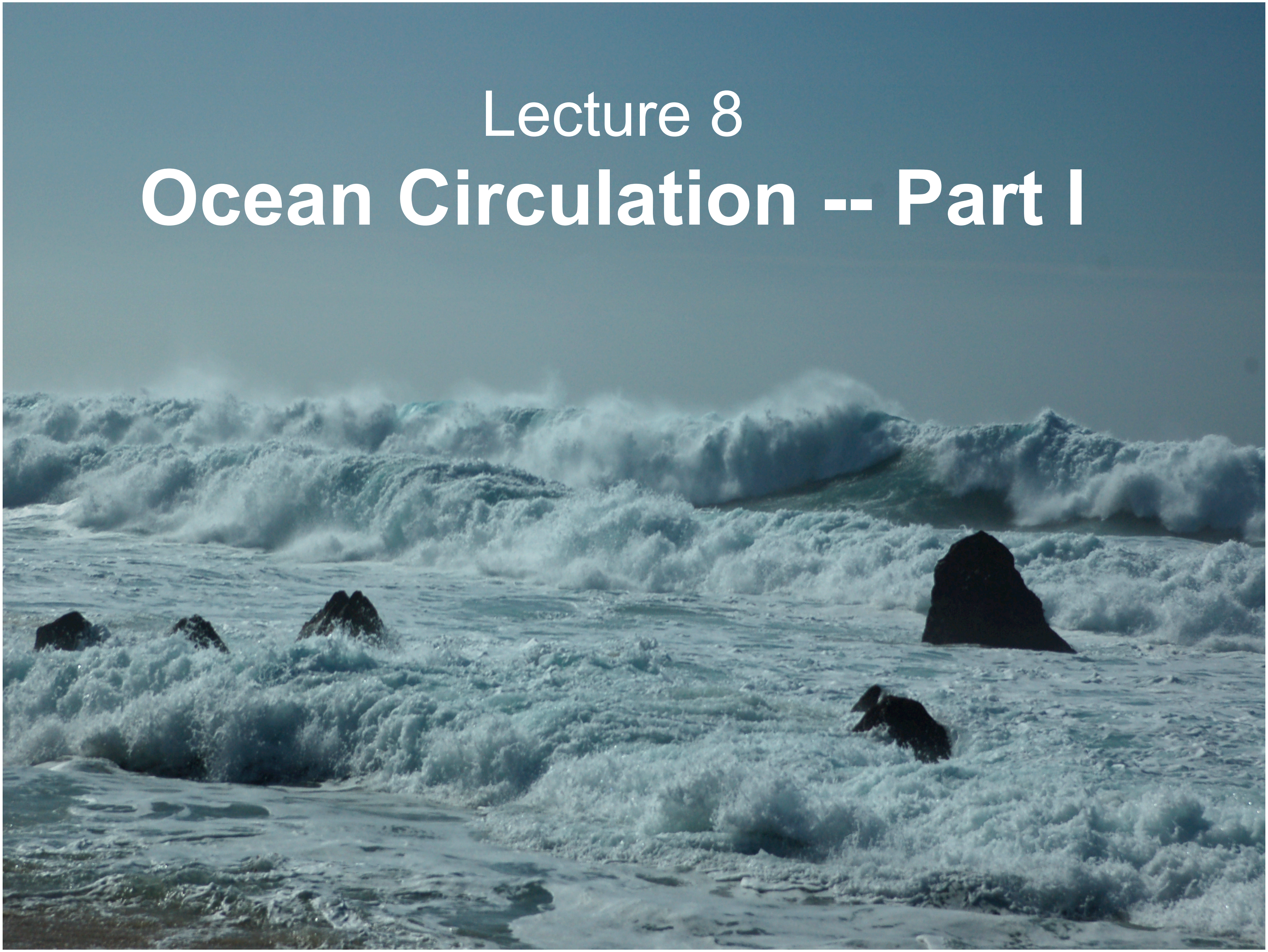
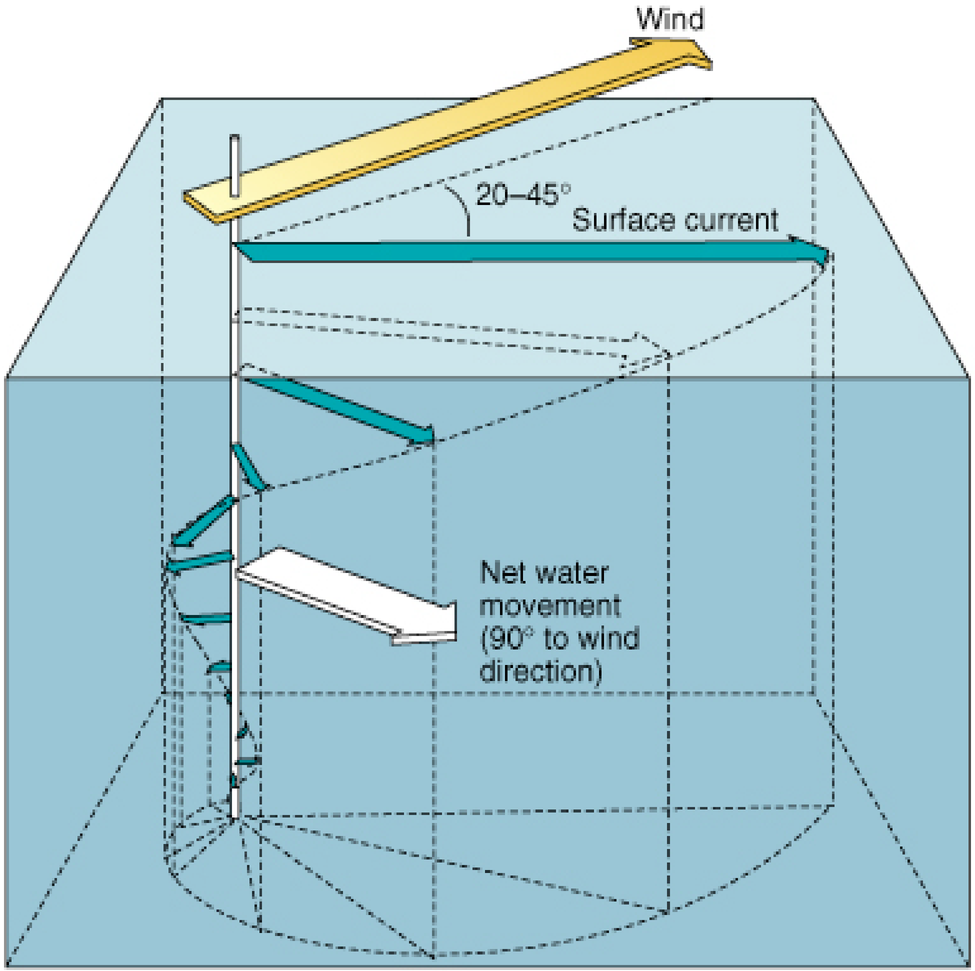
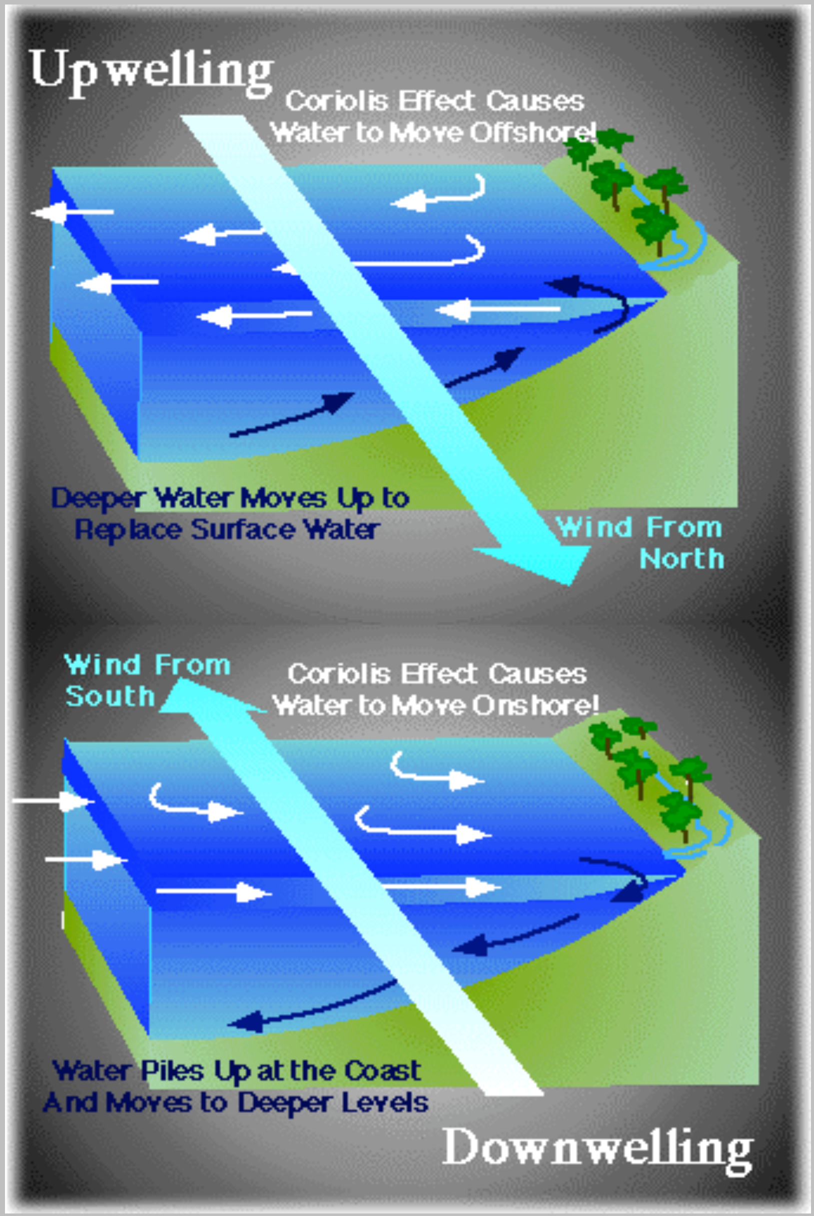

Lecture 8
Ocean Circulation -- Part I

EKMAN DRIFT AND VERTICAL MOTION

Ekman drift refers to the mechanical response of the ocean to wind blowing across its surface. The surface water is dragged along with the wind. However, due to the Coriolis force, it is deflected somewhat to the right (in the NH). The surface water



drags along the water immediately beneath it but at a somewhat slower speed, and this layer is also deflected to the right under the influence of the Coriolis force. The result is a spiraling pattern in the current direction with ever decreasing current speeds with depth. **The net transport of water is to the right of the wind.**



The Ekman mechanism is also responsible for **coastal upwelling and downwelling**. In the northern hemisphere, if one is moving with the wind and the coast is on the left, water will be transported away from the coast by the Ekman mechanism. Deep water will be pulled up to compensate for the lost surface water at the coast (upwelling).

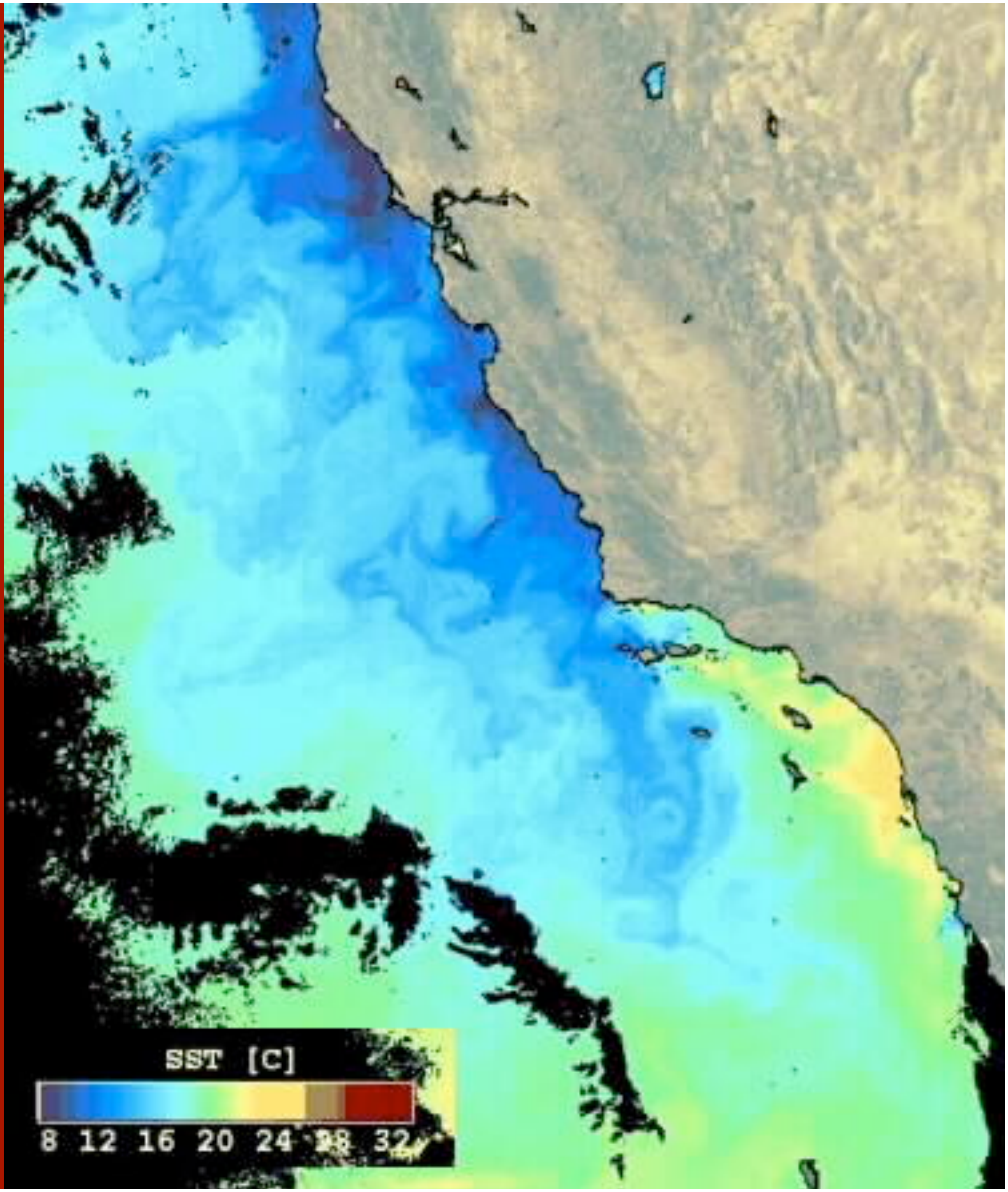
If one is moving with the wind and the coast is on the right, water is transported toward the coast and the surface waters are driven downward (downwelling).

One can often see evidence of upwelling and downwelling by examining sea surface temperatures.

Upwelling often occurs off the coast of California.

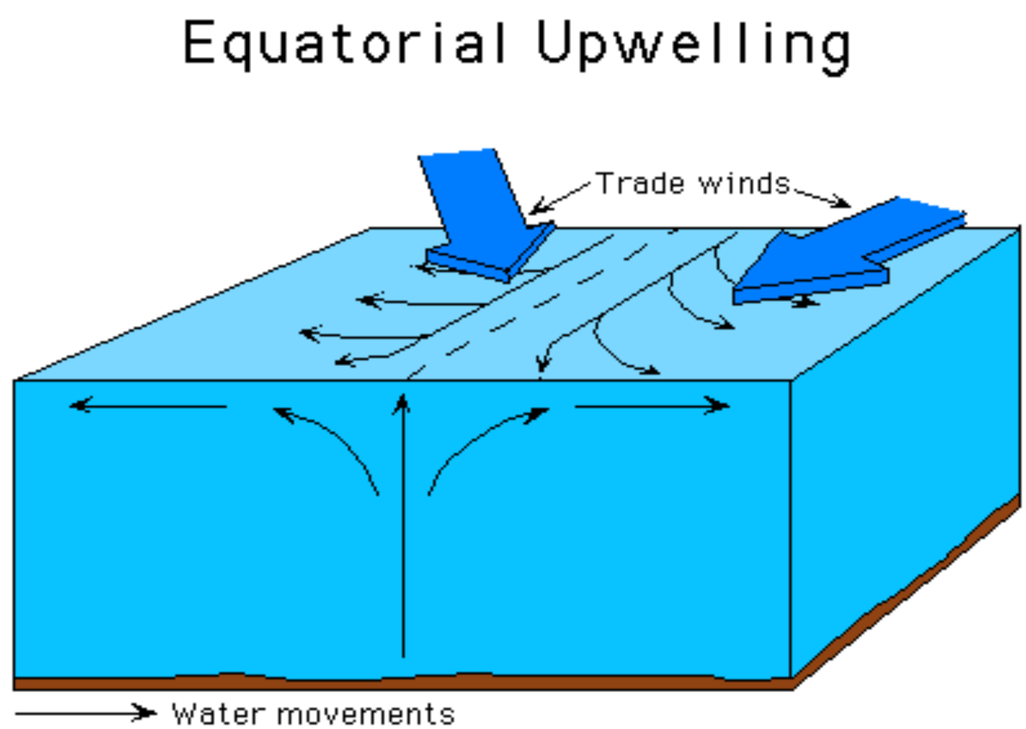
This satellite image shows cold temperatures all along the California coast, indicating that deep cold water is being pulled to the surface.

Winds blow equatorward along the coast, east of the subropical high.

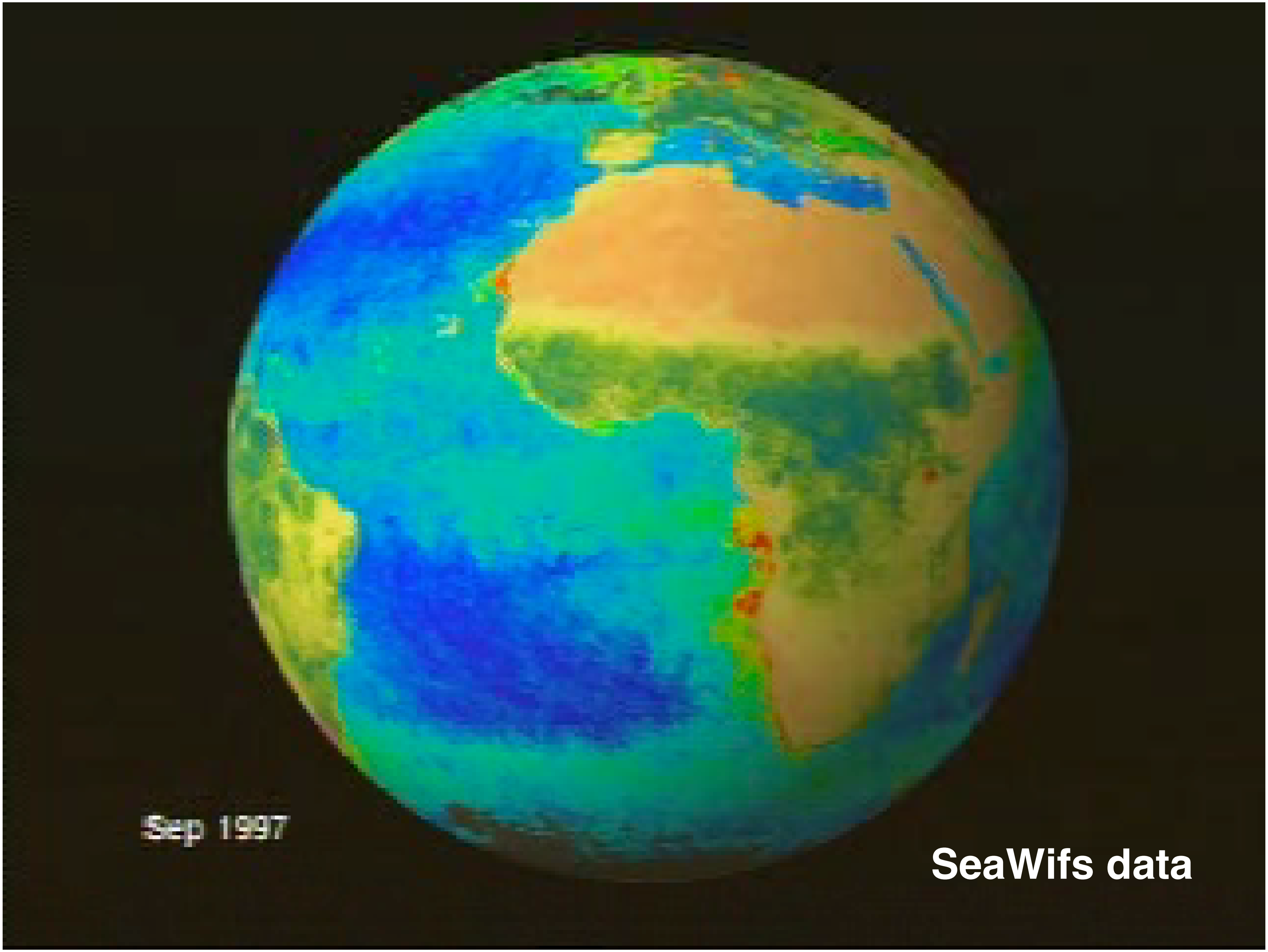


The Ekman mechanism also drives **Equatorial Upwelling**. Near the equator, trade winds blow toward the west. These winds transport water poleward in both hemispheres, forcing cold deeper waters to the surface at the equator.

Deep waters are rich in nutrients. For this reason, zones of upwelling can be very clearly seen from satellite images of chlorophyll, the chemical that makes plants green.



Adapted from Thurman, Harold V. (1997) **Introductory Oceanography, 8/E.** Prentice-Hall, Inc., New Jersey.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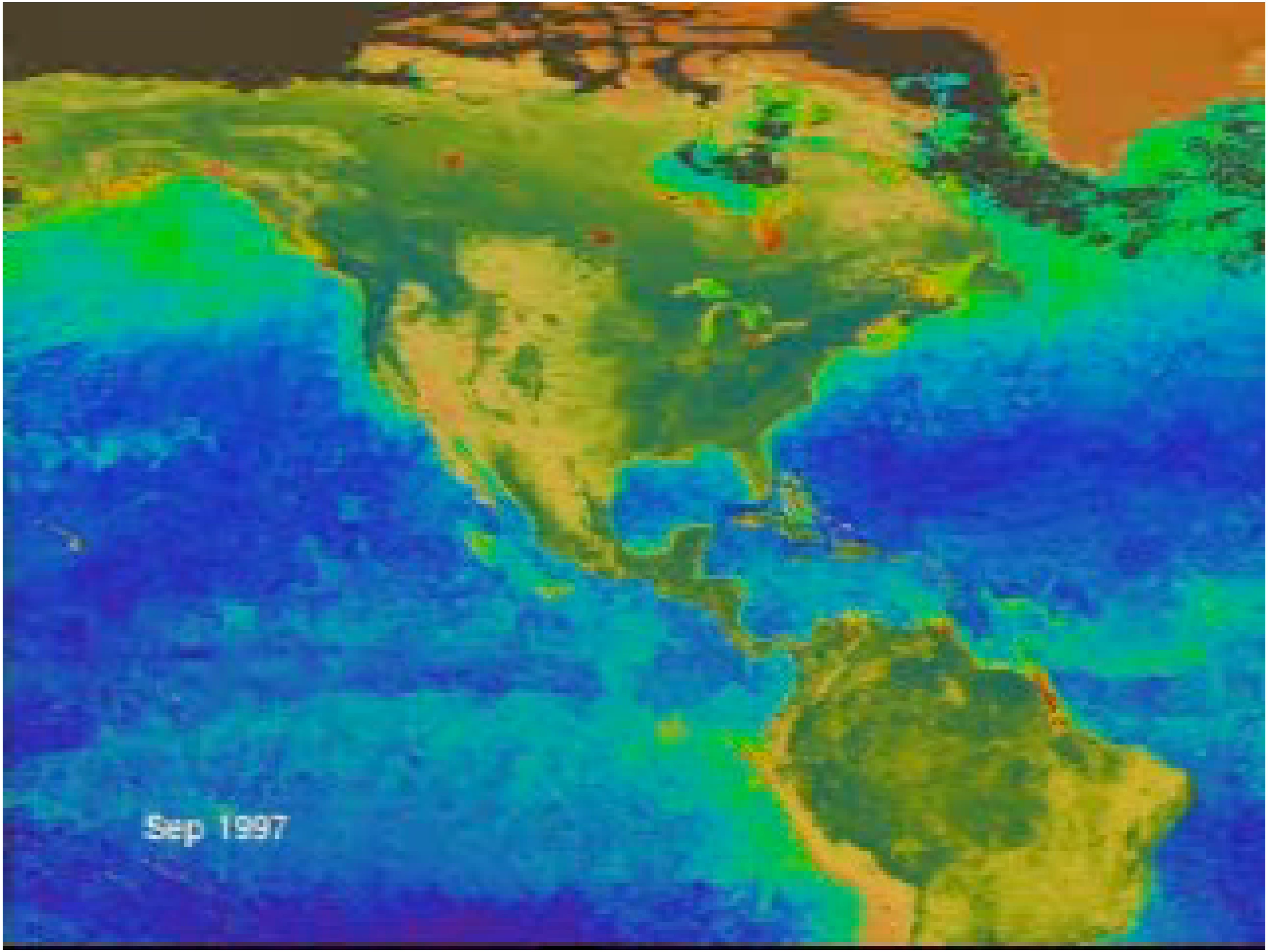
SeaWifs data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GEOSTROPHIC MOTION AND THE SURFACE CURRENT DISTRIBUTION

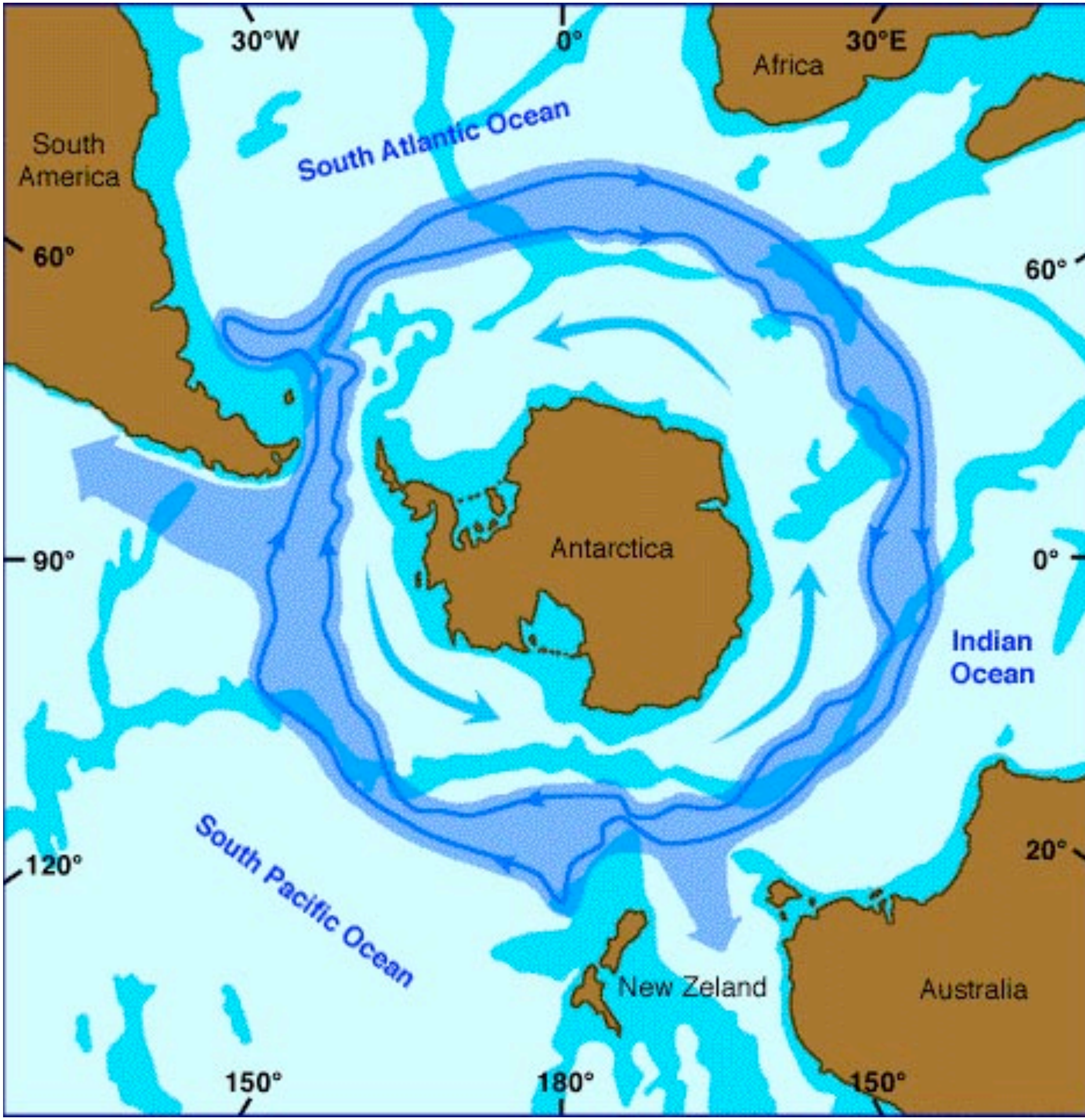
GEOSTROPHY

In atmospheric and oceanic flows, geostrophic balance or geostrophy is a key concept. Geostrophy prevails when the forces accelarating a parcel are small compared to the Coriolis force. It can be derived from a scaling analysis of the primitive equations of motion of a rotating fluid. In general, the larger the spatial scale of the motion or the slower the motion, the greater the influence of the Coriolis force.

When geostrophy prevails, the pressure gradient force is balanced by the Coriolis force.

$$-\rho \cdot f \cdot v = \partial P / \partial x$$

$$\rho \cdot f \cdot u = \partial P / \partial y$$



We can use the concepts of Ekman Drift and Geostrophy to piece together a rudimentary understanding of the causes of the near-surface ocean circulation.

We begin with the Antarctic Circumpolar Current. This is the most intense of the ocean's currents. The surface current speeds approach 1 m/s and the average transport through the Drake Passage is roughly 135 Sverdrups (m^3/s). For comparison, the world's rivers transport about 1 Sv.

The annual-mean surface winds over the Circumpolar ocean are strongly westerly…

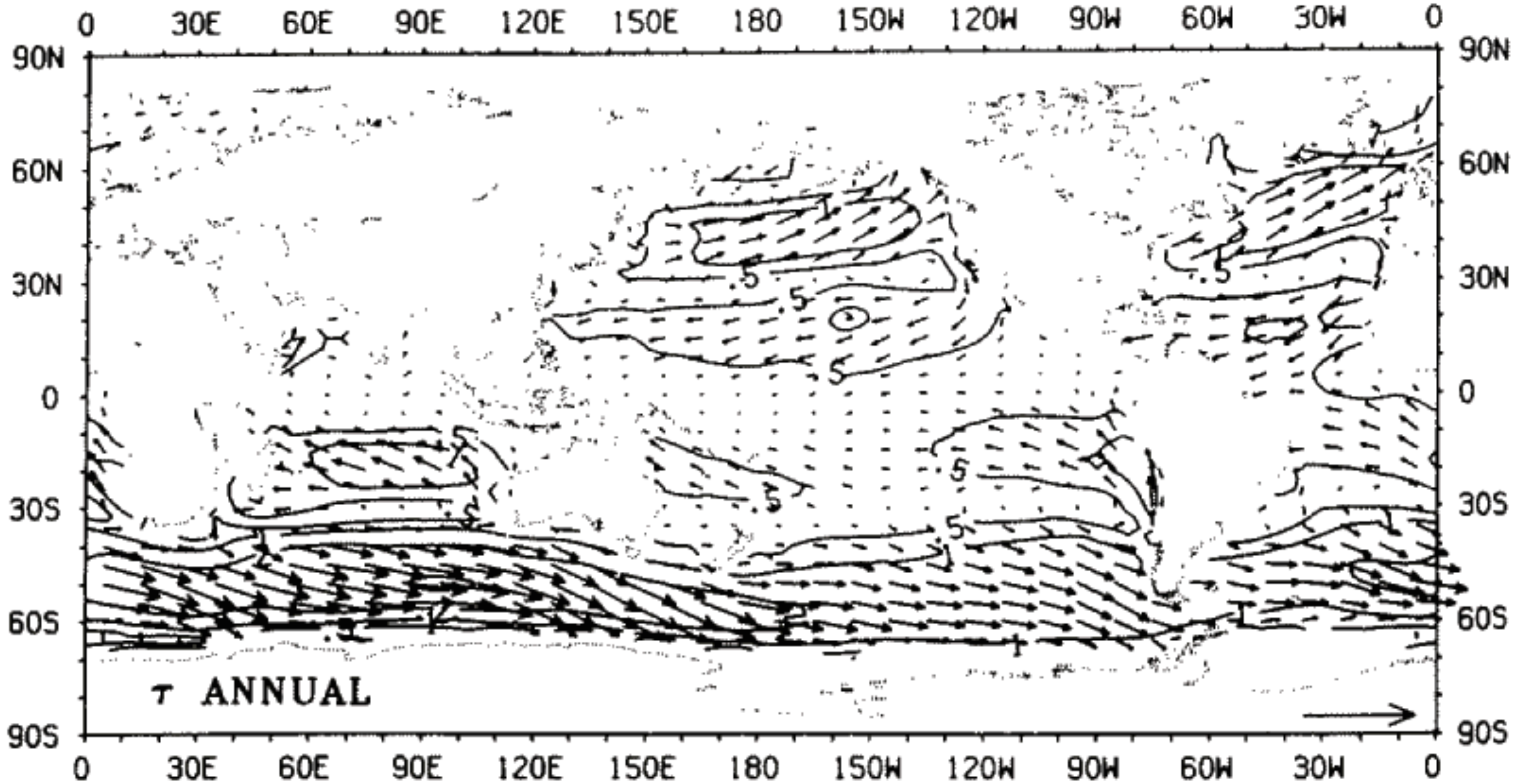
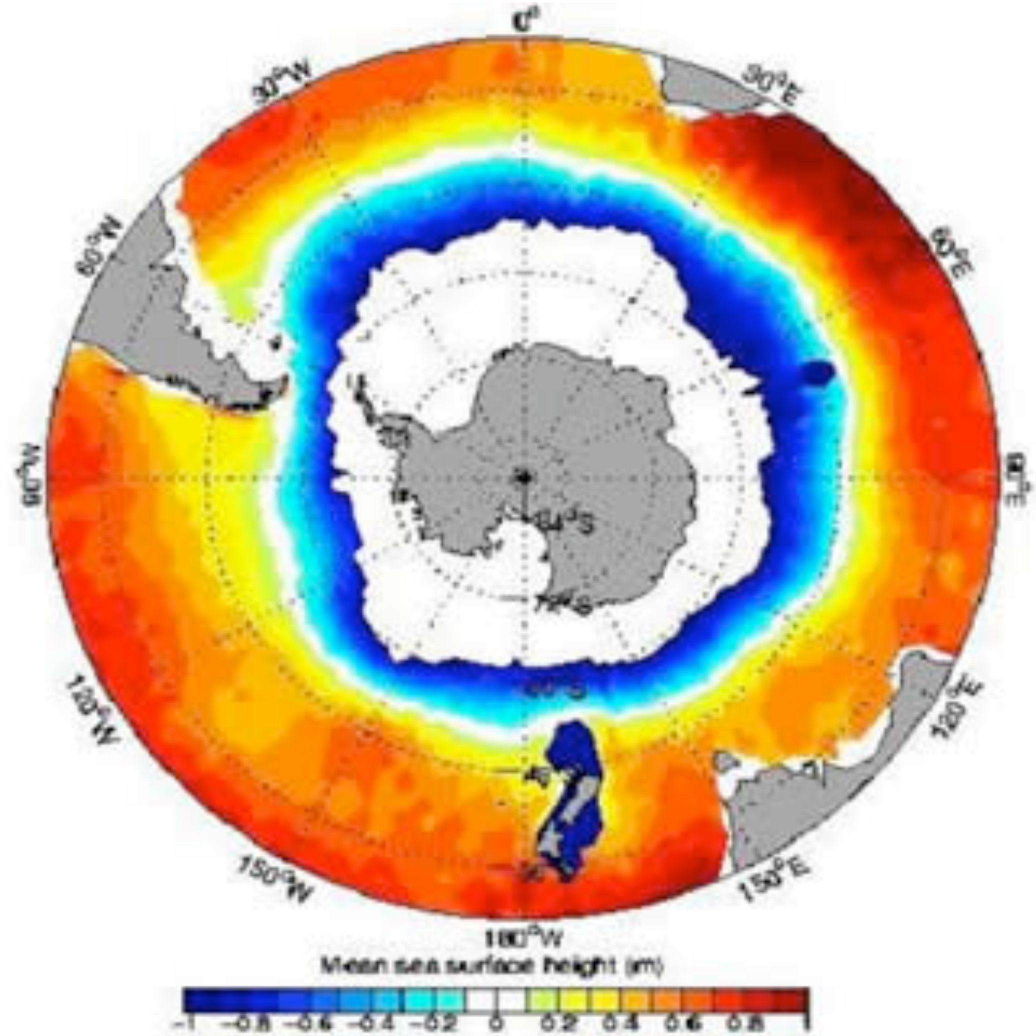
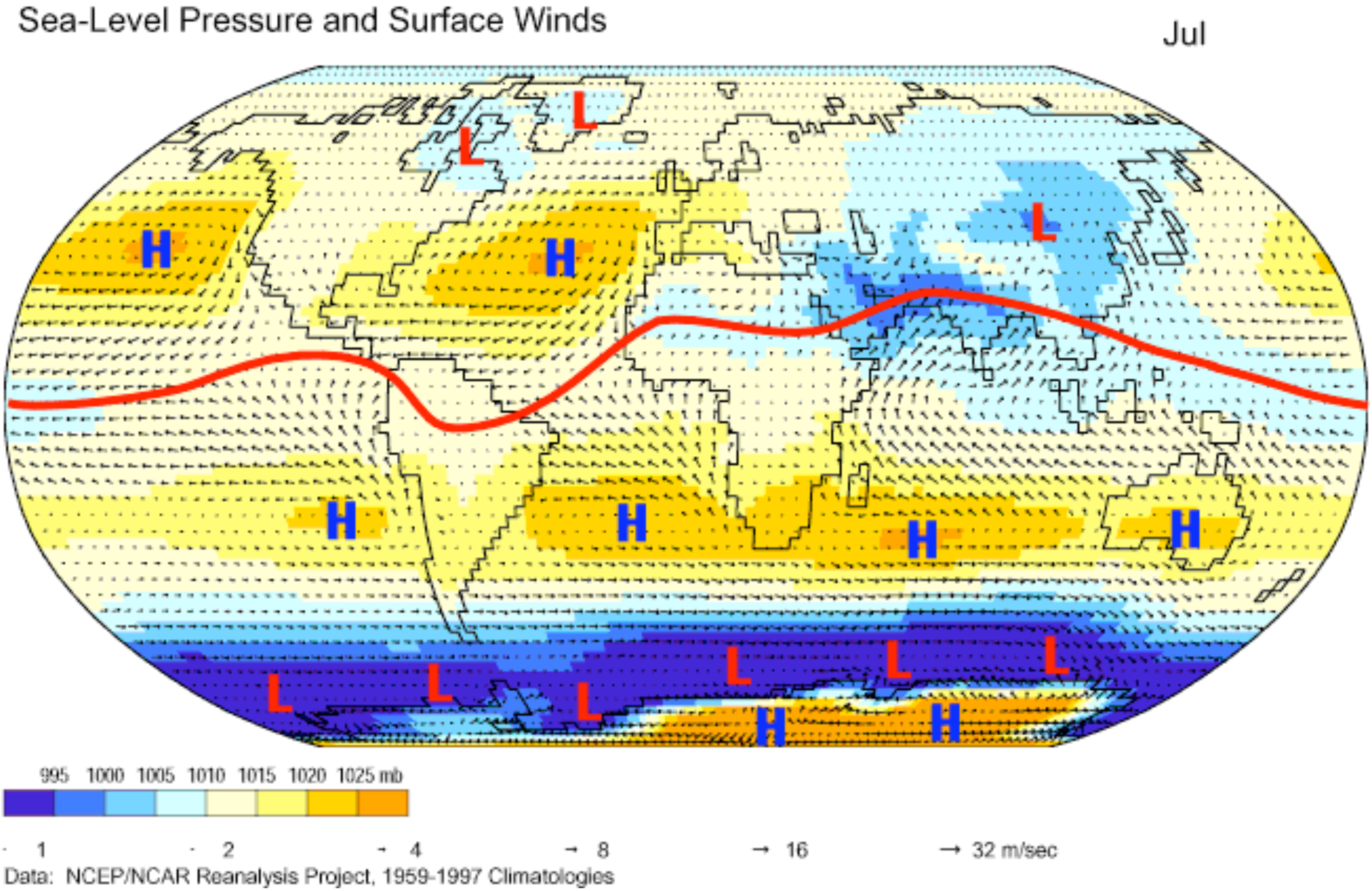


Fig. 7.13 Annual mean wind stress over the global oceans depicted as vectors. The arrow at bottom right corresponds to 5 dyn cm^{-2} and contours of magnitude of 0.5, 1, 2, and 3 dyn cm^{-2} are plotted (1 dyn cm^{-2} = 0.1 N m^{-2}). [From Trenberth *et al.* (1990). Reprinted with permission from the American Meteorological Society.]

Climatological sea surface height in the circumpolar region.





Climatological surface winds are organized by zones of high and low pressure. Note the subtropical high pressure zones over ocean basins stemming from relatively cool temperatures there.

The highs can be seen in the wind stress field…

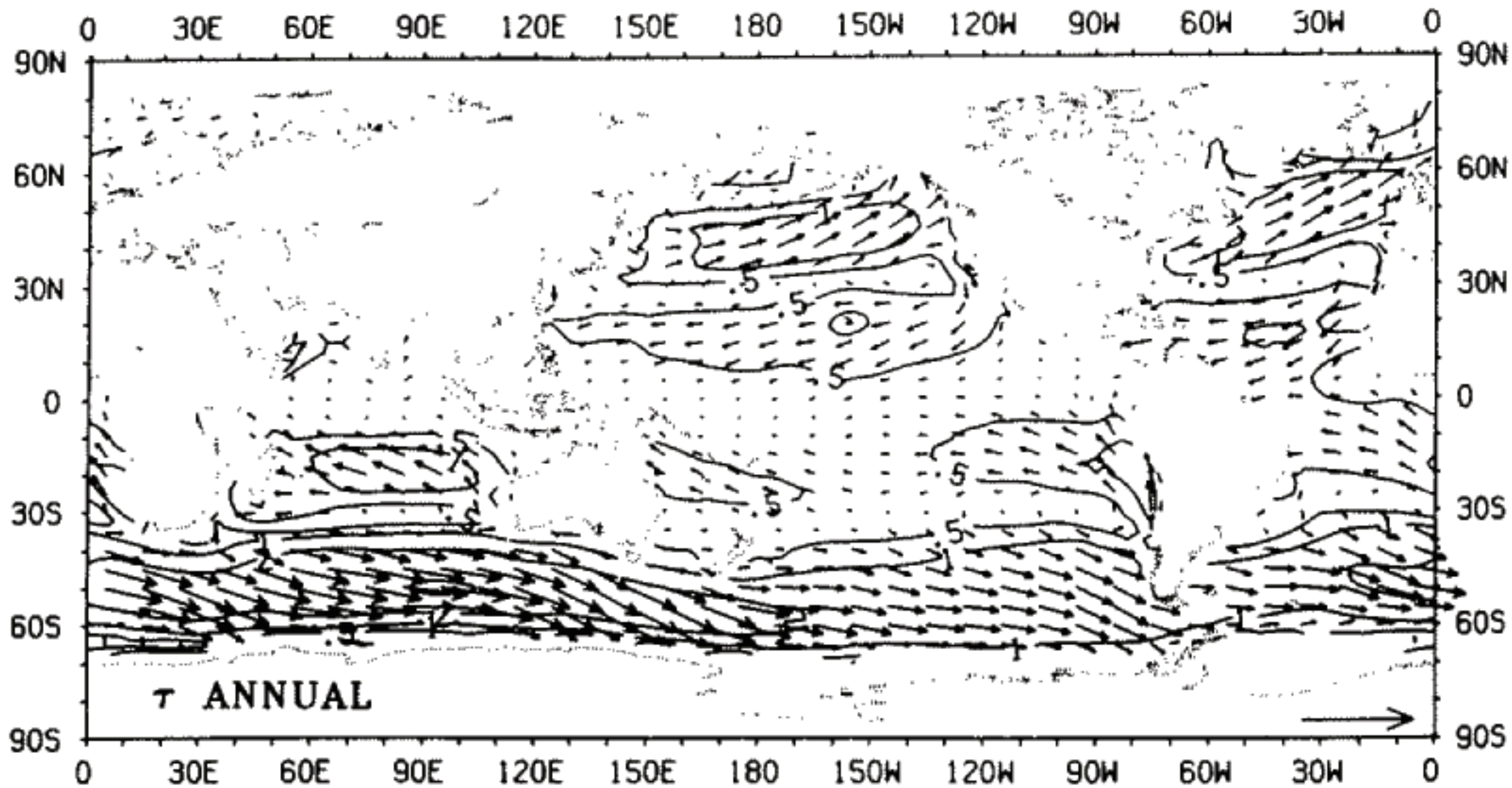
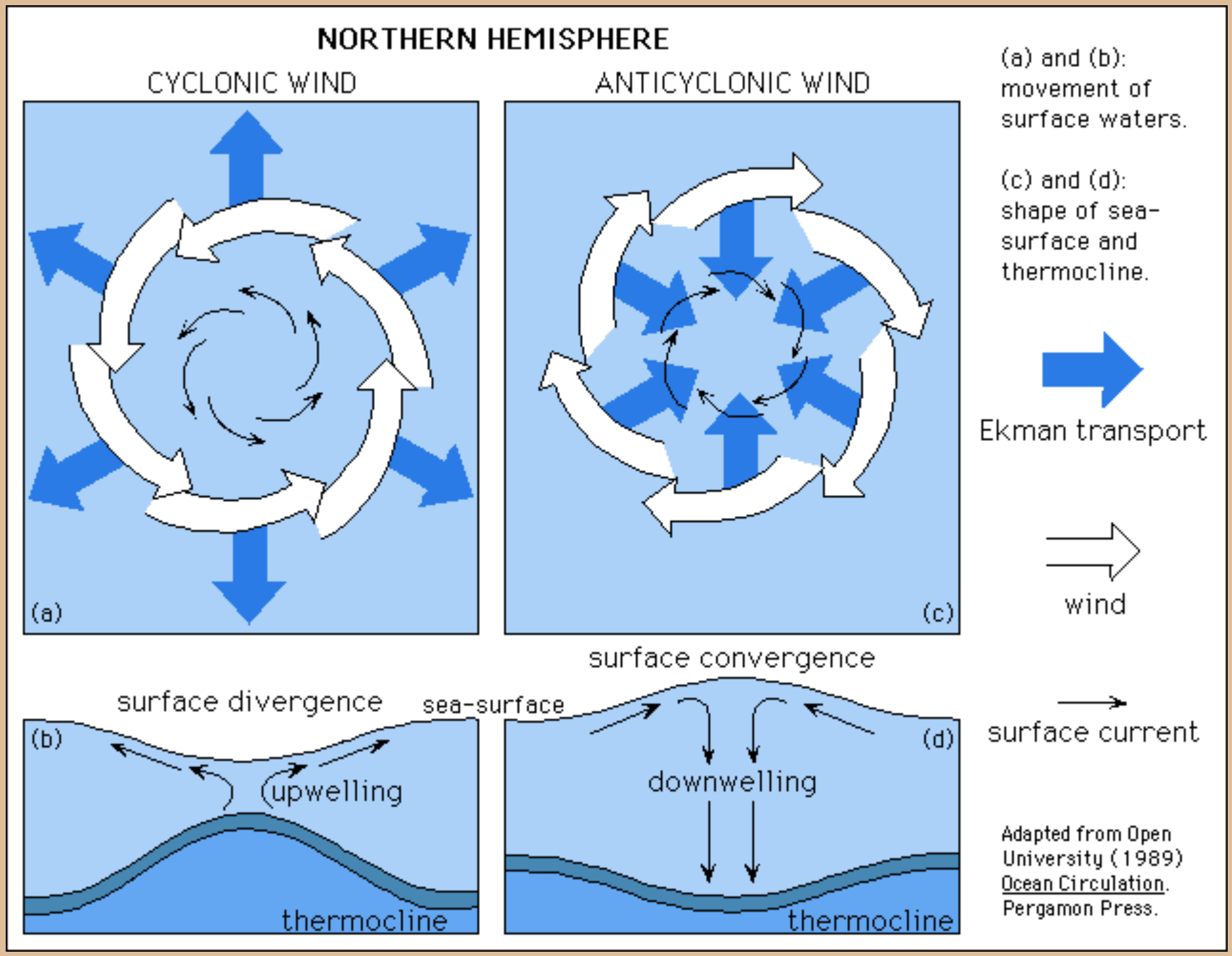
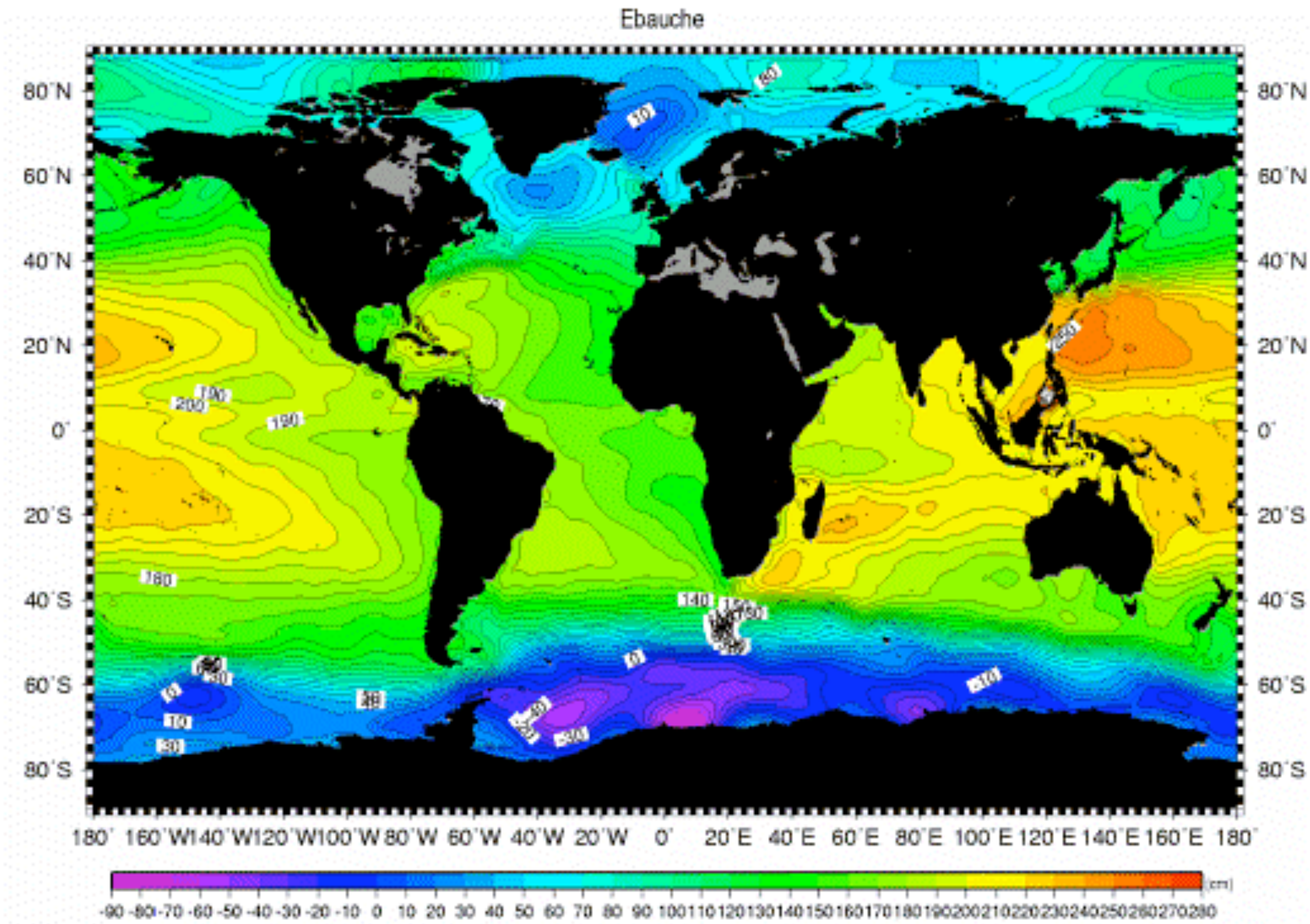


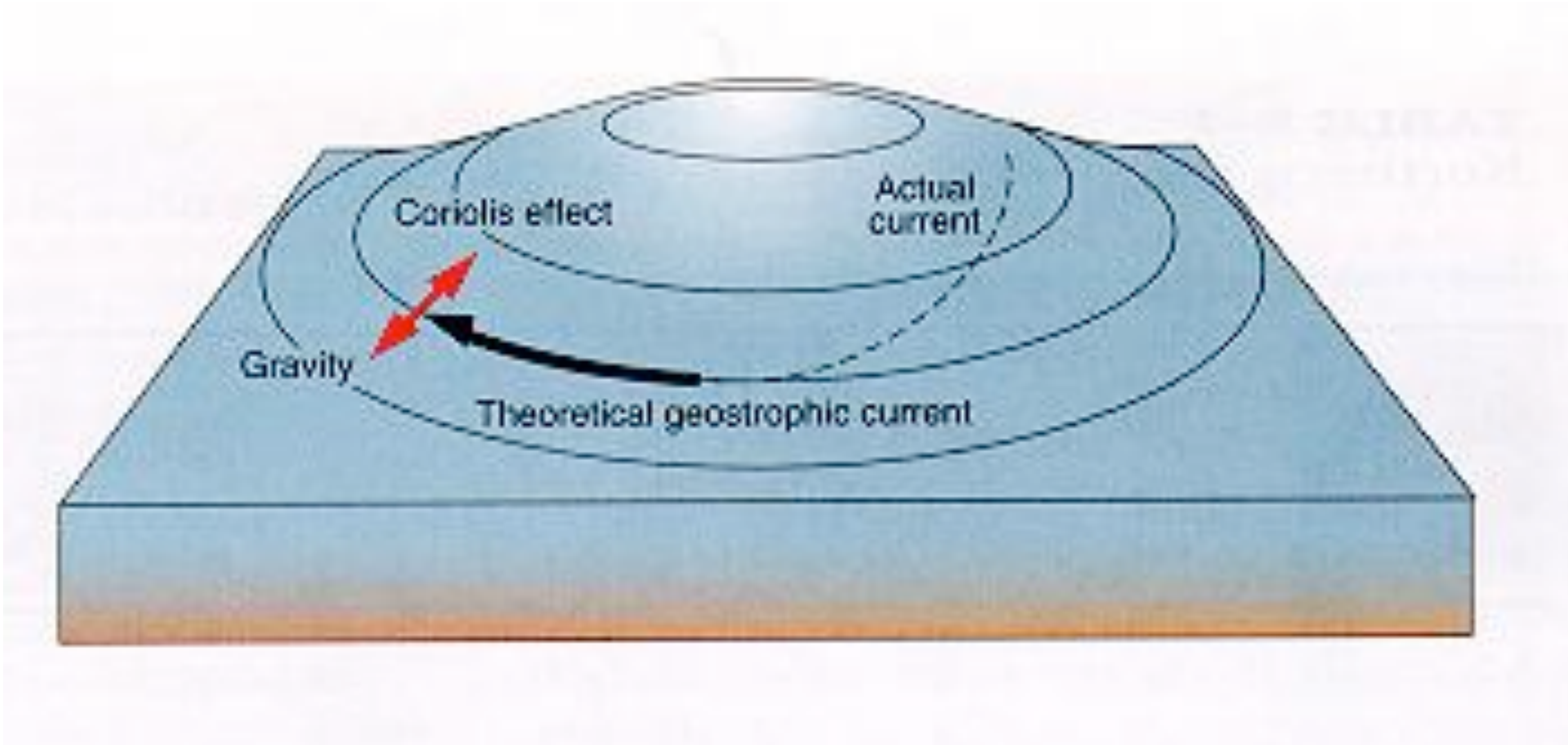
Fig. 7.13 Annual mean wind stress over the global oceans depicted as vectors. The arrow at bottom right corresponds to 5 dyn cm^{-2} and contours of magnitude of 0.5, 1, 2, and 3 dyn cm^{-2} are plotted (1 dyn cm^{-2} = 0.1 N m^{-2}). [From Trenberth *et al.* (1990). Reprinted with permission from the American Meteorological Society.]

Through the Ekman mechanism, the clockwise atmospheric flow (in the northern hemisphere) creates a pile-up of water in the middle of the ocean basin.





Mean sea surface height of the ocean as given by a merging of *in situ* and satellite measurements.



The geostrophic current resulting from the pile-up of water in the center of the basin is clockwise. This is what generates the sub-tropical gyres.

Surface Ocean Currents