Ocean Currents

For Prelims: Waves, Tides, Ocean currents, Coriolis effect, Antarctic Circumpolar Current (ACC), Monsoon, Gulf Stream, Kuroshio Current, Agulhas Current, Indian Ocean.

For Mains: About Ocean Current, Types, Characteristics, Formation, Impact on Climates, Fishing and Navigation, Major Ocean Currents.

What are Ocean Currents?

- **About:**
  - The movement of ocean water is continuous and can be categorized into three types: waves, tides, and Ocean currents.
  - Ocean currents are the **continuous, predictable, directional movement** of seawater. It is a massive movement of ocean water that is caused and influenced by various forces.
  - They are like river flows in oceans.
  - Ocean water moves in 2 directions: **horizontally** and **vertically.**
    - Horizontal movements are referred to as currents, while vertical changes are called upwellings or downwellings.
- **Types of Ocean Currents:**
  - **Based on Depth:**
    - **Surface Currents:** These currents, driven primarily by global wind systems powered by solar energy, occur in the upper 400 meters of the ocean and constitute about **10%** of the ocean's total water.
      - By moving warm water from the tropics toward the poles, surface currents play a critical role in moderating local and global climates.
      - For Example: Gulf Stream (Atlantic Ocean), Kuroshio Current (Pacific Ocean) , Agulhas Current (Indian Ocean).

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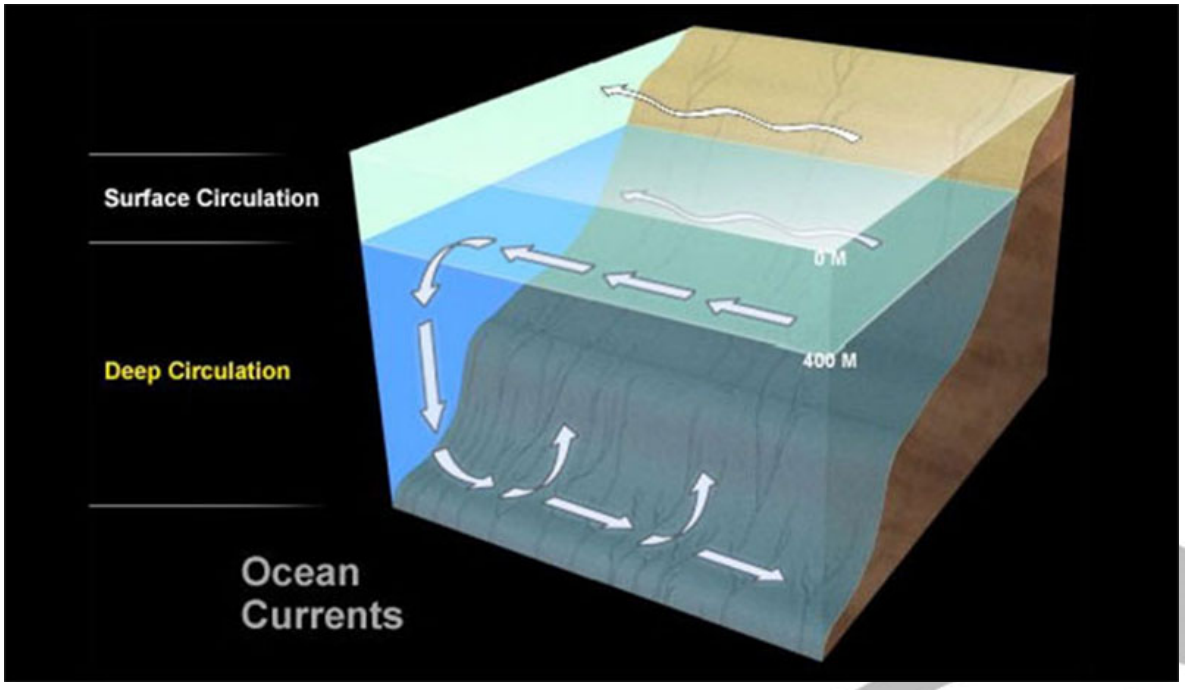


- **Deep Water Currents**: The remaining 90% of ocean water is influenced by changes in water density due to temperature and salinity variations, known as thermohaline circulation.
    - These currents are generated when dense, cold water sinks into deep ocean basins, especially in high-latitude regions, creating a global "conveyor belt."
    - This vast, interconnected system of surface and deep currents circulates throughout the world's oceans over thousands of years, impacting **climate** stability and the cycles of carbon dioxide and **nutrients** in the ocean.
    - For Example: North Atlantic Deep Water (NADW), Antarctic Bottom Water (AABW).

    - **Based on Temperature:**
        - **Cold Currents**: Cold currents **carry cooler water into warmer regions.**
            - They are typically found along the **western coastlines of continents** in low to mid-latitudes and along eastern coastlines at higher latitudes.
            - These currents help **moderate temperatures in coastal regions** and contribute to nutrient upwelling, supporting marine life.
            - For Example: Kurile or Oyashio Current (North Pacific Ocean), California Current (Pacific Ocean).
        - **Warm Currents**: These currents **transport warm water into colder areas** and are usually found along the eastern coastlines of continents in lower and mid-latitudes, as well as along the western coastlines in the northern hemisphere at higher latitudes.
            - Warm currents significantly affect coastal climates, often resulting in milder weather conditions.
            - For Example: Gulf Stream (North Atlantic Ocean), Antilles Current (North Atlantic Ocean)

What are the Factors Responsible for Origin of Ocean Currents?

- Ocean currents are influenced by a combination of primary and secondary forces. These forces initiate, direct, and modify the movement of ocean waters, shaping global climate and supporting marine ecosystems.
- **Primary Forces:**
    - **Insolation**
        - Heating by **solar energy** causes water to expand, making ocean levels slightly higher near the **equator** than at mid-latitudes by around 8 cm. This creates a minor gradient, causing water to flow gently from east to west.

- **Wind (Atmospheric Circulation)**
    - Winds blowing across the ocean surface exert frictional force, pushing water in the direction of the wind. Wind affects both the strength and direction of ocean currents, which is further influenced by the Coriolis effect.
        - For instance, monsoon winds drive the seasonal reversal of currents in the Indian Ocean.
    - **Oean circulationc** patterns often reflect atmospheric circulation, with **anticyclonic** (high-pressure) systems typically prevailing in mid-latitudes, while **cyclonic** (low-pressure) systems are more common in higher latitudes.
    - In areas affected by **monsoonal winds,** such as the Northern **Indian Ocean,** the current direction changes seasonally with the wind patterns.
- **Gravity:**
    - Gravity pulls water downwards, affecting the gradient and contributing to variations in ocean current flow.
- **Coriolis Force:**
    - The coriolis effect, caused by the Earth's rotation, causes moving water to be **deflected to the right in the Northern Hemisphere** and to the **left in the Southern Hemisphere.**
    - This results in the formation of **large circular currents** known as gyres.
        - For example the **Sargasso Sea** in the North Atlantic Ocean.
        - The **Sargasso Sea** is a region in the Atlantic Ocean bounded by four currents, forming a circular ocean gyre driven by wind movements and the Coriolis effect, which determines the circulatory patterns.

- **Secondary Forces:**
    - **Salinity Variations in Water:**
        - Variations in water density, influenced by both temperature and salinity, drive the vertical movement of ocean currents.
        - **Higher salinity results in denser water,** and similarly, colder water is denser than warmer water. This difference causes **denser water to sink,** while **lighter water rises,** creating a **continuous vertical circulation.**
    - **Temperature differences of Water:**
        - In polar regions, **cold, dense water sinks** and gradually moves toward the **equator,** forming **cold-water currents a**long the ocean floor.
        - Conversely, **warm-water currents originate at the equator,** where warm water **flows along the surface toward the poles** to replace the sinking cold water.
        - This exchange forms a **global "conveyor belt"** that **redistributes heat,** influences climate patterns, and maintains the temperature balance in marine ecosystems.

What are the Key Characteristics of Ocean Currents?

- **Coriolis Effect and General Movement of Currents:**
    - The general movement of ocean currents follows a **clockwise direction in the Northern Hemisphere** and an **anticlockwise direction in the Southern Hemisphere,** primarily due to the **Coriolis force.** This pattern is consistent with Ferrel's law.
    - An important exception is the **Indian Ocean,** where the direction of currents reverses seasonally in response to the monsoon winds.
- **Movement of Warm and Cold Currents:**
    - Warm currents typically move toward colder regions, while cold currents flow toward warmer seas.
    - In low latitudes, warm currents flow along the eastern coasts of continents, and cold currents along the western coasts. This pattern reverses in higher latitudes, where warm currents flow along western coasts and cold currents along eastern coasts.
- **Convergence and Divergence:**
    - Convergence occurs when **warm and cold currents meet, often leading to mixing and nutrient upwelling,** which supports marine life.
    - Divergence happens when a **single current splits into multiple currents** flowing in different directions, facilitating the distribution of heat and nutrients across vast oceanic areas.

- **Coastal Influence:**
  - The shape and position of coastlines significantly influence the direction and movement of ocean currents. Coastal topography can guide currents, affecting their flow patterns.
- **Subsurface Currents:**
  - Ocean currents are not confined to the surface but also occur beneath the water due to differences in salinity and temperature.
  - For instance, the dense, saline water of the Mediterranean Sea sinks and flows as a subsurface current past the Strait of Gibraltar.

What is the Impact of Ocean Currents on Regional Climates, Fishing and Navigation?

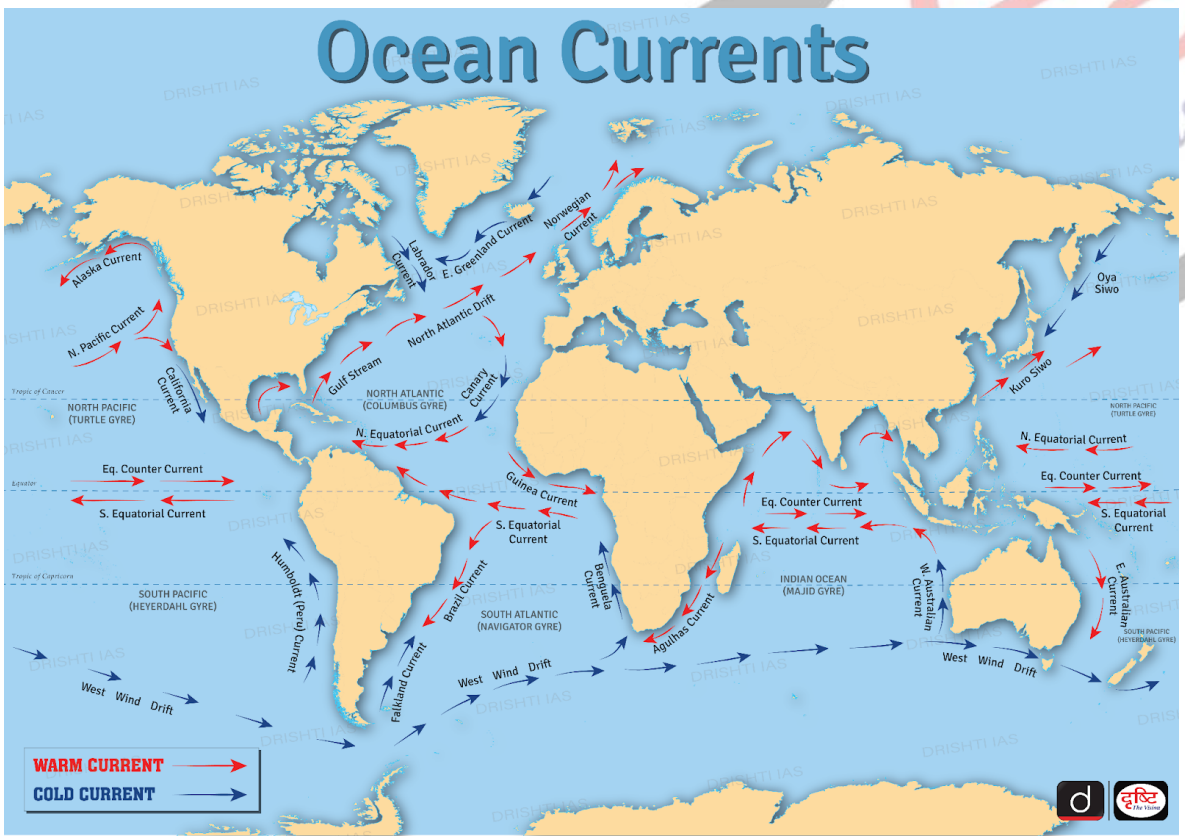
- **Desert Formation:**
  - Cold ocean currents have a direct influence on **desert** formation, particularly along the **western coasts** of **tropical and subtropical continents.**
  - These currents **cool the air,** leading to a **reduction in moisture,** which in turn causes **arid conditions and foggy weather.**
    - For example, the **cold** Humboldt current off the coast of Peru contributes to the formation of the Atacama Desert, one of the driest places on Earth.
- **Impact on Rainfall Patterns:**
  - Warm ocean currents are responsible for bringing rain to coastal regions and sometimes even to interior areas.
  - In tropical and subtropical latitudes, warm currents flow **parallel to the east coasts** of continents, which contributes to warm and rainy climates, particularly in regions like Florida and Natal.
  - These areas, lying on the western margins of **subtropical anticyclones,** experience significant rainfall, especially during summer months.
- **Moderating Effect on Coastal Temperatures:**
  - Ocean currents help moderate temperatures along coastlines. For instance, the North Atlantic Drift brings warmth to Western Europe, especially to the **British Isles** (a group of islands in the North Atlantic Ocean), preventing extremely cold winters.
  - The Canary Current, a cold current off the western coast of Africa, has a cooling effect on Spain, Portugal, and nearby regions, moderating temperatures and influencing regional climates.
- **Fishing Grounds:**
  - The **mixing of cold and warm ocean currents** creates some of the richest fishing grounds in the world. These areas are rich in nutrients and plankton, which serve as the primary food source for fish.
    - Examples include the **Grand Banks near Newfoundland,** Canada, and the **Northeastern Coast of Japan**, both of which are renowned for their abundant marine life.
  - The **movement and mixing of ocean currents** help **replenish oxygen levels** and promote the growth of **plankton,** making these areas ideal for fishing.
- **Drizzle and Fog Formation:**
  - The meeting of warm and cold ocean currents often leads to the formation of foggy weather, where precipitation occurs in the form of light drizzle. This phenomenon is particularly noticeable in regions like Newfoundland, where the Labrador current (cold) meets the Gulf Stream (warm), resulting in foggy conditions that **affect navigation and weather patterns** in these areas.
- **Tropical Cyclones:**
  - Warm ocean currents play a significant role in the formation and intensification of tropical cyclones. These currents accumulate warm water in tropical regions, which provides the necessary energy for the development of cyclonic storms. The **Indian Ocean** and **Atlantic Ocean** are notably affected by these processes.
- **Impact on Navigation:**
  - Ocean currents aid maritime navigation by **influencing ship routes.** Currents such as the **North Equatorial Drift** assist ships traveling westward, as in the case of a vessel moving from Mexico to the Philippines.
  - Conversely, when ships need to travel eastward, such as from the Philippines to Mexico,

they can take advantage of counter-equatorial currents.
    - A thorough understanding of ocean currents, including their direction and speed, is crucial for optimizing maritime navigation routes and enhancing fuel efficiency in global trade.

What are the Major Ocean Currents?

- **Equatorial Current System:**
    - **North and South Equatorial Currents:** They are present in all major oceans except the Arctic. They flow east to west, driven by the prevailing trade winds.
    - **Equatorial Counter Current:** They are positioned between the North and South Equatorial Currents, it flows from west to east, countering the equatorial currents' direction. This current plays a key role in balancing equatorial water movement.
- **Antarctic Circumpolar Current (ACC):**
    - It is also known as the **West Wind Drift**. It is unique currents encircling Antarctica.
    - It flows clockwise, from west to east, and serves as a major conduit of cold water across the **Southern Ocean**, connecting the **Atlantic, Pacific,** and **Indian Oceans.**
- **Humboldt or Peruvian Current:**
    - This **low-salinity current** has a large marine ecosystem and serves as one of the major nutrient systems of the world.
        - It flows from the southernmost tip of Chile to northern Peru, along the west coast of South America.
- **Kurile or Oyashio:** This sub-arctic ocean current circulates in a counterclockwise direction.
    - It originates in the Arctic Ocean flows south via the Bering Sea in the western North Pacific Ocean.
    - It is a **nutrient-rich current.**
    - It collides with Kurioshio off the Japanese eastern shore to form the North Pacific Drift.
- **California Current:** It is the extension of the Aleutian Current along the west coast of North America in a southward flowing direction.
    - It is a part of North Pacific Gyre.
    - It is a region of strong Upwelling.
- **Labrador Current:** It flows from the **Arctic Ocean** towards the south and meets the warm northward moving **Gulf Stream.**
    - The combination of cold Labrador Current and warm Gulf Stream is known for creating one of the richest fishing grounds of the world.
- **Canary**: It is a low salinity current extending between Fram Strait and Cape Farewell.
    - It connects the Arctic directly to the North Atlantic.
    - It is a major freshwater sink for the Arctic.
    - It is a major contributor to **sea-ice export** out of the Arctic.
- **Benguela Current:** It is a branch of the West Wind Drift of the Southern Hemisphere.
    - It flows in the eastern portion of South Atlantic Ocean Gyre.
    - It has low salinity, presence of upwelling and excellent fishing zone.
- **Falkland Current:** It is a branch of Antarctic Circumpolar Current.
    - It is also known as Malvinas Current.
    - It is named after the Falkland Islands.
    - This cold current mixes with warm Brazil current and forms the Brazil-Malvinas Confluence Zone which is responsible for the region's temperate climate.
- **Northeast Monsoon Current:** Indian North Equatorial Current flows southwest and west, crossing the Equator.
- **Somali Current:** It is analogous to the Gulf Stream in the Atlantic Ocean.
    - The Current is heavily influenced by monsoon.
    - It is a region of major upwelling systems.
- **Western Australian Current**: It is also known as West Wind Drift.
    - It is a part of the Antarctic Circumpolar Current.
    - It is a seasonal current- strong in summer and weak in winter.'
- **Kuroshio**: This west boundary current is also known as Japan current or Black Current. The term "Kuroshio" in Japanese means "Black Stream ''.
    - It is the Pacific analogue of the Gulf Stream in the Atlantic Ocean.
    - The average surface temperature of this current is warmer than the surrounding ocean.
    - This also helps in regulating the temperature of Japan, which is relatively warmer.

- **North Pacific Current:** It is formed by the collision of **Kurioshio & Oyashio.**
    - It circulates counterclockwise along the Western North Pacific Ocean.
- **Alaskan Current:** It results from a northward diversion of a part of the North Pacific Ocean.
- **East Australian Current:** It acts to transport tropical marine fauna to habitats in sub-tropical regions along the southeast Australian coast.
- **Florida Current:** Flows around Florida Peninsula and joins the Gulf Stream at Cape Hatteras.
- **Gulf Stream:** It is a western intensified current-driven mainly by wind stress.
    - It splits into North Atlantic Drift (crossing Northern Europe & southern stream) and Canary Current (recirculating of West Africa)
- **Norwegian Current:** This wedge-shaped current is one of the two dominant Arctic inflows of water.
    - It is a branch of North Atlantic Drift and sometimes also considered as an extension of the Gulf Stream.
- **Brazilian Current:** It flows along the south coast of Brazil till Rio de la Palta.
    - It joins the cold Falkland Current at the Argentine Sea making it a temperate sea.
- **Mozambique Current:** It flows between Mozambique and the island of Madagascar along the African east coast in the Mozambique Channel.
- **Agulhas Current:** It is the largest western boundary ocean current.
    - Flows south along the east coast of Africa.
- **Southwest Monsoon Current**: It dominates the Indian Ocean during the southwest monsoon season (June–October).
    - It is a broad eastward flowing ocean current that extends into the Arabian Sea and Bay of Bengal.



UPSC Civil Services Examination, Previous Year Questions (PYQs)

Prelims

Q) What explains the eastward flow of the equatorial counter-current (2015)

a. The Earth’s rotation on its axis
b. Convergence of the two equatorial currents
c. Difference in salinity, of water

d. Occurrence of the’ belt of calm near the equator

Answer: (b)

Mains

Q) How do ocean currents and water masses differ in their impacts on marine life and the coastal environment? Give suitable examples. **(2019)**

Q) Explain the factors responsible for the origin of ocean currents. How do they influence regional climates, fishing, and navigation? **(2015)**