MODELING NONLINEAR PHYSICAL-BIOLOGICAL INTERACTIONS: SARGASSUM IN THE NORTH ATLANTIC

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RESEARCH SUMMARY

The macroalgae commonly known as "gulf weed," *Sargassum fluitans* and *Sargassum natans*, are keystone species in the Atlantic Ocean and the Gulf of Mexico, where they serve as habitat and forage for a diverse floating ecosystem [1, 2]. Satellite observations [3] indicate a seasonal cycle of *Sargassum* distribution with high abundances in the Gulf of Mexico in the spring and early summer, and in the Sargasso Sea in fall and winter, however, the drivers of this seasonal pattern are not well understood. Recent changes in *Sargassum* biomass and extent [4] coincide with increasing reports of wash-ups on beaches in Africa, the Caribbean, and the Gulf of Mexico which negatively impact fishing and tourism. I have used a coupled modeling approach to understand the drivers of *Sargassum* distribution across temporal and spatial scales.

To simulate ocean circulation in the North Atlantic, I have generated a Hybrid Coordinate Ocean Model (HYCOM) [5] domain at 1/12° resolution which is forced using the National Centers for Environmental Prediction Climate Forecast System Reanalysis for the years 1992-2010. This domain is coupled to a biogeochemical model adapted from the work of Fennel [6] that includes phytoplankton, zooplankton, and variable nutrient stoichiometry relevant to *Sargassum* growth in oligotrophic conditions. Also coupled to this model system are a Lagrangian particle model and an individual-based *Sargassum* growth model developed for this study.

The addition of the *Sargassum* individual-based model resulted in a threefold increase in percent areal match with observations compared with particle advection from the physical model alone. Over the seasonal cycle at the basin scale, the coupled model system can generate a *Sargassum* distribution that is consistent with observations (Fig. 1) from a randomly distributed particle initial condition. Typically the Sargasso Sea is considered the critical *Sargassum* habitat in the north Atlantic, however analysis of particle locations and growth rates highlights the importance of the tropics as a reservoir for the *Sargassum* population. Connectivity matrices generated using the Lagrangian particle model show high retention of *Sargassum* in the Sargasso Sea, as expected, but also show moderate retention in the western Gulf of Mexico. These retentions suggest that the western Gulf of Mexico region may contain a seed population of *Sargassum* that remains local while a fraction of its biomass gets advected out towards the central gyre.

The combination of the circulation model and the *Sargassum* growth model has also allowed for examination of mortality and export. This model system shows a hot spot of *Sargassum* mortality and sinking that is consistent with observations of *Sargassum* on the sea bed at the western boundary of the Sargasso Sea [7]. Physical advection tends to aggregate *Sargassum* in the Sargasso Sea with less than a 30% probability of escape to better growth conditions at timescales of one year.

At spatial scales less than 100km and temporal scales less than one month, mesoscale eddies can influence *Sargassum* transport as well as nutrient conditions via differential vertical velocities. Preliminary Lagrangian coherent structure analysis in the Gulf of Mexico at the start of the *Sargassum* growing season illustrates the difference between the relatively quiescent western Gulf of Mexico and the eddy field associated with the Loop Current in the east (Fig. 2). Because particles tend not to cross Lagrangian coherent structures, these features may present a boundary that helps explain the high retention of *Sargassum* in the western Gulf of Mexico.

Investigation of the links between mesoscale features and *Sargassum* is ongoing. I will examine transects of nutrient concentrations and *Sargassum* location and growth across eddies and fronts in the tropics, the Gulf of Mexico, and along the Gulf Stream wall, and attempt to link these features with the large-scale *Sargassum* distribution. Application of these results will help forecast costly *Sargassum* wash-up events more effectively. I also plan to conduct comparisons of these results with those from a coarse resolution model system to gain insight into the spatial and temporal resolutions at which online coupling is necessary for individual-based models.

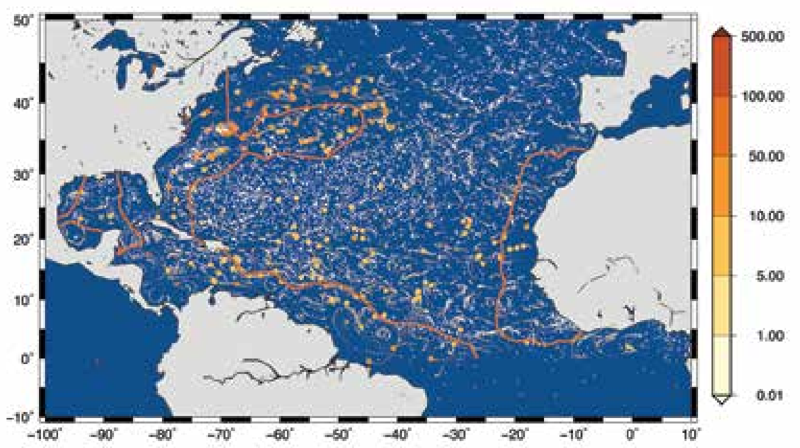

FIGURE 1: Modeled Sargassum distribution in November. Particle color indicates Sargassum biomass normalized to initial condition, orange contours are regions of high Sargassum biomass observed via satellite.

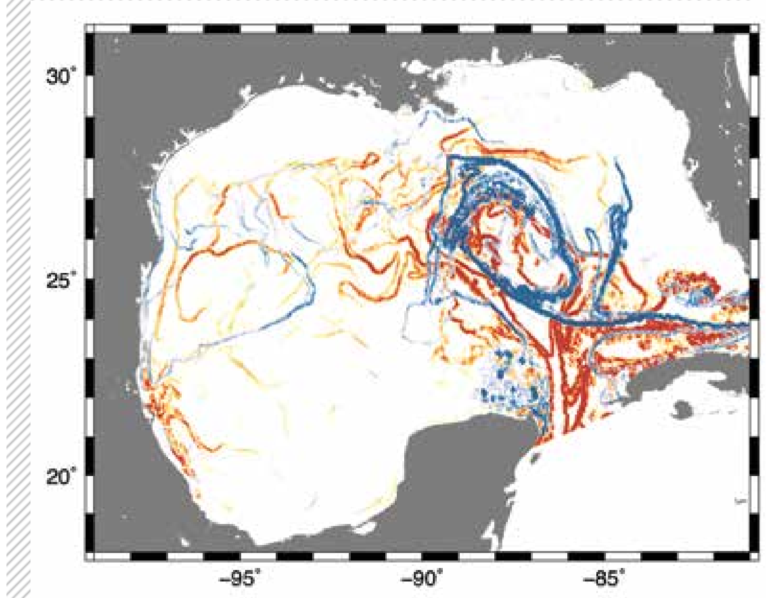

FIGURE 2: Lagrangian coherent structures (LCS) in the Gulf of Mexico at the start of the Sargassum growing season (mid-May). At short time scales Sargassum will aggregate along lines of attracting LCS (blue) and be exported from regions of repelling LCS (red).

WHY BLUE WATERS

Access to Blue Waters has been critical to the success of this project. Modeling ocean circulation at this scale and resolution has a high computational cost, and the capabilities of Blue Waters have allowed me to couple both physics and biogeochemistry. The expert staff at NCSA have been extremely responsive to my questions and needs and have helped me grow from a novice into a proficient user with plans to continue using high-performance computing to study physical-biological interactions across marine ecosystems.

PUBLICATIONS AND DATA SETS

Brooks, M. T., V. J. Coles, R. R. Hood, and J. F. R. Gower, Linking satellite observations with coupled bio-physical models of *Sargassum*. *AGU/ASLO/TOS Ocean Sciences Meeting*, New Orleans, LA, February 21-27, 2016.

Maureen T. Brooks is in the third year of her Marine-Estuarine Environmental Sciences Ph.D. studies at University of Maryland. She expects to graduate in the spring of 2018 and wishes to pursue a career at the interface between applied science and resource management.

"Ideally, I would like to conduct applied research that will better inform marine resource policy. The Blue Waters Fellowship has opened doors for me by providing firsthand experience with the high-performance computing resources necessary for cutting-edge science in oceanography. This experience has directed me to choose a career that will allow me to help ensure that advances in scientific understanding are translated into the best management of our shared natural resources."