Tuesday Sep 30th

SIT ANYWHERE TODAY!

TODAY: Topic # 6 Wrap-Up

&

TOPIC # 7 THERMODYNAMICS

& Energy Transformations

RQ-4 was due before class today

Missed it? FAQ #22

TEST #2 is a week from today

The "Top 10" will be posted on Thursday

The MIDTERM EXAM is two weeks from Thursday

on Thursday Oct 16th

WRAP UP:

TOPIC #6
Atmospheric Structure & Composition

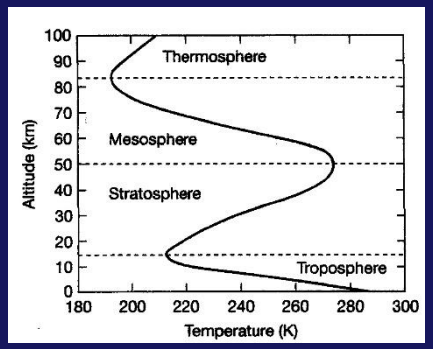
SUMMARY OF KEY CONCEPTS: short version

1. Four gases N_2, O_2, Ar, & CO_2 comprise about 99% of the volume – but "minor" trace Greenhouse Gases are extremely important. **Which of the 4 is a GHG?**

2. Most of the MASS of the atmosphere is in the bottom few kilometers (i.e. the Toposphere!)

3. Different gases are abundant at certain levels in the atmosphere. The effect of radiation absorbed by these gases is seen in the vertical temperature profile

4. . . . which leads to the vertical structure of the atmosphere:

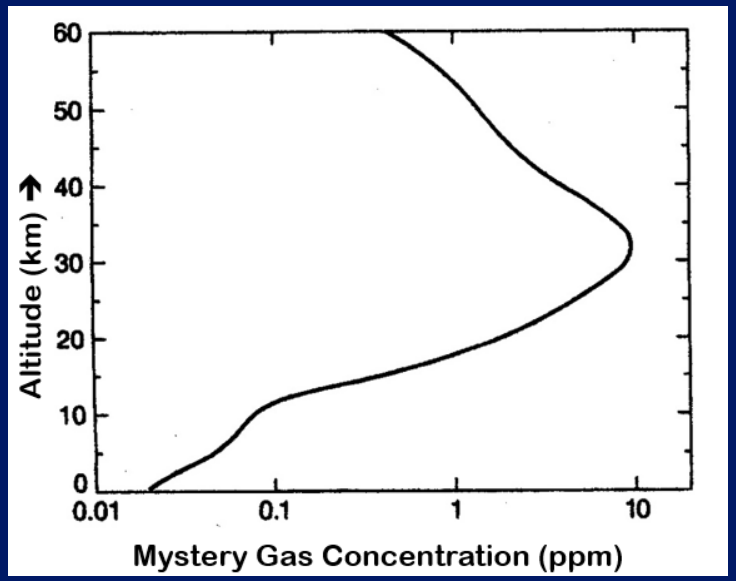


Last class . . .

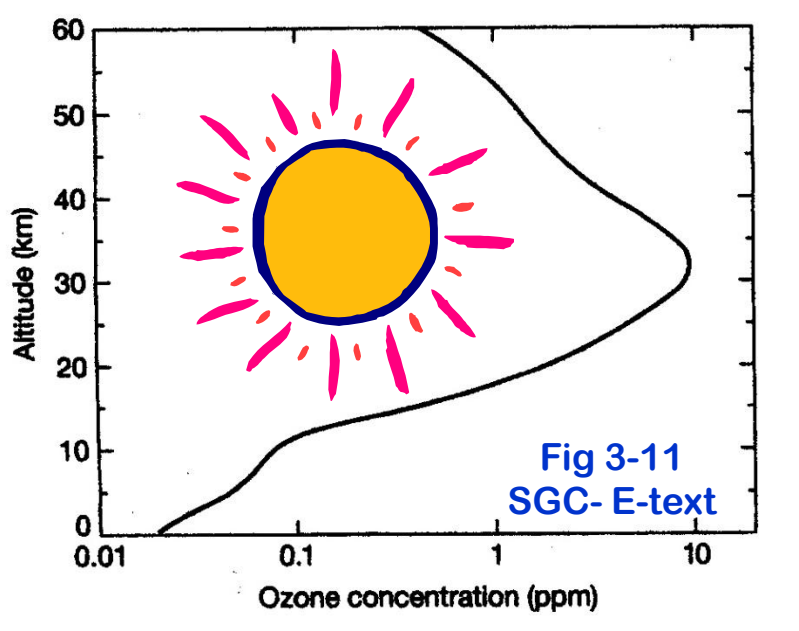
Name that GAS!!!

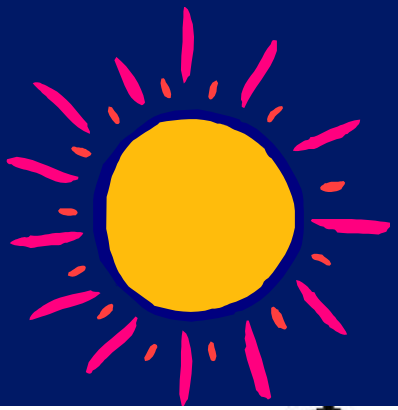
(this one's a visual hint only!)

MYSTERY GHG # 7



OZONE: Sources





Produced naturally in photochemical reactions in STRATOSPHERIC ozone layer --"good ozone"

Has *increased* in TROPOSPHERE due to photochemical smog reactions -- "bad ozone"

☺ Table on p 38

OZONE
Time series trends

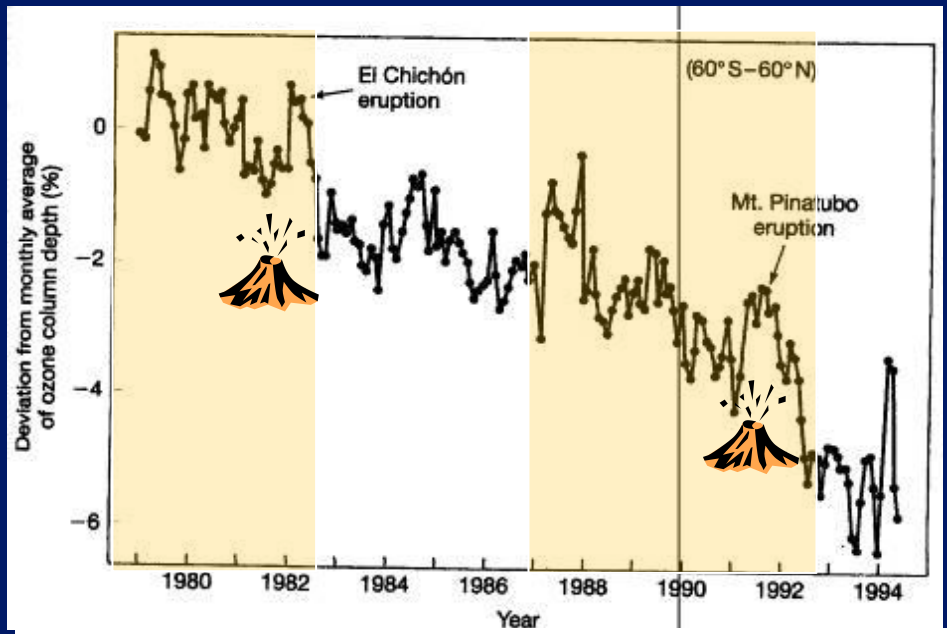
Overall, O3 is decreasing in the STRATOSPHERE➔

Year-to-year variability in Stratospheric ("good ozone") is affected by:

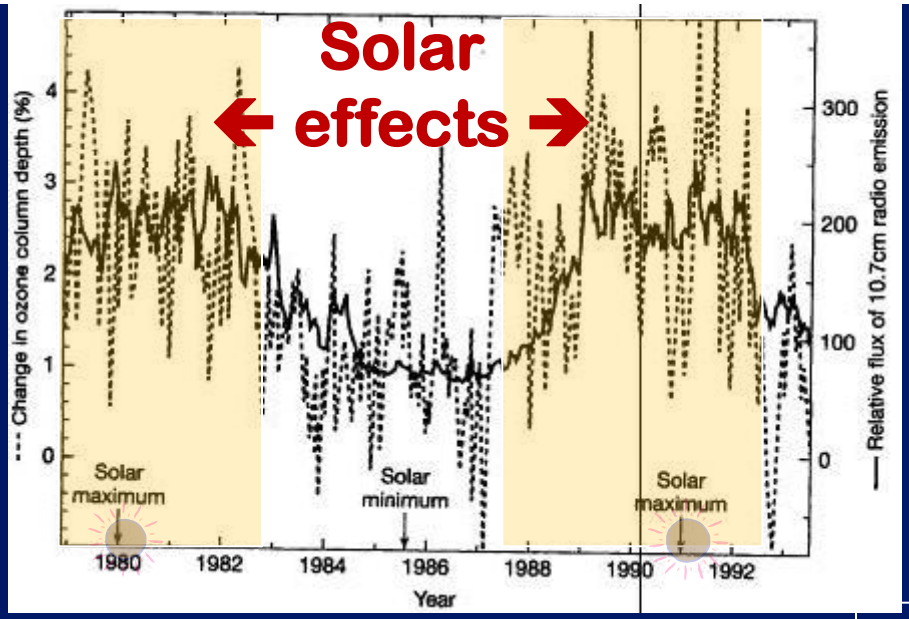
1. **SOLAR radiation**
(more sun ➔ more O3 production)

2. **VOLCANIC eruptions**

3. **Chemical reactions due to CFCs**



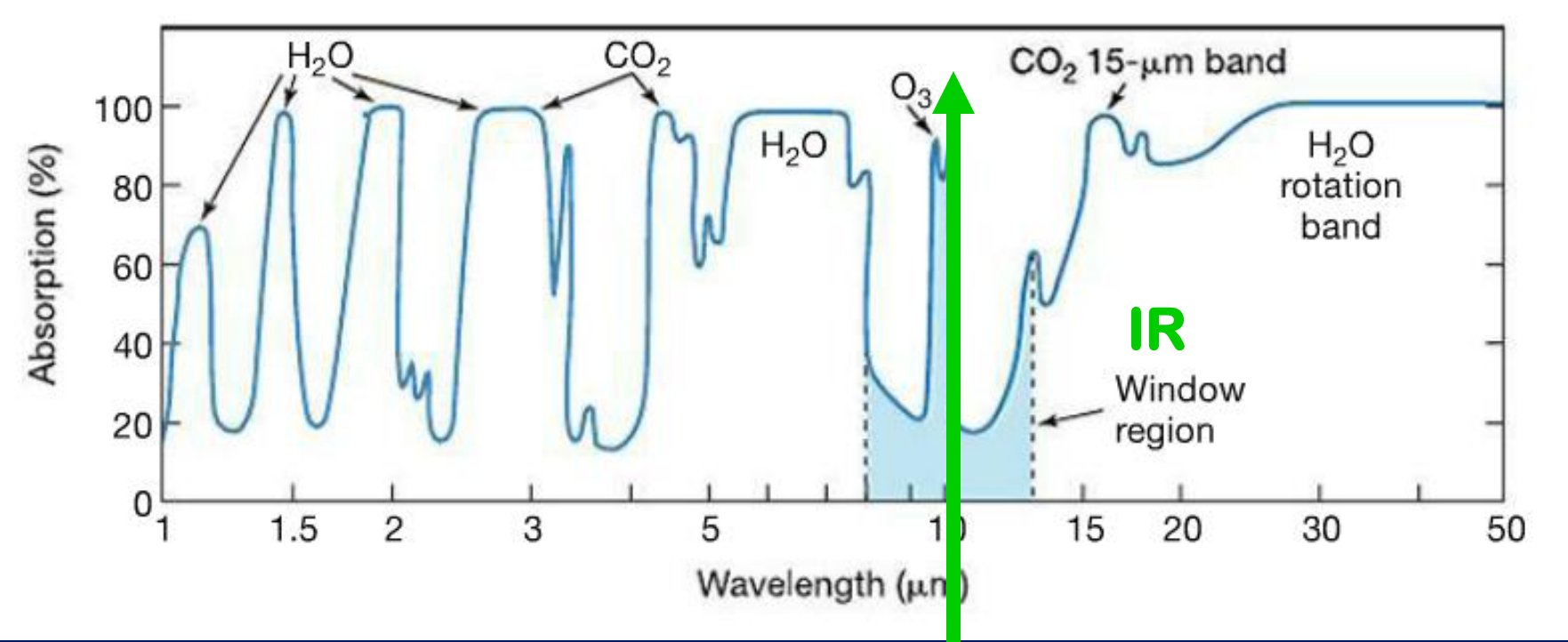
Trend in graph ↑ is removed in graph ↓ to show natural variability



Much more on OZONE later on in the semester!!

☺

O_3 absorbs IR radiation of 9.6 µm, VERY close to wavelength of maximum terrestrial radiation (10 µm)



CHAPTER 3 in E-text Fig 3.13

Therefore . . .

OZONE has a HIGH Global Warming Potential

OZONE has a HIGH Global Warming Potential:

GLOBAL WARMING POTENTIAL (GWP) – An index that measures how much a **given mass of greenhouse gas** is estimated to contribute to global warming.

GWP depends on:

- **absorption of infrared radiation,**
- **location** on the **spectrum**
- the atmospheric **lifetime** of the gas

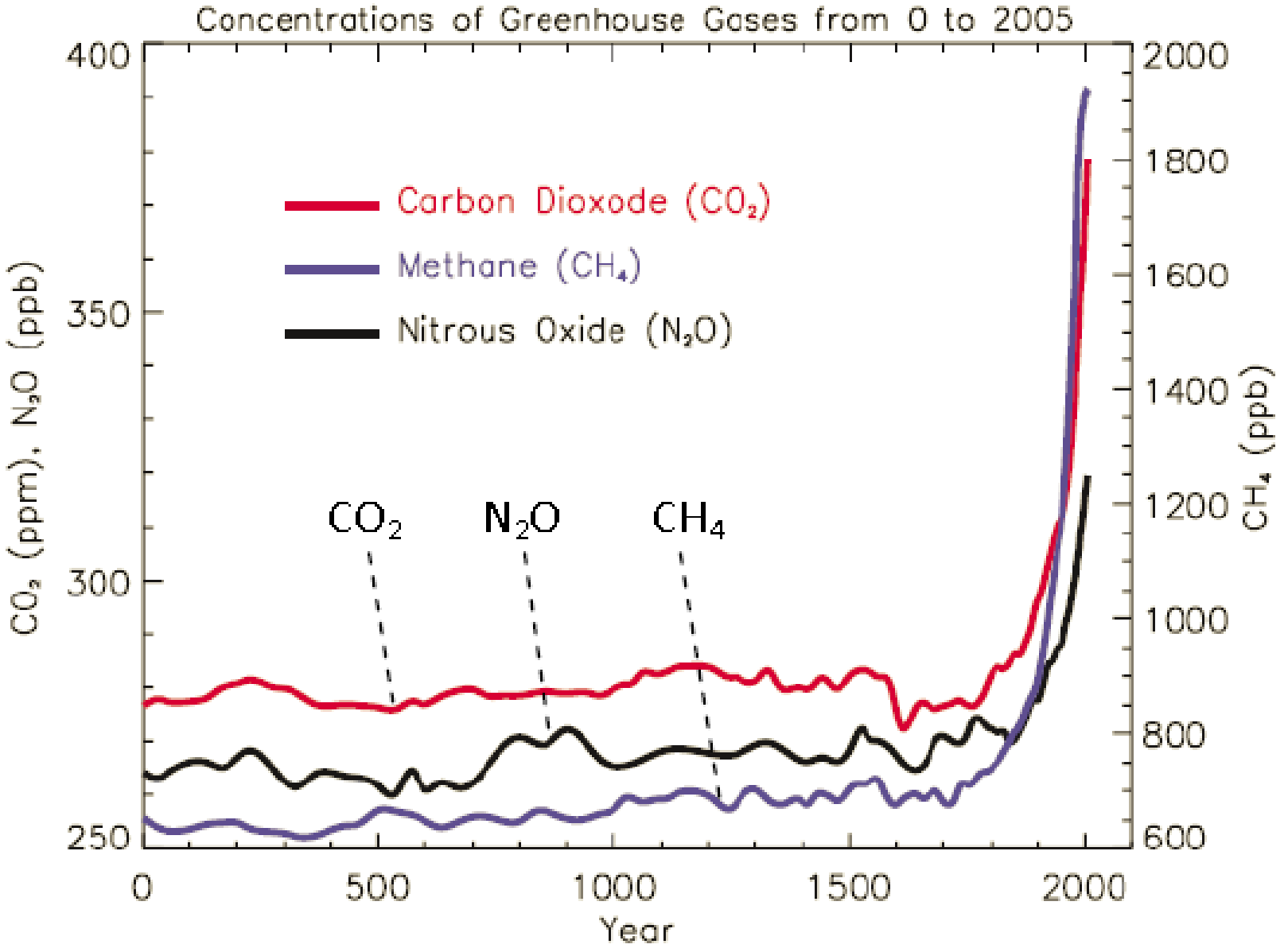
GLOBAL WARMING POTENTIAL (GWP) of other GHG's

LIFETIME AND GLOBAL WARMING POTENTIAL OF HUMAN-GENERATED GREENHOUSE GASES

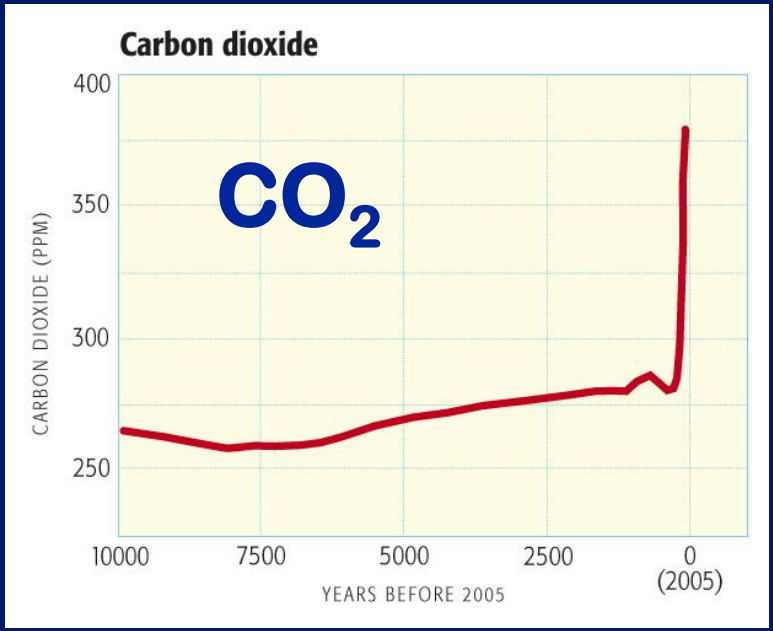
Gas	CO_2	CH_4	N_2O	CFC-11	CFC-12	HCFC-22
Lifetime years	Multiple	12	114	45	100	12
Global warming potential calculated over . . .						
20 years	1	72	289	6,730	11,000	5,160
100 years	1	25	298	4,750	10,900	1,810
500 years	1	8	153	1,620	5,200	549

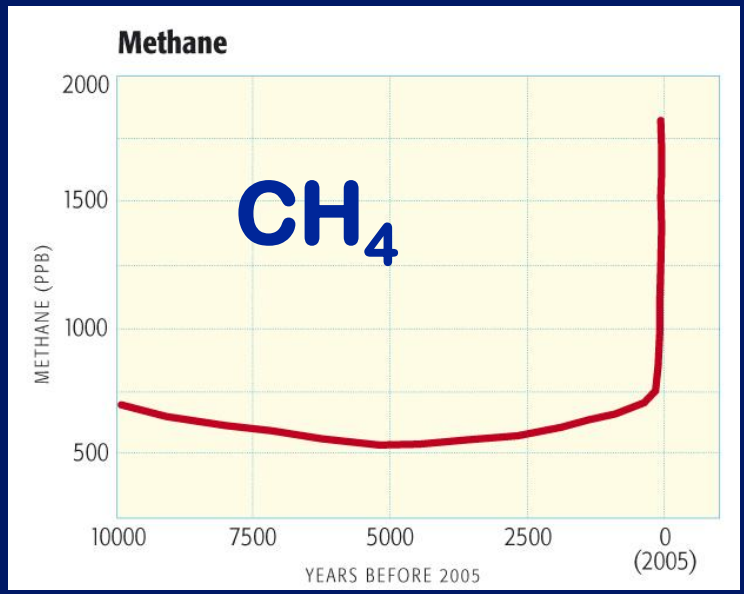
"If you have an equal mass of CO_2 and CH_4, the methane will trap 72 times more heat than the carbon dioxide over the next 20 years"

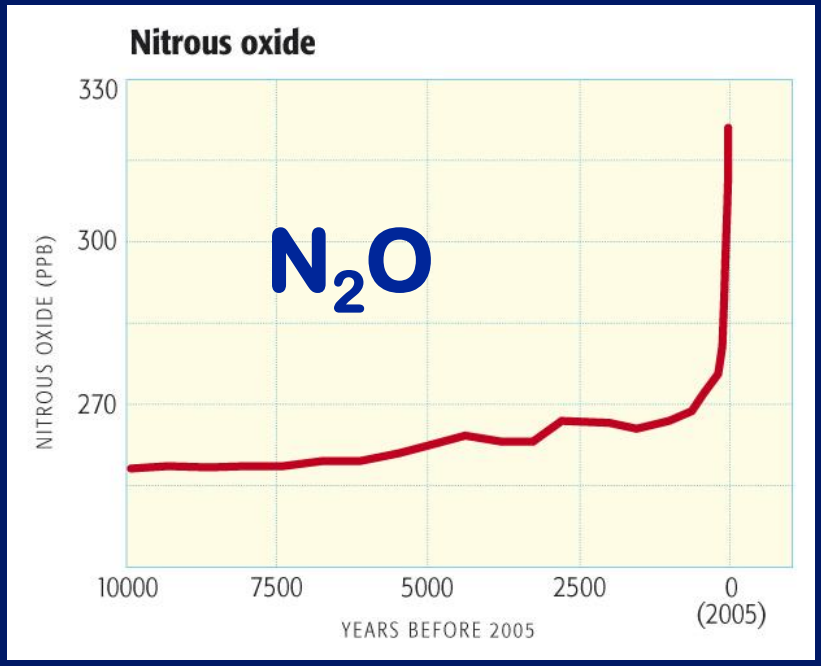
See pp 29-29 in *Dire Predictions*


Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO_2)
Methane (CH_4)
Nitrous Oxide (N_2O)
CO_2
N_2O
CH_4
CO_2 (ppm), N_2O (ppb)
CH_4 (ppb)
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000
Year

Updated figures from Dire Predictions p 33

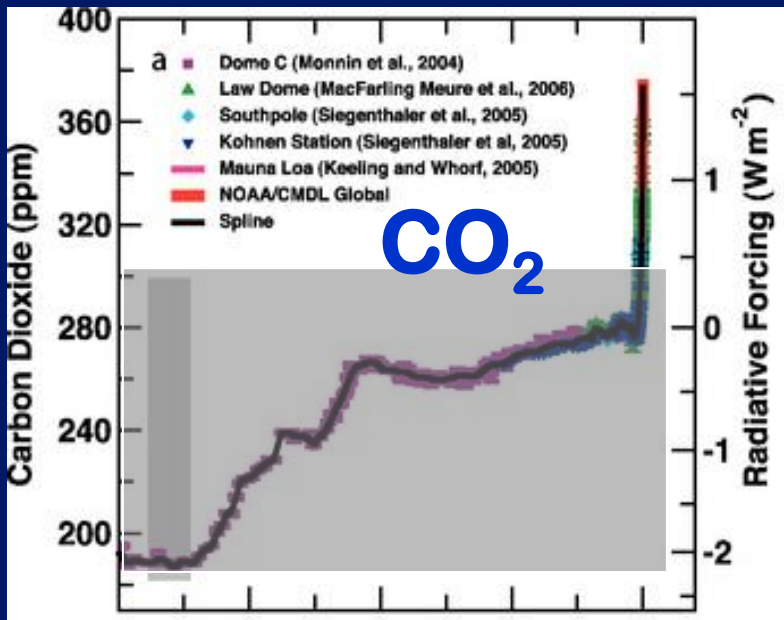


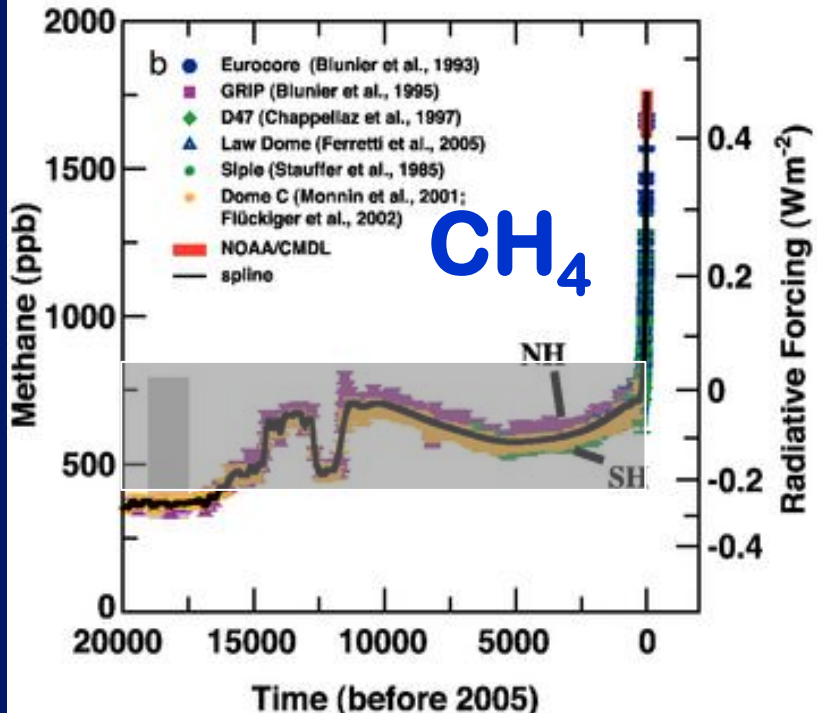


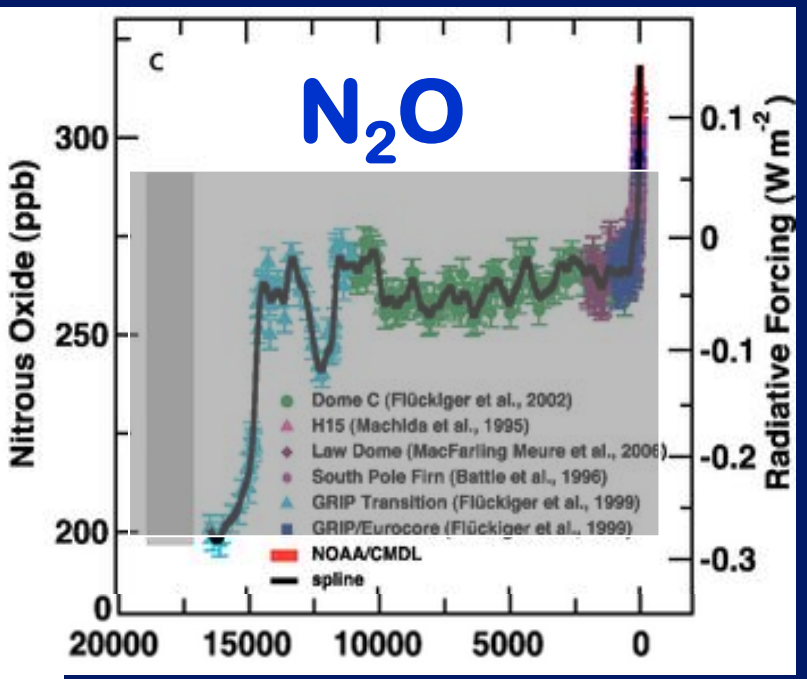


Natural vs Human-Influenced GHG Concentrations

*The grey bars show the ranges of **natural variability** for the **past 650,000 years!***







These graphs go WAY back in time: 20,000 years ago!

☺

Now on to today’s topic . . . .

TOPIC # 7
LAWS OF THERMODYNAMICS & ENERGY TRANSFORMATIONS

The Next Piece in the Puzzle to Understand Global Changes

CLASS NOTES:
pp 40-47

Featuring . . . .

OUR QUOTE OF THE DAY . . .

. . . is from HOMER SIMPSON

THERMODYNAMICS

(def) = The study of the general properties of ENERGY.

THERMAL energy plays a central role in understanding these properties, hence the study of energy can also be called "thermodynamics."

Forms of Energy - Review

- **Kinetic** (KE) = energy of *motion* *or* the ability of a mass to do work.

  (related to mass and velocity)

- **Potential** (PE) = energy a system possesses if it is capable of doing work, but is NOT doing work now

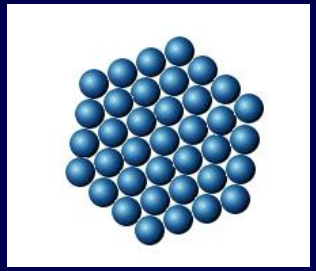
[*Includes: gravitational, elastic, chemical, electrical, magnetic . . . and* ELECTROMAGNETIC]

review

Thermal Energy

Thermal energy (def) = the grand total of all energies inside a substance:

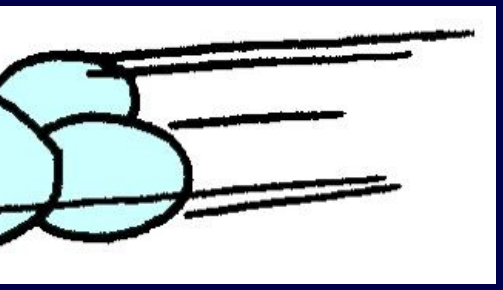
-- specifically: a measure of the quantity of *atomic kinetic & potential energy* contained in every object



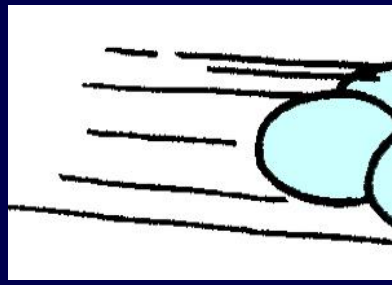
Thermal Energy & Temperature

- ***Temperature*** = tells how warm or cold a body is with respect to some standard (e.g., Fahrenheit (°F), Celsius (°C), or Kelvin (K) standard scales).

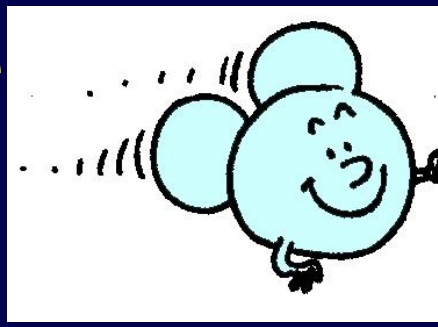
- **Temperature is a "**measure" of the average kinetic energy of each molecule in a body.



If a body has a high temperature, each of its molecules has, on the average, a large amount of kinetic energy.

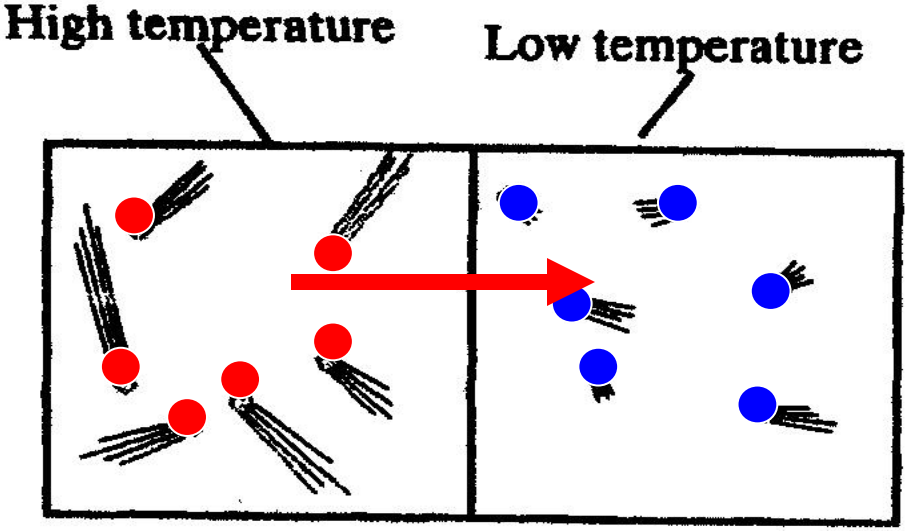


if a body has a low temperature, each molecule on the average has a small amount of kinetic energy.



(and if atoms lose all their kinetic energy, they reach the **"absolute zero"** of temperature)

Thermal Energy Flow (Transfer)



(a) *A hot box of gas and a cold box of gas, at the instant they are put into contact: Most of the molecules in the hot box move rapidly, while most of the molecules in the cold box move slowly.*

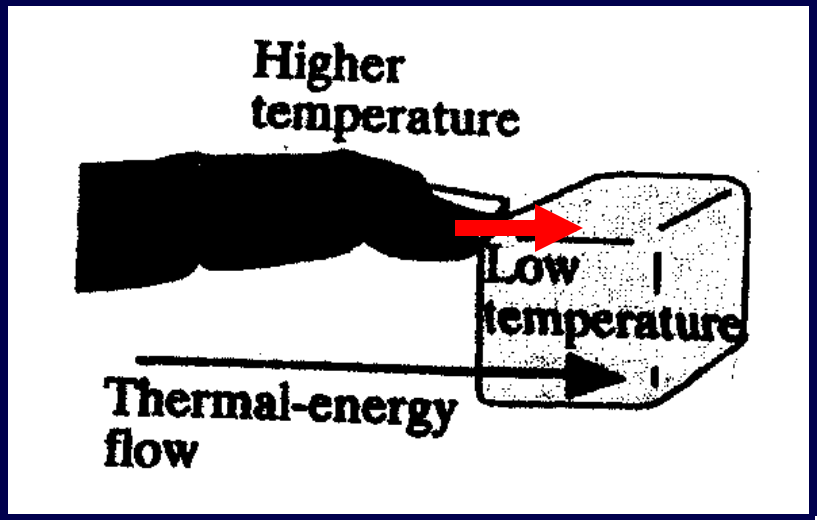
In which direction will THERMAL ENERGY be transferred?

Thermal energy flow = HEAT

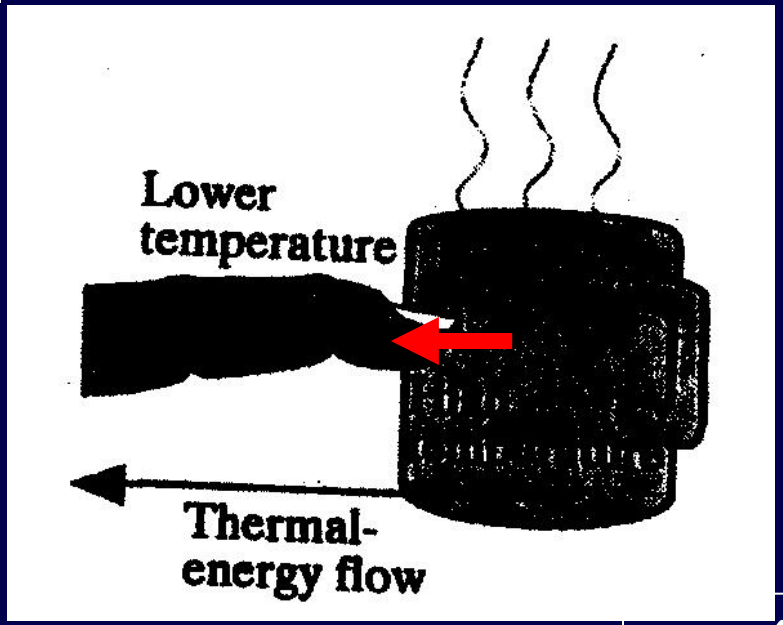
Thermal Energy vs. Heat

Heat = the thermal energy that is *transferred* from one body to another because of a temperature difference.

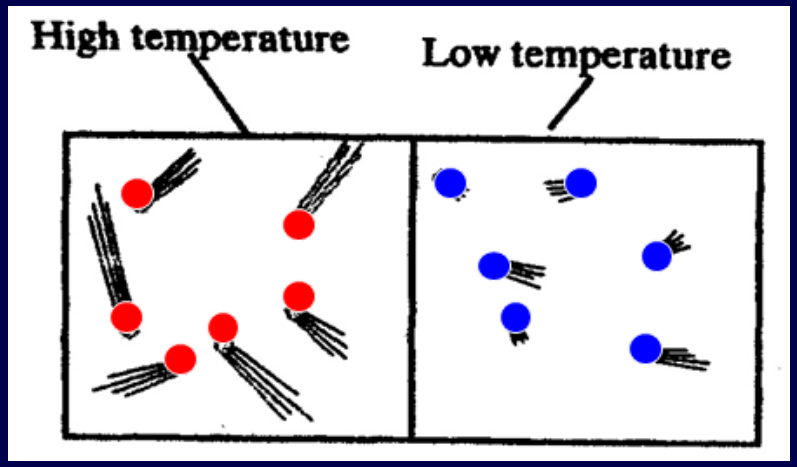
PART A - Thermal Energy Background



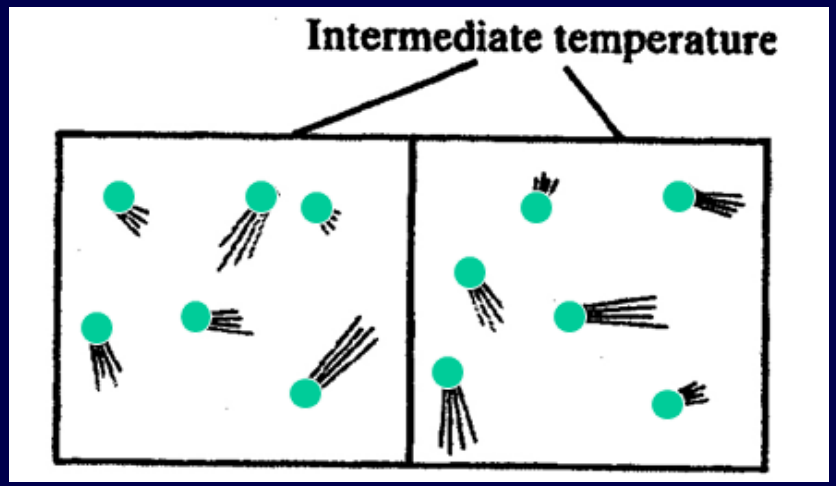
Heat will always pass from a substance of higher temperature to a substance of lower temperature, until both come to a common temperature.



PART A - Thermal Energy Background



Reaches equilibrium



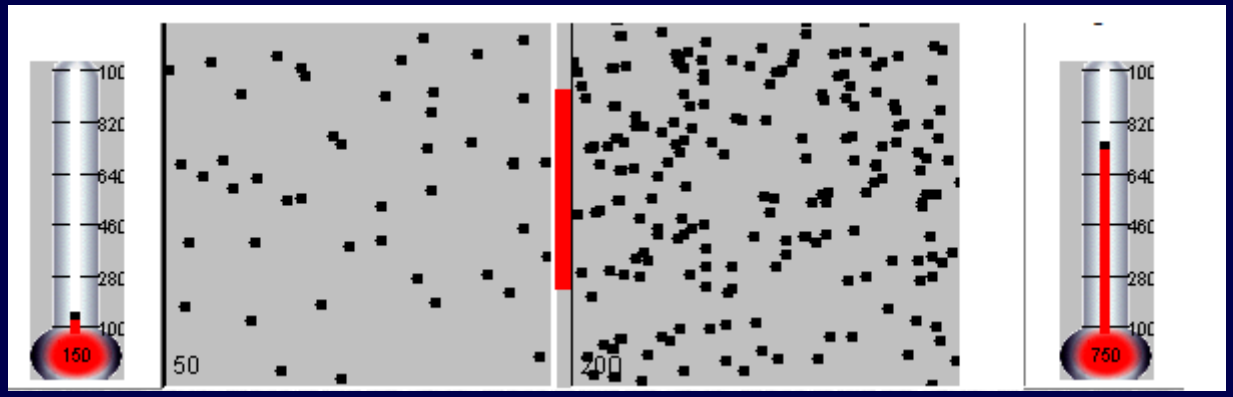
Will not spontaneously return to previous condition!

PART A - Thermal Energy Background

door closed

Cold chamber

Warm chamber



Yay! Another
Sustainability Segment!

http://www.pbs.org/wgbh/nova/tech/saved-by-the-sun.html

PART B – Temperature Responses & Thermal Energy Storage in Different Substances

First, some more background is needed . . . . .

- Unit of Measure of Thermal Energy
  (i.e., the joule or calorie)
- Specific Heat
- Heat Capacity

Quick Review: Thermal Energy Units

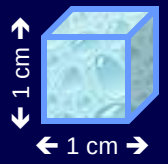
Unit for Thermal Energy
= the *joule* or *calorie*.

"Low Joule Cola"

Label from a soda bottle purchased in Europe

A CALORIE is the amount of thermal energy required to change the temperature of 1 gram of water by 1°C (specifically from 14.5°C to 15.5°C) 1 calorie = 4.186 joules

(one gram of water is roughly equivalent to the weight of one cubic centimeter of water



. . . or about the mass of 1 small paper clip!)

review

PART B – Temperature Responses & Thermal Energy Storage in Different Substances

. . . But we're not talking about *"nutrition calories"*
(they are really kilocalories)

"Munch"

1 "nutrition calorie" =
1000 calories
or 1 kilocalorie (Kcal)

review

2 Key Terms:

Specific Heat & Heat Capacity

Specific Heat = the amount of thermal energy (in calories) required to raise the temperature of 1 gram of ***any substance*** by 1°C.

Specific heat =
1.00 calorie

1 g
of water

vs.

Specific heat =
0.24 calorie

1 g
of air

vs.

Specific heat =
0.20 calorie

1 g
of sand

PART B – Temperature Responses & Thermal Energy Storage in Different Substances

Heat Capacity = **Specific Heat x Mass (density)**
(i.e., mass of a substance for a given <u>VOLUME</u>.

(**DENSITY** is measured in grams per cubic centimeter.)

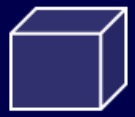
"Heat capacity represents the capacity of a substance to <u>absorb</u> and <u>store</u> heat in relation to its ***<u>volume</u>*** and ***<u>density</u>***."

Heat capacity =
1.00
calorie / cubic cm

1 cubic cm
of water

vs.

Heat capacity =
0.00024 – .00034
calorie / cubic cm



1 cubic cm
of air

vs.

Heat capacity =
0.1 – 0.6 *higher if wet*
calorie / cubic cm

1 cubic cm
of sand

Specific Heat & Heat Capacity for Different Substances

Substance	Specific Heat		Heat Capacity
	cal	*joules*	
water	1.00	4.186	1.00
air	0.24	1.005	0.00024 - 0.00034
concrete	0.21	.879	0.50
sand	0.20	.837	0.10 - 0.60 (higher if wet)
iron	0.105	.440	0.82
silver	0.056	.234	0.59

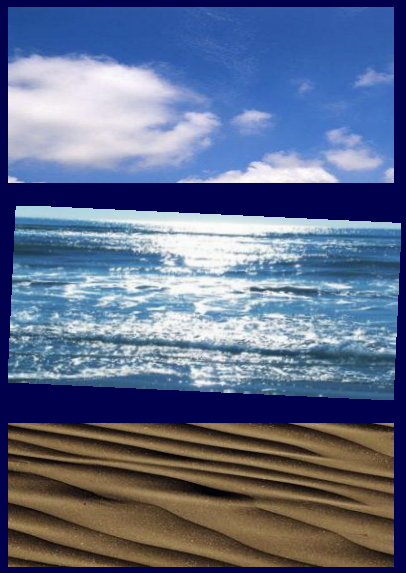
Note the HEAT CAPACITY differences between higher density substances (like water, iron) vs. the low density substance of AIR.

CLICKER Q's➔

Clicker Q1 - Assume you have an equal volume of WATER, AIR & SAND.

Which will HEAT UP THE FASTEST if the same amount of thermal energy is transferred into the substance?

1. AIR
2. WATER
3. SAND



HINT: the greater the heat capacity, the LONGER it will take to heat up the substance.

Clicker Q1 - Assume you have an equal volume of WATER, AIR & SAND.

Which will HEAT UP THE FASTEST if the same amount of thermal energy is transferred into the substance?

1. AIR
2. WATER
3. SAND

Explanation:

The lower the heat capacity, the quicker the response to a transfer of heat into the substance!

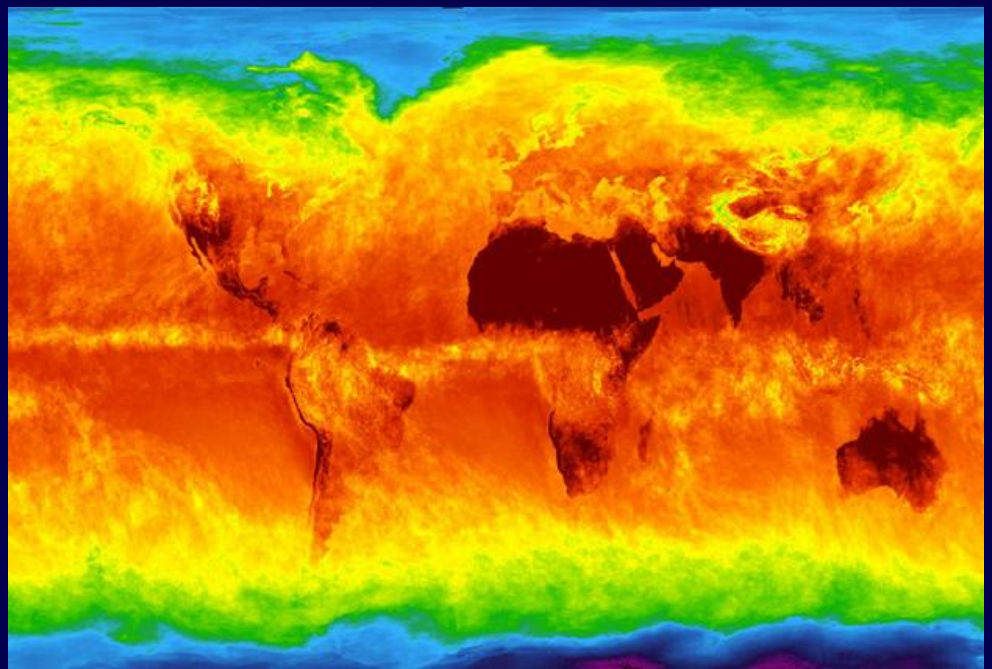
Clicker Q2 – As global warming is occurring we will be able to detect it FIRST where?

1 = the ocean temperature

2 = the land surface temperature (i.e., soil)

3 = actually, they will both heat up at the same rate

Map of global surface temperatures



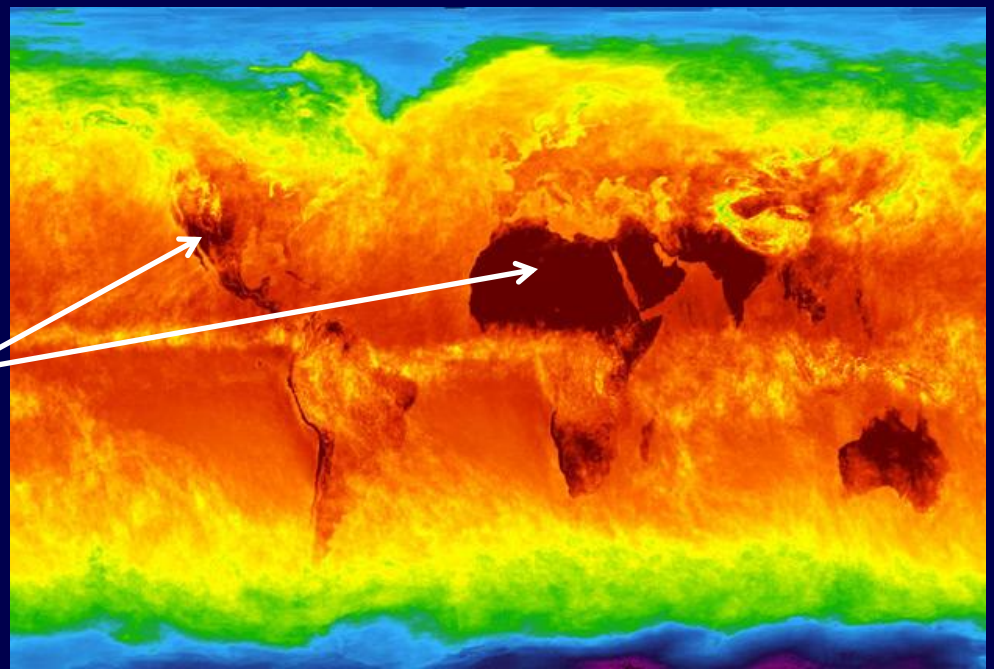
Clicker Q2 – As global warming is occurring we will be able to detect it FIRST where?

1 = the ocean temperature

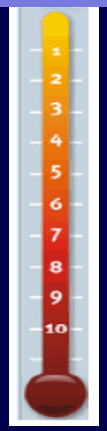
2 = the land surface temperature (i.e., soil)

3 = actually, they will both heat up at the same rate

Note where the hottest temperatures occur

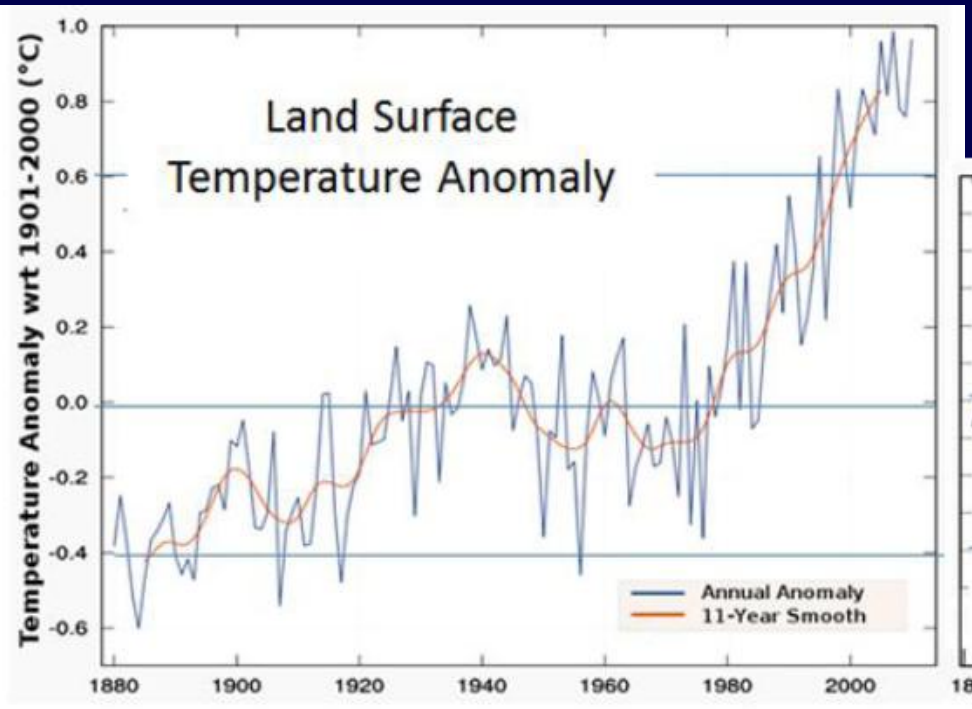


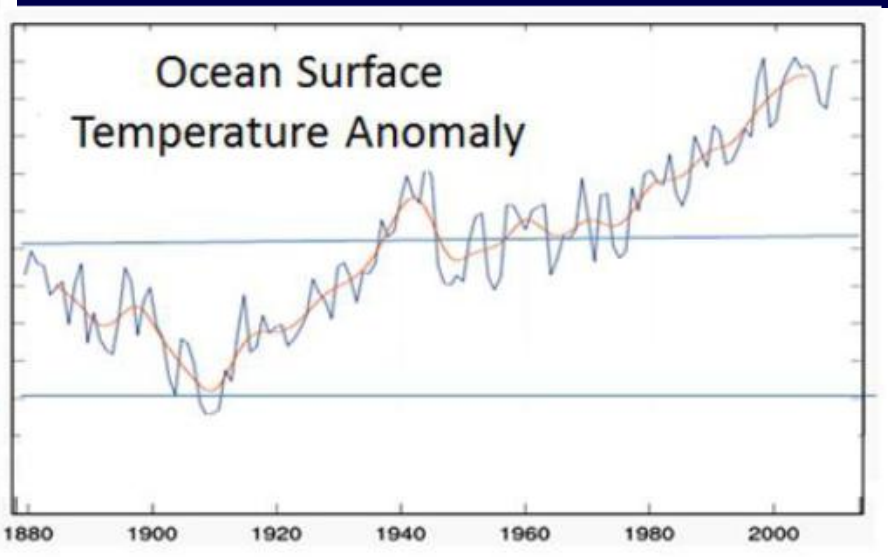
PART B – Temperature Responses & Thermal Energy Storage in Different Substances



EXPLORING THE EVIDENCE . . .

Thought Q1. Why does the ocean surface warm more slowly than the land surface?





http://www.ncdc.noaa.gov/cmb-faq/anomalies.php

Clicker Q3 - Why will he burn his tongue, even if the pie crust is cool enough to hold?

1 - Because due to the high specific heat of the water in the apple pie filling, the filling will heat up faster and to a much higher temperature than the crust can achieve

2 – Because, due to the high specific heat and heat capacity of the water in the apple pie filling, the filling will hold the thermal energy longer than the crust will after the pie is taken out of the oven.

3 - BOTH

Clicker Q3 - Why will he burn his tongue, even if the pie crust is cool enough to hold?

1 - Because due to the high specific heat of the water in the apple pie filling, the filling will heat up faster and to a much higher temperature than the crust can achieve

2 – Because, due to the high specific heat and heat capacity of the water in the apple pie filling, the filling will hold the thermal energy longer than the crust will after the pie is taken out of the oven.

3 - BOTH

Clicker Q4 - Which component of the EARTH SYSTEM has the ability to store thermal energy the longest -- once it heats up?

1. The ATMOSPHERE
2. The CONTINENTS
3. The OCEAN

Clicker Q4 - Which component of the EARTH SYSTEM has the ability to store thermal energy the longest -- once it heats up?

1. The ATMOSPHERE
2. The CONTINENTS
3. The OCEAN

PART B – Temperature Responses & Thermal Energy Storage in Different Substances

EXPLORING THE EVIDENCE . . .

Thought Q2.

Why is the total heat CONTENT of the ocean so much greater than the land?

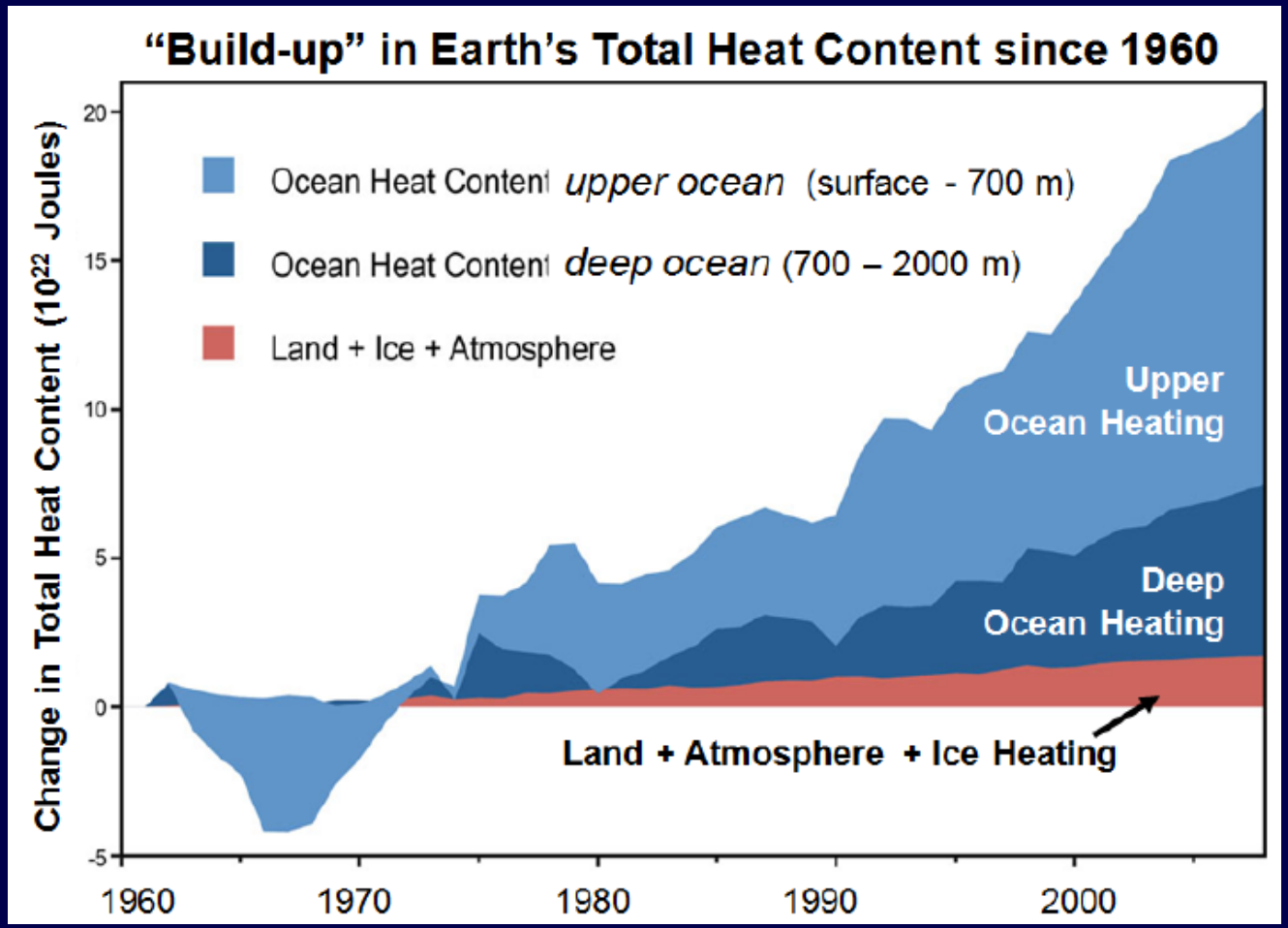


Figure: http://www.skepticalscience.com/earths-climate-system.html updated Dec 2013

Got all that Homer?

boring . . . . !

THERMAL ENERGY TRANSFER
(aka "Heat Transfer")

Heat Transfer

the process by which thermal energy moves from one place to another . . .

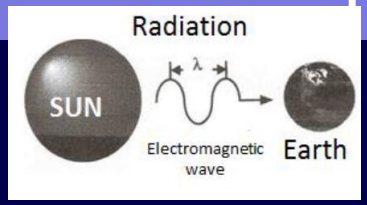
CONDUCTION = passage of thermal energy through a body **without large-scale movement of matter** within the body. Occurs through the transfer of **vibrational energy from one molecule to the next** through the substance. In general, solids (esp. metals) are good conductors & liquids and gases (esp. air) are poor conductors.

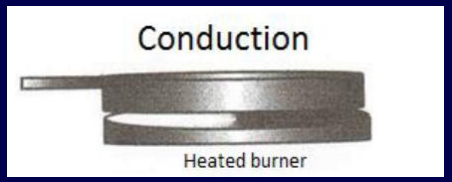
CONVECTION = passage of thermal energy through a fluid (liquid or gas) **by means of large-scale movements of material within the fluid,** as in a ***convection cell.***

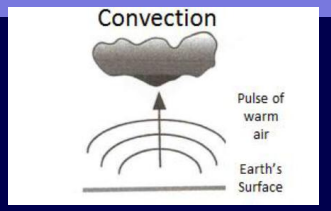
RADIATION = the transfer of thermal **energy in a wave or pulse of *electromagnetic radiation*** (as in a photon) or IR wavelength. The only one of the three mechanisms of heat transfer that **does *not* require atoms or molecules (matter)** to facilitate the transfer process.

3 ways of heat transfer

PART C – Thermal Energy Transfer







https://www.youtube.com/watch?feature=player_embedded&v=7Y3mfAGVn1c

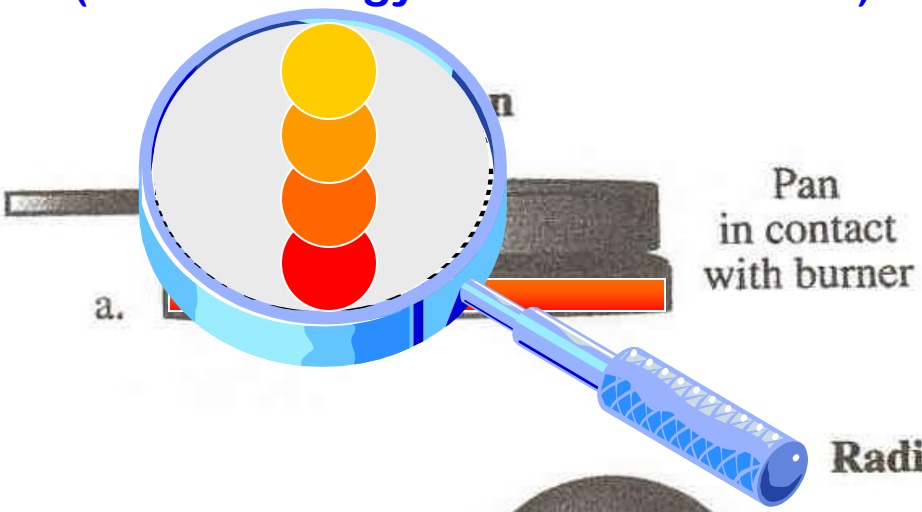
HEAT TRANSFER

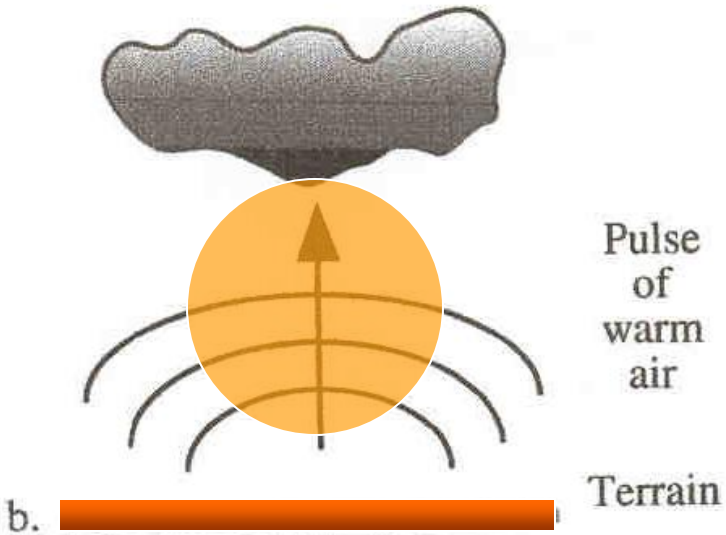
CONVECTION

Mass of warm air or liquid heats, expands, rises

CONDUCTION

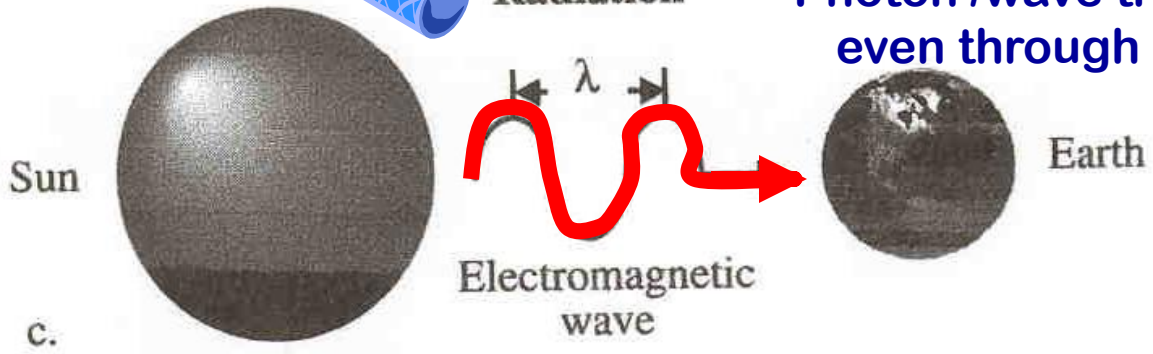
Jiggling molecule ➔ jiggling molecule
transfer of heat
(kinetic energy at molecular scale)





RADIATION

Photon /wave transport: even through a void!



Electromagnetic Radiation

(a KEY POINT about it!)

Electromagnetic energy (radiation) is not heat energy.

It does not become heat (jiggling molecules) until it strikes an object, is absorbed by the object and sets the molecules in the object in motion, thereby heating up the object.

Electromagnetic Radiation

WHAT IS THE LINK TO GLOBAL CHANGE?

The sun's energy comes in as radiant (electromagnetic) energy, and is converted to measurable heat only after it is absorbed (e.g., by the surface of the earth, by certain gases in the atmosphere -- by the GREENHOUSE GASES

CLICKER SELF-TEST TIME!!! . . . .➔

Clicker Q5 - Which way is heat being transferred?

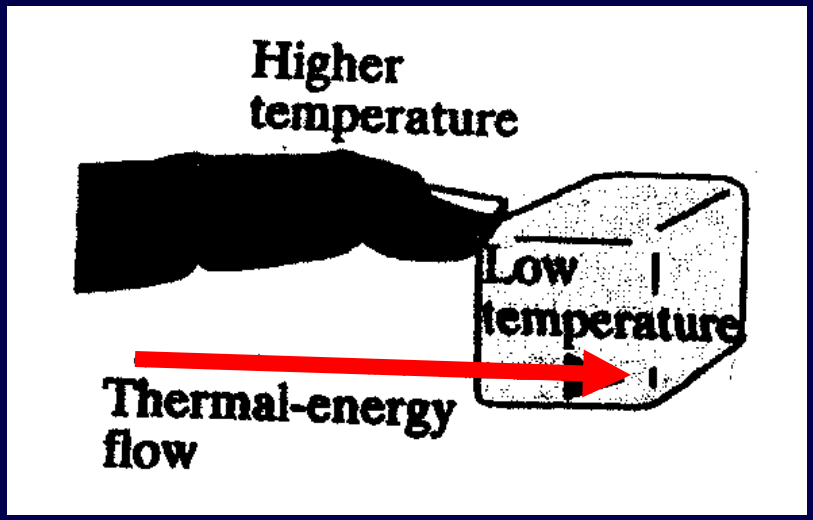
1. From the cold beer can into Homer's warmer beer belly

2. From Homer's beer belly to the colder beer can

3. From BOTH the beer can to Homer and Homer to the beer can

Clicker Q5 - Which way is heat being transferred?

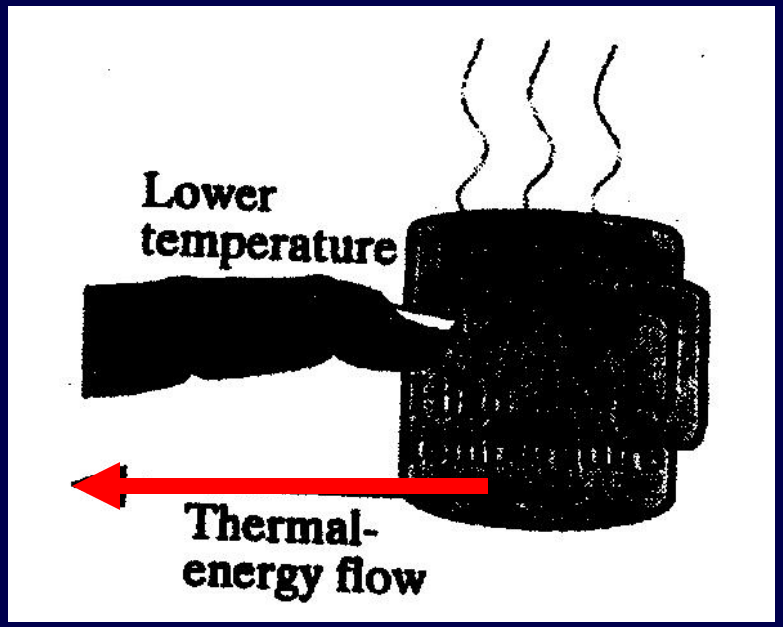
1. From the cold beer can into Homer's warmer beer belly
2. From Homer's beer belly to the colder beer can
3. From BOTH the beer can to Homer and Homer to the beer can



Explanation for answer to Q5:

The 2nd Law of Thermodynamics!

Heat will always pass from a substance of higher temperature to a substance of lower temperature, until both come to a common temperature.



Got all that Homer?

Can I go now????

YES!!