Simulating Temporal Variations in Nutrient, Phytoplankton, and Zooplankton on the Inner Oregon Shelf

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Abstract

We used a nutrient-phytoplankton-zooplankton model coupled to a two-dimensional circulation model of the Oregon shelf to examine the role of physical processes in determining temporal variations in nitrate, chlorophyll-*a*, and copepod biomass. During the 1999 upwelling season, temporal variations in nitrate, chlorophyll-*a*, and copepod biomass at NH-5 were related to variations in wind stress, suggesting bottom up controls. During the 2000 upwelling season, the model reproduced temporal variations in temperature, nitrate, and chlorophyll-a; however, the model did not reproduce variations in copepod biomass. Model simulations suggest that temporal variations in nitrate, chlorophyll-*a*, and copepod biomass at NH-5 are related to variations in coastal wind forcing, rather than offshore wind forcing.

1. Introduction

Along the Oregon coast, upwelling primarily occurs between April and September. During this period, upwelling occurs as intermittent events with time scales on the order of days. Variations in physical forcing results in differences in supply of nutrients to the euphotic zone that drive variations in phytoplankton and zooplankton. The complexity of the processes and the variability of the forcing result in high degree of spatial and temporal variability, which makes it difficult to interpret observations.

The objective of this study is to use a numerical model as a tool to interpret observations (nitrate, chlorophyll-*a*, and copepod biomass) on the inner shelf of an upwelling region. We will examine the role of meteorological variability in determining temporal dynamics of nutrient, phytoplankton and zooplankton in the inner shelf. This study will focus on variability occurring on time scales ranging from days to years.

2. Approach

In this study, we used a simple three component ecosystem (nutrient-phytoplankton-zooplankton) model coupled to a two-dimensional primitive equation circulation model (based on Edwards, *et al.,* 2000). The model is configured to represent the topography off of Newport, OR and extends 200 km offshore and 200 m deep. We simulated the upwelling season (May - September) for 1999 and 2000. Time-dependent, spatially uniform wind stress was applied using 10-minute wind observations. To examine the effect of spatial variations in wind stress associated with the presence of the coast, simulations were performed using wind observations from offshore (Station 46050 located at the 130-m depth contour) and a coastal site (Station NWPO3 at the coast). A constant surface heat flux of 166 W m^{-2} was imposed based on Allen, *et al.* (1995).

Time-dependent solar irradiance was specified for light-limited nutrient uptake using Brock (1981). The model was initialized with observed temperature profile which was assumed to be uniform in the cross-shelf direction. The vertical structure of the initial nutrient concentration was initialized using a temperature versus nitrate relationship based on observations from the Newport line. Model parameters were chosen based on publish values when available and previous modeling studies. Simulated temperature, nitrate, phytoplankton and zooplankton biomass were compared to observations from NH-5 (Depth ≅ 60 m).

Table 1. Parameters used in study

Variable	Value	Source
Maximum phytoplankton growth rate	2 d^{-1}	Kokkinakis and Wheeler (1987)
Half saturation constant for nitrate uptake	1 μM	Dickson and Wheeler (1995)
Phytoplankton sinking rate	1 m d^{-1}	
Phytoplankton mortality rate	0.1 d^{-1}	
Maximum grazing rate	0.6 d^{-1}	
Half-saturation constant for grazing	3.0 μM	
Zooplankton mortality (quadratic)	0.05 (μM d)$^{-1}$	
Assimilation efficiency	0.3	
Horizontal eddy viscosity/diffusivity	2 m^2 s^{-1}	

3. Results

Figures 1 and 2 show time-series of modeled surface temperature (A), surface nitrate (B), surface phytoplankton biomass (C), and depth-averaged zooplankton biomass at NH-5 for 1999 and 2000.

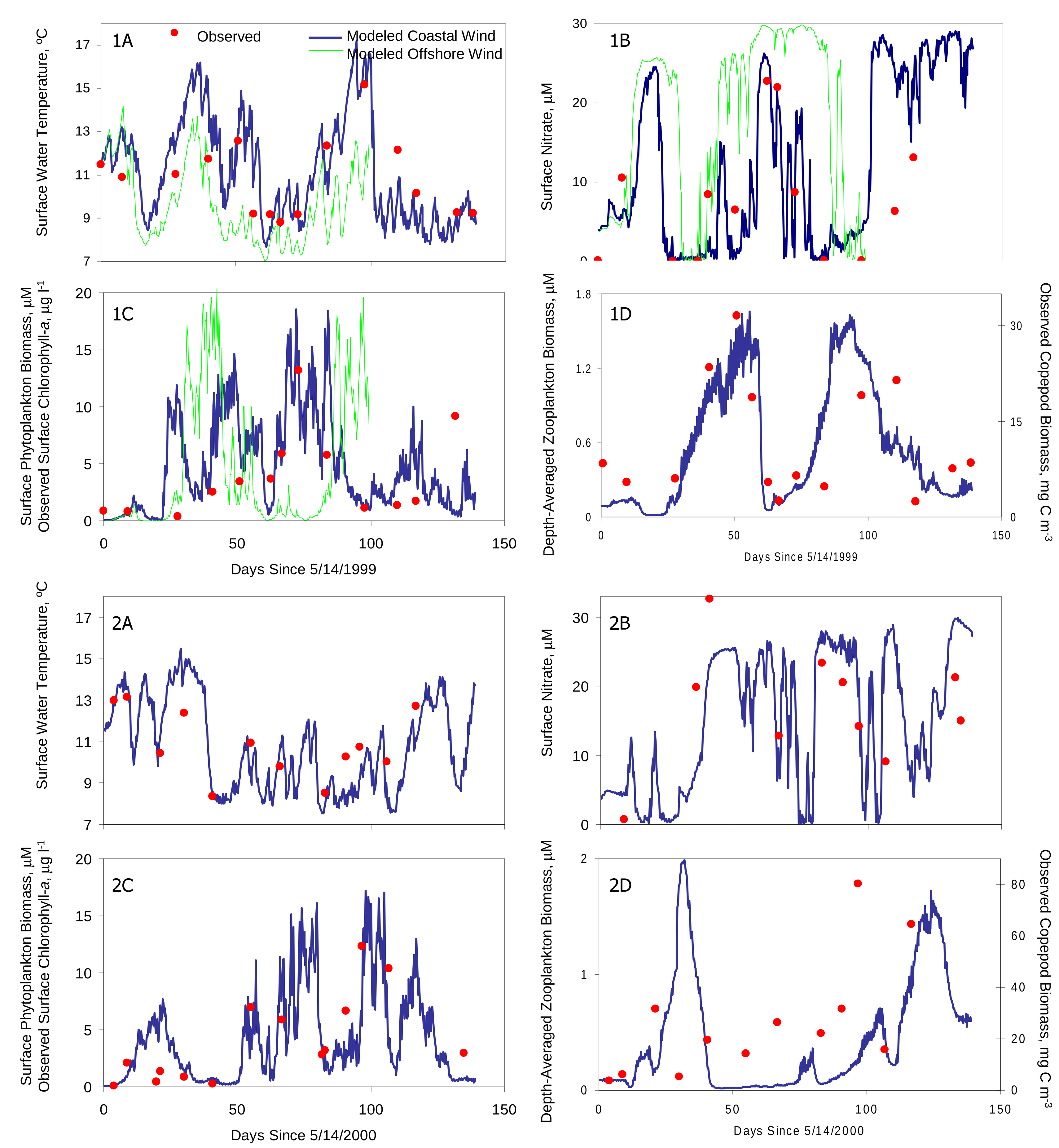

Table 2. Mean values of simulated temperate, nitrate, phytoplankton, and zooplankton biomass.

Year	Surface Temperature (ºC)	Nitrate (μM)	Phytoplankton (μM)	Zooplankton (μM)
1999	11.2	12.3	4.8	0.6
2000	10.7	15.1	4.2	0.4

4. Conclusions

Although the model is a simplification, it is able to reproduce a substantial amount of the temporal variability in the observations at NH-5. The agreement between the model and observations suggests that the variations in temperature, nitrate, chlorophyll-*a*, and copepod biomass are primarily determined by variations in wind stress, suggesting bottom up controls. In addition, the model simulations suggest that temporal variations in nutrient, phytoplankton, and copepod biomass on the inner shelf (NH-5) is primarily determined by local forcing and cross-shelf circulation patterns.

During the 1999 upwelling season, temporal variations in nitrate, chlorophyll-*a*, and copepod biomass were associated with temporal variations in physical forcing. For the 2000 upwelling season, the model reproduces temporal variations in temperature, nitrate, and chlorophyll-a; however, the model does not reproduce the patterns observed in copepod biomass or the occurrence of high pulses in biomass. This suggests that during the 2000 season copepod biomass was determined by other factors, such as top down controls or advection of zooplankton from other regions. Comparison of model simulations performed using offshore and coastal wind forcing suggest that temporal variations in observations at NH-5 are related to coastal wind forcing. Model simulations performed using offshore wind forcing had colder surface water temperature and higher nitrate levels than observations, suggesting that the wind stress was too strong. The mean values of simulated temperature, nitrate, phytoplankton and zooplankton biomass for 1999 and 2000 were approximately equal.

The success at reproducing temporal variations at NH-5 suggests that using a NPZ model coupled to a physical model may be a useful tool for interpreting observations in this highly variable region. The key to the success of the this modeling study was the availability of high resolution time-series data.

Future Work

Determine what processes are controlling variability and what causes events.
Examine interannual variations (1998 - 2001).
Compare to observations from NH-5, NH-10, NH-15 and MiniBAT surveys to examine spatial variability.
Use observed surface irradiance for light limitation of primary production.
Sensitivity analyses (parameters and initial conditions).
Use model to examine integrated primary and secondary productivity.

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