Spring Bloom on Central Georges Bank in 1999: Its Origin and Fate

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Abstract

The possible sources and transport time scales of water parcels on the central portion of Georges Bank (inside 60-m isobath) have been estimated to examine the origin and fate of the spring phytoplankton bloom in that region. An "off-line" Lagrange particle trajectory approach was used in this study. The hydrodynamic flow field was interpreted from hourly model outputs of FVCOM (Finite Volume Coastal Ocean Model), which was driven by the realistic meteorological forcing from MM5 model output, with inclusion of SST and observed current velocity data assimilation. Particle trajectory results show that the "blooming" water in the southern part of the central bank during February and March was mainly from the northern edge of the bank, and was relatively older than the "non-blooming" water in the north. The water parcels on the central bank had an average exposure time (time spent inside the 60-m isobath) of about 20 days, and tended to leave south- or southwest-ward. Moreover, particle trajectory results also suggested that, for 1999, the phytoplankton bloom on the central bank had a limited potential contribution as food source for zooplankton population in the deeper flank areas.

Introduction

The spring phytoplankton bloom on central Georges Bank usually occurs earlier than that in the surrounding deeper regions. The broad-scale survey on Georges Bank during spring time 1999 showed such a typical pattern of spatial and temporal variation (Figure 1). It is believed that shallow water depth in the central well mixed portion of the bank satisfy the Sverdrup critical depth relationship earlier than the deeper region and make it a favorable area for the growth of phytoplankton. A few interesting questions raised from the observation data are:

- why does the southern part of the central bank tend to bloom earlier than the rest of that area during 1999?
- was the bloom in the central bank a single 3-month-long bloom or did it consist of multiple blooms (e.g. "chemostatic" or "batch-culture" type of system)?
- what was the contribution of the spring bloom to the deeper flank area where the secondary productivity is of interest?

To address these questions, an attempt was made to identify the possible origin and fate of the spring bloom by tracking the particle trajectory and calculating the time scale of transport for the water parcels in the central bank.

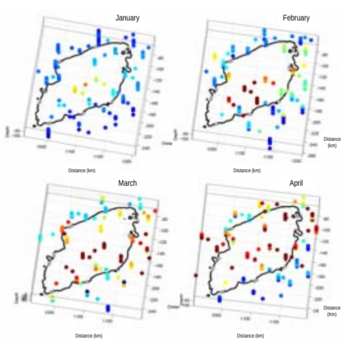


Figure 1. The temporal and spatial variation of chl-*a* concentration during spring, 1999. The position of each dot indicates the location and depth of the water sample and the color indicates the concentration.

Methods

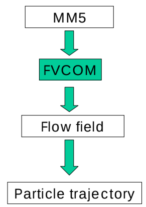
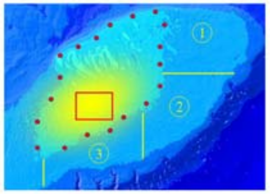


Figure 2. The schematic of the modeling approach. The Finite Volume Coastal Ocean Model (FVCOM) is driven by the realistic wind and sea surface heat flux forcing output from a meteorological model (MM5), with inclusion of SST and observed current velocity data assimilation. The model provided the hydrodynamic fields for the Lagrange particle trajectory experiments.

"Offline" Lagrangian particle tracking uses the 3-D velocity fields generated from FVCOM to solve the follow equation,

$$\frac{d\vec{x}}{dt} = \vec{v}(\vec{x}(t), t)$$

where $\vec{x}$ is the particle position at a time t, and $\vec{v}$ is the velocity interpolated from the surrounding model grids in space and from hourly model output in time. The equation is solved by a classic 4th order 4-stage explicit Runge-Kutta method with a time step of 2 minutes.



The following information is derived from the particle trajectory experiments:

1. Source and age of water parcels

Particles were released in the middle depth from the edge of the 60-m isobath on January 1, 1999 (Figure above) and samples were taken on year day 45, 75 and 100. The time for each particles spent inside the 60-m isobath is calculated as the relative age of water parcel. The source of the water parcels inside the red square is identified by tracing back its original location of release.

2. Residence time and exposure time of water parcels:

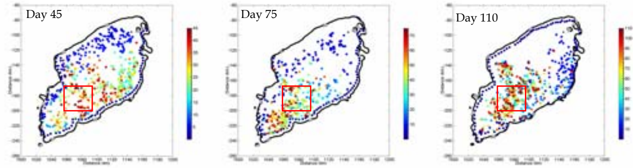
Particles were released inside the 60-m isobath. Residence time is how long a water parcel will remain inside the 60-m isobath before exiting. Exposure time is the total time for each particle spent inside the 60-m isobath. Different from residence time, exposure time allows the water parcels to exit and re-enter the domain.

3. Relocation of water parcels

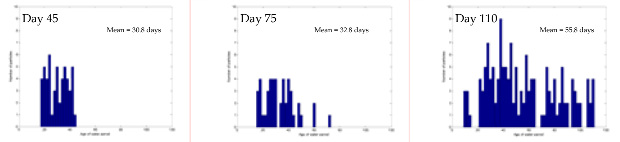
Particles were released inside the 60-m isobath. The percentage of particles moved to a pre-defined zone is recorded to estimate the relocation of the water parcels from the central bank to the flank area between the 60- and 100-m isobaths, which is divided into three zones labeled 1, 2 and 3 in the figure above.

Results

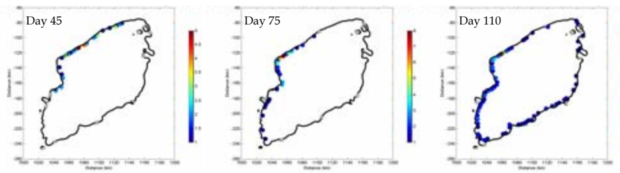
- Age distribution of water parcels inside the 60-m isobath (particles were sampled on day 45, 75, and 110).

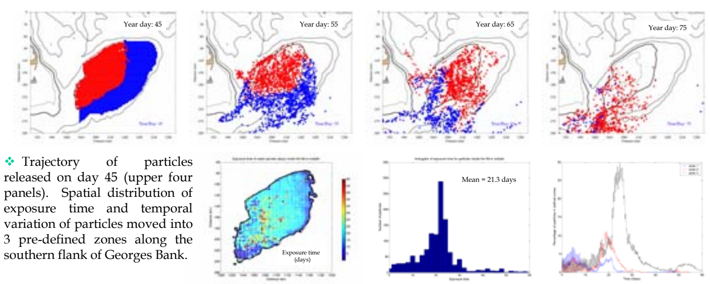


- Histogram of age distribution for water parcels inside the red square (particles were sampled on day 45, 75, and 110).

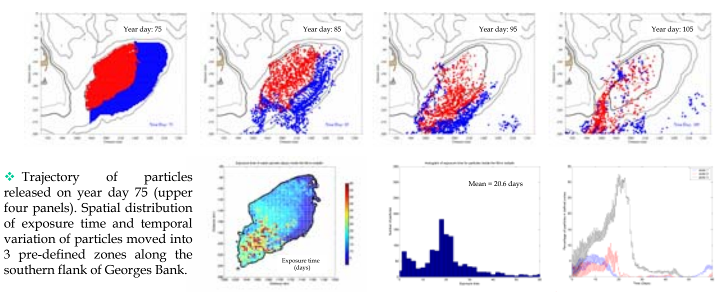


- Source of water parcels inside the red square. Colored dots along the edge of the 60-m isobath indicate the location and number of particles that were initially released.





- Trajectory of particles released on day 45 (upper four panels). Spatial distribution of exposure time and temporal variation of particles moved into 3 pre-defined zones along the southern flank of Georges Bank.



- Trajectory of particles released on year day 75 (upper four panels). Spatial distribution of exposure time and temporal variation of particles moved into 3 pre-defined zones along the southern flank of Georges Bank.

Summary

- Particle trajectory results show that the "blooming" water in the southern part of the central bank during February and March 1999 was mainly from the northern and northwestern edge of the bank and was relatively older than the "non-blooming" water in the north. The "blooming" water in the northeastern part of the central bank during April was probably advected directly from the Gulf of Maine.
- The water parcels on the central bank during February and March 1999 had an average exposure time of about 20 days, and tended to leave south- or southwest-ward, suggesting that the phytoplankton community is exposed to a system better described as "chemostatic" instead of "batch-culture" type.
- During February and March 1999, less than 10% of particles moved from the central bank (inside the 60-m isobath) to the southeastern (zone 2) and southern (zone 3) flanks of the bank, while about 30% of particles moved to the Northeast Peak (zone 1). These results indicate that the phytoplankton bloom on the central bank may have a limited potential contribution as a food source for zooplankton population in the deeper flank areas.

On-going work

- Include random walk for horizontal and vertical diffusion processes.
- Release particles at multiple vertical layers at different times in one tidal cycle.
- Perform passive tracer experiments and conduct comparisons with particle trajectory experiments.
- Extend this approach to the zooplankton/fish larvae study (including using Video Plankton Recorder data).

Acknowledgement

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