COMPOSITION, STRUCTURE AND TEMPERATURE OF ATMOSPHERE

I. WEATHER AND CLIMATE

A. Meteorology- study of weather and atmosphere
   1. Aristotle "Meteorologica" = "Discourse on Things Above"

B. Weather- state of atmospheric conditions at a particular place for a short period of time
   1. changes by hour, day, season

C. Climate- average composite of atmospheric conditions for a given area over a long period of time
   1. Influences
      a. vegetation, land use, soil types, surface geology, geomorphology, shape and feel of landscape, human habitation

D. Descriptive Properties of Atmosphere
   1. air temperature
   2. humidity
   3. type and amount of cloudiness
   4. type and amount of precipitation
   5. air pressure
   6. speed and direction of wind

II. COMPOSTION OF ATMOSPHERE

A. Average composition of elemental gases in dry air
   1. Nitrogen (N_2)= 78%
   2. Oxygen (O_2)= 21%
   3. Argon (inert) = 0.93%
   4. Carbon Dioxide (CO_2) = 0.035%

      a. Ability to absorb heat in atmosphere from energy radiated from earth's surface, helps keep the atmosphere warm

   5. All Others = trace

B. Water Vapor
   1. range of water vapor content in air: 0-4% by volume
   2. Important source of clouds, precipitation, water budget
   3. Like CO_2 has ability to absorb heat given off by earth's surface as well as solar energy
      a. important for warming atmosphere

   4. Water vapor has high heat capacity, and can absorb and release heat

      a. important agent of heat transfer in atmosphere from one region to another

      b. latent heat in water vaport provides energy for driving storms

C. Dust/Particulate Matter

1. fine mineral dust, pollen, spores, seeds, man-made pollution
   a. derived from earth's surface
   b. abundant in lower atmosphere, also carried to upper portions of atmosphere

2. Particulates necessary for nucleation of water droplets (condensation) in clouds to form precipitation

3. Under extreme conditions of volcanic eruptions, volcanic dust high in the atmosphere may reflect incoming solar radiation, resulting in short term atmospheric cooling.

4. Dust creates colors of sunsets/sunrise

D. Ozone (O_3)

1. triatomic form of oxygen, occurs in very low amounts, concentrated to upper atmosphere known as stratosphere (10-50 km above the surface, 6-31 miles)

2. Formation: at high altitudes in atmosphere

   a. O_2 absorbs incoming ultraviolet radiation from sun (harmful to life on planet in high doses).
   b. O_2 splits into single atoms of oxygen
   c. $O + O_2$ + neutral catalyst molecule = O_3 (ozone).... "ozone layer"

3. Ozone acts as filter absorbing harmful ultraviolet radiation from sun, if ozone layer were depleted, life may be rendered uninhabitable on the planet.

   a. CFC's = chlorofluorocarbons used in aerosol sprays, freon/refrigerants, plastics and cleaning solvents

   b. CFC's inert in lower atmosphere, readily travel to upper atmosphere undegraded

   c. UV radiation breaks CFC's into components in upper atmosphere, Chlorine atoms released react to destroy ozone molecules

   d. "Ozone Hole" - diminished levels of O_3 detected over the southern polar region by Antarctic Scientists in 1979, fluctuates seasonally especially low during southern hemisphere spring (Sept. to Oct.)

III. EXTENT AND STRUCTURE OF ATMOSPHERE

A. Atmosphere divided according to thermal structure/temperature

1. Lower Limit of Atmosphere = air/water, air/land interface at earth's surface

2. Troposphere (0-12 Km altitude = 0-7.4 miles on avg.)
   a. bottom layer of atmosphere
   b. vertical mixing of air
   c. clouds, precipitation and storms restricted to troposphere ("weather sphere")
   d. "Normal Lapse Rate": temperature decreases systematically upward in troposphere
      (1) temp. gradient = 6.5 C/km altitude = 3.5 F/1000 Ft

3. Tropopause: boundary between underlying Troposphere and overlying Stratosphere

4. Stratosphere (12-50 km)
   a. temp. constant from 12-20km, then gradual increase in temp to height of 50 km
   b. Ozone concentrated in stratosphere, hence the reason for the temperature increase (O3 absorbing UV from Sun)

5. Stratopause: boundary between underlying stratosphere and overlying thermosphere (at ~50 km)

6. Mesosphere (50 km to 80 km)
   a. Temperatures decrease with increasing altitude

7. Mesopause (80 km) boundary between mesosphere and overlying thermosphere
   a. Temp. at 80 km =~ -90 C

8. Thermosphere 80 km - ???

   a. contains only minute fraction of earth's atmospheric gases, very rarefied air, low pressure.

   b. Temp. again increases with > altitude due to solar energy absorption by atoms of oxygen and nitrogen

      (1) "Temp" = 1000 C max (i.e. measure of molecular motion)

         (a) however, there are so few atoms of oxygen and nitrogen that heat is generally not transferred, hence satellites in this region are cool.

B. Altitude vs. Air Pressure

Altitude (km)	Percent of Air Press. at Sea Level (avg = 1000 mbar = 1 kg/sq. cm)
0	100 (full column of air)
5.6	50
16.2	10
31.2	1
48.1	0.1
65.1	0.01
79.2	0.001
100	0.00003

IV. EARTH-SUN RELATIONSHIPS

A. General

1. The earth's dependence on the sun for solar energy is essential for all life, drives biosphere, atmosphere, and hydrosphere.

2. Movements of the Earth: Rotation vs. Revolution

a. Rotation- the earth rotates on its axis from west to east (counter clockwise direction viewed from top), complete revolution of 360 ° every 24 hrs.

(1) Sidereal Day: view of revolution of the earth with respect to astronomical view of stars: takes 23 hrs 56 mins and 4.1 secs

(2) Since the earth spins from west to east, the moon and sun and stars appear to relatively move (rising and setting) in the opposite sense: east to west.

(3) Speed of rotation of the earth is greatest at the equator and decreases to 0 at the poles, function of revolving different diameters about a pole.

b. Effects of the Rotation of the earth

(1) Constancy of the earth's rotation results in coriolis effect in which the flow of air and water on the earth's surface is deflected by the centrifugal forces

(2) rotation brings varying portions of the earth into increasing and decreasing gravitational fields relative to the moon and sun, thus driving diurnal tidal fluctuations

(3) rotation results in diurnal variation of lightness and darkness, as the earth turns relative to the position of the sun

c. Revolution Around the Sun: earth revolves around the sun in a similar west to east rotation, once every 365.25 days (known as the tropical year)

(1) The path of the earth's orbit around the sun is not a circle but an ellipse with varying radius of orbit.

(2) Perihelion- position on January 3, the earth = 91,445,00 miles from the sun

(3) aphelion - position on July 4, the earth = 94,555,000 miles (farthest from the sun in our summer).

Perihelion and aphelion are oriented at 180° to one another: do not so significant effects on seasonal temperature variation.

B. Season Temperature/Weather/Insolation Changes

1. Plane of the ecliptic- the plane the passes through the sun and earth, enscribing the orbital path of the earth around the sun.

2. The axis of the earth and the plane of the equator is tilted approximately 23.5° with respect to the plane of the ecliptic (i.e. polar axis is not perpendicular to the plane of the ecliptic).

a. The axis of the earth is always parallel to itself, pointing at all seasons of the year towards polaris the north star..

b. The rotation, revolution, and tilt of the earths axis is such that the amount of insolation or energy the hits the earth is at different angles throught the year of revolution.

THE MORE DIRECT THE STRIKE OF THE SUN'S RAYS, THE EFFECTIVE IS THE HEATING OF THE EARTH'S SURFACE

THE MORE OBLIQUE THE STRIKE OF THE SUN'S RAYS, THE MORE DIFFUSED THE ENERGY IS OVER A LARGER LAND SURFACE.

3. Latitudinal changes in insolation with seasons

a. SUMMER SOLISTICE: NORTHERN HEMISPHERE

(1) Tropic of Cancer- 23.5° north latitude, marks the northernmost location reached by the vertical/direct rays of the sun in annual revolution pattern (occurs on the summer solistice in the northern hemisphere, June 21)

(2) At solistice, all points lying north of the Arctic Circle (66.5° N.) are placed within the circle of illumination for 24 hours continuously

(3) At northern solistice, all points south of the anarctic circle (66.5° S) are placed in continual darkness, outside the circle of illumination

b. WINTER SOLISTICE: NORTHERN HEMISPHERE

(1) Tropic of Capricorn- 23.5° S. latitude, marks the southernmost location reached by the vertical/direct rays of the sun in annual revolution pattern (occurs on Dec. 21, more or less).

(2) At winter solistice, all points lying south of the Anarctic Circle lay continually within the circle of illumination, whereas, points north of Arctic circle lay within continual darkness.

c. EQUINOXES: (spring March 20, and fall: sept. 22)

(1) The perpendicular rays of the sun strike the equator

(2) The circle of illumination just touches both poles

(3) The periods of daylight and darkness are each 12 hours long all over the earth

(4) equinoxes represent midpoints in the shifting of direct rays of the sun between the Tropic of Cancer and the Tropic of Capricorn

V. RADIATION

A. Sun emits EM Radiation (spectrum presented previously)
1. EM radiation travels through vacuum of space at 186,000 mi/sec
2. Long waves : infrared radiation- can't be seen but felt as heat
3. short waves: ultraviolet radiation- sunburn wavelengths

B. Basic concept: absorption of EM radiation
1. When objects absorb EM radiation, > molecular motion, resulting in increase in temperature

VI. MECHANISMS OF HEAT TRANSFER

A. Conduction- transfer of heat through matter by molecular activity

1. e.g. spoon left in hot pan, heat conducted to spoon
2. Good conductor: metals
3. Poor Conductor: air/fiberglass insulation

B. Convection- transfer of heat by the movement of mass from one place to another (takes place primarily in liquids and gases)
1. Atmospheric convection - primary mode of heat transfer, i.e. transfer of heat with air

a. Atmospheric convection = vertical mass movement
b. Atmospheric advection = horizontal mass movement (winds)

C. Radiation- passage of radiant energy as wave energy, e.g. radiation from sun in vacuum of space
1. conduction or convection is not possible in space

VII. HEATING THE ATMOSPHERE

A. Solar Radiation Relationships with Earth

1. Absorbed radiation- solar radiation absorbed by atmosphere
a. Gases are selective absorbers of particular portions of the EM spectrum, depending on chemical composition

(1) N_2 poor absorber
(2) O_2 and O_3 good absorbers of UV radiation
(3) Water vapor good absorber

b. 20% of total incoming solar radiation absorbed by atmosphere and clouds

c. Atmospheric gases do not absorb visible light portion of spectrum thus all of it reaches the earth's surface

(1) atmosphere most effectively absorbs terrestrial radiation from the earth's surface (reflected and directly from the earth).

(2) Atmospheric absorption of terrestrial radiation primary mechanism of heat transfer and weather phenomena

d. "Greenhouse Phenomena": Water vapor and CO_2 allow shorter wavelength solar radiation to enter atmosphere, where it heats earth's surface inside, the earth's surface re-radiates longer wavelength terrestrial radiation, which is trapped by the water vapor and CO_2, thus heating the air of the lower atmosphere

(1) Greenhouse necessary to point, however runaway greenhouse effect could be detrimental in terms of severe global warming.

e. Climatic examples

(1) arid southwest, US
(a) high daily temp. fluctuation, low humidity, rapid warming of air, but also rapid heat loss due to low water vapor content (low absorptive capacity)
(2) humid northeast, US
(a) high humidity, high absorbtive capacity, daily temperature fluctuation at a minimum

VIII. CONTROLS OF TEMPERATURE

A. Land and Water

1. Land has lower heat capacity than water

   a. land heats more rapidly and to higher temps. than water, and cools more rapidly and to lower temps. than water

2. Reasons for differential heating of land compared to water

   a. water has high specific heat (i.e. it takes more energy to raise temp. of water than similar volume of land)

   b. Land surfaces are opaque, thus heat only absorbed at surface. Water is transparent and allows heat to penetrate throughout body

   c. Water transfers heat by convection, thus distributing the heat through a larger mass

   d. Evaporation (a cooling or heat loss process) from water bodies is greater than that for land

3. Example Coastal Areas

   a. ocean bodies can have a buffering effect on local climates, due to high heat capacity and lag in heat transfer, warming air above ocean and influencing air temps inland.

B. Altitude

1. > altitude, < atmospheric content, < heat capacity, < T

C. Geographic Position (Latitudinal Position with Respect to Sun)

1. Latitudinal influences on amount of incoming solar radiation

   a. Tropics vs. arctic