1 ***Air-Sea Interaction***

Chapter 6

2 **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.

3 **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.
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4 **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.

5 **Earth's Seasons**

- Earth's tilt, not orbit, causes seasons.

6

7 **Earth's Seasons**

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

8 **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

9 **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.

10 **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

11 **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

12 **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

13 **Sun Elevation and Solar Absorption**

14 **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
-

15 **Heat Gained and Lost**

16 **Physical Properties of the Atmosphere**

- Composition
- Mostly nitrogen (N_2) and oxygen (O_2)
- Other gases significant for heat- trapping properties

17 **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

18 **Density Variations in the Atmosphere**

- Convection cell – rising and sinking air
- Warm air rises (Less dense)
- Cool air sinks (More dense)

19 **Water Vapor in Air**

- Partly dependent upon air temperature
  - Warm air typically moist
  - Cool air typically dry
- Influences density of air

20 **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

21 **Movement of the Atmosphere**

- Air *always* flows from high to low pressure.
- Wind – moving air
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22 **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
-

23 **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
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24 **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

25 **The Coriolis Effect**

26

27 **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

28 **Global Atmospheric Circulation**
- High pressure zones – descending air
  - Subtropical highs – 30 degrees latitude
  - Polar highs – 90 degrees latitude
  - Clear skies

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

30 **Three-Cell Model of Atmospheric Circulation**

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32 **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
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33 **Global Wind Belts**
- Prevailing westerly wind belts – from 30–60 degrees latitude
- Polar easterly wind belts – 60–90 degrees latitude
-

34 **Global Wind Belts**
- Boundaries between wind belts
  - Doldrums or Intertropical Convergence Zone (ITCZ) – at equator
  - Horse latitudes – 30 degrees
  - Polar fronts – 60 degrees latitude

35 **Characteristics of Wind Belts and Boundaries**

36 **January Atmospheric Pressures and Winds**

37 **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

38 **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.

39 **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
-

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41 **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
-

42 **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

43 **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

44

45 **Fronts**

- Storms typically develop at fronts.
- Jet Stream – narrow, fast-moving, easterly air flow
  - At middle latitudes just below top of troposphere
  - May cause unusual weather by steering air masses
  -
  -
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46 **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

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

48 **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)

49 **Saffir-Simpson Scale of Hurricane Intensity**

50 **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
  -

51 **Historical Storm Tracks**

52 **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

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55 **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
-

56 **Hurricane Destruction**
- High winds
- Intense rainfall
- Storm surge – increase in shoreline sea level
-
  -
-

57 **Storm Destruction**
- Historically destructive storms
  - Galveston, TX, 1900
  - Andrew, 1992
  - Mitch, 1998

- Katrina, 2005
- Ike, 2008
- Irene, 2011

58 **Damage from Hurricane Irene, 2011**

59 **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

60 **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

61 **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

62 **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

63 **Future Hurricane Threats**

- Loss of life decreasing due to better forecasts and evacuation
- More property loss because of increased coastal habitation
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64 **Ocean's Climate Patterns**

- Open ocean's climate regions are parallel to latitude lines.
- These regions may be modified by surface ocean currents.
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65 **Ocean's Climate Patterns**

66 **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

67 **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

68 ***El Niño and La Niña***

69 **Sea Ice Formation**
- Needle-like crystals become slush
- Slush becomes disk-shaped pancake ice.
- Pancakes coalesce to form ice floes.

70 **Sea Ice Formation**
- Rate of formation depends on temperature.
- Self-perpetuating
- Calm waters allow pancake ice to form sea ice.
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71 **Iceberg Formation**
- Icebergs break off of glaciers.
  - Floating bodies of ice
  - Different from sea ice
-
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72 **Iceberg Formation**
- Arctic icebergs calve from western Greenland glaciers.
- Carried by currents
- Navigational hazards

73 **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.

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

75 **Global Ocean Wind Energy**

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