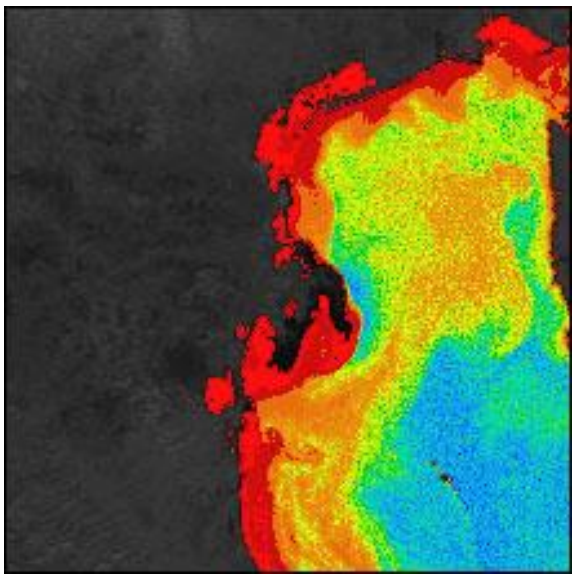
Chapter 10: River Plumes and Estuaries

Since the CZCS mission directed much of the instrument's observing time to the coastal zone, some of the most visible features are the interface where fresh water encounters salt water—where rivers meet the sea. The influx of fresh water (frequently laden with sediments and organic matter) into the oceans induces a variety of physical, chemical, and biological phenomena that show up clearly in many CZCS images.

In Chapter 5, the influence of the Orinoco River on the Caribbean Sea during the rainy season was evident in an October CZCS composite image. The CZCS image shown below, acquired on October 9, 1984, highlights the plume of sediment discharging into the Adriatic Sea from the mouth of the Po River, just south of Venice, Italy. The adjoining photographic image was obtained by astronauts on board the Space Shuttle Challenger on the same day that the CZCS observed the region. The island city of Venice is visible in the lagoon located at the upper center of the shuttle photograph.



CZCS image of Venice and the Po River sediment plume

Space Shuttle astronaut photograph of Venice and the Po River sediment plume

The visibility of riverine sediment plumes in the ocean exhibits considerable variation. The Po River plume is particularly easy to see because it has a large amount of carbonate rocks in its watershed, which are easily eroded to produce light-colored, reflective sediments. Other rivers, such as the Yellow and Yangtze rivers in Asia, have high sediment loads because of the large amount of rainfall in their watersheds, which transfers a large amount of soil to the rivers.

River sediments can also transfer man-made pollutants to the ocean. Chemicals such as pesticides and chlorinated organic compounds can be adsorbed on the surface of soil particles. As the soil is carried away by rain and into the rivers, it will be transferred to the river mouth and to be deposited in the large amount of bottom sediments in deltaic regions.

Estuaries

In many cases, the interface of a river with the ocean forms an **estuary**, an area that is characterized by variations in salinity due to the mixing of fresh and salt water. The size of estuaries depends on the volume of water transported by the river, the strength of the tidal cycle, the local geology, and the rate of sediment deposition.

The picture below, taken from an airplane, shows the boundary between two water masses in the ocean just north of Winyah Bay, South Carolina. Winyah Bay is located near Georgetown, SC, and receives fresh water from both the Pee Dee and Waccamaw rivers. The reddish water is from Winyah Bay, while the greenish water is from the coastal Atlantic Ocean.

Riverine and ocean water mass boundary near Winyah Bay, SC.

Estuaries tend to be highly productive areas, where the larvae of many fish species spend their first part of their life cycle. Furthermore, estuaries frequently have high concentrations of organisms that are utilized by fish for food, such as shrimp. Estuaries can also have numerous bottom-dwelling (or **benthic**) organisms such as oysters, crabs, clams, and scallops. These crustaceans and mollusks, many of which are called **filter-feeders** because they filter the water of the estuary to remove digestible particles. Thus, pollutants in the particles can be concentrated in their tissues. Because these organisms are frequently food for other marine organisms (or humans) pollutants in these sediments can be transferred up the food chain.

Another interesting aspect of estuaries is their chemical behavior. As fresh water mixes with salt water, dissolved metals (particularly iron) will form microscopic particles called **flocculants**, or flocs. Because they have a large surface area due to their diffuse "fluffy" nature, flocs can also adsorb pollutants. As they settle, they will also take harmful materials with them into the sediments. Thus, estuaries can act as filters for water entering the sea, but these areas will therefore be particularly sensitive to many types of pollution discharged into rivers.

Estuaries are usually quite shallow, tend to have very turbid water, and are surrounded by land. Most estuaries thus pose difficult problems for ocean color data acquisition. However, they are also highly productive areas, which makes them of significant interest to biological oceanographers. In most images of estuaries, such as numerous CZCS images of the Chesapeake Bay, the algorithm that calculates the pigment concentration fails due to a combination of productivity, suspended sediments, and shallow water. So most estuaries appear red on the CZCS false color scale, indicating high pigment concentrations, which may or may not be true. (In the CZCS image of the Po River plume, the reflectivity of the sediments was so high that the data processing algorithm interpreted part of the plume as land, which appears black in the image.)

Optical water type classification

Scientists who study ocean optics have classified water into two basic optical types: Case 1 and Case 2, as defined by Morel and Prieur. Case 1 waters are usually in the open ocean, are very clear, and have low primary productivity. Case 2 waters are usually found near the shore, and have highly variable clarity due to a combination of higher productivity and suspended particulates. Determining accurate measurements of photosynthetic pigments in Case 2 waters is a significant challenge to ocean color scientists. Another aspect of Case 2 waters is the water depth, as light reflecting off the bottom in shallow water creates an optically-bright area. Because of these factors, extracting the pigment (and chlorophyll) signal in Case 2 waters is a complex problem. Due to the higher productivity in coastal areas, it is an important problem to solve.

If the volume of a river is particularly large, for rivers such as the Mississippi or Amazon, turbid sediment plumes can be transported long distances before dissipating. After huge 1993 floods in Iowa and Missouri, the plume of sediment disgorged from the Mississippi River could be observed from space using data from the Advanced Very High Resolution Radiometer (AVHRR). The plume of sediment extended almost 300 km from the Mississippi River delta in Louisiana. Ocean color data could be used to observe similar phenomena.