NOAA Pacific Marine Environmental Laboratory
Ocean Climate Stations Project

DATA ACQUISITION AND PROCESSING REPORT FOR PA003

Site Name:	Ocean Station Papa
Deployment Number:	**PA003**
Year Established:	2007
Nominal Location:	50°N 145°W
Anchor Position:	50.13°N 144.84°W
Deployment Date:	June 13, 2009
Recovery Date:	June 17, 2010
Project P.I.:	Dr. Meghan F. Cronin
Report Authors:	N.D. Anderson, J.A. Keene, M.F. Cronin
Data Processors:	S. Brown, C. Fey, P. Plimpton
Date of Report:	September 14, 2017
Revision History:	

Special Notes:

A clock error in the primary data acquisition system (ATLAS) occurred on June 8, 2010. Data were flagged bad from this day to the end of deployment, so primary meteorological data are not available for the last few days.

Table of Contents

List of Tables

List of Figures

Data Acquisition and Processing Report for OCS Mooring PA003

1.0 Mooring Summary

The NOAA Ocean Climate Stations surface mooring at Ocean Station Papa was initiated through a National Science Foundation Carbon and Water in the Earth System project "North Pacific Carbon Cycle" to Dr. S. Emerson (UW). NOAA's Office of Climate Observations (OCO), now the Ocean Observing and Monitoring Division (OOMD), took over support of the mooring in 2009. The mooring deployment and servicing occurred in collaboration with the Fisheries and Oceans Canada, Pacific Region, Line-P Program aboard the CCGS JOHN P. TULLY. OCS is thankful for the generous ship time provided by Fisheries and Oceans Canada, as part of a cruise headed by the Institute of Ocean Sciences (IOS). The captain, crew, and scientists aboard are also gratefully acknowledged for their contributions.

The PA003 mooring was deployed in June 2009 at Ocean Station Papa to monitor ocean-atmosphere interactions, carbon uptake, and ocean acidification. PA003 was the third NOAA OCS mooring deployment at this site.

A separate subsurface ADCP mooring was anchored 10.2km from the PA003 anchor. The map below shows the mooring locations, and additional details on the subsurface mooring can be found in Appendix C.

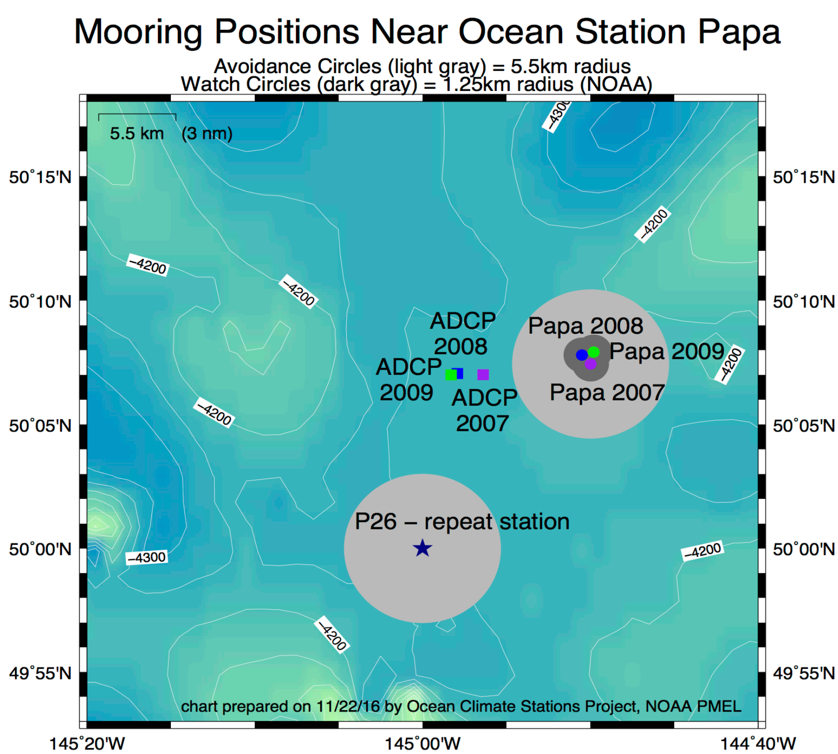

Figure 1: Mooring positions around station P26.

1.1 Mooring Description

The PA003 mooring was a taut-line mooring, with a nominal scope of 0.985. Non-rotating 7/16" (1.11cm) diameter wire rope, jacketed to 1/2" (1.27cm), was used in the upper 325m of the mooring line. The remainder of the mooring consisted of plaited 8-strand nylon line to the acoustic release in line above the anchor. The 6,850lb (3,107kg) anchor was fabricated from scrap railroad wheels.

The surface buoy was a solid-hull fiberglass-over-foam discus buoy, with a water tight center well. It had an aluminum tower and a stainless steel bridle. A load cell was deployed on the PA003 bridle.

A CO_2 flux monitoring system was also deployed on the PA003 mooring, in collaboration with the PMEL Carbon Group. OCS is not responsible for the acquisition or processing of these data. No further discussion of that system is included in this report. For further information on the Papa biogeochemistry data, see http://www.pmel.noaa.gov/co2/.

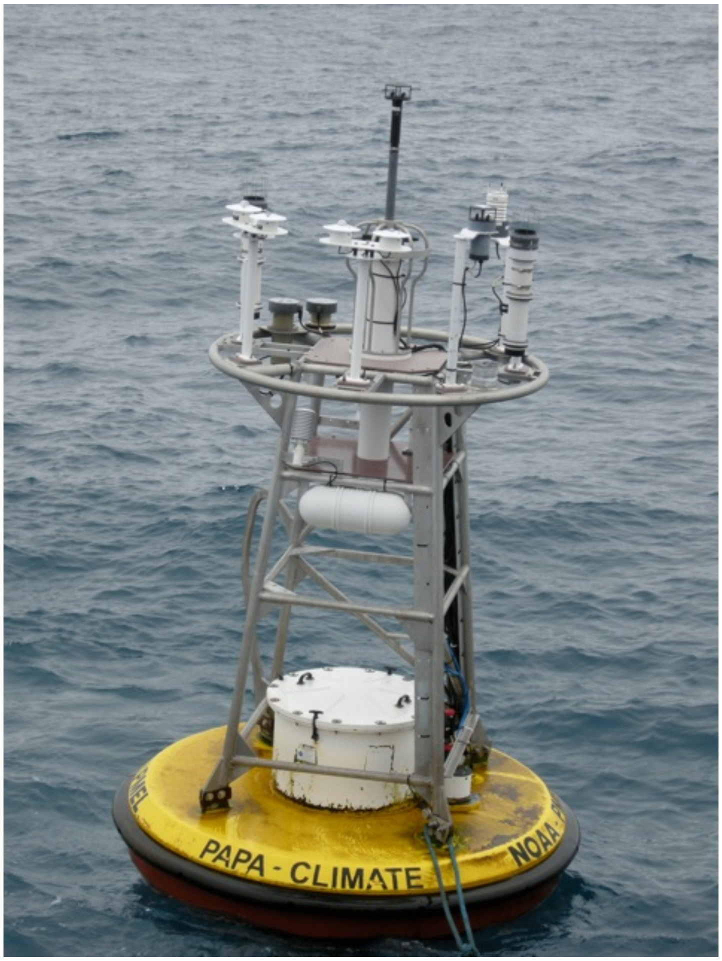

Figure 2: PA003 mooring upon recovery.

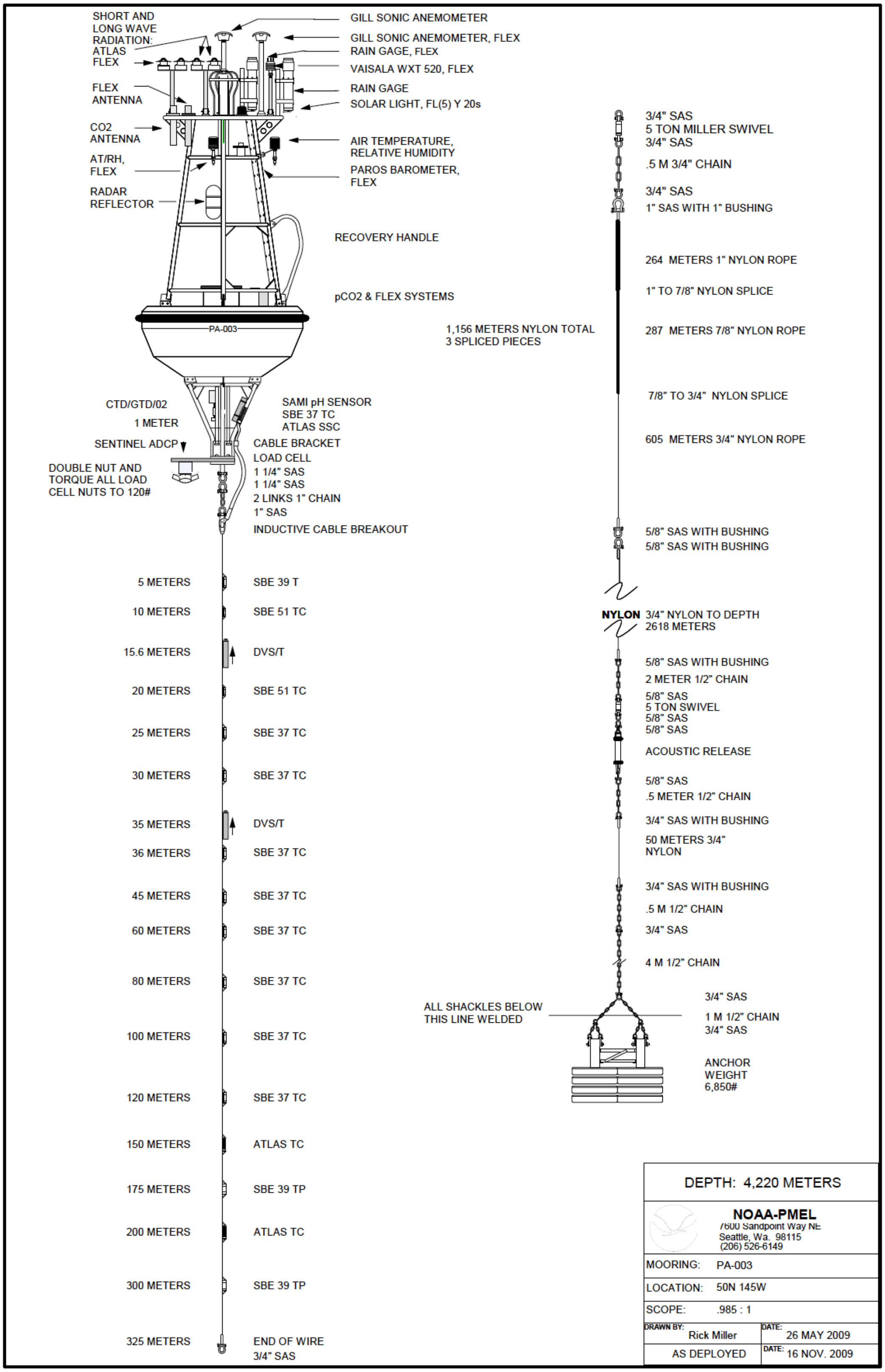

Figure 3: PA003 mooring diagram.

1.2 Instrumentation on PA003

The following instrumentation was deployed on PA003. Redundant data acquisition systems were used, ATLAS and Flex. ATLAS meteorological sensors are considered primary, except in cases where a sensor was only deployed on the Flex system (e.g. BP).

DEPLOYMENT: PA003					
Met Sensors				**Serial #**	**Notes**
Height	Acquisition		**ATLAS**	688	w/ C100 compass
2.6m	ATRH		Rotronics MP101	91577	
3.6m	Rain		RM Young/50203	748	
3.7m	SWR		Epply PSP	32426	
3.7m	LWR		Epply PIR	32773	
4.2m	Wind		Gill Windsonic	42213	
	Acquisition		**Flex**	0002	
2.6m	ATRH		Rotronics MP101	58365	
3.6m	Rain		RM Young/50203	971	
3.7m	SWR		Epply PSP	31647	
3.7m	LWR		Epply PIR	32768	
3.7m	Wind		Gill Windsonic	073805	w/ C100 compass (#070801773)
3.7m	Combo		Vaisala WXT520	D3840028	w/ C100 compass (#080801754), swapped out Vaisala D3840026
2.6m	BP		Paroscientific/MET1-2	101762	
CO2	Electronics		PMEL	0015	Matching air block & antenna can
	Span gas			JA02244	525psi recovered, 437.13 ppm
Subsurface					
Bridle					
1m	SSC		ATLAS SSC module	13763	
1m	SSTC		Seabird SBE-37SMP	3802	titanium
1m	pH		SAMI (UW)	3	interfaced with mapCO2;
1m	CTD/GTD/O2		SBE16 + (UW)	5105	
1m	Load Cell		3PS Pancake	A0608173	
2m	ADCP		Sentinel	9773	downward looking; failed
Depth		ID			Flex Inductive
5m	TC	1	Seabird SBE-39T	3285	
10m	TC	2	Seabird SBE-51TC	0004	
15.6m	Current mtr	3	RDI DVS	0012	Upward-facing, 1m bin centered at 15m
20m	TC	4	Seabird SBE-51TC	0005	
25m	TC	5	Seabird SBE-37TC	6072	
30m	TC	6	Seabird SBE-37TC	6073	
35m	Current mtr	8	RDI DVS	0015	Upward-facing, 1m bin centered at 34m.
36m	TC	7	Seabird SBE-37TC	6074	Swapped from 35m to 36m to avoid potential DVS interference
45m	TC	9	Seabird SBE-37TC	6075	
60m	TC	10	Seabird SBE-37TC	6076	
80m	TC	11	Seabird SBE-37TC	6077	
100m	TC	12	Seabird SBE-37TC	6078	
120m	TC	13	Seabird SBE-37TC	6079	
150m	TC		ATLAS TC module	12986	not realtime; TCV setup as TV
175m	TP	14	Seabird SBE-39TP	4379	
200m	TC		ATLAS TC module	12411	not realtime; TCV setup as TV
300m	TP	15	Seabird SBE-39TP	4380	
325m	end of wire				

Table 1: Instruments deployed on PA003.

2.0 Data Acquisition

Two independent data acquisition systems were deployed on PA003. The ATLAS data acquisition system transmits daily average and intermittent spot meteorological measurements to shore through Service Argos satellites. The Flex system uses Iridium satellite communications to regularly transmit data. For PA003, Flex was connected to most of the subsurface instruments using an inductive line. High resolution surface data from the acquisition systems, as well as internally logged data from the subsurface instruments, were downloaded upon recovery of the mooring.

The ATLAS system does not acquire or store position information, but buoy positions are provided by the Service Argos satellites. When four or more satellites are in the buoy's field of view during data transmissions, the satellites assess the Doppler shift of the known transmission frequency to generate estimates of latitude and longitude. These opportunistic position estimates are then appended to the data transmissions.

More accurate Global Positioning System (GPS) data were also acquired and telemetered to shore, via two Iridium Positioning beacon Systems (IPS) on the buoy. GPS/IPS positions were recorded by the Flex system at approximately six-hour intervals.

2.1 Sampling Specifications

The tables below describe the high-resolution sampling schemes for the PA003 mooring. Observation times in data files are assigned to the center of the averaging interval.

PRIMARY SENSORS *No data recovered from the profiling ADCP.

Measurement	Sample Rate	Sample Period	Sample Times	Recorded Resolution	Acquisition System
Wind Speed/Direction	2 Hz	2 min	2359-0001, 0009-0011…	10 min	ATLAS
Air Temperature + Relative Humidity	2 Hz	2 min	2359-0001, 0009-0011…	10 min	ATLAS
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	ATLAS
Shortwave Radiation	1 Hz	2 min	2359-0001, 0001-0003…	2 min	ATLAS
Longwave Radiation (Thermopile, Case & Dome Temperatures)	1 Hz	2 min	2359-0001, 0001-0003…	2 min	ATLAS
Seawater Temperature, Pressure & Conductivity	1 per 10 min	Instant.	0000, 0010,…	10 min	Internal
Ocean Currents (Point)	1 Hz	2 min	2359-0001, 0059-0101…	60 min	Internal
Ocean Currents (Profile)	1 Hz	2 min	2359-0001, 0029-0031…	30 min*	Internal

Table 2: Sampling parameters of primary sensors on PA003.

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
Rain Rate	1 Hz	1 min	0000-0001, 0001-0002…	1 min	Flex
Shortwave Radiation	1 Hz	1 min	2359-0000, 0000-0001…	1 min	Flex
Longwave Radiation (Thermopile, Case & Dome Temperatures)	1 Hz	1 min	2359-0000, 0000-0001…	1 min	Flex
GPS Positions	1 per 6 hrs	Instant.	0000, 0600…	~6 hrs	Flex

Table 3: Sampling parameters of secondary sensors on PA003.

2.2 Primary Data Returns

```
PA003a  2009-06-13 18:18:00 [164] to 2010-06-17 14:30:00 [168]
ATLAS Tube 688, software version 4.10a:
        Wind    42213    97.1%  - tube clock error
        AirT    91577    97.1%
          RH    91577    84.5%  - out of range values
         SWR    32426    97.1%
        Rain      748    97.1%
         LWR    32773    97.1%

Flex System 0002:
          BP   101762    82.9% (ends 4/21)

Subsurface:
     1m TC  37-3802 100.0% t, 99.7% c (142 flagged in c)
     5m  T  39-3285  28.4% dead battery, scattered flags, ends early
    10m TC  51-0004 100.0% t&c
    20m TC  51-0005 100.0% t&c
    25m TC  37-6072 100.0% t&c
    30m TC  37-6073 100.0% t&c
    36m TC  37-6074 100.0% t&c
    45m TC  37-6075  99.6% t&c 205 flags (started late)
    60m TC  37-6076 100.0% t&c
    80m TC  37-6077 100.0% t&c
   100m TC  37-6078 100.0% t&c
   120m TC  37-6079 100.0% t&c
   150m TC  12986   100.0% t&c
   175m TP  39-4379  99.1% 456 flags (1e35s scattered throughout)
   200m TC  12411   100.0% t&c
   300m TP  39-4380  99.1% 456 flags (1e35s scattered throughout)
```

2.3 Known Sensor Issues

The ATLAS system, providing all primary meteorological data (except barometric pressure), stopped transmitting on June 8, 2010 [159]. Depleted batteries were the cause, with the logic battery reporting 7.8V and the transmit battery at 9.4V. There was also a large forward time shift in the downloaded data, skipping from [159] to [168]. Timestamps were corrected to appropriately end on [159], when the ATLAS system failed.

The bridle mounted Sentinel ADCP did not return any usable data. There was a single 208 KB file containing data from 00Z June 9 to 12Z June 11, having ended before the mooring was deployed. All the settings were reviewed and found to be correct, including being set for 30 minute sampling.

The ADCP Li battery pack, which was new February 13, 2009 and had a starting voltage of 48V, was dead (7V) on recovery. There was no visible external evidence of shorting, corrosion, or other damage to the battery pack. The inside of the pressure case was dry and there was no visible damage to the unit. The data for the brief pre-deployment period shows that it was obtaining valid heading, pitch and roll measurements.

The Sentinel's firmware (50.32) was reported by the manufacturer to be bad after the deployment of PA003. Updated versions (50.36 and higher) were later provided by Teledyne RDI to address a data logging issue. In addition, TRDI discovered a problem with the PIO board of this particular instrument. During testing, a large drain in battery power was not seen, but the system did shut down unexpectedly. The PIO board was replaced free of charge.

The DVS current meter at 15m failed immediately after deployment and did not record any good temperature or velocity data, while the DVS at 35m stopped logging on January 23, 2010 [023].

The Flex system, providing all secondary meteorological data, failed on April 21, 2010 [111], after having reset issues in March. Flex data compared well to ATLAS data until this time. The Flex system ran the inductive line, but since the delayed-mode subsurface data were recovered, primary data impacts were only seen in one variable, barometric pressure. All other Flex surface data were secondary sensors. A leak in the buoy well could have contributed to the Flex system failure, and is discussed in Appendix D.

The Flex shortwave radiation delayed-mode data had missing data (Q0) 32-33 minutes after the hour every 6 hours. From August 9, 2009 [221] until April 17, 2010 [107], the data was largely missing, flagged as a mix of Q0 (missing) and Q5 (sensor failed/out of range).

The Flex longwave radiation instrument also reported highly intermittent data during this timeframe, and was flagged Q0 and Q5 accordingly.

Data from the Flex rain gauge, also 1-minute data, was intermittent starting August 9, 2009. No 10-minute rain rate values could be calculated from the sparse 1-minute data, so the values were replaced with 1E+36, indicating insufficient samples for averaging.

The PA003 mooring was recovered June 18, 2010 [169]. The acoustic release (S/N 30632) was unrecoverable, after many failed attempts to get a response or release. All other instruments were recovered from this deployment. Line was taken aboard until the tension became a safety concern, at which point 4 reels of nylon and part of a 5th reel were lost.

The Flex load cell, a test sensor, failed July 22, 2009 [203]. These data are kept for internal diagnostics, and are not processed or distributed.

3.0 Data Processing

Processing of data from OCS moorings is contracted to the PMEL Tropical Atmosphere Ocean (TAO) project group. Data processing follows the methods described below. The process included 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. Pre-deployment calibrations are applied to the data (recorded as sensor counts) to generate a data time series in engineering units. 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 greater 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, 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.

Individual time series and statistical summaries are examined by trained analysts. 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 small 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/IPS 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.

3.2 Meteorological Data

All primary meteorological sensors on PA003 remained functional, with few data issues, throughout most of the deployment. Due to a clock error in the ATLAS tube at the end of the deployment (likely caused by the dying battery), data records end June 8, 2010.

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:

http://dods.ndbc.noaa.gov/thredds/catalog/oceansites/DATA/PAPA/catalog.html

The PA003 buoy had secondary air temperature, relative humidity, wind, rain, and radiation sensors. A multi-purpose Vaisala WXT 520 was also deployed as a test sensor. Data from the Vaisala were not processed or released.

3.2.1 Winds

There are no special processing notes for winds at PA003. Refer to section 3.0 for general remarks.

3.2.2 Air Temperature

There are no special processing notes for air temperature at PA003. Refer to section 3.0 for general remarks.

3.2.3 Relative Humidity

Relative humidity data from the ATLAS system were automatically flagged in the processed files as 1E+34 (out of range) with quality Q5 (sensor failed) 6753 times. This occurs when values are measured over 100%.

3.2.4 Barometric Pressure

High-resolution Flex barometric pressure data were examined, and determined to be of good quality. Standard quality flags (Q2) were applied and no changes to the data were made. The data ended on April 21, 2010, with the failure of the Flex system. Barometric pressure was the only primary sensor connected to the Flex system that was impacted by the failure.

3.2.5 Rain

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

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

Residual noise in the filtered data may include occasional 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.

The primary ATLAS rain gauge performed well throughout the deployment. The Flex (secondary) rain gauge did not provide enough 1-minute accumulations to calculate 10-minute rain rates after August 9, 2009.

3.2.6 Shortwave Radiation

The ATLAS shortwave radiation sensor performed well during PA003 until the ATLAS system failed shortly before recovery. The Flex (secondary) shortwave radiation sensor reported values intermittently after August 9, 2009.

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).

The behavior of the ATLAS and Flex longwave radiation sensors mimicked the shortwave radiation sensors. The ATLAS LWR failed with the ATLAS system shortly before recovery, and the Flex LWR sensor reported values intermittently after August 9, 2009.

3.3 Subsurface Data

Since this mooring's subsurface instruments were inductively coupled to the Flex system, the two ATLAS modules were standalone instruments. Without being connected with the ATLAS tube, which normally corrects module clocks throughout the deployment, the module clocks began drifting from the time they were turned on. The modules were activated prior to being shipped, well before the start of the deployment. An automated script was used to correct the clock errors from May 21, 2009 to June 23, 2010, interpolating from the start to the end of the data file. Time corrections were needed for TC12986 (150m), since it had a clock error of -19.7 minutes (slow), and TC12411 (200m), since it had a clock error of -13.82 minutes (slow).

All other module and SBE clock errors were under 5 minutes, so no other timing adjustments were made. The next largest clock errors were 4.7 minutes (SBE37-6079), 4 minutes (SBE37-6073), 3.48 minutes (SBE37-6078) and 3.25 minutes (SBE37-6076). These data were not adjusted for clock errors, because the data quality was high (QC=1), and any adjustments would have caused the data to be set at QC=3, an unnecessary downgrade in data quality for a yearlong time drift less than ½ of a sampling interval.

The SBE39 data files contained numerous skipped timestamps. These were filled with 1E+35 (missing data) placeholder values, using an automated script. The missing data were believed to be caused by an incorrect download procedure, but was not caught in time to allow the data to be downloaded again. The instrument memory had already been reset.

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

3.3.1 Temperature

High-resolution temperatures are provided at the original 10-minute sampling increment of the Seabird sensors and ATLAS modules, as well as at hourly and daily resolutions. Spot-sampled hourly temperature data from the DVS current meters were not usable, and were not included in the final data files.

Data from the ATLAS modules at 150m and 200m were corrected for large clock errors, as noted in Section 3.3. These data were in columns 13 and 15 of the temperature file, and flagged as Q3 (adjusted data).

3.3.2 Pressure

Since this was a taut mooring, actual pressures are expected to be close to the pressures at nominal depths. There were two pressure sensors on the mooring line, the SBE39-TPs at 175m and 300m. Using a standard pressure threshold window of 293 - 305 dBar, there were some out-of-range pressures in the 300m data due to strong currents, but no vandalism spikes were observed. Quality flags of Q4 were assigned to the temperature, salinity, conductivity, and density data corresponding to the out-of-range pressures. The percent of data out-of-bounds was 2.25%.

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.

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

Depth:	**Drift:**
1m	-0.0086
10m	-0.0103
20m	-0.0006
25m	-0.0020
30m	0.0102
36m	0.0007
45m	0.0040
60m	0.0080
80m	0.0033
100m	-0.0006
120m	0.0013
150m	0.0024
200m	0.0006

*Negative values indicate scouring; positive values indicate fouling.

The values above indicate the change in calculated salinity data values when post-recovery calibrations were applied to the conductivity measurement, 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's effective cross-sectional area. This expansion is possibly due to scouring of the cell wall by abrasive material in the sea water. Positive values indicate a decrease in the cell's effective cross-sectional area, presumably due to fouling, and secondarily due to fouling or loss of material on the cell electrodes.

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

Manual Salinity Checks

The drift-corrected salinities were checked for continuity across deployments. The instruments compared well with salinity measurements from the previous mooring (PA002b), but there were only data available for comparison from the SBE37 at 1m, because the other instruments on PA002 were lost.

The PA002b and PA003a data at 1m appeared to match up around 32.5psu, but since the PA002b data ended so early, there was a long gap before PA003a data began. There was also a moderate gap between PA003 and PA004, so an ideal comparison in space and time was not possible.

Records from different depths were also compared to one another and checked for unusual density inversions, indicating uncorrected drift of one or more instruments, following the *in situ* calibration procedures are described by Freitag *et al.* (1999). No corrections were found to be necessary by this method.

CTD casts near the PA003 deployment site were also used for data comparison. Three casts occurred during the course of the deployment, one on June 14, 2009 (the deployment), one on August 28, 2009, and one on June 17, 2010 (the recovery). The differences between the deployment data and CTD data showed no need for adjustments.

Redundant instruments were deployed on the bridle, with data from the SBE37 (3802) considered primary and the ATLAS SSC module (13763) data considered secondary. Comparison plots showed that the SBE37 better matched the other depths in terms of drift, whereas the ATLAS SSC module data would have needed several adjustments to match the other depths, including an 8.1 minute clock error correction. The ATLAS SSC module data appeared to drift nonlinearly, becoming more fresh (fouled).

A comparison of the 1m salinities versus rain volumes showed that some of the large fresh spikes remaining after the noise-removal corresponded well to rain events, and hence were likely real.

Data from the ATLAS modules at 150m and 200m were corrected for large clock errors, as noted in Section 3.3. These were in columns 12 and 13 of the salinity / conductivity / density files. Quality flags of Q3 (adjusted data) were applied to the corrected data.

3.3.4 Currents

Two Doppler Volume Sampling (DVS) instruments and a Sentinel ADCP were deployed on the PA003 mooring. The profiling Sentinel ADCP mounted on the bridle did not log any useful data, as noted in Section 2.3.

The DVS point current meters were deployed at two depths on the PA003 mooring. The stated head depth differs from the actual current measurement, because the instruments require a blanking distance. Currents from the instruments deployed at 15.6m and 35m measured velocities at about 14.5m and 33.9m, respectively. (The 35m upward-facing DVS was originally planned to be mounted at 36m, but the position was changed during deployment in order to avoid interference from the nearby SBE37.) Since the PA003 mooring line was taut, current measurements were not corrected for negligible buoy motion.

The DVS at 15.6m (0012) did not log any usable data, returning values of -32767, the manufacturer's version of a missing value. Its temperature measurements were also bad, with a few measurements on the first day, followed by a constant and unrealistic 21.000°C throughout the deployment. The issue was determined to be faulty firmware.

The only DVS to return velocity data was the instrument at 35m. It was set-up with a blanking distance of 7cm, and bin size of 100cm. Only data from the first bin were reported. It was set to sample with 1 second between pings, at 120 pings per ensemble, to generate a two-minute average sample at the top of each hour. A magnetic declination correction of 18 degrees was applied to the data during post-processing.

The functional DVS at 35m (0015) measured the speed of sound, and internally applied sound velocity corrections to current measurements. The data were assigned values of 1E+35 and quality markers Q5 (sensor failed) at times containing suspicious vertical velocities (>10cm/s) or large error velocities (>5cm/s). Since the data were already hourly resolution, no Hanning filter was applied. A boxcar filter was applied to the hourly data to produce daily averaged values.

The 35m instrument reported data until it failed on January 23, 2010 [023]. There were irregular time stamps beginning on January 23, 2010 [023] at 04:00 UTC due to a dying battery. Data after January 23 were not adjusted and contained time errors as large as 30 minutes, so the 35m DVS data were truncated at this time. Temperature data from the 35m DVS were hourly spot measurements. It was decided not to include these in the final hourly temperature data set, because measurements at all other depths were hourly averages. A spot measurement next to an averaged measurement might cause an apparent inversion that could be confusing and difficult to work with.

A post-deployment compass check on the 35m DVS showed ± 10° variations. The instrument may have reverted to its factory calibration when the battery died. If so, the post-deployment calibration was not representative of the instrument when it was functioning. The data were assigned default quality flags, but the data should be treated carefully, as there was no way to assess compass drift prior to the battery dying.

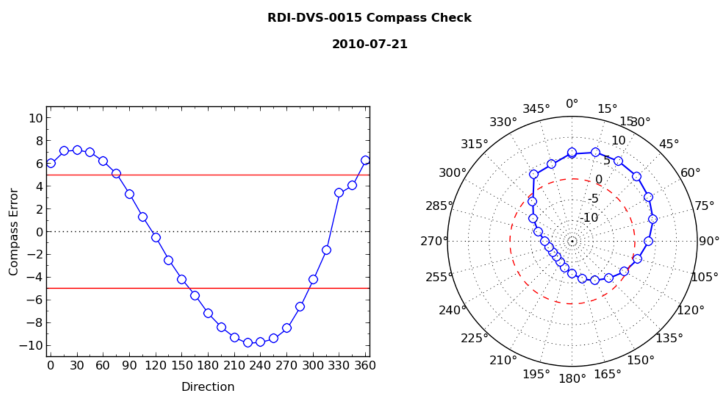

Figure 4: Failed post-deployment DVS compass check.

3.3.5 Load Cell

A load cell on the bridle provided tension readings from the mooring through mid-July 2009, when the sensor failed. These measurements were intended only for internal engineering diagnostics, and are not provided publicly. Users interested in the limited load cell data may contact OCS personnel via http://www.pmel.noaa.gov/ocs/people for additional information.

Since this report was written years after the deployment, a comparison was made to the surrounding years of load cell data, shown in Figure 5. The PA003 load cell data is highly suspect, as the tension readings steadily increased, and were nearly twice the magnitude of any other year's load cell data, despite similar instrument arrangements.

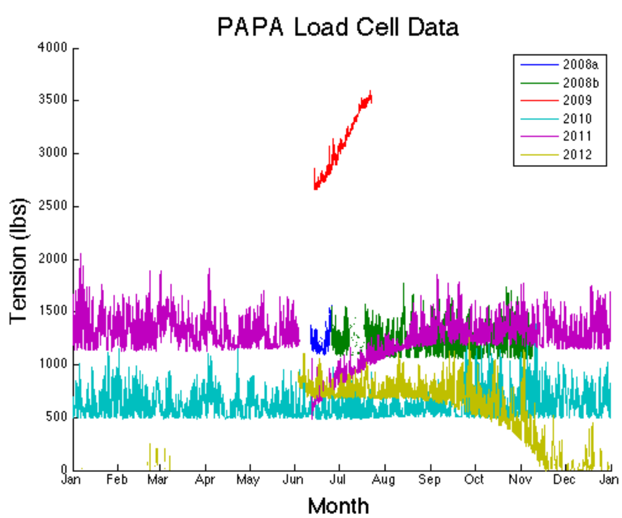

Figure 5: Papa load cell annual comparison.

4.0 References

Alford, M. H., M. F. Cronin, and J. Klymak, 2012: Annual cycle and depth penetration of wind-generated near-inertial internal waves at Ocean Station Papa in the Northeast Pacific. *J. Phys. Oceanogr.*, 42(6), doi: 10.1175/JPO-D-11-092.1, 889–909.

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.

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.

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

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

Dr. Steve Emerson (UW) was lead PI for the NSF project that funded this deployment. The OCS project office is grateful for his vision and efforts to make the NOAA surface mooring at Station Papa possible.

The OCS project office thanks the Line P program for providing shiptime, Chief Scientist, Marie Robert, and the captain and crew of the CCGS JOHN P. TULLY for the deployment and recovery of this mooring. R. Kamphaus (NOAA Corps) and M. Craig (NOAA PMEL) participated in the deployment cruise. K. Ronnholm (UW JISAO) and M. Craig (NOAA PMEL) participated in the recovery cruise.

S. Brown and C. Fey (both of UW JISAO) processed the ATLAS meteorological and subsurface data sets. P. Plimpton processed the current meter data, with additional corrections performed by N. Anderson. J. Mickett (UW APL) provided processed NP003 ADCP data, with additional averaging and reformatting by D. McClurg (UW JISAO).

6.0 Contact Information

For more information about this mooring and data set, please contact:

Dr. Meghan Cronin
meghan.f.cronin@noaa.gov

NOAA/PMEL/OCS
7600 Sand Point Way NE
Seattle, WA 98115

APPENDIX A: 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 TAO quality flags described above are mapped to the different OceanSITES quality flags shown below:

Q0 -	No QC Performed.	
Q1 -	Good Data.	(TAO Q1, Q2)
Q2 -	Probably Good Data.	(TAO Q3, Q4)
Q3 -	Bad Data that are Potentially Correctable.	
Q4 -	Bad Data.	(TAO Q5)
Q5 -	Value Changed.	
Q6 -	Not Used.	
Q7 -	Nominal Value.	
Q8 -	Interpolated Value.	
Q9 -	Missing Value.	(TAO Q0)

APPENDIX B: High Resolution Data Plots and Secondary Data Plots

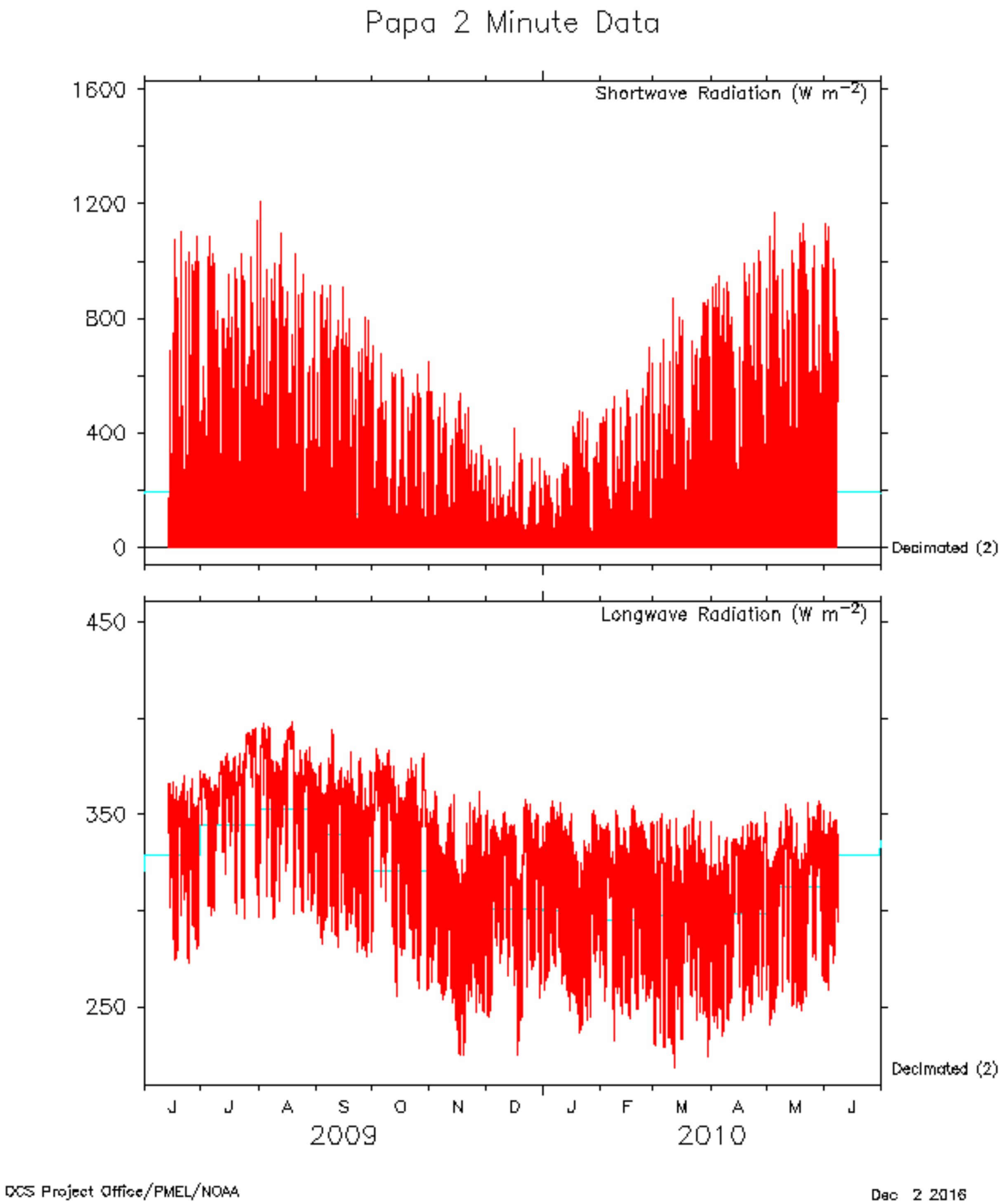

Figure B 1: PA003 primary shortwave and longwave radiation data at 2-min resolution (ATLAS).

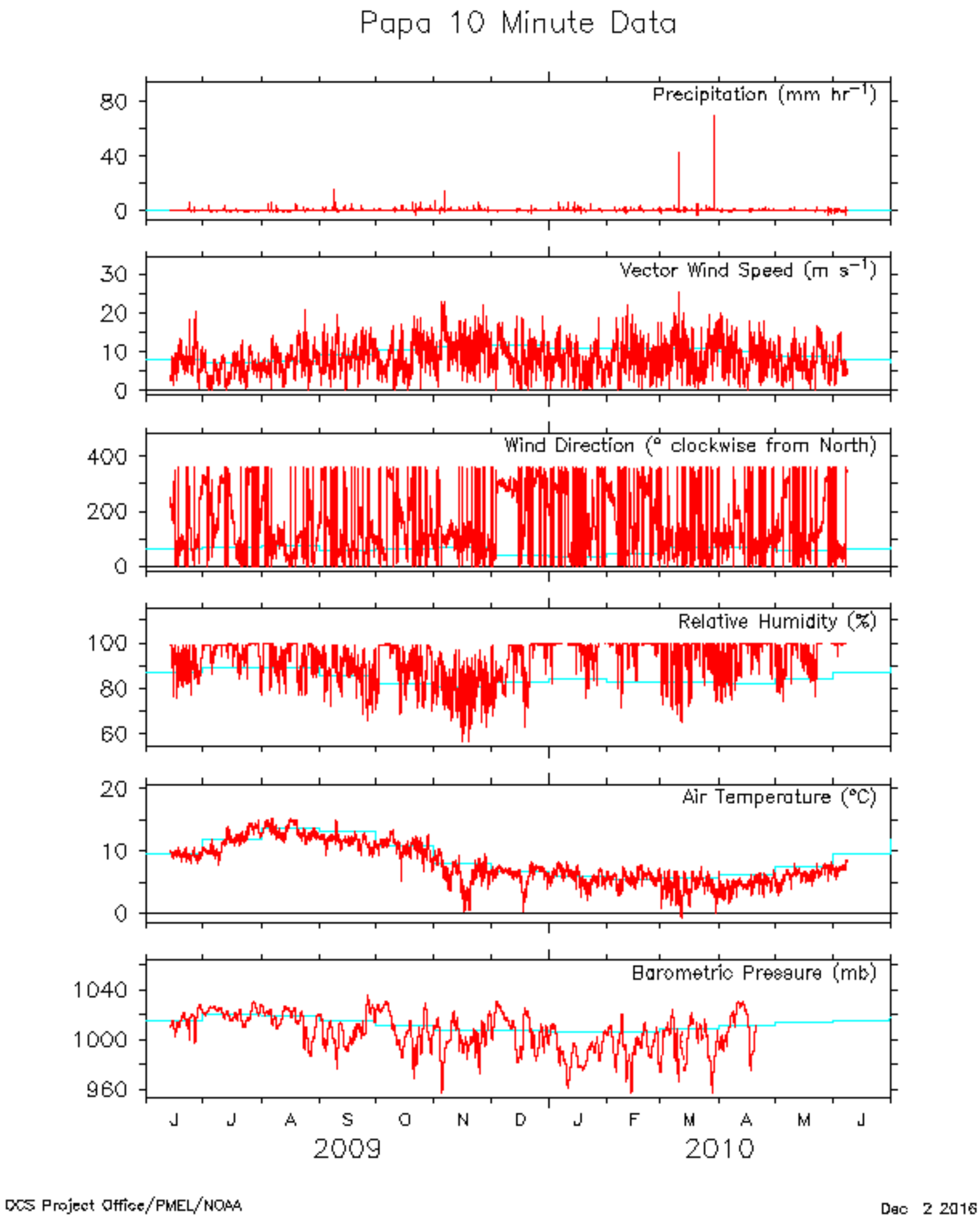

Figure B 2: PA003 meteorological data at 10-min resolution. The primary meteorological sensors failed when their respective acquisition systems failed (Flex = April 21, ATLAS = June 8).

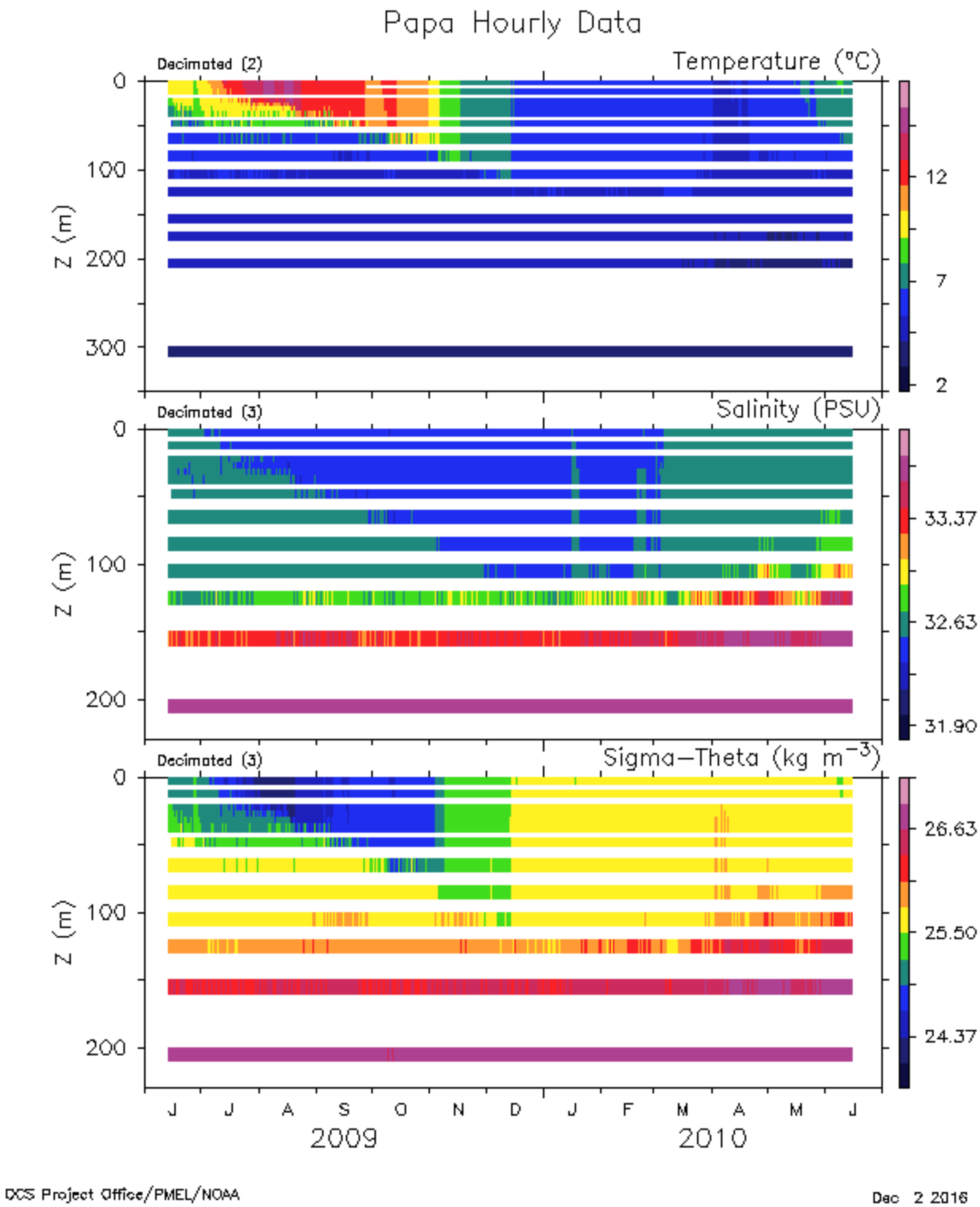

Figure B 3: PA003 subsurface temperature, salinity, and density at hourly resolution (decimated).

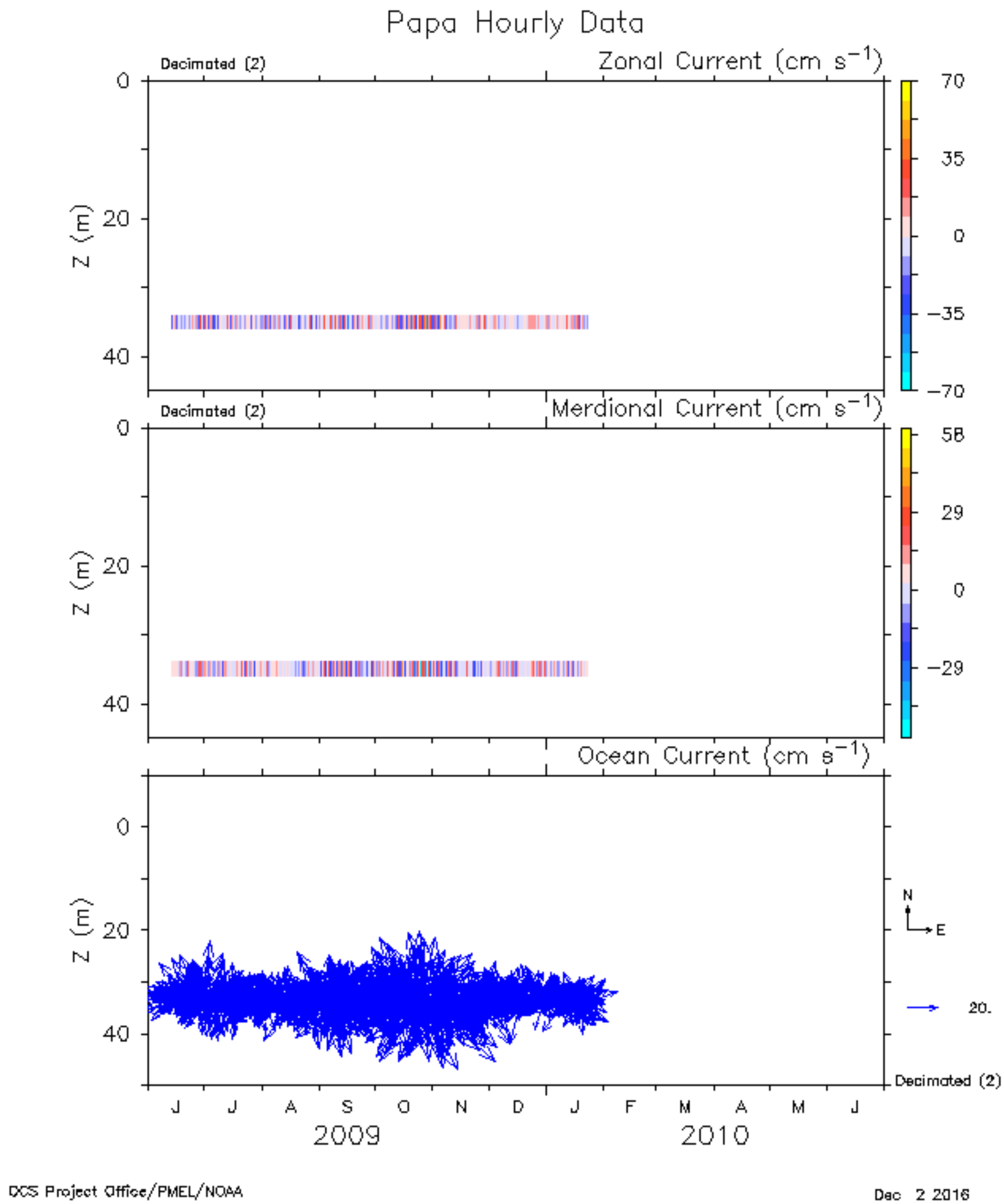

Figure B 4: Zonal and meridional current meter data (decimated) from PA003. The 15.6m DVS produced no velocities, so only the 35m DVS, which failed in January, is shown. The highest resolution of the DVS data was hourly.

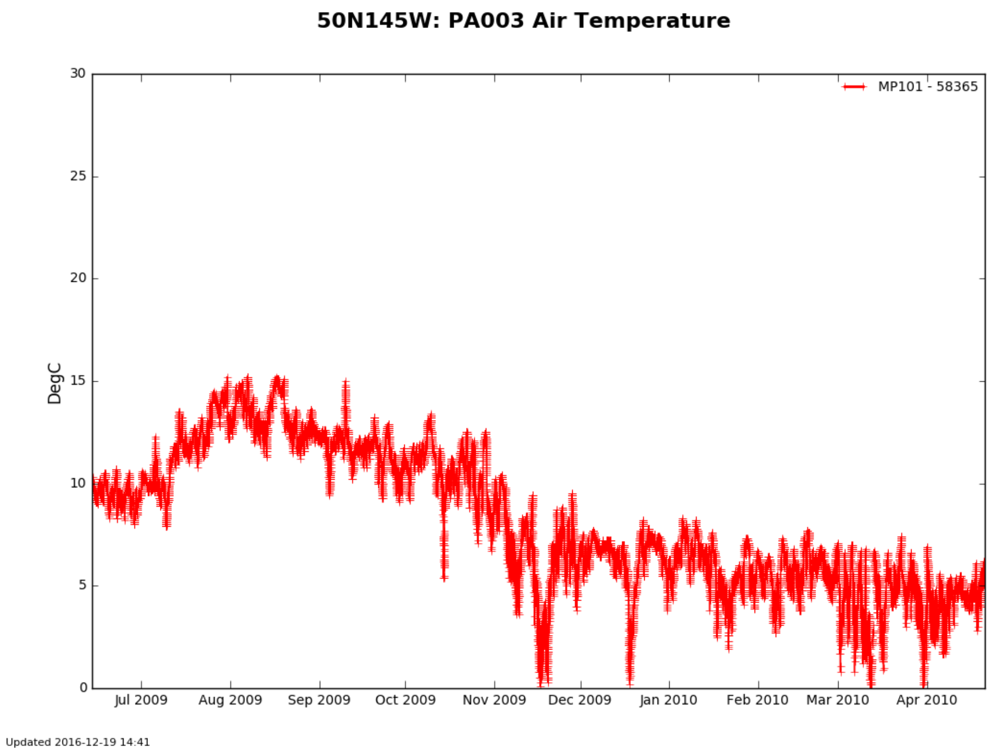

Figure B 5: Secondary (Flex MP101) air temperature sensor.

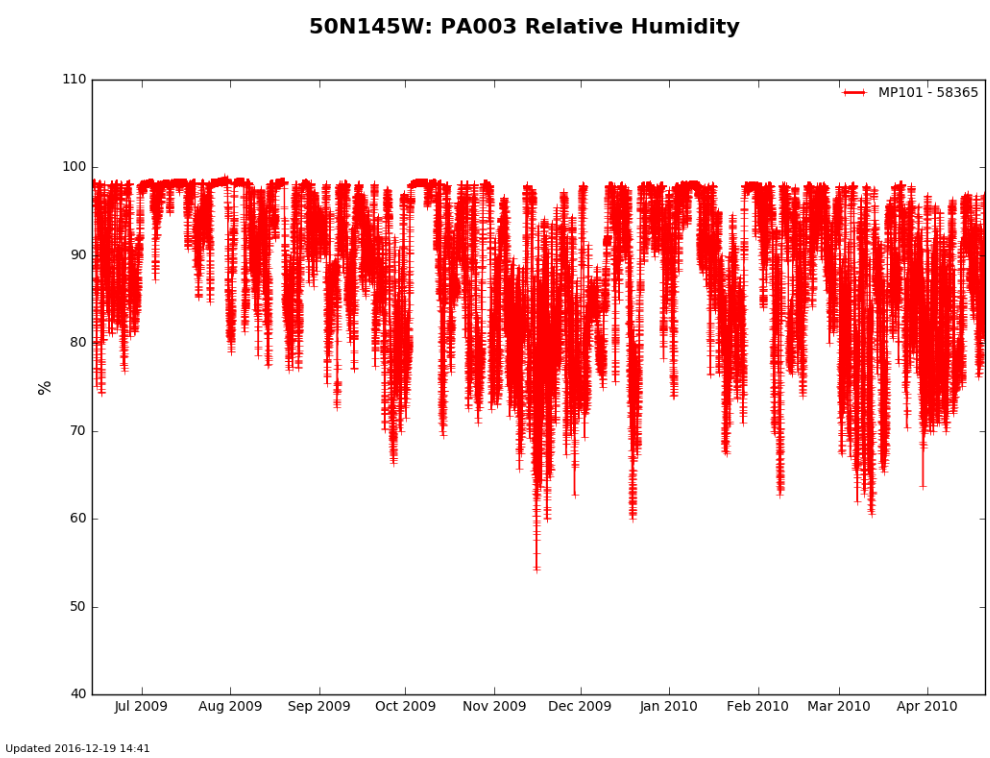

Figure B 6: Secondary (Flex MP101) relative humidity sensor.

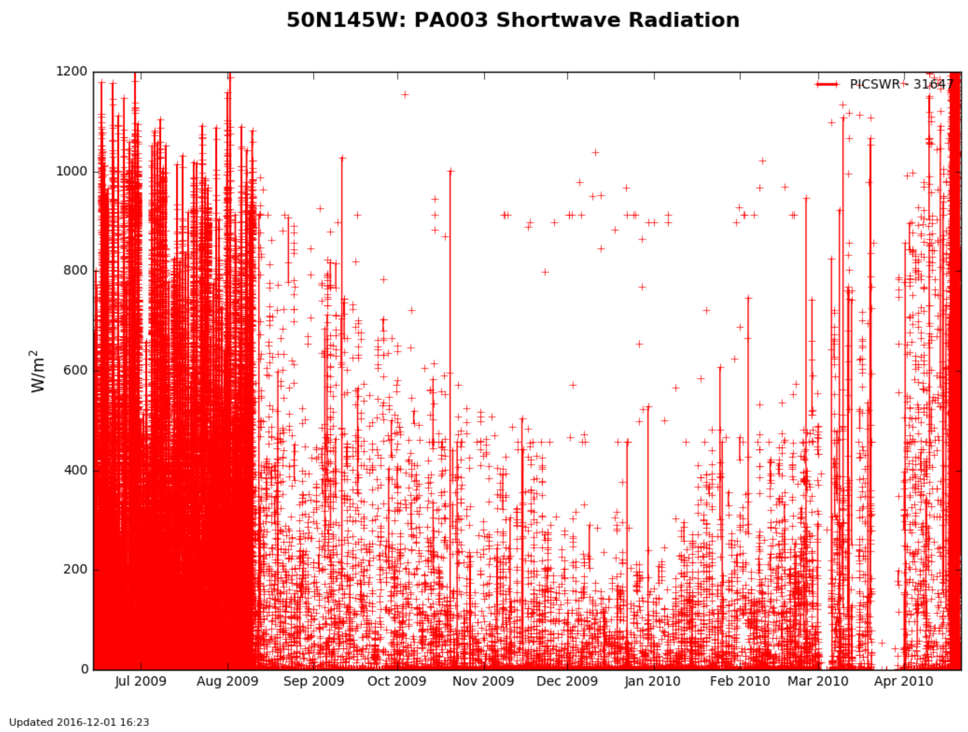

Figure B 7: Secondary (Flex Eppley PSP) shortwave radiation sensor. SWR data became sparse after August 8, 2009.

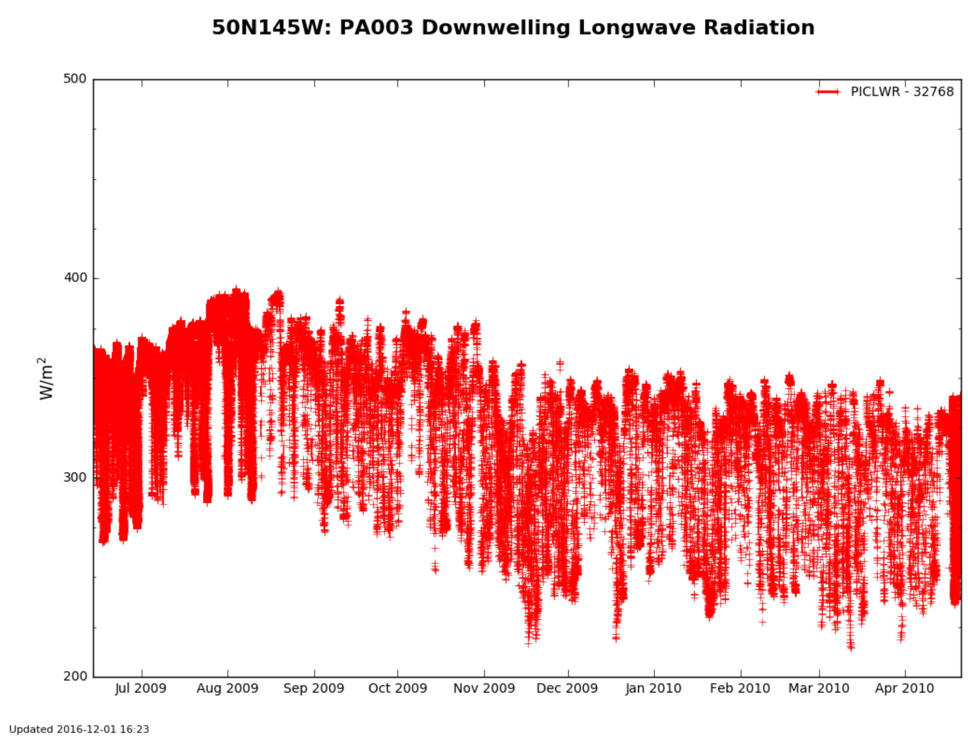

Figure B 8: Secondary (Flex Eppley PIR) longwave radiation sensor. LWR data also became sparse after August 8, 2009.

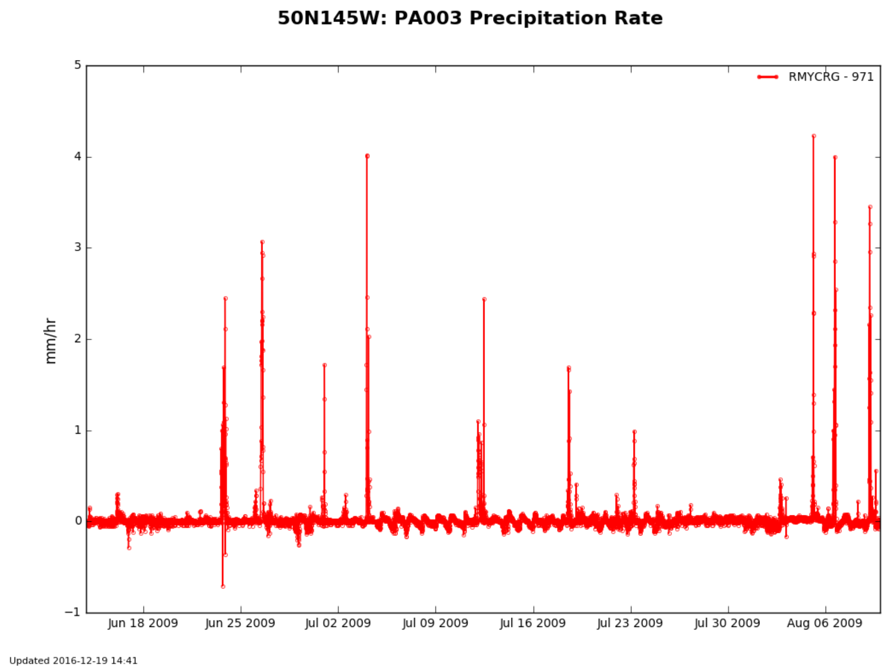

Figure B 9: Secondary (Flex RM Young) rain sensor. The 1-min accumulation data from the Flex RM Young data was too sparse after early August to calculate 10-min precipitation rates, shown here.

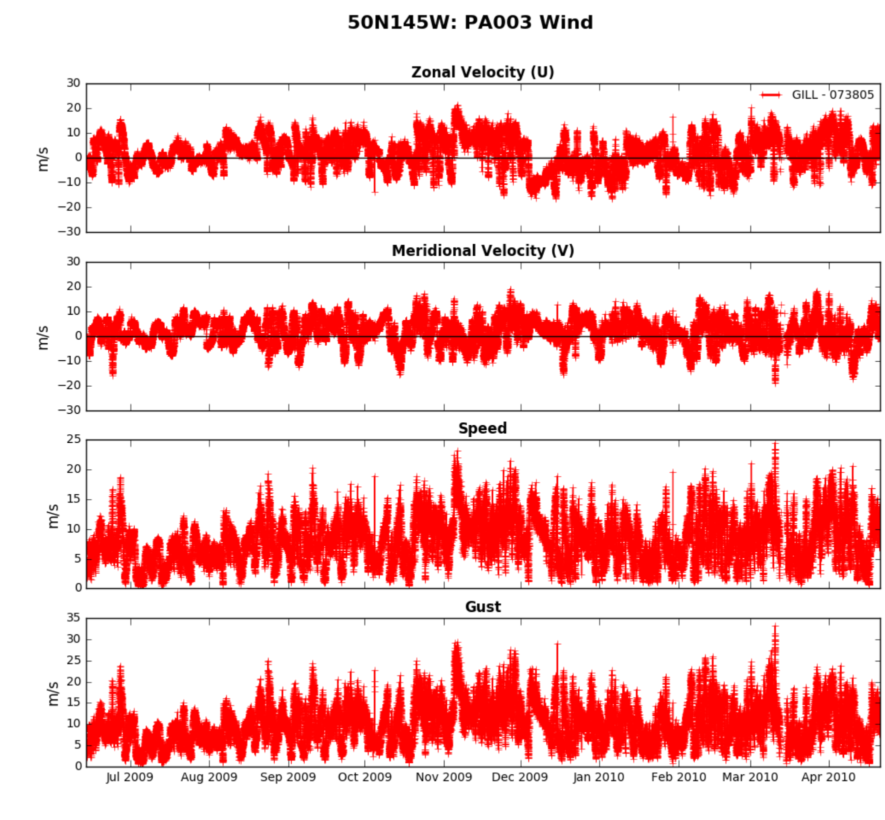

Figure B 10: Secondary (Flex Gill) wind sensor.

APPENDIX C: Papa ADCP Subsurface Mooring

Mooring Description

A separate subsurface mooring (NP003) was deployed in proximity to PA003 that contained two upward-looking ADCPs at nominal depths of 200m and 803m (corrected to 227m and 816m when deployed) and a nominal position of 50.12°N, 144.97°W. An accompanying mooring diagram is provided below in Figure C1. The design was modified by UW-APL for UW releases and UW, UVic, and PMEL instruments.

A 150KHz, upward-looking ADCP (SN 10923) from Jody Klymak of the University of Victoria was mounted at 227m depth, reporting velocity data in 4m bins every 30 minutes. A 75KHz, upward-looking long ranger ADCP (SN 11181) from Matthew Alford (UW-APL) was mounted at 816m and provided velocity data in 16m bins every 30 minutes.

Deployed June 15, 2009 and recovered June 16, 2010, the ADCPs yielded continuous data from near the surface to 800m. ADCP data were processed by John Mickett (UW-APL) and merged into standard formatted files by Dai McClurg (PMEL). The data are distributed as a merged, interpolated product, with 2m binning in the top 200m to match the binning from the previous deployment. More information about the ADCP mooring and data can be found in Alford et al., 2012 (http://journals.ametsoc.org/doi/pdf/10.1175/JPO-D-11-092.1).

The NP003 mooring also carried a Passive Acoustic Listening (PAL) Device at about 300m. PALs can be used to monitor wind speed, rain, marine mammals, and other ambient noise signals. These data are available from the PIs, Dr. Jeff Nystuen (UW APL) and Dr. Jie Yang* (UW APL).

*Dr. Jie Yang has taken over the PAL program at UW APL.

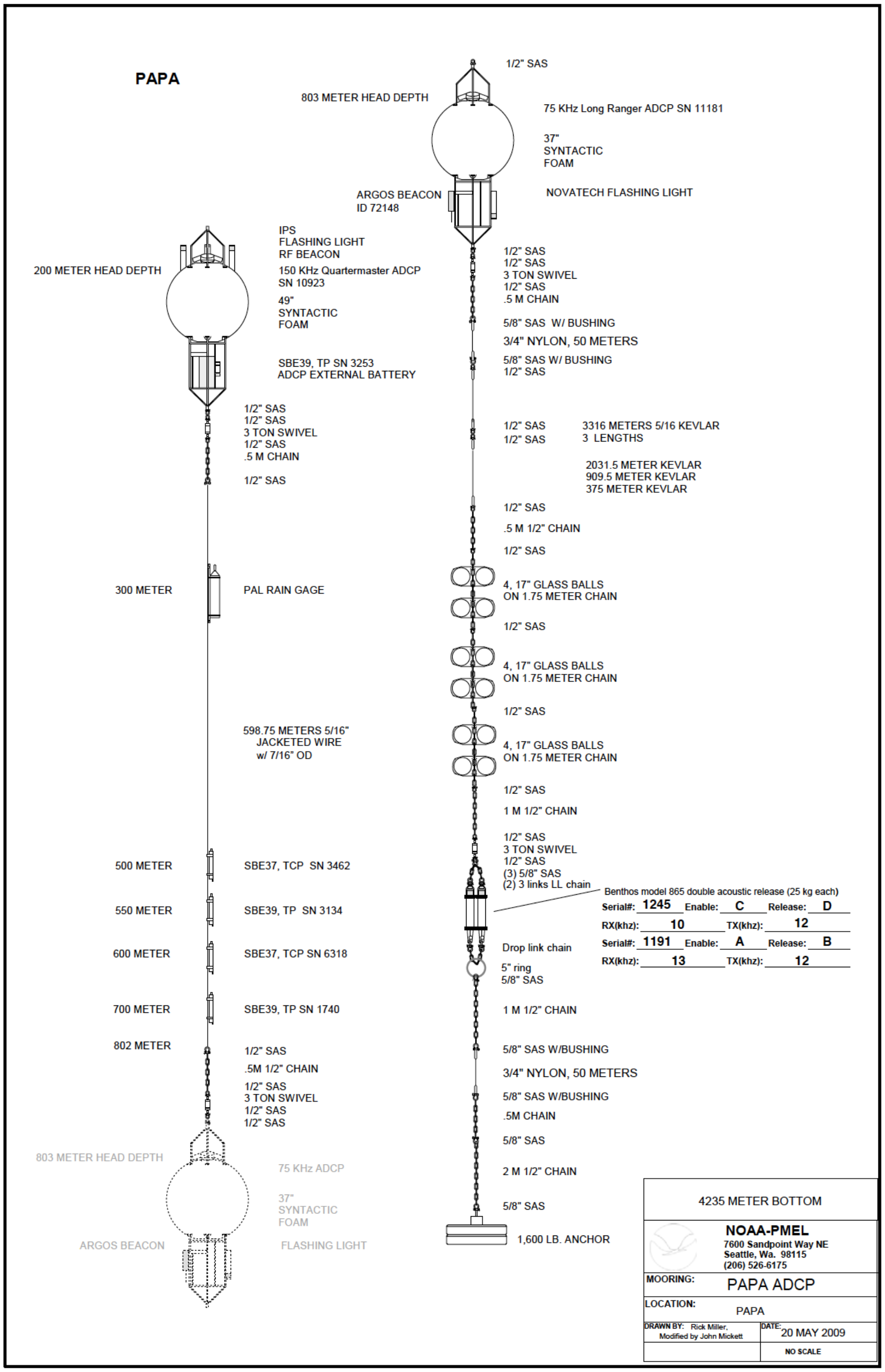

Figure C 1: Mooring diagram "as-planned" for NP003.

ADCP Data

The highest resolution data available from the PA003 subsurface mooring was 30-minute. Figure C2 shows U and V velocity data from the entire deployment.

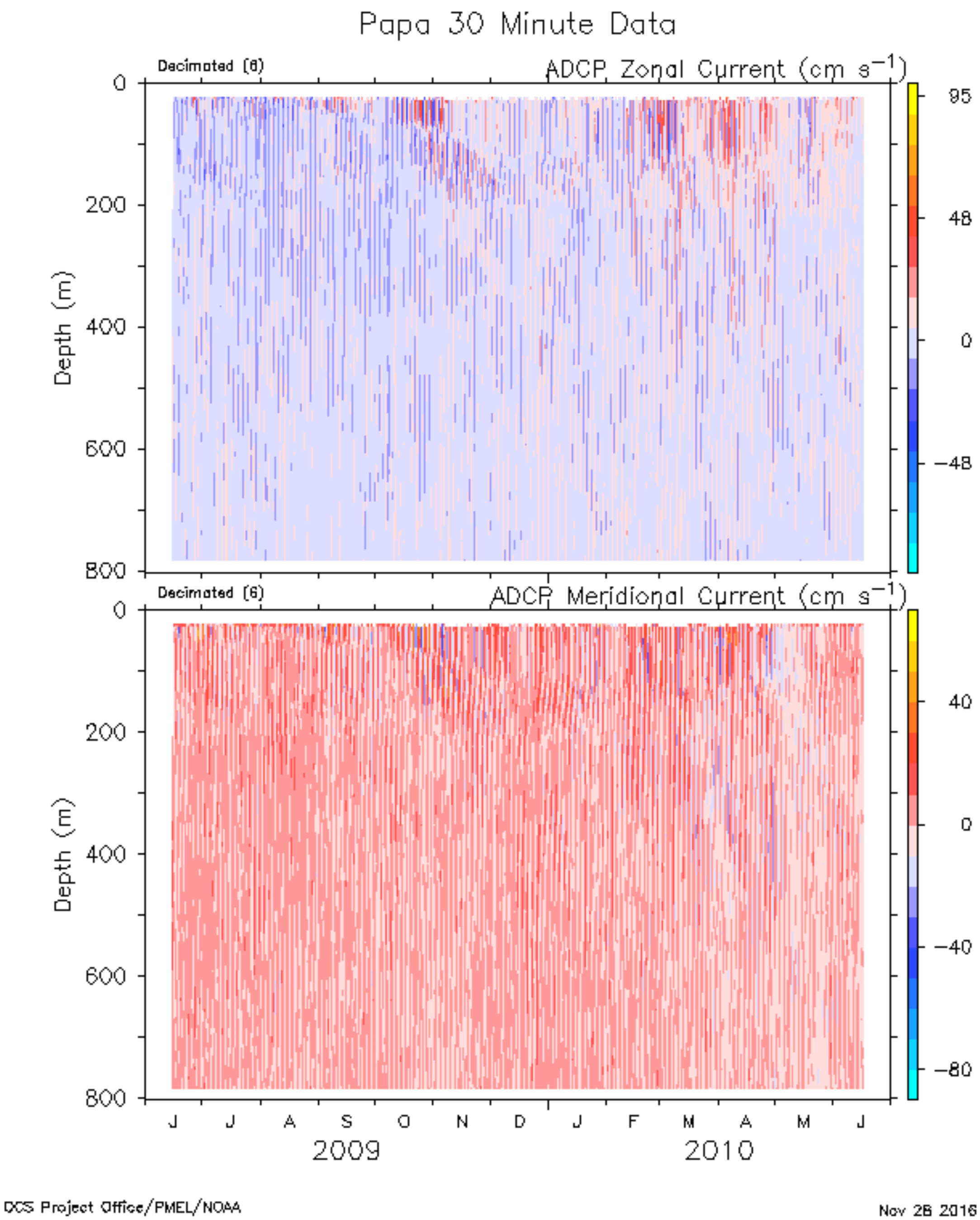

Figure C 2: ADCP data from a special subsurface deployment ("NP003") near PA003.

APPENDIX D: Papa Forensics

The PA003 buoy was evaluated upon recovery to diagnose water intrusion into the buoy well. Evidence of impacts were noticed on the CO_2 and Flex systems, though any link between the leak and the respective system failures on March 22 and April 21, 2010 is unclear.

When the lid on the central well was removed, an estimated ½ gallon of water (about 1 inch in depth) was found at the bottom. The desiccant was pink, indicating it had been fully exhausted. Condensation existed on the lid and interior walls, and various molds and/or salt crystals were found inside the well. The circuit board on the inside of the Flex faceplate was corroded and covered in salt. Mold or salt was also found along the rim of the CO_2 electronics tube, but not inside its cylindrical housing slot. The inside of the Flex box contained small patches of black mold.

The span gas and both Flex battery slots were dry, but the CO_2 battery was damp on the outside, and the bottom terminals were corroded. Water had entered the battery case from the top, which was near the faceplate. Wires on the battery connector were heavily corroded and one broke easily during the battery's removal. The photos below depict the extent of the moisture inside the buoy well.

The central well would not hold a vacuum, so pressure testing was performed. Using a soapy solution, the leak bubbled and was isolated to the lower faceplate (Flex). The double O-rings between the faceplate and the bulkhead were not holding a seal, and the faceplate would not sit flush with the bulkhead. The first O-ring was stretched/deformed from prolonged pinching, and broke upon removal. A new, smaller O-ring was tested, and fixed the problem. The well held a 5inHg vacuum overnight, and additional pressure tests confirmed the well was sealed.

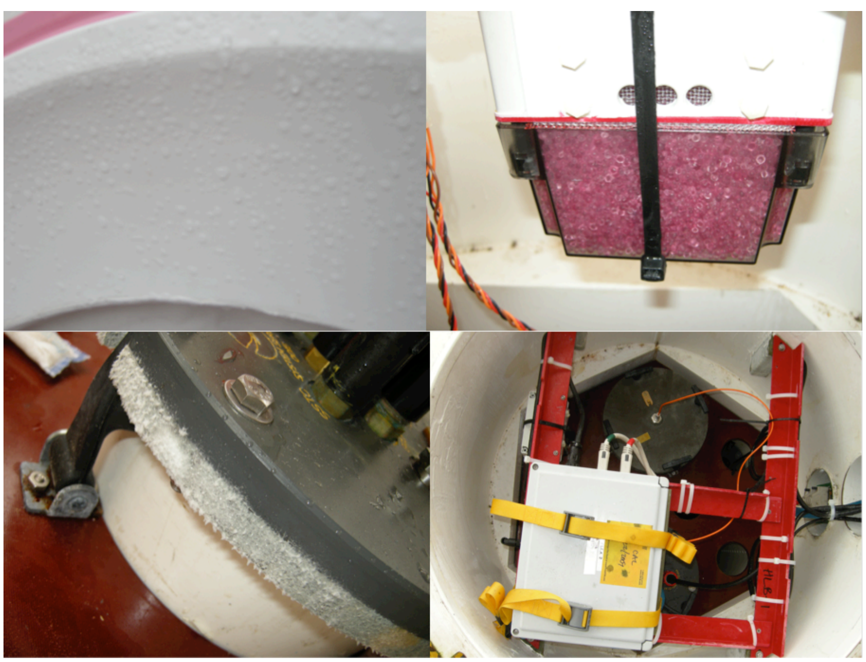

Figure D 1: Clockwise, from top-left: a) Moisture underneath the lid of the buoy well, b) Expended (pink) desiccant inside buoy well, c) View looking into the buoy well from above, and d) White mold or salt build-up around the rim of the CO_2 electronics housing.