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OCEAN UPWELLING – A PERSISTENT OCEANOGRAPHIC PHENOMENON OF THE GUAJIRA PENINSULA

La surgencia oceánica- Un fenómeno oceanográfico persistente en la península de La Guajira

Upwelling in the ocean is a phenomenon that has long captured the attention of scientists and local communities around the world. Upwelling is the process by which deeper water, sometimes at depths much deeper than 100 meters, is forced upward toward the surface by action of winds or currents. The amount of energy to move water and salt from those depths to the surface, over linear distances that often exceed hundreds or thousands of kilometers and areas that span several tens to hundreds of thousands of square kilometers, is staggering. With those motions, entire ecosystems and millions of living and dead organisms are turned over in the oceanic water column as well.

Upwelling in the ocean can happen in the middle of the ocean offshore, along coastlines or other boundaries like ice shelves, in the wake of large and small islands, along ocean fronts, and around the periphery or in the core of eddies and other ocean currents. upwelling regions are areas of active exchange of mass and energy between deeper parts of the ocean and the surface. This is where some of the most rapid and active air-land-sea interactions happen and this leads to strong and characteristic weather patterns that affect large regions. These upward currents can sometimes recirculate warm and nutrient-depleted waters in a mixed layer between a deep thermocline and the surface. Most often we associate the word "upwelling" in oceanography with large patches and plumes of cold, deep, and nutrient-rich water that come to the surface. These plumes spread horizontally away from the areas of upwelling and affect the weather, climate, and ecology of very large regions. Upwelling plumes can occur seasonally or year-round. Where sunlight is available, at any latitude, the upwelling phenomenon leads to very substantial biological productivity, including high accumulations of phytoplankton, large algae habitats like kelp beds, and large fish and invertebrate biomass around which profitable industries and artisanal fisheries have evolved. In these areas, other animals aggregate and benefit, including large populations of marine mammals, birds, and people.

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The entire southern margin of the Central Caribbean Sea is an active, "wind-driven" upwelling area spanning from Trinidad to approximately the region of the Magdalena Delta in Colombia. As the Trade Wind blows from east to west along the coasts of Trinidad, Venezuela, and Colombia, the wind causes surface waters to move. As these waters accelerate, they move to the right of the wind due to the Coriolis effect that is experience by all moving objects, including fluids, on a rotating reference framework – our rotating planet. The surface waters that move away from the coast are continuously replaced by deeper waters that move up, typically from as deep as 140 meters or more up along the bottom of the continental shelf to the surface. During the first few months of the year, the water that reaches the surface is typically higher in salinity and colder than surface waters, because that water mass is tilted upward toward the surface closer to the coast during this time of the year. This effect is the result of stronger Trade Winds and also a process of geostrophy that intensifies as the inflow of water from the open Atlantic Ocean strengthens and intensifies the Caribbean Current. The coldest upwelling is often seen in focal areas such as submarine canyons or around capes.

The upwelling in the southern Caribbean Sea is a classical textbook example of "wind-driven" upwelling, but it is also intensified by the geostrophic boundary current of the western Atlantic and by vertical mixing of the water by action of the wind and mixing along the bottom of the continental margin. There is a strong seasonality in this upwelling driven by insolation, the Trade Winds and coastal meteorology, and seasonality in the major currents flowing through the Caribbean that connect the South Atlantic and the North Atlantic as part of a global circulation pattern in the ocean.

The Guajira Peninsula experiences one of the strongest upwelling phenomena in the Caribbean Sea (Fajardo, 1979; Corredor, 1979; Andrade and Barton, 2005). This is the result of an intensification of the Trade Wind in the Central and Western Caribbean Sea which leads to winds over 9 m s^{-1} between December and March every year. The upwelling off the Guajira Peninsula reaches a maximum between February and May, and extends from the northern tip of the Guajira Peninsula to approximately the coast off Santa Marta. Cooler sea surface temperatures than waters in the central Caribbean Sea can be seen in satellite images extending over an area that exceeds 48,000 km^2 during maximum upwelling time (Castellanos et al., 2002; Rueda-Roa et al., 2018).

These waters provide critical sustenance to Wayuu indigenous communities and other local groups. They sustain very diverse fish populations (Polanco et al., 2009). Yet the fishery potential of this region is between half and perhaps up to ten times lower than that in the upwelling region of the southeastern Caribbean Sea (Gómez Gaspar and Acero, 2020; Rueda-Roa, 2012; Pauly et al., 2020). The reason for this difference is not clear. Rueda-Roa and also Gómez Gaspar and Acero have speculated that this may be due to the classical observation outlined in textbooks that phytoplankton communities have little time to develop in upwelling foci near the coast because of very strong and deep vertical mixing (which leads to insufficient exposure to light near the surface), and rapid advection of waters away from the coast of Colombia. Indeed, there are major differences in the intensity, morphology, dynamics and biological characteristics of the upwelling phenomenon in different places along the southern coast of the central Caribbean Sea. Several authors have summarized the differences between these regions as we understand them (Muller-Karger et al., 1989; Castellanos et al., 2002; Rueda-Roa et al., 2018; Gómez Gaspar and Acero, 2020).

Much remains to be understood about the oceanography of the western-central Caribbean Sea, including the biological production, circulation, and biogeochemistry of the waters off the Guajira Peninsula.

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