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Stratification on the Northwest Atlantic Shelf: Patterns, Drivers and Implications for Plankton Production

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Summary

In this study, both observation data and hydrodynamic model results were analyzed to assess the spatio-temporal patterns of stratification on the Northwest Atlantic Shelf (NWAS). One of the focuses was to identify the main drivers of stratification variability and the relative contribution of thermal vs. haline component in different regions of the NWAS. In addition, links between the variability of stratification and plankton dynamics were discussed. Our results suggest that, over the interannual time scale, the wind-driven variability of the Nova Scotian Shelf (NSS) water inflow affects the surface salinity anomaly pattern and the onset timing of stratification in the Gulf of Maine (GoM); whereas the local heating plays a more important role in the onset of stratification in the Mid-Atlantic Bight (MAB). Stratification variation is associated with the changes in the plankton community structure in the region.

Introduction

Stratification has long been recognized to affect the recruitment variability of fish populations. Observational and modeling studies have suggested that changes in the intensity of stratification modify prey fields for fish through changes in plankton community structure and productivity, and thus alter fish habitat at successive life stages (Greene and Pershing, 2007; Ji et al., 2007). Climate-related warming and freshening are considered the major drivers for the variability of stratification. On continental shelves, additional physical factors, such as wind, topography and river discharge, could affect the temporal and spatial variability of stratification (Loder et al., 2001; Castelao et al., 2010; Gong et al., 2010). A combination of observation and modeling approaches is often needed to assess the patterns, drivers of stratification and its potential impact on plankton production and ecosystem dynamics.

Material and Methods

Both in-situ ocean observations and model results were analyzed. The observation data are from (1) long-term continuous plankton recorder (CPR) surveys along two monthly transects off the east coast of the US; (2) SeaWiFS-derived concentrations of major phytoplankton functional groups (1997-2010) based on Pan et al. (2011)'s chemotaxonomic analysis; and (3) SeaWiFS-derived 8-day composite of chlorophyll concentrations (1997-2010), gap-filled using a spatio-temporal kriging approach. Using datasets (1) and (2), the occurrence of diatom was assessed. Using dataset (3), the timing of phytoplankton blooms (e.g. onset and peak dates) was calculated. Results from a data-assimilative 3D circulation model (FVCOM) were used to provide highresolution estimates of stratification on the NWAS. The total stratification is measured by the surface-to-50m Brunt–Väisälä frequency $N^2 = (-g/\rho)(\partial\rho/\partial z)$ and is decomposed into thermal $N_t^2 = (-g\alpha)(\partial T/\partial z)$ and haline $N_s^2 = (-g\beta)(\partial S/\partial z)$ components.

Results

The model-based estimates were compared with hydrographic survey data in the region (39194 sites, 1978-2010). The model performed well in hindcasting key variables of water temperature, salinity and stratification, with model-data correlation coefficients above 0.90 and model skills above 0.93.

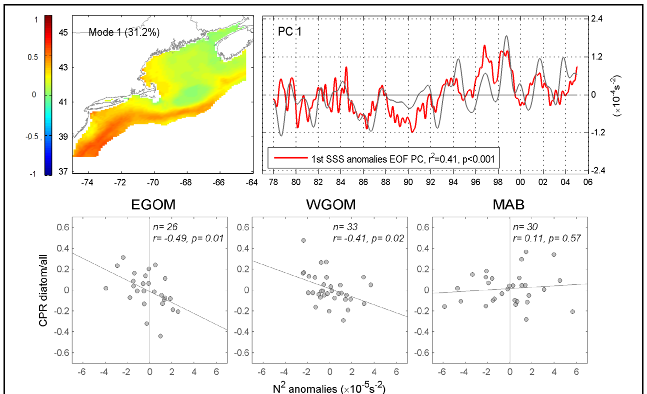

Figure 1. (top) the 1st EOF mode and PC of stratification anomalies. (bottom) the correlation between diatom occurrences and stratification anomalies in the eastern GoM (EGOM), the western GoM (WGOM) and the MAB.

A climatology of stratification was constructed from the 33-year model results. In the NWAS region, the total stratification N^2 peaks once a year and appears to follow seasonal cycle of heat flux, with a 0.5-month lag from south to north. N_t^2 decreases from south to north, with negative values from December to April. N_s^2 peaks once a year in the NSS–GoM region, with the GoM lagging the NSS by about 3-4 months. In the MAB, N_s^2 peaks twice a year and the early peak in summer appears to be associated with freshwater input from major rivers. The ratio of thermal versus haline shows that the local heating is more important than freshening for the onset of stratification in the MAB.

The stratification on the NWAS also displays significant interannual variations. Its dominant Empirical Orthogonal Function (EOF) mode is largely explained by the interannual and decadal changes of Sea Surface Salinity Anomalies (SSSA) (Fig. 1). The wind-driven variability of the fresher water inflow from the NSS is the main driver of the surface salinity variability in the GoM. Both CPR and satellite data show that diatom occurrences are inversely correlated with stratification anomalies (Fig. 1), suggesting that changes in stratification may alter environmental conditions (i.e. turbulence, nutrients) that favor specific phytoplankton groups.

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