Coastal Sea Level from the Mid-Atlantic United States to Canada – What Causes the Interannual Variability in this "Hotspot" of Sea Level Rise?

Magdalena Andres – Coastal Ocean Institute Award Final Report

While average global sea level is rising, this rise in not uniformly distributed along all coasts. One region of particular interest stretches along the coast of the mid-Atlantic United States to Canada (**Figure 1a**). The coastal sea level here is observed to rise at a rate three times faster than the global rate of sea level rise. Superimposed on this upward trend is significant year-to-year variability in sea levels (**Figure 1b** and **c**). Projecting future sea levels for this region requires an understanding of physical processes occurring at different spatial and temporal scales. Though the stakes are high – both in economic terms and human terms – accurately predicting how the *regional* sea level will respond to *global* climate changes is challenging.

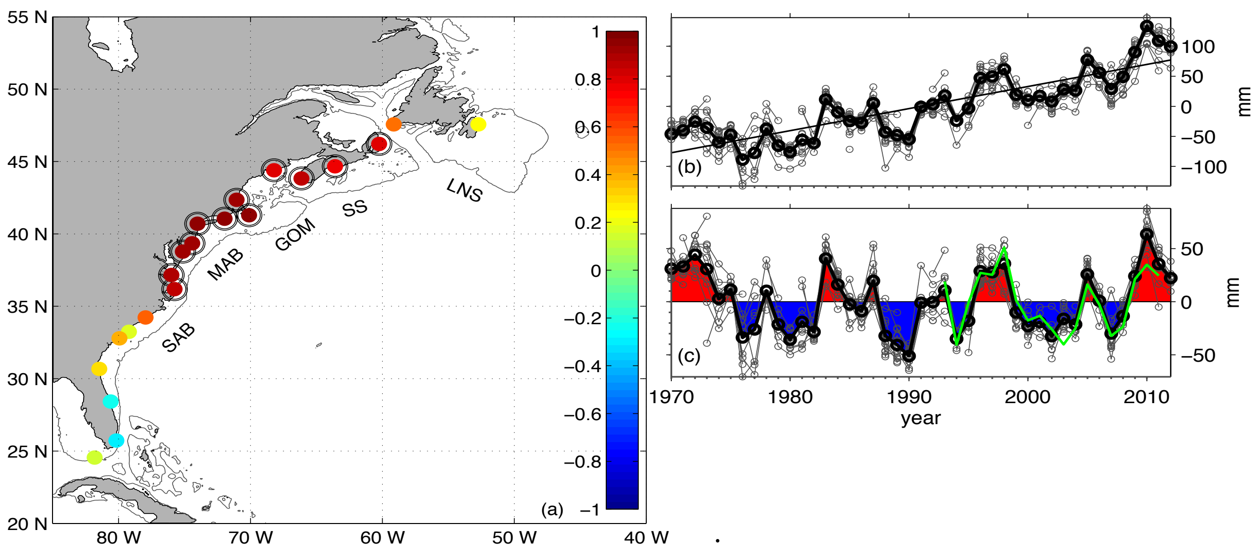

Figure 1. In panel (a) the colored dots show the locations of tide stations along the eastern U.S. with records that stretch back to at least 1970. The stations between Duck, North Carolina and Nova Scotia (highlighted with black circles) show strikingly similar behavior: these stations have all recorded a long-term increase in coastal sea level and that increase is occurring *three times as fast as the global average rate of sea level rise*. Panel (b) shows the records from the individual stations in this "hotspot of sea level rise" (grey dots) and the average across these 12 tide stations (black dots). Due to the long-term increase in sea level here (shown with the thin black line) sea level in the northeastern U.S. has increased by more that 10 cm between 1970 and 2012. In addition to this long-term trend, there is a lot of variability from one year to the next that is superimposed on this general sea level increase. This interannual variability can be seen clearly in panel (c), which shows the detrended sea level data. In some years the 12 stations all have relatively high sea levels (e.g., 1972 or 2010) and in other years they all have relatively low sea levels (e.g., 1980 or 1990). Understanding the causes and consequences of this year-to-year variability was the focus of the study supported by this Coastal Ocean Institute Award. The abbreviations in Figure 1a indicate the different regions of the continental shelf: Southern Atlantic Bight (SAB), Middle Atlantic Bight (MAB), Gulf of Maine (GOM), Scotian Shelf (SS), and Labrador-Newfoundland Shelf (LNS).

Existing theories suggest that the enhanced rate of sea level rise along the northeastern U.S. results from changes in large-scale ocean circulation in the Atlantic Meridional Overturning

Circulation (AMOC) or the Gulf Stream. Implicit in these theories, is that sea level variability over the shelves and along the coast is remotely forced. However, the analysis supported by this Coastal Ocean Institute Award suggests a different cause for the year-to-year variability in coastal sea levels along the Middle Atlantic Bight, the Gulf of Maine and the Scotian Shelf. Using sea level data from tide gauges and satellite altimetry, the analysis shows that variability in along-shelf wind stress drives variability in the cross-shelf sea level gradient. This suggests local (rather than remote) forcing of the coastal sea levels and also suggests that there must be changes in the currents over the shelf associated with this local forcing.

A manuscript summarizing these results was published in 2013 in *Geophysical Research Letters*. Results from this work were also presented in a seminar in the WHOI Physical Oceanography Department and at regional and national science meetings (the 2013 MABPOM conference in Narragansett, RI, and the 2013 AMOC Meeting in Baltimore, MD).

Motivated by these results based on sea level data, I have continued investigating the interannual variability on the shelves along the northeastern U.S. by using a 37-year long ocean temperature dataset collected since 1977 by a ship of opportunity, the CV Oleander. These data provided the foundation for a project for a 2014 WHOI Summer Student Fellow that I advised. As a result of the student's project, we now know that 1) the Oleander dataset captures the expected features of seasonal temperature variability on the shelf, 2) there is a curious two-year lagged relationship between coastal sea level anomalies and shelf temperature anomalies that warrants further study, and 3) the rate of temperature increase on the Middle Atlantic Bight has accelerated over the last 10 years (**Figure 2**).

This research with the Oleander data, motivated by the results of the investigation supported by the Coastal Ocean Institute Award, resulted in a poster presentation at the 2014 fall AGU meeting, a 2015 publication in the *Journal of Geophysical Research*, and a proposal to continue this work (this proposal is presently pending with the National Science Foundation). The *Journal of Geophysical Research* paper was the subject of a radio interview in July 2015 on WCAI's Living Lab Program and was highlighted on the NSF Radio 360 website. Additionally, the Summer Student Fellow applied to the WHOI/MIT Joint Program; he was accepted and intends to continue working on the interannual variability in the Middle Atlantic Bight for his PhD research.

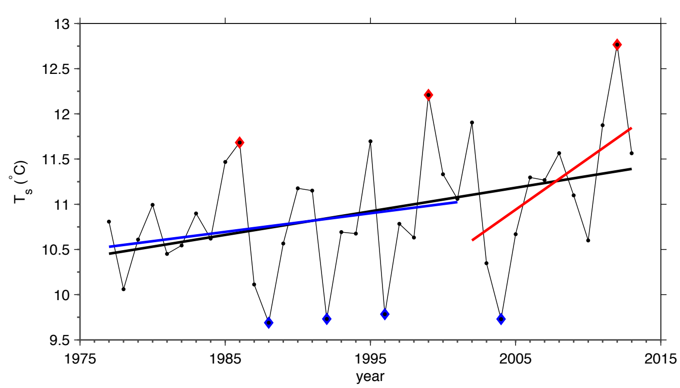

Figure 2. Ocean temperature has been increasing on the Middle Atlantic Bight shelf since at least 1977 (black trend line) and this warming has accelerated recently (red trend line). As is the case for sea levels **(Figure 1)**, there is a lot of year-to-year variability superimposed on this general increase in ocean temperatures.