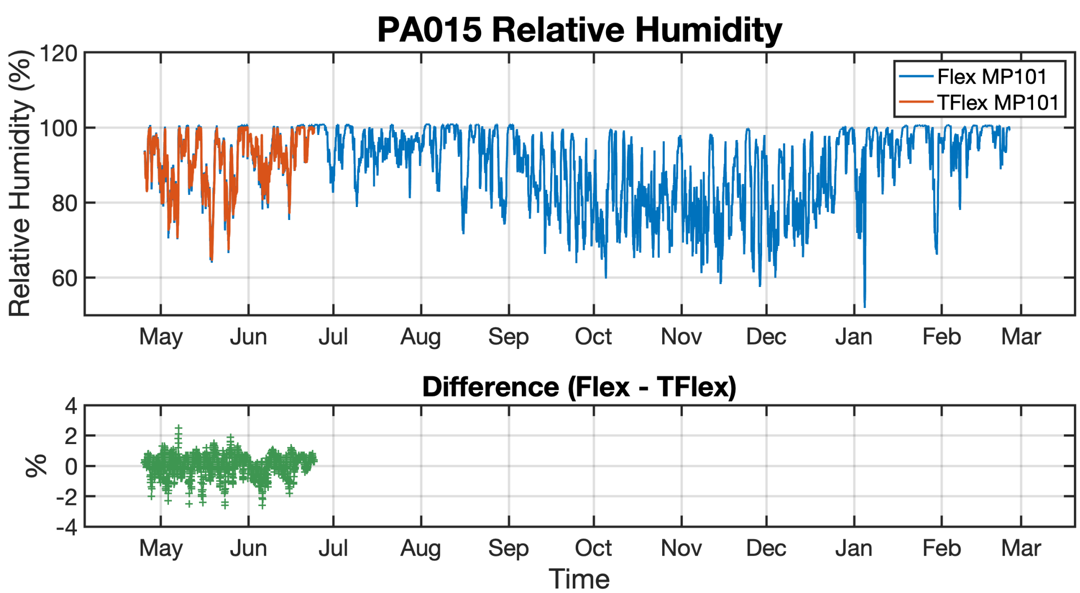

Figure 8: PA015 realtime hourly relative humidity time series.

3.2.4 Barometric Pressure

Barometric pressure sensors performed well in the context of system failures. The mean difference between the Flex and TFlex barometers was less than 0.1 hPa (RMSE = 0.14 hPa). The Flex sensor was primary due to the length of its time series, with data extending up until the Flex failure.

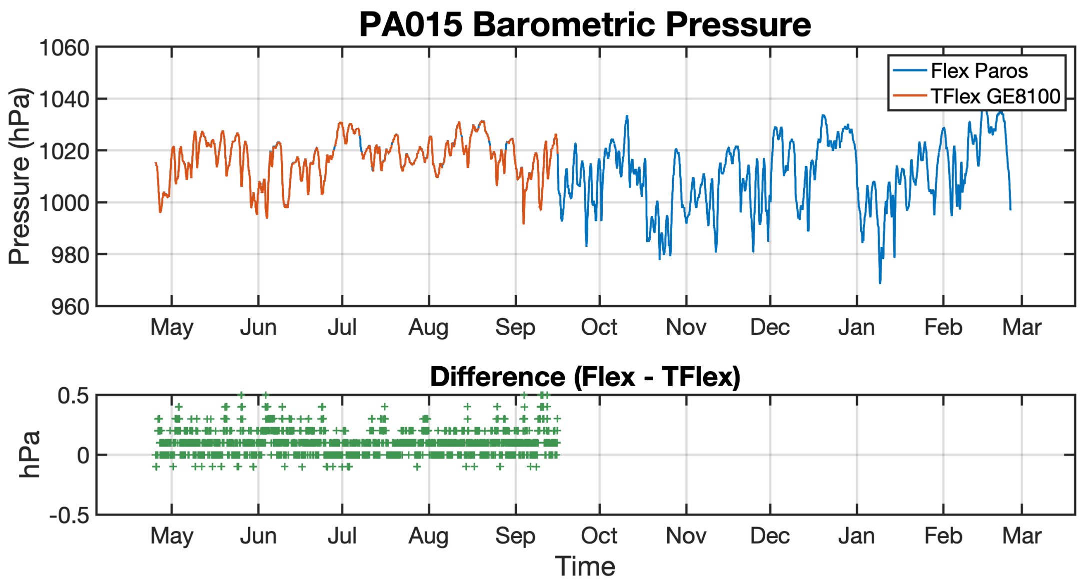

Figure 9: PA015 realtime hourly barometric pressure time series.

3.2.5 Rain

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

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

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

The top funnel of the Flex rain gauge was missing upon recovery. The exact timing of any impact to the buoy is unknown, but the sensor passed its post-calibration. No post-calibration was performed on the TFlex rain gauge, which had a cracked housing in addition to a missing funnel.

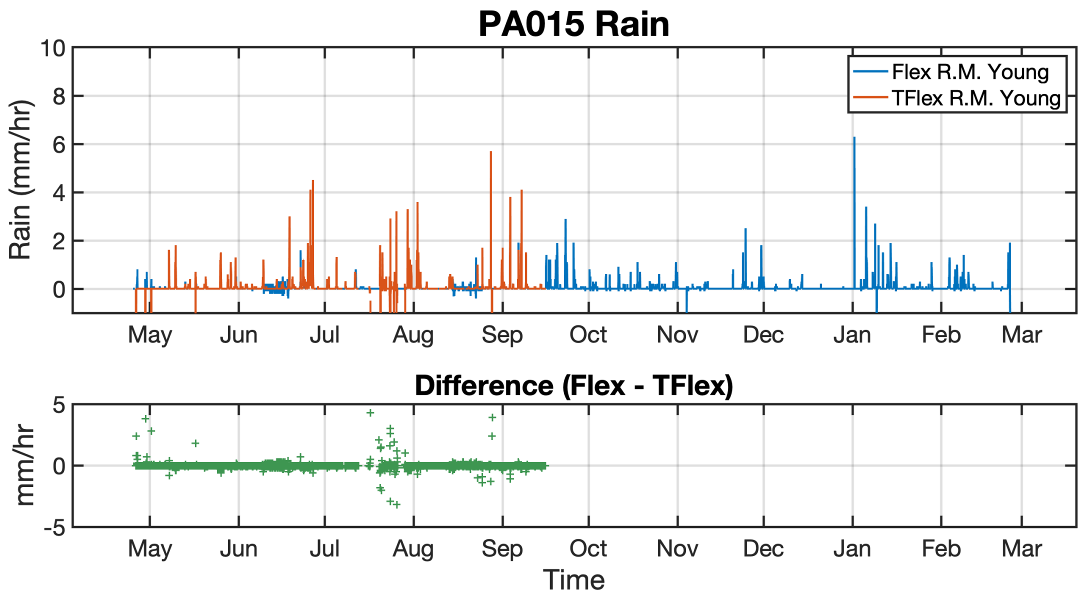

Figure 10: PA015 realtime hourly precipitation rate time series.

3.2.6 Shortwave Radiation

Kelly Balmes established the selection criteria for primary and secondary radiation sensors. Mean realtime hourly Flex and TFlex SWR values were compared, and found to differ by 0.3%. When the difference is over 1%, the higher of the two instruments is considered primary, since lower values could indicate a bent radiation mast. Otherwise, the sensor that maximizes the available data (in this case, the PA015 Flex SWR) is primary.

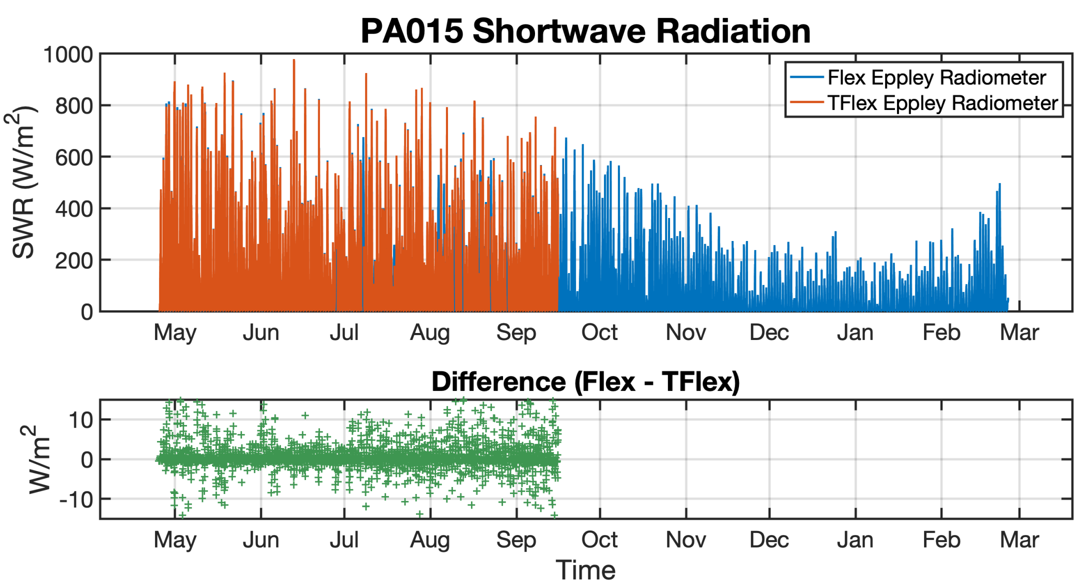

Figure 11: PA015 realtime hourly shortwave radiation time series.

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 PA015 Flex LWR was primary.

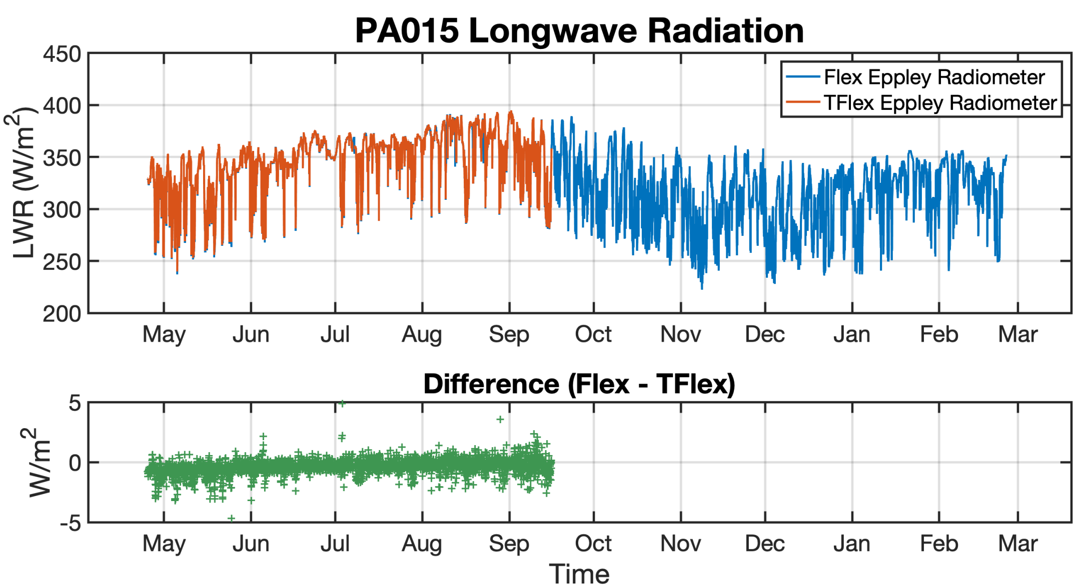

Figure 12: PA015 realtime hourly longwave radiation time series.

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 13). 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.

Type	Serial	Real Time	Inst Time	Clock Error
SBE37-TC-SMP	11555	19:11:30	19:11:37	0:00:07
SBE37-TC-SMP	7090	19:17:05	19:17:21	0:00:16
SBE37-TC-IMP	6073	17:05:55	17:06:19	0:00:24
SBE37-TC-IMP	8422	17:34:05	17:34:11	0:00:06
SBE37-TC-IMP	8423	17:20:45	17:21:09	0:00:24
SBE37-TC-IMP	8424	17:27:20	17:28:01	0:00:41
SBE37-TC-IMP	12517	17:14:15	17:14:13	-0:00:02
SBE37-TC-IMP	13248	16:47:20	16:47:06	-0:00:14
SBE37-TC-IMP	21426	16:38:40	16:38:27	-0:00:13
SBE37-TC-IMP	20087	16:54:10	16:54:34	0:00:24
SBE37-TC-IMP	21444	17:00:45	17:00:40	-0:00:05
SBE37-TC-IMP	6074	1:11:50	1:12:02	0:00:12
SBE37-TC-IMP	7788	1:07:10	1:07:57	0:00:47
SBE37-TC-IMP	6075	0:58:00	0:58:18	0:00:18
SBE37-TC-IMP	6072	0:51:35	0:51:55	0:00:20
SBE37-TCP	9413	1:17:40	1:18:04	0:00:24
SBE37-TC-IMP	12229	1:24:50	1:24:17	-0:00:33
SBE37-TCP	7780	0:37:00	0:37:50	0:00:50
SBE37-TCP	10503	4:18:01	4:18:04	0:00:03

Figure 13: Filemaker log displaying all instrument clock errors.

3.3.1 Temperature

High-resolution temperatures are provided at the original 10-minute sampling increment set in the Seabird Inc. 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. All instruments listed in Figure 13 downloaded upon recovery of the PA015 mooring, so while the highest resolution of meteorological data was constrained to the hourly realtime data by system failures, delayed-mode data were recovered for the oceanographic variables.

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 a small subset of 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)	-0.0099
1m (Flex)	-0.0081
5m	-0.0037
10m	-0.0041
14m	-0.0111
20m	-0.0023
25m	-0.0103
30m	-0.0048
37m	-0.0148
45m	-0.0076
60m	0.0055
80m	0.0028
100m	-0.0060
120m	0.0020
150m	0.0048
175m	0.0004
200m	-0.0014
300m	-0.0073
Deep T/S	0.0027

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.

Manual Salinity Adjustments

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

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

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

2021-04-19 11:32:18 to 2022-05-26 09:41:32 at 37 m adjusted -0.0145 to 0.0000
2021-04-19 11:32:18 to 2022-05-26 09:41:32 at 45 m adjusted 0.0000 to -0.0235

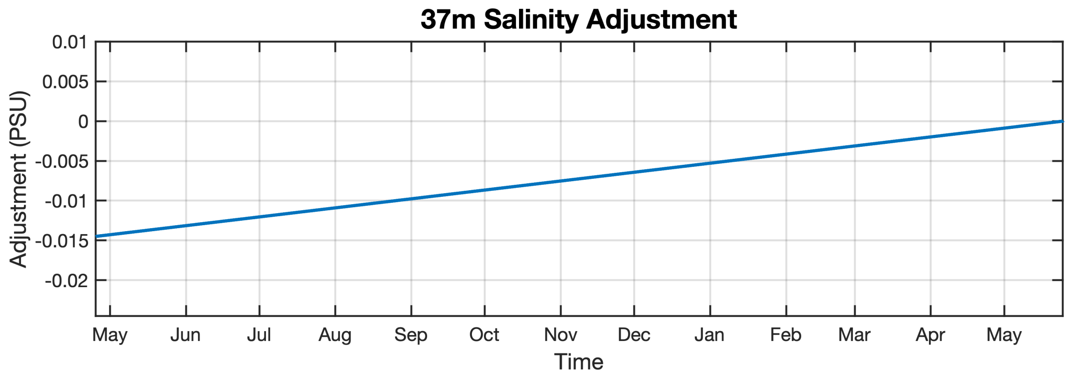

Figure 14: Minor salinity adjustments applied to the 37m instrument.

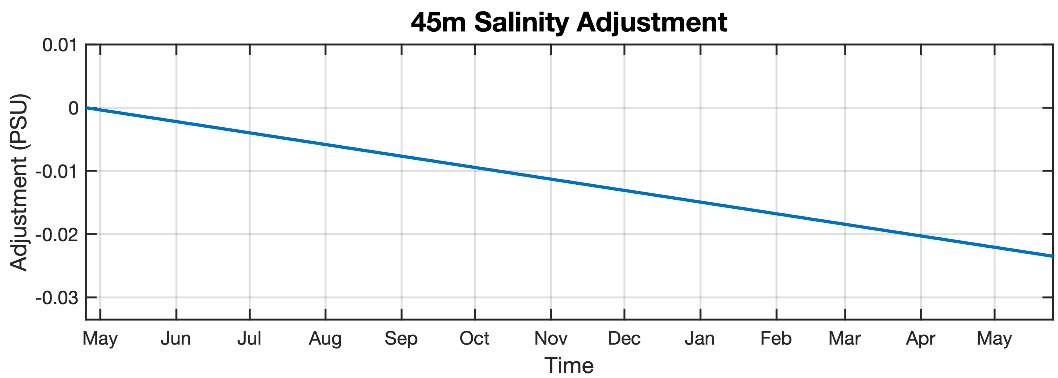

Figure 15: Minor salinity adjustments applied to the 45m instrument.

3.3.4 Deep SBE Data

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

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

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 PA015 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 PA015 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 at 55m on the PA015 mooring. To process the data, 3 corrections were applied: declination (+15 degrees), tilt correction, and head depth adjustment. Aquadopps do not have an internal setting for declination, so this correction to true heading is applied first in post-processing. Tilt correction, also called "bin-mapping," is then computed using a conversion between Earth and Beam coordinates, taking samples along each beam where it most nearly pierces defined horizontal slices of the water column. Tilts over 20 degrees are eliminated (Q5), as the manufacturer considers data beyond this threshold unusable. A head depth adjustment is needed for the profiler, as its vertical position varies slightly, unlike 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. Additional plots of eastward and northward flowing currents displayed on a time and depth axis is shown in appendix plot B6.

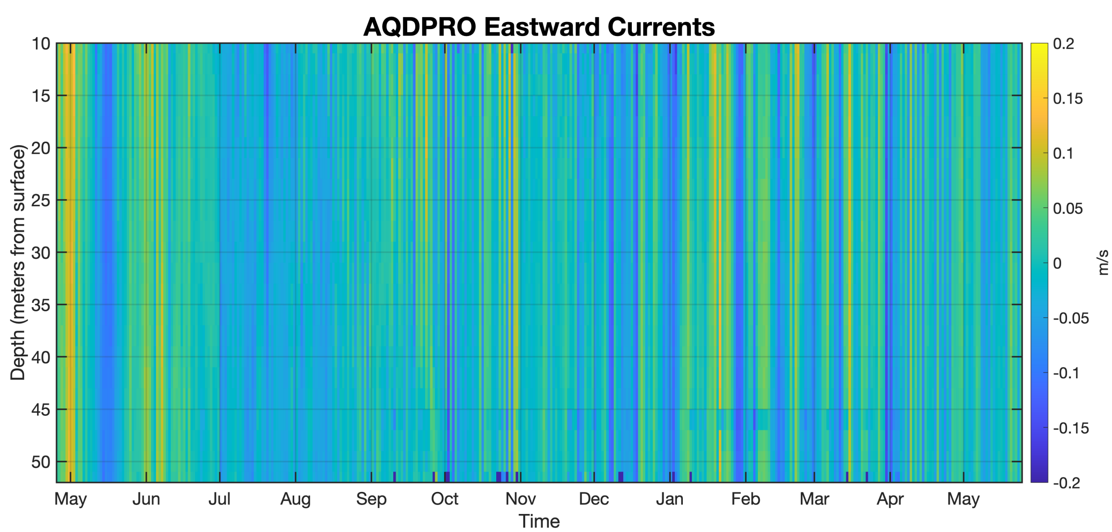

Figure 16: Aquadopp Profiler eastward velocities.

Note: No bridle-mounted, downward-looking Signature 500 ADCP (the test sensor first deployed on PA014) was deployed on PA015, but OCS intends to deploy this instrument on future missions on behalf of our partners studying bubble plumes at the University of Washington's Applied Physics Lab (PI: Dr. Jie Yang).

4.0 References

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

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

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

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 to the WHOI mooring team, who dedicated their time and efforts to assist with the recovery of PA015. The scientists, captain and crew of the NOAA ship OSCAR DYSON and SIKULIAQ are also acknowledged for their efforts and operational assistance, which made the PA015 mooring possible.

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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

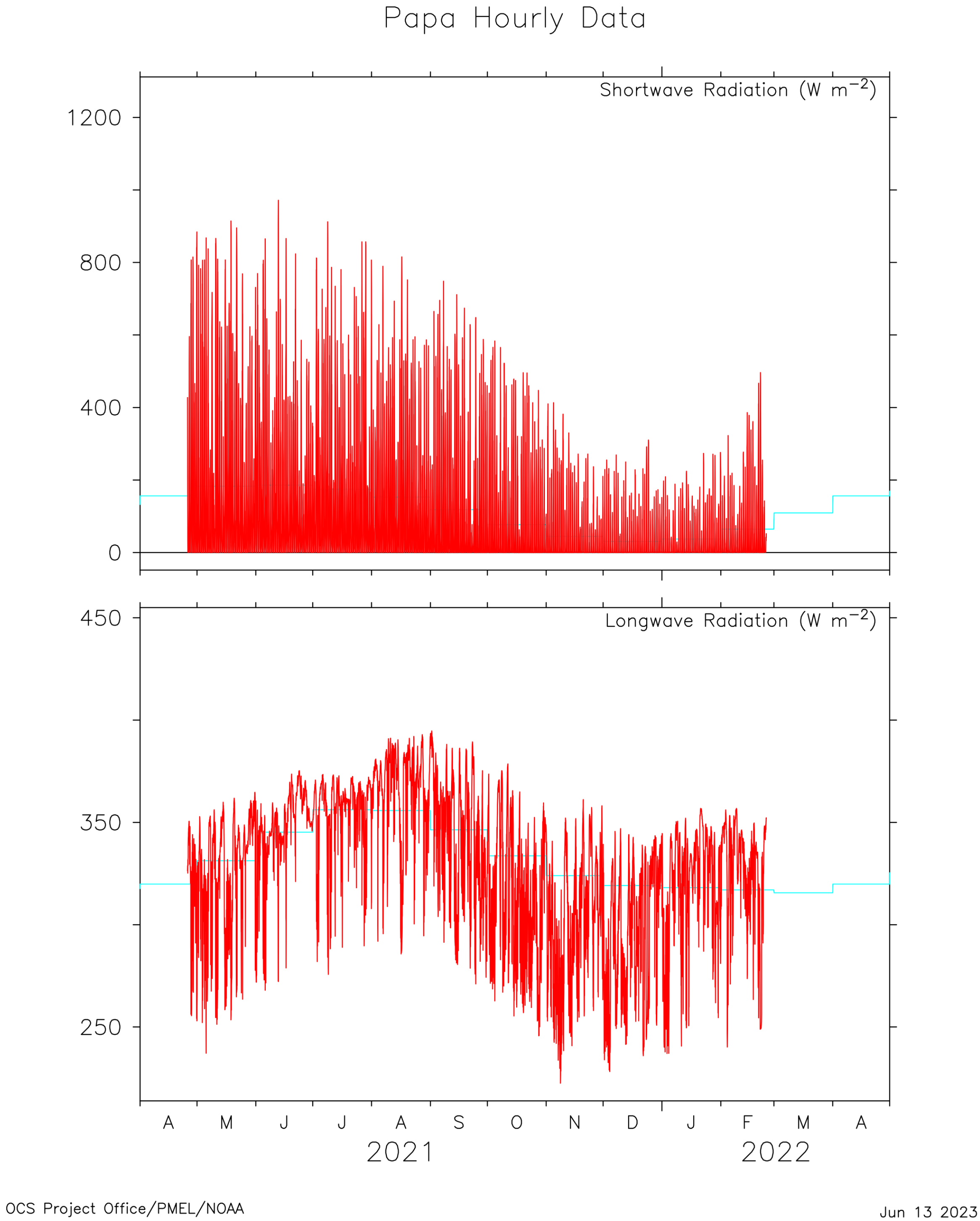

Figure B 1: PA015 primary shortwave and longwave radiation data at hourly resolution (Flex realtime).

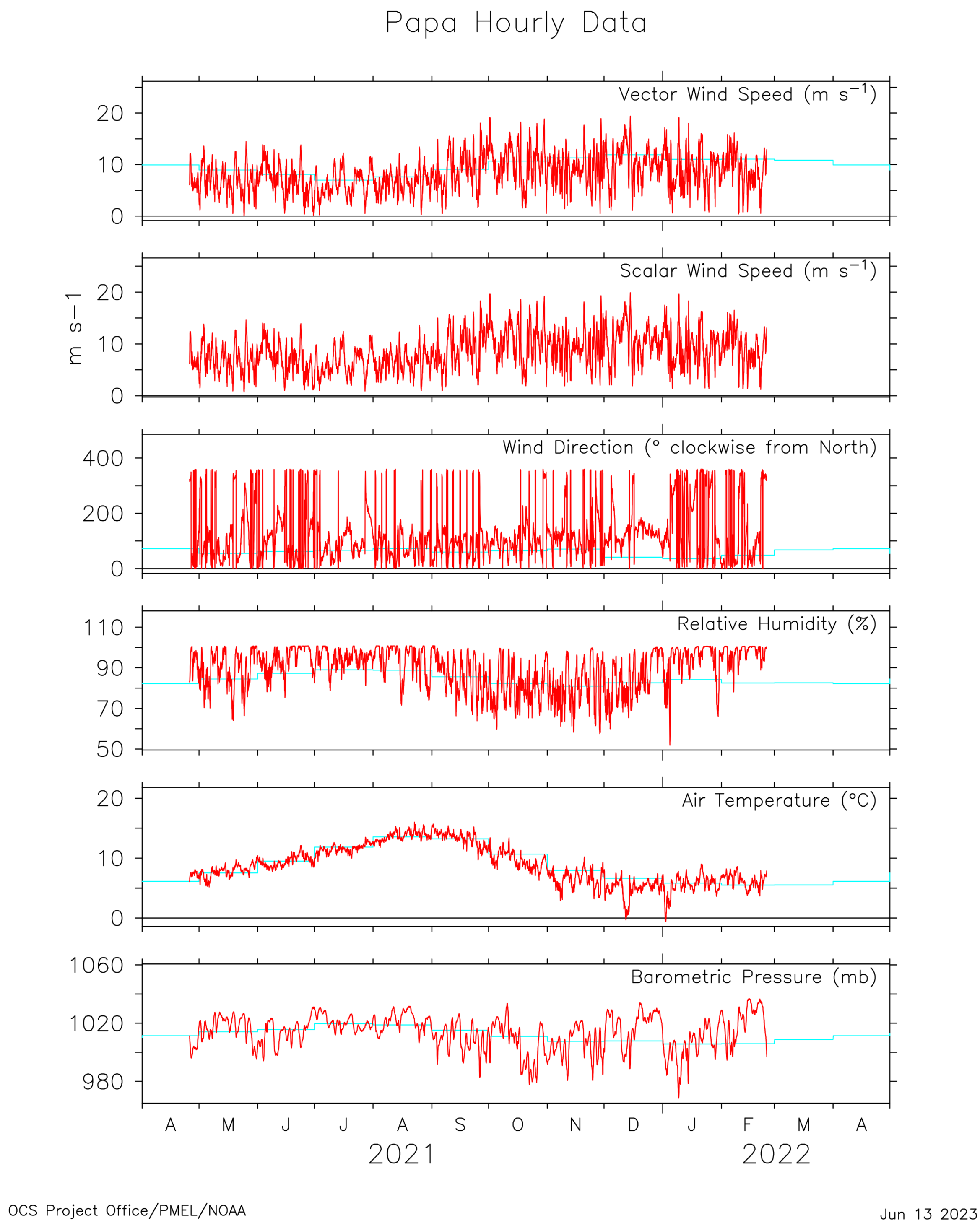

Figure B 2: PA015 meteorological data at hourly resolution (Flex realtime). Note that realtime precipitation is not released at hourly resolution, but is available as daily data.

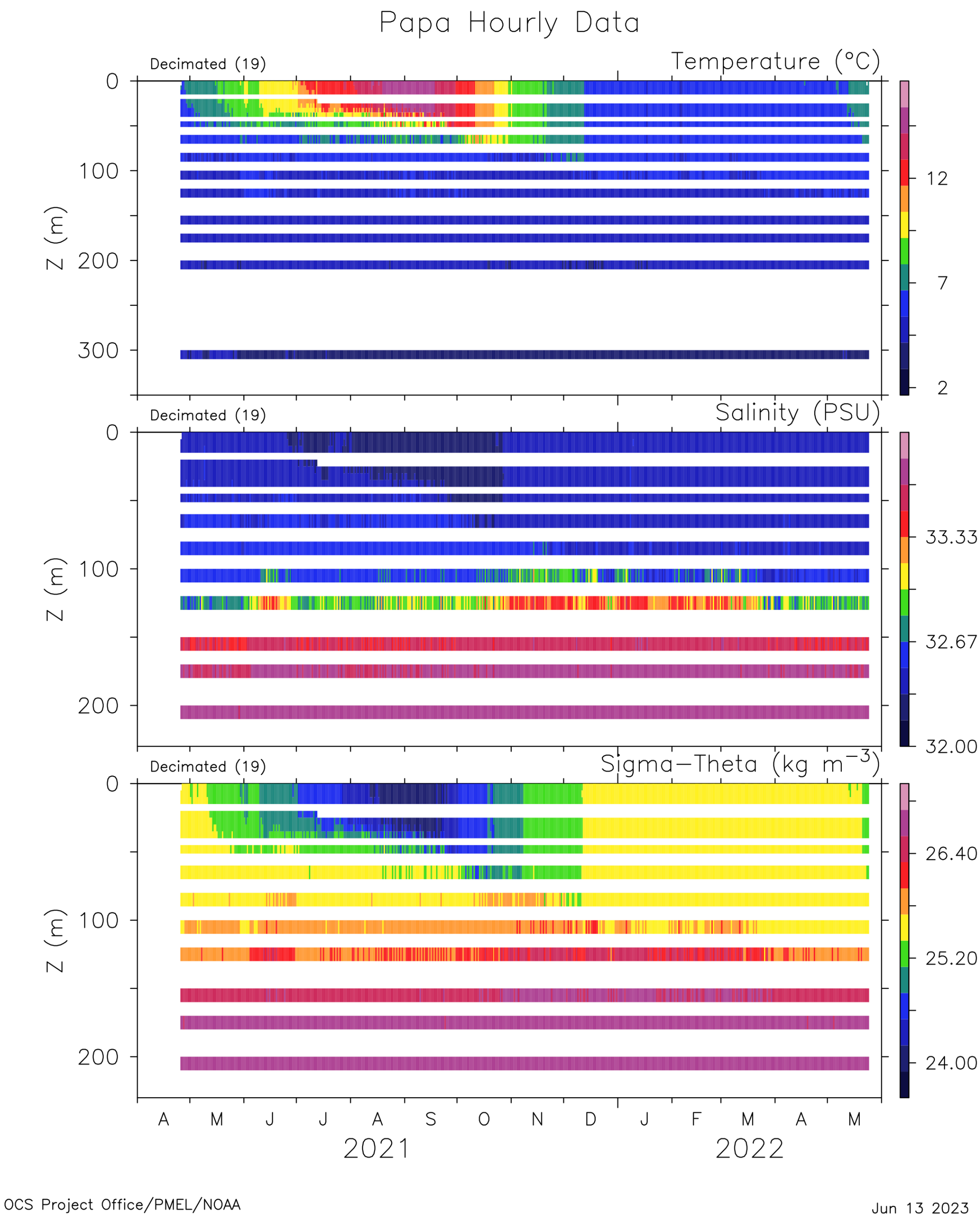

Figure B 3: PA015 subsurface temperature, salinity, and density at hourly resolution (decimated).

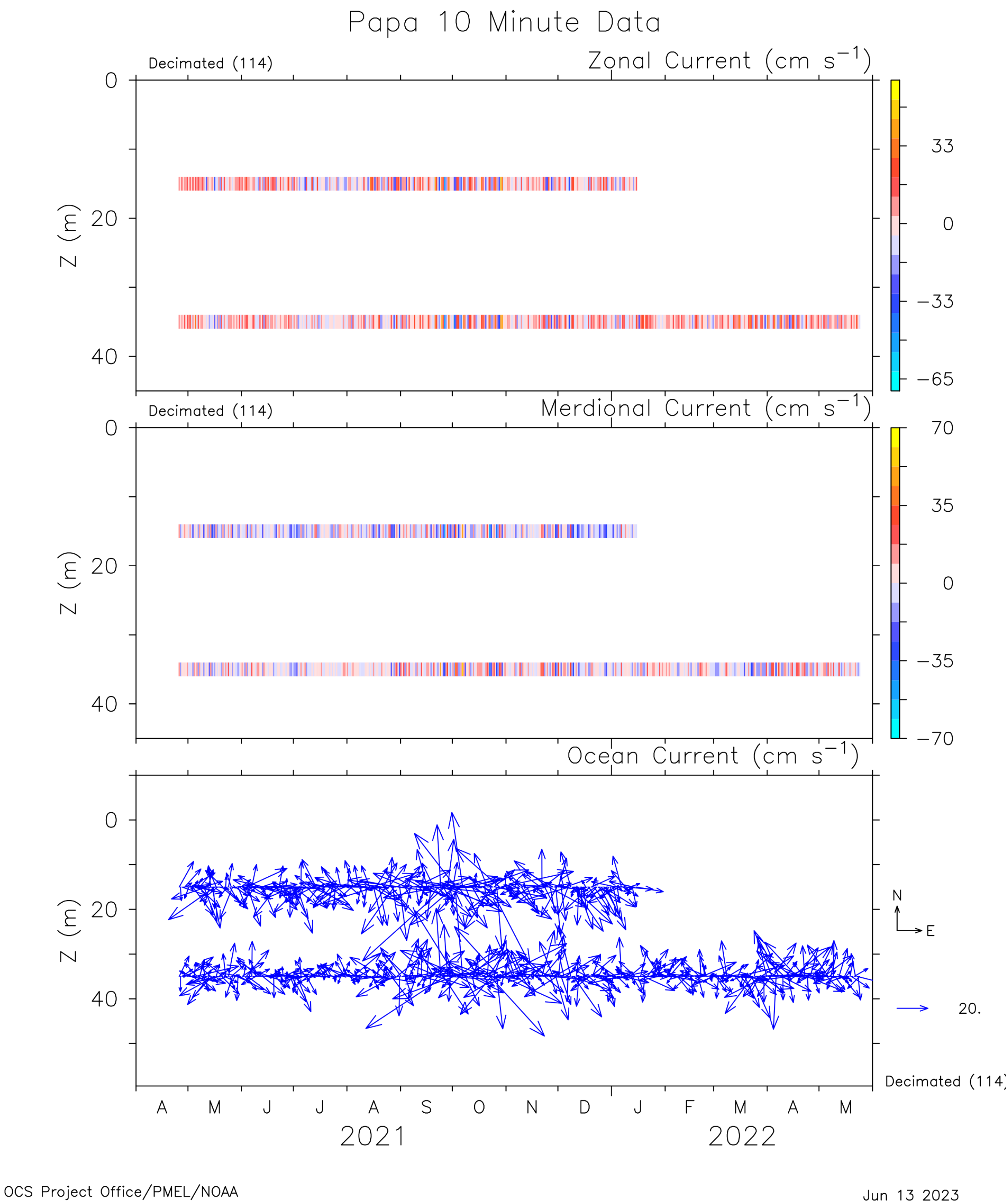

Figure B 4: PA015 Aquadopp current meter data. The 15m data ended early due to battery failure.

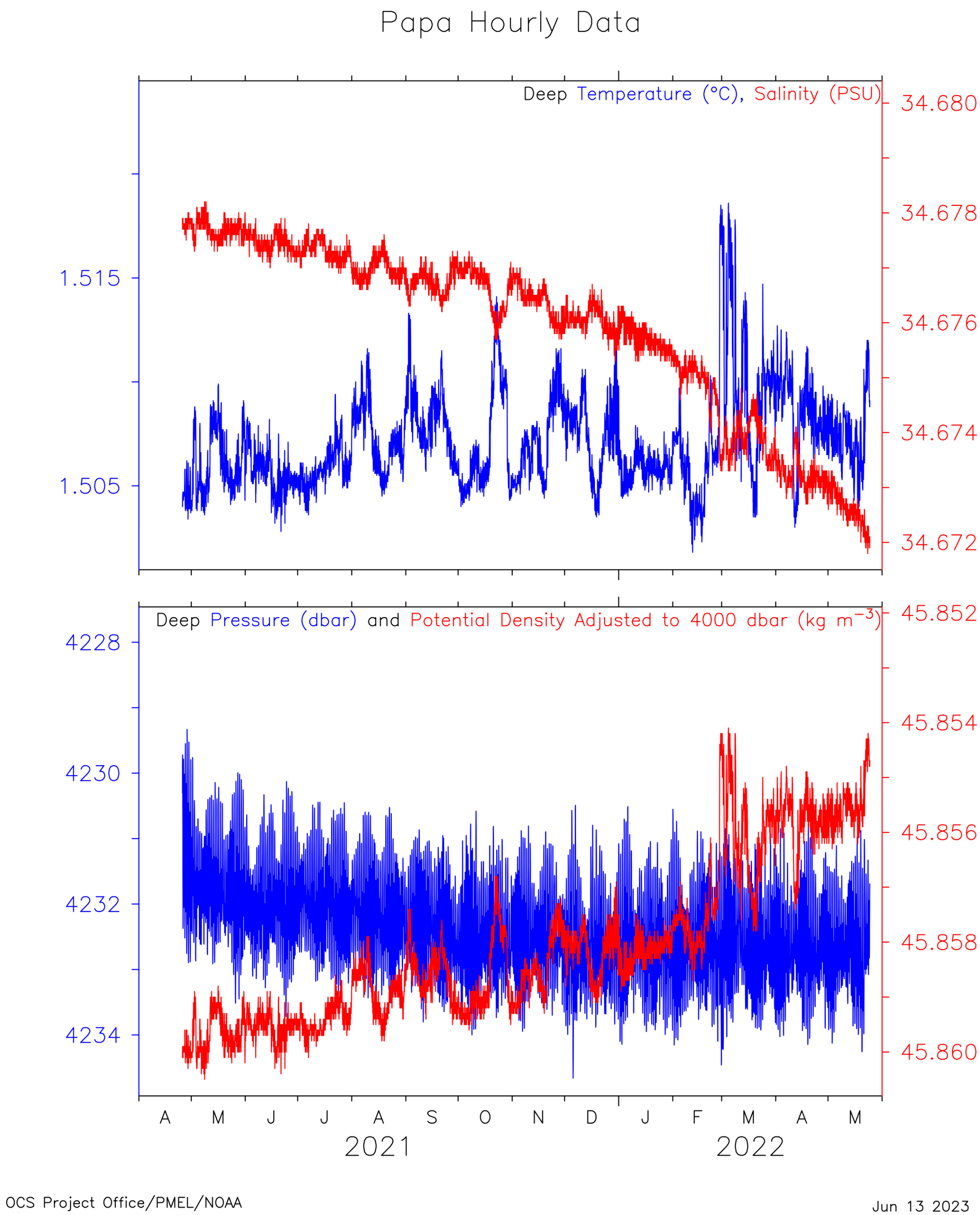

Figure B 5: Deep Seabird temperature, salinity, pressure, and density.

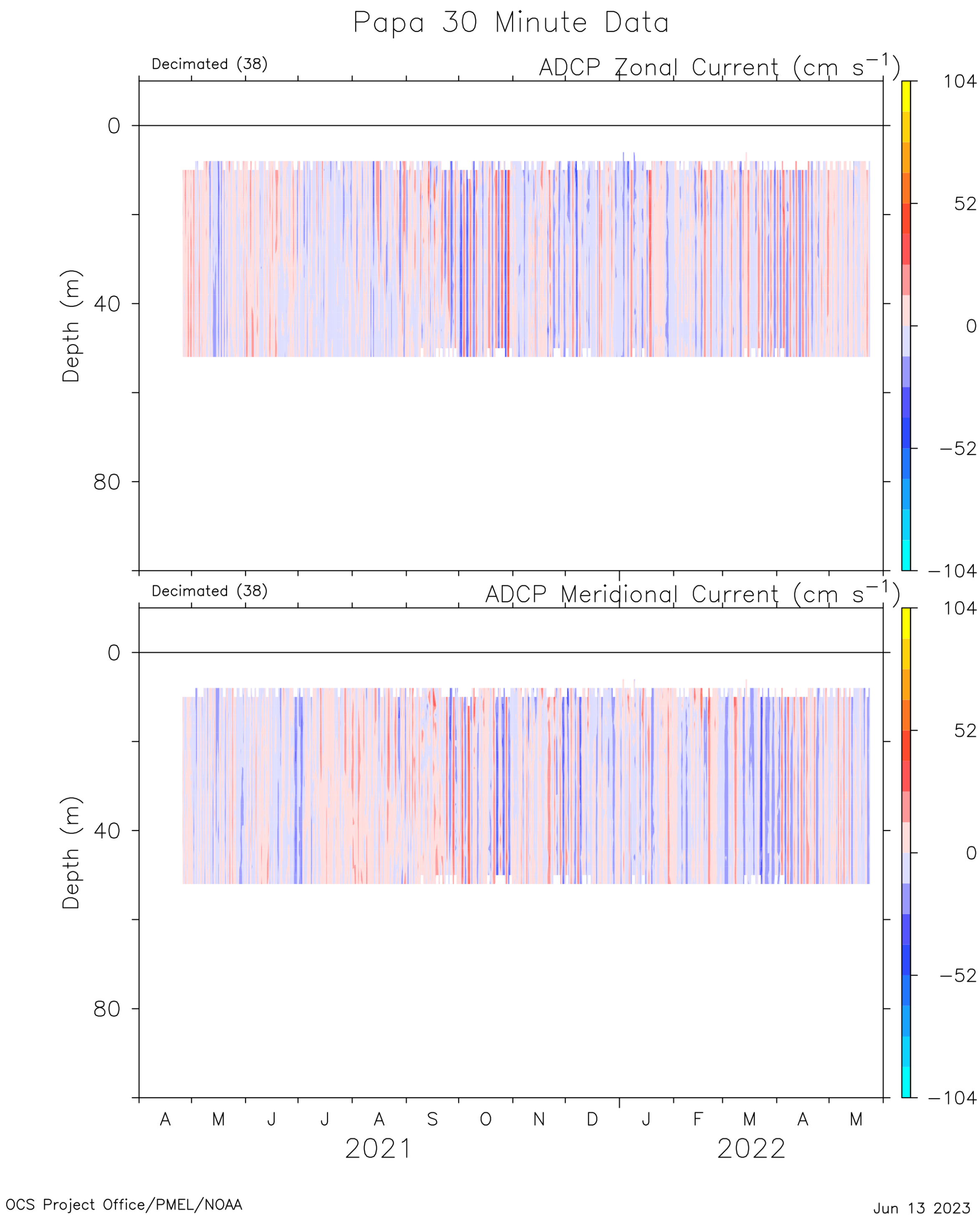

Figure B 6: PA015 Aquadopp Profiler data at half-hourly resolution.

APPENDIX C: Secondary Instrument High Resolution Data Plots

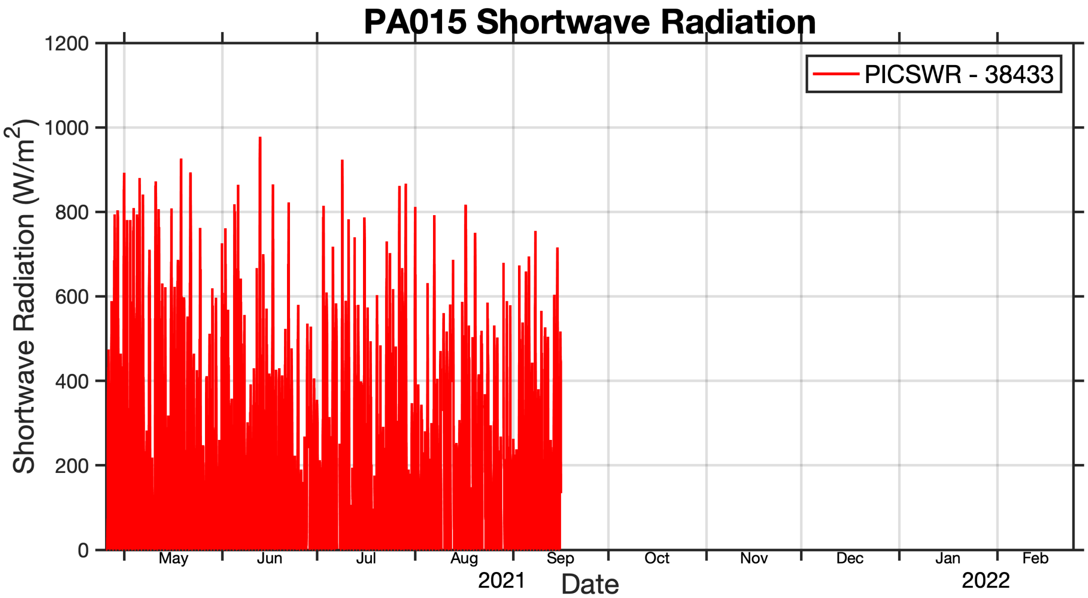

Figure C 1: Secondary (TFlex Eppley PSP) shortwave radiation sensor. The TFlex failed in September 2021.

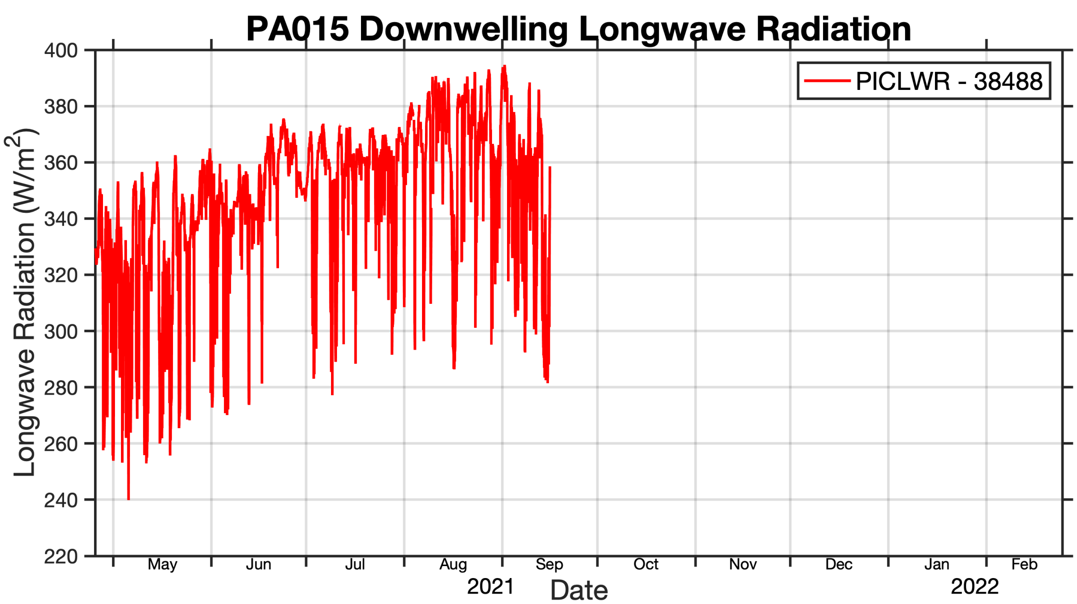

Figure C 2: Secondary (TFlex Eppley PIR) longwave radiation sensor.

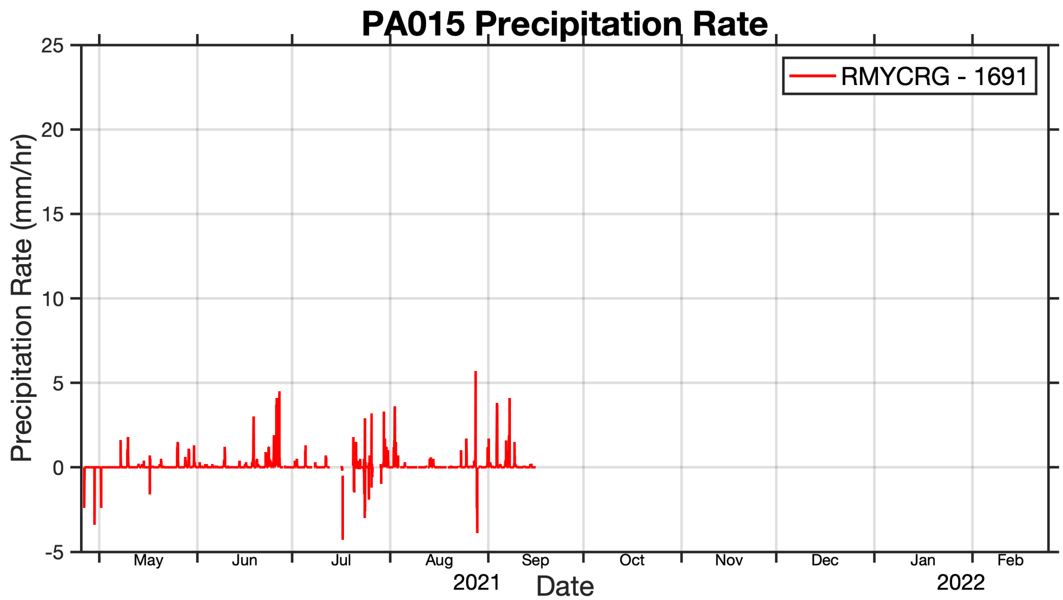

Figure C 3: Secondary (TFlex RM Young) rain sensor.

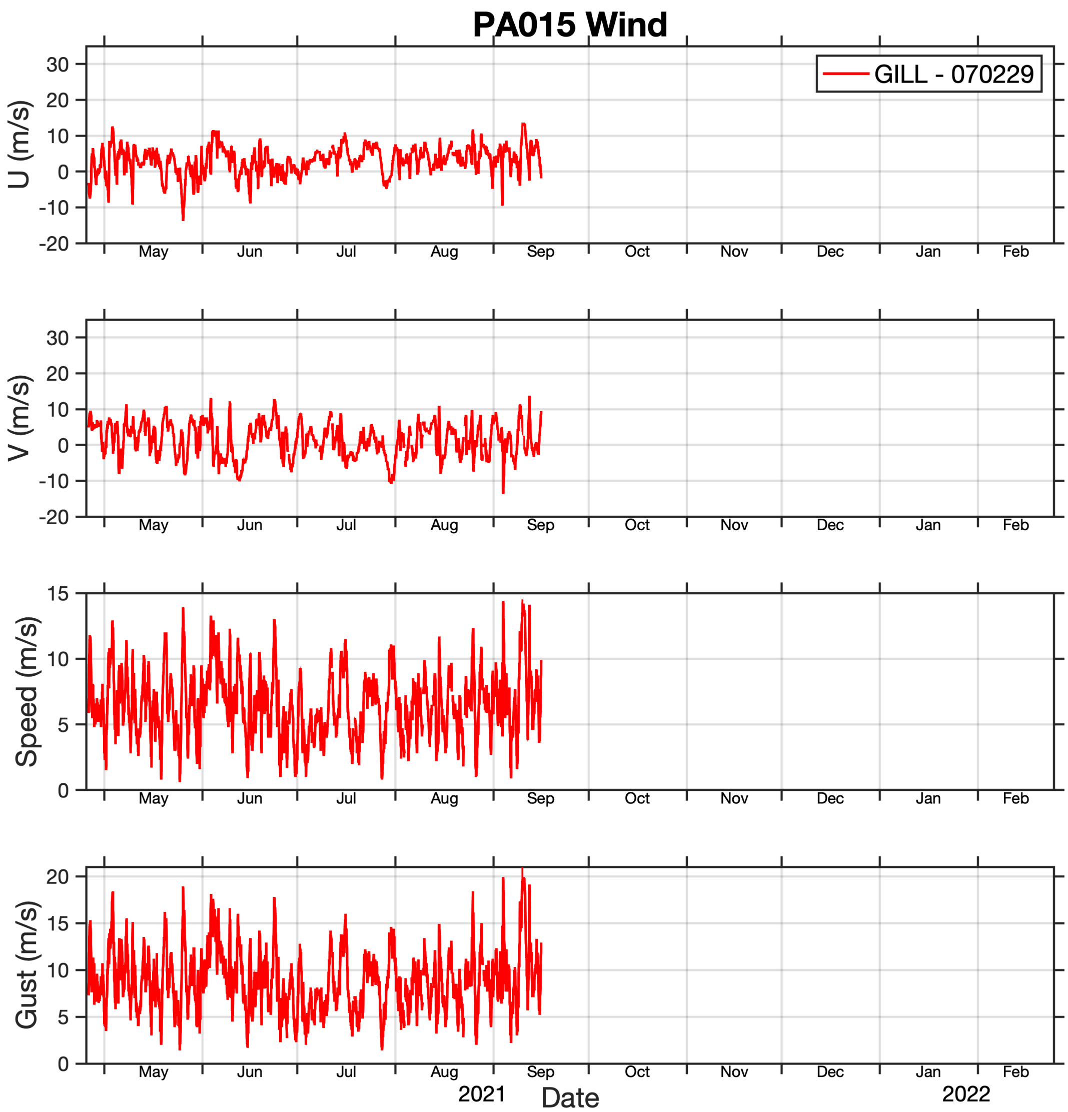

Figure C 4: Secondary (TFlex Gill) wind sensor.

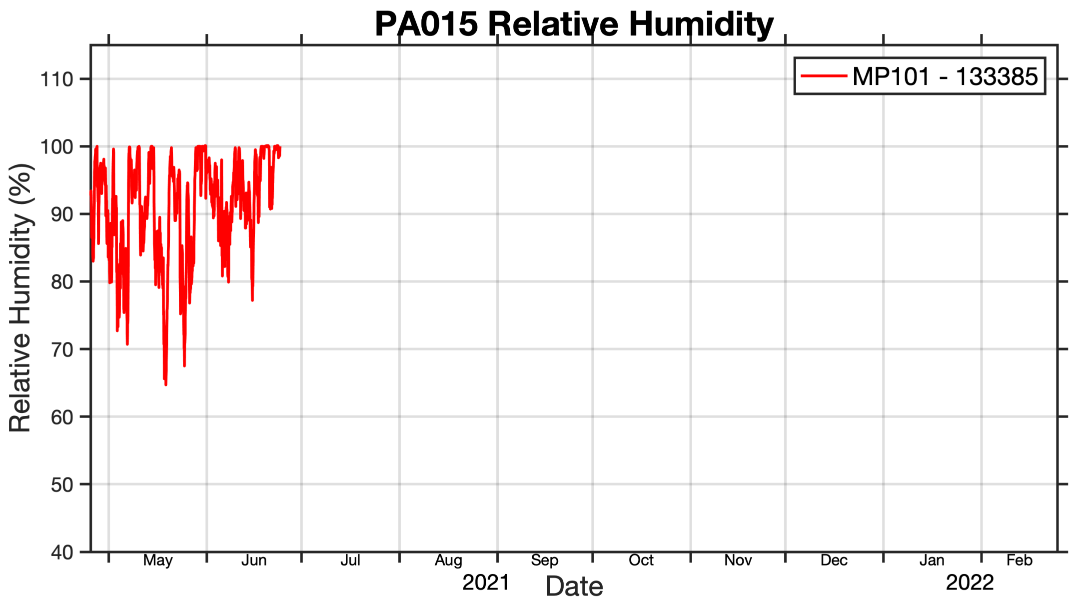

Figure C 5: Secondary (TFlex MP101) relative humidity sensor.

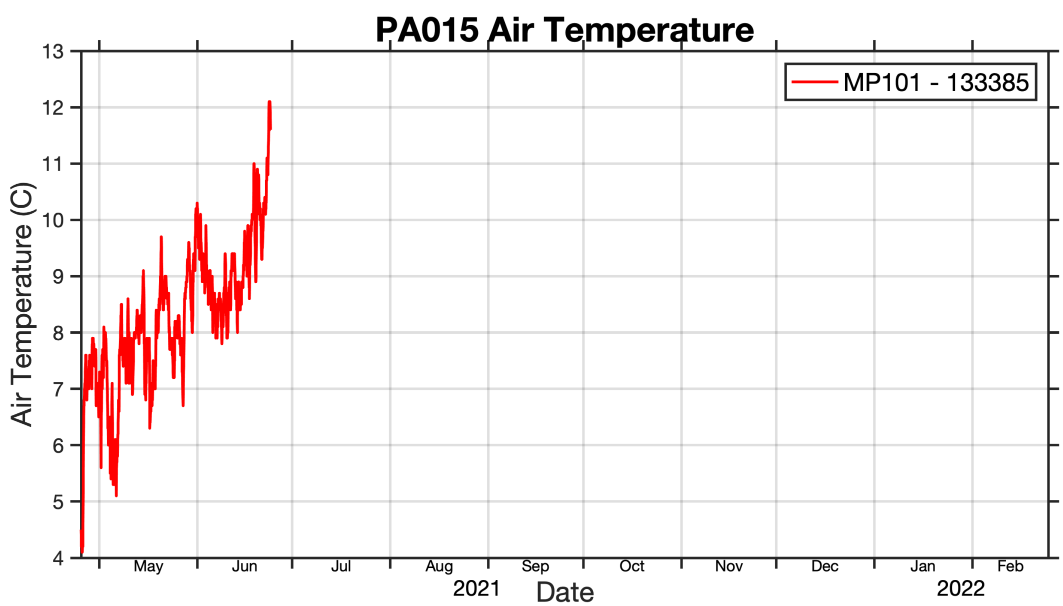

Figure C 6: Secondary (TFlex MP101) air temperature sensor.

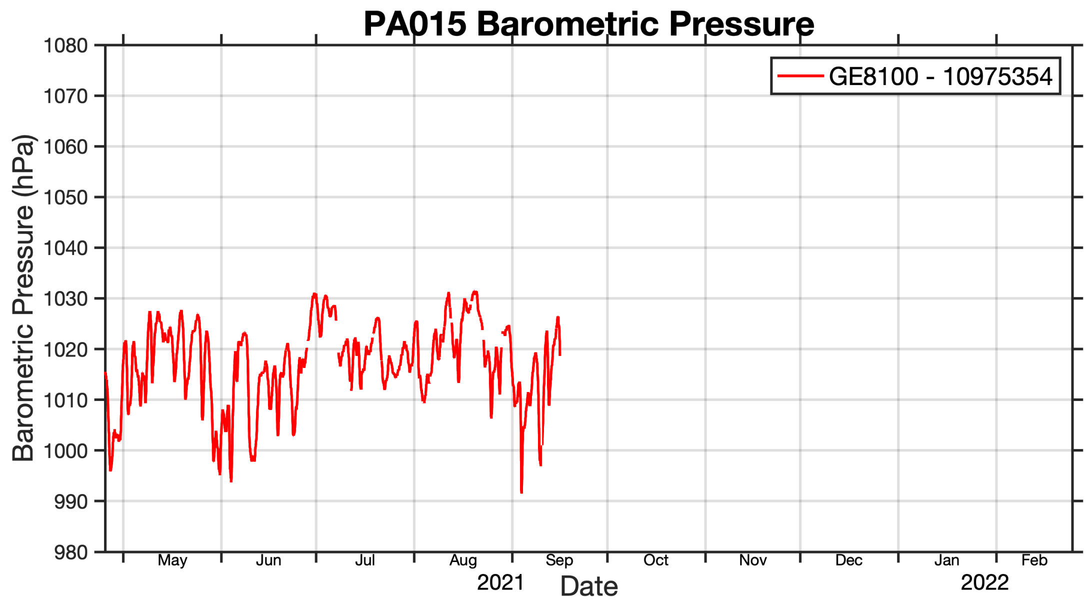

Figure C 7: Secondary (TFlex TERPS) barometric pressure sensor.

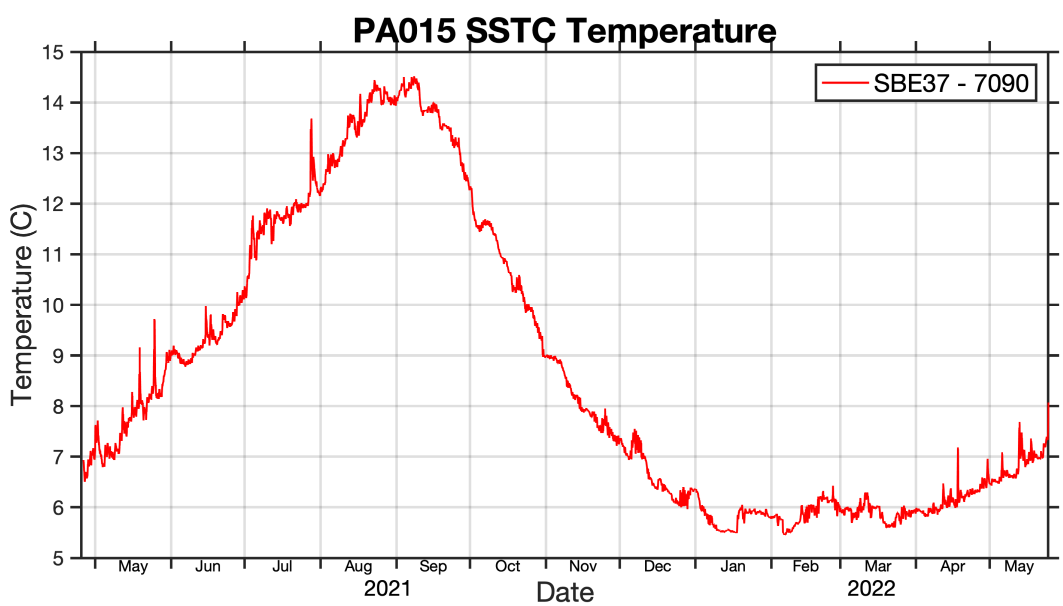

Figure C 8: Secondary (TFlex) SSTC Temperature. Despite the TFlex failure, Seabird instruments record internally and delayed-mode data were recovered post-mission.

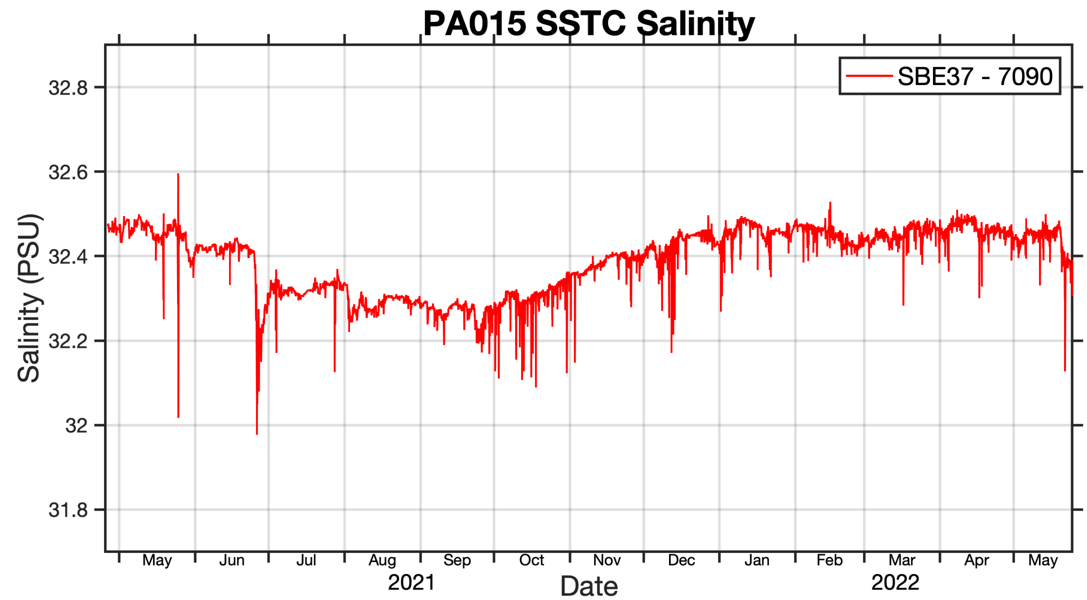

Figure C 9: Secondary (TFlex) SSTC Salinity.

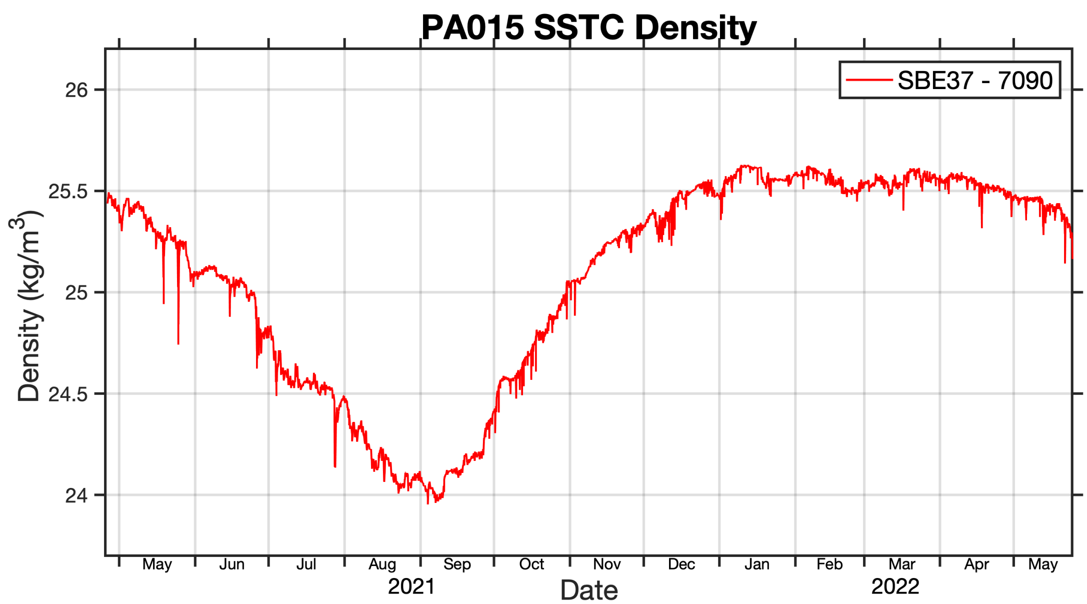

Figure C 10: Secondary (TFlex) SSTC Density.