

- I. Axial Tilt and Orbit around Sun—
 - A. Earth tilts 23.5° to orbit around Sun
 - B. Latitudes of Sun incidence
 - 1. polar circles—Arctic, Antarctic
 - 2. tropical circles—Cancer, Capricorn
 - 3. equator
 - C. Days corresponding to Sun incidence
 - 1. solstice—overhead Sun at tropical circle—June 22, December 22
 - 2. equinox—overhead Sun at equator—March 22, September 22
 - D. Day length varies with latitude and season, due to circle of illumination
 - 1. longest/shortest at solstice, at high latitudes
 - 2. equinox—equal day and night all over the world

- II. Heating
 - A. Greater heating capability with higher Sun angle
 - 1. latitude controls on Sun energy
 - 2. seasonal controls on Sun energy
 - B. Low latitudes have high Sun angle year round
 - C. Incoming Solar Radiation
 - 1. Temperature Variation greater in areas closer to poles
 - 2. Temperature Distribution—affected by land-water relation as well as latitude

- III. Heat—
 - A. Thermal energy, transferred from warm substances to cooler ones
 - B. Methods of heat transfer
 - 1. conduction—
 - a. through matter by molecular activity
 - b. air is poor conductor of heat energy
 - 2. convection—heat rises
 - a. transfer of heat by circulation within fluid
 - b. caused by expansion of heated fluid reduces density
 - c. lower atmosphere heated by Earth's surface
 - 3. radiation—through empty space
 - a. Solar radiation is source of energy for weather and climate
 - 1) Electromagnetic radiation from radio waves to gamma waves
 - 2) Visible light small segment between infra-red and ultraviolet
 - a) Infrared is heat
 - b) Ultraviolet causes sunburn, etc.
 - 3) microwaves and x rays bracket ir and uv
 - b. all objects emit radiant energy
 - 1) hotter object emit more, and at shorter wavelengths
 - 2) the better absorber of radiation, the better ability to emit energy
 - a) Earth is excellent absorber and emitter
 - b) Atmospheric gases selective absorbers of longer wave radiation

IV. Incoming solar radiation

- A. Absorbed, transmitted, redirected (reflected or scattered)
- B. Distribution
 - 1. about 50% is transmitted to surface and absorbed by Earth
 - 2. about 30% is reflected back to space
 - 3. about 20% absorbed by atmospheric gases and clouds
- C. reflection and scattering
 - 1. reflection—
 - a. changing direction of light without reducing intensity
 - b. Albedo—fraction of radiation reflected by a surface
 - 1) Affected by length of travel through atmosphere
 - 2) Affected by angle of incidence upon water
 - 2. scattering—
 - a. disperses light into many weaker rays in many directions
 - b. accomplished by dust, gas molecules
 - c. diffuses light to make shadows have light
- D. absorption
 - 1. nitrogen poor absorber of radiation
 - 2. oxygen and ozone absorb most of uv radiation high in atmosphere
 - 3. most atmospheric gases do not absorb visible wavelengths—transmit

V. Atmosphere is mixture of gases, with varying proportions with respect to location and timing

- A. Nitrogen and Oxygen make up 99% of clean, dry air up to 80 km
- B. Minor components include argon (0.93%), and carbon dioxide (0.037%)
- C. Variable components affect weather and climate
 - 1. water vapor
 - a. varies from almost none to up to 4% of atmosphere
 - b. source of all clouds and precipitation
 - c. absorbs heat from Earth and Sun
 - d. change of water's phase captures or releases 'latent heat'
 - 2. aerosols and dust
 - a. remain suspended for extended period of time
 - b. sources include sea salt, blown soil, fires, pollen, volcanic eruptions
 - c. act as surfaces for water vapor to begin condensation
 - d. reflect and scatter incoming solar energy
 - 3. ozone
 - a. molecular oxygen with three atoms has properties distinct from O₂
 - 1) damages tissue of organisms
 - 2) can be created near surface by reactions in smog
 - b. concentrated 10 to 50 km above surface in stratosphere
 - 1) Sun's radiation breaks O₂ into O and O in stratosphere
 - 2) O collides with O₂ and forms O₃ at this altitude
 - 3) Lightning makes O₃ in troposphere
 - c. Ozone important absorber of UV radiation

VI. Height and structure of atmosphere

A. Pressure is weight of overlying air

1. about 1000 millibars, 1 kg/cm^2 , 14.7 lbs./in^2
2. half of all atmosphere is below 5.6 km from surface (Mt. McKinley~6.2)
3. beyond 16 km, less than 10% of atmosphere remains
4. traces exist above 100 km, less than one millionth of it

B. temperature variation with height

1. troposphere—mixed zone includes most weather phenomenon
 - a. temperature decreases with height in troposphere
 - b. average temperature change is 6.5° C/km
 - 1) normal 'environmental lapse rate'
 - 2) not constant, monitored by weather equipment
 - c. average height of tropopause: 12 km
 - 1) height varies with location and temperature
 - 2) end of troposphere called 'tropopause'
 - d. temperature and humidity can be transferred in troposphere by turbulence and mixing
2. Stratosphere
 - a. Stratosphere lacks mixing of troposphere
 - b. Constant temperature to about 20 km
 - c. Gradually increases to about 50 km, at the 'stratopause'
 - 1) Ozone concentrated in stratosphere absorbs UV energy
 - 2) This absorbed energy creates the increased temperatures
3. Mesosphere
 - a. Temperatures in mesosphere decrease with height to ~80 km
 - b. Decreases to about -90° C at 'mesopause'
4. Thermosphere beyond mesopause
 - a. Tiny fraction of atmosphere
 - b. Subject to direct radiation from Sun
 - c. Temperature increases to " 1000° C ", but described by speed of molecules, not feeling of warmth, due to extremely low density

VII. Sun energy heats atmosphere

- A. Mostly between Tropical circles, where direct rays fall
 - 1. solstice when direct rays most poleward—June 21 and December 21
 - 2. equinox when direct rays at equator—March 21 and September 21
 - 3. day length varies between extremes at solstices, equal on equinox
- B. seasonal variations in Sun energy from constant axial tilt toward Polaris
- C. additional causes of local temperature other than day length and Sun angle
- D. Distribution of temperatures
 - 1. Cooler in polar areas
 - 2. Warmest at tropics in continental areas
 - 3. Warmness follows the direct rays of Sun: as it travels from tropic to tropic throughout year
 - 4. Oceanic currents warm western side of ocean basins, and the continents adjacent to them
 - 5. Oceanic currents cool eastern side of ocean basins and the continents adjacent to them.
- E. Heating of Atmosphere—greenhouse effect
 - 1. Atmosphere transmits about 50% of energy received to Earth's surface
 - 2. Absorbed energy by Earth's surface re-emitted as longer wavelength
 - 3. This longer wavelength is readily absorbed by atmosphere, not transmitted
 - a. Result is lower atmosphere heated from Earth's surface
 - b. WHY temperature decrease with distance from surface in troposphere
 - 4. Greenhouse effect
 - a. Incoming light is absorbed by Earth
 - b. Reradiated heat is trapped by carbon dioxide, water, methane
 - c. glass does not transmit heat, but also rely on lack of mixing with outside air to keep them warm
 - d. greenhouse effect of atmosphere makes life on Earth possible
 - e. carbon dioxide instrumental greenhouse effect gas

VIII. Temperature of Earth locations

- A. Recording of temperature
 - 1. needs to be done without direct heating of Sun in sheltered places
 - 2. daily range is maximum minus minimum
 - 3. daily minimum and maximum temperatures averaged to 'daily mean T'
 - a. monthly mean temperature is average of each daily mean Ts
 - b. annual mean temperature is average of monthly mean temps
 - c. these means used to compare one area to another, or compare one time to another within a certain area
 - 4. Isotherms are maps of temperatures
 - a. Each isotherm connects the same temperature
 - b. Intervals between isotherms constant
 - c. Closeness of isotherms show the change in temperature over distance—called temperature gradient

IX. Controls of temperature

1. mostly latitude
 - a. variation of day length,
 - b. angle of incoming Sun rays
 - c. atmospheric thickness
2. Land water relationship,
 - 1) Distribution of heat due to mobility and transparency of water
 - 2) Land has lower heat capacity than water,
 - a) water heats more slowly than land, stores lots of heat
 - b) land loses heat more rapidly and can become very cold
 - 3) evaporation is a cooling process
 - 4) Proximity to water moderates temperature
 - 5) Northern Hemisphere has greater range of temperature than Southern Hemisphere
3. Altitude
 - 1) troposphere is heated from below, from reradiation of incoming Sun energy
 - 2) change in temperature
 - 3) called the 'lapse rate'
 - 4) $6.5^{\circ}\text{C}/1000\text{ m}$ from one altitude to another
4. Geographic position, due to prevailing circulation of atmosphere and ocean currents
 - a. with respect to sea and elevation
 - b. also with respect to prevailing wind, topographic barriers and influence of ocean currents
 - 1) leeward coasts more continental in character, where windward coast more influenced by ocean (Eureka vs. NYC)
 - 2) mountain barriers block ocean effect (Seattle vs. Spokane)
5. cloud cover affects albedo
 - a. clouds reflect much solar radiation, keeping daytime temperatures lower than without clouds
 - b. clouds absorb infrared radiation from surface and reradiate it back to surface, keeping nighttime temperatures higher
 - c. snow and ice also reflect energy, rather than allowing it to be absorbed, acting to keep temperatures low

X. World Distribution of Temperature

- A. Commonly shown on maps of January and July
 1. maps corrected for elevation by adding environmental lapse rate
 2. show effects of latitude, distribution of land and water, ocean currents
- B. patterns
 1. decrease in temperatures from equator toward poles—
 - a. latitude control is extremely important
 - b. seasonal shift of warmer temperatures toward 'Sun' hemisphere
 2. extreme temperatures have additional controls of land and water
 - a. hottest temperatures within tropics, but in continental areas
 - b. coldest temperatures in continental northern areas
 3. oceanic currents can warm or cool an area
 - a. notice summer isotherms where cold currents exist at eastern edge of Pacific Ocean
 - b. Gulf Stream elevates temperatures in western Europe winter
- C. Distance from equator, and distance from ocean increase annual temperature range