25 Years and Counting: ADCPs Measure Weekly Transects Across the Gulf Stream

Teledyne RDI ADCPs Provide Invaluable Extended Time Series for Climate Studies from Volunteer Observing Ships

OVERVIEW

Next to the eastern seaboard of the United States, the strong currents of the Gulf Stream move immense amounts of warm water; thus its role in redistributing heat is fundamental for climate around the northern Atlantic. Its currents affect life in and out of the sea by transferring organisms, nutrients, and pollutants. And the Stream's strong currents affect the routes taken by shipping.

Before 1990, various methods had contributed to studying the structure and transport of the Gulf Stream. Estimates of mean transport and its downstream increase were documented. However, missing was a solid observational foundation for describing changes in transport on seasonal and longer times scales.

Since 1992, Tom Rossby (University of Rhode Island) and Charles Flagg (State University of New York) have recorded weekly oceanic transects between New Jersey and Bermuda. Operating from a volunteer observing ship, CMV Oleander, these researchers have provided a sustained view of the Gulf Stream currents for 25 years.

Based on ADCPs from Teledyne RDI, this data set supplies a unique view of the conditions, structure, and changes of this important current. Transport values for the upper ocean are measured directly. The high resolution ADCP transects have identified the local structure of the Gulf Stream and provided time series to study its annual cycle and longer term variations.

CMV Oleander entering port in Bermuda.

Credit: Bermuda Container Line, Neptune Group Limited

Products:
Ship-mounted 150 kHz BroadBand, 75 kHz Ocean Surveyor ADCPs

Application:
Sustained Transects Crossing Gulf Stream

Project:
Oleander Project

Institutions:
U. Rhode Island,
State University of New York

Principals:
Profs Tom Rossby,
Charles Flagg

Sponsors:
National Science Foundation,
Bermuda Container Line,
Office of Naval Research, National Oceanic & Atmospheric Administration

Data Collection Date:
1992 - present

Location:
Western North Atlantic

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These sustained ADCP-based data will become even more valuable for studying Gulf Stream mechanisms that affect climate variability.

SITUATION

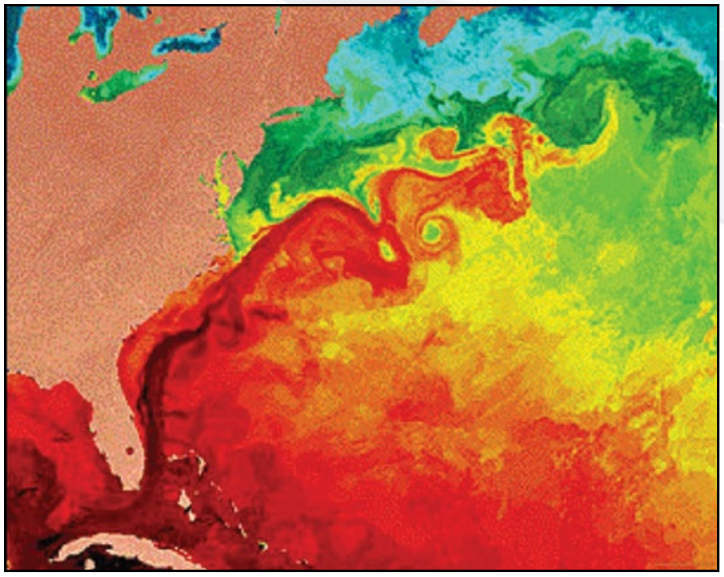
Oleander Project: 25-year Record

Beginning in 1992, Tom Rossby (University of Rhode Island) and Charles Flagg (State University of New York) introduced a fresh approach to the study of the Gulf Stream. Because the Gulf Stream meanders around more than it is wide, they needed a method for repeatedly sampling the horizontal structure of the current. For a sustained observational program, they devised an automated shipboard system. It combines and controls a hull-mounted ADCP with satellite-based positioning. The system is installed aboard a volunteer observing ship (VOS), Container Motor Vessel (CMV) Oleander of Bermuda Container Lines. During its weekly round-trip between New Jersey and Bermuda, the fast-moving ship is underway at 15 kn. The system measures currents to an accuracy of a few cm/s with 2.5 km resolution.

Weekly Transects of the Gulf Stream

At this point, this observational program has recorded weekly transects of the Gulf Stream for 25 years. Upgraded to Teledyne RDI's phased array ADCP technology for profiling deeper, the data set includes high-resolution sections of fast-moving upper-ocean currents and near-surface temperatures. Operating at 75 kHz, the ADCP provides a data set with close measurements along track and deep into the ocean. This provides detailed coverage of the velocity field. It also provides a unique basis for recording the volume of water transported by the upper waters of the Gulf Stream.

In the adjacent view, you can see the ADCP data reveals a large section of ocean in a limited amount of time. Warm colors describe the speed of currents headed north, whereas cool colors show southward flow. Currents are measured to 750 m depth with fine resolution along track. The Gulf Stream is the bright red region. Quite clear is the vertical extent of the strong currents. The pronounced variability along track is associated with circulating eddy currents, sometimes rings, to the east of the Gulf Stream.



Satellite-based thermal imagery showing the Gulf Stream off the east coast of the USA.

Credit: NASA

HIGHLIGHTS:

- Longest series of ADCP sections
- Transects of the Gulf Stream recorded weekly for 25 years
- Operates aboard a volunteer observing ship, CMV Oleander of Bermuda Container Line
- While the ship moves at 15 kn, currents are measured to an accuracy of a few cm/s
- Aboard Oleander, researchers upgraded to Teledyne RDI's 75kHz phased array ADCP for profiling deeper

SOLUTION — SHIPBOARD ADCPS

Initiated by researchers at Scripps Institution of Oceanography, ADCP technology introduced continual vertical profiling of water currents from moving ships. These ADCP data sets are 2D spatial transects—along the ship's path and through depth. They show the details of circulation patterns of current systems. At sea, they also provide real-time data to aid decision-making and to adapt field operations. Many research vessels worldwide now carry Teledyne RDI ADCPs.

For observing currents from a ship underway, two different types of measurements are merged. The first is the apparent velocity of the water when seen from the moving ship; the second is the motion of the ship. Away from coastal regions, a GNSS system generally supplies the latter.

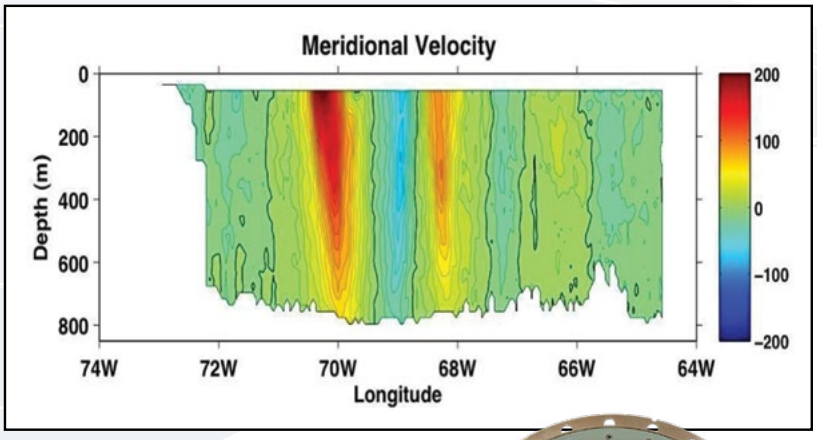
Operating from a rolling ship in high seas is a hostile environment to make measurements, particularly when using sound in the sea. Through painstaking work, researchers at the University of Hawaii developed best practices for extracting high quality ADCP measurements in these difficult situations. As well, they improved understanding of environmental influences on the vertical reach of ship-mounted ADCPs.

Accurately mapping the velocity of deep ocean currents from a ship moving faster than 3 m/s is challenging. It demands that shipboard ADCPs operate at a low frequency yet keep narrow acoustic beams. To achieve this balance, Teledyne RDI developed a phased array ADCP that emits four narrow beams of sound from a single transducer face. This permitted deeper current profiling (nominal ranges of 800-1000 m) at lower frequency (38 kHz).

The first detailed spatial surveys using Teledyne RDI's 38 kHz shipboard ADCPs revealed previously unseen deep currents off the Philippines. The observed profiling range can vary with acoustic backscattering conditions. For a Teledyne RDI ADCP, the deepest profiling range recorded has been 1600 m. This result was observed in high-latitude waters aboard a research vessel moving at 16 kn.

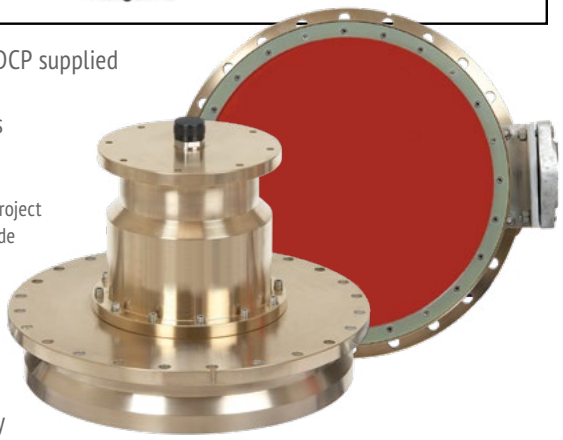
HIGHLIGHTS:

- Shipboard ADCPs show the details of circulation patterns of current systems
- They also provide real-time data to aid decision-making and to adapt field operations
- For a Teledyne RDI ADCP, the deepest profiling range recorded has been 1600 m
- The first surveys using Teledyne RDI's 38 kHz shipboard ADCPs revealed previously unseen deep currents off the Philippines



Teledyne RDI's shipboard ADCP supplied weekly transects of the Gulf Stream for 25 years and counting.

Graphic courtesy of the Oleander Project due to T. Rossby (University of Rhode Island) and C. Flagg (State University of New York). https://goo.gl/VeOfgE



Teledyne RDI's Phased Array technology pushed back the practical limits for transducer size and frequency.

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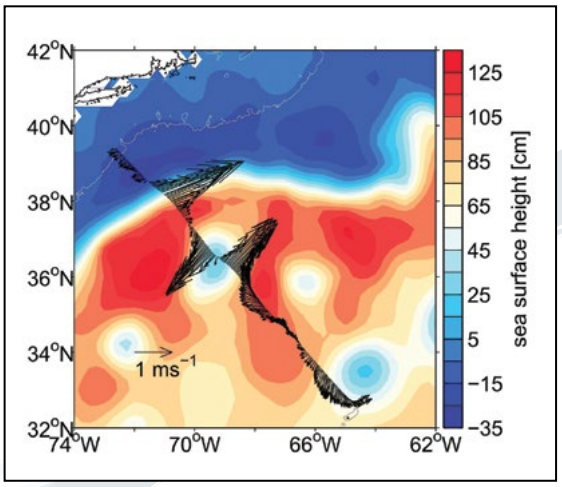
RESULTS

One powerful use of the ADCP data set was a study that provided in-situ comparison with measurements derived from satellite altimeters. Contours of sea-surface height were extracted from weekly mapped fields along the Oleander's route. From these surface contours, oceanic properties such as the velocity field were estimated.

In the adjacent figure, you can see black velocity vectors from the Oleander record that are overlaid on the contours of sea-surface height. The currents were measured at 52 m depth. Red regions are peaks while blue regions are valleys. You can see the vectors are clearly aligned with changes in sea-surface height. This result is predicted by theory. The vectors reveal the strong currents of the Gulf Stream flanked by circulating currents due to a ring to the east of the Gulf Stream.



ADCP velocity vectors at 52 m depth overlaid on a contour map of sea surface height. The latter is derived from satellite altimeter data.

Jessica S. Worst, Kathleen A. Donohue, T. Rossby (2014). J. Atmospheric and Oceanic Technology 31:6, 1422-1433.

In 2013, Rossby, Flagg, and other researchers examined the 20-year series of ADCP transects for signs of a Gulf Stream slowdown. These direct measurements showed no evidence for a decrease in transport. This analysis had been motivated by publications that inferred the Gulf Stream was weakening. The earlier work had analyzed spatial gradients in satellite altimeter data.

The determination of these researchers has paid off. Their mounting collection of transects has unmasked some compelling results in sparsely measured regions of the ocean. CMV Oleander is now slated to be replaced by a new vessel. On it, Rossby and Flagg plan to install dual ADCPs. A deep profiling phased array 38 kHz unit will probe the main thermocline. A complementary 150 kHz unit will provide finer vertical resolution for near-surface waters and shallow regions.

HIGHLIGHTS:

- ADCP measurements revealed the strong currents of the Gulf Stream flanked by circulating currents to the east
- Over the 20-year record available in 2013, ADCP transects collected by Rossby and Flagg showed no evidence for a slowdown of the Gulf Stream.
- Rossby and Flagg plan to install a deep profiling phased array 38 kHz unit to probe the main thermocline

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