J5.7 REAL-TIME OIL PLATFORM OCEAN CURRENT DATA IN THE GULF OF MEXICO: AN IOOS INDUSTRY PARTNERSHIP SUCCESS STORY

Richard Crout*, Don Conlee, Dave Gilhousen, Richard Bouchard
NOAA National Data Buoy Center, Stennis Space Center, Mississippi

Mike Garcia, Frank Demarco, Mark Livingston
Science Applications International Corporation, Stennis Space Center, Mississippi

Cort Cooper
Chevron Corporation, San Ramon, California

Robert Raye
Shell International Exploration and Production Inc., Houston, Texas

1. INTRODUCTION

The Loop Current, Loop eddies, and cross-slope flow impact operations of deep-water drilling rigs and oil production platforms in the northern Gulf of Mexico. In order to provide better estimates of these strong ocean currents and their impact on extreme loads, structural fatigue, and daily operations, the U.S. Department of Interior's Minerals Management Service (MMS) issued a Notice-to-Lessees (NTL). NTL 2005-G05 requires operators in the Gulf of Mexico to monitor and report, via an open web site, current measurements on production platforms and drilling rigs operating in water depths greater than 400 meters. Operators must collect current profiles from the near-surface to 1000 meter depths every 20 minutes and report then at least every 12 hours, although real-time transmission is encouraged. They must also measure near-bottom currents at sites deeper than 1100 meters and report those data every 6 months.

Through a cooperative effort by the Offshore Operator's Committee, MMS, and the National Oceanic and Atmospheric Administration's (NOAA's) National Data Buoy Center (NDBC) and based on suggested inputs by Teledyne RD Instruments, quality control algorithms were determined and implemented at NDBC.

* *Corresponding author address:* Richard L. Crout, NOAA's National Data Buoy Center, Stennis Space Center, MS 39529; e-mail: Richard.Crout@noaa.gov

The NTL also calls for the Acoustic Doppler Current Profilers (ADCP) data to be displayed on a publicly-accessible web page. NDBC presents the data on their web site along with other International Ocean Observing System (IOOS) data.

A metadata sheet is required for each drilling rig and production platform in order to correctly display the ADCP data on the NDBC web site. The information provided includes points of contact, rig name, position, and lease block, water depth, and most importantly, the setup for the current profilers. As drilling rigs are moved or change ownership, metadata sheets are provided to NDBC in order to update positions, ownership and maps on the NDBC web page.

2. DATA FLOW

Current observations are collected from current profilers suspended from or attached to production platforms and drilling rigs or from nearby bottom mounts. Teledyne RD Instruments 38 and 75 kHz ADCPs are used in the Gulf of Mexico oil rig applications. The current profilers may look downward (from near the surface or at mid-depth), upward (from a bottom mount or at mid-depth), or horizontally (from near the surface). The range for low frequency profilers extends across several hundred meters of the water column.

Operator assets are used to power the instruments, cable the data to a computer at the rig site, process the data, and transmit it into an FTP account at NDBC. Operators use the data locally to conduct fatigue

analyses and drilling activities, and plan remotely operated vehicle operations. NDBC reformats the observations and displays the data in NDBC graphics. NDBC also makes the raw data and the decoded data with quality control flags available on the NDBC web site. The observations are also transmitted over the Global Telecommunications Systems (GTS) in the World Meteorological Organization (WMO) FM-64 Temperature, Salinity, and Current report from a sea station (TESAC) format.

Metadata sheets provided by operators describe the setup for each of the ADCPs on the platform or rig. Included on the metadata sheet are the transducer depth, first bin depth, number of bins, and bin size. These allow NDBC to set up the database for the data to be provided by the oil companies. Observations are required at 20 minute intervals, but some provide data to NDBC at 10 minute intervals. The data are coded by year, month, date, hour, minute, bin number, depth, direction, speed, error velocity, vertical velocity, percent good for 3 beams, percent good for four beams, percent good E, echo intensity for each beam, correlation matrix for each beam, and the field of error flags.

3. DATA QUALITY

The quality control methods defined here are for earth coordinate ADCP data collected from MMS stations in the Gulf of Mexico. Measurements are evaluated according to criteria described below and summarized in Table 1.

Fail = 1, data that fail the quality control checks;
Suspect = 2, data that are suspect but not necessarily invalid; or
Pass = 3, data that pass all quality control checks.

Individual measurements, bins, and profiles are flagged according to their classification. Individual bins and profiles are flagged with the most severe flag discovered in the quality control process. The sequence of quality control checks is applied according to Table 1. These quality control checks were determined by the Offshore Operators Committee, the MMS, and NDBC, based on inputs from Teledyne RDI (Teledyne RDI, 2005) and are specific to the rig mounted 38 kHz and 75 kHz ADCPs in the northern Gulf of Mexico.

3.1 *Built-in-Test*

A Built-in-test (BIT) performed internally will ensure the general health of the instrument. The built-in-test is performed with each ping to check for such issues as demodulator and timing card errors Workhorse ADCPs (75 kHz) report BIT for each ensemble, while the 38 kHz Ocean Observer ADCPs must be commanded. Possible BIT results are:

Pass, if the BIT result is zero,
Suspect, if the BIT result is non - zero,
Fail, if the BIT result is NA.

3.2 *Error Velocity Test*

Error velocity is a measure of the disagreement of measurement estimates of opposite beams. It is derived from each pair of opposing beams and therefore represents two independent measures of vertical velocity, possibly indicating inhomogeneous flow. The error velocity for each bin are compared to the following thresholds and flagged according to:

Pass, if the error velocity in each bin is less than or equal to 15 cm/s,
Suspect, if the error velocity in each bin is greater than 15 cm/s and less than or equal to 30 cm/s or equals -32678,
Fail, if the error velocity for each bin exceeds 30 cm/s.

3.3 *Percent Good Test*

Percent good is the ratio of good pings per total pings for each ensemble. Causes of low percent good values include low correlation, large error velocity and fish detection. The percent good test ensures that the minimum number of samples and minimum theoretical standard deviation in the data are met. Gulf Oil companies use two RDI ADCP models and the test differs for each. For the Workhorse Long Ranger 75 kHz model:

Pass, if the total percent good is greater than 10 percent,

Suspect, if the total percent good is greater than or equal to five percent and less than 10 percent, and

Fail, if the total percent good is less than 5 percent.

For the Ocean Observer 38 kHz model:

Pass, if the total percent good is greater than 25 percent,

Suspect, if the total percent good is greater than or equal to 22 percent and less than 25 percent, and

Fail, if the total percent good is less than 22 percent.

The purpose of the selected thresholds is to maintain a small standard deviation. However, the percent good is meaningful only when ping number is standardized.

3.4 *Correlation Magnitude Test*

Correlation magnitude is a measure of the pulse-to-pulse correlation in a ping for each cell depth. The correlation magnitude should have a constant, though slightly variable value throughout the profile. The correlation magnitude test ensures that the highest quality velocity data are kept.

A correlation magnitude test is applied for each bin. For the Workhorse Long Ranger 75 kHz model:

Pass, if at least three of the four correlation magnitude values for the bin are greater than 64,

Suspect, if only two of the four correlation magnitude values for the bin are greater than 64, or

Fail, if one or none of the four correlation magnitude values for the bin are grater than 64.

The values for the Ocean Observer 38 kHz Narrow Band ADCP are:

Pass, if at least 3 of the four correlation magnitude values for the bin are greater than or equal to 110,

Suspect, if only two of the four correlation magnitude values for the bin are greater than or equal to 110, or

Fail, if one or none of the four correlation magnitude values for the bin are greater than or equal to 110.

The values for the Broadband Ocean Observer 38 kHz ADCP are:

Pass, if at least 3 of the four correlation magnitude values for the bin are greater than 190,

Suspect, if only 2 of the four correlation magnitude values for the bin are greater than 190, or

Fail, if one or none of the four correlation magnitude values for the bin are greater than 190.

3.5 *Vertical Velocity Test*

Using the four acoustic beams, two vertical components of the flow are calculated, in addition to the two horizontal components. The vertical velocity recorded is the average of the two vertical velocities sensed. High vertical velocities indicate turbulence in the water column and non-homogeneous horizontal currents. The vertical velocity test is applied next by comparing the vertical velocity in each bin to a threshold value and flagged accordingly.

Pass, if the difference is less than or equal to 30 cm/s,

Suspect, if the difference is greater than 30 cm/s and less than 50 cm/s, or

Fail, if the difference is greater than or equal to 50 cm/s.

3.6 *Horizontal Velocity Test*

The horizontal velocity test represents a gross error check. Current velocities are not expected to exceed a certain value. This test compares the horizontal velocity within each bin. The maximum horizontal velocity magnitude is calculated from the east and west components of the horizontal velocity, compared to a threshold value, and flagged accordingly.

Pass, if the velocity magnitude is less than or equal to 125 cm/s,

Suspect, if the velocity magnitude is greater than 125 cm/s and less than or equal to 200 cm/s, or

Fail, if the velocity magnitude is greater than 200 cm/s.

3.7 *Echo Intensity Test*

The echo intensity for an ADCP is a measure of the signal strength intensity returned to the transducer. Because the

ADCP technology uses the scattering from small particles in the water column to measure currents, reflections from larger objects associated with a drilling rig may overwhelm the scattering from the smaller particles. Objects that may reflect the transmission include the drilling riser, tensioning cables, rig support structure and other sensors suspended in the water column. If the echo intensity is high it may indicate a boundary, school of fish, or an obstruction in the water column. Low echo intensities represent insufficient scatterers in the water column or that the range limits of the sensor have been exceeded.

An echo intensity test is applied by comparing the echo intensity at a particular bin to the echo intensity of the previous bin. For this project, the test is only applied beginning with bin 15. Echo intensity is calculated for each beam and flagged as follows:

Pass, if no rise (difference between previous and current bin) is greater than 30 counts,

Suspect, if a rise on one beam is greater than 30 counts, or

Fail, if a rise on two or more beams is greater than 30 counts.

The results of the echo intensity test impact the bins beyond where it fails the Echo Intensity Test. When a "fail" or "suspect" results from the test, the flag is propagated to all affected bins.

3.8 *Profile Check*

The final test is performed to properly flag the entire ensemble of data. This check excludes bins flagged as failed or suspect in the echo intensity test since that test is a surface detection test designed to eliminate sections of the profile that are obstructed. The following conditions determine the overall profile status:

Pass, if the above values for each bin are flagged as good,

Suspect, if the above values for each bin are flagged as suspect or failed for less fewer than 50 percent of the bins; or

Fail, if the above values for each bin are flagged as suspect or failed for greater than or equal to 50 percent of the bins.

Once the data quality control checks are completed and the flags attached, oceanographers at the NDBC Data Assembly Center (DAC) compare flagged data to other products to determine their validity. DAC analysts compare against infrared sea surface temperature imagery and altimeter products.

4. DATA DISPLAY, DISSEMINATION, AND ARCHIVAL

NDBC began displaying the MMS ADCP data in June 2005. The ADCP data are displayed with depth along the vertical axis (top-to-bottom for surface-to-bottom) and time along the bottom axis (time increasing to the right). The magnitude and direction of the current is displayed as an arrow with the length of the arrow indicating magnitude and the direction being north to the top of the page. Color is used on the web page to help differentiate the magnitude of the current. An example from the Front Runner drilling rig is presented in figure 2. At this station there is a horizontal-looking ADCP at 15 meters depth and two ADCPs at 163 meters depth, one upward-looking and the other downward-looking.

Four MMS ADCP stations and a sea surface temperature product are presented in Figure 3. Low currents in the first panel indicate the low energy of the ocean west of the Loop Current region. The next three panels show the direction and high magnitude of flow around the Loop Current. DAC analysts have access to these products to enhance quality assurance.

Only recent data are displayed on the NDBC webpage. If the most recent data are older than four hours, they are flagged and not displayed. However, the data are available in tabular format by choosing "Real time Acoustic Doppler Current Profiler (ADCP) data" from the web page. All parameters are provided for further analysis. Raw binary data in the native RDI PD0 format are also available for web-based retrieval.

The observations that pass through the quality control checks are transmitted over the Global Telecommunications Systems (GTS) in the World Meteorological Organization (WMO) FM-64 Temperature, Salinity, and Current report from a sea station (TESAC) format.

5. FUTURE PLANS

Hurricanes Katrina (August 2005) and Rita (September 2005) damaged many of the ADCPs deployed on offshore oil platforms and drilling rigs in the northern Gulf of Mexico, reducing the number of reporting stations from 36 to fewer than 20. At the time of this paper submission, assessments and repairs are in progress.

Accurate and timely estimates of ocean current profiles allow the oil companies to properly plan operations and calculate fatigue of subsea components. Free and publicly available data from the NDBC web servers will likely encourage third parties to create added-value derivative products, such as more accurate numerical ocean current models, enhanced real-time data displays, and analytical tools to benefit the oil industry and others in the Northern Gulf of Mexico.

NDBC expects to apply upgrades and enhancements to the existing website and expand the number of reporting stations. The acquisition of additional ocean and meteorological information for display on their web site is also a goal. Working with IOOS partners, the standardization of quality control algorithms will be expanded.

6. CONCLUSIONS

NTL 2005-G05 provided the opportunity for industry and government to work together. The oil industry in the Northern Gulf of Mexico is adding to the United States IOOS by providing ocean current data not previously available. Third party, added-value companies now have access to large amounts of ocean data necessary to generate new displays and tools, ocean models, and other products to support the oil industry.

Additionally, a standardized set of data quality control procedures have been agreed upon by IOOS and industry and implemented. The latter effort will benefit IOOS further as standardized quality control algorithms are applied to NDBC and non-NDBC current data. As IOOS grows and the number of ocean sites increases, NDBC is also adding ocean sensors, such as ADCPs, to the present suite of instruments on their buoys. The results will be published on the NDBC web site for all to analyze.

7. REFERENCES

RD Instruments Acoustic Doppler Solutions Memorandum; Subject; QA/QC Parameters for Ocean Observer and WH Long Ranger ADCP Data, 30 March 2005.

Romeo, J., J.V. Smirren, and M.J. Vogel, “System development for profiling deeper waters in support of the oil and gas industry”, Unpublished manuscript.

Manual on Codes, WMO-No.306, Volume I.1, Part A - Alphanumeric Codes, Secretariat of the World Meteorological Organization, Geneva, 1995.

8. ILLUSTRATIONS AND TABLES

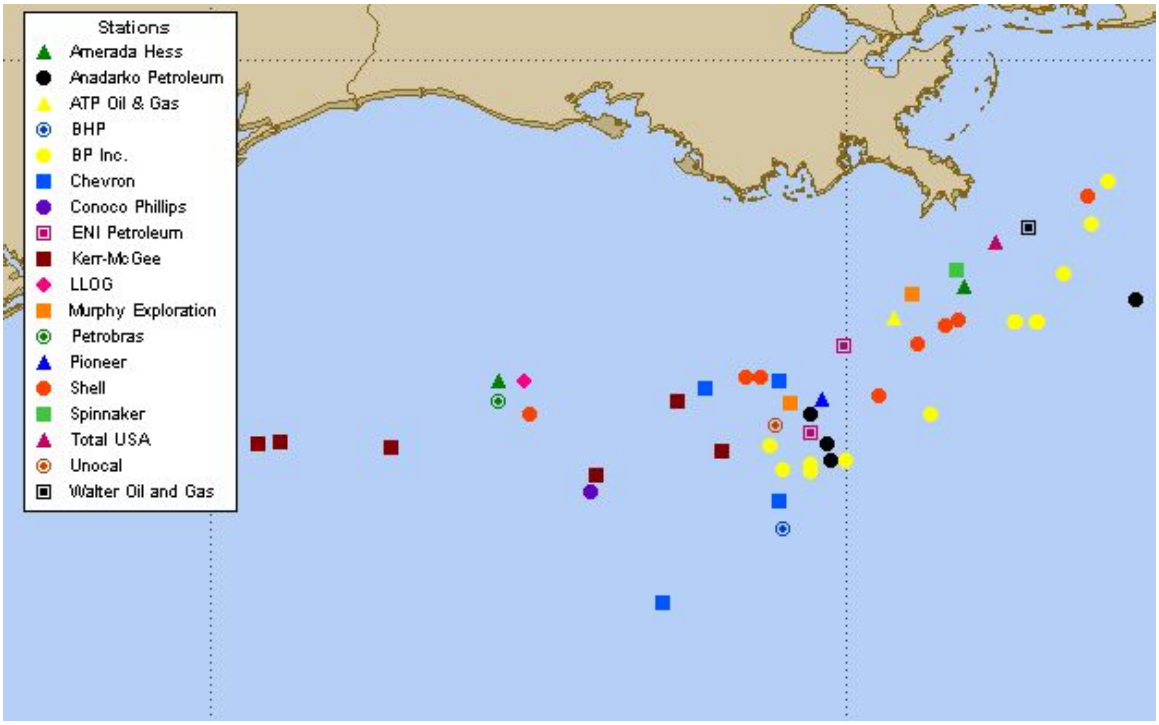

Figure 1. Distribution of ADCP-equipped oil production and drilling rigs in the Northern Gulf of Mexico and the rig operators.

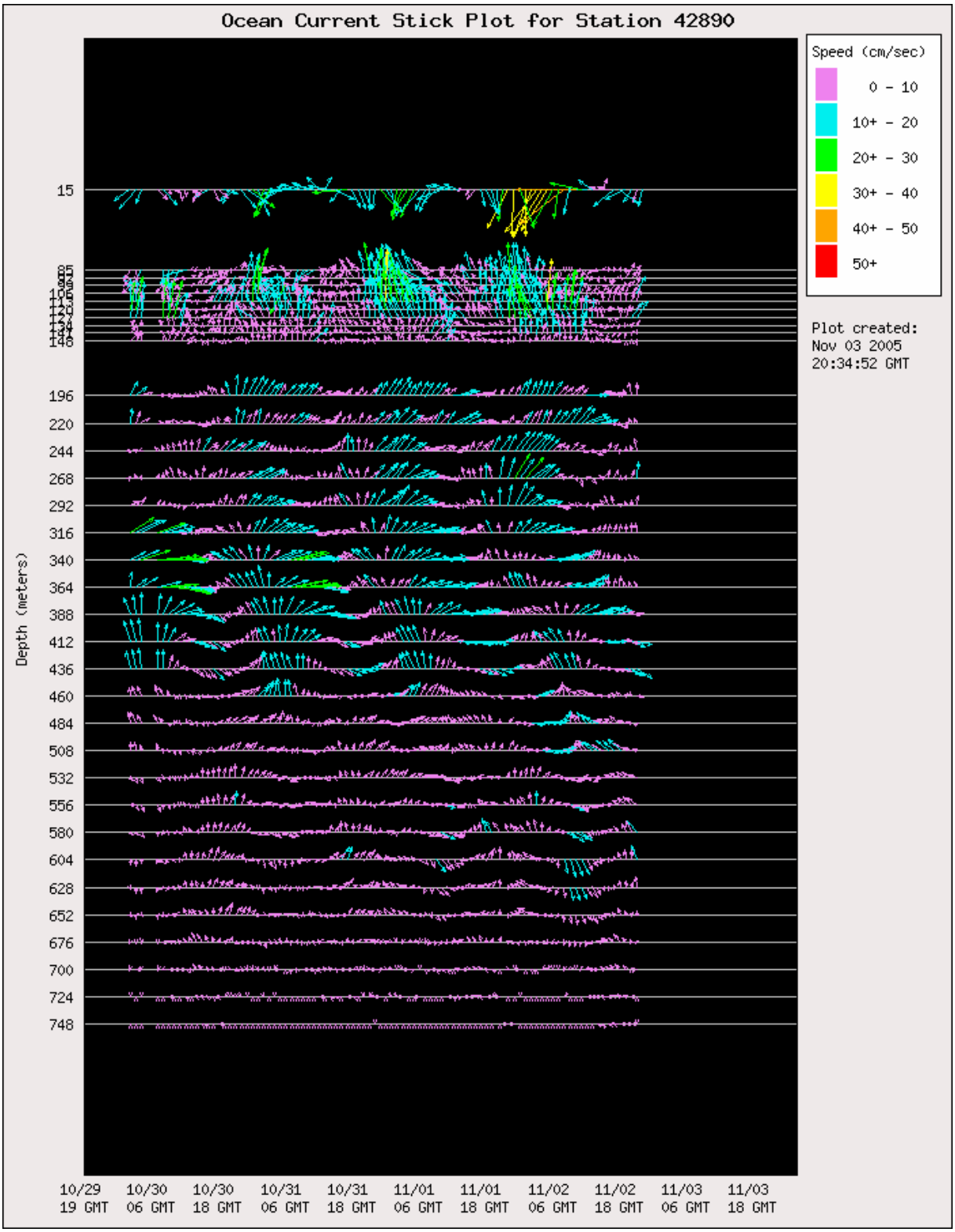

Figure 2. Current magnitude and direction plot from three ADCPs mounted on the drilling rig, Front Runner.

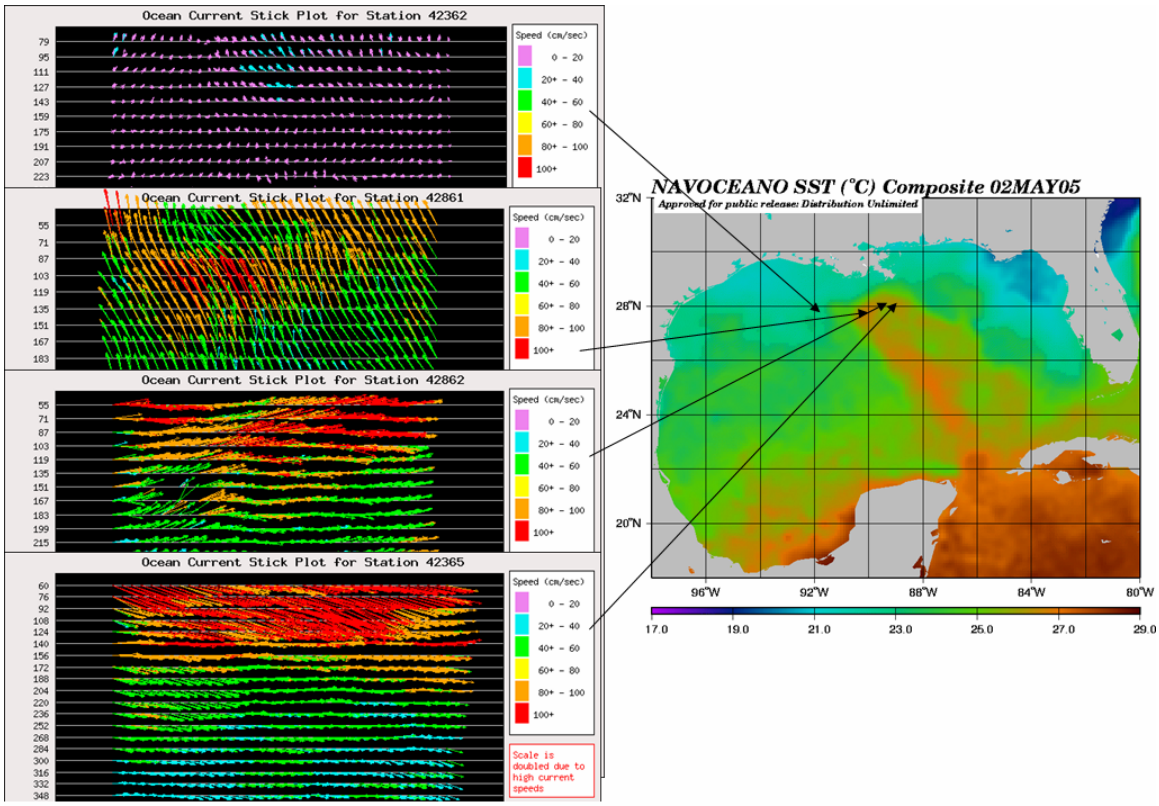

Figure 3. Current flow from four MMS ADCP stations are compared to sea surface temperature product to show magnitude and direction of currents in the Loop Current.

TEST	PASS (3)	SUSPECT (2)	FAILED (1)
BIT	Equal to 0	Not Equal to 0	Not Applicable
Error Velocity	Less than or equal to 15 cm/s	Greater than 15 cm/s and less than 30 cm/s or equal to -32678	Greater than 30 cm/s
Percent Good (38 kHz)	Greater than 25%	Less than or equal to 25% and greater than or equal to 22%	Less than 22%
Percent Good (75 kHz)	Greater than 10%	Less than or equal to 10% and greater than or equal to 5%	Less than 5%
Correlation Magnitude (75 kHz)	At least 3 of 4 correlation magnitude values are greater than 64	Only 2 of 4 correlation magnitude values are greater than 64	Fewer than 2 of the 4 correlation magnitudes are greater than 64
Correlation Magnitude (38 kHz NB)	At least 3 of 4 correlation magnitude values are greater than or equal to 110	Only 2 of 4 correlation magnitude values are equal to or greater than 110	Fewer than 2 of the 4 correlation magnitudes are equal to or greater than 110
Correlation Magnitude (38 kHz BB)	At least 3 of 4 correlation magnitude values are greater than 190	Only 2 of 4 correlation magnitude values are greater than 190	Fewer than 2 of 4 correlation magnitude values are greater than 190
Vertical Velocity	Difference is less than or equal to 30 cm/s	Difference is greater than 30 cm/s and less than 50 cm/s	Difference is greater than 50 cm/s
Horizontal Velocity	Total velocity magnitude is less than or equal to 125 cm/s	Total velocity magnitude is greater than 125 cm/s and less than or equal to 200 cm/s	Total velocity magnitude is greater than 200 cm/s
Echo Intensity	If no rise is greater than 30 counts	If a rise on one beam is greater than 30 counts	If a rise on two or more beams is greater than 30 counts
Profile	If all values for each bin are flagged as good		If less than 50 of values for each bin are flagged as suspect or failed

Table 1. Data quality tests and criteria for MMS ADCP data.