Early Student Support for "SST Control by Subsurface Mixing during Indian Ocean Monsoons"

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LONG-TERM GOALS

This grant supports Oregon State University PhD candidate Kerstin Cullen, who is framing her thesis work from efforts associated with the ongoing Air-sea Interactions Research Initiative in the Bay of Bengal DRI. Kerstin has completed her first year of classes and passed her written comprehensive exam this summer. She has already made substantial strides in her research- looking at the structure, variability, and dynamics of the Sri Lanka Dome (SLD). She is combining remote sensing, historical CTD data, Argo profiles, and data from the recently recovered Naval Research Laboratory (NRL) mooring array, which includes turbulent mixing sensors (χpods), to explore the upper ocean mixed layer properties within the SLD and modification of air-sea fluxes associated with the SLD. She recently participated in the August-September 2015 ASIRI cruise in the Bay of Bengal. She also attended and presented a poster at the University of Massachusetts ASIRI meeting in Spring 2015. She will work in close collaboration with PIs from Oregon State (Shroyer, Moum, and Nash), UW (Lee and Rainville), and NRL (Wijesekera).

OBJECTIVES

The objectives of this project are to:

1. use satellite-measured SSS, SST, and SSH to map structure and variability of the SLD, and quantify sea surface temperature and salinity anomalies associated with the dome,
2. use Argo floats and mooring data to examine the vertical structure and activeness of the dome, and relate the interior structure to sea surface anomalies,
3. use satellite measured OLR and TRMM data to quantify cloud cover, evaporation, and precipitation anomalies over the southwestern Bay of Bengal as related to the SLD,
4. combine the above information with scatterometer-based wind stress to determine the response of the SLD to local and remote wind forcing, and
5. synthesize the above information and products to examine links and feedbacks between the SST and SSS of the SLD and local precipitation.

APPROACH

Kerstin is using multiple years of satellite and mooring data along with multivariate statistics in a three-part analysis. She is currently working on the first step– to *directly characterize the development and variability of the SLD using both remote imagery and in situ data.* After fully characterizing the SLD structure and variability, she plans *to evaluate the SLD forcing mechanisms that have been previously proposed as key to dome formation using observational data.* And, finally, she *will examine effects the SLD has on regional weather and precipitation by comparing the strength of the SST anomalies to satellite-measured precipitation and outgoing longwave radiation (OLR) in the region.* Together, these three analysis paths will provide a detailed view of the character, dynamics, and air-sea interaction of the SLD.

WORK COMPLETED

This year the student participated in the August-September 2015 ASIRI cruise in the Bay of Bengal. She also participated in the May 2015 ASIRI meeting in Massachusetts, and presented a poster at that meeting. A copy of the poster follows this report. Last year she completed the majority of her academic course work and passed her written comprehensive exam for formal admission into the PhD track. Kerstin has also made significant progress in the first phase of her research. She has characterized the SLD strength, area, and location using the 20+ year sea surface height record. She is starting to look at the interannual variability in this record and determine any correlations with other climate indices. She has also looked at the internal structure of the SLD using data from the Argo float program.

RESULTS

A tracking mechanism for identification of the Sri Lanka Dome using sea surface hight perturbations has been identified and implemented for the full AVISO record. Variability in the SLD intensity, area, duration, onset, decay, and location have been quantified (Figure 1). This record is now being compared to climate indices to determine potential links between variability in the SLD and prominent atmosphere-ocean coupled modes. Internal strucutre in the SLD has been examined using opportunistic Argo profiler records (refer to poster). The upwelling signature is evident deep in the water column, spanning the thermocline. The mean development of the SLD, and outlier years have also been quantified (Figure 2). In a stypical year, the SLD forms during May or June, developing into a mesoscale feature spanning 3-5 degrees. Through July and August, the SLD continues to increase in magnitude (as indicated by a deeper sea surface low), and migrates northeastward. In September, the SLD travels eastward and dissipates, as a westward propagaing Rossby wave sets up a strong sea surface high in the former location of the SLD.

IMPACT/APPLICATIONS

This work aims to address improved predictability in the summer Indian Ocean monsoon through determination of the role of the Sri Lanka Dome in modulation of upper ocean structure and air-sea fluxes. The Sri Lanka Dome is a prominent recirculation feature that regularly appears during the summer monsoon. It migrates across the basin, and is active for several months each year. This work supports a female PhD student in Physical Oceanography.

RELATED PROJECTS

This ESS project is associated with grant N000141410236- SST Control by Subsurface Mixing during Indian Ocean Monsoons.

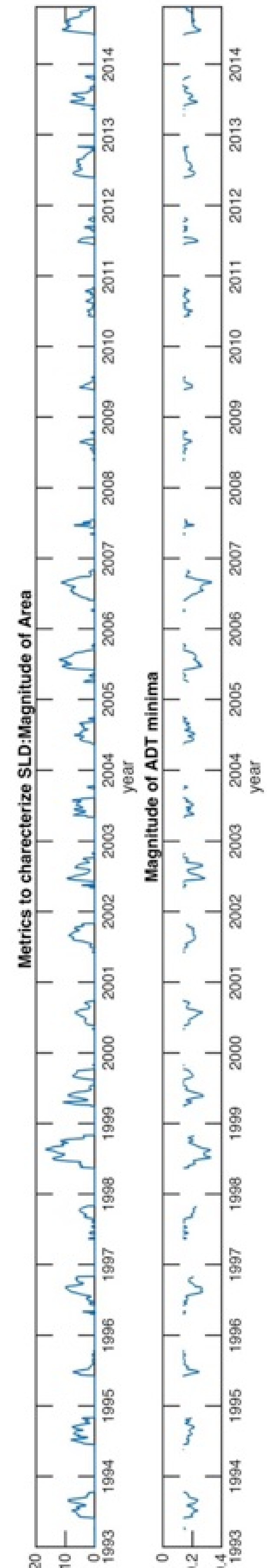


Figure 1. SLD characteristics over a 21 year time series. The top panel shows the magnitude of area the SLD computed with tracking 0.5 m contour in de-trended absolute dynamic topography sea surface deformation, the bottom shows the magnitude of maximum sea-surface deformation within the SLD.

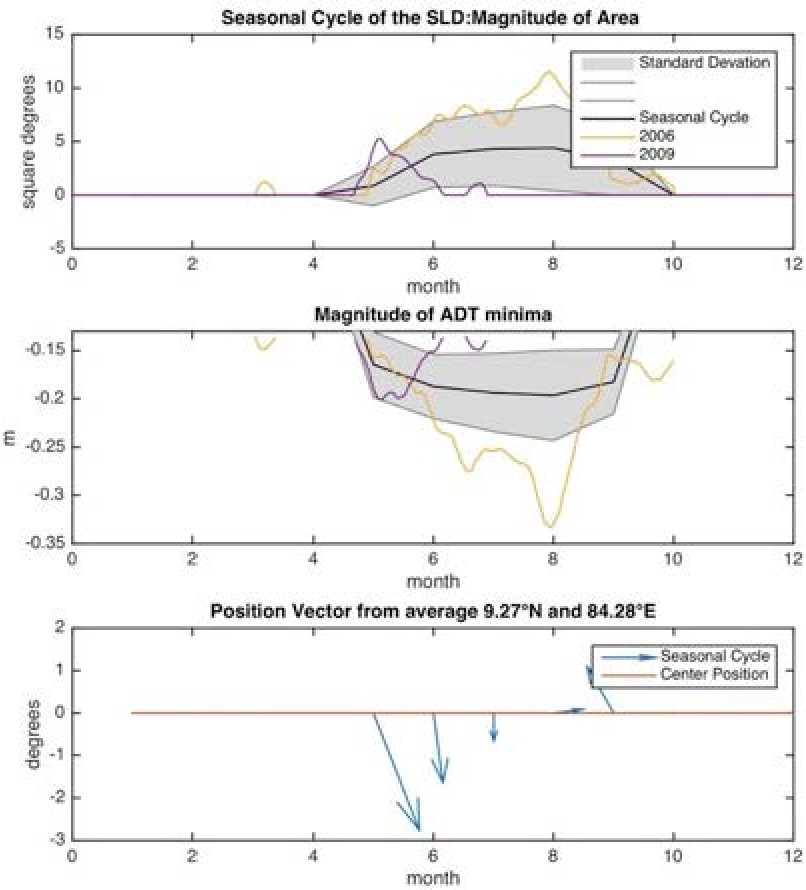


Figure 2. Seasonal cycle of three characteristics of the SLD. Top panel shows the magnitude of area, with the black line indicating monthly climatology, the grey band indicating the standard deviation, and two extreme years 2006, shown in yellow, and 2009 shown in purple. The middle panel shows the magnitude of absolute dynamic topography sea surface deformation within the SLD, with the climatological monthly averages, standard deviation, and extreme years using the same color scheme. The bottom panel displays the climatological monthly average position relative to the yearly average SLD position at 9.27° N, 84.28 E°.

The Sri Lanka Dome

Development and Interannual Variability

Kerstin Cullen, Oregon State University

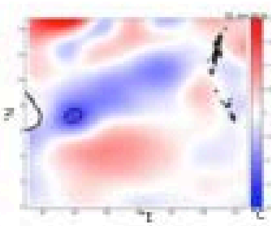
Introduction:

The Sri Lanka Dome (SLD) is a tropical thermal dome that forms east of Sri Lanka During the Southwest Monsoon. The formation of the SLD has alternately been attributed to remote and local wind forcing, and a detailed understanding of its formation and dynamics does not exist. Furthermore, interseasonal variability in the SLD has yet to be studied. The SLD forms during May or June, developing into a mesoscale feature spanning 3-5 degrees. Through July and August, the SLD often continues to increase in magnitude (as indicated by a deeper sea surface low), and migrates northeastward. In September, the SLD travels eastward and dissipates, as a westward propagating Rossby wave sets up a strong sea surface high in the former location of the SLD. The SLD displays a considerable amount of interannual variability in time of establishment and dissipation, migration path, and magnitude. Upwelled isopycnals within in the SLD could potentially impact the surface layer and air-sea interactions above the dome.

Methods for Tracking the Sri Lanka Dome:

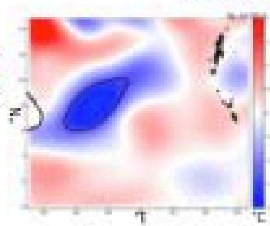
Absolute Dynamic Topography (ADT) is used to characterize and track the SLD. AVISO ADT multi-satellite product was used to identify the core of the SLD. Data was two dimensionally detrended and a cutoff of -0.15 m was used to contour the SLD. This tracking was used to identify when Argo floats entered the SLD.

Typical Seasonal Cycle (2014)



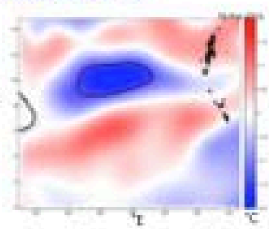
May - June

SLD appears east of Sri Lanka.



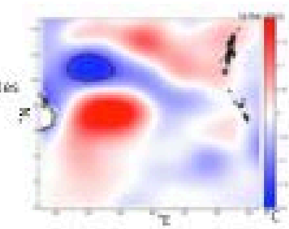
July

Size and strength increase.



August

The SLD migrates northeast.



September

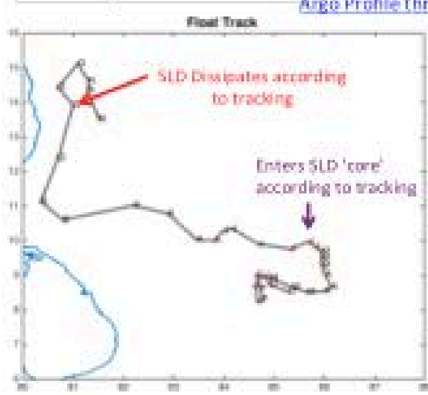
The SLD moves west, while a Rossby wave propagates westward becoming a strong high pressure in the original location of the SLD.

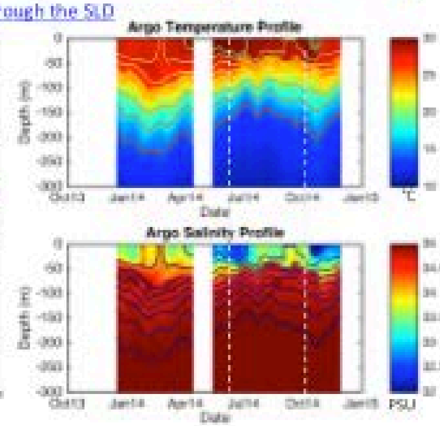
Argo Temperature Anomalies July 2014

To the right, gridded Argo temperature anomaly maps at various depths. The SLD upwelling signal is visible subsurface, but no cool temperature signature is present at the surface.

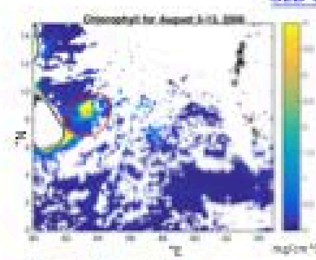
Below, track and vertical profile of an Argo float that is entrained throughout the SLD during 2014.

Argo Profile through the SLD





SLD and Chlorophyll, 2006



Left, comparison of Modis chl during a rare clear week over the SLD (contoured in red) during August 2006. During 2006, the SLD exhibited the strongest ADT anomaly in the 20+ year record of sea surface height. While a distinct sea surface temperature signal is not present for the dome, secondary effects of upwelling, such as chlorophyll, are.

Future Research:

Ongoing work is detailing the properties of the SLD using 20+ years of remote sensing data and 10 years from the Argo mission. Once the SLD is characterized, and interannual variability in the SLD assessed, I will consider the dynamics that control SLD formation, migration, and dissipation. I will also look at the potential impact to upper ocean properties and air-sea interaction. Due to the large interannual variability of both dome strength and position, effects on near surface temperature (and thus effects on air-sea interaction, may vary on interannual time scales. In order to examine these effects, my next research steps are to:

1. use Argo floats and mooring data to examine the vertical structure of the dome, and relate the interior structure to the satellite-derived tracking algorithm,
2. calculate oceanic vertical fluxes from turbulence sensors on moorings to quantify mixing above the elevated thermocline,
3. use satellite measured OLR and TRMM data to quantify cloud cover, evaporation, and precipitation anomalies over the southwestern Bay of Bengal as related to the SLD,
4. combine the above information with scatterometer-based wind stress to determine the response of the SLD to local and remote wind forcing.