

1  **CHAPTER 7**


**Ocean Circulation**

2  **Objectives:**


- Discuss how ocean currents are measured.
- Describe the location and direction of flow for all the subtropical surface gyres, and know the names of all currents involved.
- Explain the phenomenon of western intensification and how it influences boundary currents.
- Discuss the conditions that create Ekman transport.

3  **Objectives (continued):**


- Identify various causes of upwelling and downwelling and how they affect the abundance of marine life.
- Understand the mechanisms that produce El Niño-Southern Oscillation events.
- Describe the origin and effects of thermohaline (deep-water) circulation.
- Integrate knowledge of weather and climate with an understanding and realization of the importance of ocean currents.

4  **Ocean currents**

- Moving seawater
- Surface ocean currents
  - Transfer heat from warmer to cooler areas
  - Similar to pattern of major wind belts
  - Affect coastal climates
- Deep ocean currents
  - Provide oxygen to deep sea
- Affect marine life
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5  **Types of ocean currents**


- Surface currents
  - Wind-driven
  - Primarily horizontal motion
- Deep currents
  - Driven by differences in density caused by differences in temperature and salinity
  - Vertical and horizontal motions


6  **Measuring surface currents**


- Direct methods
  - Floating device tracked through time
  - Fixed current meter
- Indirect methods
  - Pressure gradients
  - Radar altimeters
  - Doppler flow meter

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8  **Measuring surface currents**

















9  **Measuring surface currents (accidentally)**

10  **Measuring surface currents**

11  **Measuring deep currents**

- Floating devices tracked through time
- Chemical tracers
  - Tritium
  - Chlorofluorocarbons
- Characteristic temperature and salinity

12  **Surface currents**

- Frictional drag between wind and ocean
- Wind plus other factors such as
  - Distribution of continents
  - Gravity
  - Friction
  - Coriolis effect cause
- Gyres or large circular loops of moving water
- 13  **Ocean gyres**
- 14  **Other surface currents**
  - Equatorial Countercurrents
  - Subpolar gyres
- 15  **Ocean Circulation**
- 16  **Ekman spiral**
  - Surface currents move at angle to wind
  - Ekman spiral describes speed and direction of seawater flow at different depths
  - Each successive layer moves increasingly to right (N hemisphere)
- 17  **Geostrophic flow**
  - Ekman transport piles up water within subtropical gyres
  - Surface water flows downhill (gravity) and
  - Also to the right (Coriolis effect)
  - Balance of downhill and to the right causes geostrophic flow around the “hill”
- 18  **Ekman transport**
  - Average movement of seawater under influence of wind
  - 90° to right of wind in Northern hemisphere
  - 90° to left of wind in Southern hemisphere
- 19  **Western intensification**
  - Top of hill of water displaced toward west due to Earth's rotation
  - Western boundary currents intensified
    - Faster
    - Narrower
    - Deeper
- 20  **Ocean currents and climate**
  - Warm ocean currents warm air at coast
    - Warm, humid air
    - Humid climate on adjoining landmass
  - Cool ocean currents cool air at coast
    - Cool, dry air
    - Dry climate on adjoining landmass
- 21  **Ocean currents and climate**
- 22  **Ocean currents and climate**
- 23  **Diverging surface seawater**
- 24  **Converging surface seawater**
- 25  **Coastal upwelling and downwelling**
  - Ekman transport moves surface seawater onshore (downwelling) or
  - Offshore (upwelling)
- 26  **Coastal upwelling and downwelling**
  - Ekman transport moves surface seawater onshore (downwelling) or
  - Offshore (upwelling)
- 27  **Antarctic circulation**
- 28  **Atlantic Ocean circulation**
  - North Atlantic Subtropical Gyre
  - North Equatorial Current

- Gulf Stream
- North Atlantic Current
- Canary Current
- South Equatorial Current
- Atlantic Equatorial Counter Current

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30  **Atlantic Ocean circulation**

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33  **Other North Atlantic currents**

- Labrador Current
- Irminger Current
- Norwegian Current
- North Atlantic Current
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**Climate effects of North Atlantic currents**

- Gulf Stream warms East coast of U.S. and Northern Europe
- North Atlantic and Norwegian Currents warm northwestern Europe
- Labrador Current cools eastern Canada
- Canary Current cools North Africa coast

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- North Pacific subtropical gyre
- Kuroshio
- North Pacific Current
- California Current
- North Equatorial Current
- Alaskan Current

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**Pacific Ocean circulation**

- South Pacific subtropical gyre
- East Australian Current
- Antarctic Circumpolar Current
- Peru Current
- South Equatorial Current
- Equatorial Counter Current

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**Atmospheric and oceanic disturbances in Pacific Ocean**

- Normal conditions
  - Air pressure across equatorial Pacific is higher in eastern Pacific
  - Strong southeast trade winds
  - Pacific warm pool on western side
  - Thermocline deeper on western side
  - Upwelling off the coast of Peru













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**Normal conditions**

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**Atmospheric and oceanic disturbances in Pacific Ocean**

- El Niño-Southern Oscillation (ENSO)
  - Warm (El Niño) and cold phases (La Niña)
  - High pressure in eastern Pacific weakens
  - Weaker trade winds
  - Warm pool migrates eastward
  - Thermocline deeper in eastern Pacific
  - Downwelling
  - Lower biological productivity
    - Corals particularly sensitive to warmer seawater

- 40  **El Niño-Southern Oscillation (ENSO):  
Warm phase (El Niño)**
- 41  **El Niño-Southern Oscillation (ENSO):  
cool phase (La Niña)**
- Increased pressure difference across equatorial Pacific
  - Stronger trade winds
  - Stronger upwelling in eastern Pacific
  - Shallower thermocline
  - Cooler than normal seawater
  - Higher biological productivity
- 42  **El Niño-Southern Oscillation (ENSO)  
Cool phase (La Niña)**
- 43  **El Niño and La Niña**
- 44  **ENSO events**
- El Niño warm phase about every 2 to 10 years
  - Highly irregular
  - Phases usually last 12 to 18 months
- 45  **ENSO events**
- Strong conditions influence global weather, e.g., 1982-1983 El Niño
  - Flooding, drought, erosion, fires, tropical storms, harmful effects on marine life
- 46  **Indian Ocean circulation**
- 47  **Indian Ocean circulation**
- Indian Ocean subtropical gyre
  - Agulhas Current
  - North and South Equatorial Currents
  - Antarctic Circumpolar Current
  - West Australian Current
  - Equatorial Countercurrent
  - Leeuwin Current
  - Monsoon (seasonal) winds
    - Winds shift from winter to summer
    - Southwest Monsoon Current replaces North Equatorial Current
  - Somali Current
- 48  **Thermohaline circulation**
- Below the pycnocline
  - 90% of all ocean water
  - Slow velocity
  - Movement caused by differences in density (temperature and salinity)
    - Cooler seawater denser
    - Saltier seawater denser
- 49  **Thermohaline circulation**
- Originates in high latitude surface ocean
  - Once surface water sinks (high density) it changes little
  - Deep-water masses identified on T-S diagram
- 50  **Thermohaline circulation**
- Selected deep-water masses
    - Antarctic Bottom Water
    - North Atlantic Deep Water
    - Antarctic Intermediate Water
    - Oceanic Common Water
  - Cold surface seawater sinks at polar regions and moves toward equator
- 51  **Thermohaline circulation**

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53  **Conveyor-belt circulation**

- Combination deep ocean currents and surface currents

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**Deep ocean currents**

- Cold, oxygen-rich surface water to deep ocean
- Dissolved O<sub>2</sub> important for life and mineral processes
- Changes in thermohaline circulation can cause global climate change
  - Example, warmer surface waters less dense, not sink, less oxygen deep ocean

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**End of CHAPTER 7**  
**Ocean Circulation**