Nutrient Supply to the GOA Shelf in Summer: The Role of Troughs and Shallow Banks

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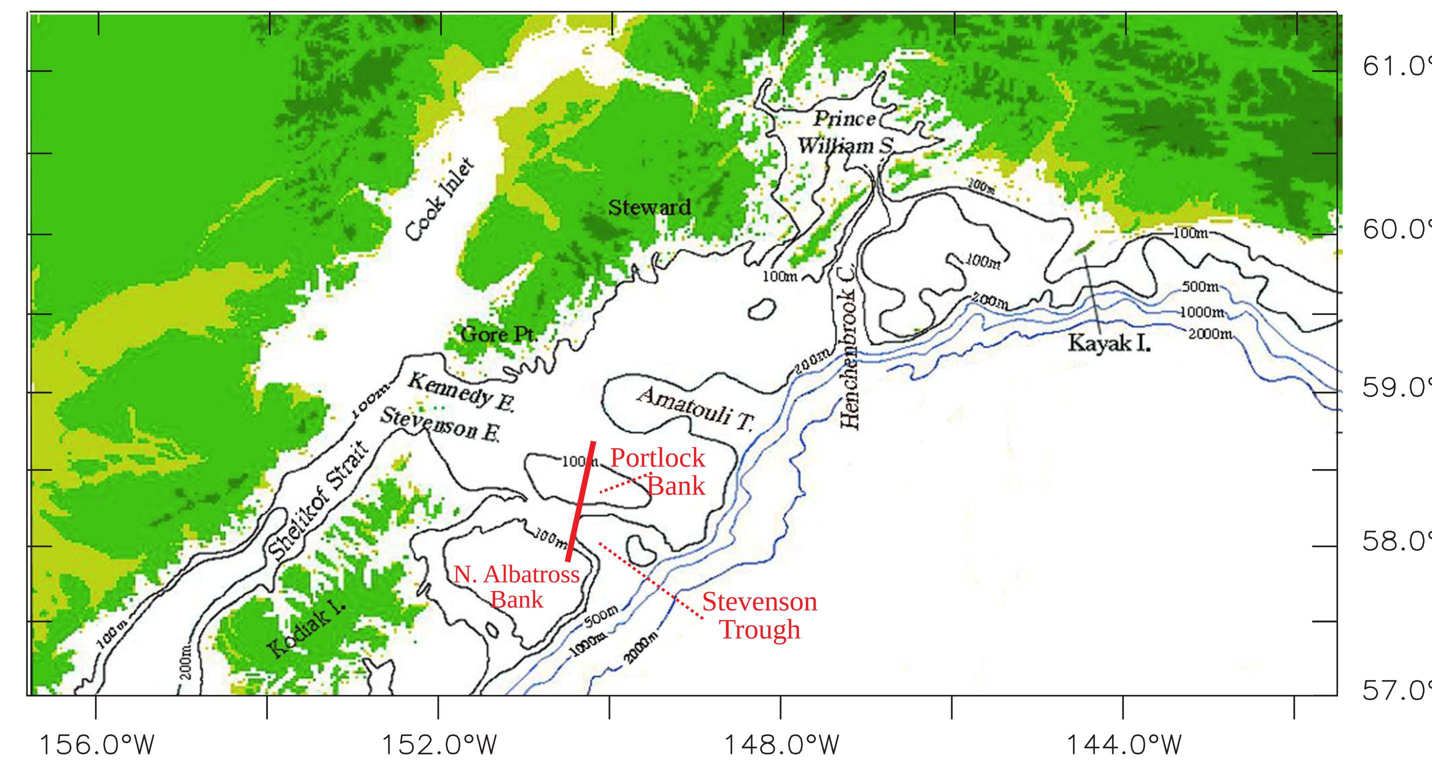
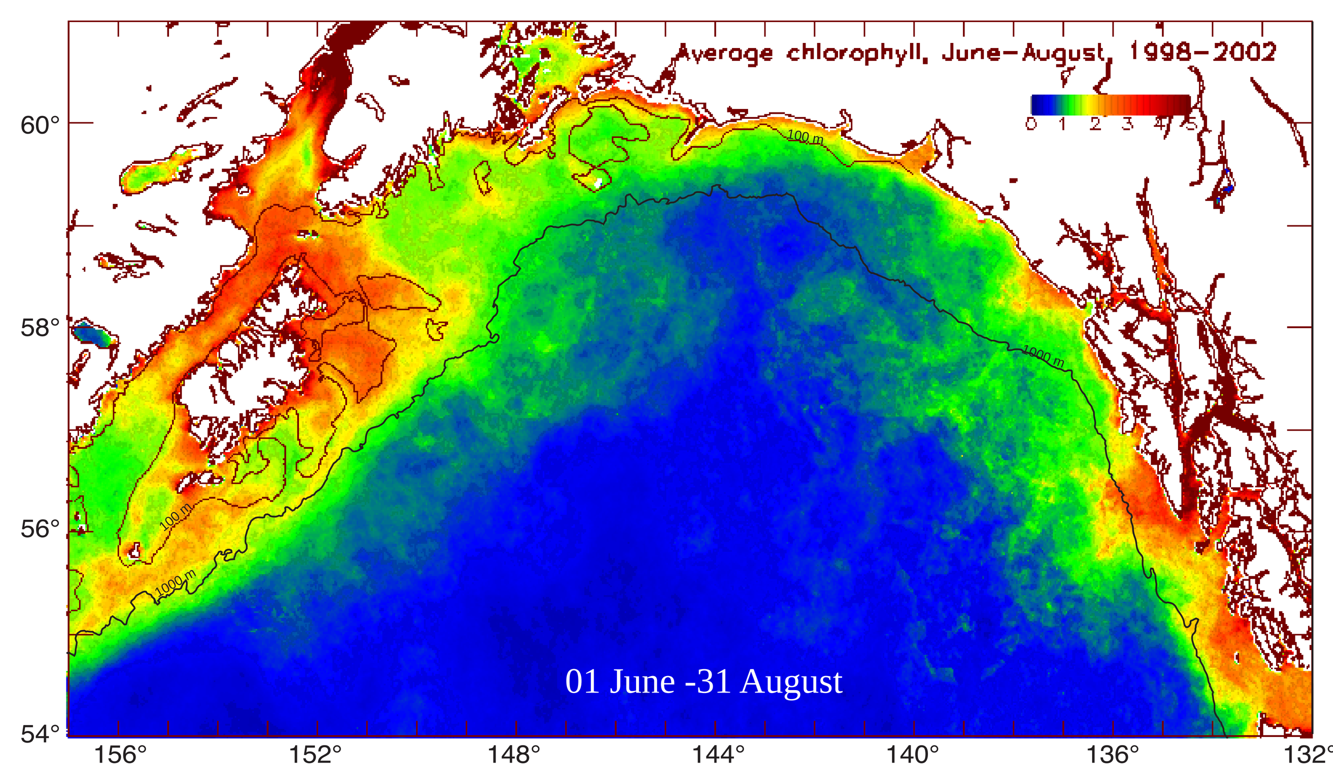
ABSTRACT

Although predominantly a downwelling system, the Gulf of Alaska shelves support a rich and complex ecosystem. The mechanisms that support this productivity are unresolved; however, observations collected as part of NEP GLOBEC provide new insight into these mechanisms.

In summer, satellite imagery of ocean chlorophyll distributions indicate higher productivity in the vicinity of Kodiak Island relative to other surface shelf-waters in the Gulf of Alaska. The bathymetry to the south and east of Kodiak Island is characterized by multiple banks and troughs. We hypothesize that nutrient-rich slope water is advected onto the shelf through canyons, and introduced into the euphotic zone by mixing over the banks. This mechanism is particularly important in summer, when the water column is strongly stratified and surface waters largely depleted of nutrients. Hydrographic transects during four cruises in 2001 and 2002 that focused on Portlock Bank, a shallow (~50m), broad plateau to the east of Kodiak Island, support this hypothesis. These transects revealed that the water column over the banks was well mixed and enriched with nutrients compared to surrounding waters.



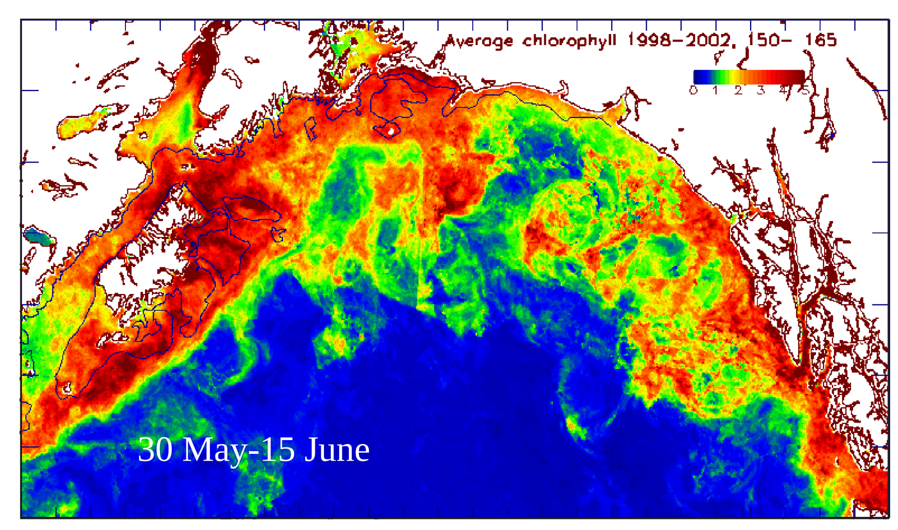


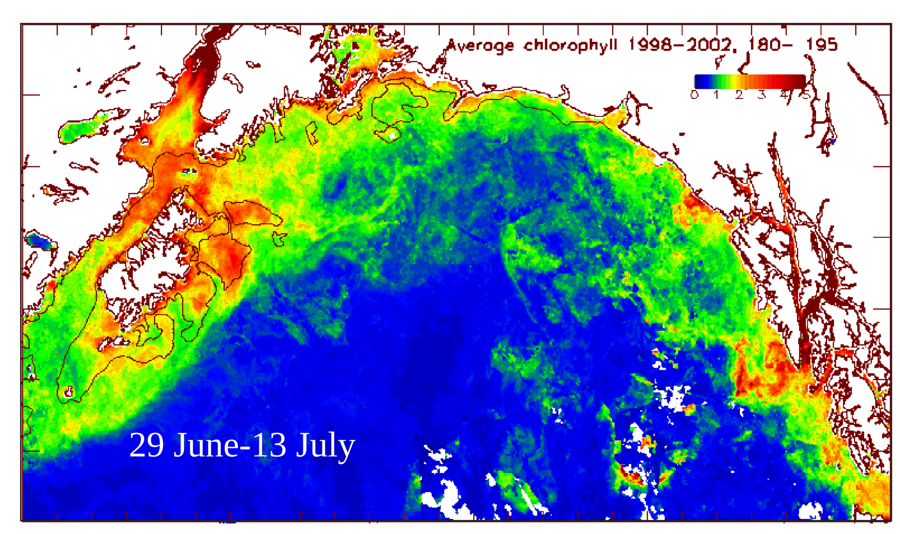
These are chlorophyll-a composites derived from SeaWiFS satellite images. Average chlorophyll concentrations during summer were greatest over the shallow banks.

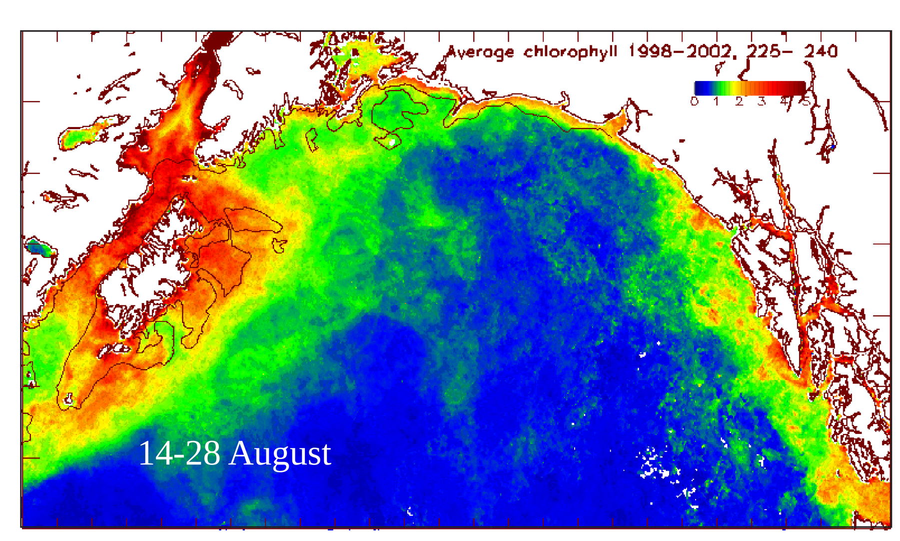
To examine the spatial patterns of surface chlorophyll-a in summer, a composite image was created using SeaWiFS L1A data. We averaged non-cloudy pixels from summer (June 15-August 30) images collected in 1998-2002. Pixels at high zenith angles (>60°) or within two pixels of land or clouds were excluded. We did not exclude pixels where turbidity was high. The SeaDas level-2 processing flagged turbidity in the near coastal (i.e., orange area east of Prince William Sound) and in Cook Inlet, but rarely elsewhere. High turbidity can either mask or enhance chlorophyll.

There is a marked difference between chlorophyll concentrations around Kodiak Island and elsewhere in the GOA. During summer, surface chlorophyll production in the GOA was concentrated over the shallower banks south and northwest of Kodiak Island, and in Shelikof Strait. Concentrations along the Kenai Peninsula are markedly less than those observed farther west, indicating there was not a persistent infusion of nutrients into the surface mixed layer during summer in these low concentration areas. A large portion of the shelf east and south of Kodiak Island is shallow and may be susceptible to significant tidal mixing. In contrast, the shelf east and south of Kenai Penninsula is deeper, with only a few small shallow banks.

The time sequence of chlorophyll-a is shown in the three adjacent panels. The remnants of the spring phytoplankton bloom is evident in the top panel. In the lower two panels, high chlorophyll is only evident over shallow banks.

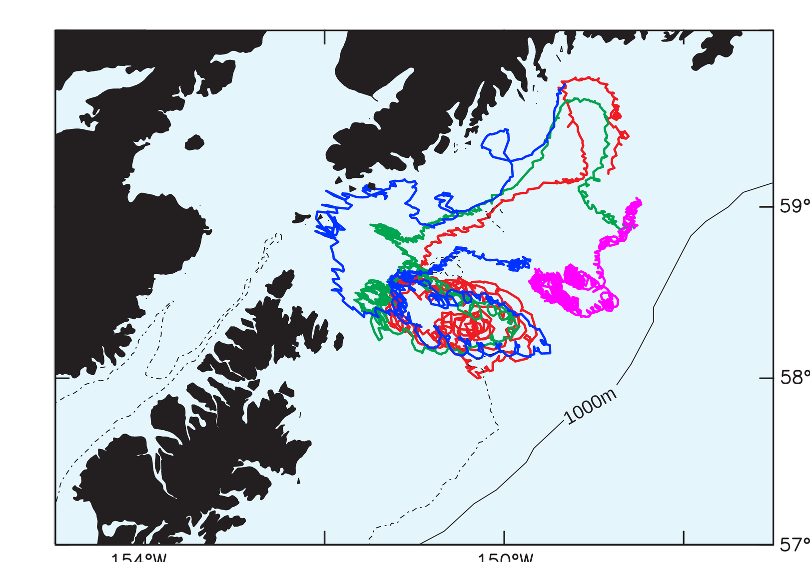


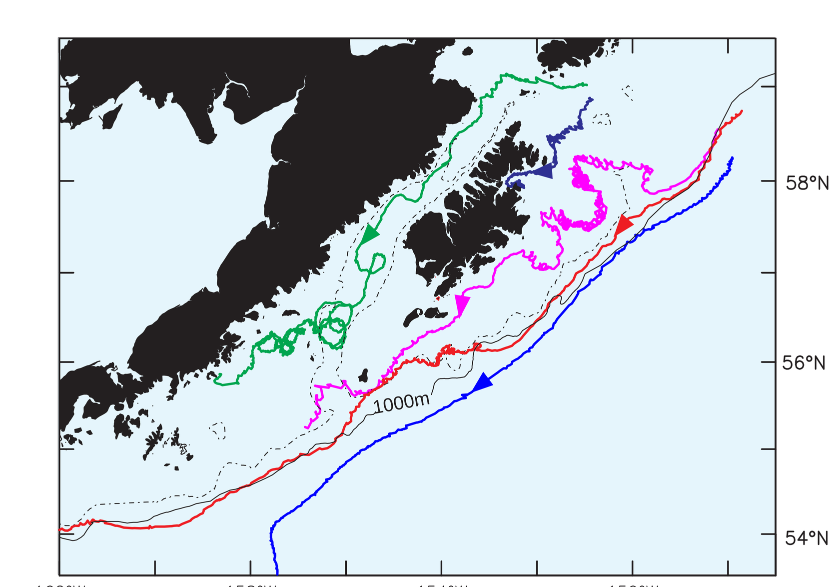


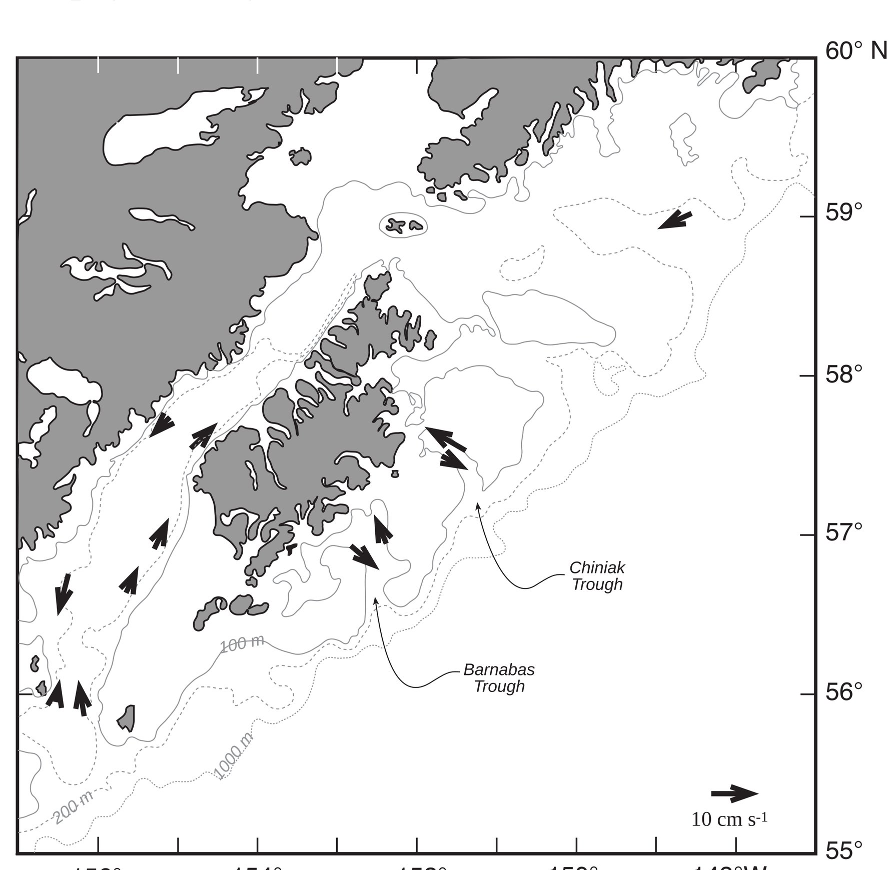


Satellite-tracked drifters (drogue depth 40m) in the vicinity of Kodiak Island. Drifters trajectories were influenced by bathymetric features.

Drifters deployed on shelf were often entrained into the circulation over Portlock Bank (upper panel). These drifters would then remain over the bank for periods of weeks to months. While most of the drifters deployed over the shelf break were transported southeastward by the Alaskan Stream, some (e.g. purple trajectory in lower panel) moved onshore along the eastern side of Stevenson Trough and offshore on the western side. It was also influenced by Chiniak Trough.





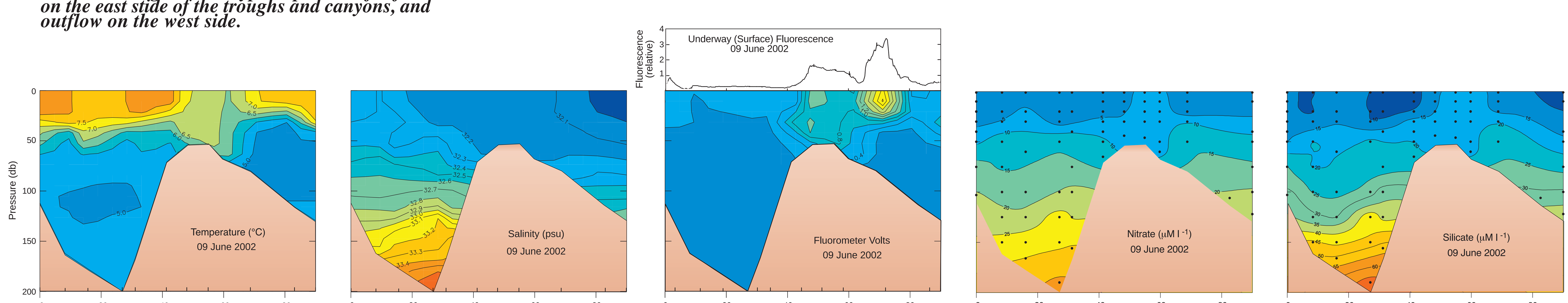


Near bottom currents measured from current meter moorings show a typical pattern of inflow on the east stide of the troughs and canyons, and outflow on the west side.

Hydrographic sections across Portlock Bank. These sections show increased mixing, nutrients and chlorophyll in the vicinity of Portlock Bank.

By early June, seasonal heating has stratified the upper 50m over the deeper parts of the shelf. Over Portlock Bank, however, the water column is well-mixed or weakly stratified in both temperature and salinity. This is likely a result of tidal mixing, which is enhanced over the banks. As a result of this mixing, near-surface nutrient concentrations over the banks are higher than in the surrounding water. There is low fluorescence over the deeper water and higher fluorescence over the banks. The highest fluorescence occurs to the east over the slope of bank. Two possible mechanisms are 1) the stronger stratification over the edge of the bank enhances production by keeping phytoplankton in the euphotic zone; or 2) advection of production from the center of the bank to the edges. The drifter trajectories indicate that at 40m there is limited exchange of water between the bank and surroundings.

We suspect that the increased nutrients over the bank are sustained throughout the summer by intrusions of nutrient rich water through near bottom mechanisms onto the banks. Nutrients are advected onto the shelf by up-canyon flow (see figure of bottom currents and lower panel of drifter trajectories). The rich nutrients observed below 50 m are then injected onto the bank through up-slope bottom processes, and then mixed by tidal currents. Thus sustained new production (as observed in the satellite images) occurs all summer.



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