1 Physical Environment:
The Atmosphere
EVPP 110 Lecture
Fall 2003
Dr. Largen

2 Physical Environment:
The Atmosphere
- Atmosphere
  - Composition
  - Vertical structure
  - Heat transfer
  - Atmospheric moisture
  - Atmospheric circulation
  - Weather and climate

3 Physical Environment:
The Atmosphere
- Earth's atmosphere
  - unique
    - solar system
    - universe
  - thin, blanket of air
  - presence contributes to physical characteristics
  - determines scope of life

4 Physical Environment:
The Atmosphere
- Earth's atmosphere
  - central in physical geography
    - heat transfer
    - water vapor transport
    - weather and climate

5 Physical Environment:
The Atmosphere
- Composition
  - Gaseous envelope
    - mixture of

- Various gases
- Water vapor and ice crystals
- aerosols

6 Physical Environment:
The Atmosphere
- Composition
  - mixture of gases
    - two gases = 99% of volume
      - nitrogen (N_2) = 78%
      - oxygen (O_2) = 21%
      - percentages fairly constant up ~ 80km
    - water vapor (H_2O)
      - concentrations vary greatly
        - vertically and horizontally

7 Physical Environment:
The Atmosphere
- Composition
  - mixture of gases
    - carbon dioxide (CO_2)
      - small percent of volume
        - ~0.036%
      - varies vertically and horizontally
      - increasing since industrial revolution

8 Physical Environment:
The Atmosphere
- Composition
  - mixture of gases
    - others
      - small amounts
        - methane
        - nitrous oxide
        - chlorofluorocarbons
        - sulfur dioxide
        - ozone

9 Physical Environment:
The Atmosphere
- Vertical structure of atmosphere

- several characteristics vary altitude
  - air density and air pressure
  - temperature
  - gaseous composition
  - electrical properties

10 Physical Environment:
The Atmosphere
- Vertical structure
  - air density and air pressure
    - air density
      - determined by
        - masses of component atoms and molecules
        - amount of space between them

11 Physical Environment:
The Atmosphere
- Vertical structure
  - air density and air pressure
    - air density
      - density
        - measure of amount of matter in a given volume
      - greatest near earth's surface
        - more atoms and molecules in given volume of air

12 Physical Environment:
The Atmosphere
- Vertical structure
  - air density and air pressure
    - air pressure or atmospheric pressure
      - force exerted by constantly moving air molecules
        - air molecules are matter
        - occupy space and have mass
      - pressure - measured in terms of
        - total mass of air above any point

13 Physical Environment:
The Atmosphere
- Vertical structure
  - air pressure and air density
    - air pressure or atmospheric pressure
      - average or standard atmospheric pressure at sea level is ~14.7 pounds/in^2
        - 1013.25 mb (millibars)
        - 29.92 in. Hg (inches of mercury)

14 Physical Environment:
The Atmosphere

- Vertical structure
  - air pressure and air density
    - air pressure or atmospheric pressure
      - more air molecules in same column
        - = more dense air
        - = higher pressure
      - fewer air molecules
        - = less dense
        - = lower pressure

15 Physical Environment:
The Atmosphere
- Vertical structure
  - air pressure and air density
    - air pressure or atmospheric pressure
      - number of air molecules decreases with increases in altitude
        - density decreases with increased altitude
        - pressure decreases with increased altitude

16 Physical Environment:
The Atmosphere
- Vertical structure
  - air density and air pressure
    - initially decrease rapidly with altitude
      - air near earth's surface is compressed
      - ~ 10 mb/100 m increase in altitude
    - decrease more slowly with altitude
      - 1013 mb at 0 km
      - 500 mb at ~ 5.5 km
      - 100 mb at ~17.0 km
      - 50 mb at ~22.0 km
      - 10 mb at ~32.0 km

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18 Physical Environment:
The Atmosphere
- Vertical structure
  - several characteristics vary with altitude
    - air density and air pressure
    - temperature
    - gaseous composition
    - electrical properties

19 Physical Environment:
The Atmosphere

- Vertical structure of the atmosphere
  - air temperature
    - vertical profile more complicated than density and pressure

    - measure of “heat” of air
      - measure of average speed of movement of air molecules

20 Physical Environment:
The Atmosphere
- Vertical structure
  - air temperature
    - normally decreases from earth’s surface up to altitude of ~11 km
      - atmosphere is heated primarily from below
        - transfer of heat energy from surface
    - lapse rate
      - rate at which air temperature decreases with altitude
      - average or standard in lower region of atmosphere is ~6.5°C per 1000 m

21 Physical Environment:
The Atmosphere
- Vertical structure of the atmosphere
  - air temperature
    - lapse rate

      - occasionally, temperature may increase with increases in altitude in lower region of atmosphere
        - = temperature inversion

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23 Physical Environment:
The Atmosphere
- Vertical structure of the atmosphere
  - air temperature
    - most common parameter used to define atmospheric layers
      - troposphere
      - stratosphere
      - mesosphere
      - thermosphere

24 Fig. 17.1

25 Physical Environment:
The Atmosphere

- Vertical structure
  - air temperature
    - troposphere
      - from 0 km to ~ 11 km
      - characterized by air temperature decreasing with height
      - region in which “weather” occurs
      - ends at point where temperature stops decreasing with height
        - boundary called tropopause

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27 Physical Environment:
The Atmosphere

- Vertical structure of the atmosphere
  - air temperature
    - stratosphere
      - from ~11 km to 20 km
        - air temperature remains constant with altitude
      - from ~20 km to ~50 km
        - air temperature increases with altitude
        - from ~ - 50°C to ~0°C
        - results in temperature inversion

28 Physical Environment:
The Atmosphere

- Vertical structure of the atmosphere
  - air temperature
    - stratosphere
      - temperature inversion attributed to ozone
        - reaches maximum concentrations in stratosphere
        - absorbs energetic UV solar energy
        - some of absorbed energy heats stratosphere

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30 Physical Environment:

The Atmosphere

- Vertical structure of the atmosphere
  - air temperature
    - mesosphere
      - separated from stratosphere by boundary called stratopause
      - from ~50 km to ~85km
      - % of N and O ~ same at this level as at sea level
        - but much less air
        - atmospheric pressure is ~1 mb at 50 km

31 Physical Environment:
The Atmosphere

- Vertical structure of the atmosphere
  - air temperature
    - mesosphere
      - air temperature decreases with altitude
        - little ozone to absorb solar radiation
        - molecules of air lose more energy than they are able to absorb
      - cooling continues up to ~ 85 km
        - where temperature reaches its lowest average value, ~ - 90°C

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33 Physical Environment:
The Atmosphere

- Vertical structure
  - air temperature
    - thermosphere
      - separated from mesosphere by boundary called mesopause
      - from ~85 km to several hundred km
      - temperature increases with altitude
        - oxygen molecules absorb solar radiation
      - actual temperature varies greatly depending on solar activity

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36 Physical Environment:
The Atmosphere

- Vertical structure
  - exosphere
    - upper limit of atmosphere
    - top of thermosphere
    - altitude of ~500 km
    - some atoms and molecules from this region
      - escape earth's gravitational pull
      - shoot off into space

37 Physical Environment:
The Atmosphere
- Vertical structure
  - atmospheric characteristics vary with altitude
    - air density and air pressure
    - temperature
    - gaseous composition
    - electrical properties

38 Physical Environment:
The Atmosphere
- Vertical structure
  - gaseous composition
    - homosphere
      - region below thermosphere where gaseous composition remains fairly constant
        - from 0 km to ~85 km
        - well-mixed region
        - ~78% N & ~21% O

39 Physical Environment:
The Atmosphere
- Vertical structure of the atmosphere
  - gaseous composition
    - heterosphere
      - thermosphere & above (>85km)
      - not well-mixed
        - heavier atoms and molecules, such as N & O, tend to settle to bottom of layer
        - lighter gases, H & He, float to top

40 Physical Environment:
The Atmosphere
- Vertical structure of the atmosphere
  - several atmospheric characteristics vary with changes in altitude
    - air density and air pressure
    - temperature
    - gaseous composition
    - electrical properties

41 Physical Environment:
The Atmosphere
- Vertical structure of the atmosphere
  - electrical properties
    - ionosphere
      - above ~60 km
      - electrified region
        - fairly high concentrations of ions and free electrons
        - atoms lose electrons and become

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43 Physical Environment:
The Atmosphere
- Heat transfer
  - occurs via a process called
    - convection
      - transfer of heat by mass movement of a fluid (such as water and air)
        - takes place because fluids can move freely and it is possible to set up currents within them
      - leads to a cycle of heated air rising and cooled air descending
        - called convective circulation

44 Physical Environment:
The Atmosphere
- Heat transfer
  - convective circulation
    - certain areas of earth's surface absorb more heat from sun than others areas
      - uneven heating of air near surface
        - heated air expands and becomes less dense
        - expanded , less dense air rises and transfers heat energy upward

45 Physical Environment:
The Atmosphere
- Heat transfer in the atmosphere
  - convective circulation
    - after warmed, expanded, less dense air rises
      - cooler, heavier, more dense air flows toward surface to replace rising air

- upon closer exposure to warm surface
  - cool air heats up, expands, becomes less dense and rises
  - and cycle is repeated

46 Physical Environment:
The Atmosphere
- Heat transfer
  - convective circulation
    - vertical exchange of heat called convection
    - rising air “bubbles” (or masses of warmed air) known as thermals
    - warmed air rises, temperature eventually decreases, sinks to surface where it can replace rising air
      - producing a convective circulation or thermal cell

47 Physical Environment:
The Atmosphere
- Heat transfer
  - convective circulation
    - any air that rises will expand and cool
      - creates areas of low pressure
    - any air that sinks is compressed and warms
      - creates areas of high pressure
  - wind
    - horizontally moving part of circulation

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50 Fig. 17.2

51 Physical Environment:
The Atmosphere
- Atmospheric moisture
  - several processes and principles interact to determine the manner in which moisture enters, moves about in, and leaves the atmosphere
    - evaporation of water from surface into atmosphere
    - transport of water vapor through the atmosphere
    - precipitation, return of water to surface

52 Physical Environment:
The Atmosphere
- Atmospheric moisture
  - in lower atmosphere, water exists in all three phases of matter
    - liquid - water
    - gas - water vapor
    - solid - ice
  - various atmospheric conditions govern change of water from one phase to

another

53 Physical Environment:
The Atmosphere
- Atmospheric moisture
  - water changes phases in atmosphere
    - sublimation
      - changing from solid (ice) to gas (water vapor) phase without passing through the liquid phase
    - evaporation
      - changing from liquid to vapor phase
    - condensation
      - changing from vapor to liquid phase

54 Physical Environment:
The Atmosphere
- Evaporation
  - water molecules escape surface & enter atmosphere as water vapor
    - energy is required
      - comes from radiant energy from sun
  - escaping molecules carry heat with them
    - evaporation = cooling process
  - rate of evaporation is affected by amount of moisture already present in a mass of air
    - affected by wind, temperature and humidity

55 Physical Environment:
The Atmosphere
- Evaporation
  - rate is affected by amount of moisture in a mass of air
    - amount of water vapor present in a quantity of air can be specified in several ways
      - absolute humidity
      - relative humidity

56 Physical Environment:
The Atmosphere
- Evaporation
  - absolute humidity
    - most direct measure of air's moisture content
    - weight of water present in given volume of air
      - affected by air temperature
        - warm air is able to contain more water vapor per unit volume than cool

air

57 Physical Environment:
The Atmosphere
- Evaporation
  - relative humidity
    - ratio of amount of water actually present in quantity of air to amount that could be held by same air if it were saturated
    - does not indicate actual moisture content
    - change in temperature of moist air = change in its relative humidity
    - temperature at which relative humidity becomes 100% = dew point

58 Physical Environment:
The Atmosphere
- Transport
  - water is transported by atmosphere in form of water vapor

59 Physical Environment:
The Atmosphere
- Precipitation
  - means by which water leaves atmosphere and returns to earth's surface
    - can take form of any of phases of water
      - liquid - rain
      - gas - fog
      - solid - ice
  - on average, amount of water that leaves atmosphere = amount that enters atmosphere

60 Physical Environment:
The Atmosphere
- Precipitation
  - several factors govern the process by which water leaves the atmosphere as precipitation
    - temperature
    - humidity
    - dew point
    - presence of condensation nuclei

61 Physical Environment:
The Atmosphere
- Precipitation
  - condensation
    - change from water vapor to liquid water
    - occurs when
      - moist air is cooled to its dew point

- cooler air can't hold as much water
- some water vapor condenses to liquid

62 Physical Environment:
The Atmosphere
- Precipitation
  - condensation
    - dust particles in air serve as condensation nuclei
      - collection centers for water molecules
      - promote growth of water droplets to a size large enough to be stable

63 Physical Environment:
The Atmosphere
- Adiabatic processes
  - combine aspects of vertical structure of atmosphere, heat transfer, moisture content and circulation
  - adiabatic cooling
  - adiabatic heating

64 Physical Environment:
The Atmosphere
- adiabatic cooling
  - temperature of rising mass of air decreases
    - air mass heated by earth's surface, rises
    - warm, rising air mass expands
      - because air pressure decreases with altitude
    - as it expands, it does work against surrounding atmosphere
      - expenditure of energy causes temperature to decrease
        - water vapor condenses to clouds

65 Physical Environment:
The Atmosphere
- adiabatic heating
  - temperature of descending air mass increases
    - air mass is cooled adiabatically, descends
    - cooled, descending air mass compresses
      - because air pressure increases with decrease in altitude
    - as it compresses, surrounding atmosphere does work against it, pushing inward
      - input of energy causes temperature to increase

66 Physical Environment:
The Atmosphere
- lapse rate
  - normally, air temp. decreases with altitude
    - ~6.5°C per 1000m increase in altitude

- dry adiabatic lapse rate
  - adiabatic cooling in absence of condensation
  - ~10.0°C per 1000m increase in altitude
- moist adiabatic lapse rate
  - adiabatic cooling in presence of condensation
  - varies with moisture content of air
  - ~5.0°C per 1000m

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68 
69 
70  The End