Moored ADCPs in Action off East Africa

Sustained Dutch ADCP Array Provides Crucial Measurements

Teledyne RD Instruments

Instruments

Products:
Self Contained ADCP:
Long Ranger (75 kHz)

Application:
Long-Duration Study of Currents in SW Indian Ocean

Project:
Defining Volume and Property Fluxes–Mozambique Channel

Organizations:
Long-term Ocean Climate Observations (LOCO) Partners

Royal Netherlands Institute for Sea Research (NIOZ)

Utrecht University

Data Collection Date:
2003-2012

Location:
Mozambique, Africa

Overview

Strong ocean currents off the east coast of continents play a crucial role in the earth's climate system. These currents carry heat from low latitudes, which improves climate downstream. Fluctuations in this process can affect regional and local weather. Any persistent changes are expected to alter the ambient environment in mid-latitudes.

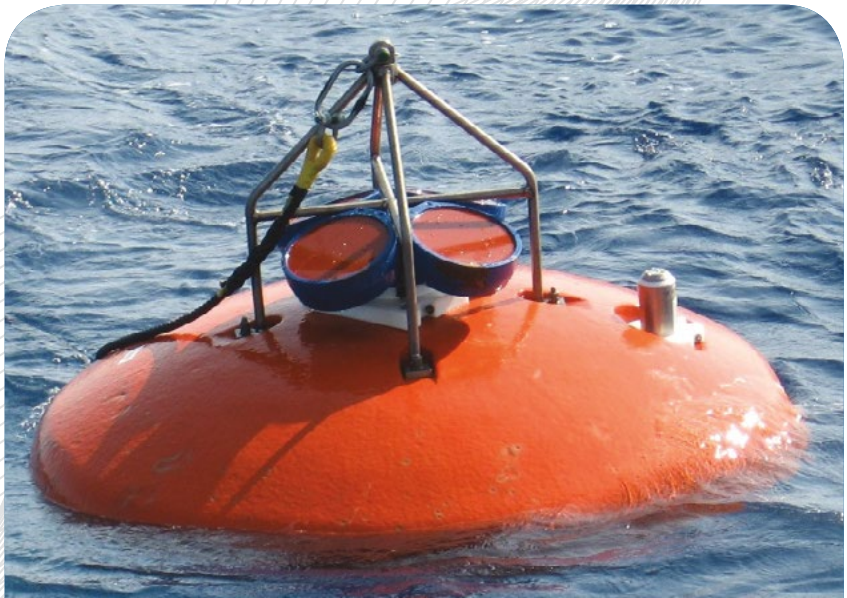
Found worldwide, these crucial ocean currents have been studied to measure their structure, transport, and fluxes—and, in recent times, their changes on seasonal and longer times scales. Exposing the details of subtle climate connections requires long-duration data sets. One compelling study was made by Dutch scientists in the Mozambique Channel off East Africa.

Researchers from NIOZ and its partners maintained an extensive array of Acoustic Doppler Current Profilers (ADCPs) for a decade. They examined upstream changes in the Greater Agulhas Current System. These changes take part in modulating leakage—around southern Africa—between the Indian and South Atlantic Oceans. For the global overturning circulation, this injection of warm, salty water to the returning limb is a possible counterbalance to melting ice off Greenland.

Measuring these currents has been challenging. Observational methods need to reach deep, be sustained, and withstand the energy of these powerful currents. For example, surface drifters, floats, and gliders are quickly swept away in strong upper-ocean currents.

Programs making long-term measurements of important currents rely on resilient moorings. And for measuring strong currents in the upper ocean, these moorings carry ADCPs.

In this case study, we review a decade-long program that measured the northern region of the Greater Agulhas Current System. To help capture this extremely dynamic system, the campaign fixed ADCPs atop mooring lines and near the seabed as part of an extensive observational array.



Teledyne RDI ADCP in Top Buoy of LOCO Mooring

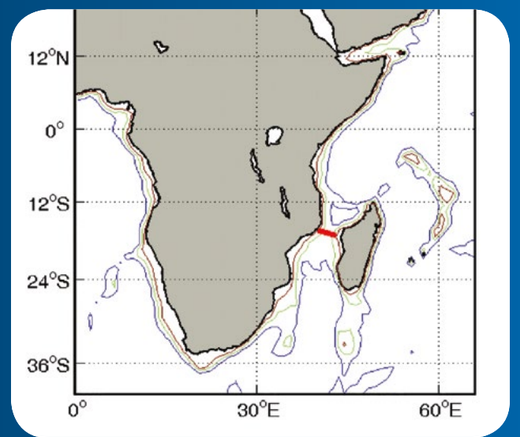
Credit: J. Ullgren (NIOZ). https://goo.gl/SJ4dWJ

Situation: Currents off East Africa

Below the tip of South Africa, meanders in the Agulhas Current close off and morph into large-diameter rings. Satellite observations suggest that this shedding of Agulhas rings is triggered by southward-moving eddies that form in the Mozambique Channel.

These rings, which propagate far westward into the central South Atlantic, dominate inter-ocean exchange from the Indian Ocean. That exchange is now recognized as an important link in the global ocean's overturning circulation.

For climate studies, understanding how widely these rings vary and what triggers meanders in the Agulhas Current is crucial. Early results from satellite altimetry indicated northern inflow to the Greater Agulhas Current System from Mozambique Channel was unexpectedly variable, and not a traditional steady boundary current as believed.



Location of LOCO moored array in Mozambique Channel

Credit: H. Ridderinkhof (NIOZ) https://goo.gl/FrCL2b

To explore this complexity, Dutch scientists mounted observational campaigns. The first was a one-year study to examine the permanence of a boundary current off East Africa. Despite a challenging observational situation, their research revealed a key result: an irregular stream of large, deep rings dominate transport through the Mozambique Channel.

This unexpected finding motivated scientists from NIOZ and its partners to include this region in their program for LOCO. They deployed and maintained an extensive moored array in the Mozambique Channel for the next decade.

A critical element was capturing the volume transported by strong currents in the upper ocean. For this reason, many of the mooring lines were topped with uplooking Teledyne RDI ADCPs.

Reports by the Dutch scientists described how much these complex circulation patterns change from year-to-year. And they identified and assessed forcing mechanisms for this variability in the northern Agulhas System.

Solution: Moored ADCP Array

In 2003, the Dutch research organization NIOZ and its partners began LOCO. This effort included a long-term observational program off the east coast of Africa at 17°S. Equipped with 50 instruments including 10 ADCPs, this program logged the longest time series of its kind for the Indian Ocean.

The researchers installed an extensive array of tall moorings across the narrowest part of the Mozambique Channel. The LOCO project redeployed the moorings several times. The full array was sustained for seven years and a reduced version even longer.

Highlights:

- Large rings formed from meanders in the Agulhas Current are of interest for climate studies
- These rings carry warmer and saltier waters far into the South Atlantic
- Understanding meanders of the Agulhas Current raised interest in energetic mesoscale features found upstream
- Dutch scientists maintained an extensive ADCP-based array in the Mozambique Channel for a decade
- ADCP measurements showed a stream of large rings passing through the Mozambique Channel—not a persistent boundary current

During LOCO, the upper 500 m contained the strongest currents. In the array, most moorings were topped with upward-looking Long Ranger ADCPs (75 kHz). These were installed about 600 m deep and housed in low-drag collars.

The design of these LOCO moorings built on experience at this site. An initial 12-month mooring campaign had recorded currents much stronger than expected. This led to difficulties with mooring blow-over and instrument loss.

Even so the observations revealed intriguing findings. There was no persistent Mozambique Current; rather, transport through the Channel was mostly due to an irregular train of large, deep (300-km diameter) eddies.

The circulation of water around an eddy has currents moving in opposing directions at different sites across the Channel. Thus, accurately measuring net transport required observations across the span of the Channel and with fine spatial resolution.

The LOCO section also included several near-bed, uplooking ADCPs on the western side of the Channel. They recorded the transport and variability of a deep equatorward undercurrent, flowing opposite to the surface waters. At its greatest depth, this deep flow carries water that originated in the North Atlantic.

Via long-term observations, the Dutch scientists reported pioneering results about ocean variability. Especially interesting was a climate-related link between tropical current regimes and the Agulhas Current system.

Results: Local Changes and Remote Connections

The LOCO moorings spanned many years with consistently impressive spatial coverage across the Mozambique Channel. This duration was required to reliably describe an oceanic region where conditions and currents vary widely. These variations are of intrinsic interest.

The LOCO program reported a weak southward flow on average. Superimposed on this flow are strong, deep currents circulating around large eddies. These eddies pass through the Channel irregularly, about five times per year.

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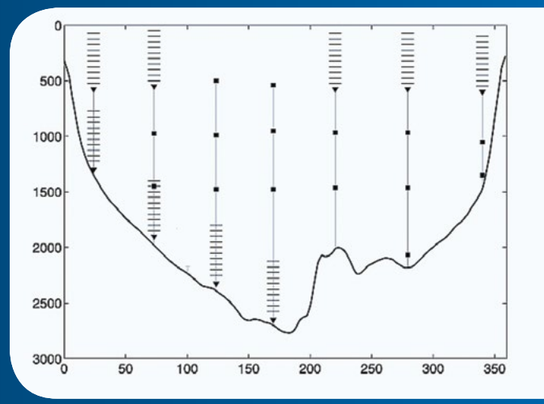
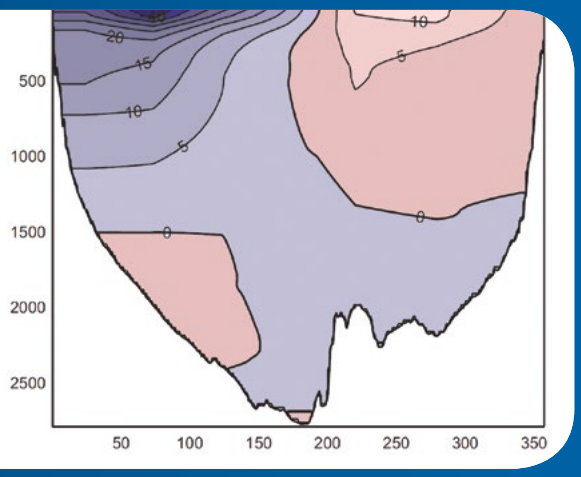
Low-drag flotation was installed on many LOCO moorings due to strong currents in Mozambique Channel.

Credit: H. Ridderinkhof (NIOZ) https://goo.gl/L6Vvdk



A later setting of LOCO moorings in Mozambique Channel. ADCP profiles are indicated. Scales: depth (m), distance (km).

Adapted from H. Ridderinkhof et al., 2010 (NIOZ) https://goo.gl/d4ZSjf



Far left: Ellipsoidal flotation collars are prepared for deployment on LOCO moorings.

Credit: J. Ullgren (NIOZ)
https://goo.gl/jmWd3z

Currents across section averaged over six-year period.
Blue: Poleward
Red: Equatorward
Scales: Depth (m), Distance (km)

Adapted from J. Ullgren et al., 2012 (NIOZ)
https://goo.gl/VBWBxZ

The combined effect on average is shown in the graph above. Across the section, the upper kilometer shows opposed flows that are not equal in strength.

The deep, equatorward undercurrent is seen hugging the continental slope at the western side. Farther east, deep currents are weak. The net volume of water through the Channel is about 16 million cubic meters per second—about half the volume moving through the Florida Straits.

From their extended time series, the Dutch scientists revealed that the pronounced changes in water volume moving through the Mozambique Channel varied at three different time scales.

For shorter time scales, the recurring large eddies passing southward dominate changes in transport. These estimates became more statistically reliable when based on the longer data record. For seasonal periods, modest changes in flow volumes were linked to wind-stress patterns over the Indian Ocean basin.

At interannual time scales, changes much larger than seasonal variations were found. These swings in volume transport were attributed to links with remote current systems in equatorial and Indonesian regions. Fluctuations in the latter are identified by a regional climate index—Indian Ocean Dipole (IOD). A lag of almost 12 months was found between changes in the IOD climate index and corresponding variation in water volumes supplied to the Agulhas Current.

Exposing these changes over time—and their subtle climate connection—was possible only with the sustained measurements, many of which came from Teledyne RDI ADCPs.

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Images:

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References:

H. Ridderinkhof et al. (NIOZ), 2010. Seasonal and interannual variability in the Mozambique Channel from moored current observations. https://doi.org/10.1029/2009JC005619

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