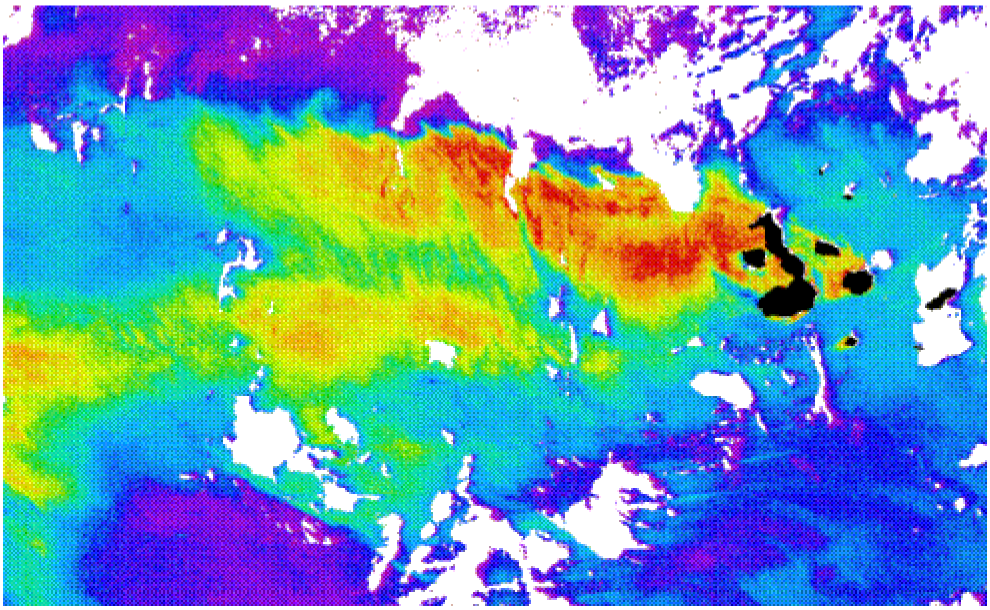
Chapter 3: The Galapagos Plume

The preceding chapter discussed an important aspect of physical oceanography called upwelling, and showed how upwelling can cause the formation of an area of high primary productivity called an upwelling zone. Now another image will be used to illustrate remarkable interactions between the physics, chemistry, and biology of the oceans.



October 31, 1983, CZCS image of the high productivity plume induced by the interaction of the South Equatorial Current with the Galapagos archipelago.

This image shows an area of high primary productivity extending to the west of the Galapagos Islands in the equatorial Pacific Ocean. The fact that the Galapagos Islands are located near the Equator is quite important, as there are several ocean currents that flow near the Equator that affect Galapagos waters. The surface current is called the South Equatorial Current (SEQ), and flows in a westward direction.

As the SEQ flows past the shallow volcanic platform of the Galapagos Islands, it induces upwelling due to Ekman flow, just as for the Benguela upwelling zone. The phytoplankton nourished by the upwelled nutrients are transported westward, forming a productive plume that extends hundreds of kilometers west of the Galapagos Islands.

One of the interesting aspects of oceanography along the Equator in the Pacific Ocean is the fact that upwelling occurs near the Equator (caused by the direction of the trade winds on either side of the Equator), yet the primary productivity is lower than would be expected based on the concentrations of nitrate and phosphate. The equatorial belt of productivity can be seen in CZCS global composite images or composite images of the Pacific Ocean.

An oceanographer named John Martin performed measurements of iron concentrations in the ocean, and determined that in areas where iron concentrations were particularly low, iron could be the nutrient that limited the rate of primary productivity in large regions of the ocean. In seawater, iron is chemically different from nitrate and phosphate, so upwelling doesn't provide iron. Dust from the continents is one of the main sources, so the greater the distance from the continent, less iron is available. Near the continents, iron is also available from the sediments in shallow waters near the coast.

Martin predicted, based on observations of the waters around the Galapagos, that if the ocean was fertilized with iron, an increase in primary productivity would result. Though he died before the experiment was conducted, it was performed successfully, providing the exact results Martin had predicted. Observations of ocean color, similar to those made by the CZCS from space, were performed from an airplane, and documented the growth of phytoplankton in the fertilized patch of the ocean.

The remaining question concerned the role of iron in the Galapagos plume. It seemed clear that the same process of iron fertilization was occurring naturally here, so oceanographers surmised that iron was being supplied by the minerals found in the volcanic ash blowing off of the Galapagos Islands. It turned out that they were both right and wrong. They were right in that the volcanic minerals supplied the iron, but it was not the ash blown off the islands. The volcanic rocks beneath the surface, and the deposited iron in the sediments around the islands, appear to be the main source of the iron that nourishes the productivity in the Galapagos plume.