Dickey et al., 1998a; Chang et al., 2001). These oscillations act similarly to tidal processes and have been reported to pump nutrients from below the mixed layer into the euphotic zone where they can be utilized by phytoplankton (McNeil et al., 1999). Persistent winds influence upwelling and downwelling and hence nutrient availability, which is often seasonally important to coast-wide and regional ecology and HABs (see Section X.2.4). Mesoscale features (scales of days to months and tens of km) include, but are not limited to: fronts (Figure X.4; Barth et al., 1998), jets (Chang et al., 2002), and eddies (e.g., McNeil et al., 1999). These physical processes can enhance or inhibit nutrient and particulate movement and hence phytoplankton bloom formation and termination (see Franks, 2005). Longer term and larger scale physical forcing associated with equatorial processes (El Niño-Southern Oscillation, ENSO; e.g., Chavez et al., 2002) and other decadal-scale processes around the earth (North Atlantic Oscillation, NAO, Pacific Decadal Oscillation, PDO, and others) can also have impacts on the coastal ocean through alterations of ocean-atmosphere interactions and nutrient and light availability.

Figure X.3
Time series of (a) current velocity at 0.38 meter above the ocean bottom (mab; u_{cx} = east-west currents, u_{cy} = north-south currents), (b) beam attenuation coefficient at 2 mab (660 nm), and (c) chlorophyll-*a* concentration at 2 mab during the passages of Hurricanes Edouard (2 September) and Hortense (14 September; 'E' and 'H', respectively) during fall 1996. These data show (a) storm-induced oscillations and intense mixing followed by (b and c) resuspension of sediments and relict pigments. All data were collected on a mooring off the coast of Cape Cod, Massachusetts in 70 m water depth.

Figure X.4
(a) Time series contour plot of chlorophyll-*a* concentration. The increase on Year Day 239 (26 August 1996) was due to convergence of phytoplankton at a shelf-slope front just south of Martha's Vineyard, Cape Cod, MA. (b) Phytoplankton absorption spectra deconvolved from *in situ* optical measurements of the total absorption coefficient (following Roesler et al., 1989) during "normal" conditions (red pluses) and during an intrusion of a shelf-slope front (blue circles), indicating an increase of diatoms. Diatoms can be discerned from other phytoplankton species by their marker pigment, fucoxanthin, which has a peak in phytoplankton absorption at about 450-470 nm (Jeffrey et al. (ed.), 1997). Data were obtained on a mooring in 70 m water depth.

Some examples of studies that have investigated physical processes and their roles in HABs follow. Tester and Steidinger (1997) found that blooms of the toxic dinoflagellate, *Karenia brevis* (formerly *Gymnodinium breve*; neurotoxic shellfish poisoning; e.g., Anderson, 1995), on the West Florida Shelf (WFS) are closely coupled with physical processes. Shoreward movements of the Gulf of Mexico Loop Current or spin-offs of eddies from the Loop Current often trigger *K. brevis* blooms on timescales of