Evaluating ecosystem change in the Gulf of Maine using biogeographic regions derived from satellite observations of sea surface temperature and chlorophyll concentration

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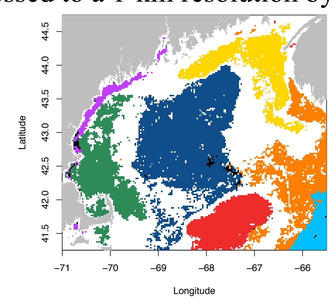
Anthropogenic climate change can alter the vertical structure of the ocean by changing the nature of thermal- and salinity-induced stratification. Changes in stratification often cause changes in phytoplankton communities due to the influence that stratification has on phytoplankton bloom dynamics. Since phytoplankton are at the base of the oceanic food-web, any significant change to their abundance, distribution, or phenology can impact the whole ecosystem through a bottom-up trophic cascade. The Gulf of Maine (GoM) is particularly sensitive to hydrographic climate forcing due to its location in the northwest Atlantic Ocean at the confluence of two major ocean currents, and therefore may be subject to a large degree of ecosystem change.

To assess if any trends or patterns in ecology exist in the GoM, an ecological context is needed to analyze the data. Biogeographic regions, regions that display like biogeochemistry, provide this context and are well-established within the field of biological oceanography[1]. These regions are defined principally through differences in annual cycles of physical and biological properties deemed important to ecosystem structure. Remotely sensed sea surface temperature (SST) and chlorophyll (Chl) concentration serve as good proxies for these properties and can therefore be used as the basis for biogeographic region classification[2].

The data used in this project was collected by the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the NASA Aqua satellite, which provides daily SST and Chl concentration data processed to a 1-km resolution by the University of Delaware since July 3, 2002. From this data we created 3-km resolution monthly averages and computed the anomaly, mean subtracted, and normalized values for SST and Chl concentration. Empirical Orthogonal Function (EOF) analysis was then performed on these time series, and biogeographic regions were identified from spatial patterns of temporally coherent variability. The original 3-km monthly data was then spatially averaged by region to look for trends and patterns in the data and compare the results between regions.

Seven biogeographic regions were successfully identified in the GoM from EOF modes representative of ecological factors (Fig. 1). Common among all of these regions is a warming trend, 0.08 – 0.13 °C/yr within the GoM and 0.21 °C/yr in the light-blue region closest in proximity to the Gulf Stream (Fig. 2a). The smoothed and detrended SST anomaly time series show that this Gulf Stream region leads the others from 2002 to 2008, is temporally correlated from 2008 to 2012, and lags the others from 2012 to 2017, clearly defining three intervals within the warming trend (Fig. 2b). Despite the observed warming, there are no significant trends in the timing and magnitude of phytoplankton blooms in the regions. However, the annual average chlorophyll concentration anomaly time series exhibits negative biomass values in the first time interval, anomalously high biomass in the second interval, and an east-west gradient in biomass in the third interval with negative biomass in western regions (Fig. 2c) and positive biomass in the eastern regions (Fig. 2d). This relationship between Chl concentration and physical dynamics suggest a growing influence of salinity-induced stratification on phytoplankton blooms within the GoM[3]. In-situ data of physical properties spanning an east-west transect of the GoM are needed to validate the mechanisms behind the observed spatial heterogeneity and interannual variability in phytoplankton biomass.



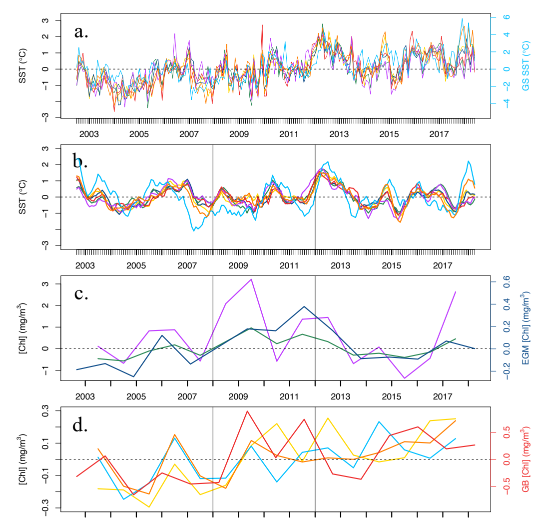


Figure 1. (Top) Locations of the seven biogeographic regions within the GoM derived from EOF modes of SST and Chl data.

Figure 2. (Bottom) SST and Chl concentration anomalies plotted by biogeographic regions throughout the 16-year time series. Colors correspond to the regions in Fig. 1. (a) The raw SST anomaly time series. (b) The smoothed and detrended SST anomaly timeseries. (c) Annually averaged Chl concentration anomalies for the western GoM regions. (d) Annually averaged Chl concentration anomalies for the eastern GoM regions.

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References:

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