Improved Quality of National Data Buoy Center (NDBC) Acoustic Doppler Current Profiler (ADCP) Measurements

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Abstract. **In 2006, NOAA's National Data Buoy Center (NDBC) began an effort to add ocean sensors (directional waves, surface currents, current profiles, and ocean temperature and salinity) to its fleet of weather buoys. In this paper, we report on the improvements in the quality of ocean currents collected from the Acoustic Doppler Current Profiler (ADCP).**

Initially, the ADCP was deployed in a cage that was suspended below the bridle of the buoy. It was an effort to remove the motion of the surface buoy from the current record. Measurements were made at intervals of 30 to 45 seconds over an hour's time and averaged. The cage required a lengthy cable to carry the current information to the payload within the buoy. The movement (twisting, swinging, and up-and-down motion) of the cage put stress on the cable, which was also exposed to long line gear and other fishing tackle, and the failure rate was high. Several iterations of cable were attempted, but the failure rate of the real-time currents remained high. Because of the averaging method, the currents were under-sampled and represented a considerable period of the changing tidal current.

The ADCP was moved inside the bridle just below the buoy to shorten the exposure of the cable to the environment. An additional result of this method is to sample closer to the ocean surface. The sampling interval was increased to 0.5 or 1.0 Hz and the samples are averaged over five minutes. The resulting measurements represent a more appropriate instantaneous current speed and direction and average out the motion of the buoy. A comparison of identically configured buoy- and bottom-mounted ADCPs at Station 41036 off the North Carolina Coast indicate that the methodology produces statistically equivalent currents at all but the surface and bottom bins [1].

ADCP data from a large number of oil and gas platforms in the northern Gulf of Mexico are collected, quality controlled, and disseminated to the public by NDBC. The quality control algorithms were developed by a consortium of oil industry, ADCP vendor, and Minerals Management Service experts and implemented by NDBC to quality control the real-time ADCP data in March 2006 [2]. The algorithms were developed for low frequency (38 and 75 kHz) Teledyne RD Instruments (TRDI) ADCPs. The algorithms have been expanded to include the 300, 600, and 1200 kHz TRDI ADCPs.

The algorithms test for echo amplitude, percent good beams, error velocity, and horizontal velocities. Additionally, a test to determine the presence of the surface or bottom allows these bins to be included in the data stream as the tide changes. These algorithms have been implemented into NDBC's real-time processing stream

INTRODUCTION

The National Data Buoy Center (NDBC) provides coastal marine weather data in real-time to the National Weather Service (NWS). In an effort to collect oceanographic parameters from the same buoys, NDBC deployed 75 kHz acoustic Doppler current profilers (ADCPs) on 10 meter buoys during the 1990s in support of the Minerals Management Service (MMS). NDBC successfully transmitted the current profile data in real time from these systems in the Santa Barbara Channel near Los Angeles, CA. The deployments were discontinued after several years.

In 2005, NDBC received funding to convert weather buoys to collect ocean parameters. NDBC purchased sensors to collect temperature and salinity with depth, surface currents and current profiles. In order to collect current profiles, the Teledyne RDI ADCPs were selected. The 75, 150, 300, 600, and 1200 kHz ADCPs allow NDBC to collect ocean currents over a wide range of depths. Buoys in depths to 20 meters require a 1200 kHz ADCP to collect data to the bottom, while the 600 kHz system can be used to depths of 50 meters. The 300 kHz ADCP collects data to approximately 120 meters and the 75 kHz ADCP can collect data to nearly 500 meters. These depths are limited due to the ADCPs operating on battery power.

When NDBC began to deploy ADCPs on 3-meter buoys during 2006, a cage was designed to contain the ADCP and it was deployed in the mooring line beneath a the buoy. The cage with the ADCP was suspended below the buoy to decouple the motion of the buoy from the ADCP. In order to retrieve the data in real-time, a cable connected the ADCP to buoy. This became the weak link in the system and a new design incorporating the ADCP into the bridle beneath the buoy was devised (fig 1). The shorter cable length is less exposed and provides data more consistently to the buoy.

The motion of a 3-meter buoy with an ADCP deployed beneath it could lead to biases in the data. For this reason, the ADCPs are set to collect for five minutes each hour. The data are sampled at one or two second intervals, resulting in a large sample of data that are averaged to remove the motion of the buoy from the current record.

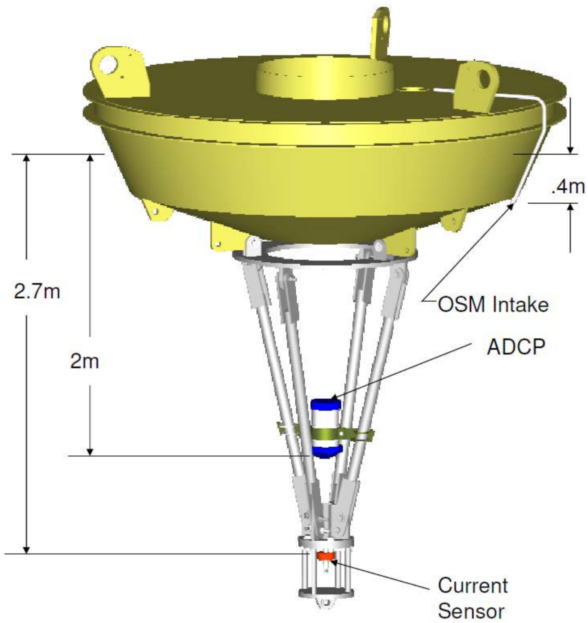

Fig. 1. ADCP in a bridle beneath an NDBC buoy.

BACKGROUND

During 2005, the Minerals Management Service (MMS) introduced a Notice to Lessees (NTL) for Outer Continental Shelf oil and gas exploration in waters deeper than 400 meters. The NTL was introduced to collect information relating to excessive forces on oil and gas platforms due to high currents associated with the Loop Current and associated Loop eddies. The NTL instructed the Oil and Gas Companies to deploy an ADCP and collect current speed and direction through the upper 1000 meters of the water column. In deeper water, a bottom ADCP was to be deployed and recovered on a three to six month basis.

The data from the upper 1000 meters was to be transmitted via FTP to NDBC, where it would be quality controlled and disseminated over the Global Telecommunications System (GTS). Bottom data were to be uploaded to the NDBC website following retrieval and it was to be processed also.

The data stream from the TRDI ADCP provides data quality indicators that allow the opportunity to apply quality assurance and quality control algorithms to the data in real-time. The parameters in the data stream include echo amplitudes and correlation magnitudes for each beam in addition to error velocity measurements and percentages of good beams.

A committee composed of the Offshore Oceanography Committee, NDBC, the Minerals Management Service, and RD Instruments (now Teledyne RDI) met to discuss automated quality control algorithms to apply to the oil company ADCP data at NDBC. The quality control algorithms [3] were successfully implemented and continue to provide quality data delivery of the MMS ADCP data.

METHODS

When NDBC began to collect ocean currents from ADCP data in 2006, rudimentary algorithms were implemented. The primary test was to scan the data form excessive horizontal speeds. TRDI-generated quality control algorithms for different frequencies of sensors were developed in the years following the MMS ADCP implementation. NDBC rewrote the quality control algorithms to reflect the updated information.

In an effort to remove the buoy motion caused by waves from the ADCP record, the ADCP samples at 1, 2, or 2.5 seconds depending on the type of ADCP and the water column depth. The currents are sampled for five minutes and an average current speed and direction over that time period generated.

Problems encountered with the cabling used to transmit the data from the cage-mounted ADCP to the buoy. Twisting and turning of the buoy and cage put stress on the transmission cable and its exposure to long line fishing resulting in frequent failures to transmit the data off of the buoy in real-time. The ADCP was moved directly under the buoy within the bridle. This effort led to a concern that buoy motion would impact the current speed and direction collected.

NDBC modified the software developed for the MMS ADCP effort to develop an automated sequence of algorithms for NDBC ADCP quality control. The tests include: Built-in-test (BIT), Error Velocity test, Percent Good test, Correlation Magnitude test, Horizontal Velocity test, Vertical Velocity test, and the Echo Amplitude test for obstructions in the water column.

The Built-in-test (BIT) is a diagnostic output by some ADCP instruments. The result is binary and simply indicates whether the instrument is providing reasonable data or not.

Error velocity is a measure of the horizontal coherence of flow. Each pair of opposing beams provides one measurement of the vertical velocity and one component of the horizontal velocity. The two independent measurements of vertical velocity can be compared. If the flow field is homogeneous, the difference between the vertical velocities should be zero.

Percent good indicates what fraction of pings passing the various error thresholds. In this case, the percentages of three and four beam solutions are summed.

Correlation magnitudes indicate the strength of the energy in each beam. A base value is provided.

Vertical velocities indicate motion up and down the water column. These values are limited by the amount of flow in a region.

Horizontal velocities are the north-south and east-west components of the current. A value of 1 m/s has been selected as the upper limit for good data. If the velocities exceed 1.5 m/s, then the data are failed.

Echo amplitude in each beam indicates whether there are any obstructions in the water column or whether the surface or bottom is encountered.

The algorithm limits for each of the quality control algorithms are provided in Table 1. Between the limits, the data are listed as suspect.

Table 1
Algorithm limits for a five minute collection of data from an ADCP.

Test	Pass	Fail
Error Velocity	< 5 cm/s	> 20 cm/s
Percent Good Threshold	>19%	< 15%
Correlation Magnitude	>115	< 63 counts
Vertical Velocity	<10 cm/s	> 20 cm/s
Horizontal Velocity	< 100 cm/s	> 150 cm/s

When the ADCP data are sampled at 2 second intervals during the five minute period, the Percent Good Threshold limits increase. The changes are shown in Table 2. Values between the two limits are considered suspect.

Table 2.
Percent good threshold limits for two second sampling interval.

Test	Pass	Fail
Percent Good Threshold	> 38 counts	<30 counts

In water shallower than 1000 meters, use of a 75 kHz ADCP requires that the sampling interval be at least 2.5 seconds in order for the transmit and receive not to interfere with each other. The change to a 2.5 second sampling interval requires a change in the quality control limits for the Percent Good Threshold, shown in Table 3. Values between the two limits are considered suspect.

Table 3.
Percent threshold limits for 2.5 second sampling interval

Test	Pass	Fail
Percent Good Threshold	> 48 counts	< 38 counts

Quality flag definitions follow from the quality control tests. The values are:

0 = data not evaluated
1 = data failed quality control
2 = data suspect
3 = data passed quality control, and
9 = data missing.

The individual quality flags are summed and a determination of the quality of each depth bin and each profile determined and saved. The location of the quality control flags in the NDBC forty-five day and historical files is shown in Table 4.

Table 4. Quality flag presentation definitions.

Column	Definition
1	Overall Bin Quality
2	Built-in-Test Quality
3	Error Velocity Quality
4	Percent Good Quality
5	Correlation Magnitude Quality
6	Vertical Velocity Quality
7	N-S Horizontal Velocity Quality
8	E-W Horizontal Velocity Quality
9	Echo Intensity Quality

RESULTS

The ADCP algorithms were implemented in July 2010. The results are generally good. The quality control flags are presented on the NDBC pages. These pages provide the hourly data and the quality control flags that are associated with each depth bin acquired by the ADCP.

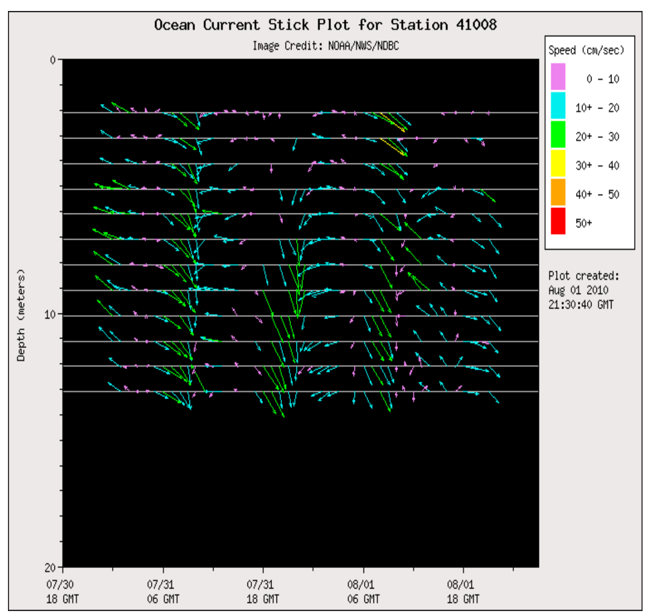

Fig. 2. Thirty-six hours of ADCP current profile data from Station 41008 at Grays Reef, GA.

Most of the tests are passed easily, but the error velocity test is a major reason that velocities fail. NDBC will investigate the error velocity issue and determine whether the limits should be changed or whether some processing of ADCP data on buoys needs to be altered.

Examples of the plots resulting from the quality control algorithm implantation are provided in figs. 2 and 3. While the general current field is presented, some of the vectors are missing. The missing vectors can be attributed to various quality control tests. Tuning of the algorithms is necessary. The error velocities are much higher than anticipated and may be related to the ADCP being mounted in the bridle of the buoy.

Quality control flags are now assigned to NDBC ADCP data. When the data are forwarded to the National Ocean Data Center (NODC) for archival, the quality flags will be included.

CONCLUSION

In an effort to improve the quality control of current profile data from NDBC buoys, several upgrades have been completed. Moving the ADCP from an in-mooring-line cage into the buoy bridle and shortening the cable between the ADCP and buoy have increased the availability of real-time ADCP data from NDBC buoys.

Quality control algorithms for NDBC's real-time, buoy-mounted ADCPs have been successfully implemented. The effort included developing the algorithms, testing, and providing the information in new pages on the NDBC website. Following the computation of the algorithms, the resulting information is presented in the NDBC 45-day file and will be relayed in historical files to be stored at NODC.

There are indications that the error velocity values are much higher than anticipated. They exceed the expected values by a large margin in some cases. It is possible that the motion of the buoy is impacting this measurement. This will be an area of investigation in the future.

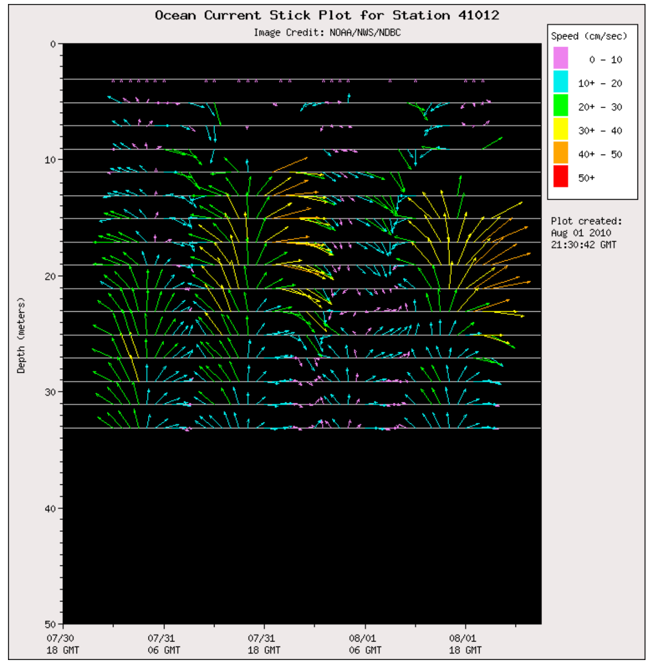

Fig. 3. Thirty-six hours of ADCP current profile data from Station 41012 near St. Augustine, FL.

REFERENCES

[1} Locke, L. and R.L. Crout 2009, A Study on the Validity of Buoy Mounted Acoustic Doppler Profilers: A Comparison of Upward and Downward Looking Systems in Onslow Bay, NC, Proceedings of the MTS/IEEE OCEANS 2009 Biloxi Conference and Exhibition, Biloxi, MS, 6 pps.

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[3] Symonds, D. 2006, QA/QC Parameters for Acoustic Doppler Current Profilers, TRDI Application Note, 1 June 2006, 17 pps.