The Colors of El Niño

I'm Mary-Elena Carr and I am a biological oceanographer at the Jet Propulsion Laboratory. I have been working with data from satellites to monitor the effect of El Niño and seasonal change on *primary productivity* and fish stocks. My area of interest is the ocean off the South American coast of Chile and Peru [Fig. 1] where the fisheries of *small pelagics* such as anchovy and sardine [Fig. 2] are a major source of food and income for the region.

The western coast of South America is characterized by the process of coastal upwelling [Fig. 3]. The dominant winds in the coastal area are northward and water is transported offshore because of Earth's rotation. Deep, cold, nutrient-rich water rises to the surface to replace the water that has moved away from the coast. Consequently, these areas are rich in phytoplankton, zooplankton, and fish. During El Niño conditions, the upper layer of the ocean is thicker and the water is warmer, sometimes by as much as 5°C. This causes the water that rises to be warm and poor in nutrients. Phytoplankton growth is limited and the food chain is modified, and this can even lead to a fish stock collapse. A collapse is when there is a large and rapid reduction in the number of fish, often to less than 5% of normal numbers.

Figure 1. The ocean offshore from Chile and Peru is a study area for Dr. Mary-Elena Carr.

We can monitor the concentration of phytoplankton in the near-surface waters using satellite data from instruments that record the color of the ocean. Phytoplankton, like all plants, contain chlorophyll, a molecule that gives them their green color. Phytoplankton affect the color of the ocean because they absorb and scatter light. Sensors that measure ocean color can provide an estimate of chlorophyll concentration. If we use a model of photosyntheis we can also estimate the primary productivity. Studies have shown that areas of high chlorophyll concentration often correspond to areas of high fish populations.

Figure 2. Anchovies are one of the pelagics that are caught in Chile and Peru. Sardine and anchovy fisheries provide a major source of income.

As part of my research, I have used ocean color measurements made from three different sensors to both get data over a long time period, and to monitor the 1997-1998 El Niño [Figs. 4]. Data over a long period are needed to understand what average conditions really are. Data which are averages over a number of years are known as *climatologies*.

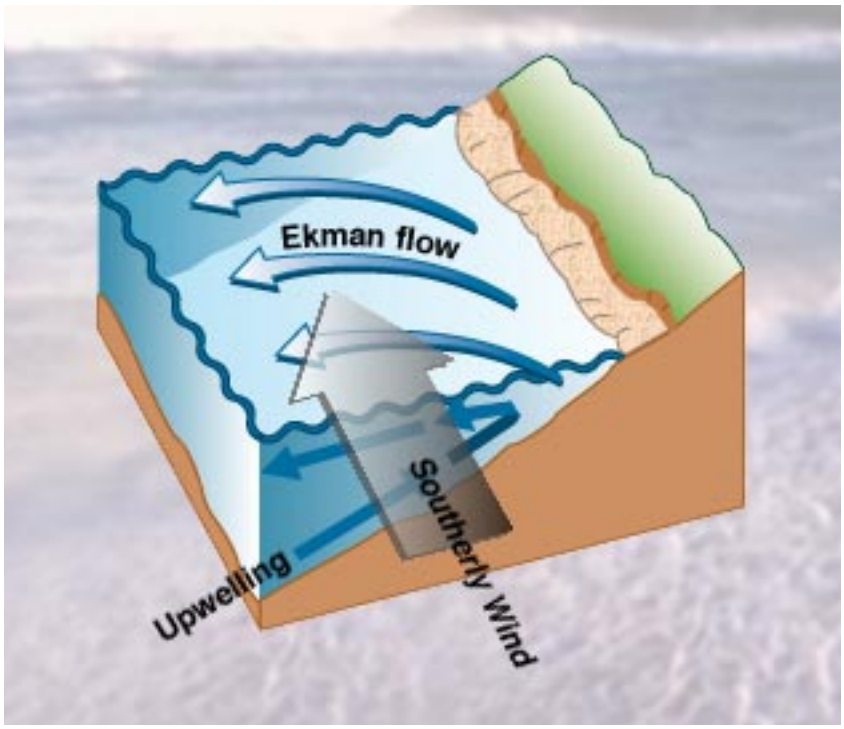

Figure 3. Upwelling along the coast due to off-shore winds. This process brings nutrient-rich water to the surface.

In my case, I use monthly climatologies which provide us with the usual values to be expected in the region for that month. Once we understand the climatologies, we can determine whether and how phytoplankton concentrations differ from the average. Climatologies for December, June and September were obtained from the Coastal Zone Color Scanner (CZCS) over the period of 1978-1986.

The December 1996 and June 1997 phytoplankton concentrations were measured by the Ocean Color and Temperature Sensor (OCTS), a Japanese ocean color sensor flown on the ADEOS satellite. The September 1997 value is from the Seaviewing Wide Field of View Sensor (SeaWiFS), launched on Seastar in August 1997.

From the climatologies, concentration off the coast of South America is strongly affected by season [Fig. 4, top row]. Along Peru's coast the phytoplankton concentrations are greater in December than in September, but along the Chilean coast the concentrations are higher in September. This results from the seasonal pattern of wind forcing which drives upwelling. 'Upwelling-favorable' conditions bring nutrients to the surface and result in higher phytoplankton concentrations.

You can see the difference that an El Niño makes to pigment concentration, and primary productivity, by comparing data taken during an El Niño to the climatologies. December 1996 values [Fig. 4], measured before an El Niño, were fairly similar to the climatology. In these data, zones of high productivity, shown as yellow and orange, were found close to the coast and extended almost 100 km offshore. Satellite imagery from June 1997 [Fig. 4], while an El Niño was developing, show that the concentration was lower than usual and that high values were found in a narrow band next to the coast. These effects became more extreme in September 1997 [Fig. 4] during the full blown El Niño conditions.

In 1998, the Year of the Ocean, I will be working with SeaWiFS data to monitor the effects of the 1997-98 El Niño on primary production and the fishing industry.

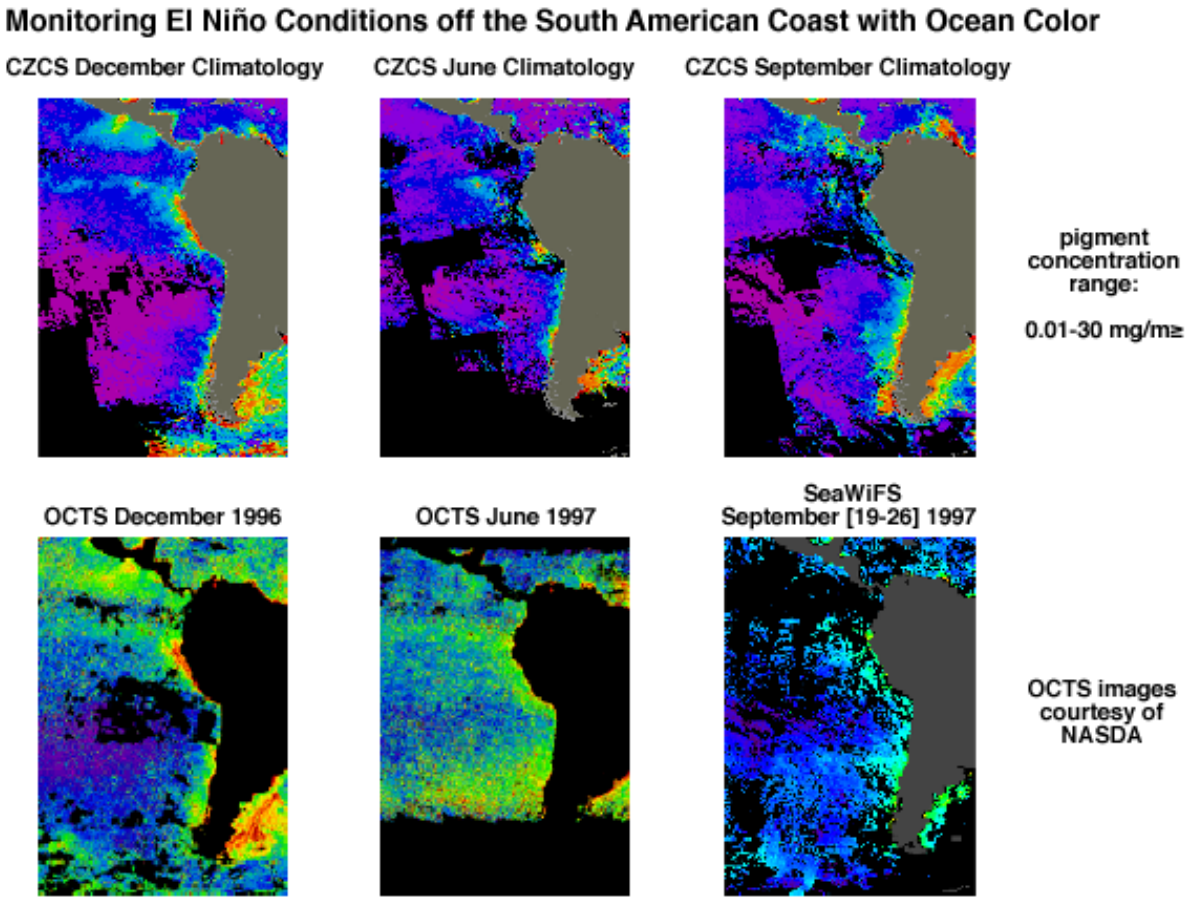

Figure 4. The colors cover a range from 0 to 30 milligrams of chlorophyll per cubic meter. Purple and blue are lower values and red corresponds to the highest values. The land is gray and areas where there is no data are black. Climatologies are average data which can be compared with non-El Niño conditions in December 1996 and El Niño conditions in September 1997.