The Atmosphere

(gasses held in place by gravity)

I. Two Divisions of the Atmosphere

A. Heterosphere (80km and higher): Layer where gasses are NOT evenly mixed. Primary function is to filter out (absorb) dangerous solar radiation before it arrives on Earth.

B. Homosphere (0-80km): Layer where gasses ARE evenly mixed.

II. Composition of the Homosphere

A. Nitrogen (78%) **(see text)**

B. Oxygen (21%) **(see text)**

C. Argon (approx. 1%) **(see text)**

D. Carbon dioxide (0.0415%): Concentrations decrease during the Northern Hemisphere summer and increase during the Northern Hemisphere winter. Very important as an absorber of longwave energy (called a radiatively active or greenhouse gas).

E. Water vapor (approx. 1%): Varies, also important as an absorber of longwave energy (called a radiatively active or greenhouse gas).

F. Ozone – O_3 (< .001%) **See next page for further discussion…**

III. Temperature Layers of the Homosphere

A. Mesosphere (80-50km)

B. Stratosphere (approx. 14-50km)

C. **Troposphere (0-approx. 14km):**

Contains 90% of all atmosphere.
Where our weather takes place.
The top is called the "tropopause."

1. Normal Lapse Rate (6.4C° / 1000 meters or 3.5F° / 1000 feet): The normal lapse rate is the average temperature decreases as you move up and away from Earth's surface toward the tropopause.

2. Environmental Lapse Rate: This is the ***actual (observed)*** rate of temperature decrease as you move up and away from Earth's surface toward the tropopause. It is measured at a given place and time!

IV. Pollution in the Troposphere

A. Specific Natural Pollutants (see text – know the main ones)

B. Specific Anthropogenic Pollutants

1. Ozone – O_3 (see text under "Photochemical Smog"; also see below for further discussion!)

2. Acid Deposition (see text)

3. Industrial Smog and Sulphur Oxides (see text)

C. A Complicating Factor – The Temperature Inversion: see text

Temperature Inversion (or Warm Air Inversion)
(see text for simple diagram)

V. Ozone (O_3) Revisited: Ozone exists naturally in the upper atmosphere, but the ***same exact gas*** can be found in pollution at Earth's surface. Understand the differences!!!

Type of Ozone	Naturally Occurring ("good")	Anthropogenic ("bad")
Where found?	In Ozonosphere (15-55km above Earth's surface)	At Earth's surface (ground level).
Origin?	Produced naturally (see book for details; you will not be tested on the specific chemical reactions involved.)	Produced at Earth's surface when smog (mostly vehicular emissions) is exposed to sunlight and heat on hot summer days (called a photochemical reaction – I call it "cooked smog")
Impact on humans?	Important in absorbing (blocking) dangerous ultraviolet (UV) radiation from reaching Earth.	Highly reactive and damaging to plants and animals – "*burns leaves and lungs*"
Current trends/issues?	●Levels have dropped, especially over poles during the respective winters, due to use of Chloro Flouro Carbons (CFCs) in various industries. CFCs destroy O_3! ●Incidences of skin cancer and sunburn increasing in humans.	Problem worsening, especially in Sac Region, and especially in Sierra Foothills east of Sacramento.
Potential Solutions?	The Montreal Protocol international agreement (1987) began the phase out of CFCs globally; ozone is currently slowly improving.	Drive less! Spare the Air programs are having some impact.

Energy Budgets

Electromagnetic Radiation: **To understand energy relationships in the Earth/Atmosphere system, one must first understand the nature of electromagnetic radiation. Electromagnetic radiation (also called radiant energy or just radiation) is emitted in the form of waves which travel quickly away from the surface of ALL objects (the sun, rocks, ice, trees, soil, etc).**

I. Radiation Wavelength Review:

The wavelength of radiation emitted by an object decreases as the temperature of the object increases (i.e. hotter objects emit shorter wavelengths). We will lump radiation into two types.

A. Shortwave (Solar)

1. Wavelengths < 3 μm (peaks at 0.5 μm) (μm stands for micrometers)

2. Also called "insolation": (short for incoming solar radiation)

B. Longwave (Terrestrial)

1. Wavelengths > 3 μm (peaks at 10 μm)

2. Also called "thermal infrared"

II. Important Radiation Terms

A. Emitted: Given off.

B. Transmitted: Allowed to pass; unchanged by atmosphere or water

C. Reflected: Bounced in the opposite direction by atmosphere or water

D. Absorbed: Converted into heat energy (which is somewhat different than radiation).

III. Radiation Budgets:

Longwave and shortwave radiation flow through the environment constantly. With the help of satellites and ground instruments, we can measure these flows to better understand where the energy is coming from and going to…

A. Overall Budget for Earth/Atmosphere System:

Averaged over many years, incoming radiation EQUALS outgoing radiation for the entire earth/atmosphere system. (Bank account example!!!) In other words, INPUT equals OUTPUT; the earth/atmosphere system balances!!!

INPUTS	OUTPUTS
•100 units solar radiation received at top of atmosphere (shortwave)	**•31 units solar reflected back to space - called albedo** (shortwave)** **•21 units (reflected by clouds)** **•7 units (reflected by atmosphere)** **•3 units (reflected by land or sea)** **•69 units emitted by Earth and atmosphere to space (longwave)**
100 units of Input	**100 units of Output**
Input = Output **Overall Radiation Budget for the Earth/Atmosphere System Balances!!!**	

****Albedo (percent reflectivity) = shortwave reflected ÷ total shortwave received x 100**

Earth/Atmosphere Average, 30%; Asphalt, 5-10%; Forest, 10-20%; Dry concrete, 17-27%; Water, 10-60%; Fresh Snow, 80-95%

B. Radiation Flow Between Surface and Atmosphere (This is referred to as the Greenhouse Effect; which is a natural, normal process!!!)

- Some sunlight (shortwave) is absorbed by the atmosphere and clouds (24 units), but a significant amount passes through passes through (it is transmitted) and is absorbed at Earth's surface (45 units).
- This causes the surface of Earth to heat up and emit longwave toward atmosphere (118 units).
- Much of this longwave is absorbed by the atmosphere and then emitted back toward Earth (called **counterradiation**; 96 units)
- This is the **Greenhouse effect**, the natural effect of the atmosphere.
- Without an atmosphere, days would be scorching and nights would be freezing.

C. Net Radiation at Earth's Surface (add inputs and subtract outputs)

FORMULA

Net Radiation = SW↓ - SW↑ + LW↓ - LW↑

1. Net Surplus of Radiation (ultimately heats the air)

- Occurs when INPUTS of radiation (short and longwave) EXCEED OUTPUTS of radiation (short and longwave)
- Surplus causes surface to heat…
- Heated surface then heats the air by conduction (molecule to molecule transfer of heat energy from surface to air)……
- Heated air rises by convection (heat energy moving with a moving substance)
- Generally occurs during the day

2. Net Deficit of Radiation (ultimately cools the air)

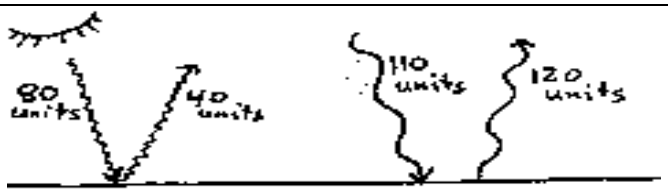
- Occurs when OUTPUTS of radiation (short and longwave) EXCEED INPUTS of radiation (short and longwave)
- Deficit causes surface to cool…
- Cooled surface then cools the air by conduction (molecule to molecule transfer of heat energy from air to surface)……
- Usually occurs during the night

D. Global Pattern of Net Radiation (causes Poleward Heat Transport)

- Radiation surpluses occur globally at low latitudes (between 36° North and South Latitude) due to the high sun angles.
- Substantial heat is subsequently produced at low latitudes
- This heat flows poleward (toward the high latitude radiation deficits), carried by wind and ocean currents
- This process is called **Poleward Heat Transport**

E. Calculating Net Radiation at a Specific Time and Place (see problem below)

80 units shortwave received at surface (input)
40 units shortwave reflected by surface (output)
110 units longwave received and absorbed (input)
120 units longwave emitted (output)



ANSWER THE FOLLOWING QUESTIONS:

- **Is this a surplus or deficit?**
- **How many units of surplus or deficit?**
- **Is the surface heating or cooling?**
- **Is this in the daytime or nighttime?**
- **What is the albedo?**

TIPS:

- **When calculating net radiation (surplus or deficit), add all inputs, then subtract all outputs. Do this regardless of wavelength.**
- **Use *only* shortwave data to calculate albedo; your answer will be in percent (see formula a few pages back)!!!**

Sample Questions: Questions similar to these will be on your exam. As you study you should anticipate how I might use these questions to create new questions on the same concepts.

1	You are at an elevation of 4000 feet and the temperature is 60°F. Based on the normal lapse rate of 3.5F°/1000ft, what should the temperature be when you arrive at an elevation of 9,000 feet?
2	Which of these surfaces would likely have the lowest albedo? A. Snow covered field. B. Green pasture. C. Blacktop parking lot. D. Sandy beach.
3	Which of the following reflects the **most** shortwave radiation back toward space? A. clouds. B. atmospheric gasses. C. the Earth's land and water surface.
4	As a scientist, you gather the following data for a radiation budget of a parking lot surface: 125 units incoming shortwave, 25 units outgoing shortwave (reflected), 85 units incoming longwave, 105 units outgoing longwave. Which is the correct value for net radiation? A. 55 units surplus B. 80 units surplus C. 125 units deficit D. 20 units deficit E. budget is balanced
5	In the previous question, what is the albedo?
6	Which of the following would be an example of Poleward Heat Transport? A. a warm ocean current flowing from California toward the Equator. B. a warm wind blowing from 70° North latitude to 10° North latitude. C. water vapor blowing from the North Pole toward the Equator D. a warm ocean current flowing from 10° South latitude toward 70° South latitude
7	By what specific process does Earth's surface transfer heat energy to the air? A. radiation B. reduction C. advection D. conduction E. convection
8	***Possible Essay Question:*** What is a temperature inversion, and how does it affect air pollution?
9	***Possible Essay Question:*** What is "poleward heat transport," and why does it occur?
10	***Possible Essay Question:*** During the day it would be normal (and very common) to measure a ground level radiation surplus on most types of surfaces (dirt, grass, water, pavement, etc). Explain in detail the *cause* and *effect* of a normal, everyday radiation surplus such as this.
11	***Possible Essay Question:*** Ozone occurs both at Earth's surface AND 15-55km above Earth's surface (in the ozonosphere). Compare and contrast these two types of ozone.

GOOD NEWS!!! The practice questions above - plus *many*, *many* more – can be found in the online practice quizzes discussed in your syllabus and in class. You can take each quiz multiple times, and each time you will get some new questions. Once submitted, the quizzes are graded automatically, with the correct answers provided immediately. ***This is a great way to prepare for the exams!!!***

SERIOUSLY, TAKE THE ONLINE PRACTICE QUIZZES!!!

TIP: Review online notes before every lecture! TIP: Review your notes as soon as possible after every lecture!