NOAA Pacific Marine Environmental Laboratory
Ocean Climate Stations Project

DATA ACQUISITION AND PROCESSING REPORT FOR PA002

Site Name:	Ocean Station Papa
Deployment Number:	**PA002**
Year Established:	2007
Nominal Location:	50°N 145°W
Anchor Position:	50.13°N 144.83°W
Deployment Date:	June 11, 2008
Recovery Date:	January 11, 2009
Project P.I.:	Dr. Meghan F. Cronin
Report Authors:	J.A. Keene, M.F. Cronin, N.D. Anderson, K.B. Ronnholm, and H.P. Freitag
Data Processor:	S. Brown
Date of Report:	August 4, 2017
Revision History:	June 30, 2017

Special Notes:

The PA002 buoy went adrift on November 11, 2008, due to a break in the mooring line at the connection to the bridle. All high-resolution subsurface data were lost with the instruments on the wire.

Table of Contents

List of Tables

List of Figures

Data Acquisition and Processing Report for OCS Mooring PA002

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 in-kind support was provided through the Office of Ocean and Atmospheric Research. The mooring deployment 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 PA002 mooring was deployed in June 2008 at Ocean Station Papa to monitor ocean-atmosphere interactions, carbon uptake, and ocean acidification. PA002 was the second NOAA OCS mooring deployment at this site. It was ready to be deployed in February 2008, but no mooring work could be completed on this cruise, due to weather. The OCS project is grateful to the Line P program for including the project on the June 2008 cruise on short notice.

The mooring was serviced on June 25, 2008 by the R/V MILLER FREEMAN to replace a failed ATRH sensor. Due to failure of the SSC (with no secondary sensor on the bridle), K. Ronnholm (UW JISAO) joined the NOAA SHIP DYSON transect cruise in early September 2008. The repair would have involved 3 divers provided by the DYSON crew. Unfortunately, weather conditions deteriorated and the repair was not performed. On November 11, 2008, the PA002 buoy went adrift due to a break in the mooring line at the connection to the bridle. All high-resolution subsurface data were lost with the instruments on the wire. The drifting buoy was recovered at 49.1°N, 128.5°W, by the F/V AQUILLA on January 11, 2009. The OCS group extends great appreciation to all ships and crew for the repair and recovery missions.

Mooring Line Failure

Upon recovery of the buoy, it was discovered that the nilspin had pulled out of the top termination boot. All instruments below the bridle were not recovered, including OSU sensors provided by Dr. Ricardo Letelier (OSU). S. Emerson's (UW) 10m sensors were mounted to a metal frame attached to the mooring line and were also lost when the mooring broke free. In retrospect, the setup may have imparted additional torque on the line that contributed to the break.

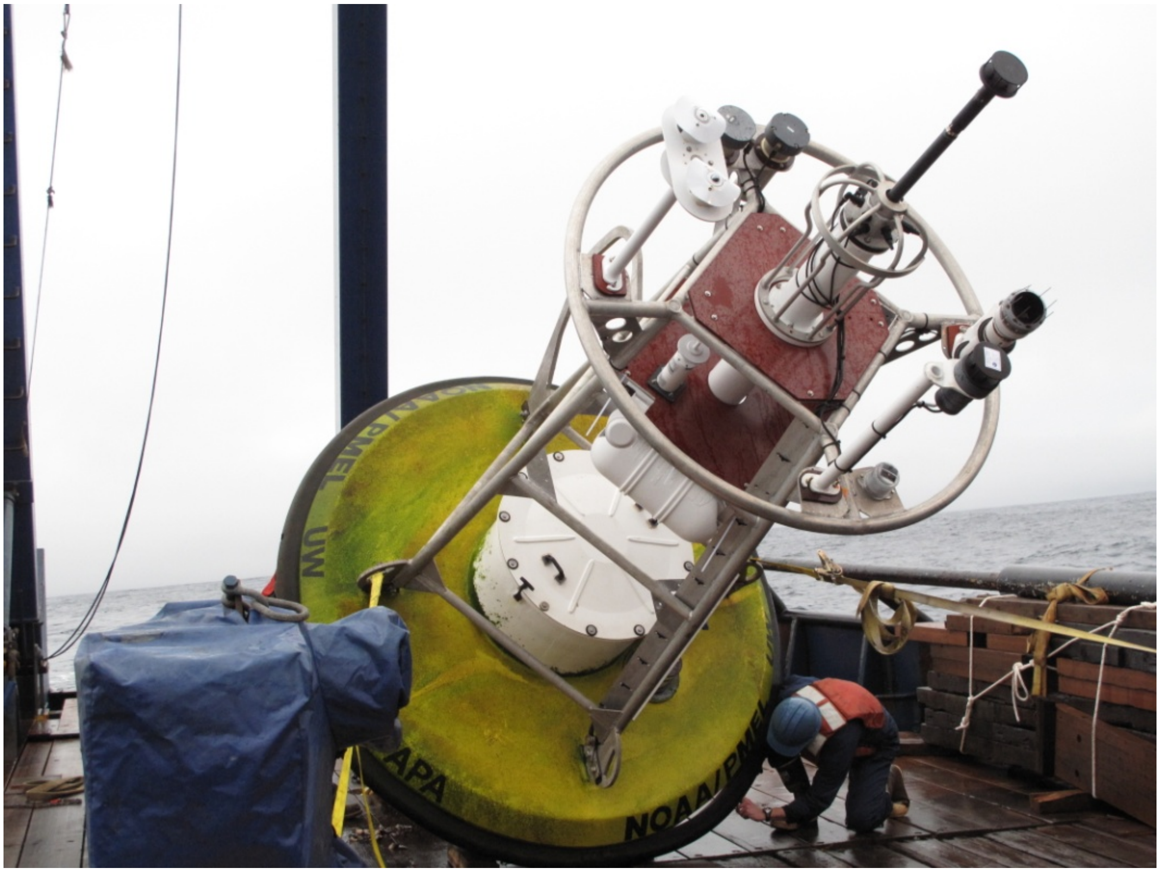

Figure 1: PA002 mooring after recovery.

A separate subsurface ADCP mooring was anchored 8.9km from the PA002 anchor. The map below shows the mooring locations, and additional details on the subsurface mooring can be found in Appendix C.

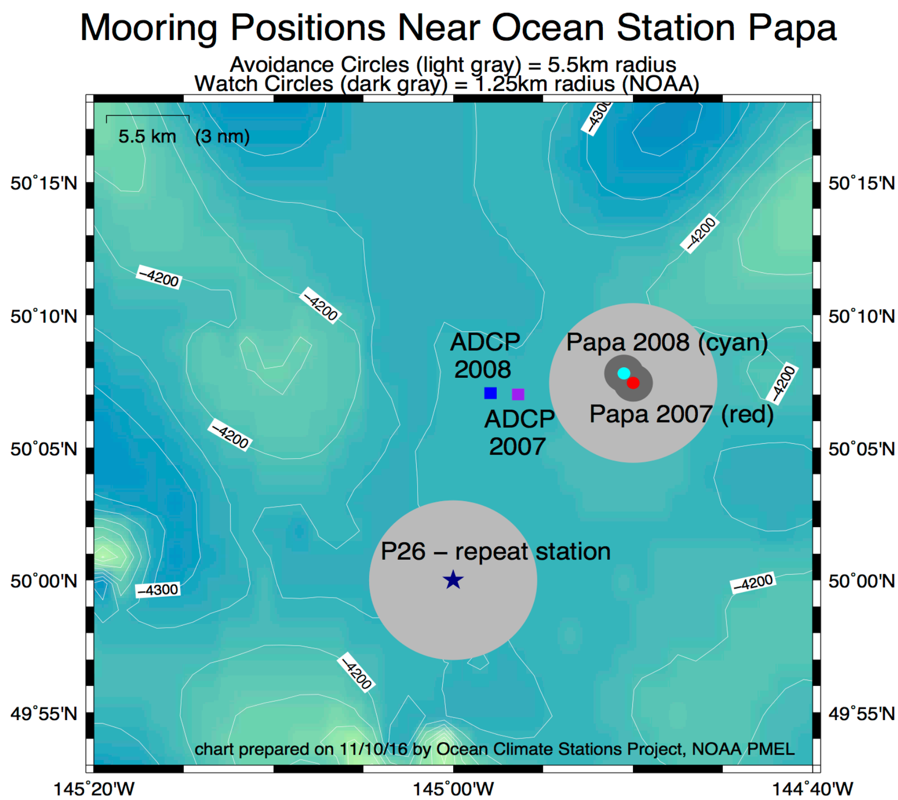

Figure 2: Mooring positions around station P26.

1.1 Mooring Description

The PA002 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 700m 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 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 PA002 bridle.

A CO_2 flux monitoring system was also deployed on the PA002 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/.

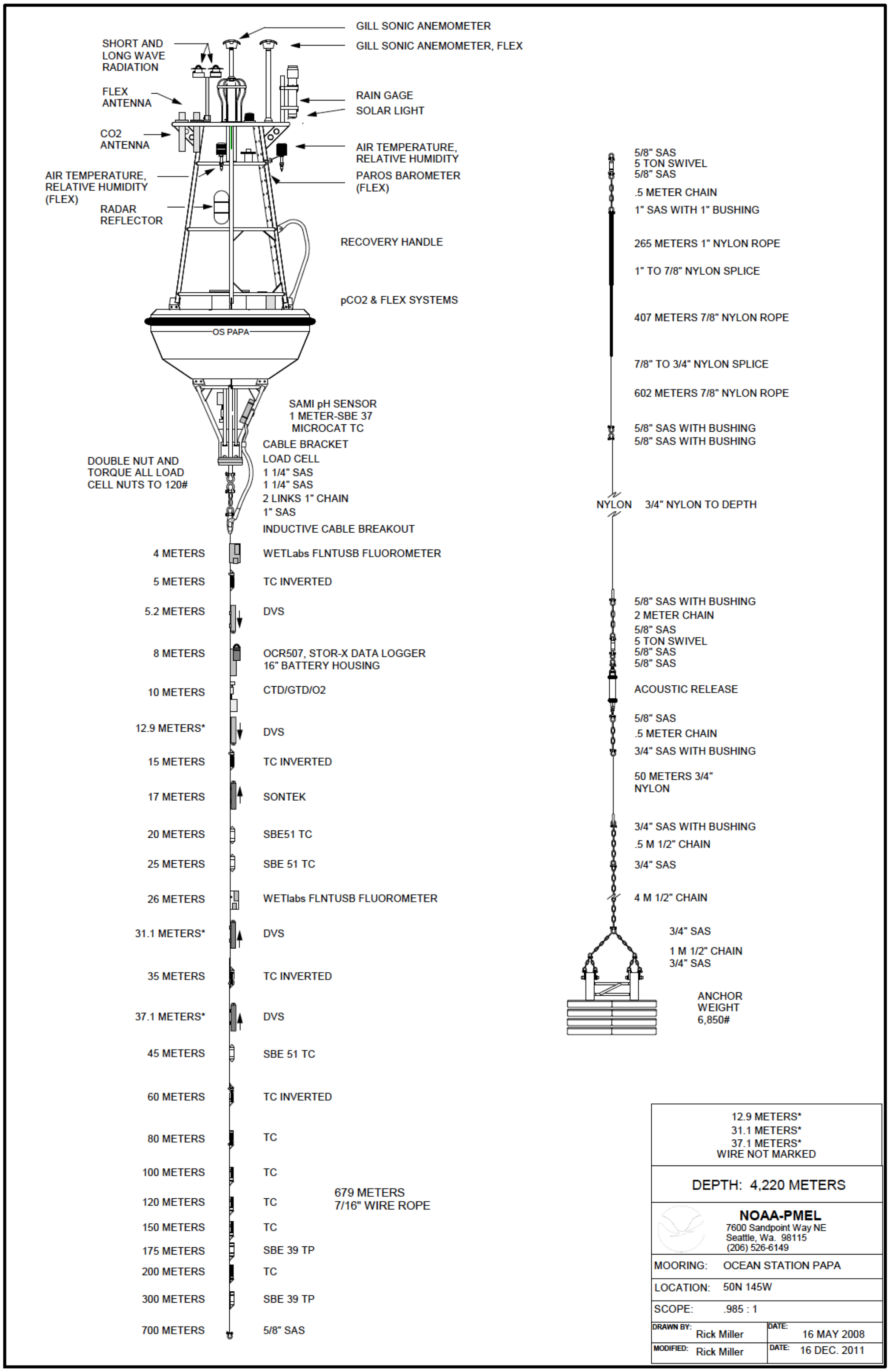

Figure 3: PA002 mooring diagram.

1.2 Instrumentation on PA002

The following instrumentation was deployed on PA002. 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: PA002					
Met Sensors				**Serial #**	**Notes**
Height	Acquisition		**ATLAS**	686	w/ C100 compass
2.6m	ATRH		Rotronics MP101	56599	Replaced with 91577 on 08/177
3.6m	Rain		RM Young/50203	1034	
3.6m	SWR		Epply PSP	32394	
3.6m	LWR		Epply PIR	33341	
4.2m	Wind		Gill Windsonic	51414	
	Acquisition		**Flex**	0004	
2.6m	ATRH		Rotronics MP101	58338	
3.7m	Wind		Gill Windsonic	073805	
2.6m	BP		Paroscientific/MET1-2	101762	
CO2	Electronics		PMEL	0019	
	Span gas			JA02090	
Subsurface					
Bridle					
1m	SSTC		Seabird SBE37TC	3802	titanium
1m	pH		SAMI (UW)	13	interfaced with mapCO2
1m	Load Cell		3PS Pancake	A0608173	
Depth					Flex Inductive
4m	Fluorometer		WETLabs FLNT-USB	709	(OSU)
5m	TC		ATLAS TC Module	12117	
5.2m	Current mtr		RDI DVS	0013	Downward, 50cm bin at 6m
8m	Radiometer		Satlantic	184	3 housings (OSU)
10m	CTD		Seacat/SBE16+	4468	(UW, w/ SBE43 SN 333 attached)
	GTD		Pro-Oceanus	103538	(UW)
	O2		Aanderaa Optode	663	(UW)
12.9m	Current mtr		RDI DVS	9837	Downward, 100cm bin at 14m
15m	TC		ATLAS TC Module	12408	Inverted
17m	Current mtr		Sontek Argonaut	602	Upward, 100cm bin at 16m
20m	TC		Seabird SBE-51TC	0001	
25m	TC		Seabird SBE-51TC	0002	
26m	Fluorometer		WETLabs FLNT-USB	703	(OSU)
31.1m	Current mtr		RDI DVS	9948	Upward, 100cm bin at 30m
35m	TC		ATLAS TC Module	12419	Inverted
37.1m	Current mtr		RDI DVS	9948	Upward, 100cm bin at 36m
45m	TC		Seabird SBE-51TC	0003	
60m	TC		ATLAS TC Module	12435	Inverted
80m	TC		ATLAS TC Module	12729	
100m	TC		ATLAS TC Module	12779	
120m	TC		ATLAS TC Module	13123	
150m	TC		ATLAS TC Module	13162	
175m	TP		Seabird SBE-39TP	3288	
200m	TC		ATLAS TC Module	13164	
300m	TP		Seabird SBE-39TP	3290	
700m	End of wire				

Table 1: Instruments deployed on PA002.

2.0 Data Acquisition

Two independent data acquisition systems were deployed on PA002. 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 PA002, Flex was connected to certain subsurface instruments using an inductive line. High resolution surface data from the acquisition systems were downloaded upon recovery of the mooring, but high resolution data from the subsurface sensors were lost when the mooring broke free.

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 PA002 mooring. Observation times in data files are assigned to the center of the averaging interval.

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	ATLAS
Air Temperature	2 Hz	2 min	2359-0001, 0009-0011…	10 min	ATLAS
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)	0.5 Hz	2 min	2359-0001, 0059-0101…	60 min*	Internal

Table 2: Sampling parameters of primary sensors on PA002.

*All subsurface instruments were lost. Internally recorded high-resolution data were not recovered. Certain real-time data are available as hourly and daily averages.

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	1 Hz	2 min	2359-0001, 0009-0011…	10 min	Flex
Relative Humidity	1 Hz	2 min	2359-0001, 0009-0011…	10 min	Flex
GPS Positions	1 per 6 hrs	Instant.	0030, 0630…	~6 hrs	Flex

Table 3: Sampling parameters of secondary sensors on PA002.

2.2 Primary Data Returns

```
PA002a  2008-06-11 06:00:00 [163]  to  2008-06-25 15:00:00 [177]
ATLAS Tube 686, software version 4.10:
        Wind    51414   100.0%
        AirT    56599   100.0%
          RH    56599   0.0%  all flagged (data out of range)
         SWR    32394   100.0%
        Rain     1034   100.0%
         LWR    33341   100.0%

Flex System 0004:
          BP   101762   51.9%

PA002b  2008-06-25 16:30:00 [177]  to  2009-01-11 19:00:00 [011]
ATLAS Tube 686, software version 4.10:
        Wind    51414   100.0%
        AirT    91577   100.0%
          RH    91577   90.9%  sensor failed 08/359
         SWR    32394   100.0%
        Rain     1034   90.8%  sensor failed 08/359
         LWR    33341   100.0%

Flex System 0004:
          BP   101762   90.6%

Modules:
          1m    SBE37  3802   9.5% sensor failed 08/184
```

All other subsurface instruments were lost, along with their high resolution data. Real-time data return statistics from the subsurface instruments connected inductively to the Flex system are given in Section 3.3.

2.3 Known Sensor Issues

All subsurface instruments were lost when the buoy went adrift on November 11, 2008. Real-time data were available from a fraction of the subsurface instruments, as detailed in Section 3.3, but high resolution subsurface data were not recovered. The surface data were recovered for the pre-adrift and post-adrift portions of the deployment, with the exceptions noted here.

The SBE37-SMP temperature and conductivity sensor on the bridle at 1m stopped logging after 21 days, due to a low battery. No delayed-mode or real-time data at 1m were available after this time.

From July 7 [189] to July 18, 2008 [200], the Flex system reset hourly. Minor reset issues had also occurred in June. Depending on the instrument, the resets resulted in a large data gaps or highly intermittent data (both real-time and delayed-mode) from the instruments attached to the Flex system. The issue was fixed after shutting off a DVS current meter that was causing the resets.

The DVS current meter at 37m did not function from the start of the deployment. The DVS instruments at 12.9m and 31.1m transmitted temperatures, but not velocities, until their real-time data stopped June 13 [165] and July 18, 2008 [200], respectively. The Sontek was not inductively coupled to the Flex system, so there was no real-time data. Real-time current data and temperatures exist from the 5.2m DVS. The short real-time temperature data from the 12.9m and 31.1m DVS instruments were included in the temperature files.

The Rotronic MP-101 ATRH sensor, S/N 56599, which was connected to the ATLAS system, was replaced by S/N 91577 on June 25, 2008 [177] by the R/V MILLER FREEMAN. The relative humidity values from the original sensor had been maxed out during most of the deployment, but the instrument passed calibration tests after recovery, so the cause is unknown. It is possible that the sensor got wet and subsequently dried.

Both the ATLAS and Flex RH sensors failed at the same time later in the deployment, on December 24, 2008 [359], after the buoy went adrift. At recovery, both were found to be tilted over, as if they had been hit. It is possible that a wave soaked and/or impacted both. The AT sensors continued working, so if a wave caused the damage, it appeared to have only soaked the hygrometer in the tip of the sensor and did not leak into the electronics to damage the rest of the sensor.

The rain gauge top was found tilted and broken upon recovery. The body was cracked, the flange on the tower was bent, and when tested, the gauge produced no output. The instrument had reported high "percent time raining", and data became noisy at the same time as the RH sensors failed on December 24, 2008 [359], after the buoy was adrift.

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 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

Meteorological data files from both the Flex and ATLAS systems were truncated when the buoy went adrift on November 11, 2008 [316] at around 16:00 UTC. The last subsurface Flex data telemetered via Iridium satellite was around this time, so this timestamp was used as a divider between pre-adrift and post-adrift data. For users interested in data from the drifting period, or from any of the secondary sensors, these data can be found in the OceanSITES repository here:

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

The Flex system, which controlled all secondary sensors except barometric pressure, reset frequently over the course of the year. Evidence suggested the Flex system clock was affected by the resets, which resulted in a clock discrepancy between the ATLAS and Flex systems. By correlating the processed 10-minute air temperatures from both systems, the Flex clock was adjusted. See Appendix D for more details.

3.2.1 Winds

The PA002 mooring was deployed with dual sonic anemometers on the tower; one on the ATLAS system at the top of the tower, and one connected to the Flex system and located on the ring. ATLAS data are considered primary.

This deployment was used as a test of the dual sensors. The Flex system reset frequently during the deployment, causing gaps in the secondary wind data, but wind speed and direction from both sensors were within accuracy specifications of 0.3 m/s or 3% of the measured speed, and ±5° from the measured heading. A comparison of the wind speed and direction data from each system is included in Appendix D.

3.2.2 Air Temperature

Both ATRH sensors were found bent outward at 45 degrees when the buoy was recovered, but no change in data quality was observed, so the standard data quality flags were applied during processing.

3.2.3 Relative Humidity

From the start of the deployment until the ATLAS RH sensor swap, performed on June 25, 2008 [177], the RH data were mostly saturated around 100% RH. It was unknown whether the values under 100% recorded during this time could be trusted, so data were replaced with placeholder values of 1E+33, and flagged Q5 (instrument failed) from the start of the deployment until the swap.

Both the Flex and ATLAS RH sensors independently failed on December 24, 2008 [359], after the buoy went adrift. The ATLAS RH data went to 1E+34 (out of range) just a few hours prior to the Flex RH reporting a constant, unrealistic value of 109%. Prior to that, the data appeared reasonable, except for a few short and possibly real instances, where it saturated around 100% RH. A comparison with the PA001 RH data looked good, so no additional flagging was performed.

3.2.4 Barometric Pressure

The BP sensor initially functioned intermittently from the start of the deployment. However, it stabilized after July 18, 2008 [200], when a DVS current meter, which had been causing the Flex system resets, was shut off. Missing data caused by these resets were flagged Q0 (datum missing), and the remaining data received the default quality flags. No spikes or unusual values were observed requiring additional 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 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.

In the latter part of the deployment (November - December), after the buoy was adrift, several siphons occurred at extremely low rain volumes (around 100ml, 150ml and 300ml). The accumulations appeared normal, so only the drops were flagged, using 11-points each, to insure they would not register as negative rain rates. The rain gauge may have tilted sufficiently that water sloshed out or siphoned prematurely.

The rain gauge was not functional upon recovery, and lab tests confirmed that the instrument produced no output. Data had become noisy starting December 24, 2008 [359]. Bad data values were replaced with 1E+36 markers (insufficient data) and flagged as Q5 (instrument failed) from this point to the end.

Since the failure occurred after the buoy went adrift and the files were truncated to November 11, 2008, the data around the time of failure were not included in the released files, except those provided to OceanSITES. The timing of the rain gauge failure corresponds with the event that caused the Flex and ATLAS RH sensors to fail.

3.2.6 Shortwave Radiation

There are no special processing notes for shortwave radiation at PA002. Refer to Section 3.0 for general remarks.

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).

3.3 Subsurface Data

When the mooring broke at the bridle, the buoy went adrift and all instruments on the wire were lost. There are no high-resolution subsurface data available for this deployment, except for the short record from the sensor on the bridle at 1m.

For instruments that transmitted data inductively through the Flex system during the deployment, real-time data are available as hourly and daily averages. This did not include any of the ATLAS modules, or instruments deployed by partners (UW, OSU). The following instruments were inductively connected to the Flex system, and provided real-time data. Real-time data returns from the 1m bridle instrument are not included here, as the delayed-mode data were retrieved (see Section 2.2).

Depth:	Instrument:	PA002a:	PA002b (*only through 11/11/2008):
5.2m	DVS (T/V)	74.3% (t and v)	62.9% (t and v)
12.9m	DVS (T)	13.6%	0.0% ← Failed June 13
20m	SBE51-TC	74.3% (t and c)	75.2% (t and c)
25m	SBE51-TC	74.3% (t and c)	75.1% (t and c)
31.1m	DVS (T)	74.3%	8.1% ← Failed July 18
37.1m	DVS (T)	0.0%	0.0% ← Failed (deployment)
45m	SBE51-TC	74.3% (t and c)	75.5% (t and c)
175m	SBE39-TP	74.3% (t and p)	27.2% (t and p)
300m	SBE39-TP	74.3% (t and p)	73.9% (t and p)

*Multiply column by 3336 / 4803 to get percentages through recovery on 1/11/2009 at 19 UTC.

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

Only the SBE37-SMP temperature and conductivity sensor from the bridle was recovered, and its battery had failed 21 days into the deployment. High-resolution 10 minute data are available during this short period, at 1m depth. Temperature data from the DVS instruments are included in the hourly and daily averaged files with the data from the Seabird instruments.

The 1m temperature data were compared to the real-time temperatures from the Seabird instruments at 20m, 25m, and 45m. The data tracked well, and no adjustments were performed. Dr. Cronin compared the DVS at 5.2m to the SBE37 on the bridle during the beginning of the mooring deployment. Based on the comparison shown in Figure 4, the error bars for the temperature measured by the DVS at 5.2m have been set to ±0.03°C, an improvement on the manufacturer's precision rating of ±0.4°C. The difference spikes in Figure 4 of greater than 0.03°C corresponded to periods of low winds. During summer days with winds less than 4-5m/s, heating from the sun can cause the upper ocean to stratify, meaning these spikes are likely real.

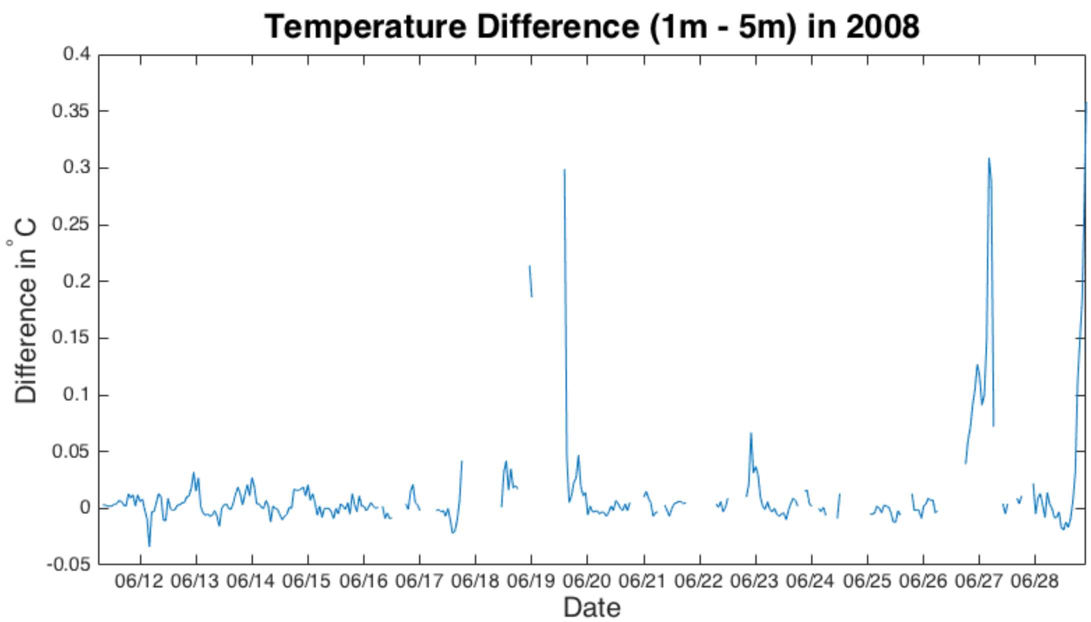

Figure 4: Difference in temperature measurements from SBE37 at 1m and DVS at 5.2m.

Users should treat the DVS temperature data at the remaining depths with caution. Comparisons with adjacent instruments were not performed for other depths, and the specifications for the DVS temperature sensors are much lower than that of the Seabird sensors (±0.4°C vs. ±0.003°C). The quality flag has been left at the default value for all DVS measurements.

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. Only hourly and daily averaged real-time values are available, and standard quality flags were assigned to the data.

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 1m 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. Salinity was calculated from both the pre and post conductivity values to determine the drift in the salinity measurement.

<u>Salinity Drift in PSU for PA002a (post - pre):</u>

1m -0.0078

<u>Salinity Drift in PSU for PA002b (post - pre):</u>

1m -0.0077

*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.

This level of processing was only performed for the short data record of the recovered instrument at 1m. Post-deployment calibrations could not be performed on the instruments that were lost. Additional data checks against other deployments, adjacent depths, and two CTD casts are described below, but resulted in no further adjustments. The real-time data were combined into an hourly file and released.

Manual Salinity Checks

The drift-corrected salinities were checked for continuity across deployments. The instrument at 1m compared well with salinity measurements on PA001 and PA003, so no further adjustments were made.

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.

Comparison with a CTD cast on June 11, 2008 showed that the 1m salinities were low by about 0.02PSU, and the densities low by about 0.04. Since the CTD data were actually from a depth of 2.9m, rather than 1m, this small difference could be real and the 1m data were not adjusted.

Density differences (in kg/m^3) between the CTD and the hourly real-time data from the other three depths (CTD - mooring) at the same time (June 11, 2008 19:00) were:
20m: 25.571-25.5922 = -0.0212
25m: 25.621-25.6336 = -0.0126
45m: 25.719-25.7152 = 0.0038

Comparison with a second CTD cast on August 21, 2008 was performed after the 1m instrument had failed with a low battery (July 1). Salinity differences, in PSU (practical salinity units), between the CTD and the other three real-time hourly depths at the same time (August 21, 2008 1:30) were:
20m: 32.490 - 32.4936 = 0.0036
25m: 32.490 - 32.4955 = 0.0055
45m: 32.630 - 32.6058 = 0.0242

Density differences (in kg/m^3) were:
20m: 24.743-24.8147 = -0.0717
25m: 24.747-24.8272 = -0.0802
45m: 25.736-25.7663 = -0.0303

All of the sensors drifted a bit lower (more fresh), but not enough to adjust. Since the mixed layer separates in August, there can be more noise in the 20 and 25m layers. This may contribute to the differences between the second CTD and the mooring data.

3.3.4 Currents

Point current meters were deployed at five depths on the PA002 mooring. The stated head depth differs from the actual current measurement depth, because the instruments require a blanking distance. Currents from the instruments deployed at 5.2m, 12.9m, 17m, 31.1m, and 37.1m measured velocities at about 6m, 14m, 16m, 30m, and 36m, respectively. Since the PA002 mooring line was taut, current meters were not corrected for negligible buoy motion.

The only DVS to return velocity data in real-time was the instrument at 5.2m. The instrument reported both temperature and velocity until it was lost November 11, 2008. It was set-up with a blanking distance of 7cm, and bin size of 50cm. Only data from the first bin were reported. It was set to sample with 2 seconds between pings, at 60 pings per ensemble, to generate a two-minute average sample. A magnetic declination correction of 18 degrees was applied to the real-time data.

The DVS current meter at 37.1m did not function from the start of the deployment. The DVS at 12.9m reported temperature data until June 13, 2008, and the DVS at 31.1m reported temperatures until it was turned off on July 18, 2008. The decision was made to shut off some DVS sensors that caused persistent hourly Flex system resets between July 7 and July 18 (referenced in Appendix D). No real-time velocities were available from the 12.9m, 31.1m and 37.1m DVS instruments.

The Sontek current meter was not inductively coupled to the Flex system, so no real-time data exist. When the mooring line broke, all subsurface sensors were lost, along with their delayed-mode data. The real-time temperature data from the DVS instruments were included in the temperature file.

3.3.5 Load Cell

A load cell on the bridle provided tension readings from the mooring through November 2008, 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.

4.0 References

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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 of this mooring. P. A'Hearn (UW JISAO) and LCDR R. Kamphaus (NOAA Corp) participated in the first deployment cruise (where no mooring work could be completed due to weather) and P. A'Hearn participated in the rescheduled deployment cruise. P. A'Hearn and R. Kamphaus participated in the recovery cruise. The captain and crew of the NOAA SHIP MILLER FREEMAN are gratefully acknowledged for performing the replacement of the failed ATRH sensor. The captain and crew of the NOAA SHIP DYSON and K. Ronnholm (UW JISAO) are gratefully acknowledged for their attempted repair of the failed SSC sensor. A special thanks is extended to the captain and crew of the F/V AQUILLA for recovering the drifting buoy.

S. Brown (UW JISAO) processed ATLAS meteorological data, surface temperature, and conductivity/salinity data. J. Mickett (UW APL) provided processed NP002 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:

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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

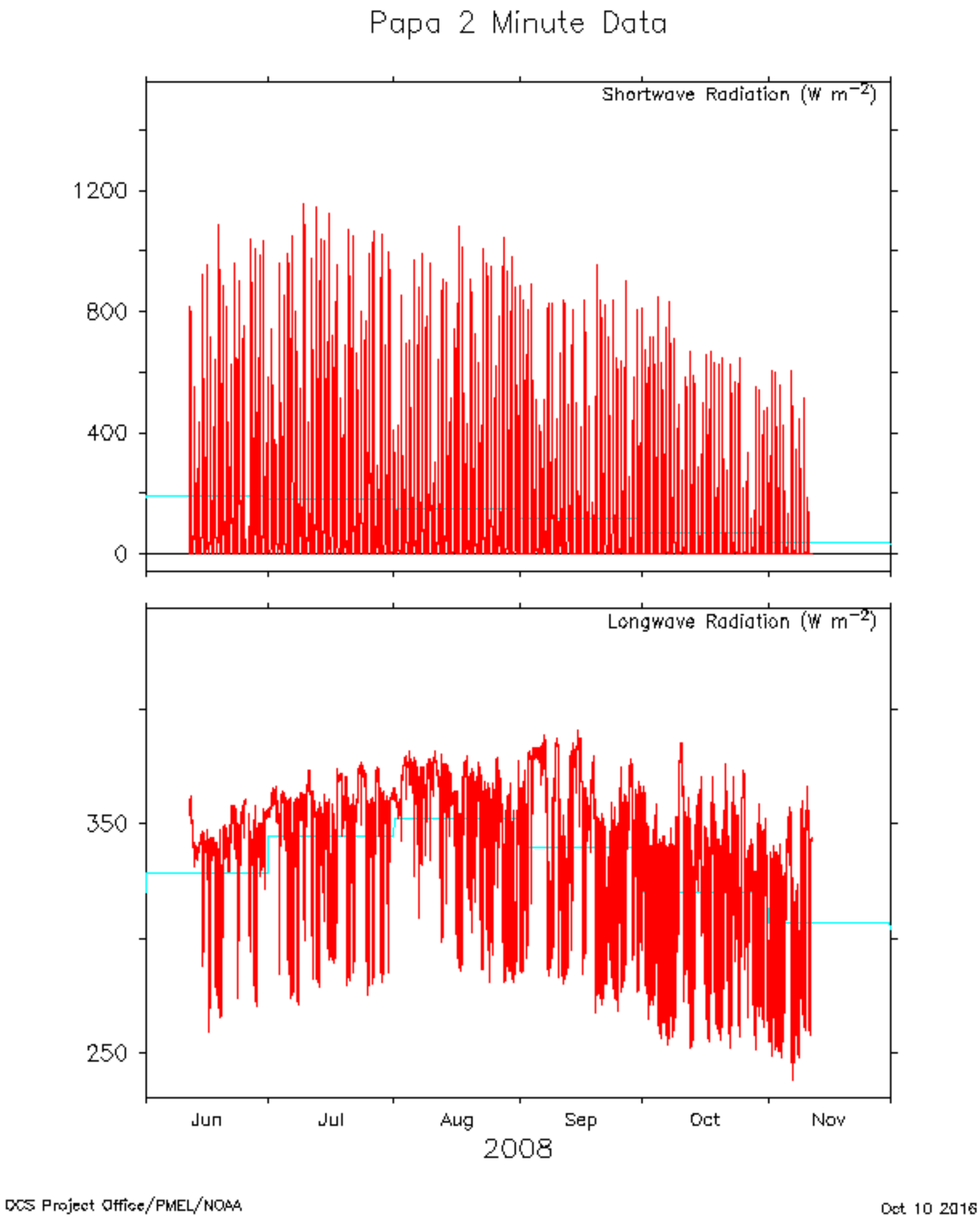

Figure B 1: PA002 shortwave and longwave radiation data in 2-min resolution.

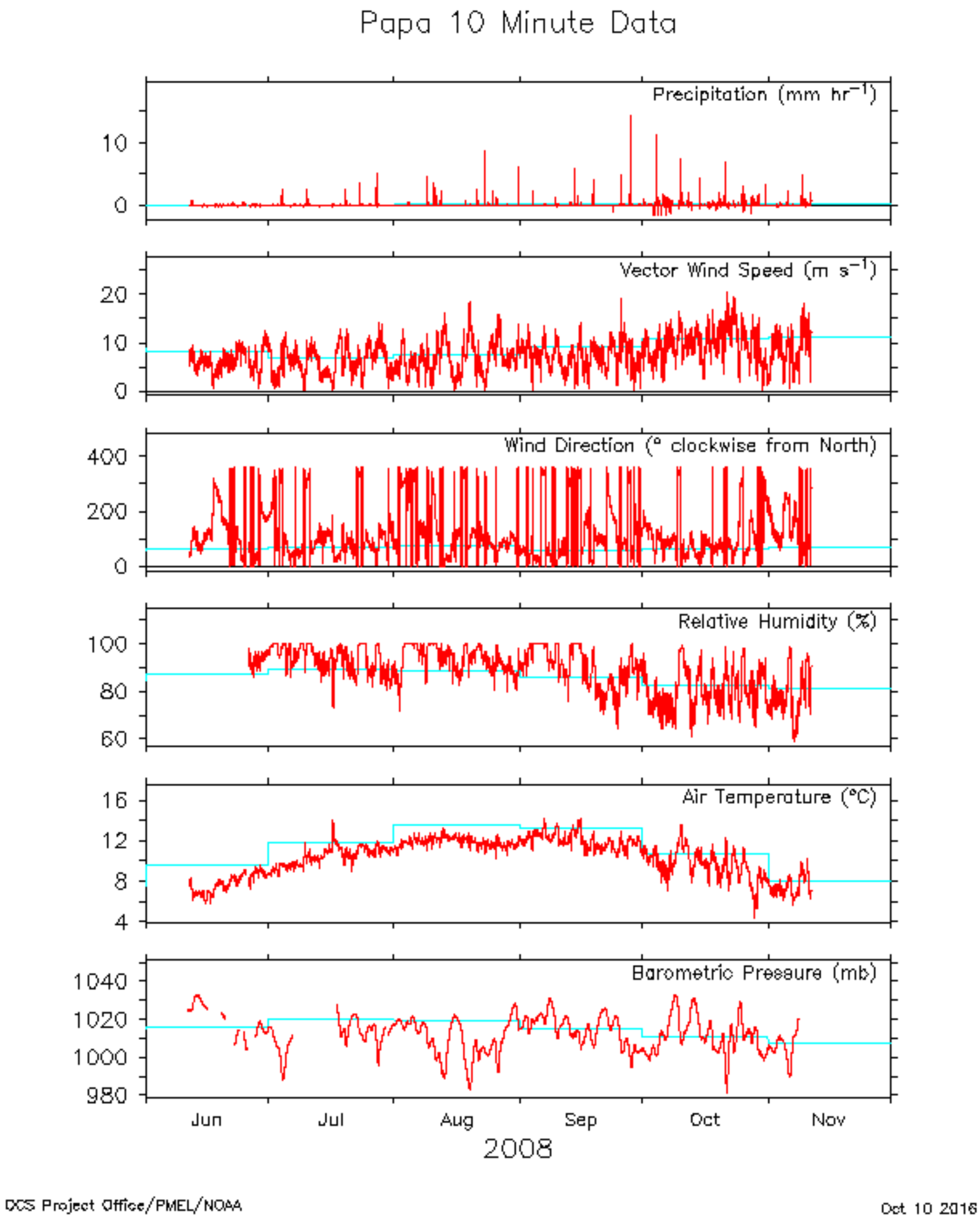

Figure B 2: PA002 meteorological data in 10-min resolution. Early RH is flagged Q5 until the sensor swap, while early BP was afflicted by the Flex system resets.

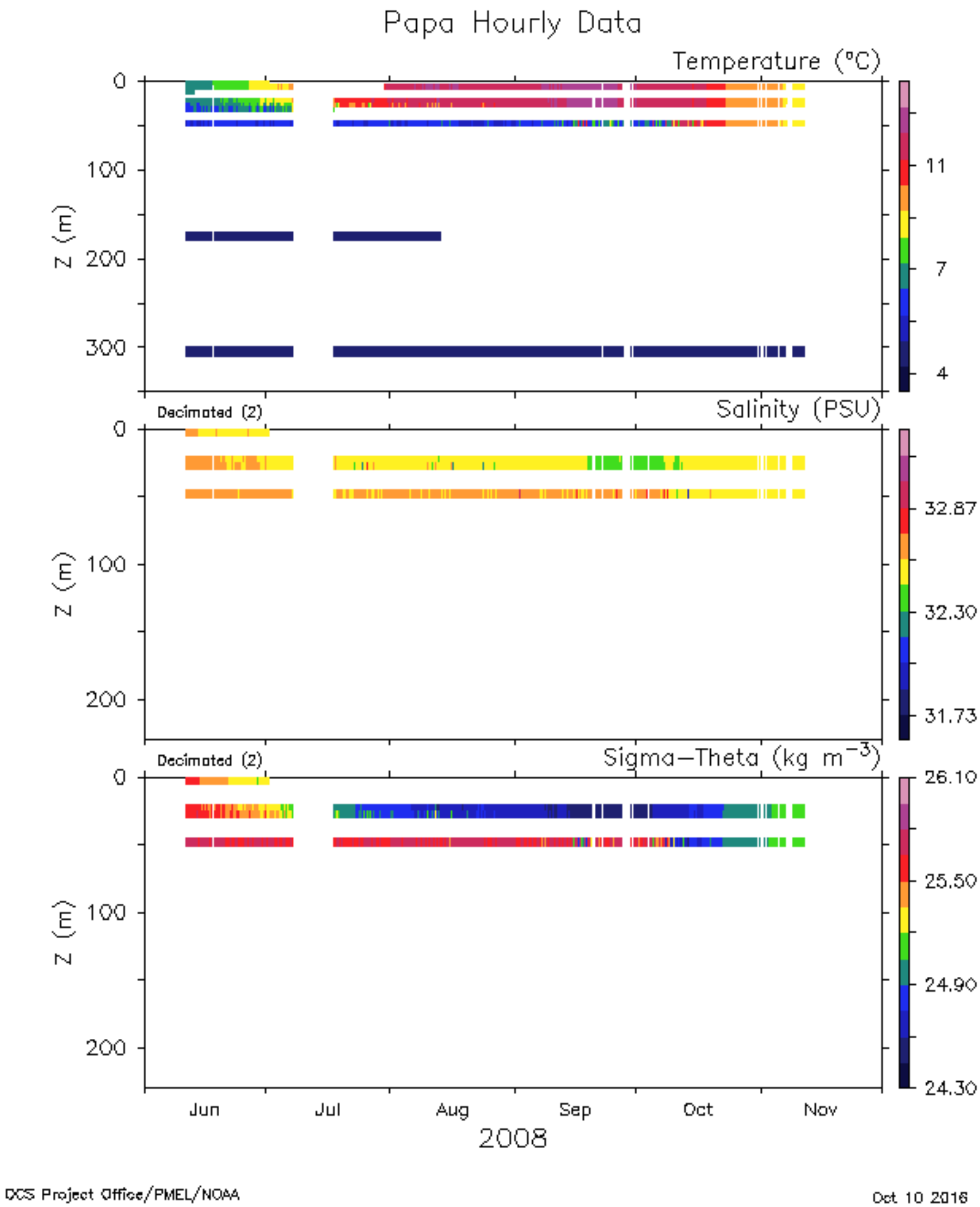

Figure B 3: PA002 subsurface temperature, salinity, and density at hourly resolution. The 1m SSTC data was recovered, but all other data are in real-time, as subsurface instrumentation was lost.

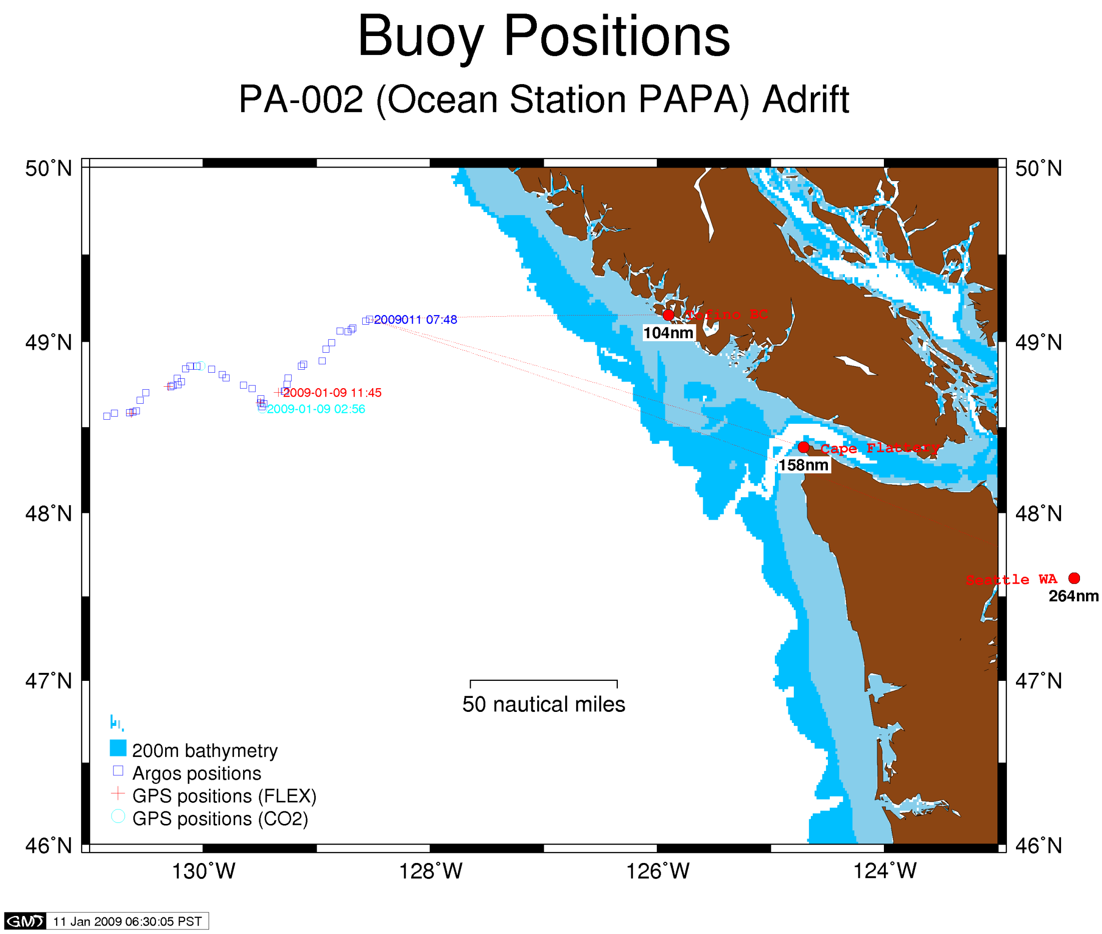

Figure B 4: Buoy positions from the Flex and CO_2 GPS/IPS systems, along with Argos estimates, as PA002 drifted toward North America.

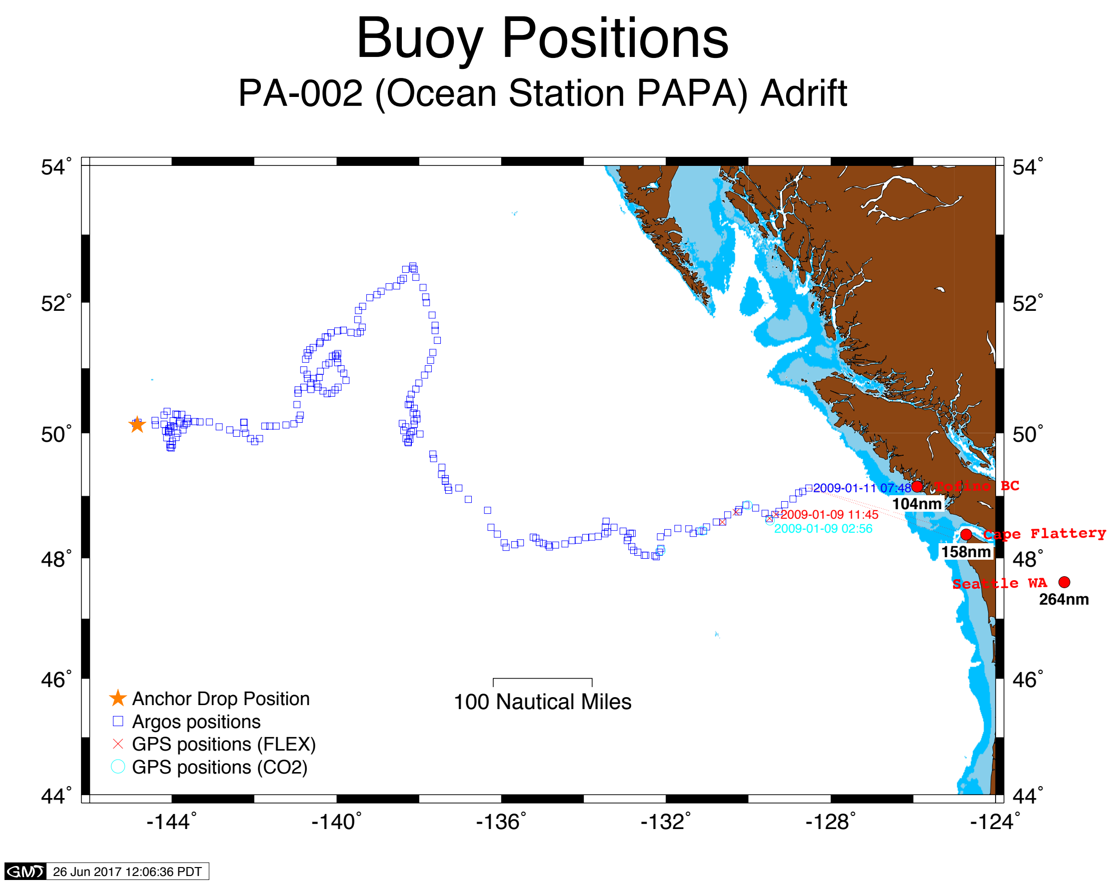

Figure B 5: Same as B4, but zoomed out for perspective.

APPENDIX C: Papa ADCP Subsurface Mooring

Mooring Desciption

A separate subsurface mooring (NP002) was deployed in proximity to PA002 that contained two upward-looking ADCPs at nominal depths of 135m and 800m (corrected to 154m and 835m when deployed) and a nominal position of 50.12°N, 144.97°W. Two accompanying mooring diagrams are provided below in figures C1 and C2.

A 300KHz, upward-looking ADCP (SN 578) on loan from the PMEL RAMA group was mounted at 154m depth, reporting velocity data in 4m bins every 30 minutes. A 75KHz, upward-looking long ranger ADCP (SN 4021) provided by Dr. M. Alford (UW APL) was mounted at 835m and provided velocity data in 16m bins every 30 minutes.

Deployed June 10, 2008 and recovered June 13, 2009, the ADCPs yielded continuous data from near the surface to 800m. 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 NP002 mooring also carried a Passive Acoustic Listening (PAL) device at about 200m. 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.

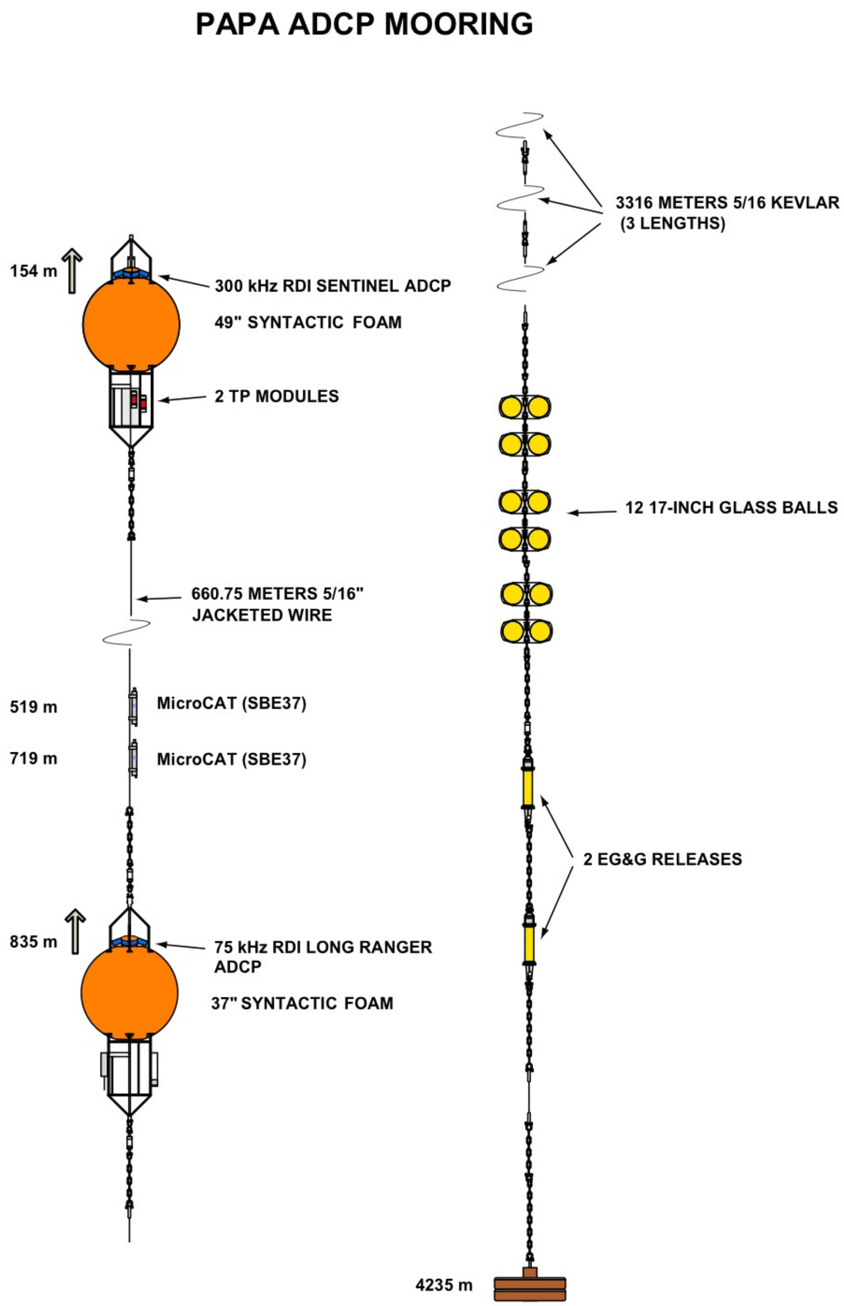

Figure C 1: APL graphic of the subsurface Papa ADCP mooring NP002, with corrected depths.

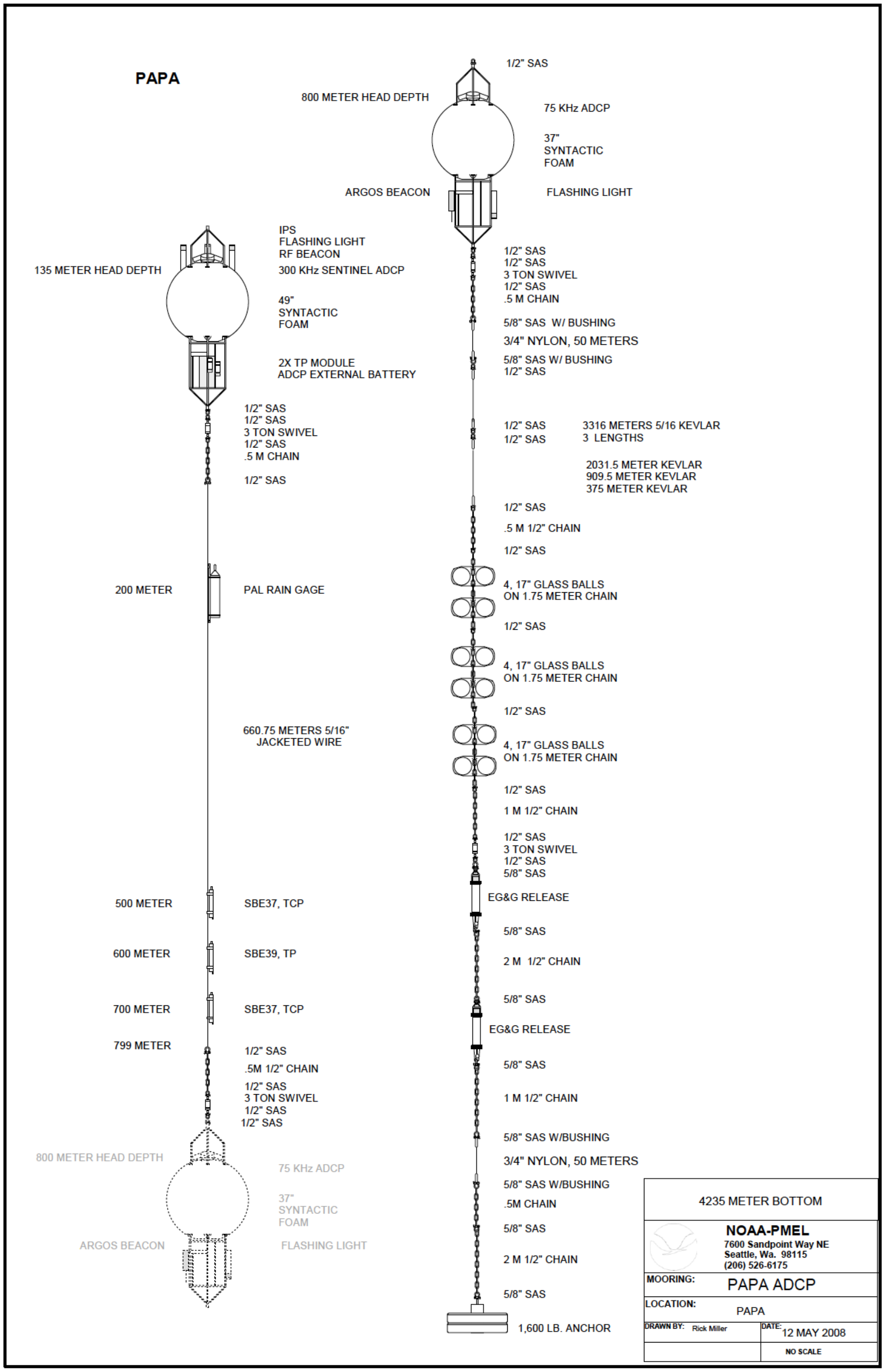

Figure C 2: Mooring diagram “as-planned” for NP002.

ADCP Data

The highest resolution data available from the PA002 subsurface mooring was 30-minute. Figure C3 shows U and V velocity data throughout the entire deployment, although the nearby Papa buoy went adrift November 11, 2008.

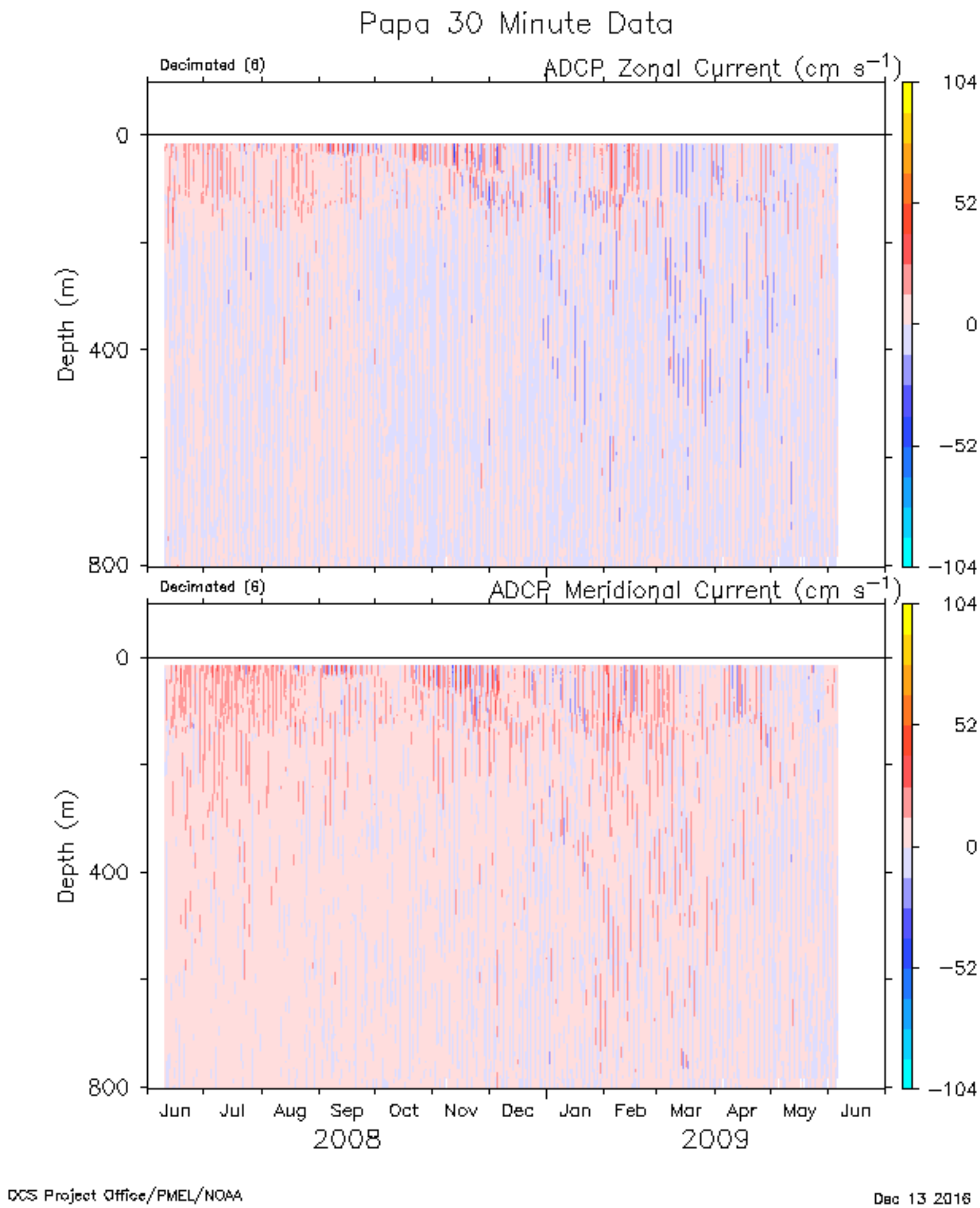

Figure C 3: ADCP data from a special subsurface deployment ("NP002") near PA002.

APPENDIX D: PA002 Wind Speed and Direction Comparison

The following report was prepared by P. Freitag.

1.0 Introduction

PAPA mooring PA002 had duplicate Gill anemometers, one on an ATLAS system, and the other on a Flex system. The major events during the deployment were:

- June 11, 2008: Deployed
- June 25, 2008: ATLAS ATRH replaced (RH had failed)
- October 11, 2008: Adrift
- January 11, 2009: Recovered from crab boat

Other than the anemometers, there were no duplicate met sensors on or above the ring. (Both systems had ATRH at the standard location below the ring). Relative to the buoy lubber line the locations of the met sensors were: ATLAS Rain at 0°, Flex Gill at 90°, and ATLAS SWR/LWR at 180°. The sensors on the tower sustained a significant damage, presumably after the buoy went adrift. The ATLAS Gill was missing the cover of the top reflecting plate, but was functioning on recovery without it.

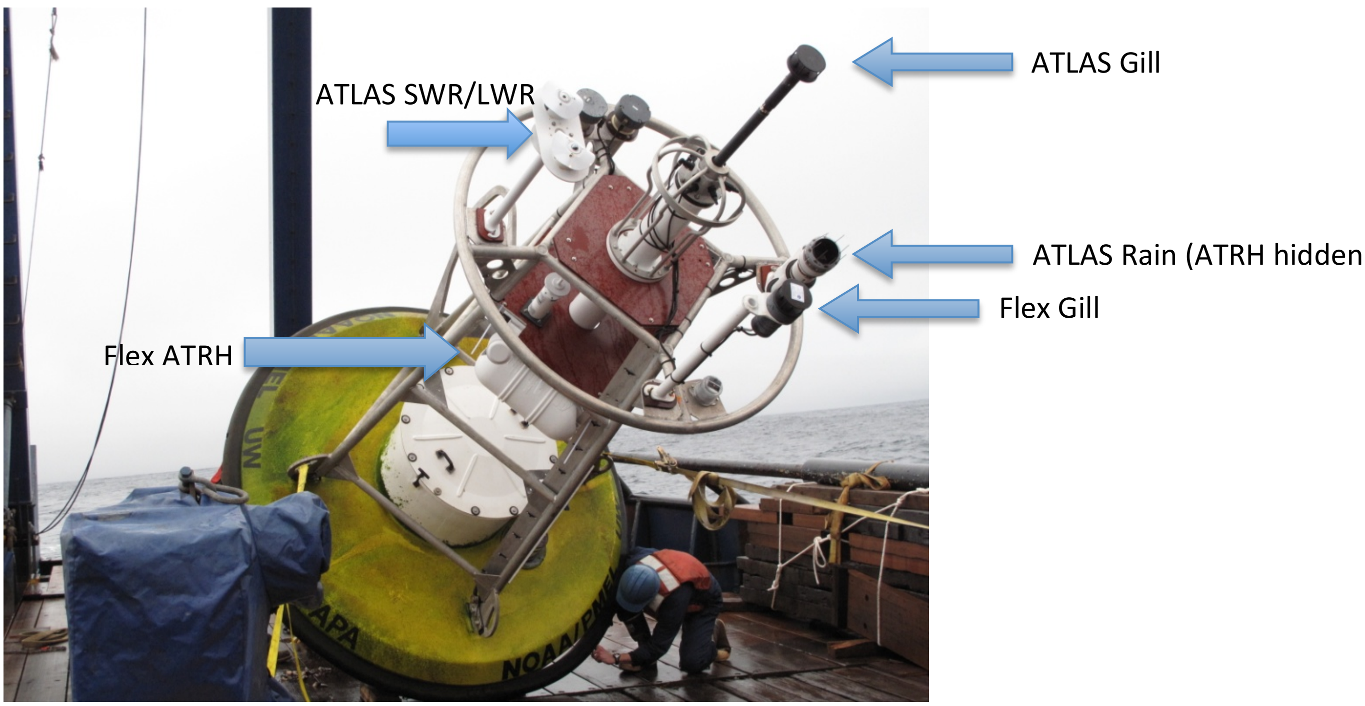

Figure 1. PA002 recovery photograph.

Both Gills were calibrated before deployment. The uncalibrated ATLAS differed from the standard by <1%, the Flex Gill by <2%. The ATLAS Gill was not calibrated after recovery, presumably due to being damaged. Its location is unknown at this time. The Flex Gill was post-calibrated in May 2009. The coefficients indicated that the sensor calibration had changed such that uncalibrated values were more than 5% high. As was the case for the KE006 Flex Gill, the post-recovery calibration was done using a new mounting fixture which appears to induce Flex Gill sensors to overspeed.

	S/N	Slope	Offset
ATLAS Gill Pre	51414	1.005	-0.059
Flex Gill Pre	73805	0.982	0.004
Flex Gill Post		0.950	-0.037

Table 1. PA002 anemometer calibration coefficients.

Both compasses were calibrated before deployment and were within normal limits. Both also passed calibration checks after recovery.

The Flex system reset repeatedly in the early part of the deployment, which resulted in several data gaps, one of which lasted more than 10 days. The problem was determined to be related to the DVS current meters. After turning the DVS off on July 17, resets ceased. There was evidence that the Flex system clock was not correct after resets. Based on air temperature comparison with the ATLAS system, the Flex clock was adjusted by 20 min on July 29 and by more than 5 days on November 9.

The ATLAS data have been separated into a file before the ATRH swap, one from the ATRH swap until the buoy went adrift, and one while adrift. The winds have been compared during the middle period because the time series was longer and more complete than the initial period and the buoy was presumably more stable when moored than when adrift.

2.0 Wind Speed Comparison

The ATLAS wind speed ranged from near zero to 21 m s^{-1}. The ATLAS-Flex mean wind speed difference was < 0.1 m s^{-1} and the RMS difference was <0.6 m s^{-1} (Fig 2.). The minimum and maximum differences were -4.4 m s^{-1} and 4.0 m s^{-1}, respectively. There was some indication that speed differences (both + and -) were larger when wind speed was larger (compare differences in Fig. 2 to speed in Fig. 3). The variance in speed difference appeared to have increased sharply near the later part of July and remained relatively larger than before for the rest of the time period. This could be related to a clock shift at that time, but there was no concurrent Flex reset indicated in the record.

Least square linear regression yielded the relationship Flex = ATLAS*0.9651 + 0.23 (Fig. 3, lower). Differences computed from this relationship are within our specified accuracy of ±0.3 m s^{-1} or 3%.

Unlike for mooring KE006, wind speed difference was not correlated with the vane orientation.

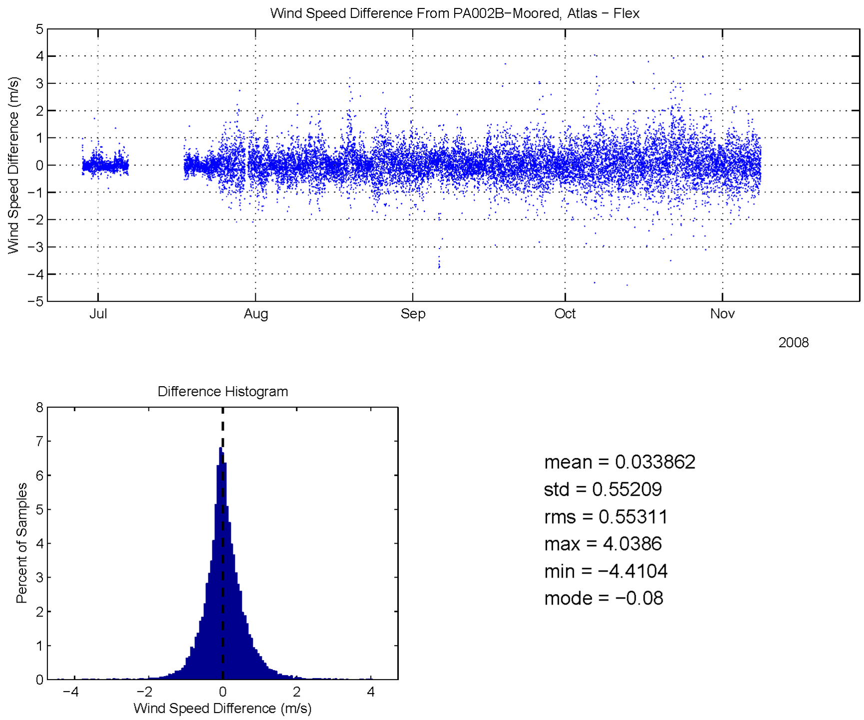

Figure 2. ATLAS – Flex wind speed difference time series, histogram and statistics.

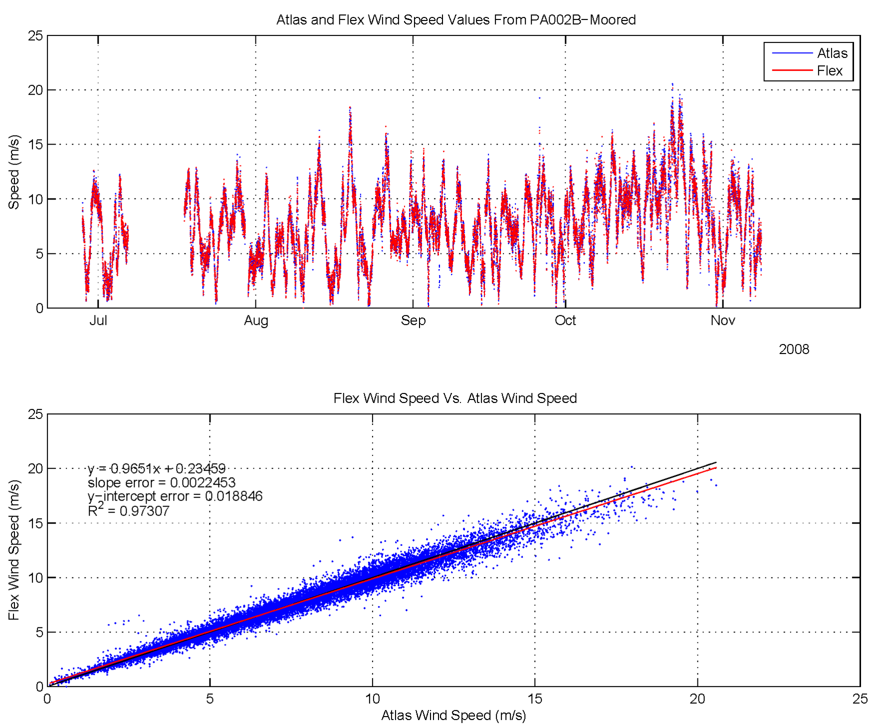

Figure 3. Time series of ATLAS and Flex wind speed, scatter plot and least squares linear regression.

3.0 Wind Direction Comparison

Wind direction was generally towards the NNE, with the majority of values between ~20° and ~120° (Fig. 4). Direction differences were relatively small, with a mean of -4.8° and an RMS of 6.8° (Fig. 5).

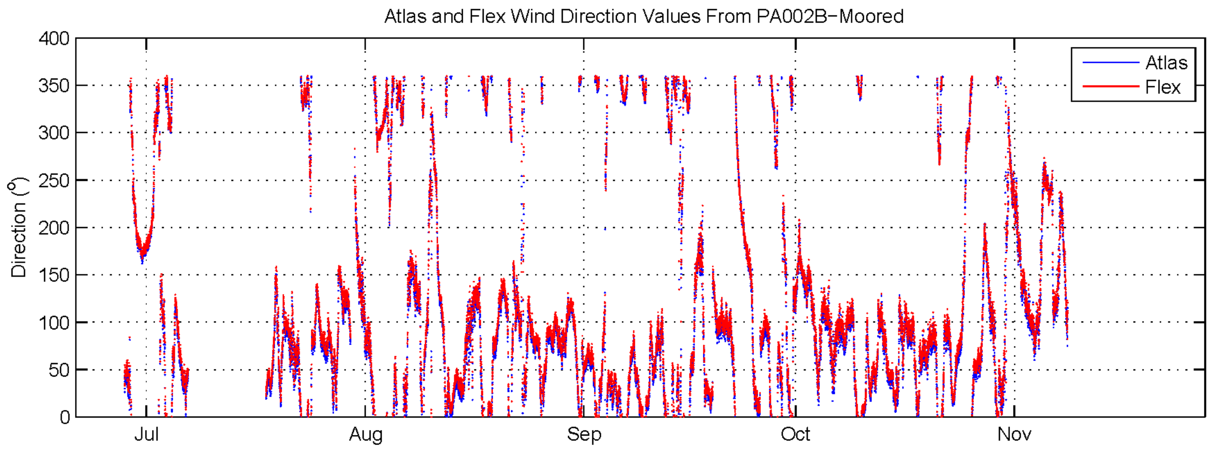

Figure 4. ATLAS (blue) and Flex (red) wind direction time series.

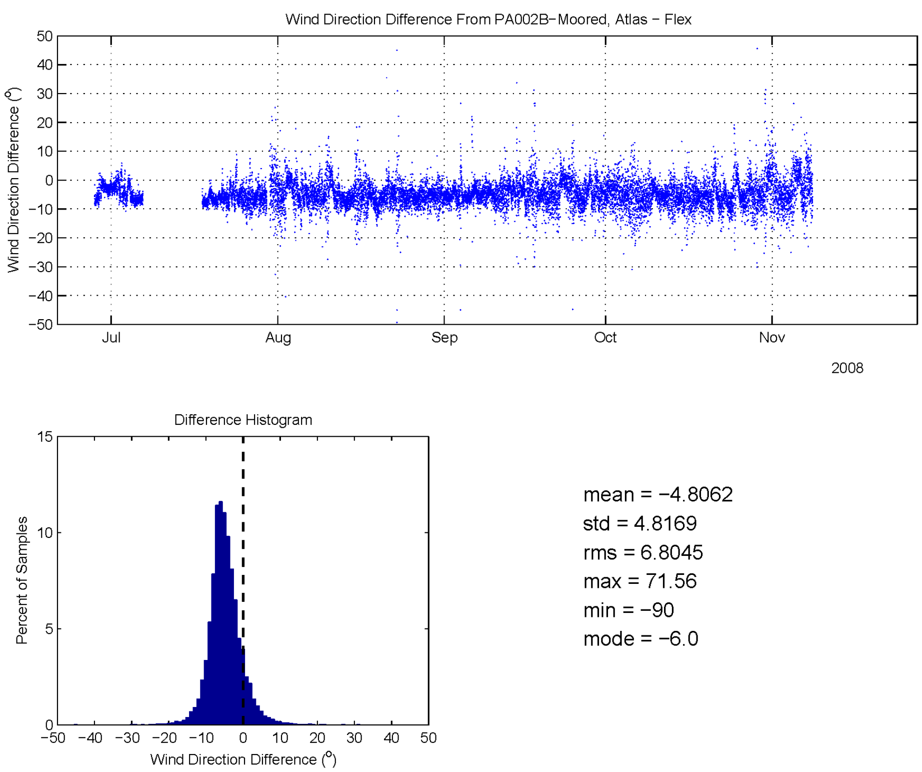

Figure 5. ATLAS-Flex Wind direction difference time series, histogram and statistics.

Wind direction differences were not correlated with the vane (Fig. 6), but there was an S curve with magnitude of a few degrees when plotted against compass (Fig. 7). The buoy was oriented between 30° and 150° most of the time. When in this orientation the wind direction differences were centered near 5°. At other orientations the wind direction differences were centered closer to 0°. The magnitude of mean compass and vane differences were larger than wind direction differences, with the mean compass difference (-17.2°) of opposite sign as the vane difference (12.7°), indicating that the two instruments were not aligned on the tower, probably differing by more than 10°.

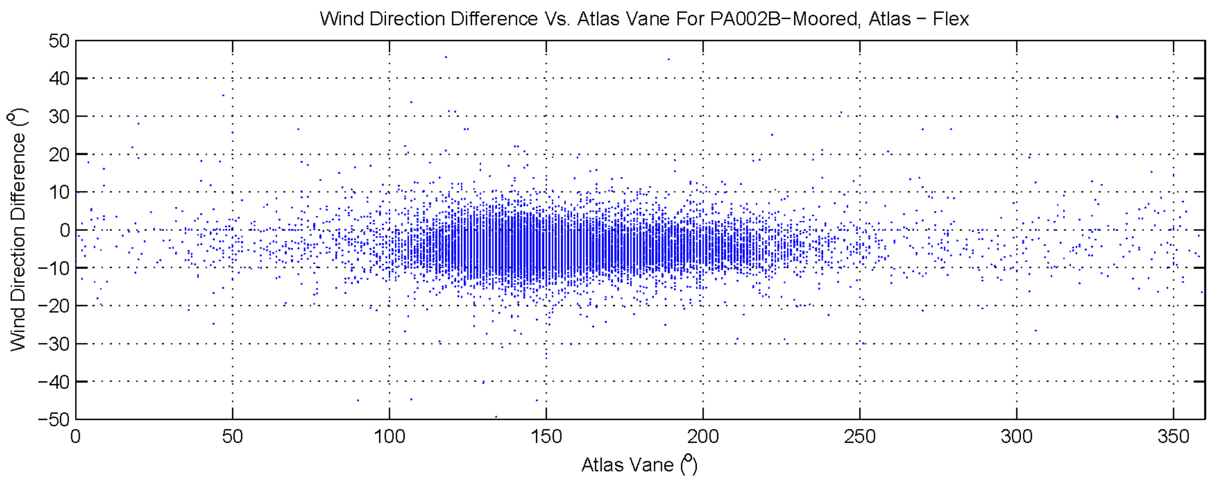

Figure 6. ATLAS-Flex wind direction difference vs ATLAS vane.

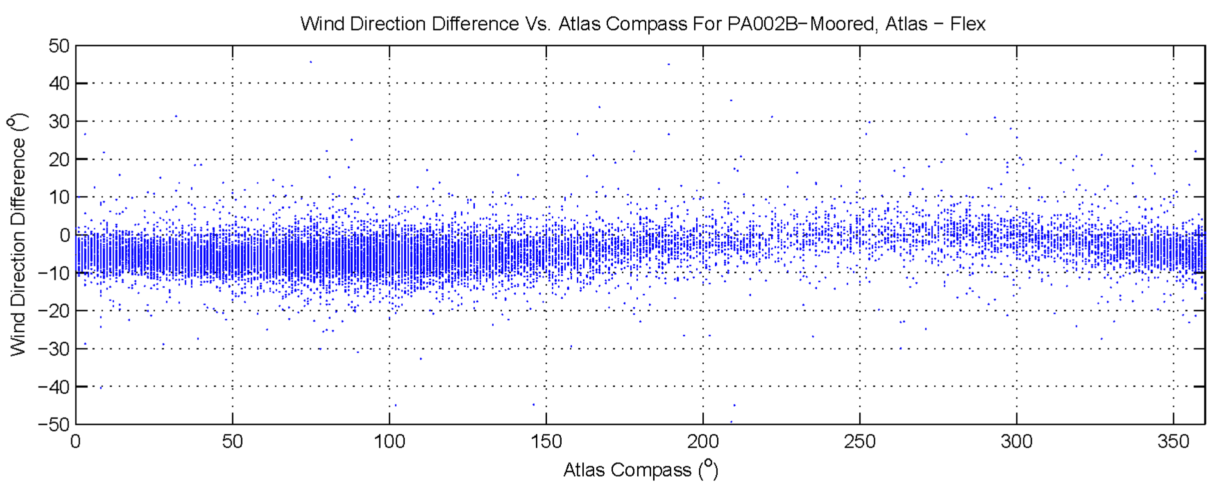

Figure 7. ATLAS-Flex wind direction difference vs ATLAS compass.

While both compasses passed post-recovery checks (having errors less than ±5°) the Flex compass had ±4° errors centered near 30° and 270° (Fig. 8). The positive Flex compass errors are consistent with negative ATLAS-Flex wind direction differences (Fig 7) for compass headings in the 0° to 150° range.

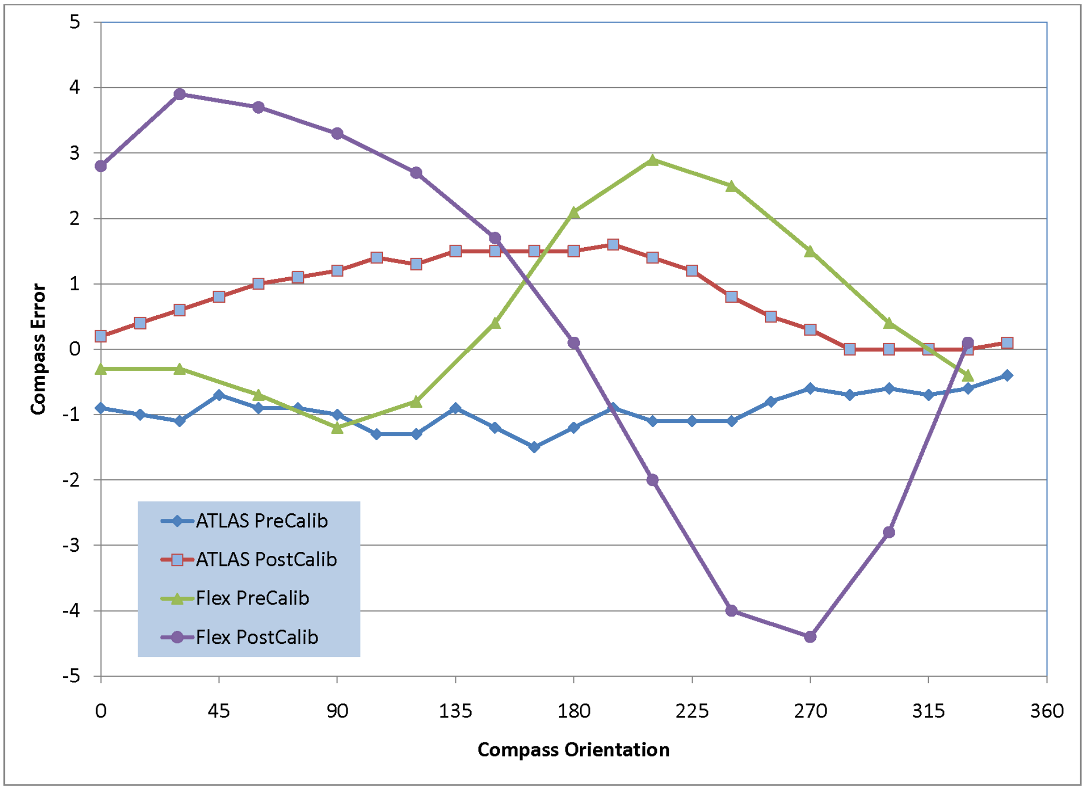

Figure 8. Pre-deployment and post-recovery ATLAS and Flex compass errors.

4.0 Summary

Wind speed and direction on mooring PA002 from ATLAS and Flex systems were within our accuracy specifications, 0.3 m s^{-1} or 3%, and ±5°. Unlike mooring KE006, there was no indication of the Flex wind speed being biased low due to blockage from other instruments, presumably because PA002 had fewer met sensors on the tower. Small, but measureable, wind direction difference was probably due to Flex compass error.

The Flex system had reset problems which resulted in data loss and possibly higher variance in differences with the ATLAS system. The ATLAS time series should be considered the primary data source.