Oleander Workshop II: 25 Years of Operations
URI/GSO
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Abstract

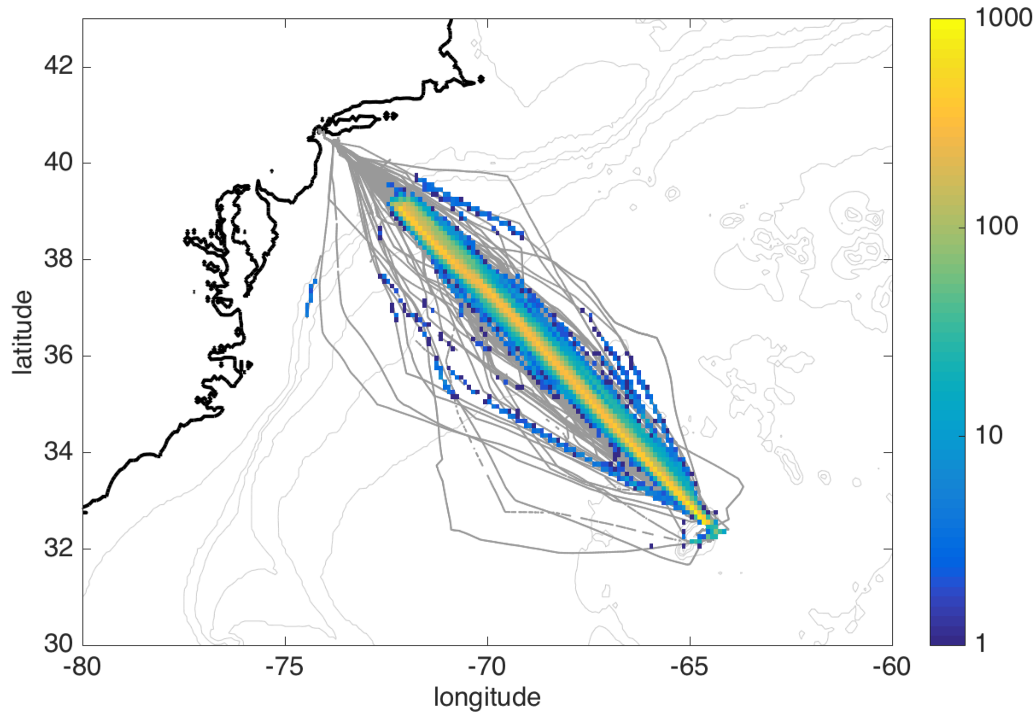
A workshop to discuss past, present and future trajectories of the Oleander Project was convened at the University of Rhode Island, Graduate School of Oceanography (URI/GS) campus in Narragansett, RI on October 26-27, 2016. Hosted by Tom Rossby, lead PI for the NSF-funded observational program, the workshop provided a constructive forum for the group to assess ongoing and future scientific objectives, logistical details, and strategies to broaden the program's visibility and utility across multiple research disciplines. In addition to the project PIs (Rossby, Flagg, Donohue, Curry), the group welcomed participants from NOAA/AOML (Goni, Dong, Bringas, Baringer), NOAA Northeast Fisheries (Melrose), and researchers addressing topics of ocean circulation, biogeochemistry and climate (Andres, Palter, Omand). Presentations and discussions highlighted impending upgrades (new ship and instruments), the roles now played by BIOS and NOAA, a new website and data dissemination infrastructure, a novel suite of proposed interdisciplinary observations, and a set of focused scientific questions to be addressed with the Oleander datasets.

I. The Oleander Project: some background information

The container vessel *MV Oleander* conducts weekly round-trip transits between New Jersey and Bermuda, crossing diverse and dynamic ocean regimes that are critically important to ocean circulation, heat transport, biological productivity and the carbon cycle: i.e. the US continental shelf, Slope Sea, Gulf Stream and Sargasso Sea. Routine measurements began in 1981 with installation of an eXpendable Bathythermograph (XBT) recorder and Continuous Plankton Recorder (CPR) towing davit by members of the NOAA/NMFS Atlantic Environmental Group based in Narragansett, RI. This was made possible by the generous cooperation of Oleander's officers and owners, the Bermuda Container Line (BCL) of Hamilton Bermuda. Once per month, volunteer riders would launch hourly XBTs and tend the CPR along the outbound transit providing records of the cross-shelf temperature structure and plankton communities of the Mid Atlantic Bight shelf and the Slope Sea to the Gulf Stream north wall.

In 1991 BCL built a new ship which included a CPR towing davit and space in the hold for an Acoustic Doppler Current Profiler (ADCP) an addition that was initiated by Rossby and Flagg with NOAA support. NOAA's Atlantic Oceanographic and Meteorology Lab (AOML) installed a thermosalinograph (TSG) to measure surface water temperature and salinity. The ADCP was subsequently installed and horizontal current measurements began in 1992 using a 150kHz ADCP. In 1999, the U.S. National Science Foundation (NSF) began to support the Oleander program, and a 75kHz ADCP was installed, extending the depth range of current velocities from ~200 m to ~600 m. The ship was outfitted with an automated carbon dioxide (CO_2) analyzer in 2006 as part of a larger US initiative (the US Carbon Cycle Science Program) to routinely measure pCO_2 in surface water and air from commercial vessels. In 2009, XBT coverage was extended across the Gulf Stream and into the Sargasso Sea and in 2011 the program was partially automated with development of the Automated eXpendable Instrument System (AXIS) by WHOI engineers. The ship's bosun was then able to tend the launcher eliminating the need for volunteer riders.

Figure 1. Number of deep (>600 m) acoustic profiles from Oleander 75 kHz ADCP (total = 59,400, 2005-2016). Note the logarithmic color scale. Figure credit: Daniele Bianchi, UCLA.



Having just celebrated its 25th year of operations, the Oleander Program embraces its future as an opportunistic, multi-disciplinary research platform. Plans for a new ship are now being negotiated by the Neptune Group Ltd (formerly BCL) with a target date of early 2018 for its delivery and launch. In conjunction, several improvements to the Oleander observational capabilities are being implemented. NOAA/AOML has included the program into its High Density XBT Network, increasing spatial resolution to ~25 km. NSF has granted support to replace the single ADCP with 2 hull-mounted instruments – a 150 kHz unit to acquire high resolution observations of the near-surface layers, and a 38 kHz unit to penetrate to ~1200 m offshore of the continental shelf.   A new TSG system will be installed, the pCO2 measurements will continue, and additional observations – e.g. LIDAR optical backscatter and meteorological sensors – are being proposed. Ways to continue the CPR measurements are being actively pursued, with an eye toward maintaining the long time series of phyto- and zooplankton assessments, supplemented by optical and acoustic backscatter measurements. Combined with satellite altimetry, the sum of observations will provide powerful tools for addressing scientific topics including ocean circulation and transports, primary productivity of the surface waters, and the marine carbon cycle in these regions of the western Middle Atlantic.

II. Oleander Observations

A. Continuous Plankton Recorder (CPR) time series (Chris Melrose)

The NOAA Northeast Fisheries Science Center (NEFSC) performed monthly CPR observations from the original Oleander and its successor since 1981 (and from US Coast Guard and NOAA vessels for a decade before. This is the longest zooplankton time series in the Mid-Atlantic region. Until the 1990s, samples were analyzed at the NEFSC, but were subsequently sent to MIR in Poland for analysis. In December of 2013, the NEFSC ceased CPR operations due to a loss of U.S. Federal funding. Operational control of the project was transferred to the Sir Allister Hardy Foundation for Ocean Science (SAHFOS) in the U.K., which resumed tows in 2014. SAHFOS archived samples for later analysis when funds become available. If SAHFOS cannot identify funding within the next 6 months, they will likely have to abandon the Oleander's CPR operations.

Details of the CPR method are described in the following paper:

http://publicationslist.org/data/m.j.witt/ref15/Richardson_2006_ProgOceanogr.pdf

The Global Alliance of Continuous Plankton Recorder Surveys (GACS) global ecosystems status report describes trends in temperature and plankton abundances for the MAB shelf ecosystem (in particular page 13) :

https://www.sahfos.ac.uk/media/1063/ecostatno10.pdf

Two papers using the MAB CPR zooplankton data:
http://plankt.oxfordjournals.org/content/27/5/401
http://journal.nafo.int/43/kane/6-kane.html

B. NOAA's Ship of Opportunity / Global XBT Network (Gustavo Goni)

NOAA/AOML currently contribute to the Global XBT Network by conducting XBT deployments and data management in partnership with several institutions in the US, Argentina, Australia, Brazil, Italy, France and South Africa. During the period October 2015-Septeber 2016 NOAA/AOML and partners completed 7218 XBT deployments along 11 transects in the Atlantic and Indian Ocean (AX01, AX02, AX07, AX08, AX10, AX18, AX25, AX97, IX01, IX12, IX28) and Scripps Institution of Oceanography (SIO) completed 4608 deployments along 9 transects in the Pacific, South Atlantic and Indian Ocean (AX22, IX21, PX05, PX09, PX13, PX31, PX37, PX38, PX40). AOML quality controls and distributes through the GTS and NOAA/NCEI all SIO XBT data.

More information about this program can be found at:
http://www.aoml.noaa.gov/phod/videos/load.php?varid=xbt_network

C. Incorporating Oleander into NOAA's data management system (Bringas)

AOML recently renewed its collaboration with the Oleander Project providing XBT probes to conduct monthly deployments from Newark NJ to Bermuda (the AX32 transect) in high density mode, with deployment every 25-30 km (approximately 50 XBT deployments per cruise). This collaboration maintains the XBT operations in Oleander that have been conducted regularly since 1977.

All XBT data received at AOML, including those from Oleander, are submitted to Automatic Quality Control (AQC) procedures. AQC Tests include: Date, Location, Depth, Gross Check (for temperature and depth), Constant Value, Spike, Vertical Gradient, Climatology, and Analysis. Profiles that fail the AQC are submitted to Visual QC (VQC). All good profiles are submitted to the Global Telecommunication System (GTS) and NOAA/NCEI for global distribution and archival.

After cruises are completed the entire XBT data-set collected is submitted to Science Quality (Expert) QC with additional QC tests including: Ship Speed, Position, Duplicates, Hit Bottom, and Local Climatology. The expert QC is a manual and visual procedure. The resulting data-set is distributed through NOAA/NCEI and AOML's High Density XBT website (http://www.aoml.noaa.gov/phod/hdenxbt) and the Oleander Project website file://localhost/(http/::oleander.bios.edu:data:xbt-data:)

D. Using acoustic backscatter to assess distributions and abundance of mesopelagic fauna (Jaime Palter)

Ocean velocities acquired by the Oleander ADCP have yielded great insight into ocean dynamics and variability. The ADCP backscatter intensity also provides a biological signal that has not yet been the subject of systematic study. The organisms that influence the backscatter intensity are comprised principally of aggregations of zooplankton and micronekton, including euphausiids and mesopelagic fish. These animals are critical for the strength of the biological pump, and the carbon, oxygen, and nutrient inventories of the ocean. They are equally important as a food source to a range of marine predators. Yet, the mesopelagic zone is vastly under-observed and poorly represented in models, which limits our basic knowledge of the animals that spend much of their lives respiring in this layer. Scientists at URI (Palter, Mouw) and UCLA (Dr. Daniele Bianchi) have proposed to use the *Oleander* data, along with analogous data from collected by other instrumented merchant vessels, to characterize the variability of animal acoustic aggregations along the line at space scales ranging from the mesoscale (10 km) to the basin scale, and time scales from diurnal to interannual. We will synthesize their relationships with remotely-sensed ecological and physical drivers, as well as the cross-track velocity field and the inferred geostrophic density field. Such a synthesis will reveal, through statistical and biogeographical modeling, the nature of the association between scattering layers and ocean properties and dynamics.

III. Oleander Project Infrastructure

A. Transition of operations from SUNY to BIOS (Ruth Curry)

Oleander's present operations have been maintained by a coalition of people and institutions: the XBT and TSG hardware, sampling and data processing have been run by Charlie Flagg (SUNY/Stonybrook), Jeff O'Brien (WHOI) continues to oversee the AXIS system, Jules Hummon and Eric Firing (U of Hawaii) maintain the ADCP acquisition components, and Sandra Fontana (URI/GSO) processes the weekly ADCP data streams. The forward plan for the program is to transfer a portion of logistical support (XBT / TSG operations, and ADCP processing) to Bermuda Institute of Ocean Sciences (BIOS) under Ruth Curry over the next 3-4 years.

In 2016, BIOS began servicing Oleander with XBTs provided by NOAA/AOML and built a new project website to be the public face of Oleander, including a portal to the program's various datasets (XBT, TSG, ADCP) and data products.

http://oleander.bios.edu/

Over the next two years, BIOS will update and streamline the Oleander data dissemination infrastructure, and work closely with NOAA's data management team to implement format, quality and analysis standards developed for the larger Global XBT network. Flagg and Curry will work with Neptune Group Ltd in the design and building of the new ship, install and troubleshoot the new instruments (including dual 38 and 150 kHz ADCP systems) and undertake data processing and archiving functions at BIOS.

B. New ship and instruments (Charlie Flagg)

The *CV Oleander* was commissioned in 1991 and so at this writing is 25 years old. Five years ago the ship underwent an extensive overhaul but this is still quite old for a commercial vessel and the Neptune Group have been considering a new ship with expanded capabilities for some time. At this point a newly built ship is expected to arrive sometime in 2018. As with the existing *Oleander* during its design phase, we have been asked to provide detailed requirements for the mounting of scientific instrumentation to the designers of the new vessel. This time there will be a unified description of the science needs that will encompass two ADCPs, the automated XBT launching system, the TSG and PCO2 sensors, meteorological sensors, an attitude GPS, a data acquisition and processing system, and satellite telemetry.

The biggest change will be the installation of two ADCPs, a short range 150kHz unit with finer vertical resolution but restricted range, and a long range 28kHz unit that will reach past 1000m extending well into and in some places through the ocean's main thermocline. The use of dual ADCPs requires the development of a data acquisition system that is capable of handling two data streams at the same time maintaining a single time base. The University of Hawaii's Drs. Firing and Hummon have developed such a data acquisition system called UHDAS and in the past year have extended its capabilities to operate autonomously. Autonomous operation is an absolute necessity for any equipment destined for use on commercial vessels operating without the services of a shipboard science team. Another advantage of the UHDAS system is that it is capable of sending emails reporting the status of the systems and a subset of data products. This will be facilitated with the addition of a Fleet Broadband satellite link to shore and to the Oleander Project's website.
The TSG and PCO2 systems operate in tandem and will be co-located in a place with access to a seawater intake from the ship's bottom that will support an inflow temperature sensor. This is a pumped system which needs to be turned off while the ship is in port to avoid contamination. Consideration will be given to controlling this pump using GPS data from the data acquisition system.

The automated XBT launching system, referred to as the Autonomous eXpendable Instrument System or AXIS, has been developed over the past decade and is now in regular use on two VOS ships, the *Oleander* and *Norrona* which operates between Denmark and Iceland. This system is mounted on the ship's fantail with its own data acquisition system, a 12-probe carousel, a GPS receiver, and satellite telemetry. When the ship approaches a pre-determined position, the carousel moves a new probe into position, checks for the condition of the probe and, if it passes, launches the probe. The data are then sent ashore to a central file server at which time the unit inquires whether or not a new mission that could change the planned XBT deployments is ready for uploading. Keeping the AXIS supplied with probes is now the responsibility of the ship's bosun who is given a small stipend, with a new supply of probes delivered to the ship each month.

C. Proposed LiDAR measurements (Melissa Omand)

Integration of a compact, hull--mounted light detection and ranging (LiDAR) package has been discussed, and early, exploratory actions are being taken. This effort is in collaboration with Fraser Dalgleish at Harbor Branch Oceanographic Institution. The LiDAR system wound provide sustained profiles of particle concentrations that can be inverted to retrieve beam attenuation and absorption coefficients, volume backscatter coefficient, and the depth of shallow light-scattering layers. When compared to airborne systems, the operation of a submerged LiDAR moving at normal vessel cruising speeds, allows for the discrimination of fine structure within the water column, and avoids beam corruption and losses when penetrating the air-water interface, respectively.
Thermosalinograph data will be used to observe submesoscale (and larger) horizontal physical gradients, and coupled to vertical gradients of biological parameters returned

from the LiDAR. The relatively large speed ship (16 knots) means that it is minimally affected by spatial-temporal aliasing that plague slower platforms, making it suitable for synoptically capturing small-scale structures in the surface ocean. The two wavelength LiDAR will overlap with the spectral range of the band placement of the upcoming NASA mission PACE.

IV. Scientific results from Oleander Data

A. Slope Sea (Charlie Flagg)

The slope sea lies between the edge of the continental shelf and the Gulf Stream, and extends from Cape Hatteras to the Grand Banks. It is a very active area subject to meanders from both the shelfbreak front and the Gulf Stream, often populated by warm core rings and through which flow upper and lower deep western boundary currents. It exhibits substantial seasonal changes in surface properties due to winter mixing and feels the impact of ocean-scale forcing from the NAO and AMO through variable inputs from the Gulf Stream and the Labrador Sea. It also plays an under-appreciated but outsized role in supplying vital nutrients to the productive shelfbreak front and shelf regions. This is illustrated by the long-term history of near surface temperatures and salinities along the Oleander line after removing seasonal variability, which shows that several months to year-long anomalies in temperature and salinity are coherent across the shelf, shelf break and slope sea. This can only be explained, since the slope sea is many times more massive than the shelf, by the shelf responding to intruding slope waters onto the shelf. How those intrusions occur is not well resolved. There are several candidates, i.e. turbulent mixing, internal wave breaking, frontal eddies and Gulf Stream rings, but the relative importance of these is at best, poorly understood. However, contained in these intruding slope waters are the new nutrients that sustain this highly productive region.

B. Gulf Stream (Tom Rossby)

The key selling point for the Oleander ADCP operation was monitoring the strength of the Gulf Stream (GS). At that time, the only direct measurements, both across the stream and to the bottom, were those of the Pegasus program in the early 1980s. Everything else had involved geostrophy in one form or another. (Not quite accurate, there was SYNOP in the latter 1980s and Mindy Hall's mooring in the middle of the GS a bit farther downstream.)

A few years after Oleander started, we published our first report in BAMS. It was less about hard-hitting results and more about the kinds of things that can be done with the ADCP: e.g. describing the structure of the GS, its seasonal and interannual variability. One neat result was that if you consider only the core of the stream (velocities > 1m/s) then there is virtually **no** seasonal signal! Taking its full width into account (from 0 to 0 velocity), seasonal variations do emerge that are clearly associated with the seasonal thermoclines to either side. We also demonstrated that integrating normal velocity geostrophically produces valid sea level difference across the GS, and to somewhat greater distances. No altimetry was available then, but we showed that the same sea level results apply regardless of direction of travel – significant because it indicated that any biases in the integration must be very minor. This is a very powerful result for it tells us that with proper attention to calibration of the GPS compass (bottom track), very accurate (and bias-free) over-the-bottom or geo-referenced velocities can be obtained.

Before long, Zhang and Rossby published a detailed dynamical analysis of the Gulf Stream, its stiffness, its vertical and lateral shear, how it flexes, and tilts in meander crests and troughs. We used velocity and XBTs to investigate the potential vorticity (PV) structure and demonstrated a remarkably sharp PV front between the northern and southern sides. We also described GS energetics in geographical and stream coordinates.

Published updates from the Oleander data have reported interannual variations in transport (near the surface). A 2014 GRL paper focused on the question of trend. This was almost forced on us because several papers were suggesting that the GS is slowing down. Our direct measurements showed unmistakably that this was not the case. Further, between this work and the earlier paper by Sato and Rossby there is little to suggest a slow-down taking place on longer time scales (since the 1930s). We do see significant interannual variations of a few % and it appears from the discussions we had that a model study of these might be possible in the near-future (Zhao - postdoc at WHOI). Of course, the GRL paper results are not a statement about the future, but the GS is part of a huge interconnected system, therefore the suggestions we've read about the MOC slowing down make little sense unless such variations can be corroborated elsewhere. OSNAP is one example, and a good one, but we could argue that the Oleander route is a fine section too: Given the GS's key role as the pipeline of all warm water flowing east and north (all water flowing north in the MOC must do so between Bermuda and the mainland) this section provides a very powerful check on GS metrics. Given additional information (SSH, XBT, Argo) it should also give us a firm handle on the MOC.

C. Sargasso Sea and eddies (Tom Rossby)

The Sargasso Sea (SS) has been covered by the ADCP from its inception. At first there was an obvious focus on the GS, but of course simple statistics of mean flow and EKE were part of the reports. In 2008 Dave Luce published his Master's thesis study of coherent vortices (CV) in the SS. He had developed an algorithm for detecting circular structures from how the velocity vector rotated as the ship passed through the structure. He found near-equipartition of cyclonic and anticyclonic CVs and provided a number of quantitative findings about size and velocity. Closer to the GS a separate class of cold core rings stands out as quite distinctive in size, intensity or relative vorticity. He also found some intense anticyclonic CVs. This study needs to be revisited with the much larger and deeper reaching ADCP data we now routinely acquire. It would be good to enlist a young smart person to develop a new, robust CV detection algorithm, one that can include vertical structure - the previous one looked only at one depth (which was almost all we had then with the limited reach of the 150 kHz ADCP). Future studies in the SS will benefit greatly from the AXIS now operating on the Oleander. We can now release XBTs or even XCTDs in these structures for more detailed studies.

Another very striking feature to emerge in the SS analyses is a see-saw pattern to the westward flow between the GS and Bermuda on time scales of several years. If the northern half exhibits strong flow to the southwest, the southern portion of circulation is weaker, and vice versa. A very striking pattern that remains unexplained, but almost certainly is wind-driven.

D. Heat transport from repeated high density XBT lines (Shenfu Dong)

There are four XBT transects that monitor the Gulf Stream at different locations (AX32, AX10, AX08, and AXWBTS). AX10 runs between New York City and Puerto Rico, along which about 100 XBTs are deployed in each realization; a total of 77 realizations have been carried out since its implementation. Examination of AX10 data shows that the Gulf Stream experiences strong north-south shifts, which can exceed +/-1 degree of latitude from its mean position. However, during the last 20 years both its position and transport did not exhibit significant trends. The 20-year measurements using AX10 data show that below the seasonal mixed layer the largest temperature variability in the Gulf Stream occurs between 300-600m depth. Geostrophic velocity derived from AX10 suggests that the temporal variations in the velocity are vertically coherent.

The synergy between AX10 and altimetry observations has helped to understand the Gulf Stream changes over a larger region (50W-80W), with the Gulf Stream experiencing a strong southward shift to the east of 65W after the Gulf Stream passes the New England Seamount chain during 1993-2012. The same analysis for the Gulf Stream transport indicated that this southward shift is accompanied by a weakening of the Gulf Stream. However, to the west of 70°W, no significant trends were observed.

E. Combining altimetry with Oleander ADCP and XBT records (Kathy Donohue)

In Worst et al. 2014, we asked how well do Oleander ADCP surface velocities compare to altimeter fluxes determined via geostrophy? Three subregions, Slope Sea, the Gulf Stream and the Sargasso Sea as well as the full transect were considered. It was critical to define regional end-points for the comparison based on local minima in sea surface height variability in order to minimize the mismatch between the horizontal scales resolved by the Oleander and the altimeter. The Oleander ADCP and altimeter surface fluxes agreed well with correlations greater than 0.85 for the Gulf Stream region and greater than 0.94 and in the slope and Sargasso Seas, and less so for the long Sargasso and full transect sections where correlations were 0.64 and 0.58, respectively. Velocity uncertainties were additive. A slight seasonal shift in the error was evident suggesting that ageostrophic Ekman contributions produced by large-scale weather systems might be responsible for the discrepancies between the two systems. Analysis of the Ekman signal building on the work by Stoermer 2002 is warranted.

F. *Gulf Stream meandering trends (Andres)*

V. Near term science priorities and activities

A. Oleander review paper

B. Organize a special session at Ocean Sciences
"Obtaining sustained ocean observations with commercial vessels"

C. Continue the CPR observations

D. Identify, construct and maintain a set of indices derived from XBT/SSH data for use by modelers

E. Additional sensors for the new ship

F. Data archaeology of SST from historical ship crossings (Rossby)

G. Science Question and Objectives

The group collectively constructed a list of topics which can and should be addressed using Oleander data in conjunction with other datasets.

- Dynamic biogeography
- Vertical Eddy-driven fluxes in Mixed Layer
- Connectivity to Line W (e.g. the slope jet)
    - comparing Oleander ADCP / LineW
    - HYCOM / ROMS (Ke Chen)
- Eddy/meander driven fluxes GS – Slope Sea
- Heat content interannual variability
- PV structure
- Reynolds stress divergence - momentum forcing terms
- What drives interannual variability : Shelf, Slope Sea, GS, Sargasso and RCG
- Bermuda circulation : tidal rectification? Mesoscale-topography interactions?
- What controls Slope Sea gyre? (e.g. h_n in Shenfu's SSH analysis)
- AX10, AX08, and AX32
    - GS stream coordinate view XBT, Geostrophic ADCP
    - Interannual T anomalies
    - Does sampling account for differences in transport time series?
- Coherent eddies adjustment: circulation and backscatter
- Use Oleander to benchmark submesoscale-resolving Remote Sensing datasets (VIIRS, SWOT)

VI. Close of meeting

At the end of the meeting Tom gave a brief overview of how the expanded Oleander line (38 kHz ADCP) plus XBTs will put us in a good position to monitor the MOC on seasonal to longer time scales. Having several MOC monitoring lines: the southern ones (SAMOC), the RAPID line, the Oleander line, a line at 47°N, the OSNAP line, the Nuka Arctica line and the Norröna line all contribute to the question of meridional coherence or lack thereof. These lines also resolve current patterns along their routes so they can be quite informative beyond just the MOC metric.

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