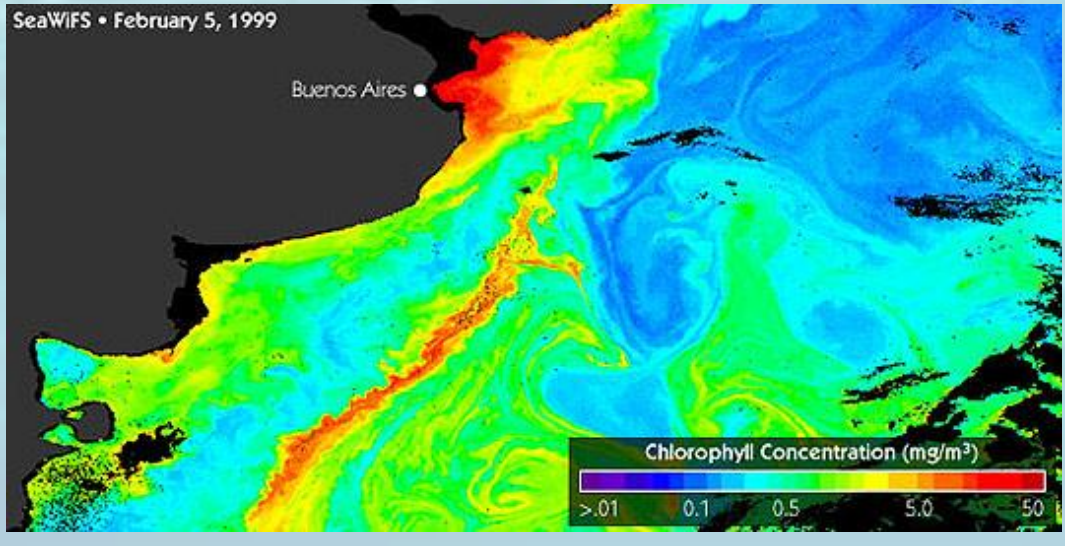
SCIENCE FOCUS: CONVERGENCE ZONES

Convergence Zones—Where the Action Is



When geologists use the term "convergence zone", they are discussing the region where two tectonic plates are colliding, with one plate sliding beneath the other. The result is geological turbulence: fault zones that produce earthquakes, and generated heat that gives rise to explosive volcanoes. When meteorologists use the term "convergence zone", they are describing a phenomenon in the atmosphere which works in an analogous fashion. Near the equator, warm air rises and colder air moves in beneath it. As the warm air rises, it forms huge bands of clouds and thunderstorms over the ocean, an area called the Intertropical Convergence Zone, or ITCZ, which is an obvious feature of global weather satellite imagery [Figure 1 – larger version is available at the end of this article). The clouds indicate the formation of **Hadley cells** (Figure 2) in the atmosphere.

Figure 1: ITCZ From GOES

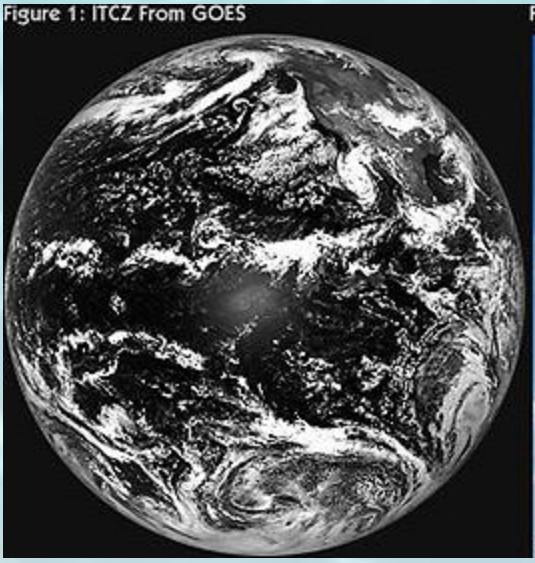
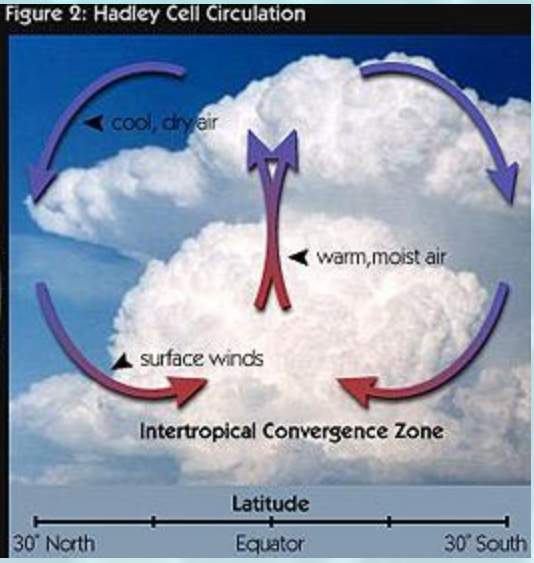


Figure 2: Hadley Cell Circulation

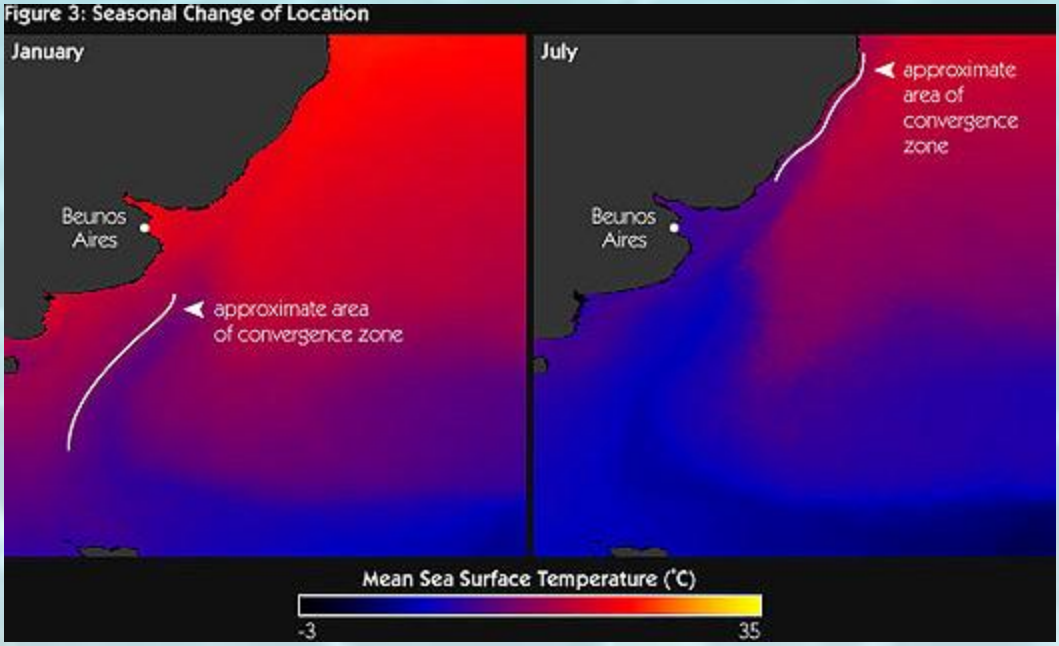


When oceanographers use the term "convergence zone", they too are speaking of an area of converging forces. In this case, the forces in opposition are strong ocean currents. The result is that oceanic convergence zones are usually marked by sharp demarcations in temperature and water mass characteristics, and outbreaks of high biological productivity.

The featured image at the beginning of this article is a SeaWiFS image obtained on February 5, 1999, offshore of the coast of Argentina in South America. The most notable feature in this image is a long and narrow band of high productivity, stretching for hundreds of kilometers from near Buenos Aires and the Rio de la Plata estuary, toward Patagonia. This band of high productivity marks the convergence zone between two current systems—the warm, coast-hugging, southward-flowing Brazil Current and the cold, northward-flowing Malvinas/Falkland Current.

The interaction of the Brazil Current and the Malvinas Current is quite interesting. The Malvinas current is actually an offshoot of the Antarctic Circumpolar Current, a branch that veers northward along the South American continental shelf. The boundary between the cold Malvinas Current water and warmer inshore water parallels the coast until about the latitude of Buenos Aires, where the Malvinas encounters the Brazil Current. This interaction creates a very complicated fluid dynamics problem: the flow of the Malvinas Current is turned (retroflected) into the South Atlantic Ocean, while the warm Brazil Current waters are pushed toward the coast. The exact location of this boundary varies with the seasons, as seen in sea surface temperature imagery (Figure 3).

Figure 3: Seasonal Change of Location



The result of this water motion, which causes the bright band of productivity seen in the SeaWiFS image, can be visualized as two rotating cylinders of water parallel to each other (Figure 4). [Remember that the actual situation is much more complicated, as it involves the mixing of different water mass types, interaction with bottom topography, and is also influenced by surface winds.] At the convergence zone, where the two cylinders meet, the "inside" circulation of each cylinder is moving downward (a water movement called downwelling). In the cylinder on the cold side (the Malvinas Current side) of the convergence zone, the "outside" circulation is upward (called upwelling, of course), bringing nutrients to the surface. When the phytoplankton utilize the nutrients and sunshine at the surface, they grow rapidly, leading to high phytoplankton concentrations. On the warm side (the Brazil Current side), the upward circulation near the coast only brings warm, low nutrient water to the surface, so the surface water on this side of the convergence zone has low phytoplankton concentrations. The large difference in the abundance of phytoplankton chlorophyll is clearly visible in the SeaWiFS ocean color image.

Now for a bit more about the physical oceanography of this situation (this is still very basic). The areas on the outside circulation of the cylinders, where upwelling occurs, are zones of "negative convergence", more commonly called *divergence*. Because mass is conserved, convergence in one area requires an equal amount of divergence somewhere else to balance it. To summarize: convergence usually means downwelling, divergence usually means upwelling, and upwelling frequently (but not always) is associated with enhanced biological productivity.

Figure 4: Diagram of Convergence Zone

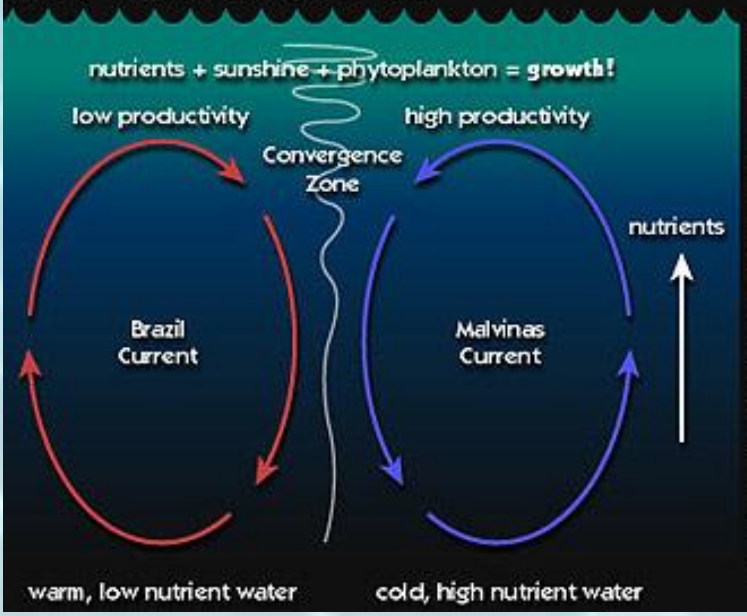


Figure 5: Radar Image

Convergence zones are of interest to oceanographers for several reasons. Because they frequently mark the boundaries of currents, their position can be used to model the interaction of different oceanic current systems. Obviously, biological oceanographers study them because they are areas of high biological activity, from microscopic phytoplankton to large fish like marlin or bluefin tuna. Even loggerhead turtles have been shown to frequent the area of convergence zones in the Pacific Ocean (*Backscatter* magazine, November 1999, page 29-30).

A variety of remote sensing technologies can be used to view convergence zones, due to the abrupt changes in water mass characteristics that define them. One of the most interesting applications that can view convergence zones is synthetic aperture radar (SAR). SAR is extremely sensitive to very small variations in the surface of the ocean, so it can actually be used to view the wakes of ships. Convergence zones show up clearly due to several factors. One factor is that a height difference of a few centimeters actually marks the boundary of the warm water and the cold water, so that the zone can actually be marked by waves and surface turbulence. Another factor is that chemical substances called surfactants (either natural or from human sources, like oil) concentrate in these zones, and they can actually affect the small waves that form at the surface of the ocean from the wind. Thus, convergence zones show up as smooth areas, or slicks, due to the reduced wave action caused by the presence of surfactants.

Figure 5 shows a SAR image obtained from an airplane (using the Jet Propulsion Laboratory's AirSAR instrument) of an area off the coast of California, where the dark areas are smooth slicks, and the bright areas are areas of increased wave action. Note near the center of the image where the bright and dark areas are roughly parallel, delineating the convergence zone.

One of the most dramatic examples of a convergence zone was called the "Line in the Sea". It occurred in the Pacific Ocean in 1992, and was photographed from the Space Shuttle [Figure 6 – two larger images are available at the end of the article. Researchers in the Joint Global Ocean Flux Study (JGOFS) Equatorial Pacific program also happened to be in this area at the same time, and documented the sharp changes that occurred at this particular convergence zone (Yoder et al., 1993).

Figure 6: The Line in the Sea

Convergence zones need not be as dramatic as the "Line in the Sea" or the boundary of the Brazil Current and the Malvinas Current. Observation of a smooth lake surface during a rainstorm will also show the development of smooth linear areas parallel to rougher areas. These features are due to the slight differences in temperature between rain water and lake water cause the formation of upwelling and downwelling areas. Surfactants converge here too, dampening the wave action and causing the smooth areas on the surface. These features are commonly called "windrows", but the technical term for them is **Langmuir cells**, after Irving Langmuir, who first described the circulation that caused them.

References

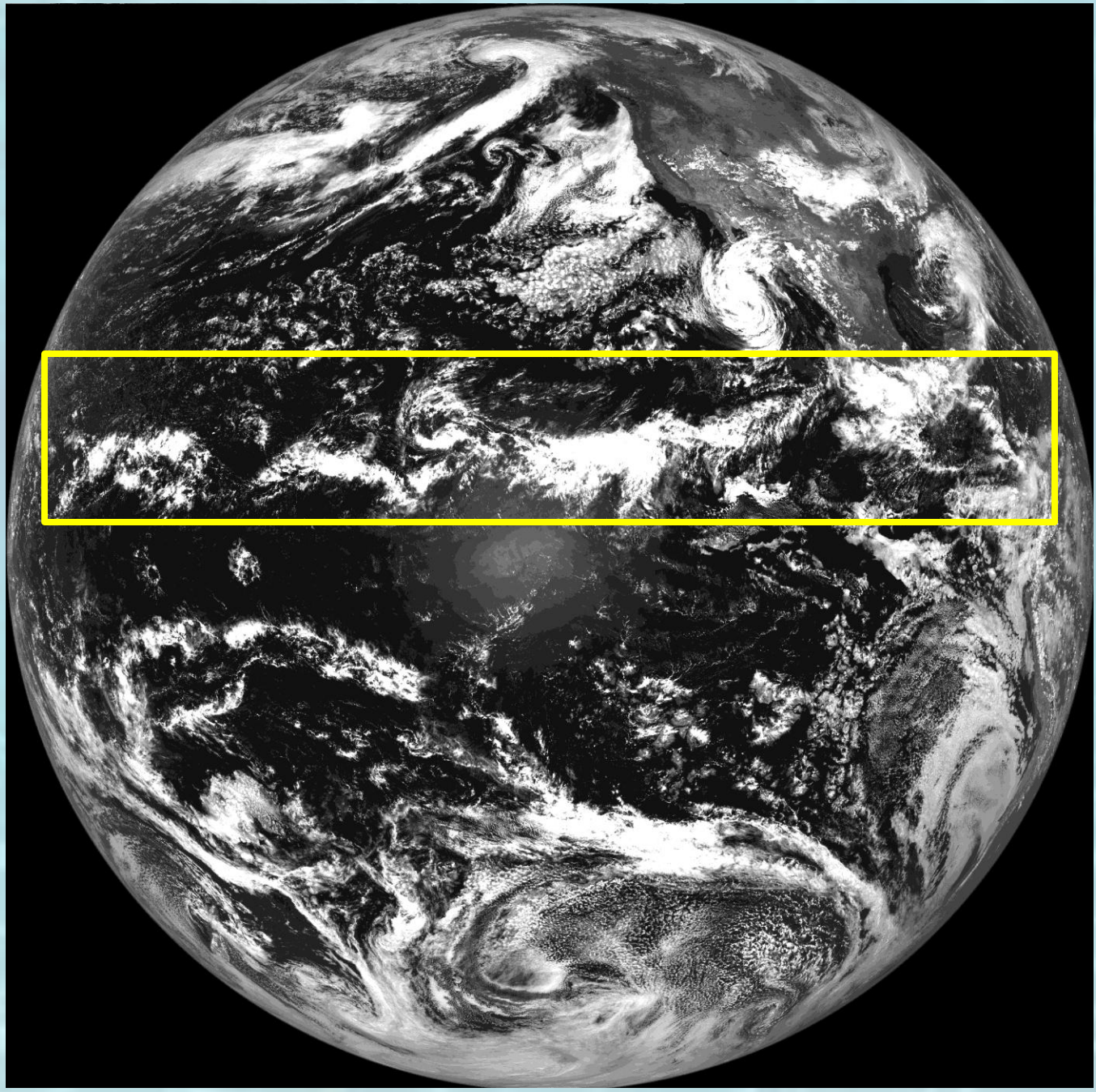
James A. Yoder, Steven G. Ackleson, Richard T. Barber, Pierre Flament and William M. Balch. 1994: A Line in the Sea. *Nature* 371: 689-692

Associated URLs

Line in the Sea
Langmuir circulation
UAVSAR

ACKNOWLEDGMENT
The authors wish to thank Dr. Dennis Kirwan of the University of Delaware for assistance with the text of this article. We also thank Dr. James Yoder (University of Rhode Island) who provided Space Shuttle photographs of the "Line in the Sea". We also thank the authors of the Web pages which provided associated information and imagery.

GOES hemispheric image. The clouds of the ITCZ are indicated within the yellow box.



The “Line in the Sea” in the Pacific Ocean below the orbiting Space Shuttle.

Image of the “Line in the Sea”.