The restless ocean

The waters of the ocean move because of the action of three main mechanisms:

- Cooling near the polar regions and warming near the equatorial region,
- The force exerted by the winds on the ocean surface, and
- The tides arising from gravitational pull of the moon and the sun.

**Conveyor belt:** Water is cooled near the poles. As a result, its density increases and it sinks to great depths, setting up a global scale circulation known as the conveyor belt or thermohaline circulation. Water sinks in the north Atlantic and upwells (rises) in the Pacific and Indian Oceans. The velocity associated with this circulation is typically a small fraction of a cm/s and the time scale associated with it is a few centuries. Since it is difficult to measure directly, its existence must be inferred from analysis of the distribution of temperature, salinity, and other fields.

**Wind forced surface circulation:** Motion forced by winds is most noticeable within the upper 1 km from the surface. The most striking feature of the wind-forced surface circulation is the sub-tropical gyre, in which a strong poleward (towards the pole) current near the western boundary (east coast of a continent) is balanced by a gentler equatorward drift over the rest of the basin. In the Atlantic and Pacific Oceans, the strong western boundary currents are called the Gulf Stream and Kuroshio respectively. The strongest ocean current is the Antarctic Circumpolar Current, which flows all round the globe in the Southern (or Antarctic) Ocean.

**Seasonal winds and surface currents** over North Indian Ocean: The circulation in the north Indian Ocean is unique because it experiences strong seasonal winds called the monsoons. Hence, unlike in much of the Pacific and Atlantic Oceans, the currents in the north Indian Ocean change with season. Recent research shows that the Arabian Sea, the Bay of Bengal, and the equatorial Indian Ocean function as a single dynamical entity, making the current at any location in the basin a response not just to the local winds, but also to winds elsewhere in the basin. For example, the strongest currents along the east coast of India occur not only during the summer monsoon, when the winds are strongest, but during March-April, a period of weak winds.

**Motion due to tides** is strongly periodic and leads to upward and downward movement of the water surface. The up and down motion of the surface is accompanied by horizontal currents that are also periodic. Tidal motion is most conspicuous in shallow coastal areas. Its importance, in comparison to wind-driven circulation, reduces in deeper waters.

**Conveyor belt:** The Global Ocean Conveyor Belt (red arrows warm, blue arrows cold).

**Wind forced surface circulation:** Schematic of wind-forced surface circulation. Note the poleward currents near the western boundaries in the Pacific, Atlantic, and south Indian Oceans. (KS = Kuroshio, GS = Gulf Stream, ACC = Antarctic Circumpolar Current).

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Sea level (cm) measured by the tide gauge at Mormugao Port, and tidal currents (cm/s) off Mormugao. Note the rhythmic changes associated with the tides and how the tidal current vector rotates over a day.

**Seasonal winds and surface currents** in the north Indian Ocean.

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The seasonally reversing surface currents (cm/s) in the north Indian Ocean.