MAR 110 LECTURE #11
Ocean Circulation Dynamics

Earth’s Rotation Effects
To an Earth observer in the northern hemisphere, the Coriolis “force” (due to the rotation of the earth) causes the trajectory of an “freely-moving” object to curve to the right of its direction.

Ekman Transport
It is due to the Coriolis force, that the surface current caused by the drag of the wind on the water flows 45 degrees to the right of the wind (in the northern hemisphere). The surface current drags the deeper currents along, but they also are deflected to the right in an Ekman Spiral Flow. The net transport of water – the Ekman Transport - in this upper layer due to the wind is perpendicular to the right to the direction of the wind. (II)
Ekman Transport & Coastal Upwelling

Depending on which direction the wind blows along a coast, the associated Ekman transport will be either offshore onshore or pushed offshore. When the wind is blowing with the coast to its left in the Northern Hemisphere (NH), the offshore Ekman Transport (ET) is replaced by upwelling waters from below. When the NH wind has the coast to its right, the ET is onshore and downwelling results. Upwelling brings deeper and generally more nutrient-rich water up to the surface along the coast, while downwelling pushes the nutrient-poor warm surface water down. (ItO. LEiO)
Global Wind Patterns. In the North Atlantic subtropical ocean basin (box), the dominant surface wind forcing is a combination of the northeastward moving Prevailing Westerlies and the southwestward moving Northeast trades. The Coriolis Effect on these Hadley and Ferrel cell surface winds are illustrated.
Subtropical Ocean Basin Gyre Circulation
The Ekman Transport associated with the Westerlies and Trade Winds push surface water towards the center of the ocean basin –forming a mound of water about 1 m high. The slope of the mound produces a horizontal pressure gradient force $G$ that initiates the downhill motion of a water parcel. Once moving the Coriolis force $C$ acts to the right of its motion causing the trajectory of the water parcel to curve to the right until the $C$ and $G$ are in opposite directions and in balance. The resulting flow is a geostrophic current flows around the mound following the elevation contours of the mound. (LEiO)
Principles of Geostrophic Ocean Flow
Geostrophic Ocean Flow is straight-line flow due to a balance of the Coriolis force to the right (NH) and a pressure gradient force (PGF - usually due to sea surface slopes).

Atlantic Ocean Basin Gyre Circulation
The North Atlantic Gyre, with the Sargasso Sea at its center, is defined on the west by a narrow, swift northeastward-flowing geostrophic current called the Gulf Stream; and on the east by broad, slow southwestward-flowing Canary Current. Because of the Earth rotation effects, the ridge of the Ekman-Transport generated mound is shifted towards the west, thus forming a Western Boundary Current (WBC)– in this case the Gulf Stream. (LEiO)
Atlantic Ocean Basin Gyre Circulation Schematic

The northern hemisphere Westerlies and Northeast Trade Winds produce the North Atlantic Subtropical Gyre, with the North Equatorial Current; The southern hemisphere Westerlies and Southeast Trade Winds produce the South Atlantic Subtropical Gyre, with the South Equatorial Current. The Equatorial Countercurrent returns eastward in the doldrums between the North and Southeast Trades.

Subtropical Ocean Gyres

The global winds produce geostrophic flow gyres in the principal subtropical ocean basins. The gyres are defined by western boundary currents (Gulf Stream, Brazil Current, Kuroshio), eastward flowing currents on the polar sides, broad equatorward currents (Canary & California currents) on the eastern side, and east and west zonal currents in the tropics. (LEIO)
Gulf Stream Dynamic Topography
The sea level hill (dashed) in this transect across the Gulf Stream (see Figure 16.10) is consistent with the (a) the warmer, thicker (because of thermal expansion) layer to the right, which rises higher than the thinner, colder layer to the left. The sea surface slope-induced pressure gradient force toward the left balances the Coriolis force, which is to the right of a geostrophic Gulf Stream, which flows straight into the page. (VA)
Dynamic Topography of the California Current - an Eastern Boundary Current
The California Current is a broad, slow eastern boundary current, much like the Canary Current in the North Atlantic. (LEIO)
Equatorial – Tropical Current System

(Below) The North and South Trade Winds force westward-flowing North and South Equatorial currents. Because of continental blockage, Equatorial Countercurrents and Undercurrents flow back in the doldrums region. (Above) The Ekman Transports for the Trades produce upwelling along the equator.