Pilot Upgrade of NOAA NDBC Coastal Weather Buoys for Improved Monitoring of Weather and Climate

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Project Description

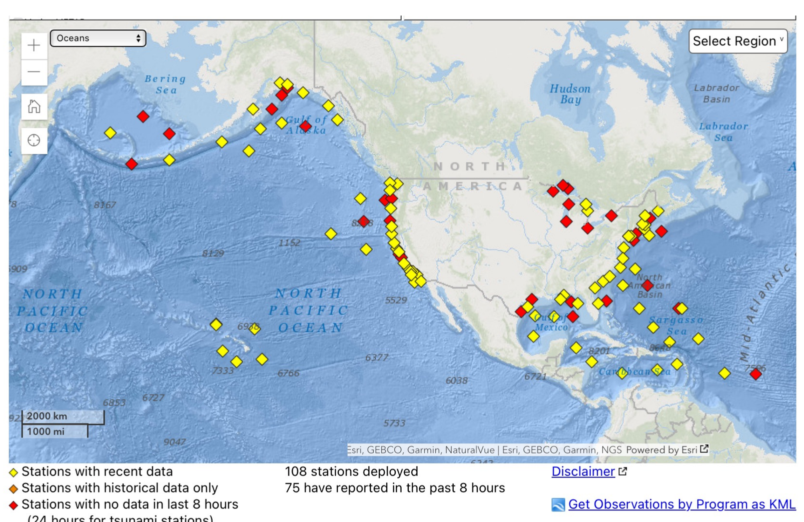
The main objective of this project is to design a prototype operational NDBC Coastal Weather Buoy (CWB) that measures collocated subsurface and surface variables in real-time and provides post-deployment quality-controlled data capable of characterizing air-sea interaction and subsurface ocean heat content and mixed layer variability in the Gulf Stream extension region on the New England Shelf (NES). Current NDBC CWBs observe air temperature, dew point, sea surface temperature (SST), wind speed and direction, surface pressure, and wave height, period, and direction. The proposed additional measurement capabilities **include longwave and shortwave radiation**, **surface currents and salinity**, and **subsurface profiles of temperature, salinity and currents**. To **fully quantify the air-sea heat fluxes within the Gulf Stream extension region** important for coupled model data assimilation, we need to include shortwave and longwave radiation and surface currents (e.g., Cronin et al. 2019). Subsurface temperature and salinity are also important for calculating **upper ocean heat content**, which strongly impacts, for example, storm tracks, storm intensity, and storm transition from warm core to cold core (e.g., Lin et al. 2012).

The expected outputs from this project are: (1) an "all-in-one" operational CWB capable of reporting full air-sea heat and momentum fluxes, wave properties, and ocean current, temperature and salinity profiles of the upper ocean that can be adopted to upgrade NDBC's CWB network where needed; (2) real-time and post-processed quality controlled data and their real time display and delivery from the upgraded CWB; and (3) manuscripts describing the prototype mooring capability and case studies demonstrating the importance of collocated air-sea flux and ocean mixed layer observations for understanding and predicting coupled physics in weather and climate variability.

This project involves substantial collaboration with NOAA research (PMEL and UW/CICOES) and operations (NDBC). NDBC manages the deployment, operations, and maintenance of the national buoy networks and is the anticipated primary end user of the new CWB prototype. The National Weather Service and national and international modeling centers are the anticipated primary end users of the proposed new data products. Additionally, these co-located air-sea measurements will be useful for verifying satellite retrievals near the U.S. coastline and the next generation of coupled assimilative models and to improve process understanding regarding the ocean's influence on weather and climate.

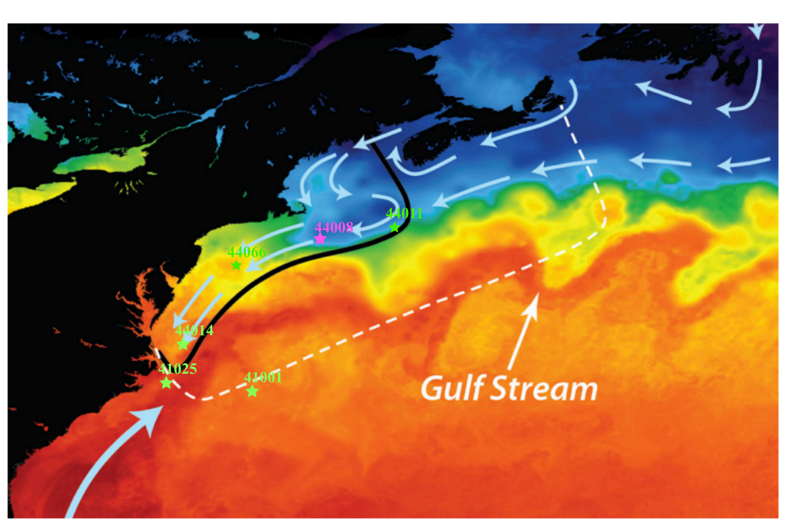
NOAA WPO Award **NA23OAR4590404**

Motivation for New England Shelf Pilot Monitoring



The Coastal Weather Buoy (CWB) Observing System

- There are **104** NDBC moored coastal weather buoys (CWBs) and key off-shore buoys. *These buoys currently do not observe the subsurface ocean.*
- **33** of the 104 stations are along the US East Coast and Gulf of Mexico where tropical storms and hurricanes make landfall, extra-tropical transition can occur, marine heatwaves are a growing concern, and the Gulf Stream strongly influences both atmosphere and ocean dynamics and ecosystems.

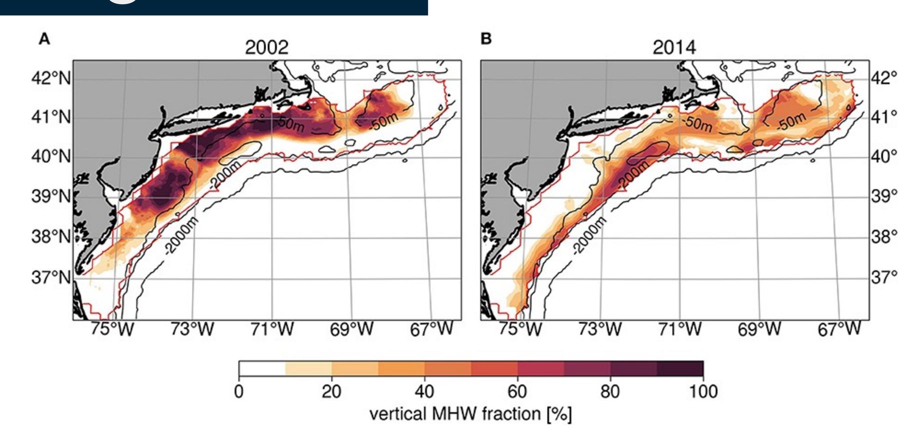


Approximate location of the NDBC CWBs along the MAB. Satellite Sea Surface Temperature (SST) image from NASA Worldview, 10 July 2010. Image credit: Dr. Gordon Zhang's NES-LTER website https://nes-lter.whoi.edu/about/.

Focus on the Gulf Stream extension region

★ #44008 (40.50N 69.25W, 72 m):

- Near former National Science Foundation Ocean Observatories Initiative (OOI) NES Pioneer Array (https://oceanobservatories.org/array/coastal-pioneer-array/), contributing to a growing body of literature on shelf dynamics and ecosystems and an active user community.
- Region of cross-shelf dynamics with implications for ecosystems along the US northeast coast (e.g., Zhang and Garwarkiewicz 2015).
- Region with surface ocean warming that exceeds the global average (Gawarkiewicz et al. 2018).

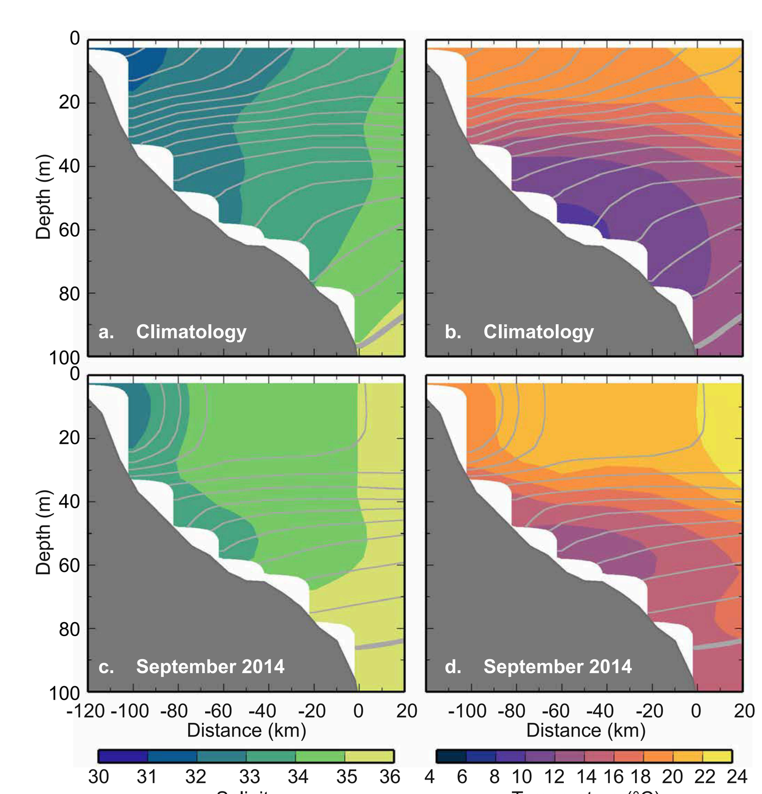


New England shelf marine heat wave vertical fraction in (A) 2002 and (B) 2014, where vertical fraction refers to the percent of the water column that met the study definition of a heatwave. Study uses 1/4° NEMO (Nucleus for European Modeling of the Ocean, v3.6) hindcasts with 1/20° nest in study region. Image adopted from Großelindemann et al. (2022).

Marine Heat Waves

"*Due to the lack of subsurface observations, the depth-extent of MHWs is not well-known, which hampers the assessment of impacts on pelagic and benthic ecosystems.*" - Großelindemann et al. (2022)

Großelindemann et al. (2022) find that the 2002 MHW was mainly confined to the upper water column (< 50 m), while in 2014 the MHW was focused more at 100 m, though there is a seasonal evolution to these events.



Cross-shelf transects of (a), (c) Salinity and (b), (d) Temperature from NOAA Northeast Fisheries Science Center Ecosystem Monitoring cruises. (a) and (b) climatology based on September 1981-2010. Image adopted from Gawarkiewicz et al. (2018).

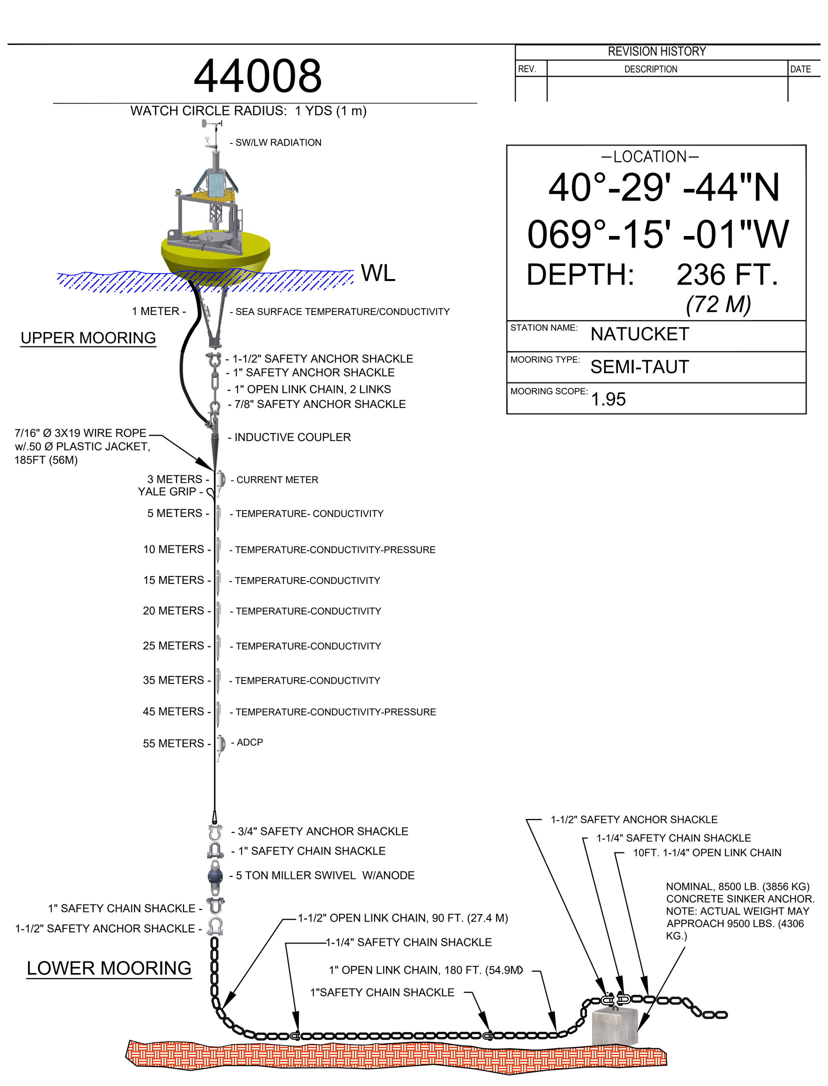
New England Shelf Temperature and Salinity Intrusion Events

"*… the entire shelf was substantially warmer and saltier than average in late summer 2014, consistent with other ring intrusions documented by the OOI Pioneer Array*" – Gawarkiewicz et al. (2018).

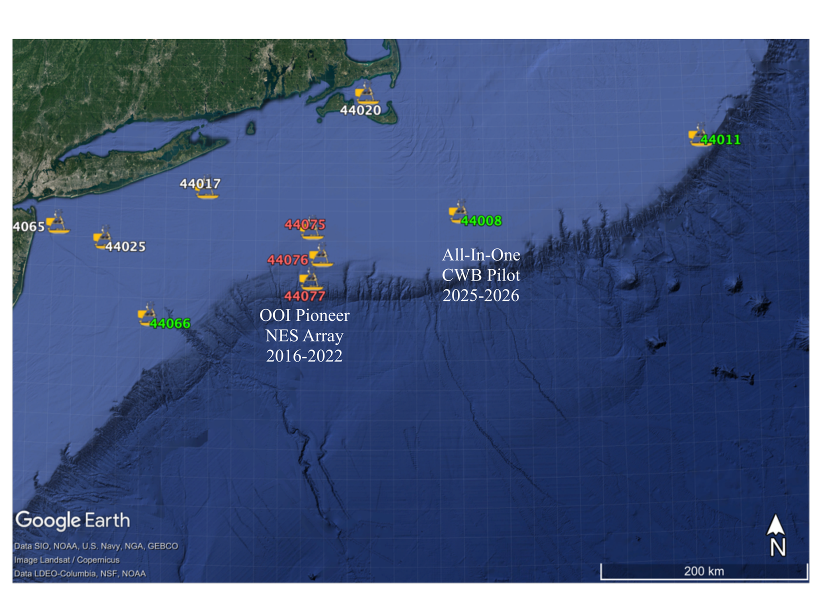
The OOI NES Pioneer Array data show that the warm core intrusion events are penetrating further onshore than in the past (Gawarkiewicz et al. (2018).

Recent studies suggest Gulf Stream meanders have increased in amplitude and with more frequent warm core rings compared to a decade or so ago (Gawarkiewicz et al. 2018 and references therein).

Mooring Configuration

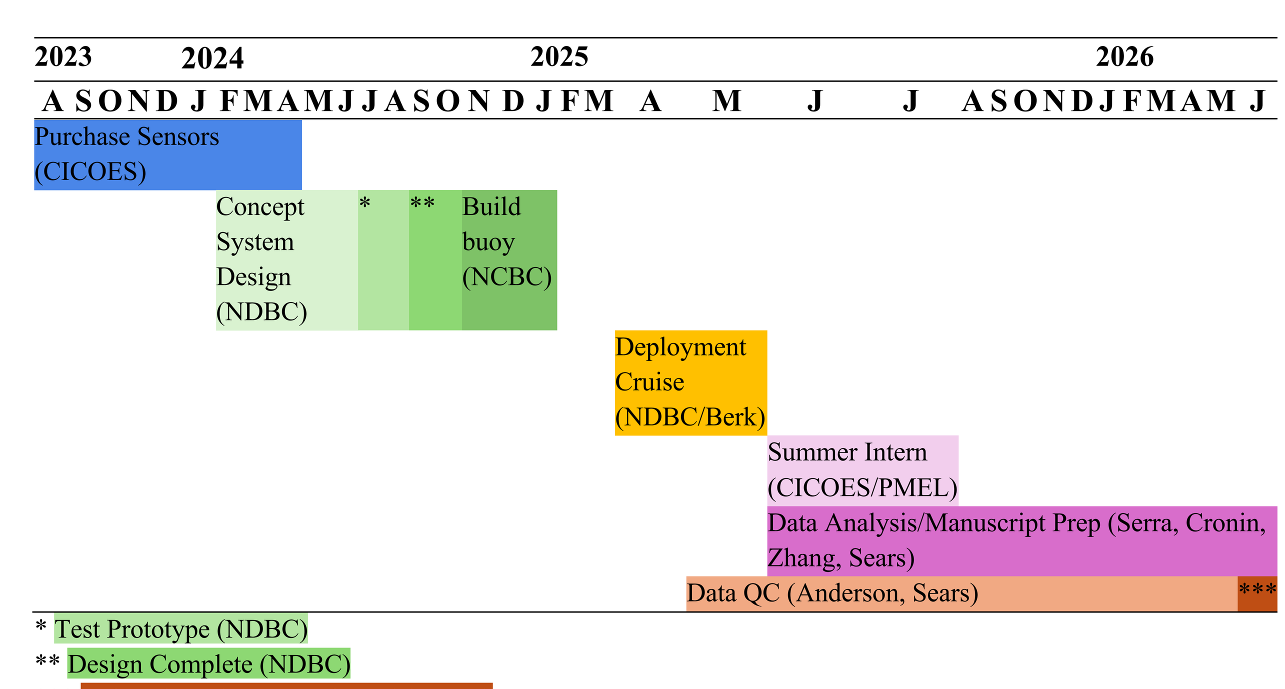


The "all-in-one" mooring configuration shown here adds sea surface salinity at 1-meter depth, a current meter at 3-meter depth, a series of 7 temperature-conductivity/temperature-conductivity-pressure sensors 10 meters apart to 45 meters, and an upward looking ADCP at 55 meters. Solar and infrared radiometers are also added to the mooring frame following recommended standards (Riihimaki et al. 2024).



The CWBs along the New England shelf considered for this study are highlighted in green text. The OOI NES Pioneer Array, deployed in 2016 and recovered in 2022, is also shown for reference. CWB 44008 was ultimately chosen for this pilot upgrade.

Project Timeline



Future Plans

The CWB observing system offers valuable long-term monitoring of U.S. coastlines. This project will build upon that valuable dataset by adding subsurface and full-flux monitoring capabilities to a single mooring in the NES region. Following this 2-year deployment (Spring 2025 – Spring 2027), we hope to continue to work with NDBC on the following near-term goals:

- Explore avenues of funding to maintain the all-in-one mooring past 2027
- Provide monitoring of Gulf Stream meanders and warm core ring encroachments onto the NES, as observed using the OOI NES Pioneer Array dataset
- Provide monitoring of MHWs on the NES to validate modeling studies and improve understanding of these events
- Work with modeling centers to gauge the impact of these data and potentially additional all-in-one deployments on MHW and storm track/intensity forecasts along the mid-Atlantic Bight region.

References

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