

Shepard Meander 2006-2007 MOOS Science Experiment: Data Return and Lessons Learned

Rev.

1.9 8SEP08 Final version with plots. Mark Chaffey

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2. Complete instrument list by location
3. Surface float data return
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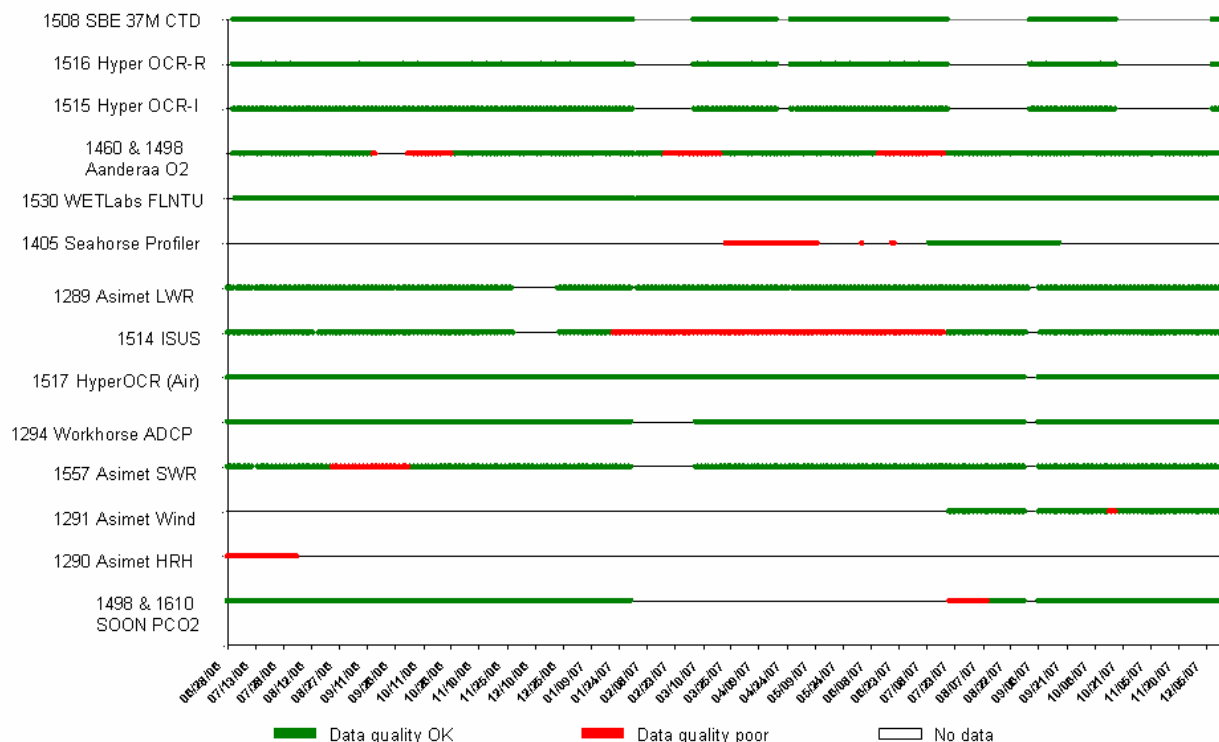
1. Summary

The data from MSE is available from the following sources

- a. SIAM raw data is available from this site by entering the device ID number:
<http://new-ssds.mbari.org:8080/ssds/siamRawDataStep1.jsp>
- b. Mooring data NetCDF files and QC plots are available here:
<http://dods.mbari.org/data/ssdsdata/deployments/mse2006/>

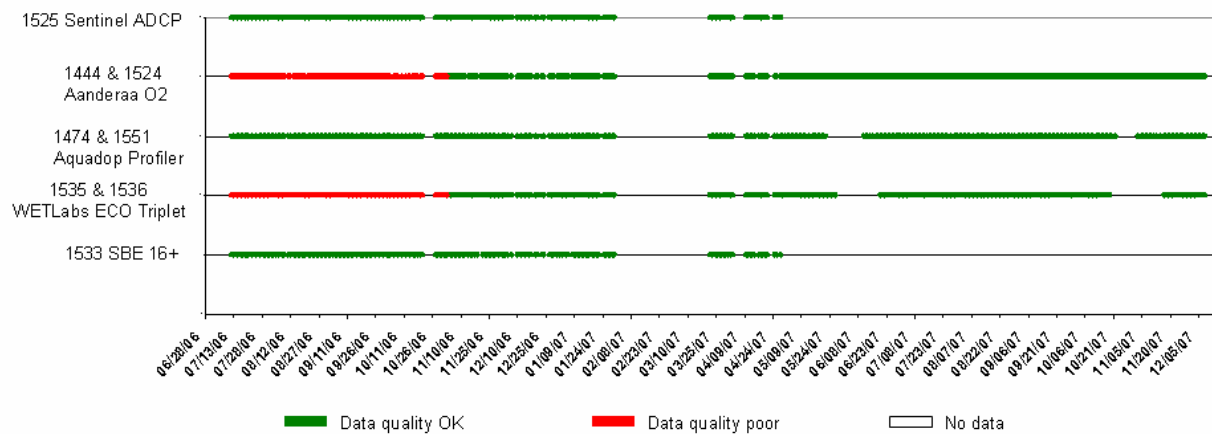
The data return from the Surface mooring and the “Snubber node” at 20 meters is summarized in the graph shown below. Overall, in total the fourteen science instruments on the three nodes of the Surface mooring returned 73% of the total possible data return, of which about 8% of this returned data was bad. The length of the data gaps varied from instrument to instrument with some instruments returning 99% of the possible data. The largest data gaps were caused by failed instruments. The next most significant cause of gaps was hardware failures in the mooring system itself. For example, the loss of the wind turbine and subsequent power emergency caused a large data gap in February and March 2007 that lasted until the system could be restored by a field visit. This shutdown also caused the SOON instrument to expend its internal batteries and fail to restart. The most significant cause of poor quality data was sensor bio-fouling. The satellite telemetry problems experienced in November 06 through March 07 did not have a significant impact on the Surface mooring data return because it was highest on the download sequence and was almost always downloaded.

MSE Surface Instrument Data Return
June 2006 – December 2007



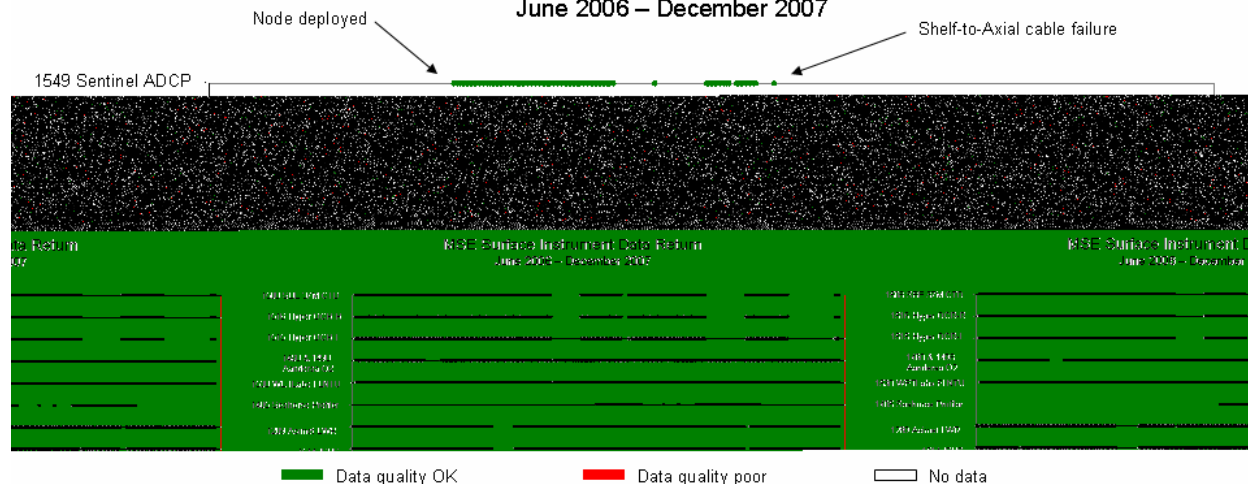
The data returned from the instruments of the Shelf BIN are summarized graphically below. Overall the five science instruments on the Shelf BIN returned 59% of the total possible data return, of which about 13% of this data was poor quality. The bad data was caused by leaving the protective caps on the WETLabs and O2 sensors during the initial deployment. Following the April 28, 2007 Shelf BIN swap the spare BIN that was installed did not include an ADCP or SBE 16+ CTD. The absence of these instruments greatly impacted the total data return. Instruments that were deployed for the entire deployment, such as the Aquadopp current profiler, returned over 70% of the possible data for 17 months. The large data gap in February – March 2007 is due to the loss of the surface wind power turbine and the subsequent system power emergency. The data gaps in the Aquadopp and WETLabs instruments are caused by the instruments “locking up” and not responding to instrument service requests until restarted. There are a significant number of < 1 day gaps in the data record caused by the “coma” bug in the BIN node controller.

MSE Shelf Node Instrument Data Return June 2006 – December 2007



The data returned from the instruments of the Axis BIN are summarized graphically below. Overall the five science instruments on the Axis BIN returned 26% of the total possible data return from the deployment in November of 2006 to the termination of the experiment in December of 2007. The large data gap in February – March 2007 is once again due to the loss of the surface wind power turbine and the subsequent system power emergency. There also are gaps in the Aquadopp data in December and January from unknown causes. This node ceased operation in late April 2007 when the Shelf-to-Axis cable failed (see MSE failure report at <https://oceana.mbari.org/confluence/display/MOOS/Home>).

MSE Axis Node Instrument Data Return June 2006 – December 2007



2. The complete list of nodes and instruments by location.

Surface float and 1 meter (bridle) Instrument cage.

SURFACE

ID 1446, PANGAI chassis, June 28, 2006 to October 3, 2006. Replaced to upgrade Medusa watchdog.

ID 1407, SURTSEY chassis, October 3, 2006 to October 26, 2006. Replaced with ID 1446 because 1407 kept locking up every few days.

ID 1446, PANGAI chassis, October 26, 2006 to December 10, 2007. Worked reliably.

ISI ID	Descr	Comments
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1594	Surface power can s/n 4.	This is a replacement for ID 1547 which was replaced March 22, 2007 after misconnection of wind generator in early March caused fuse failure in power can.
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1502	Snubber Node Power Control	
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1610	SOON pCO2	(replaced 1498)
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1339	Triaxys	(replaced 1286)
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1290	ASIMET HRH	
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1291	ASIMET WND	(added July 2007)
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1557	ASIMET SWR	
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1294	Workhorse LR ADCP	75kHz
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1566	Garmin GPS	
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1447	MSP430	
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1441	Medusa	
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SECONDARY (node on the mooring float)

node421 aka node21, KAO chassis, secondary (ID 1481), June 28, 2006 to December 10, 2007

ISI ID	Descr	Comments
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1517	Satlantic HyperOCR	
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1514	Satlantic MBARI ISUS	Needs cleaning
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1504	Garmin GPS	
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1289	ASIMET LWR	
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1405	Seahorse profiler	
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1530	WETLabs ECO	
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1586	Radar repeater power	
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1498	Aanderaa Optode	
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1483	MSP430	
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1442	Medusa	
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SNUBBER (20 meter deep node)

node410 aka node10, NOMUKA chassis, ID 1482, June 28, 2006 to October 16, 2007. Data record intermittent after power cycle and stops before mooring recovery. Cause of failure to start after power cycle unknown but suspect MMC power supply.

ISI ID	Descr	Comments
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1515	Satlantic HyperOCR	
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1516	Satlantic HyperOCR	
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1508	Seabird-37SM	
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1484	MSP430	
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1505	Medusa	
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SHELF NODES

node1, shelf (ID 1520) July 12, 2006 to April 21, 2007

port ID	Descr
1554	BIN 400-12V Switch
1533	SBE-16+
1535	WETLabs ECO-Triplet
1474	Aquadopp Current Meter
1444	Aanderaa Optode
1525	WH Sentinel ADCP 300 kHz
1527	MSP430
1526	Medusa

node1, shelf (ID 1520) redeployed for April 27-28, 2007

port ID	Descr
1554	BIN 400-12V Switch
1533	SBE-16+
1535	WETLabs ECO-Triplet
1474	Aquadopp Current Meter
1444	Aanderaa Optode
1525	WH Sentinel ADCP 300 kHz
1527	MSP430
1526	Medusa

node2, shelf (ID 1598): April 28, 2007 – December 10, 2007. Deployed as a spare to replace 1520 when over-current trip occurred in power supply switch output to the Axis BIN. Did not have full instrument compliment.

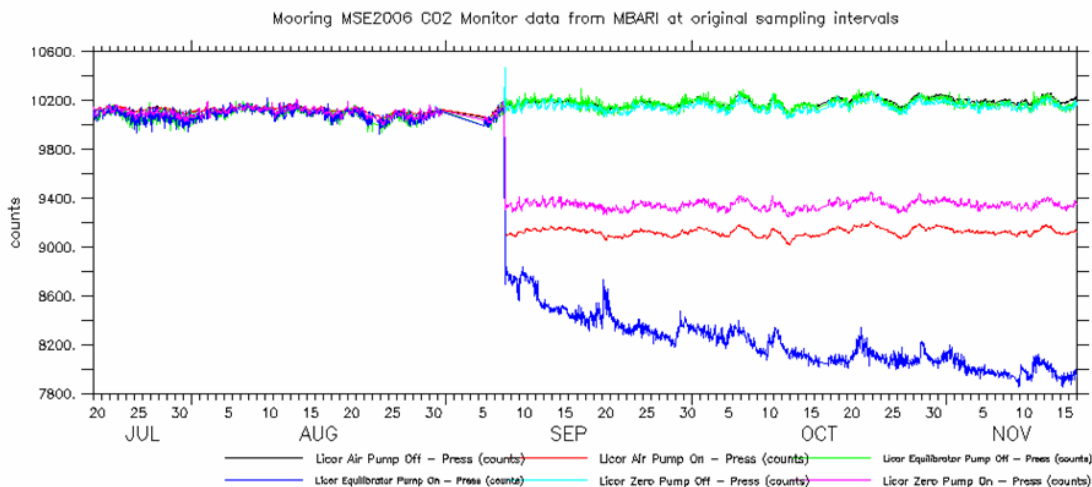
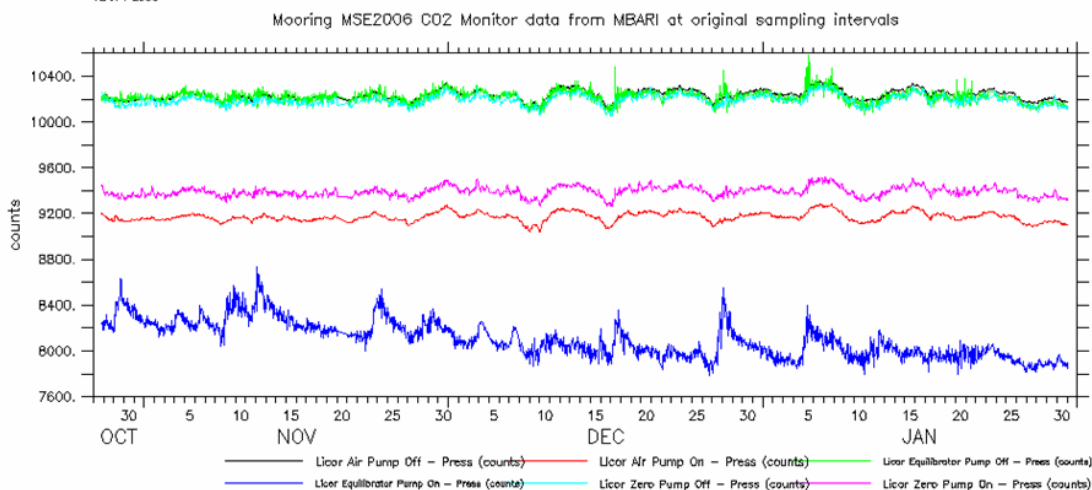
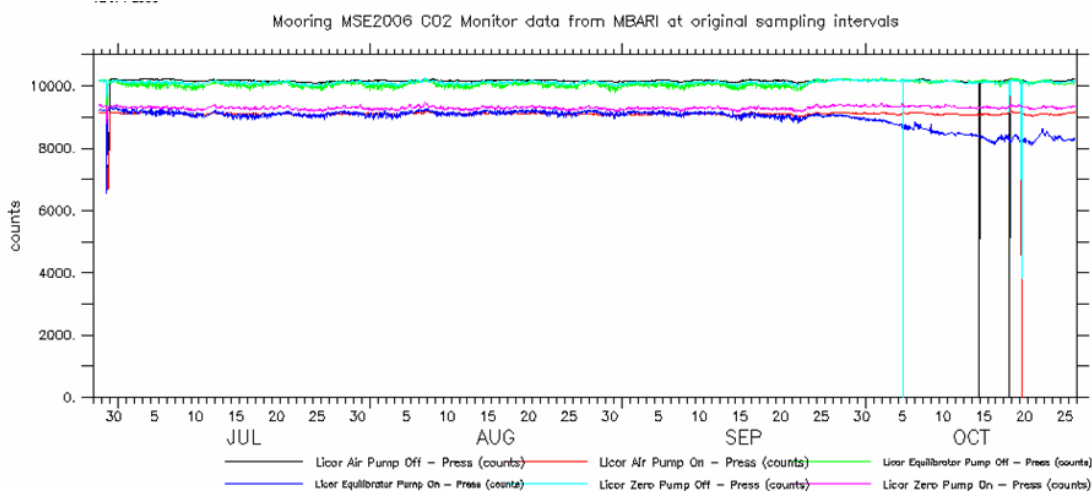
port ID	Descr
1555	BIN 400-12V Switch
1536	WETLabs ECO-Triplet
1553	Aquadopp Current Meter
1524	Aanderaa Optode
1599	MSP430
1542	Medusa

AXIS NODE, node11 aka node411, axis (ID 1522): November 5, 2006 – April 28, 2007

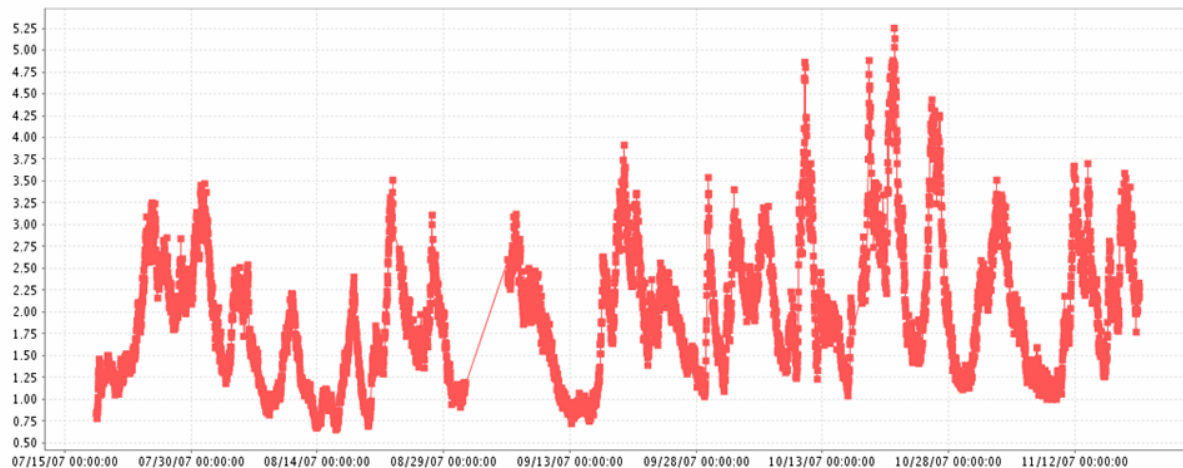
port ID	Descr
1593	BIN 400-12V Switch
1546	SBE-16+
1537	WETLabs ECO-Triplet
1473	Aquadopp Current Meter
1445	Aanderaa Optode
1510	McLane Profiler
1549	WH Sentinel ADCP 300 kHz
1523	MSP430
1596	Medusa

3. SURFACE node (ID 1446) instrument data return summary:

1498 and 1610 - SOON pCO₂ Example data plots. There is a large data gap following the February 2007 power shutdown due to the instrument not being properly shutdown and depleting the instruments internal batteries. The instrument was fully restored to operation on a Zephyr maintenance trip in July 2007. Overall it returned data for 63% of the deployment. The sample period was 1 hour.

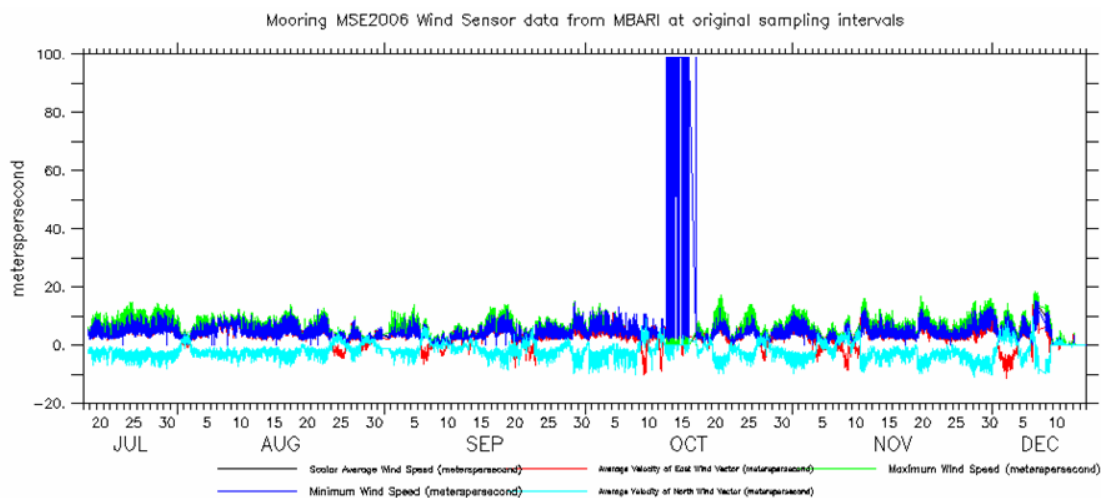


1339 - Triaxys Wave Sensor (replaced 1286). The original instrument (1286) was destroyed on the inverted launch in July 2006. A replacement unit was field installed on the July 18, 2007 Zephyr maintenance trip. Example 2007 data plot from replaced instrument. Plot is from the SSDS SIAM raw data plotting function and shows the significant wave height in meters (Hs).

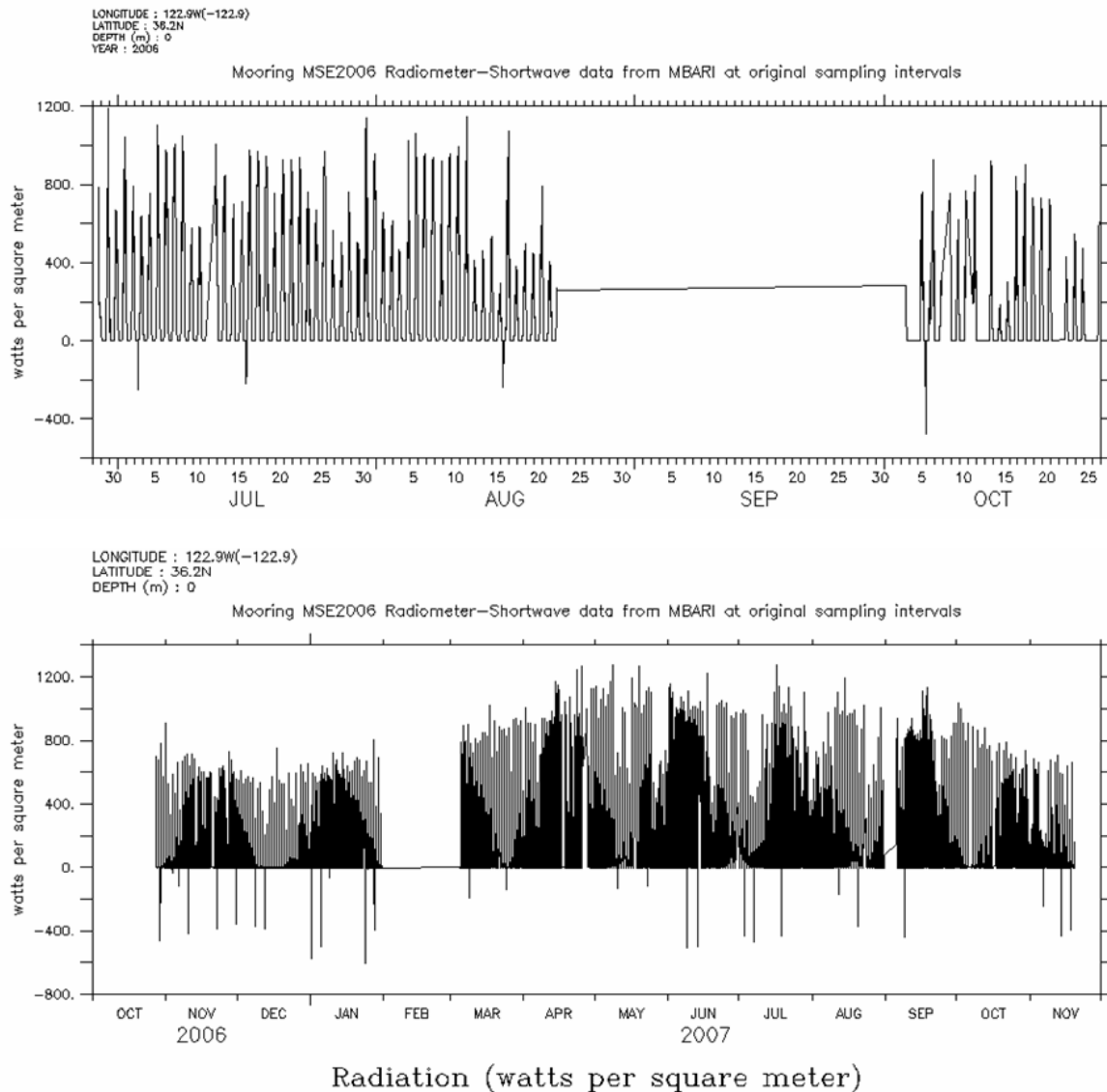


1290 - ASIMET HRH. This sensor was also heavily damaged on the inverted launch in July 2006. Due to the long repair and calibration time (over one year), a replacement unit was not received in time to install it on a maintenance cruise during the experiment. The sample period was 10 minutes.

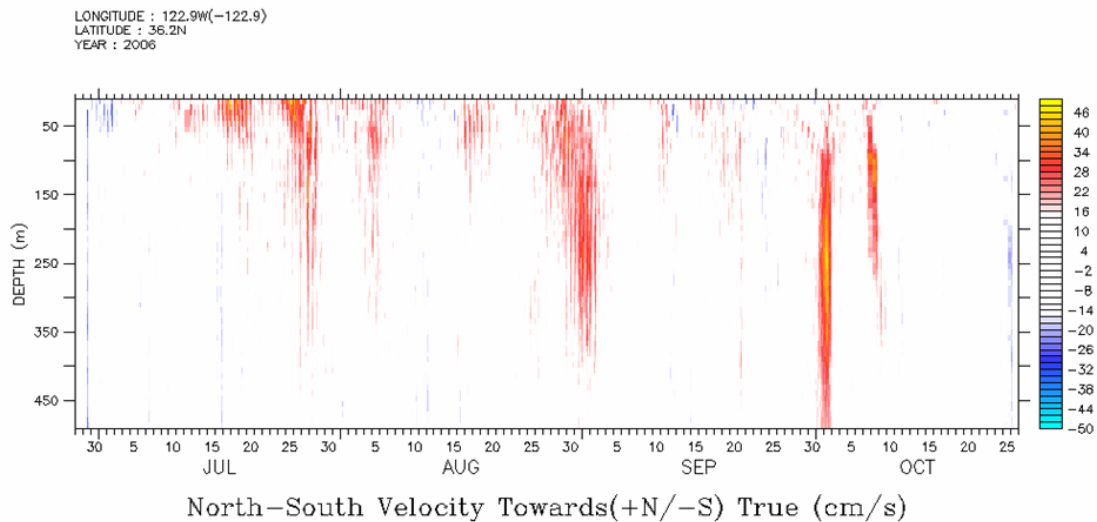
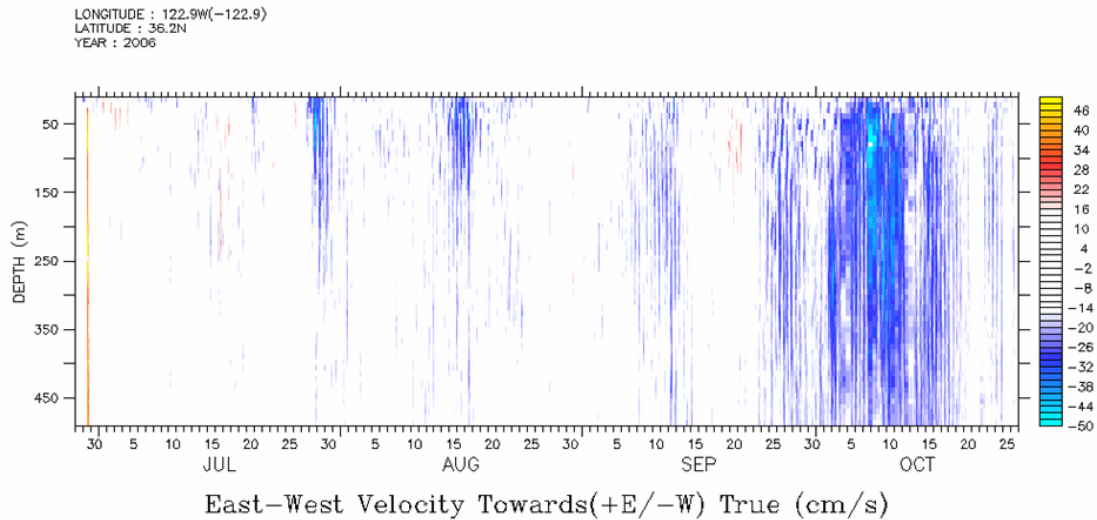
1291 - ASIMET WND. This sensor was also badly damaged on the inverted launch in July 2006. A replacement unit was installed in July 2007. An example data plot for 2007 is shown below. The cause of the spikes in the minimum wind readings in October are unknown, but disappeared after an instrument power cycle. The sample period was 10 minutes.



1557 - ASIMET SWR. Example data plots from 2006 and 2007 are shown below. The large data gap in 2006 is caused by the instrument failing to respond to serial commands. Data retrieval from the instrument was restored after an instrument power cycle. The simple automated data stream checking in place at the time did not report the instrument timeout error strings as data stream failures so data failure was not noticed for over a month. The instrument returned good data for 84% of the deployment. The sample period was 10 minutes.

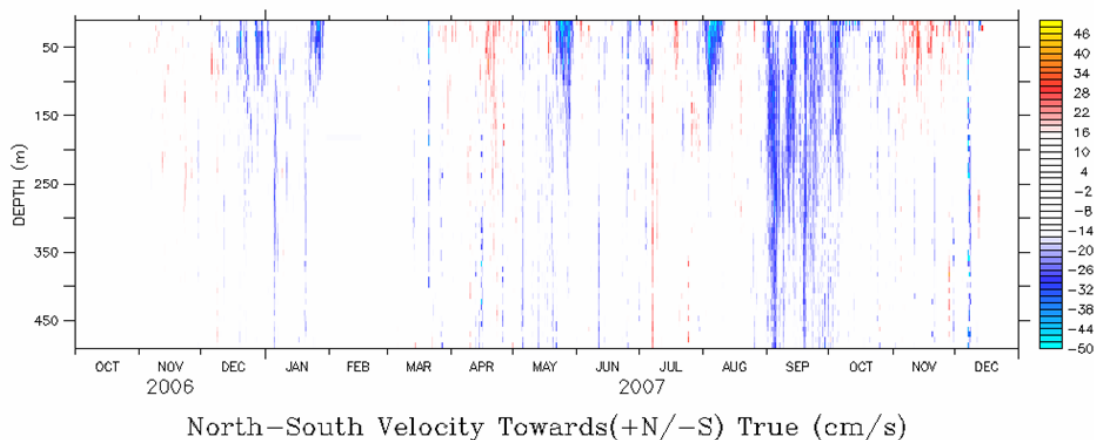
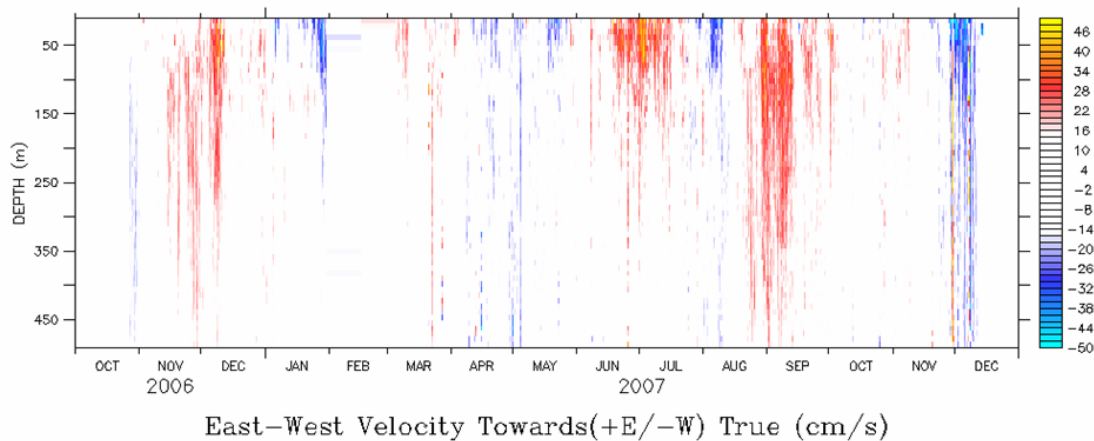


1294 - Workhorse LR ADCP 75kHz. This instrument produced excellent data from deployment with the exception of the data gap in February – March 2007. This data gap was due to the loss of the surface wind power turbine and the subsequent system power emergency. Example data plots are shown below. It returned good data for 92% of the deployment. The sample period was 10 minutes.



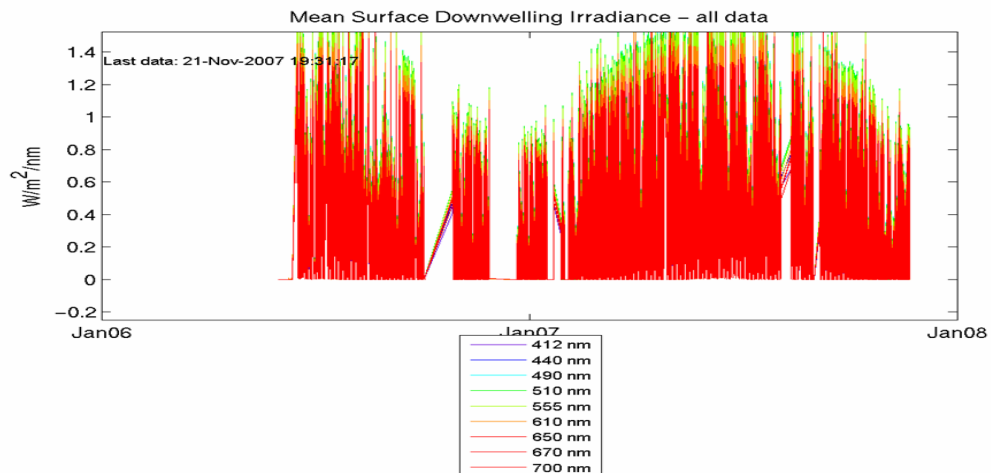
1294 - Workhorse LR ADCP 75kHz. Continued.

LONGITUDE : 122.9W(-122.9)
LATITUDE : 36.2N

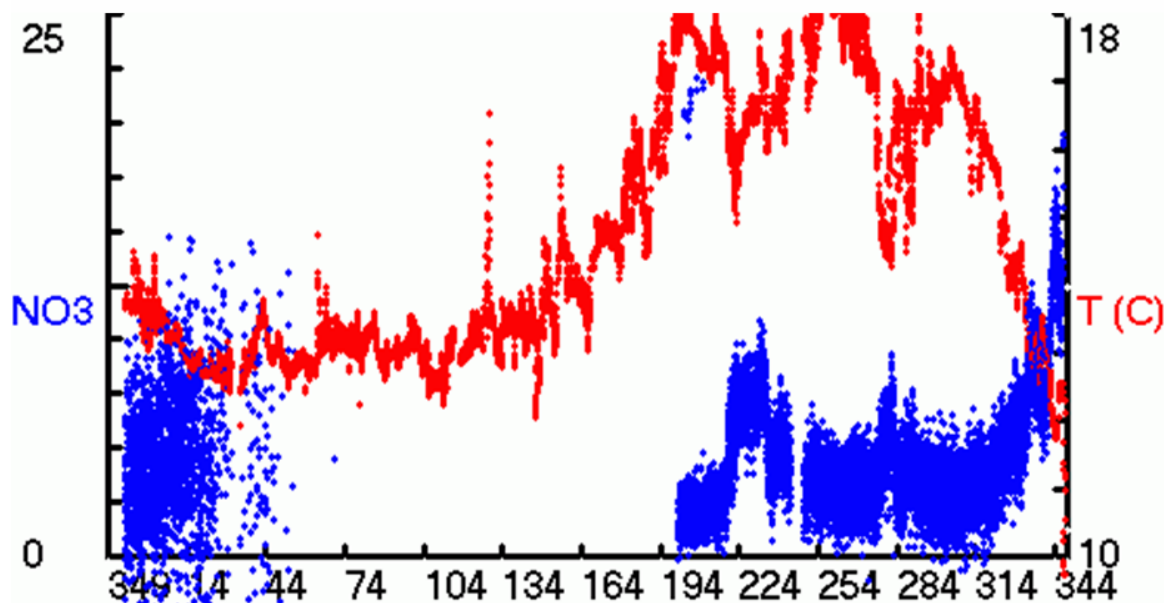


4. Secondary surface node421 aka node21, secondary (ID 1481):

1517 - Satlantic HyperOCR. Below is an example data plot from the surface air hyperspectral irradiance sensor. The data record for this instrument is nearly complete for the duration of the deployment. Most of the data gaps shown in the quick look plot below did not appear in the raw data. The instrument returned good data for 99% of the deployment. The sample period was 10 minutes.

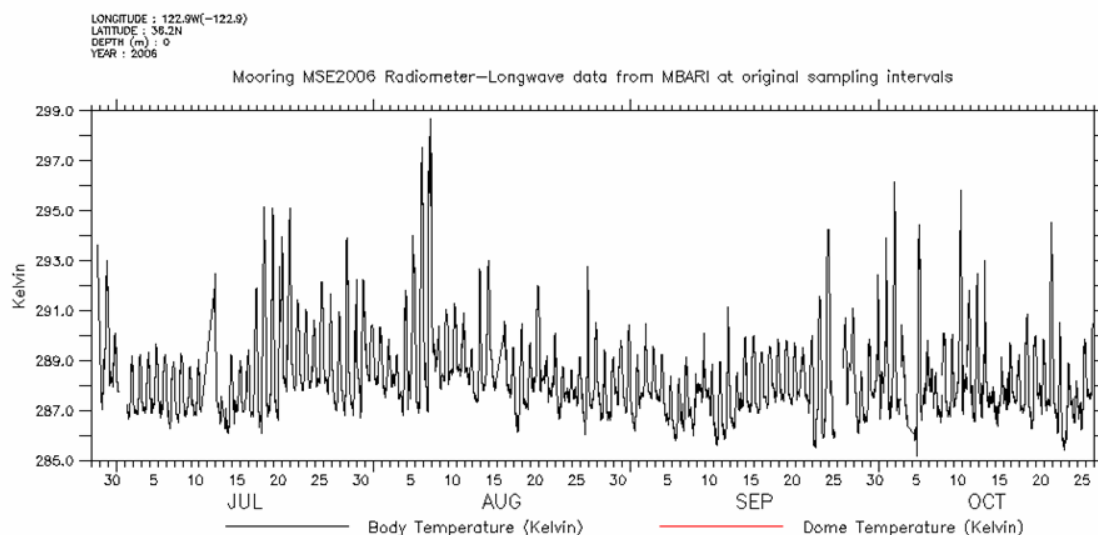


1514 - Satlantic MBARI ISUS. <http://www.mbari.org/chemsensor/MSE> Example plot from the 2007 deployment year by Julian day. The ISUS optical head was cleaned several times over the summer to restore good data return. It returned good data for 60% of the deployment and bad data for about 33% of the deployment, mostly due to biofouling and possibly knocking the optics out of alignment during deployment which reduced the signal-to-noise ratio.

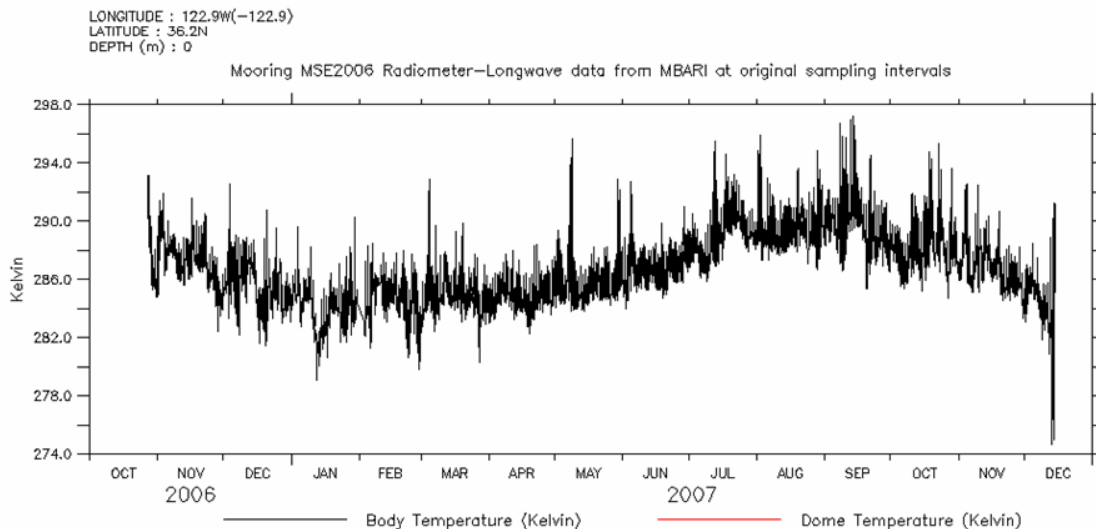


Nitrate (μM - blue) and Temperature ($^{\circ}\text{C}$ - red) measured at the MSE mooring in Monterey Bay are plotted versus the Year Day over the previous 365 days. [As temperature goes down, the concentration of nitrate rises.](#) Decreasing temperature indicates upwelling of cold deep water that is also rich in nutrients. (From Chem. Sensors website).

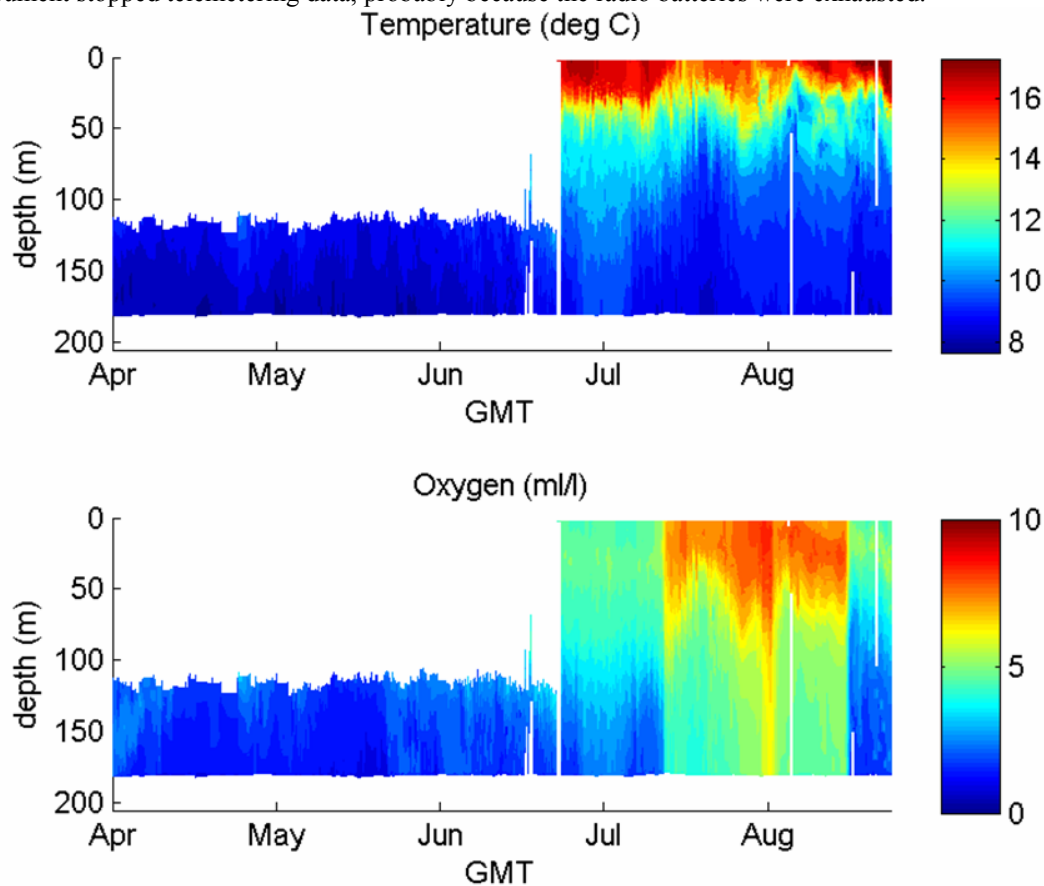
1289 - Asimet LWR. Quick look example plots are shown below from 2006 and 2007 showing the data return history. This instrument had a nearly complete data return. It returned good data 93% of the deployment. The sample period was 10 minutes.



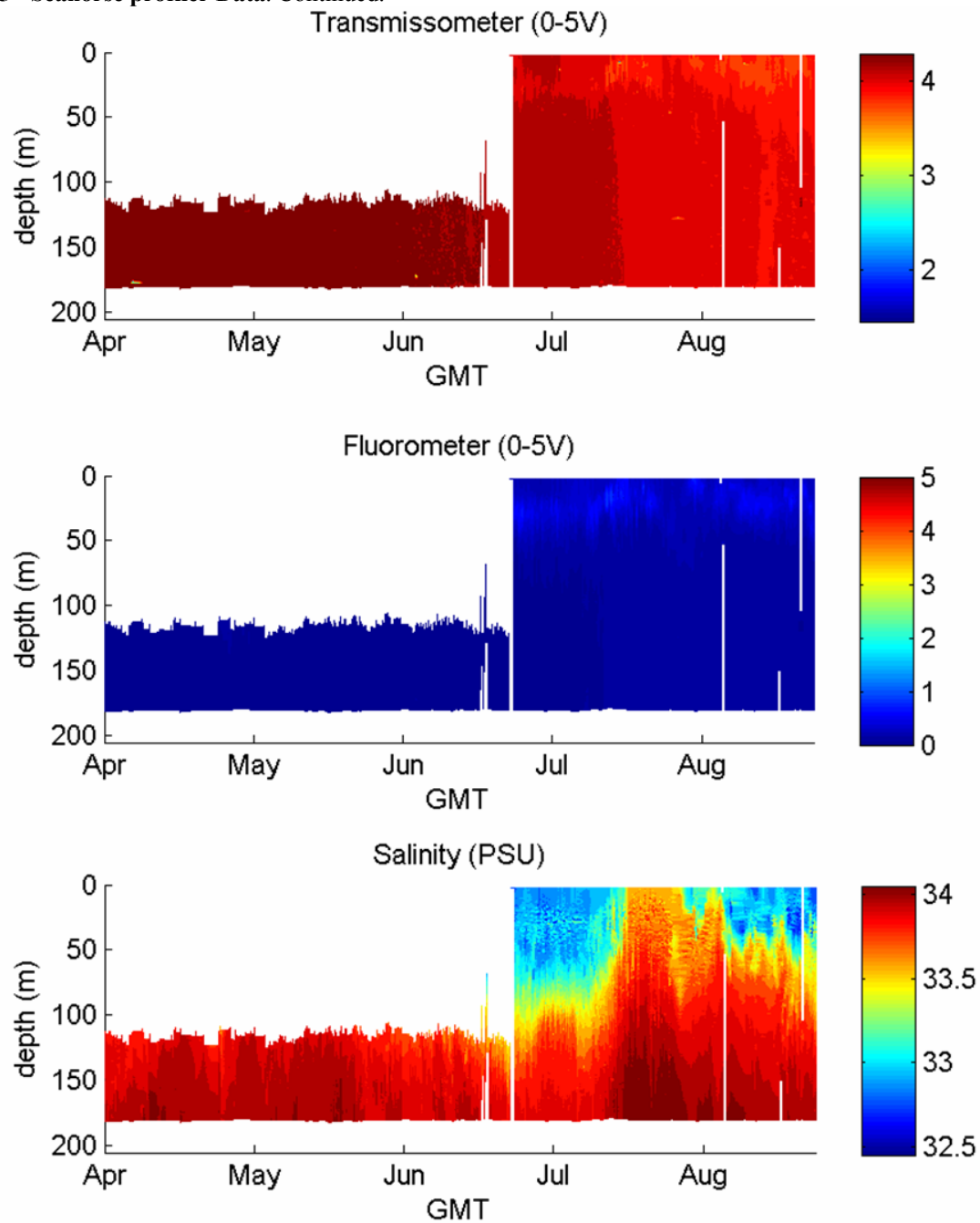
1289 - Asimet LWR. Continued



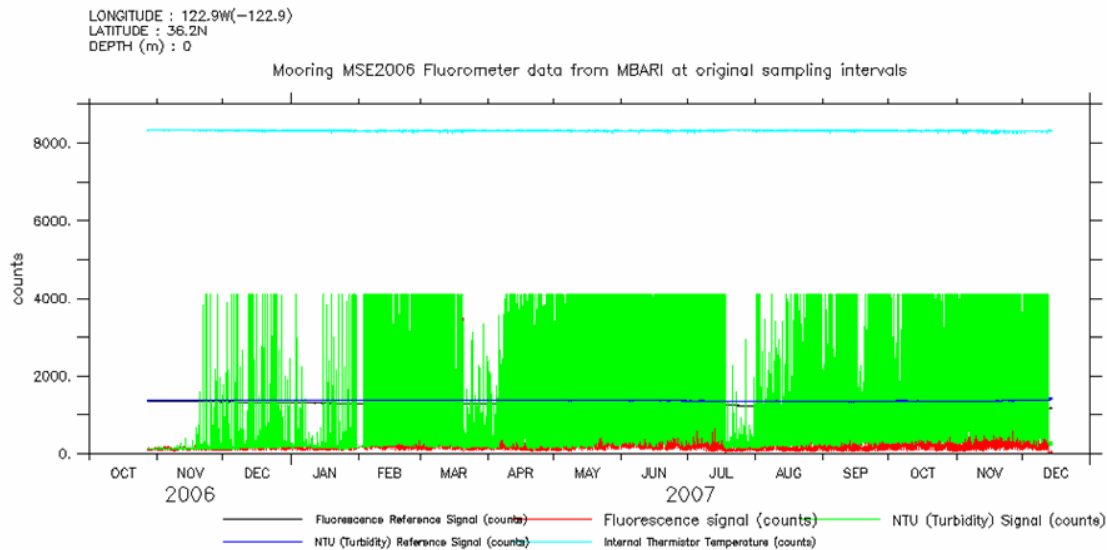
1405 - Seahorse profiler Data. Shown below are quality control plots from the entire telemetered deployment. This data was passed to the MSE mooring by short-range radio telemetry. The incomplete data record from April 2007 through late June 2007 is caused by a program configuration error (delay for vertical transit) due to a mathematical calculation error. The problem was corrected during a Zephyr field visit. In June 2007 the instrument stopped telemetering data, probably because the radio batteries were exhausted.



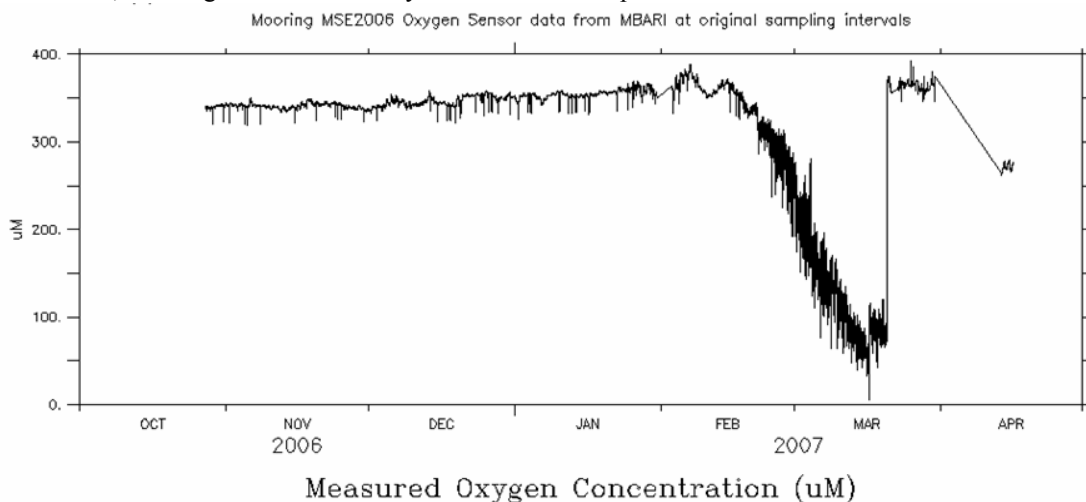
1405 - Seahorse profiler Data. Continued.



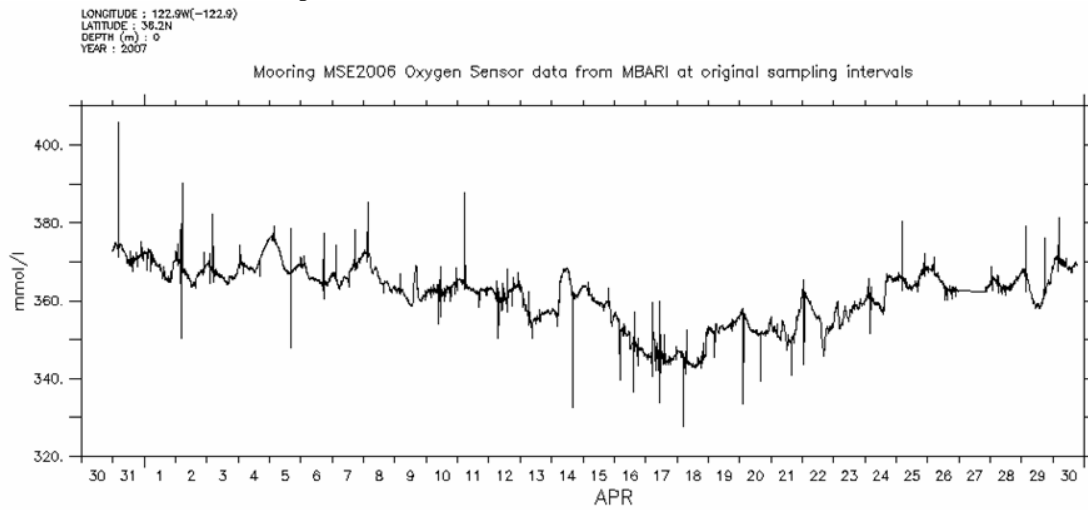
1530 - WETLabs ECO FLNTU. Quick look data plots shown below, showing data return history. This instrument returned 99% of the data possible over the duration of the deployment. The sample period was 10 minutes.



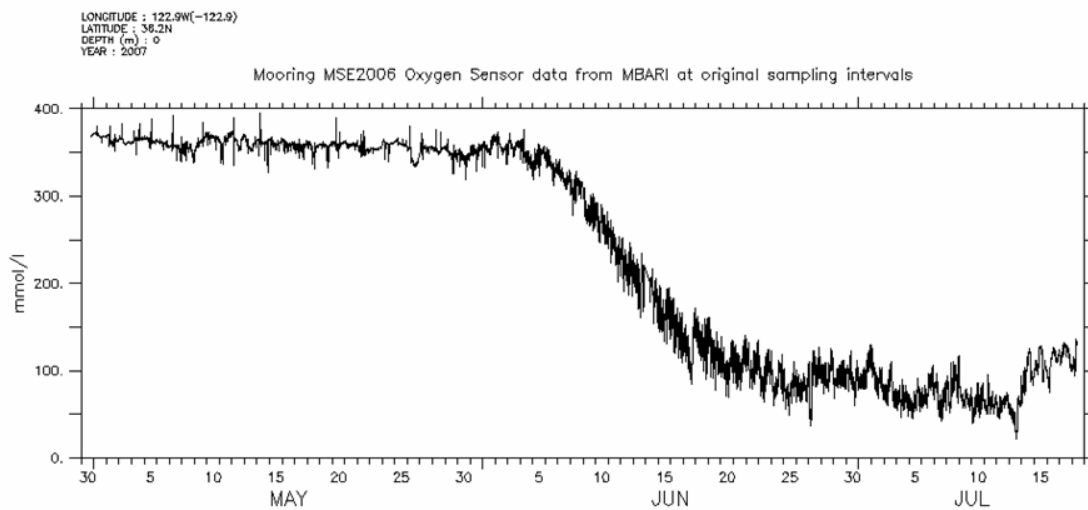
1460 and 1498 - Aanderaa Optode. (1460 replaced 1498 on July 18, 2007) The O₂ sensor had problems with the instrument service that took a long time to resolve. The sensor also fouled and was replaced and/or cleaned several times. It returned good data about 79% of the deployment and bad data about 17% of the deployment, mostly due to biofouling. The sample period was 10 minutes. Quick look data plots are shown below, showing data return history. Note that the last plot has an error in the axis labels.



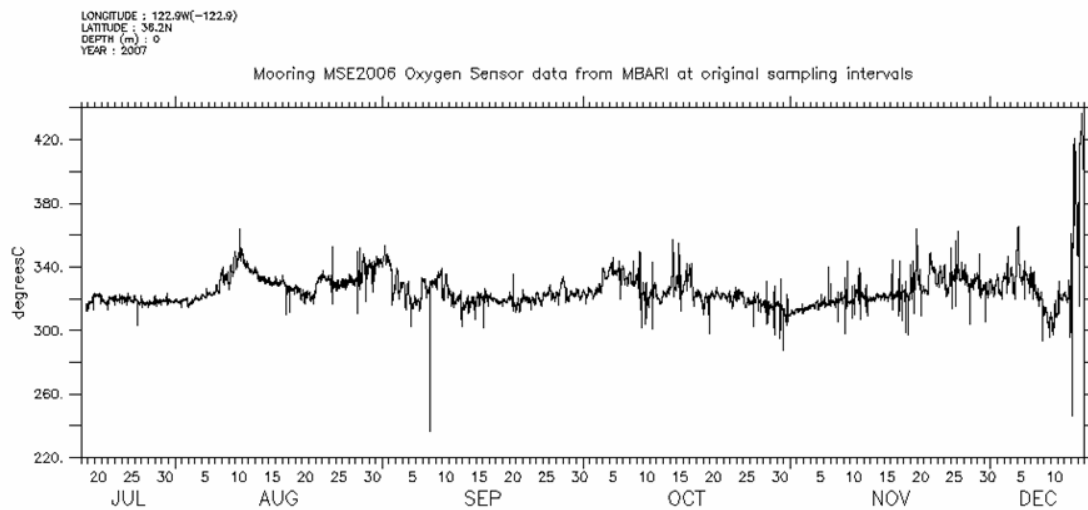
1460 and 1498 - Aanderaa Optode. Continued.



Dissolved Oxygen (mmol/l)



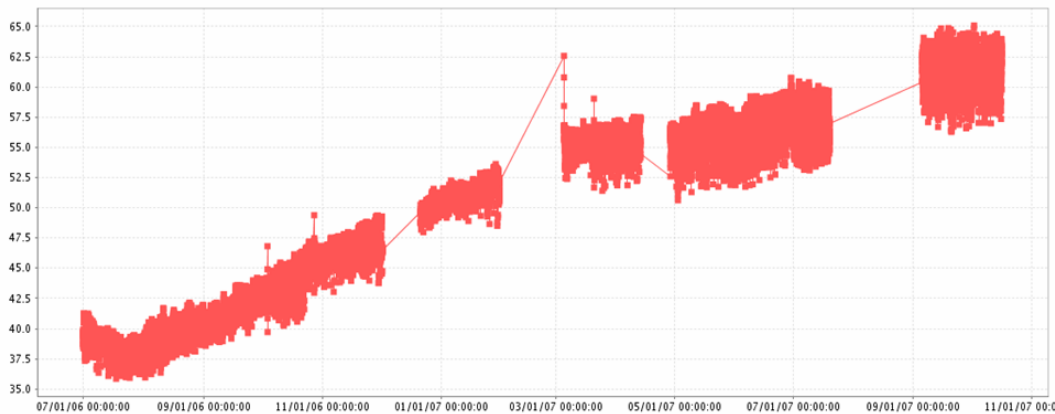
Dissolved Oxygen (mmol/l)



Measured Temperature (degreesC)

5. node410 aka node10, Snubber (ID 1482):

The Snubber node has large data gaps. Several times the node failed to boot after a power cycle. Attempts to restart the node are generally not successful, although it has restarted on a cold boot on occasion. In mid October 2007 the node was power cycled during a reboot and did not restart. Subsequent attempts to restart it failed. When in failure mode it does not appear to draw nominal power from the Surface DPA switch. The humidity shows an increasing trend that reached 63% at 20 degrees C. before operation ceased, but after recovery the internal electronics were dry with no evidence condensation at room temperature. Evidence points to a power supply start-up problem on the MMC and possibly Medusa cards, possibly humidity related. The graph below shows the Snubber housing internal humidity trend.

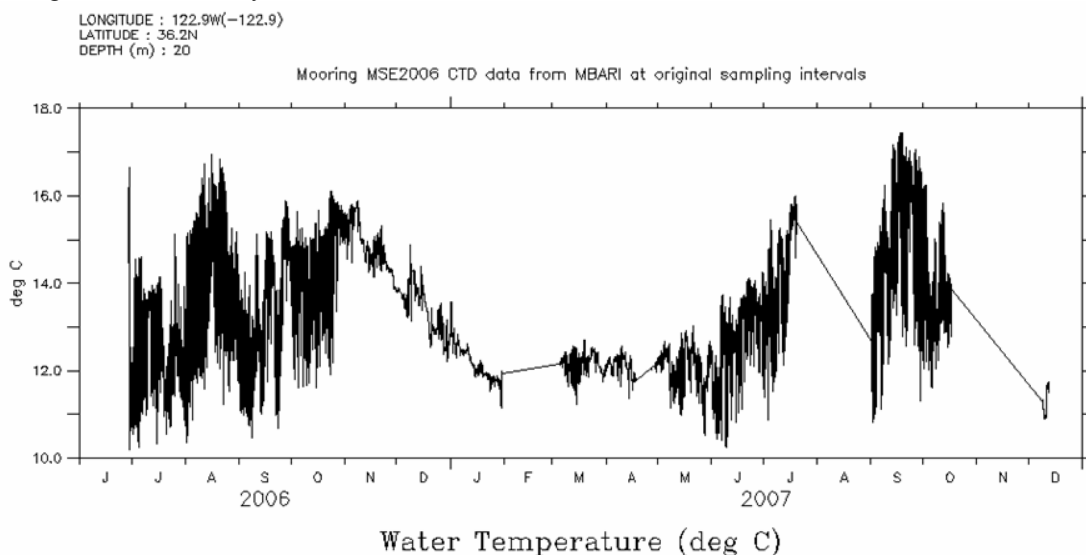


Snubber housing internal humidity trend over the course of the deployment.

1515-I - Satlantic HyperOCR Binary data, no graphical representation available. Data has been archived but is not currently being processed. This instrument returned 74% of the data possible over the deployment. The missing data is due to the Snubber controller problem discussed above. The sample period was 10 minutes.

1516-R - Satlantic HyperOCR Binary data, no graphical representation available. Data has been archived but is not currently being processed. This instrument returned 74% of the data possible over the deployment. The sample period was 10 minutes.

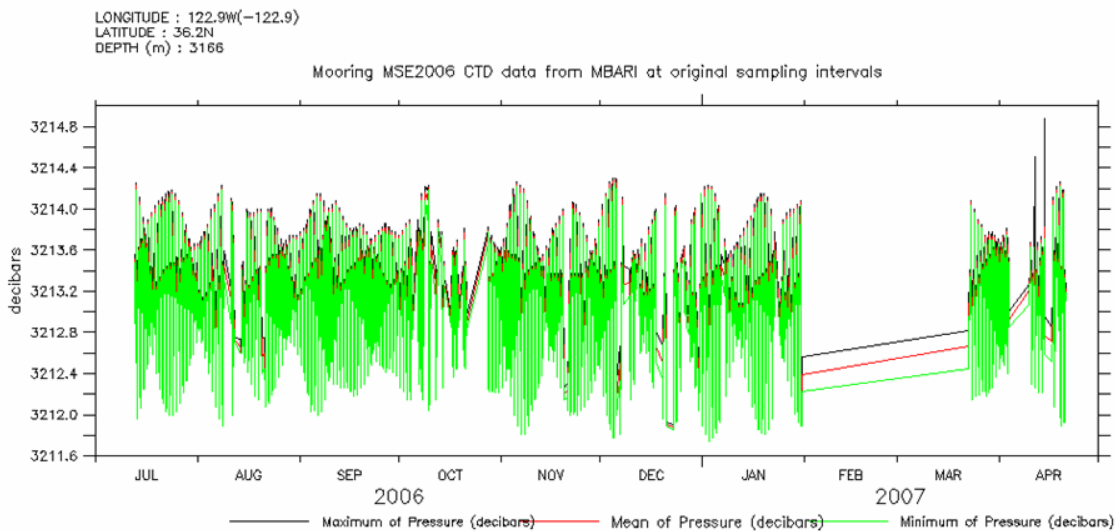
1508 - Seabird-37SM. Example CTD data plots. As explained above, the gaps in the data are caused by the node failing to come up consistently after a power cycle. This instrument returned 74% of the data possible over the deployment. The sample period was 10 minutes. Quick look data plots are shown below, showing data return history.



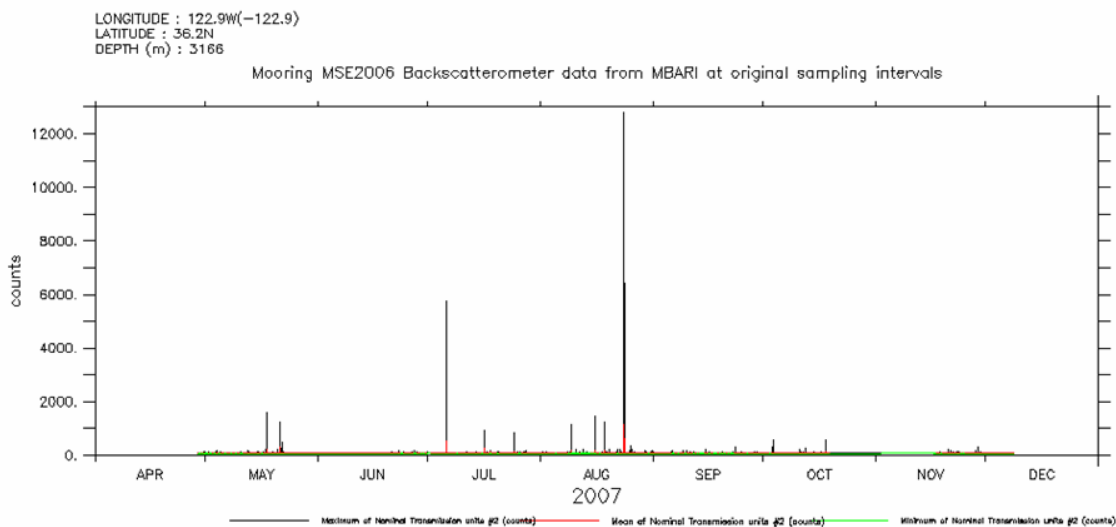
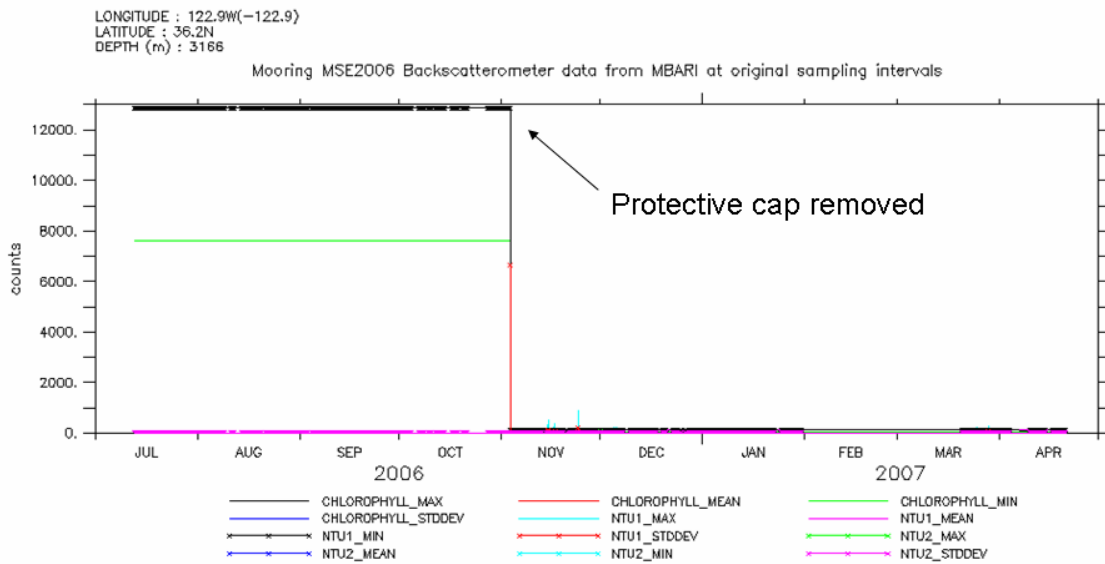
6. SHELF BIN node2, shelf (ID 1520)

July 12, 2006-April 24, 2007 and node2, shelf (ID 1598): April 24, 2007 – December 12, 2007. The Shelf BIN was inflicted with intermittent bouts of the “coma” bug that caused data logging and telemetry outages of a few hours to 24 hours. The large data gap in February and March 2007 on all instruments is due to the loss of the surface wind power turbine and the subsequent system power emergency that required shutting down logging until the wind turbine was replaced.

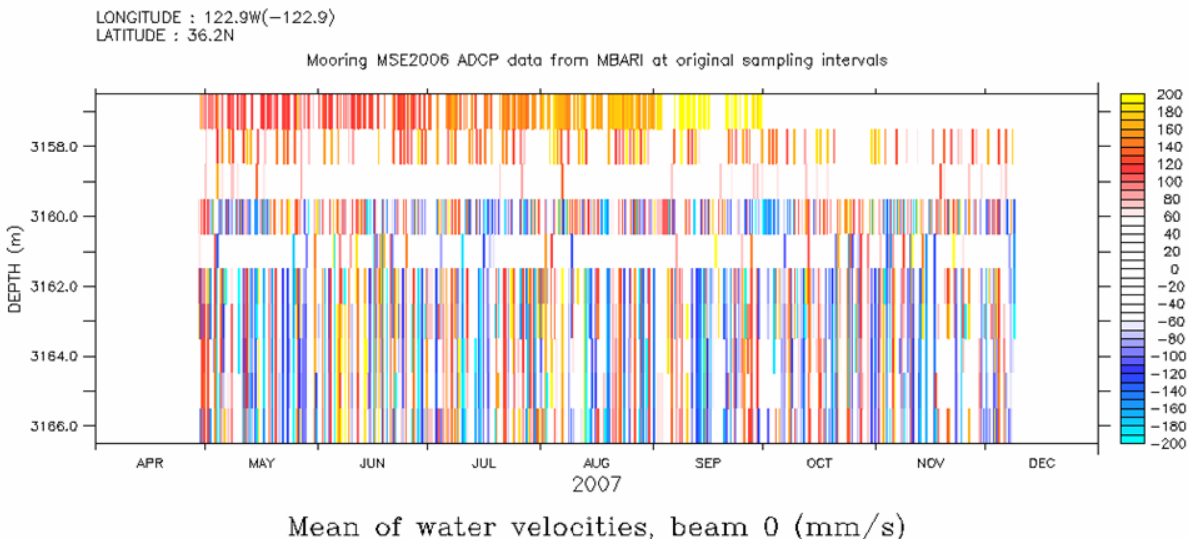
1533 - SBE-16+ CTD. Deployed on Shelf BIN from July 12, 2006 until April 24, 2007. The plots below show the summary data returned through the telemetry link. The full data set recovered from the BIN following recovery did not fill in the data gaps significantly. The benthic cable failure and subsequent BIN swap resulted in the CTD not being redeployed after April 2007. This instrument returned 39% of the data possible over the deployment, the low percentage due mostly to not being redeployed after April 07. The sample period was 5 minutes with one hour summaries for telemetered data. Quick look data plots are shown below, showing the data return history.



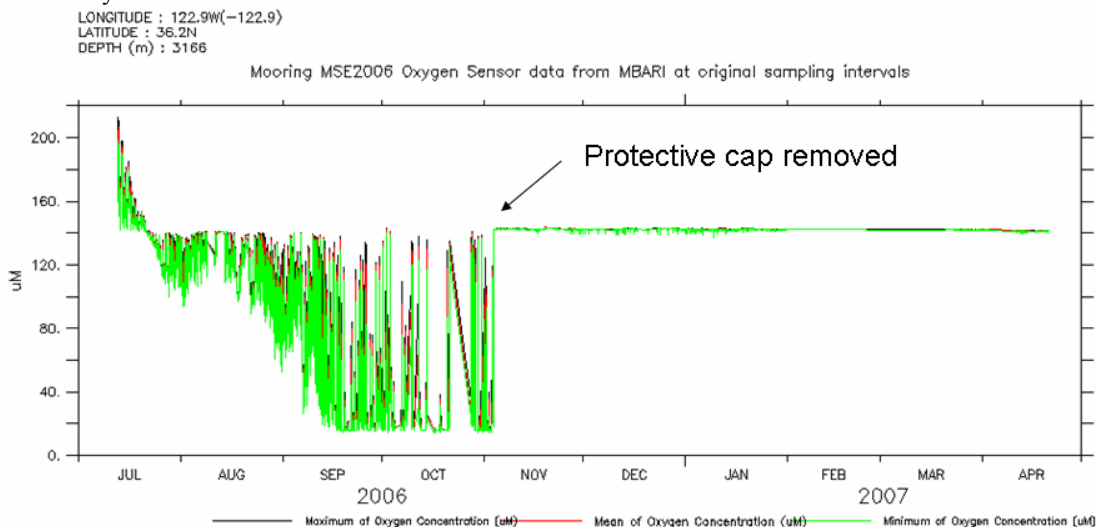
1535 and 1536 - WETLabs ECO-Triplet. 1536 replaced ID 1535 on April 28, 2007. The large step in the data is due to the protective cap being accidentally left in place over the optical port on deployment. The cap was subsequently removed by the ROV Tiburon during the Axis deployment dive in early November 2006. The large data gap in February and March 2007 was due to the loss of the surface wind power turbine and the subsequent system power emergency. The plots below shows data returned and where there are gaps in data. Instrument 1536 stopped sending data for unknown reasons on several occasions and resumed when the instrument and service were restarted. The instrument ID was inadvertently left off of automatic "failmail", which caused the long October-November data outage when the missing data stream was not noticed. This instrument returned 53% valid data over the deployment and 19% bad data, mostly due to having the protective cap in place. The sample period was 5 minutes with one hour summaries for telemetered data. Quick look data plots are shown below, showing the data return history.



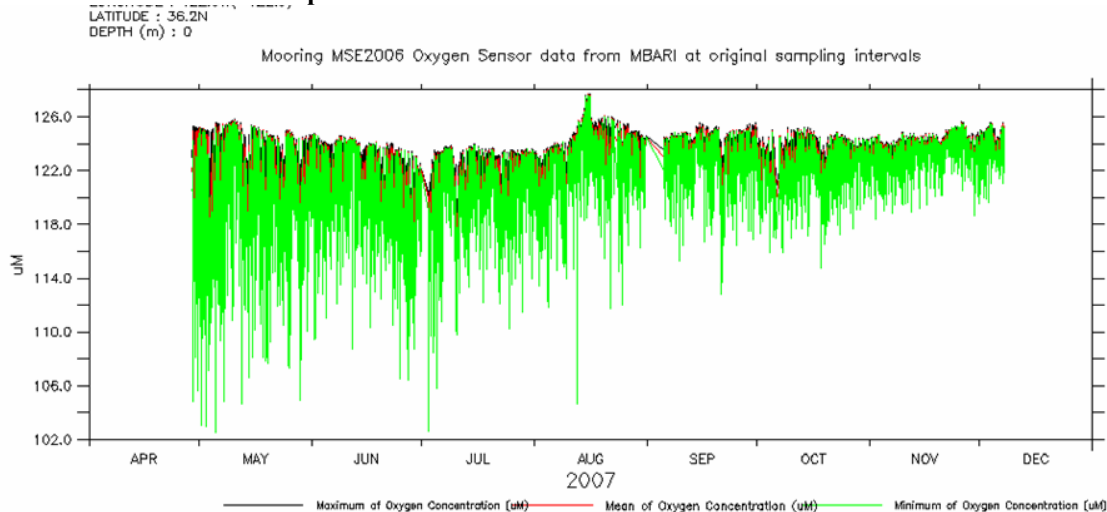
1474 and 1553 - Aquadopp Current Meter. 1474 was deployed July 12, 2006 through April 25, 2007. 1553 was deployed April 28, 2006 through December, 2007. The instrument returns binary data, and no quick look graphical representations are available that show actual water current results. The data has been archived but has not yet been processed by the proprietary software that is used. From looking at the data telemetered it appears that the instrument service software summarizer was broken from July 2006 until April 2007. The post-recovery data has superseded the summarized telemetered data and it appears complete. This instrument has returned 77% of the data possible over the deployment. The sample period was 5 minutes with one hour summaries for telemetered data. The plot below is a quick look plot showing the general availability of the data record for 2007 (the data is binary and is not graphed properly).



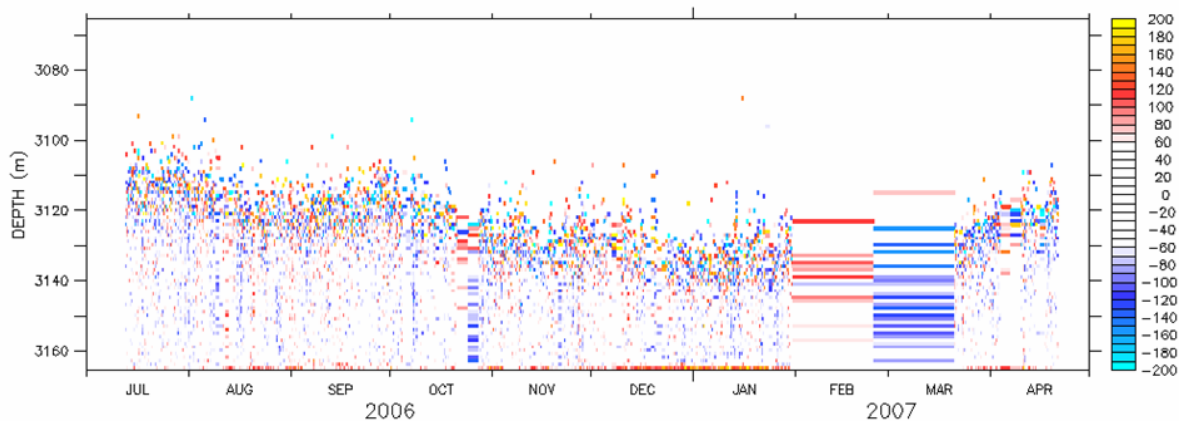
1444 and 1524 - Aanderaa Optode. 1444 deployed July 12, 2006 through April 25, 2007. 1524 was deployed April 28, 2007 through December 2007. The sample period is 5 minutes with one hour summaries for telemetered data. The O2 sensors returned valid data for 50% of the total deployment duration and 19% bad data, usually due to biofouling contamination and the protective cap being left on from the initial deployment until it was removed in early November. The plots below are quick look plots of the O2 data showing data return history.



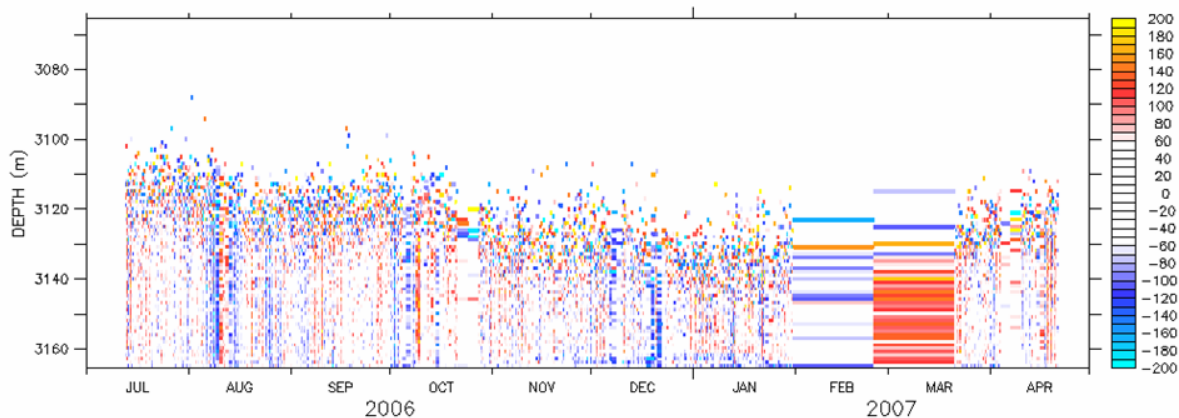
1444 and 1524 - Aanderaa Optode. Continued.



1525 - WH Sentinel ADCP 300 kHz. Upward looking. Deployed July 12, 2006 through April 25, 2007. The sample period is 5 minutes with one hour summaries for the telemetered data. This instrument has returned 39% of the data possible over the deployment, the low percentage due mostly to not being redeployed after April 07 and the large data gap in February – March 2007 due to the previously mentioned lower power emergency. There also are smaller data gaps where the instrument service or instrument failed to return data for periods of several days. The cause of this is unknown. Quick look data plots of the full data set are shown below, showing the data return history.



East-West Velocity Towards(+E/-W) True (mm/s)(regrid: on T)



North-South Velocity Towards(+N/-S) True (mm/s)(regrid: on T)

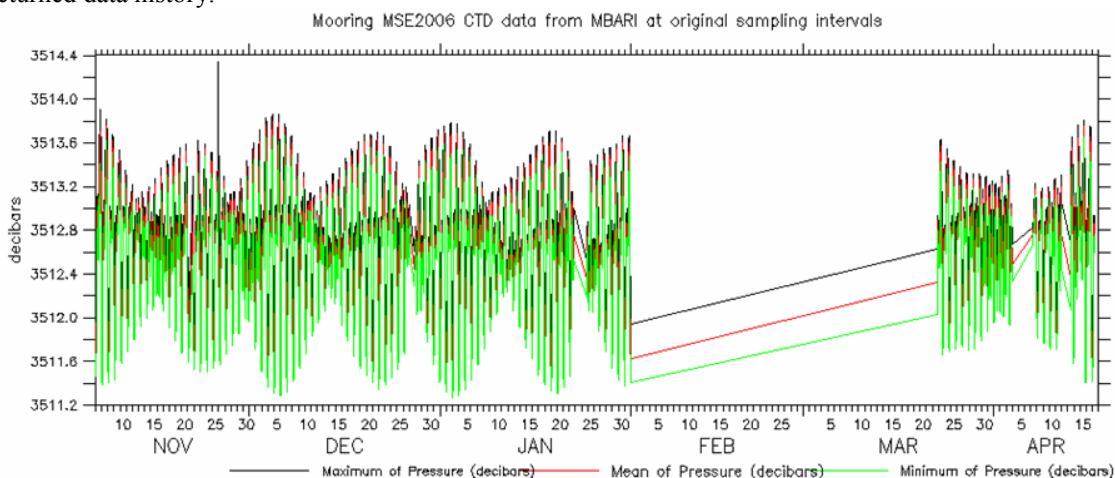
7. AXIS NODE, node11 aka node411, axis (ID 1522)

Deployed November 2006 – April 27, 2007. The Axis BIN functioned from deployment in November 2006 until the power cycle and subsequent failure of the Shelf-to-Axial seafloor cable on April 27, 2007. The full details of the Axial failure are available through the project Wiki page here:

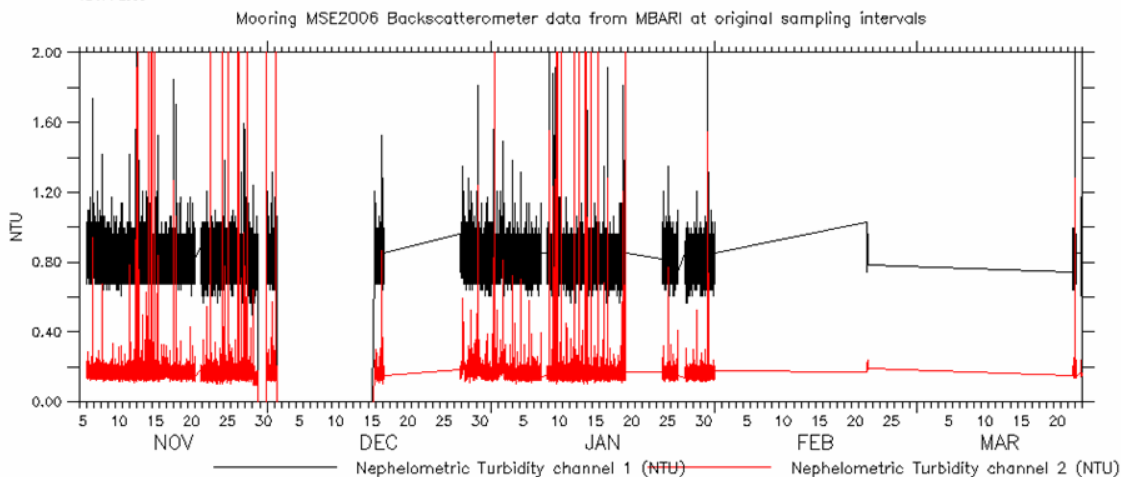
<https://oceanambari.org/confluence/display/MOOS/Home>

The large data gap in February and March 2007 on all instruments was due to the loss of the surface wind power turbine and the subsequent system power emergency. Note that the data is much higher resolution than the ability of these plots to display. The sampling rate of each of the instruments on this BIN was between 10 seconds and one minute.

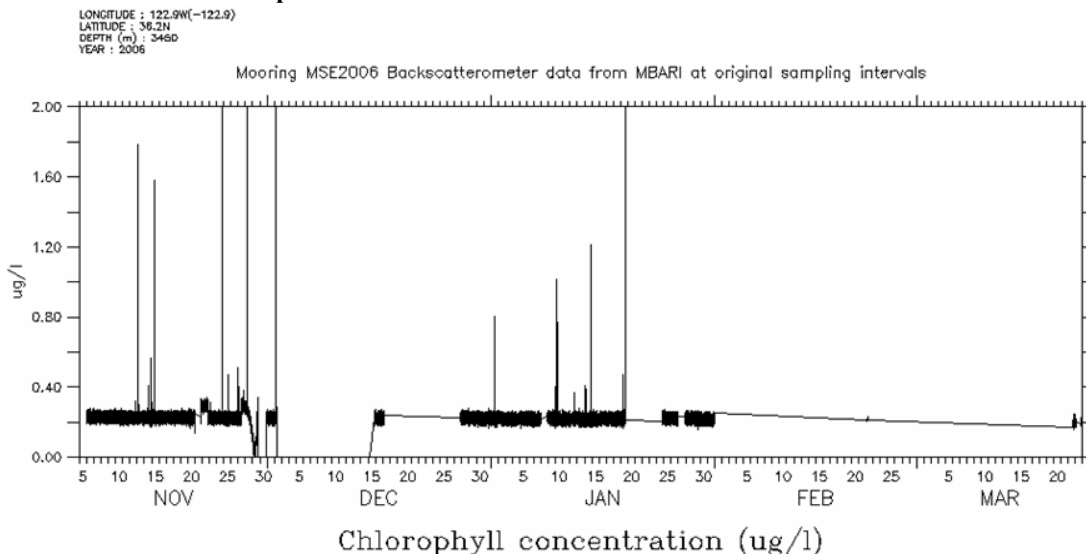
1546 - SBE-16+. Deployed November 8 through April 18, 2007. The sample period is nominally 15 seconds, however sometimes it was as much as 30-40 seconds. The average sample period was 18 seconds. Telemetered data was returned in one hour summaries. This instrument has returned 28% of the data possible over the deployment, the low percentage due mostly to the February – March 2007 power failure and the Shelf-to-Axial cable failure. There also was a problem with one of the ROVmate connector hoses intermittently drifting into the beam of the transmissometer causing spikes in the data. Quick look plots are shown below showing the returned data history.



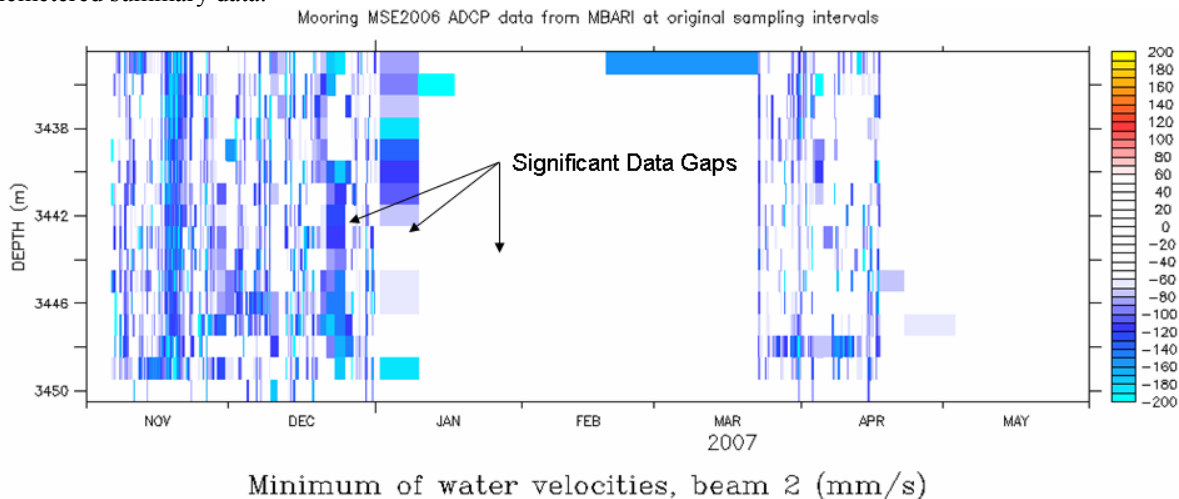
1537 - WETLabs ECO-Triplet. The sample period was 10 seconds. Telemetered data was returned in one hour summaries. The instrument has returned 28% of the data possible over the deployment, again, the low percentage due mostly to the February – March 2007 power failure and the Shelf-to-Axial cable failure. The large December data gap is due to the instrument failing to return valid data after query, causing an instrument service time-out. The cause of this is unknown but restarting the instrument service and instrument restores proper data return. The quick look plots below show the returned data history.



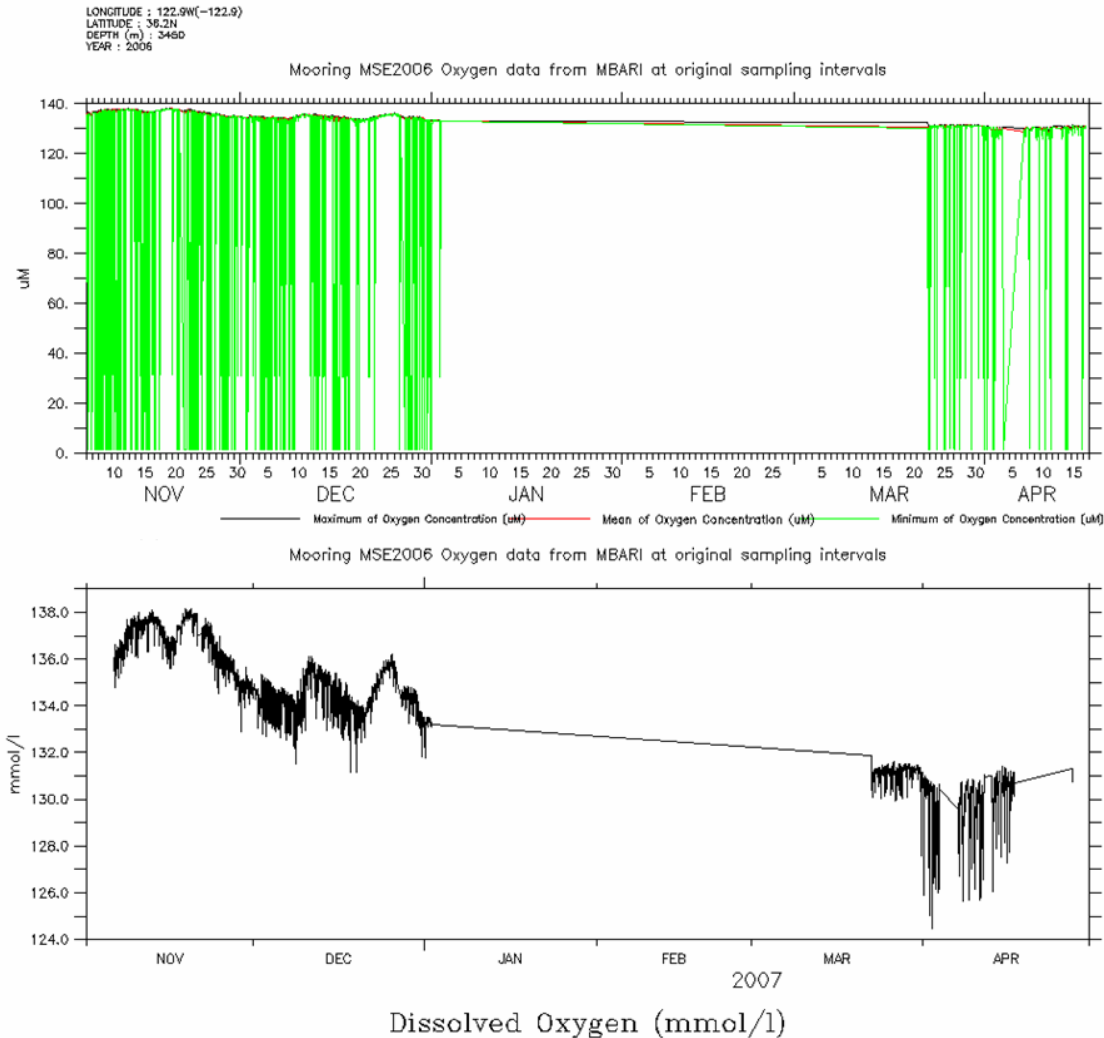
1537 - WETLabs ECO-Triplet. Continued.



1473 - Aquadopp Current Meter. The sample period appears to vary between 2-10 seconds and averages around 5 seconds. Telemetered data was returned in one hour summaries. This instrument has also returned 17% of the data possible over the deployment, again, the low percentage due mostly to the February – March 2007 power failure and the Shelf-to-Axial cable failure. The instrument also had a problem with tripping the MMC over-current breaker circuit causing outages in December and January. The Shelf unit did not have this problem. The data has been archived but has not yet been processed by the proprietary software that is used. The instrument returns binary data, and no quick look graphical representations are available that show water current results, however the quick look plot below gives a representation of the returned data history from the telemetered summary data.



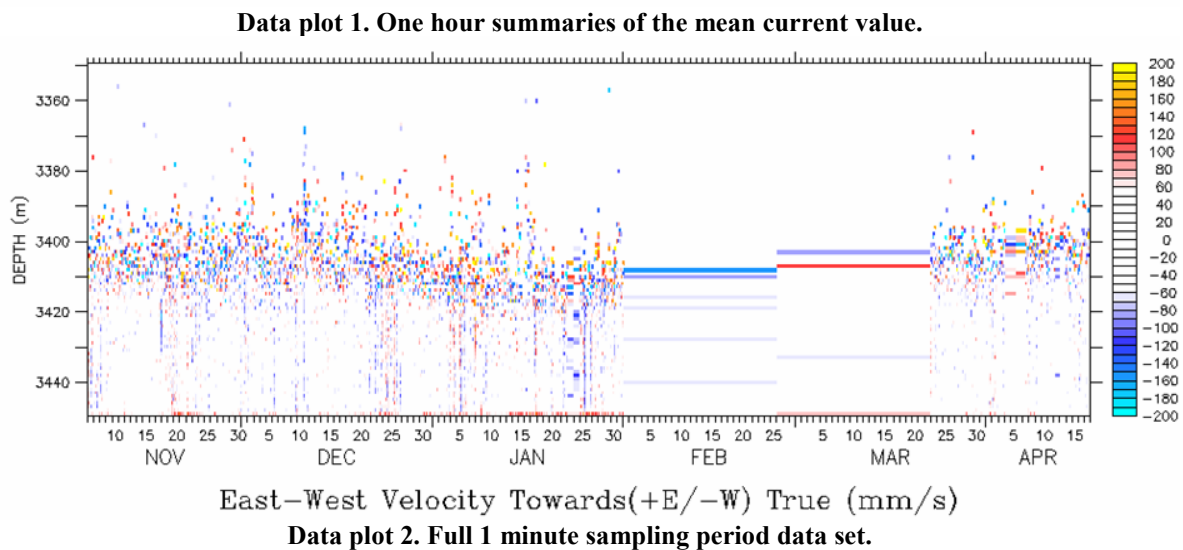
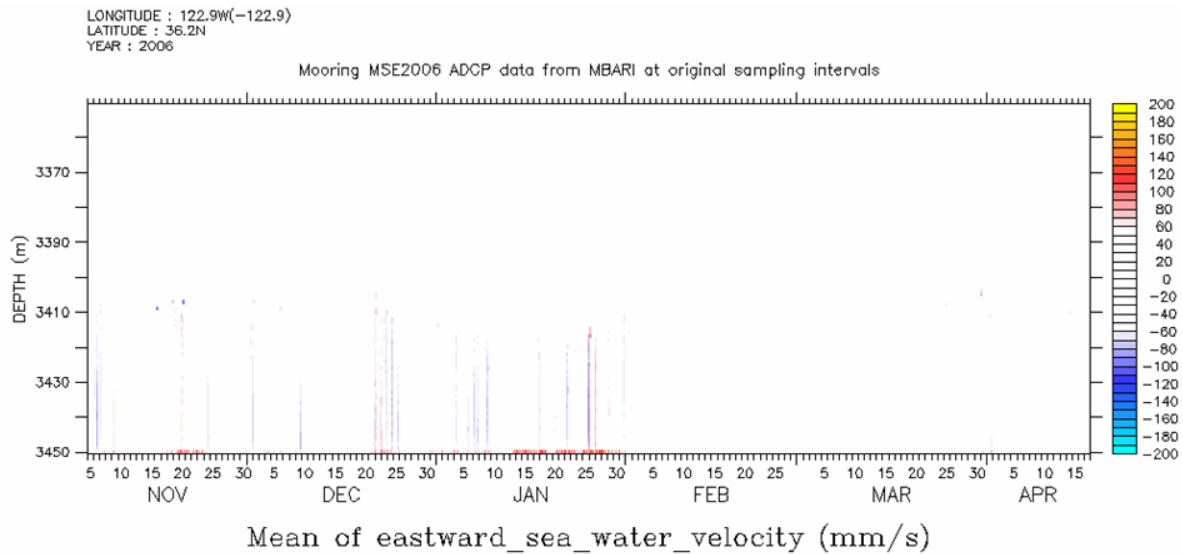
1445 - Aanderaa Optode. The sample period was nominally 10 seconds and the timestamps vary between 9 and 12 seconds. Telemetered data was returned in one hour summaries. This instrument has also returned 28% of the data possible over the deployment, again, the low percentage due mostly to the February – March 2007 power failure and the Shelf-to-Axial cable failure. The first quick look plot below shows the returned summarized data history. The spikes to zero in the O2 “minimum value” data appear to be a processing problem in the summarizer or plotting function. The second plot shows the full data record and does not include the data spikes.



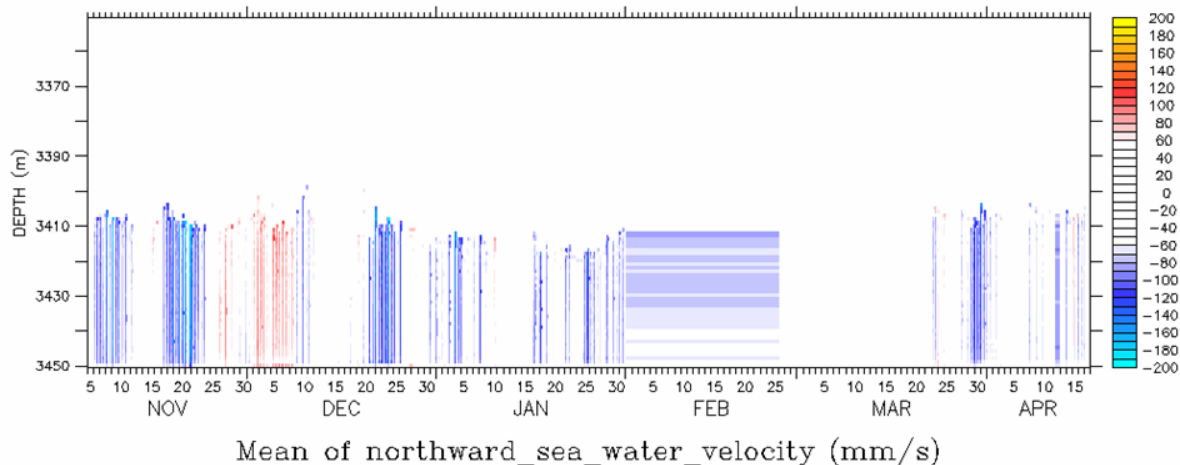
1510 - McLane Profiler

No data was retrieved through MOOS mooring system.

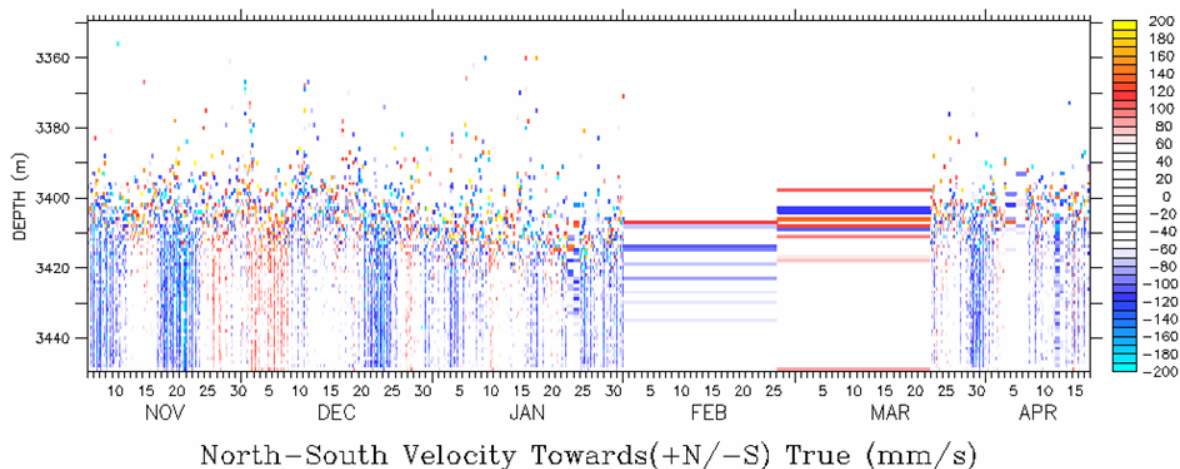
1549 - WH Sentinel ADCP 300 kHz. The sample period appears to be nominally 1 minute. Telemetered data was returned in one hour summaries. This instrument has returned 28% of the data possible over the deployment, again, the low percentage due mostly to the February – March 2007 power failure and the Shelf-to-Axial cable failure. The first plot of each pair of quick look plots below shows the returned summary data for the “mean” value. The second plot of each pair shows the entire high resolution data record. Note that the high resolution data record includes many more points than are shown in the data plot 2 figure below, the instrument was generating 1440 data point per day.



1549 - WH Sentinel ADCP 300 kHz. Continued.

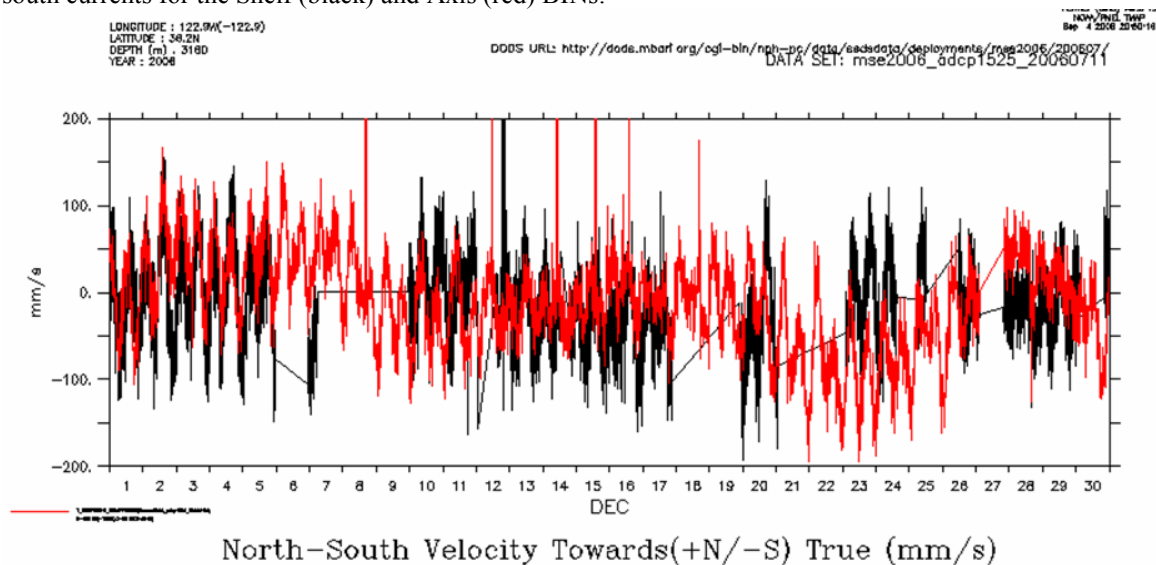


Data plot 3. One hour summaries of the mean current value.



Data plot 4. Full 1 minute sampling period data set.

The data sets in SSDS can be retrieved and displayed in various relationships, for example, Mike McCann quickly plotted this data representation showing the combined ADCP data sets for December 2006 of the north-south currents for the Shelf (black) and Axis (red) BINS:



8. Factors that prevented data return or affected data quality.

- a. **Satellite telemetry bottleneck.** The MSE system telemetry system returned all available data until the Axial BIN was installed in November of 2006. The data volume from this rapidly sampling node (nominally 10 second period) increased our daily payload from 2.5Mb to 3-5 Mb per day. This exposed several weaknesses in the telemetry systems that were not caught in pre-deployment testing. The major factor not in our control is that unbeknownst to us, the Globalstar network had been gradually degrading from about 95% availability to about 40%. The average connection time also decreased from about 13 minutes to 6 minutes. There were also several areas in the MSE telemetry algorithm design that caused the efficiency of the telemetry link performance to significantly degrade as the data backlog increased. Finally, we had several instruments that created large files that were at or near the end of the telemetry queue (the ADCP's). The download of these files was often interrupted by the link breaking. All of these factors combined to create a situation of degrading performance as the link capacity, which was hovering around our telemetry volume, was reached. Surprisingly, most data was returned in spite of these problems, but often after a delay of hours or sometimes days.

All of these problems (except the satellite availability) were corrected in January and February of 2007 and installed on the mooring system in April. This mitigated the decrease in Globalstar satellite coverage that had occurred over the previous year and resulted in an increase in our daily capacity of up to 30 Mbytes, 10 times the previous capability and easily enough to carry our fully loaded MSE system data payload of 3-5 Mbytes per day. The lesson from this experience was that we should have completed more extensive testing of the telemetry system in pre-deployment testing to verify the long-term performance at load factors at and above the full system telemetry volume. Because we had previously deployed the system and verified the load factor when the satellite availability was 95%, we assumed this was still the case and had extrapolated the data capacity. In limited pre-deployment testing we did not realize we were running right at the system limit.

- b. **Low power emergency shutdown and subsequent wind turbine failure.** As designed the MSE power system was to deliver full system power with 95% "availability". This figure was chosen as a tradeoff between science loads, battery capacity and wind and solar collection areas. There was the probability that during any deployment there may be periods of minimum winds and very poor solar insolation that exceed the capacity of the batteries to sustain the full system load for a few days. The probability was that this would occur about once in a years period. In fact this occurred twice during the deployment, for 5 days in December of 2006 and for about an equal time in late January 2007 (see figure 1, below). In each of these cases the MSE system was partially shut down to prevent an uncontrolled shutdown as the available energy reached a critical level. When the wind and sun returned after the January shutdown the wind generator did not restart and was deduced to be frozen. This in fact turned out to be the case and the available system power was severely impacted during this relatively sunless season. The wind generator was replaced by OSG after about 30 days but the protective fuse in the power system simultaneously failed. The cause is suspected to be miss-plugging of the connector. The system then remained in a low power, minimal operation state for 14 more days until the power can was replaced, restoring full functionality. Better system documentation in the form of labeling the deployed connectors, having clear instructions and possibly a step-by-step checklist and strictly adhering to these resources might have prevented the failed fuse and subsequent 14 days of additional data gap. In addition the instrument loads could have been more carefully managed to get some data during this period. Our difficulty with the satellite telemetry and the subsequent delays in command execution discouraged us from putting more effort into day-to-day power load management.

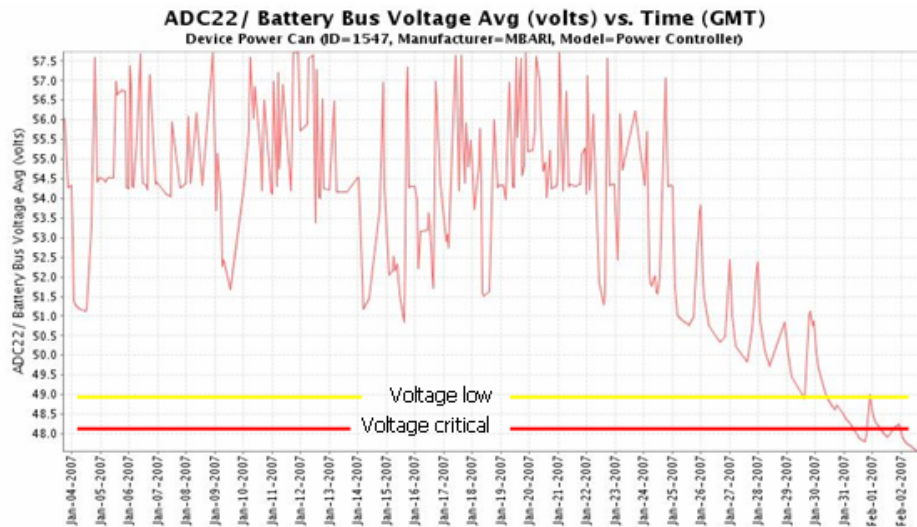


Figure 1. Voltage levels leading to the January 2007 low power shutdown event.

- c. **Node watchdog timeouts.** The MSE system controllers on the Surface mooring and in the seafloor BINS include a “watchdog” timer. The function of the watchdog timer is to autonomously restart the local controller if it has not been able to achieve a data download connection to shore for 24 hours, on the assumption that there has been a software or hardware failure. The nominal time between data downloads is 20 minutes. In addition, the design of the buoy 400V power system is fail-safe, that is, is the system restarts, the 400V power is shutdown until manually (remotely from shore) restarted. This is to prevent an unanticipated startup that energizes the system unexpectedly, for example, when people may be working on the mooring. These design features conspired with the telemetry system backlog to produce data gaps. When the system became backlogged to the extent that a given node was not in contact for 24 hours, the node would be restarted, causing the power system to reset and require manual action from shore to restore the system to full functionality. Until this happened there would be a gap in the logged data. If the restart occurred on a Friday it was sometimes not restarted until Monday or Tuesday.
- d. **Controller “Coma” bug.** A defect in the driver for the controller flash memory causes the controller to fail to come out of sleep mode and resume logging. The problem manifests itself when the controller is writing to memory when commanded to sleep and varies with frequency across the controllers in the system. It causes a data gap up to 24 hours until the watchdog timer forces a system restart and logging resumes. This occurred on average of about once per month on most controllers during the course of the deployment. A software bug fix has been identified and will be installed before future deployments.
- e. **Leaving protective caps in place on sensors.** During the initial deployment of the Shelf BIN two protective caps were not removed before the BIN was launched from the Western Flyer. This has been rectified by implementing and rigorously following a pre-launch checklist.
- f. **Hoses occluding optical sensors (Axial transmissometer).** In a on-the-spot decision during the subsea hook-up of the Axial BIN, it was decided to leave the ROVmate cable plug for the future addition of a camera system fastened to the BIN sphere, rather than remove from the sphere and place in the “window pane” cable holder. The rationale for this was that the camera was unlikely to be installed before the BIN was replaced and by leaving the cable in place about a half an hour of ROV time could be saved. Unfortunately it was not anticipated that this allowed the cable to float up and partially occlude the transmissometer beam causing intermittent spikes in the data (see figure 2 below). The corrective action for this is to consciously designate the cable and ROVmate connector locations desired after installation and choreograph the ROV manipulator moves required to achieve this rather than leaving the manipulation of the BIN cables to adhoc decision making during deployment. The use of checklists should be extended to the subsea installation and include a final check that all instrument sensing area are free from interference.

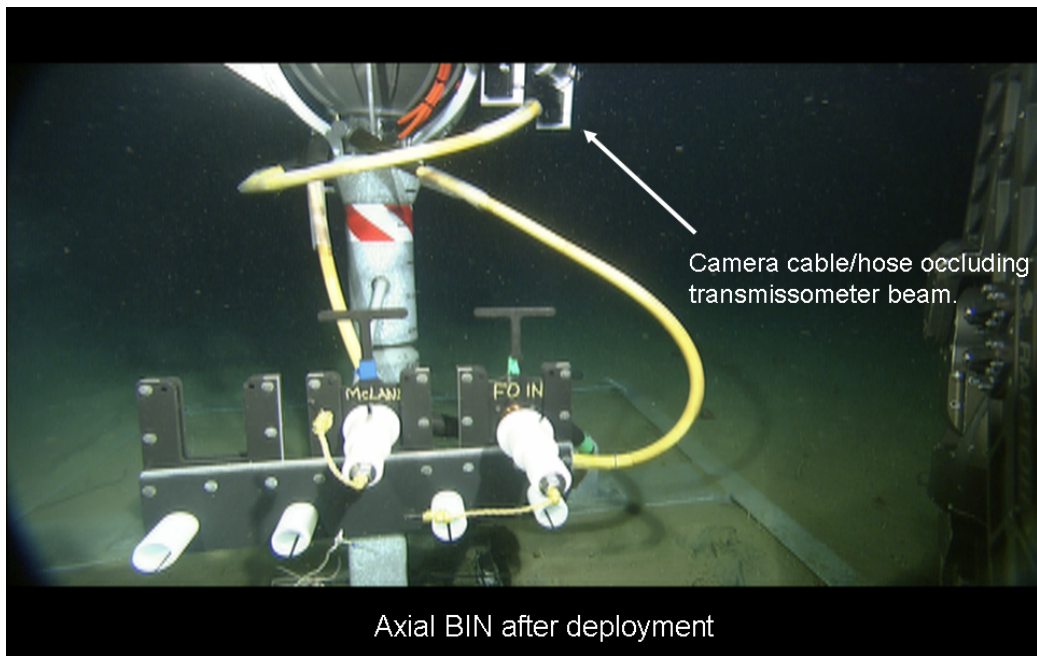


Figure 2. Image of the Axial BIN after deployment showing the hose interference with the transmissometer.

- g. **Summarizer failure (Aquadopp).** The Aquadopp micro-current profiler data summarizer collects an hours data collected every 10 seconds and produces a summary that includes the minimum, maximum, mean and standard deviation value for each data bin. The summarizer had a bug that prevented valid data telemetry from the Aquadopp on the Shelf BIN from deployment until it was fixed in April of 2007. Testing the Aquadopp with real data generated by submerging in the test tank during the final integration and test period would probably have caught this bug before deployment.
- h. **Instrument or Instrument service failure. (Axial Wetlabs).** The Axis Wetlabs instrument appeared to intermittantly fail, or the instrument service fail, in such as way as to cause *"ERR: :readUntil() Timed out:readUntil()"* messages to be returned. Unfortunately, these text strings were not interpreted by the SSDS "failmail" utility to be bad data so the failure went unnoticed for long periods on occasion. A similar problem also occurred on the surface O2 sensor. Better automated data checking would have caught these failures early and allowed correction before significant data gaps occurred.
- i. **Over-current trips on instrument power. (Aquadopp).** The Aquadopp ADCP micro profiler tripped the over-current circuit several times during the experiment. The instrument appeared to occasionally draw very sharp surges of current far above it's stated specifications. This was mostly resolved by remotely setting the over-current trip point in the MMC to 12 Amperes, but did cause several large data gaps before resolved. This might have been caught in testing by submerging the instrument in the test tank during the final integration period and running for a number of days.
- j. **Upside down buoy launch. (Wind, HRH, Heave (wave) sensor).** During surface mooring launch the buoy was released when nearly horizontal and before the snubber and cage had been slipped far enough down to put a vertical load on the base of the mooring. As a result the buoy hit the water past it's stability "point of no return" and inverted for about 20 minutes until it was pulled upright by tension on the mooring cable. Water damage occurred in several sensors and one of the GPS antennas. The shock of the instrument elevator sliding as the buoy inverted may also have knocked the ISUS optics out of alignment. This can be prevented in the future by: 1. Changing the lift point on the mooring so that it balances well within it's water stability range. 2. Changing the launch procedure to put some righting moment on the base of the mooring before the surface float is released.

9. Recommendations for improving the data return (see also full “Lessons Learned” list in appendix a below).

- a. Perform system final integration and test verification checks with system running at greater than anticipated load. Rigorously track down the cause of any observed anomalies. Perform system checks that include the entire data path and include data products such as quick-look plots as part of the tested system. This includes in-water testing for instrumentation that does not return valid data unless submerged, such as ADCP's.
- b. Generate and use detailed checklists for any critical steps of the testing and installation. Note: the project had several steps of checklists in place but for the initial installation did not have one for the subsea equipment pre-launch.
- c. Consider the BIN cable routing carefully and choreograph the manipulator movements required for underwater installation accordingly.
- d. Consider any data gap as significant and manage the system to aggressively address any causes of missing data.
- e. Provide redundancy for critical systems that have poor reliability, such as the power generation wind turbine.
- f. Schedule regular maintenance cruises to address any problems that arise that can only be remedied by a field visit. Note: For the most part this was done with MSE.
- g. Maintain a stock of “hot spares” for any mission critical parts of the system and have them available when performing system installation or maintenance.
- h. Maintain current copies of all pertinent documentation and have this available during any mooring field work.
- i. Ensure that instrument specialist and instrument service developer address desired procedures for each instrument under non-standard conditions, such as long down periods, commanded power shutdowns, etc.
- j. Have automated data checking that verifies that there is data being returned in the proper range. Having some automated data checking created a false confidence in the data streams and manual checking becomes less of a priority. Subsequently data stream failures undetected by the automated system can go unnoticed for long periods of time.
- k. Resolve the MMC “COMA mode” bug.
- l. Resolve the Medusa switch lock-up issue.
- m. Reduce the power consumption of the system infrastructure to increase the power margin and reduce the dependence on wind power.
- n. Modify surface mooring lift point and launch procedures to ensure a vertical launch.

10. Appendices

a. Complete MTM4 Lessons learned and Major Bug list (note that many of these items were addressed during the MSE deployment period).

Rev.

1.0 24FEB06 – initial release mrc

2.0 17 JUL06 – Updated after Surface and Benthic (phase1) deployment. Mrc

3.0 03OCT06 – Updated after Surface Cans swap.

4.0 18JUN07 – Updated after SHELF BIN swap.

5.0 26AUG08 – Post-recovery final version.

Category 1 – These items are considered potentially fatal bugs and should be fixed before the phase 2 deployment scheduled for September 27 – October 4, 2006.

Category 2 – These items are considered potentially serious bugs and should be fixed as soon as resources and budget are available. Some of these items need to be fixed before the next major surface deployment or turn-around.

Category 3 – These items are design changes for new builds, enhancements to improve reliability or maintenance and general project lessons learned. It is anticipated that some of these items will be included in the project plan for 2007. At the end of this category are general items in the “lessons learned” spirit.

Category 1.

1. Computing and telemetry system.
 - a. Medusa card failure to reboot on watchdog reset.
 - b. Medusa card loop-back causing network failure – inability to reliably operate passive optical loop-back.
2. SIAM application software.
 - a. Aquadopp summarizer needs revision.
3. Cable and cable laying sled.
 - a. Need improved cable for benthic lay.
 - b. Need DVL software modification to get true distance-along-track.
4. General items.
 - a. Need pre-dive checklist for BINs (Fluorometer cap!). All needs to be ready to go 1 day before planned launch.
 - b. Need organized and labeled cable collection.
 - c. Need preconfigured Freewave stash with cables, antennas and configuration guide.
 - d. Need to run through checklist 2-3 days before deployment – not the night before!
 - e. Need safety belt in go-to-sea equipment.
5. Operational items.
 - a. Need pre-dive consultation with mooring team before diving ROV within watch-circle to double-check mooring location and verify mooring cable is not a significant risk.

Category 2

1. Computing and telemetry system.
 - a. Jump to boot loader on any console transition during booting.
 - b. Satellite connection algorithm improvements (immediate retry?).
 - c. Boot loader on boot-up bug (if ANY character is received at console).
 - d. NV ram corruption bug (not confirmed).
 - e. Upgrade to wider envelope Globalstar antenna.
 - f. Medusa card loop-back, need continuous or near continuous readout of optical power when cable laying instead of intermittent readings.
2. Power system.
 - a. Control logic/component failure on BIN power board can keep back-up power supply on, increasing power consumption.
 - b. Switch control logic in BIN can glitch and turn on switch channels uncommanded.
3. SIAM application software.

- a. Globalstar communications algorithms need improvement for greater efficiency. Using too much satcom time for amount of data sent. Connection times are often short and long downloads are interrupted. Retry after delay needed.
 - b. Need data moving scheme for parceling out data archives on mooring system on available memory.
 - c. Need to streamline BIN shutdown procedure. Need to make it easier to “safe” ADCP.
- 4. Cable and cable laying sled.
 - a. Need fail-safe lock-out on storage drum rotation so that will not payout if overboarding sheave stops.

Category 3

- 1. Computing and telemetry system.
 - a. Wake-up fails after broadcast storm on network.
 - b. Nodes lock-up on occasion for no known cause.
- 2. Every micro-processor subsystem needs to be on a global reset line and also have the internal watchdog enabled – even if just a simple implementation.
- 3. All software/firmware should have a way of confirming version number without having to reload software image.
- 4. When estimating number of PCB’s needed for complex systems (like SideARM and Medusa) make sure and take into account that the build and test yield is NOT 100% (more like 60-70%)!
- 5. Cable arrived from JDR damaged – again. MUST be packaged so that it can not be damaged by improper forklift lifting. If it can happen it will. Lagging needs to allow forking from any lifting direction.
- 6. Coilecords were defective but each vendor blamed the other. In the future one vendor needs to be responsible for the whole article. A factory visit when the cable is being run wouldn’t be a bad idea either.
- 7. Watchdog timer bug came in right at the end. Watchdog was being “fed” when system went to sleep. Why it was not caught earlier?
 - a. A functional test on the full system was not done. It was scheduled but not completed when planned and was pushed back. Fortunately a PG&E power failure a week before closed can exposed it.
 - b. The lab test system where the testing was conducted was not running the same code and did not replicate the deployed system as it was supposed to. Because the development systems were used to build the lab test rig, development continued on this system rather than having it running the current release. The watchdog was not tested in a sleep-enabled environment!
- 8. Cable laying sled and cable laying.
 - a. Stripes on benthic cable and horizontal bars would improve ability to visually judge payout speed/distance. Cable should be marked.
 - b. Good rubber jaws for manipulator arm would make cable handling with the arm easier.
 - c. A level-wind on the cable laying sled would allow cable recovery if necessary (buoyancy a big issue with this).
 - d. Payout reel motor drive should be able to run backwards so cable can be reeled in if necessary without taking cable from overboarding sheave.
 - e. Guides to make it impossible for cable to jump off drum.
 - f. Would “steel-lite” be more suitable for subsea cable laying?
 - g. Should always have cutter available that can cut any section of the cable being laid to salvage the connectors.
- 9. BIN assembly.
 - a. Need contrasting colors between ROV-mate connector paddles and “window” holders.
 - b. Should choreograph placement of BIN cables in “window” holders before dive so movements are not adhoc during dive.
 - c. BIN lift point needs to be improved. Pilots prefer hard tubing with solid ring at the balance point.
 - d. ROVmate “T-handle” paddles should be modified to have just a tab protruding upward.
 - e. Need portable full BIN test set-up with HV power supply, optics and ROV-mate connector.
- 10. Miscellaneous.
 - a. Need to make certain GF testing is performed on deployment hardware as part of final integration.

- b. Need to make sure GF scanning is disabled on non-primary power-connected nodes.
- c. Spares of computing systems, tested and in housings.
- d. Spares of water sensitive surface equipment in case of dunking.
- e. Buoy lift point needs to be higher to ensure vertical launch.
- f. Label everything!
- g. "ShutdownPort" should force shutdown if comms are lost.
- h. Be very conscious of which way the BIN cables are wrapped prior to deployment. Cable should wrap so that RA connectors fit easily into the holders.
- i. Make sure BIN is always ballasted correctly – even if all the instruments are not in place.
- j. Change sample rates for engineering items to the shortest nominal processing period before performing invasive manipulations on network, i.e. the power data processing period was increased from once every 10 minutes to once per hour during normal operations to reduce the total returned data volume when the satellite system became a severe bottleneck. When the Shelf-to-Axial cable failure occurred, the event was not captured with full resolution.