1 ***CHAPTER 6***

Air-Sea Interaction

Oceanography 320 Spring 2008

2 ***Chapter Objectives***

- Describe the causes of uneven solar heating on Earth.
- Understand why Earth has seasons and how seasonal changes in solar energy affect atmospheric temperature, pressure, and density.
- Explain the nature, origin, and consequences of the Coriolis effect in both the Northern and Southern Hemisphere.
- Discuss the locations and characteristics of Earth's major atmospheric circulation cells, pressure belts, wind belts, and boundaries.

3 ***Chapter Objectives***

- Know the difference between weather (meteorology) and climate (climatology).
- Indicate the conditions required for the formation of tropical cyclones (hurricanes) and explain what types of destruction are caused by them.
- Describe the cause of Earth's greenhouse effect and why it has increased in the recent past.

4 ***Overview***

- Atmosphere and ocean one interdependent system
- Solar energy creates winds
- Winds drive surface ocean currents and waves
- Examples of interactions:
  - El Niño-Southern Oscillation
  - Greenhouse effect

5 ***El Niño and La Niña***

6 ***Seasons***

- Earth’s axis of rotation tilted with respect to ecliptic
- Tilt responsible for seasons
  - Vernal (spring) equinox
  - Summer solstice
  - Autumnal equinox
  - Winter solstice
- Seasonal changes and day/night cause unequal solar heating of Earth’s surface

7 ***Seasons***

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9 ***Uneven solar heating***

- Angle of incidence of solar rays per area
  - Equatorial regions more heat
  - Polar regions less heat
- Thickness of atmosphere
- Albedo
- Day/night
- Seasons

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12 ***Oceanic heat flow***

- High latitudes
  - More heat lost than gained
    - Albedo of ice
    - High incidence of solar rays
- Low latitudes
  - More heat gained than lost

13 ***Physical properties of atmosphere***

14 ***Physical properties of atmosphere***

- Warm air, less dense (rises)
- Cool air, more dense (sinks)
- Moist air, less dense (rises)
- Dry air, more dense (sinks)

15 ***Movements in atmosphere***

- Air (wind) always moves from regions of high pressure to low
- Cool dense air, higher surface pressure
- Warm less dense air, lower surface pressure

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17 ***Movements in air on a rotating Earth***

- Coriolis effect causes deflection in moving body
- Due to Earth's rotation to east
- Most pronounced on objects that move long distances across latitudes
- Deflection to right in Northern Hemisphere
- Deflection to left in Southern Hemisphere
- Maximum Coriolis effect at poles
- No Coriolis effect at equator

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19 ***Movements in air on a rotating Earth***

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21 ***Global atmospheric circulation***

- Circulation cells as air changes density due to:
  - Changes in air temperature
  - Changes in water vapor content
- Circulation cells
  - Hadley cells (0^o to 30^o N and S)
  - Ferrel cells (30^o to 60^o N and S)
  - Polar cells (60^o to 90^o N and S)

22 ***Global atmospheric circulation***

- High pressure zones
  - Subtropical highs
  - Polar highs
  - Clear skies
- Low pressure zones
  - Equatorial low
  - Subpolar lows
  - Overcast skies with lots of precipitation

23 ***Global wind belts***

- Trade winds
  - Northeast trades in Northern Hemisphere
  - Southeast trades in Southern Hemisphere
- Prevailing westerlies
- Polar easterlies
- Boundaries between wind belts
- Doldrums or Intertropical Convergence Zone (ITCZ)
- Horse latitudes
- Polar fronts

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25 ***Modifications to idealized 3-cell model of atmospheric circulation***

- More complex in nature due to
  - Seasonal changes
  - Distribution of continents and ocean
  - Differences in heat capacity between continents and ocean
    - Monsoon winds

26 ***Actual pressure zones and winds***

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28 ***Ocean weather and climate patterns***

- Weather
  - conditions of atmosphere at particular time and place
- Climate
  - long-term average of weather
- Northern hemisphere winds move counterclockwise (cyclonic) around a low pressure region
- Southern hemisphere winds move clockwise (anticyclonic) around a low pressure region

29 ***Coastal winds***

- Solar heating
- Different heat capacities of land and water
- Sea breeze
  - From ocean to land
- Land breeze
  - From land to ocean

30 ***Fronts and storms***

- Air masses meet at fronts
- Storms typically develop at fronts

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34 ***Tropical cyclones (hurricanes)***

- Large rotating masses of low pressure
- Strong winds, torrential rain
- Classified by maximum sustained wind speed

35 ***Hurricane morphology and movement***

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37 ***Hurricane destruction***

- Fast winds
- Flooding from torrential rains
- Storm surge most damaging
  - Historical examples:
    - Galveston, TX, 1900
    - Hurricane Andrew, 1992
    - Hurricane Mitch, 1998
    - Hurricanes Katrina & Rita, 2005

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40 ***Ocean's climate patterns***

- Open ocean's climate regions parallel to latitude
- May be modified by surface ocean currents
  - Equatorial regions
    - warm, lots of rain
  - Tropical regions
    - warm, less rain, trade winds

- Subtropical regions
  - rather warm, high rate of evaporation, weak winds

41 ***Ocean's climate patterns***
- Temperate regions
  - strong westerlies
- Subpolar regions
  - cool, winter sea ice, lots of snow
- Polar regions
  - cold, sea ice, polar high pressure

42 ***Ocean's climate patterns***

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44 ***Polar oceans and sea ice***
- Sea ice or masses of frozen seawater form in high latitude oceans
  - Begins as small needle-like ice crystals
  - Slush turns into thin sheets that break into
  - Pancake ice that coalesce to
  - Ice floes
- Rate of formation depends on temperature

45 ***Polar oceans and sea ice***

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47 ***Polar oceans and icebergs***
- Icebergs
  - fragments of glaciers or shelf ice

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50 ***Polar oceans and icebergs***

51 ***Greenhouse effect***
- Trace atmospheric gases absorb heat reradiated from surface of Earth
- Infrared radiation released by Earth
- Solar radiation mostly ultraviolet and visible region of electromagnetic spectrum

52 ***Earth's heat budget***
- Earth maintained a nearly constant average temperature because of equal rates of heat gain and heat loss

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54 ***Greenhouse gases***
- Absorb longer wave radiation from Earth
- Include:
  - Water vapor
  - Carbon dioxide (CO_2)
  - Other trace gases:
    - Methane
    - Nitrous oxide
    - Ozone
    - Chlorofluorocarbons

55 ***Greenhouse gases***

56 ***Global warming over last 100 years***
- Average global temperature increased
- Part of warming due to anthropogenic greenhouse (heat-trapping) gases such as CO_2

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60 ***Possible consequences of global warming***
- Melting glaciers
- Shift in species distribution
- Warmer oceans
  - More frequent and more intense storms
  - Changes in deep ocean circulation
- Shifts in areas of rain/drought
- Rising sea level

61 ***Reducing greenhouse gases***
- Greater fuel efficiency
- Alternative fuels
- Re-forestation
- Eliminate chlorofluorocarbons
- Reduce CO_2 emissions
  - Intergovernmental Panel on Climate Change 1988
  - Kyoto Protocol 1997

62 ***Ocean's role in reducing CO_2***
- Oceans absorbs CO_2 from atmosphere
- CO_2 incorporated in organisms and carbonate shells (tests)
- Stored as biogenous calcareous sediments and fossil fuels
- Ocean is repository or sink for CO_2
- Add iron to tropical oceans to "fertilize" oceans (increase biologic productivity)

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