Project Outline for EEOS 465/627
March 24th to May 12th (7 weeks)

Modeling riverine carbon monthly flux from Neponset River Watershed to the ocean

1. Background

The global carbon cycle is important in the global climate system. The terrestrial ecosystem is one of the major reservoirs for carbon. This reservoir interacts with other carbon reservoirs through processes of riverine flux to the sea, removing CO_2 from atmosphere and releasing CO_2 into the atmosphere. These processes involve photosynthesis of land biota, respiration of microorganisms in the soil, respiration of land biota, deforestation and land clearing, and litter fall and below ground losses from plant roots transferring carbon to the soil. Human activities and natural events can significantly alter the changes in the distribution and cycling of carbon among the terrestrial ecosystems, the ocean and the atmosphere. In addition to the carbon exchanges between terrestrial ecosystems and atmosphere reservoirs, the world's rivers deliver about 0.4 gigatons of total organic carbon to the ocean each year (Schlesinger, 1991). Recalcitrant organic compounds in the ocean sequester carbon from active cycles for several thousand years (Williams and Druffel, 1987; Bauer et al., 1992), and can act as a long-term sink for atmospheric carbon dioxide. However, the dynamics of the carbon cycle at the land-sea interface are not well understood due to complex interacting processes, multiple sources of organic carbon, high biogeochemical reactivity in estuaries, and a lack of the high temporal and spatial resolution data needed to assess these fluxes at a global scale during times of rapid (decadal) changes in source and transport mechanisms. In order to understand the global carbon cycle and the fate of anthropogenic carbon dioxide, it is crucial to quantify the sources and transport mechanisms of DOC in the coastal oceans.

Due to physical complexity, the multiple scales of freshwater systems and biogeochemical reactivity at the land-water interface, DOC fluxes, sources and transformations to coastal waters and the open ocean from terrestrial environments such as salt marsh, forest, agricultural, industrial and residential lands are currently not well-known. Changes in the carbon dynamic of the terrestrial ecosystem may have strong correlation with climactic conditions, which affects productivity and decomposition rates, aquatic transport and transformation of carbon, and changes in surface energy budget. DOC in several English estuaries has been shown to act conservatively throughout the year (Mantoura and Woodward, 1983; Alvarez-Salgado and Miller, 1998). On the other hand, several studies on the East Coast of the United States (Fry et al., 1990; Peterson et al., 1994; Winter et al., 1996), especially in tidal estuaries dominated by salt marshes, have shown *in situ* DOC production, and therefore net carbon export from the estuaries. The ensuing debate has continued--some estuaries act as passive transport areas, others as regions of active production of organic carbon, and still others act as net sinks of terrestrial organic matter (Findlay et al., 1992; Argyrou et al., 1997). It is therefore difficult to generalize about the effect of an estuary on the delivery of terrestrial (soil, riverine) DOC to the coastal ocean. Estuarine DOC flows across the entire US eastern continental shelf (Moran et al., 1991; Vlahos et al., 2002), is entrained into major ocean current systems such as the Gulf Stream (Atkinson, 1977; Vlahos et al., 2002) and therefore may represent a major flux of carbon from land to sea. Most estimates of terrestrial DOC fluxes are based on the largest 40 or so rivers in terms of annual water flux; the estimates are usually not from process-based analysis due to lack of sufficient field measurements. Therefore, current estimates have great uncertainty since they can not handle factors such as carbon degradation rates in the transport processes, changes in concentration with hydrological characteristics and land covers and land physical properties. Without the consideration of these factors, the estimation could not analyze the impacts of human activities and natural events on carbon dynamic in terrestrial ecosystems. That means that the majority of the freshwater supplied by smaller rivers and estuarine systems, that, due to higher areas of interaction between freshwater and marine systems, may well supply greater DOC fluxes per liter of freshwater delivered to the ocean. Similarly, the land managements and climatic conditions might change carbon distribution, storage and significantly increase fluxes to sea. What is needed is a more general study of rivers and estuaries on different spatial scales and land physical properties.

Since high DOC concentration doesn't mean high fluxes, a watershed hydrological model can play an important role in estimating carbon fluxes from terrestrial ecosystems. With hydrological characteristics and land cover information, watershed modeling can be used to explain DOC transport processes and to link landscapes to coastal waters. Transports in streams and rivers are one of the major pathways of carbon to coastal ecosystems. Vlahos et al.(2002) reported that concentrations of DOC in estuaries increase towards the mouth of the estuary suggesting that DOC is produced within the estuary or can be increased due to tributaries draining a diversity of watersheds. Also the concentrations of DOC in rivers vary with discharge and biophysical conditions in watersheds. The total DOC inventory on the shelf is higher in autumn than in spring because plant roots transform more carbon to soil and because more litter falls in autumn. However, DOC in-stream degradation, storage and transport are not well understood. Once in the stream channel, both the flux and composition of the various carbon inputs may be modified by complex physical, biological and chemical processes. The physical factors include morphology of stream and river channels and associated hydrology (Moeller et al., 1979). Important biological processes are the breakdown of particulate organic matter due to oxidation and respiration by micro-organisms and invertebrates through scavenging processes (Lock, 1981), and in-stream production through aquatic plants, suspended bacteria, phytoplankton, invertebrate excretion. The chemical processes affecting DOC compounds in rivers include adsorption, precipitation, reduction and complexation (Thurman, 1985). In addition, ecological and hydrological processes in coastal watersheds are more complex because both ground water discharge and surface runoff can contribute a substantial portion to DOC fluxes to the coastal ocean (Moore and Matos, 1999; Taniguchi, 2000). There is clearly a need for incorporating ecological models into a suitable hydrological model for modeling DOC dynamics and transport from landscapes to coastal waters. Such a model would estimate carbon fluxes in different temporal and spatial scales, and can be used to reduce uncertainty of the current carbon estimations from terrestrial ecosystems.

2 Objectives

In this proposed study, we aim to study carbon mass balance dynamics in the terrestrial ecosystem and to model the **carbon sources** and **monthly**/**daily** flux of DOC from landscape to rivers in a coastal environment. The model will associate DOC concentration or flux with land physical biological, climatic and hydrological characteristics. We will quantify the change of carbon concentration and total riverine fluxes to the sea at a regional scale. In addition to mathematical modeling, effort will be complemented by a GIS approach to estimate DOC total fluxes at a river plume region. This proposed research will integrate our previous research results in climate change and carbon cycles, process-based watershed modeling, and *in situ* measurement of biochemical materials in ocean and remote sensing to study carbon cycle in coastal watersheds. The proposed study will answer following questions: 1) What land surface factors affect the variability of organic carbon inventory and runoff rate? 2) Is DOC content associated with human activities and natural disturbances? Our efforts will take advantage of the spatial and increasing temporal coverage of available satellite remote sensing data. The decadal changes of land use in coastal watersheds will be used to study recent environmental changes and their corresponding impacts on DOC distributions in coastal waters.

Specific Objectives

1) To study the variations of DOC concentration (end members) of different land cover types, corresponding to water runoff, seasonal productivity and soil properties, by analyzing discrete measurements over a period of 24 months.
2) To study seasonal trends in DOC flux to coastal waters in the last two decades in the NE region
3) To estimate percentage of the difference of total annual DOC flux due to land cover type changes in the north east region in the past decade. Similarly, we will analyze scenarios for the impacts of climate and LULC changes on DOC flux to coastal water.

3 Study Site

The study site is Neponset River watershed in NE region. A significant portion of the study site is covered by wetlands, forests and agricultural lands. The Neponset River estuary (250 km^2 watershed, ~2 m^3s^{-1} discharge) is a small, urban estuary located in south Boston. The flow varies significantly with season (up to 37 m^3s^{-1} in spring down to <1.4 m^3s^{-1} in the summer) and so provides an excellent system to study seasonal flow effects on DOC flux. UMass Boston's RV Neritic has been used to tow-yo the Mini-Shuttle instrument package from 10 cm to 2 meters depth, and physical processes as well as salt marsh inputs have been observed. A clear seasonal trend in the estuarine production of DOC by salt marsh grasses is apparent. Additionally, variability at the well-defined freshwater endmember, research efforts within the watershed allow access to all of the sub-watersheds and land use types.

Time schedule:

25th March to 8th April:	Conceptual model
8th to 22nd April:	Formulation or implementation
22nd to 29th April:	Verification and Validation
29th April to 13th May:	Preparation for final presentation and final report
13th May:	Final presentation
22nd May:	Final report due