Chapter Overview

- The atmosphere and the ocean are an interdependent system.
- Earth has seasons because it is tilted on its axis.
- There are three major wind belts in each hemisphere.
- The Coriolis effect influences atmosphere and ocean behavior.
- Oceanic climate patterns are related to solar energy distribution.

Atmosphere and Oceans

- Solar energy heats Earth, generates winds.
- Winds drive ocean currents.
- Extreme weather events may be related to ocean.
- Global warming affects oceans.

Earth's Seasons

- Earth’s axis of rotation is tilted 23.5 degrees with respect to plane of the ecliptic.
  - Plane of the ecliptic – plane traced by Earth’s orbit around the Sun
- Earth’s orbit is slightly elliptical.

Earth’s tilt, not orbit, causes seasons.
Earth's Seasons

- **Vernal (spring) equinox**
  - About March 21
- **Autumnal equinox**
  - About September 23
- Sun directly overhead at the equator on equinoxes

Earth's Seasons

- **Summer solstice**
  - About June 21
  - Sun directly overhead at Tropic of Cancer – 23.5 degrees north latitude
- **Winter solstice**
  - About December 21
  - Sun directly overhead at Tropic of Capricorn – 23.5 degrees south latitude

Earth's Seasons

- Sun's **declination** varies between 23.5 degrees north and 23.5 degrees south latitudes.
  - Declination – angular distance of Sun from equatorial plane
- Region between these latitudes called the **tropics.**

Earth's Seasons

- **Arctic Circle**
  - North of 66.5 degrees north latitude
  - No direct solar radiation during Northern Hemisphere winter
- **Antarctic Circle**
  - South of 66.5 degrees south latitude

Distribution of Solar Energy

- Concentrated solar radiation at low latitudes
  - High angle of incidence
- Solar radiation more diffuse at high latitudes
  - Low angle of incidence

Distribution of Solar Energy

- Atmosphere absorbs radiation
  - Thickness varies with latitude
- **Albedo** – 0–100%
  - Reflectivity of a surface
  - Average for Earth is 30%
- Angle of sun on sea surface
Sun Elevation and Solar Absorption

<table>
<thead>
<tr>
<th>Elevation of the Sun above the horizon</th>
<th>90°</th>
<th>60°</th>
<th>30°</th>
<th>15°</th>
<th>5°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflected radiation (%)</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Absorbed radiation (%)</td>
<td>98</td>
<td>97</td>
<td>94</td>
<td>80</td>
<td>60</td>
</tr>
</tbody>
</table>

Oceanic Heat Flow

- High latitudes – more heat lost than gained
  - Ice has high albedo
  - Low solar ray incidence
- Low latitudes – more heat gained than lost

Heat Gained and Lost

Physical Properties of the Atmosphere

- Composition
  - Mostly nitrogen (N₂) and oxygen (O₂)
- Other gases significant for heat-trapping properties

Temperature Variation in the Atmosphere

- Troposphere – lowest layer of atmosphere
  - Where all weather occurs
  - Temperature decreases with altitude
  - Extends from surface to about 12 km (7 miles) up

Density Variations in the Atmosphere

- Convection cell – rising and sinking air
- Warm air rises (Less dense)
- Cool air sinks (More dense)
**Water Vapor in Air**
- Partly dependent upon air temperature
  - Warm air typically moist
  - Cool air typically dry
- Influences density of air

**Atmospheric Pressure**
- Thick column of air at sea level
  - High surface pressure equal to 1 atmosphere (14.7 pounds per square inch)
- Thin column of air means lower surface pressure
- Cool, dense air sinks
  - Higher surface pressure
- Warm, moist air rises
  - Lower surface pressure

**Movement of the Atmosphere**
- Air always flows from high to low pressure.
- Wind – moving air

**Movements in the Air**
- Fictional non-spinning Earth
- Air rises at equator (low pressure)
- Air sinks at poles (high pressure)
- Air flows from high to low pressure
- One convection cell or circulation cell

**The Coriolis Effect**
- Deflects path of moving object from viewer’s perspective
  - To right in Northern Hemisphere
  - To left in Southern Hemisphere
- Due to Earth’s rotation

**The Coriolis Effect**
- Zero at equator
- Greatest at poles
- Change in Earth’s rotating velocity with latitude
  - 0 km/hour at poles
  - More than 1600 km/hour (1000 miles/hour) at equator
- Greatest effect on objects that move long distances across latitudes
The Coriolis Effect

Global Atmospheric Circulation

- Circulation Cells – one in each hemisphere
  - Hadley Cell: 0–30 degrees latitude
  - Ferrel Cell: 30–60 degrees latitude
  - Polar Cell: 60–90 degrees latitude
- Rising and descending air from cells generate high and low pressure zones

Global Atmospheric Circulation

- High pressure zones – descending air
  - Subtropical highs – 30 degrees latitude
  - Polar highs – 90 degrees latitude
  - Clear skies

Global Atmospheric Circulation

- Low pressure zones – rising air
  - Equatorial low – equator
  - Subpolar lows – 60 degrees latitude
  - Overcast skies with abundant precipitation

Three-Cell Model of Atmospheric Circulation
Global Wind Belts

- Portion of global circulation cells closest to surface generate winds
- Trade winds – From subtropical highs to equator
  - Northeast trades in Northern Hemisphere
  - Southeast trades in Southern Hemisphere

Global Wind Belts

- Prevailing westerly wind belts – from 30–60 degrees latitude
- Polar easterly wind belts – 60–90 degrees latitude

Characteristics of Wind Belts and Boundaries

<table>
<thead>
<tr>
<th>Region (degrees latitude)</th>
<th>Seasonal Patterns</th>
<th>Dominant Winds</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equatorial (0-5 degrees)</td>
<td>Unpredictable</td>
<td>Light</td>
<td>Light, variable winds, frequent thunderstorms, and much precipitation.</td>
</tr>
<tr>
<td>5-30 degrees</td>
<td>Trade Winds (summer)</td>
<td>Strong, steady winds from the east.</td>
<td></td>
</tr>
<tr>
<td>30 degrees</td>
<td>Zone of Doldrums (Equatorial)</td>
<td>Light</td>
<td>Light, variable winds, fog, rain, thunderstorms, and little stability in the wind.</td>
</tr>
<tr>
<td>30-60 degrees</td>
<td>Polar Front (Boreal)</td>
<td>Strong</td>
<td>Strong, steady winds from the east.</td>
</tr>
<tr>
<td>60-90 degrees</td>
<td>High-Latitude Fronts</td>
<td>Variable</td>
<td>Variable winds, light, fog, rain, and often storms, cold temperatures, and little precipitation.</td>
</tr>
</tbody>
</table>

January Atmospheric Pressures and Winds

- Boundaries between wind belts
  - Doldrums or Intertropical Convergence Zone (ITCZ) – at equator
  - Horse latitudes – 30 degrees
  - Polar fronts – 60 degrees latitude
Idealized Three-Cell Model

• More complex in reality due to
  – Tilt of Earth’s axis and seasons
  – Lower heat capacity of continental rock vs. seawater
  – Uneven distribution of land and ocean

Weather vs. Climate

• Weather – conditions of atmosphere at particular time and place
• Climate – long-term average of weather
• Ocean influences Earth’s weather and climate patterns.

Winds

• Cyclonic flow
  – Counterclockwise around a low in Northern Hemisphere
  – Clockwise around a low in Southern Hemisphere
• Anticyclonic flow
  – Clockwise around a low in Northern Hemisphere
  – Counterclockwise around a low in Southern Hemisphere

Sea and Land Breezes

• Differential solar heating is due to different heat capacities of land and water.
• Sea breeze
  – From ocean to land
• Land breeze
  – From land to ocean

Storms and Air Masses

• Storms – disturbances with strong winds and precipitation
• Air masses – large volumes of air with distinct properties
  – Land air masses dry
  – Marine air masses moist
Fronts

- Fronts – boundaries between air masses
- Warm front
  - Contact where warm air mass moves to colder area
- Cold front
  - Contact where cold air mass moves to warmer area

Tropical Cyclones (Hurricanes)

- Large rotating masses of low pressure
- Strong winds, torrential rain
- Classified by maximum sustained wind speed
- Typhoons – alternate name in North Pacific
- Cyclones – name in Indian Ocean

Hurricane Origins

- Low pressure cell
- Winds feed water vapor
  - Latent heat of condensation
- Air rises, low pressure deepens
- Storm develops

Hurricane Development

- Tropical Depression
  - Winds less than 61 km/hour (38 miles/hour)
- Tropical Storm
  - Winds 61–120 km/hour (38–74 miles/hour)
- Hurricane or tropical cyclone
  - Winds above 120 km/hour (74 miles/hour)
### Hurricanes

- **About 100 worldwide per year**
- **Require**
  - Ocean water warmer than 25°C (77°F)
  - Warm, moist air
  - The Coriolis effect
- **Hurricane season is June 1–November 30**

### Historical Storm Tracks

![Historical Storm Tracks](image)

### Hurricane Anatomy

- **Diameter typically less than 200 km (124 miles)**
  - Larger hurricanes can be 800 km (500 miles)
- **Eye of the hurricane**
  - Low pressure center
- **Spiral rain bands with intense rainfall and thunderstorms**

### Hurricane Anatomy and Movement

![Hurricane Anatomy and Movement](image)
Impact of Other Factors

- Warmer waters favor hurricane development
  - Global warming may impact
- Out of phase relationship with Atlantic and Pacific hurricanes
- Wind shear
- El Niño/La Niña

Hurricane Destruction

- High winds
- Intense rainfall
- *Storm surge* — increase in shoreline sea level

Storm Destruction

- Historically destructive storms
  - Galveston, TX, 1900
  - Andrew, 1992
  - Mitch, 1998
  - Katrina, 2005
  - Ike, 2008
  - Irene, 2011

Damage from Hurricane Irene, 2011

2005 Atlantic Hurricane Season

- Most active season on record
  - 27 named storms
  - 15 became hurricanes
- Season extended into January 2006
- Five category 4 or 5 storms
  - Dennis, Emily, Katrina, Rita, Wilma

Hurricane Katrina

- Costliest and deadliest U.S. hurricane
- Category 3 at landfall in Louisiana
  - Largest hurricane of its strength to make landfall in U.S. history
- Flooded New Orleans
Hurricanes Rita and Wilma

- Rita – September 2005
  - Most intense Gulf of Mexico tropical cyclone
  - Extensive damage in Texas and Louisiana
- Wilma – October 2005
  - Most intense hurricane ever in Atlantic basin
  - Multiple landfalls
  - Affected 11 countries

Historic Hurricane Destructions

- Most hurricanes in North Pacific
- Bangladesh regularly experiences hurricanes
  - 1970 – massive destruction from storm
- Southeast Asia affected often
- Hawaii
  - Dot in 1959
  - Iwa in 1982

Future Hurricane Threats

- Loss of life decreasing due to better forecasts and evacuation
- More property loss because of increased coastal habitation

Ocean’s Climate Patterns

- Open ocean’s climate regions are parallel to latitude lines.
- These regions may be modified by surface ocean currents.

Ocean’s Climate Zones

- Equatorial
  - Rising air
  - Weak winds
  - Doldrums
- Tropical
  - North and south of equatorial zone
  - Extend to Tropics of Cancer and Capricorn
  - Strong winds, little precipitation, rough seas
- Subtropical
  - High pressure, descending air
  - Weak winds, sluggish currents
Ocean's Climate Zones

- Temperate
  - Strong westerly winds
  - Severe storms common
- Subpolar
  - Extensive precipitation
  - Summer sea ice
- Polar
  - High pressure
  - Sea ice most of the year

Sea Ice Formation

- Needle-like crystals become slush
- Slush becomes disk-shaped pancake ice.
- Pancakes coalesce to form ice floes.

Iceberg Formation

- Icebergs break off of glaciers.
  - Floating bodies of ice
  - Different from sea ice
Shelf Ice

- Antarctica – glaciers cover continent
  - Edges break off
  - Plate-like icebergs called shelf ice
- Shelf ice carried north by currents
- Antarctic iceberg production increasing due to global warming.

Wind Power

- Uneven solar heating of Earth generates winds.
- Turbines harness wind energy.
- Offshore wind farms generate electricity.

Global Ocean Wind Energy

End of CHAPTER 6