TODAY:

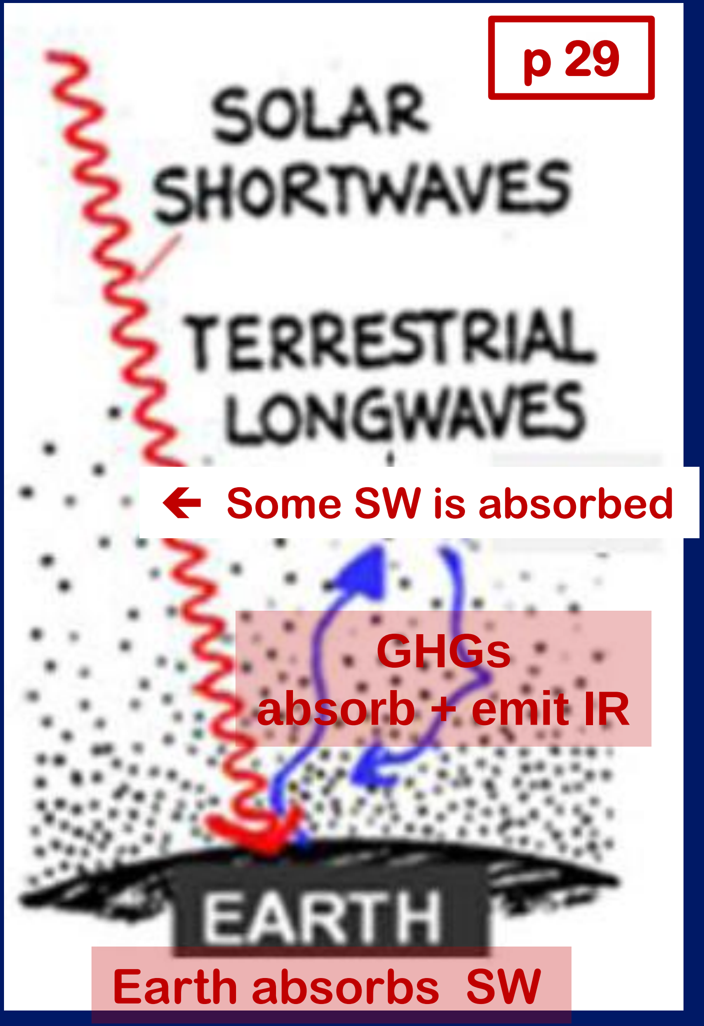
TOPIC #6 WRAP UP!!
Atmospheric Structure & Composition

There's one more thing to correct in our the depiction of incoming Solar . . . .

. . . the atmosphere is NOT totally TRANSPARENT to INCOMING Solar SW radiation!

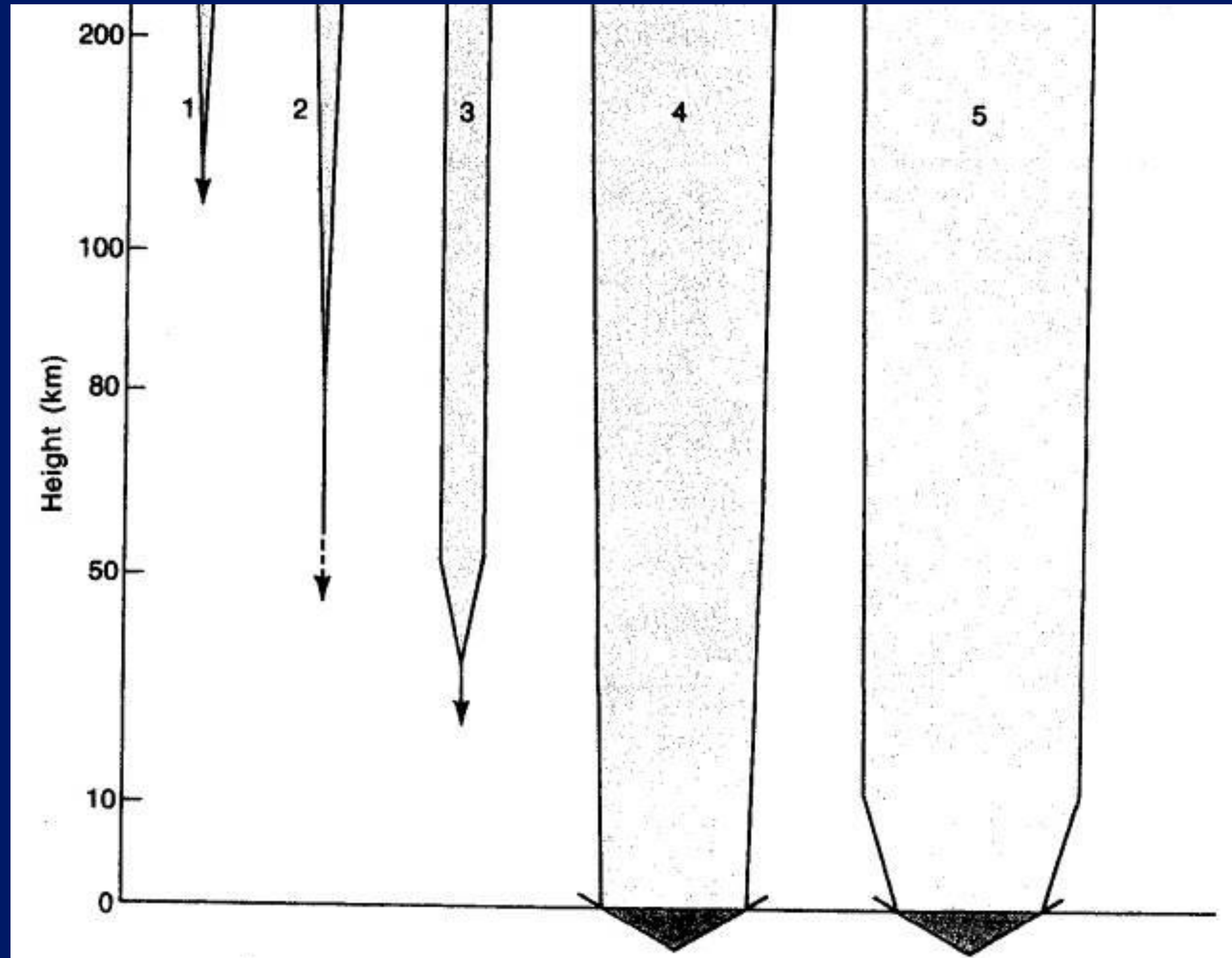
Some SW radiation gets ABSORBED on its way down to the surface! →

Add this point to the FIGURE➔ on the Bottom of p 29



Q➔ WHAT IS DOING THE ABSORBING of SW?

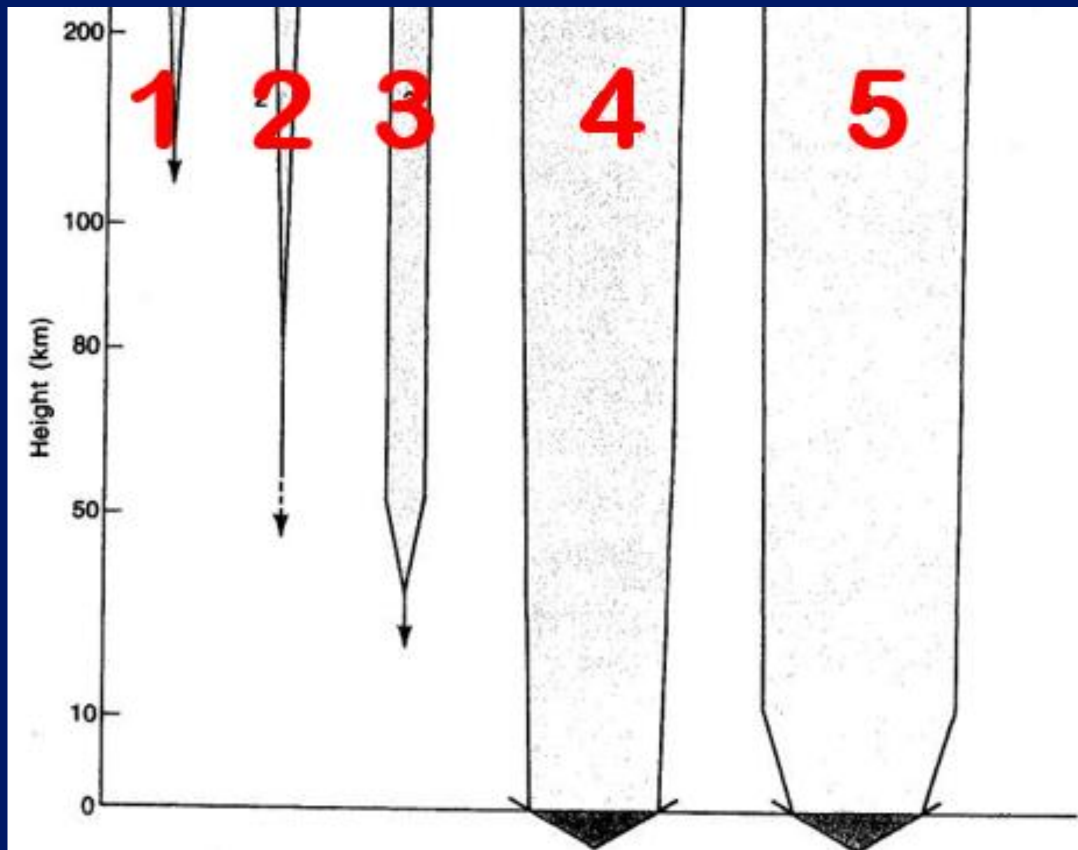
How **incoming SOLAR radiation** of different wavelengths gets <u>EITHER</u> **TRANSMITTED** <u>OR</u> **ABSORBED** by different gases on its way to the Earth's surface



1. UV, $\lambda < 0.12$ µm, absorbed by N_2 and O_2 in upper atmosphere
2. UV, 0.12 µm $\leq \lambda < 0.18$ µm absorbed by O_2
3. UV, 0.18 µm $\leq \lambda < 0.34$, µm absorbed by O_3 in ozone layer
4. Near UV and visible, 0.34 µm $\leq \lambda < 0.7$ µm transmitted nearly undiminished except for scattering
5. Near IR, 0.7 µm $\leq \lambda < 3.0$ µm , absorbed slightly by O_2 and in troposphere by H_2O

Reminder: ***Ultraviolet radiation:*** *UVC = 0.20 - 0.29* *UVB = 0.29 - 0.32* *UVA = 0.32 - 0.40* µm

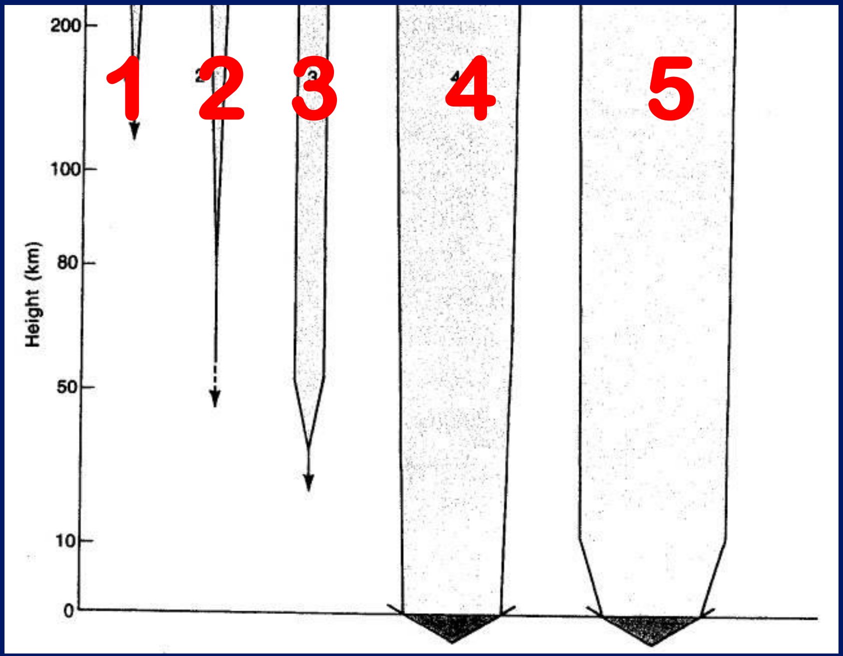
1. UV < 0.12 μm
2. UV 0.12 – 0.18 μm
3. UVC + UVB 0.18 – 0.34 μm
4. Near UVA & Vis 0.34 – 0. μm
5. Near IR 0.7 – 3.0 μm



p 32

Q 1. **The GREATEST amount of incoming solar energy (represented by the width of the arrows) is transferred to Earth via which wavelengths of electromagnetic radiation?**

1. UV < 0.12 μm
2. UV 0.12 – 0.18 μm
3. UVC + UVB
4. BOTH arrow s 4 + 5



Q. The GREATEST amount of incoming solar energy (represented by the width of the arrows) is transferred to Earth via which wavelengths of electromagnetic radiation?

1. UV < 0.12 μm
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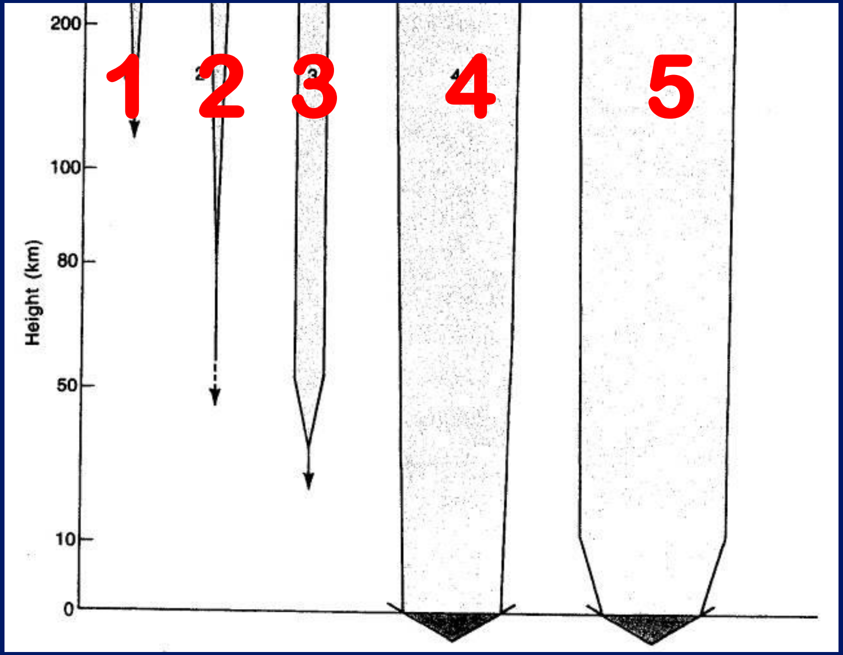
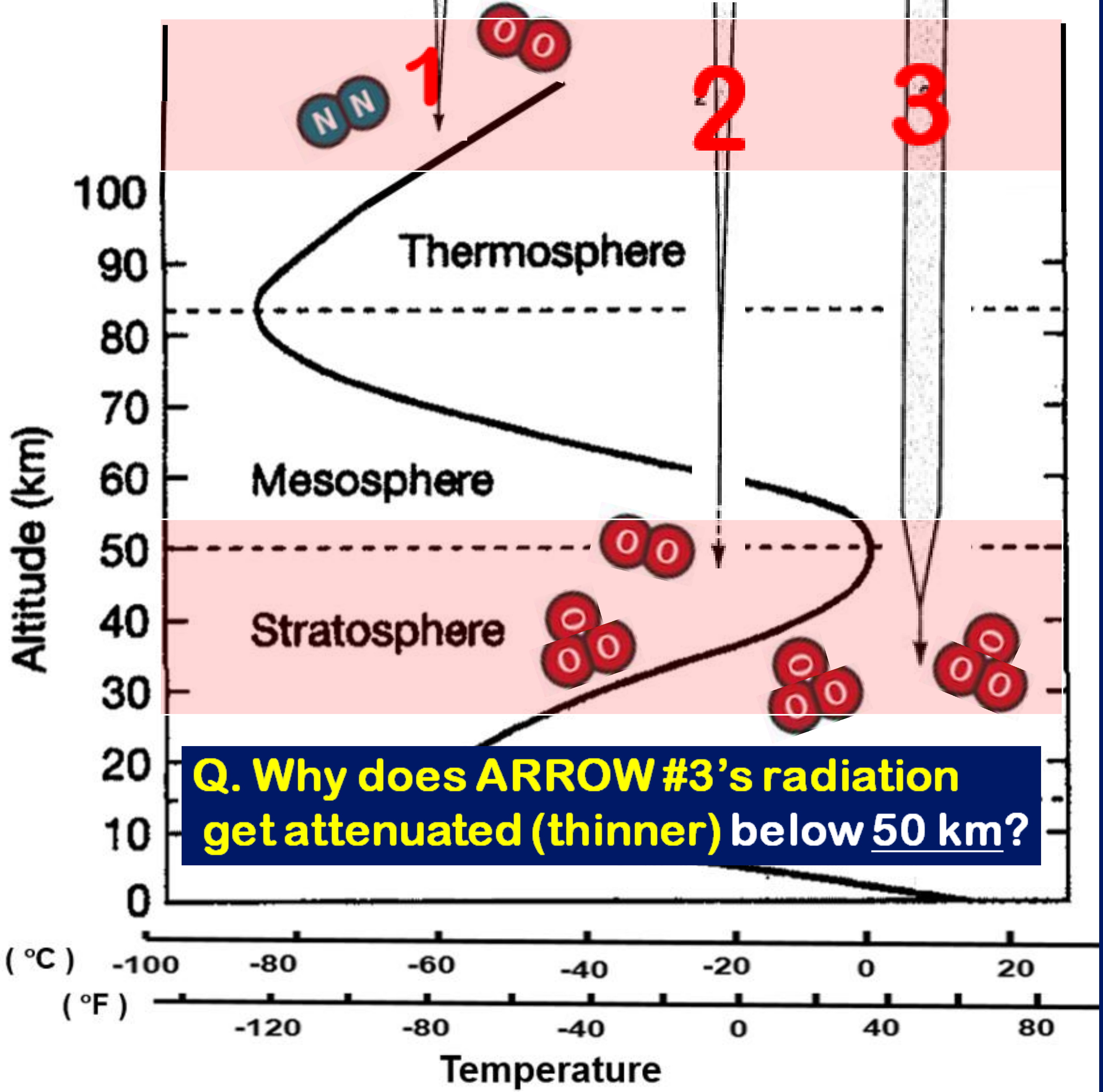


UV
< .12
µm

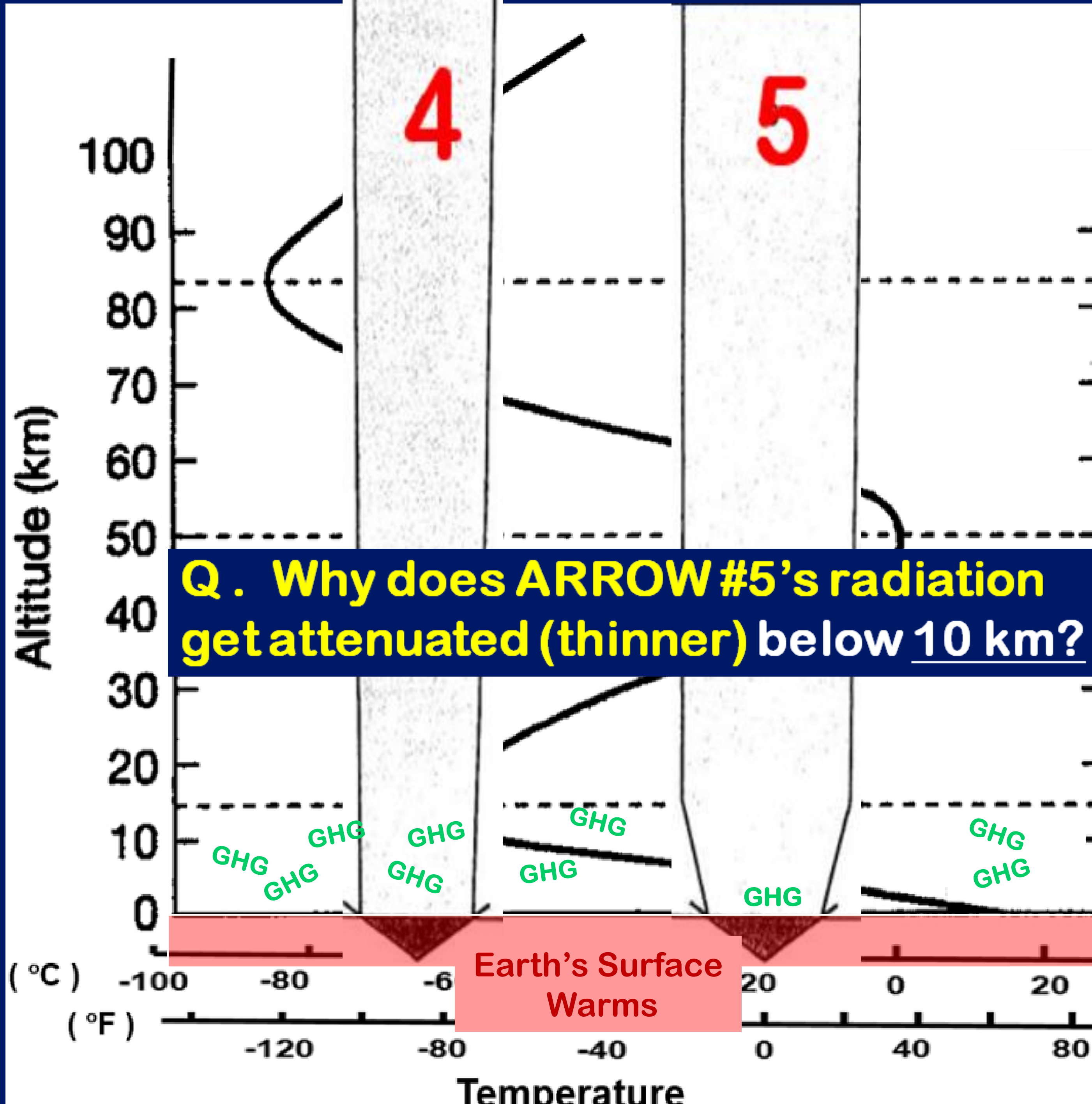
UV
.12 to
.18
µm



UVC
+
UVB

UVA
+
Vis

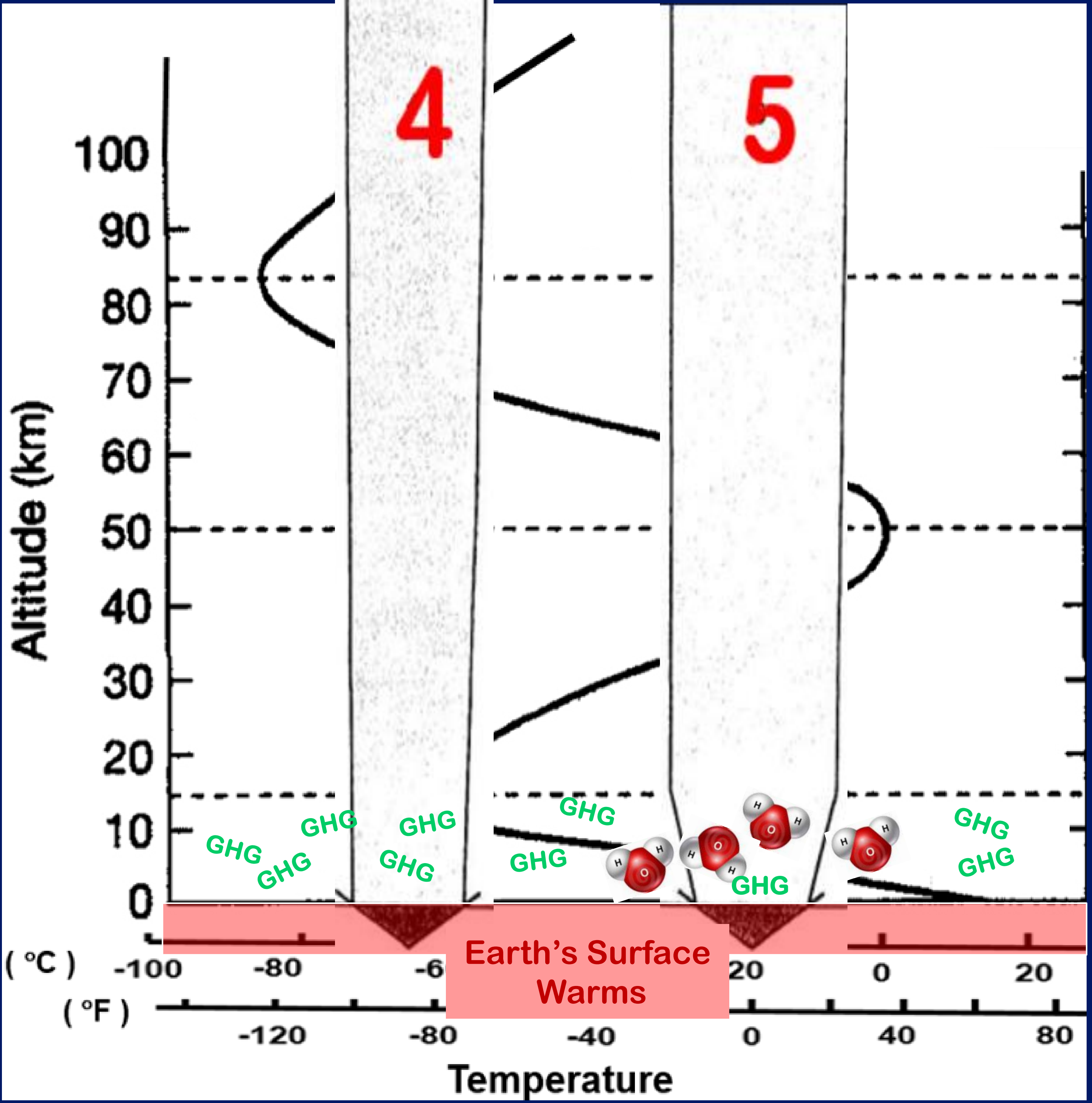
Near
IR



Q. Why does ARROW #5's radiation get attenuated (thinner) below 10 km?

UVA
+
Vis

Near
IR



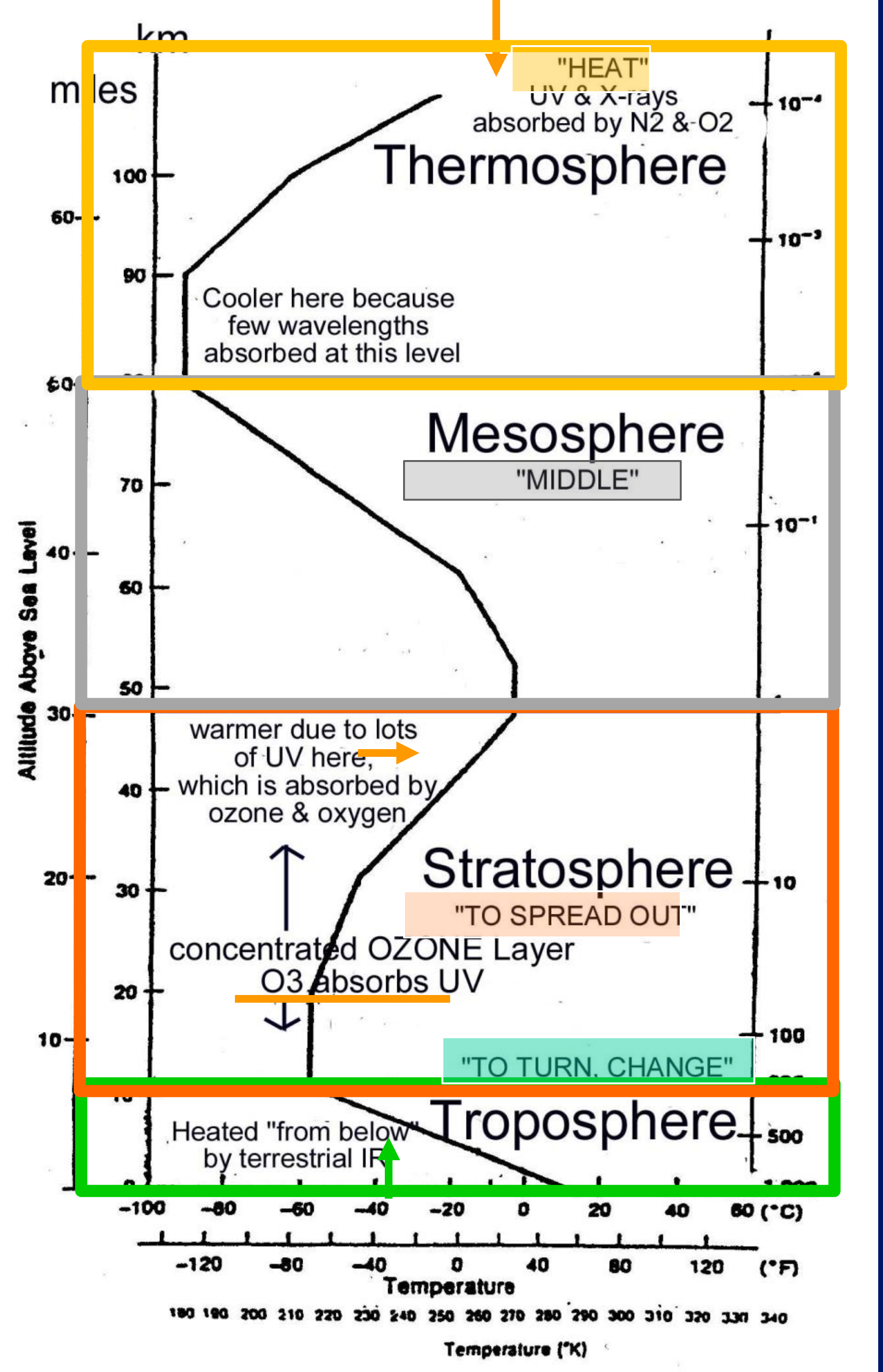
VERTICAL STRUCTURE OF THE ATMOSPHERE:

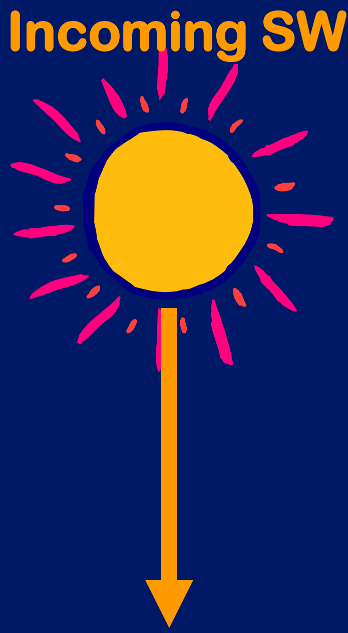
The layers are defined by TEMPERATURE TRENDS:
- cooler with increasing height

or

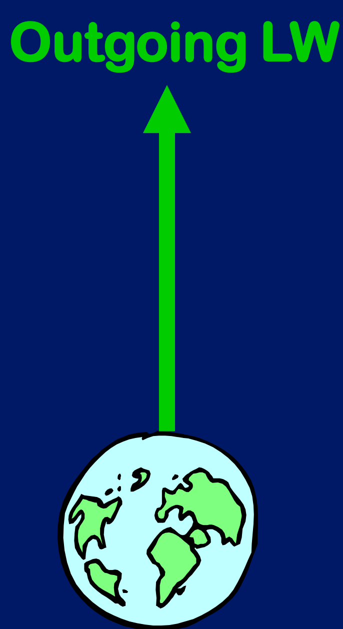
- warmer with increasing height

The temperature trends are caused by differential **ABSORPTION** of different wavelengths by gases at different altitudes





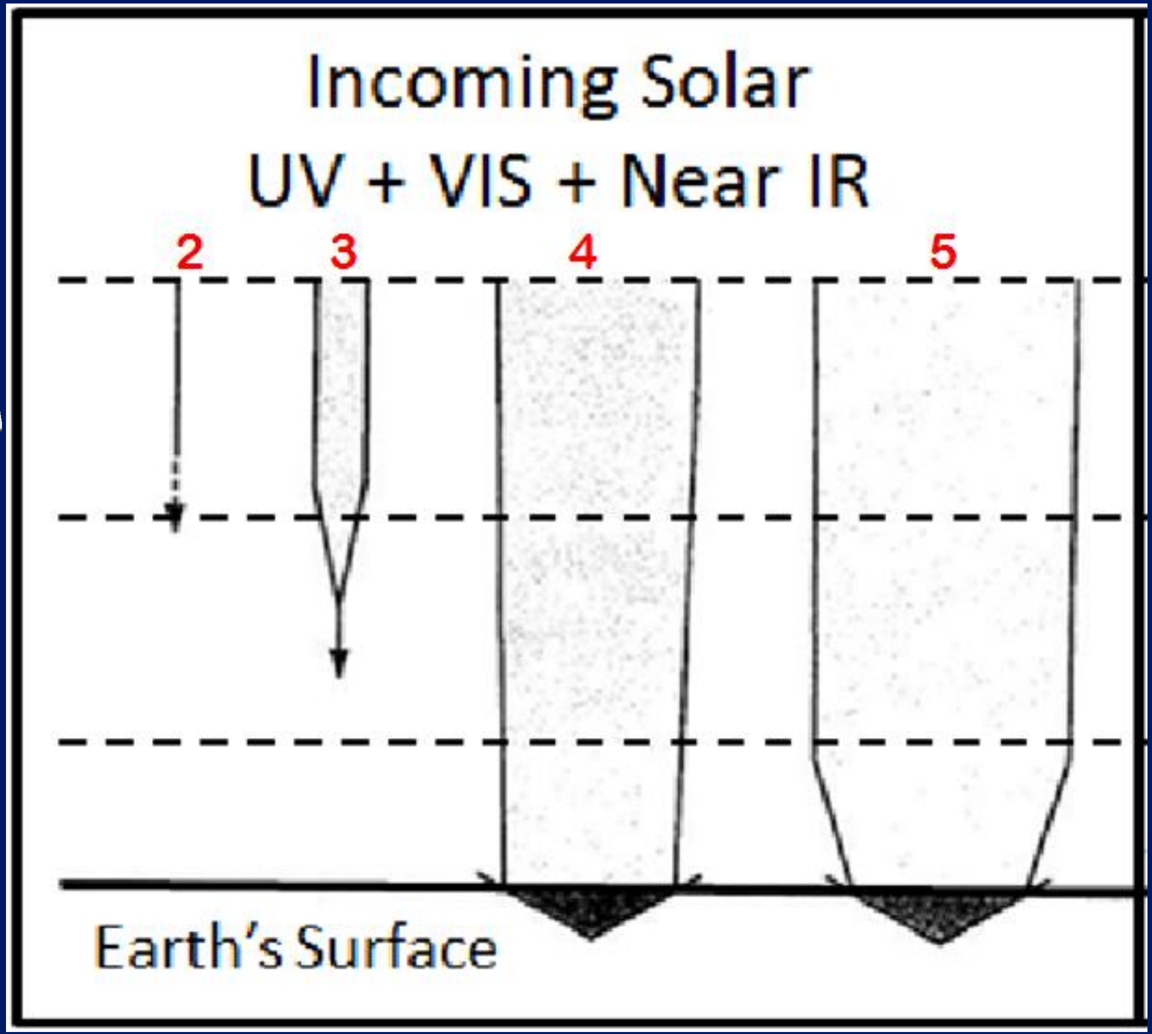
OK – so that explains what happens in different layers of the atmosphere to the **INCOMING SOLAR Shortwave (SW)** on its way down to the Earth's surface . . . .



. . . But what happens to the **OUTGOING TERRESTRIAL Longwave (IR)** radiation when it radiates from the Earth's surface upwards??

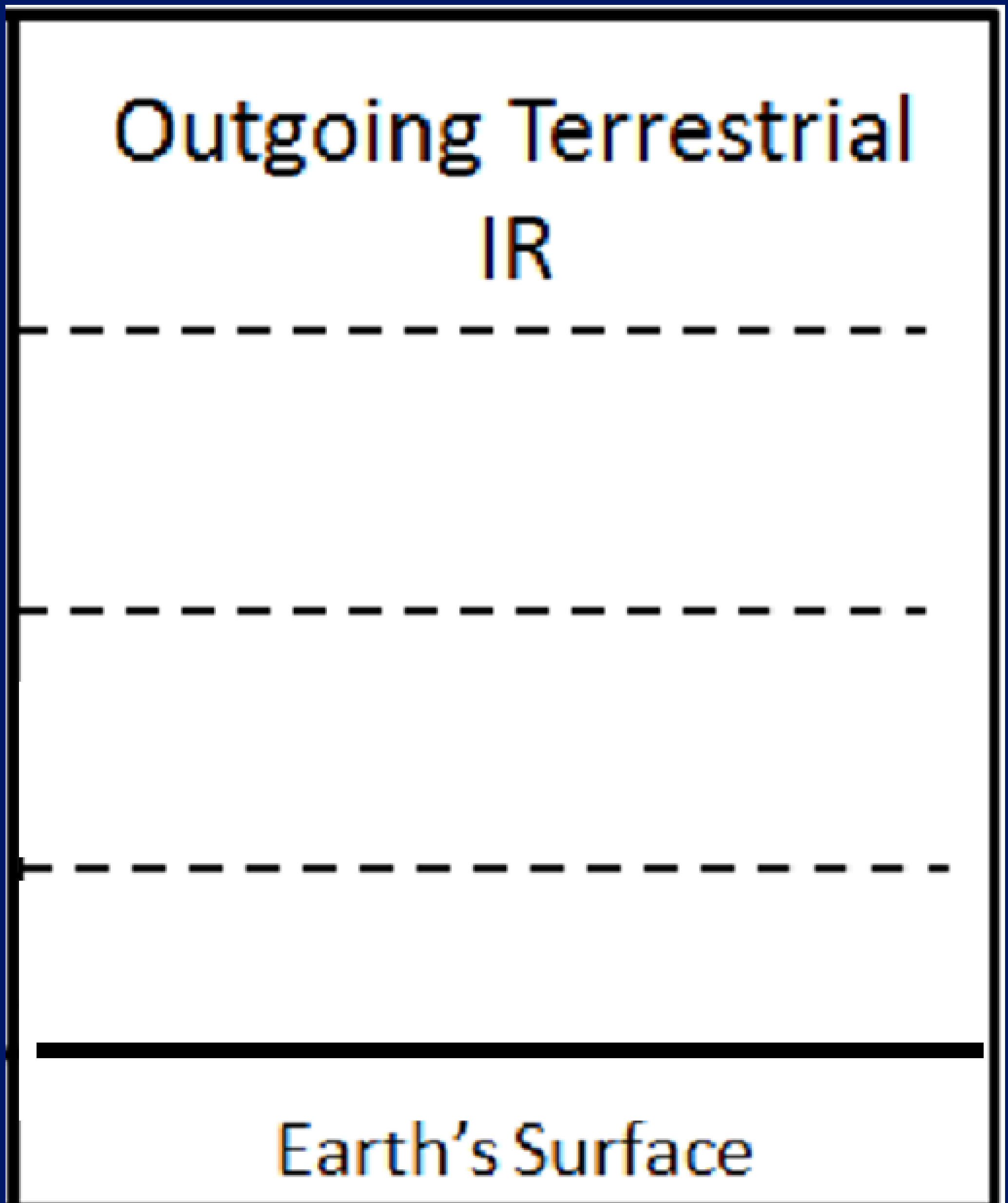
CLASS NOTES CLOSED!!!

Write in the names of the layers:



CLASS NOTES CLOSED!!!

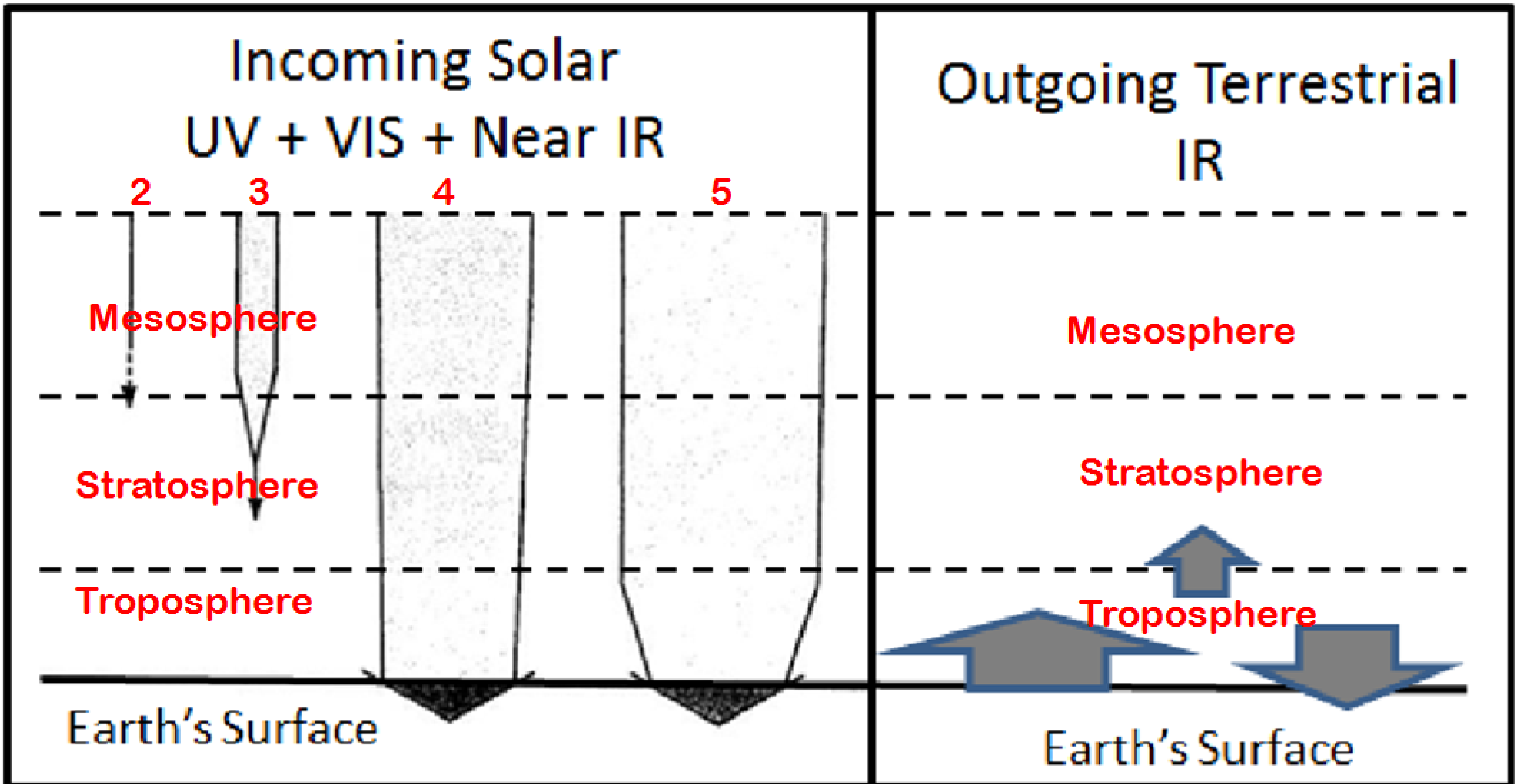
Take a stab at
DRAWING in ARROWS (of appropriate width)
for the OUTGOING TERRESTRIAL IR (including the GHE)



DISCUSS IN YOUR GROUPS:

WHY IS THE STRATOSPHERE SO COLD?

(esp the lower stratosphere, below the ozone absorption layer)

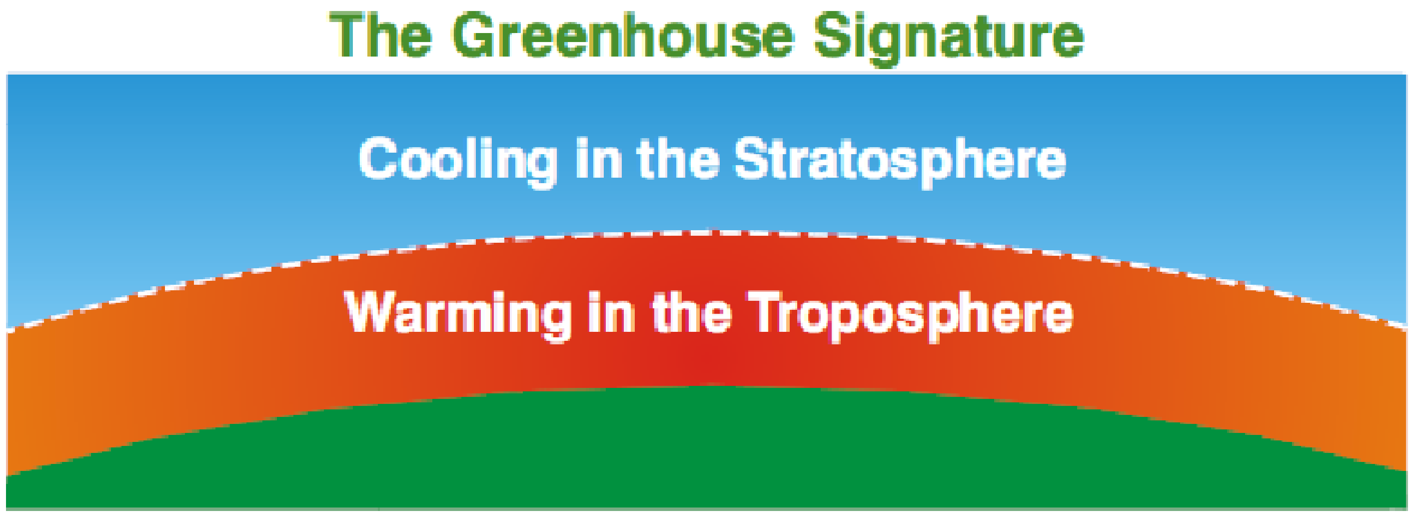


Remember: "THE ATMOSPHERE IS HEATED FROM BELOW"

EXPLORING THE EVIDENCE . . .

The Greenhouse Warming Signature:
"Increasing CO2 warms the Troposphere and cools the Stratosphere"

The "Greenhouse Effect" Warming Signature



What would a SOLAR Warming Signature look like?

ATMOSPHERIC COMPOSITION

Which gases?
What concentration?
Which ones are
Greenhouse Gases (GHG)?
Where do the GHG's come from?

Which GHG's are changing in concentration due to HUMAN ACTIVITIES?

Quick SKIM of the Tables on
Pages 33 & 34
to familiarize yourself with each of the GHG's

Then get ready for the
"NAME THAT GAS!"
Team Competition!

ATMOSPHERIC COMPOSITION

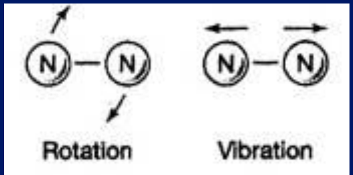
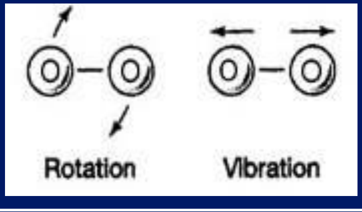
*** = Greenhouse Gas (GHG)** **RF = Radiative Forcing of GHG's in Wm^{-1}**

Gas	Symbol	Percent Concentration (by volume dry air)	Concentration in Parts per Million (ppm)	*RF W/m^2
Nitrogen	N_2	78.08	780,800	
Oxygen	O_2	20.95	209,500	
Argon	Ar	0.93	9,300	
* **Water Vapor**	H_2O	0.00001 *(South Pole)* – 4 *(Tropics)*	0.1 *(South Pole)* – 40,000 *(Tropics)*	*varies*
* **Carbon Dioxide**	CO_2	0.0390+ (*2009*) http://co2now.org/	390+ (*2010*) http://co2now.org/	1.66
* **Methane**	CH_4	0.0001774 *(in 2005)*	1.774	0.48
* **Nitrous Oxide**	N_2O	0.0000319	0.319	0.16
* **Ozone**	O_3	0.0000004 *(in 70s)*	0.01 *(at the surface)*	*varies*
* **CFCs** (e.g. Freon-12) (Chlorofluorocarbons)	CCl_2F_2	0.0000000538	0.000538 *RF for all CFC Totals:*	0.170 0.268
* **HCFCs** (e.g., HCFC-22) (Hydrochlorofluorocarbons)	$CHClF_2$	0.0000000169	0.000169 *RF for all HCFC Totals:*	0.033 0.039
Neon, Helium, Hydrogen, Krypton, Xenon	Ne, He, H, Kr, Xe	0.0018 – 0.000009	18 – 0.09	
Particles (dust, soot)	--	0.000001	0.0001	

For more on GHG concentrations see: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf Table 2.1

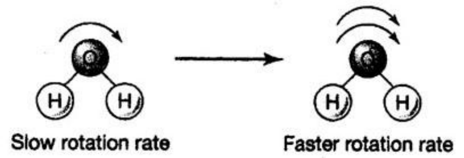
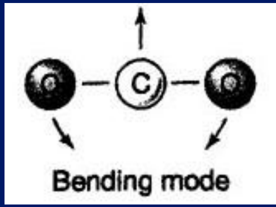
Top of p 33

Most Abundant Gases in the Atmosphere

GAS	Symbol	% by volume	% in ppm
Nitrogen 	N_2	78.08	780,000
Oxygen 	O_2	20.95	209,500
Argon	Ar	0.93	9,300

Total = 99.96%

Next Most Abundant Gases:

GAS	Sym bol	% by volume	% in ppm
Water Vapor 	H_2O	0.00001 (South Pole) to 4.0 (Tropics)	0.1 - 40,000
Carbon Dioxide 	CO_2	0.0390 (and rising!)	360 (in 1997) **390 !** (in May 2009)

Greenhouse Gases !

Other Important Greenhouse Gases:

GAS	Symbol	% by volume	% in ppm
Methane	CH_4	0.00017	1.7
Nitrous Oxide	N_2O	0.00003	0.3
Ozone	O_3	0.0000004	0.01
CFCs (Freon-11)	CCl_3F	0.000000026	0.00026
CFCs (Freon-12)	CCl_2F_2	0.000000047	0.00047

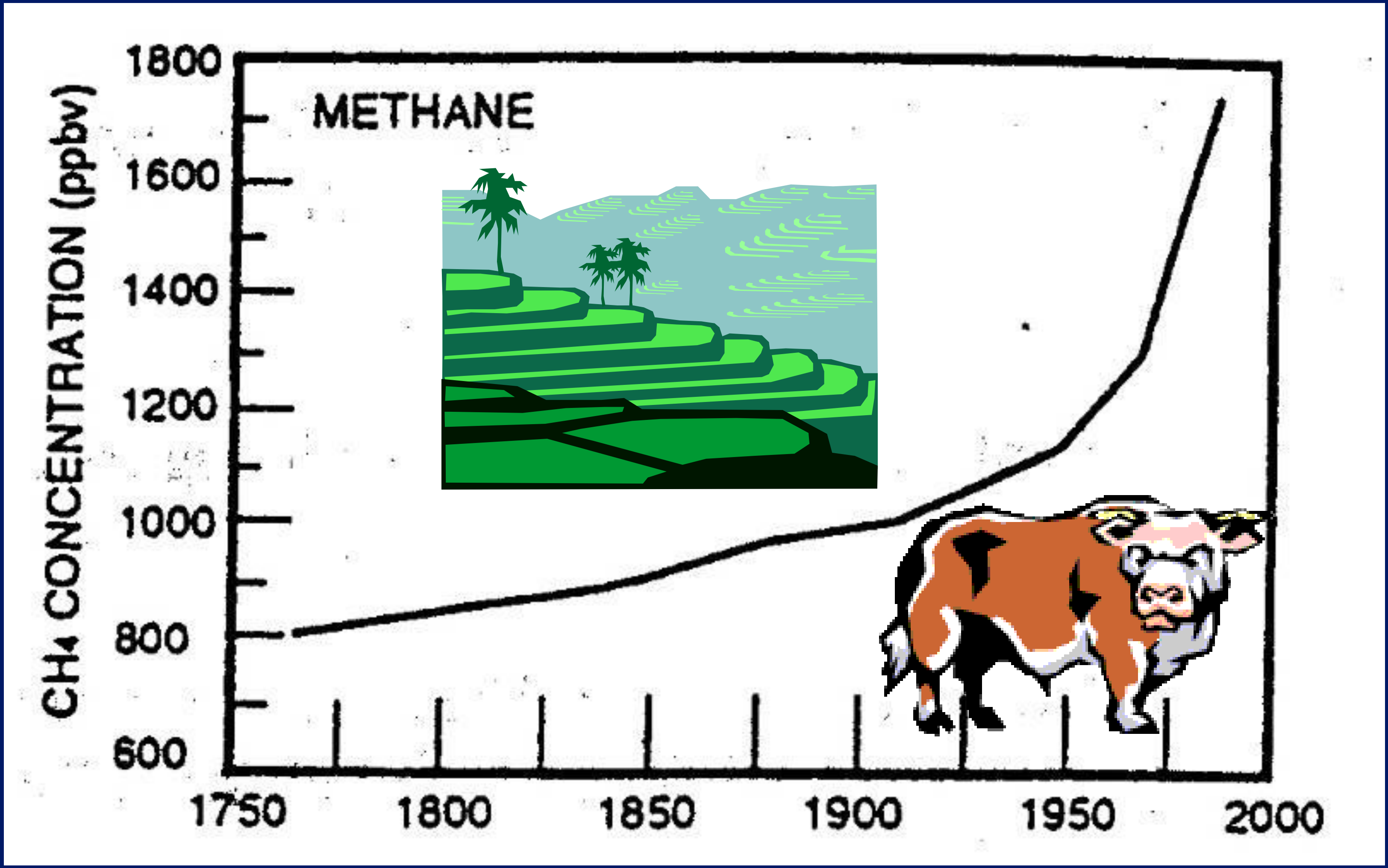
Greenhouse Gases!

Infrared Radiators GROUPS:
1, # 2, #3, #4, #5

Name that GAS!!!

MYSTERY
GHG # 1

METHANE: Trends



METHANE (CH_4):
Sources

* Produced naturally in anaerobic processes (e.g., decomposition of plant material in swamps & bogs)

* Has increased due to the following activities: raising cattle / livestock, rice production, landfill decomposition, pipeline leaks

* Has relatively short atmospheric residence time because it reacts with OH (~10 years)

☺ Table on p 34

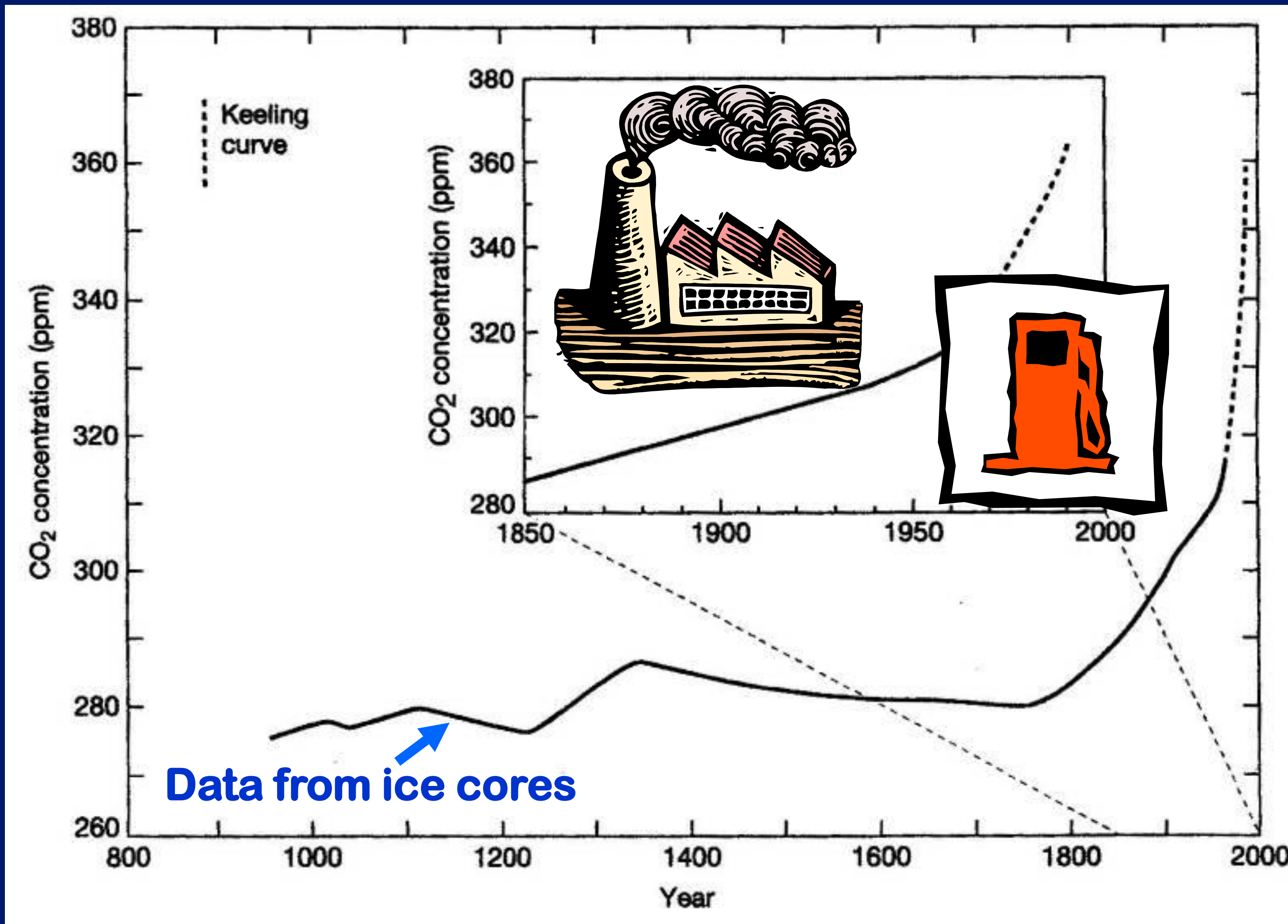
Tangerine Tazers

GROUPS: # 6, 7, 8, 9, 10

Name that GAS!!!

MYSTERY
GHG #2

CARBON DIOXIDE: Trends



CARBON DIOXIDE :

* Arrives in atmosphere naturally through the natural carbon cycle

* Has increased dramatically since the 1800s due to:

FOSSIL FUEL COMBUSTION:

oil, coal, gas (automobiles) . . .
But especially **COAL**

☺ Table on p 34

CARBON DIOXIDE (cont.):

* **RESIDENCE TIME** in the atmosphere of CARBON ATOMS in the carbon cycle = ~ 12.7 years;

but residence time of CO_2 GAS MOLECULES is estimated at about 100 years

Plus it takes 50 to 100 years for atmospheric CO_2 to adjust to changes in sources or sinks.

If we make changes now, it will still be many, many years before the effect will be felt!

☺ Table on p 34

Mellow Yellow Reflectors

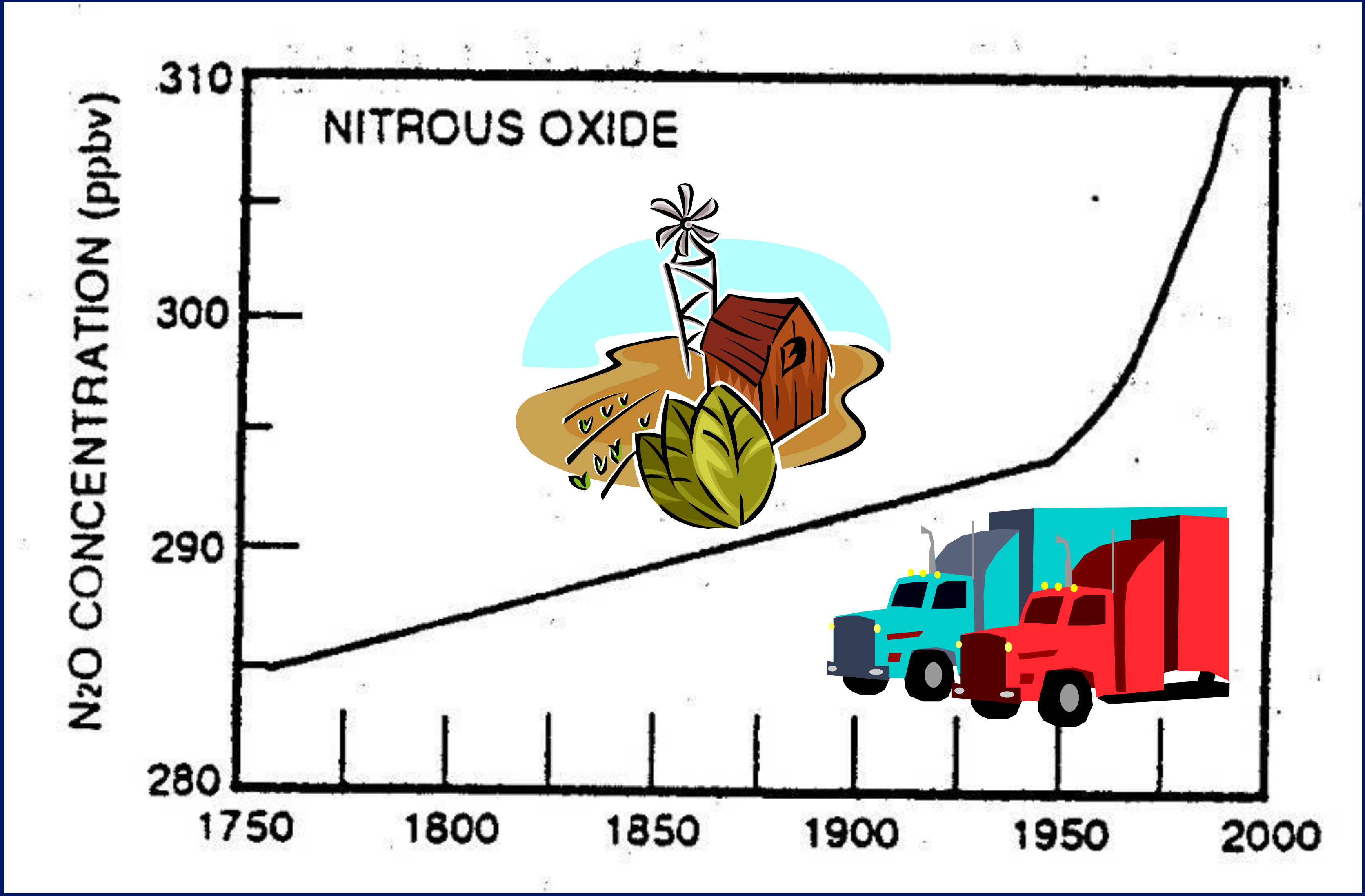
GROUPS: # 11, 12, 13, 14, 15

Name that GAS!!!

MYSTERY

GHG # 3

NITROUS OXIDE: Trends



NITROUS OXIDE (N_2O): Sources

* Produced naturally in soils

* Has increased due to fossil fuel combustion (esp. diesel), forest burning, use of nitrogen fertilizers

* Has long atmospheric residence time (~ 150 years)

☺ Table on p 34

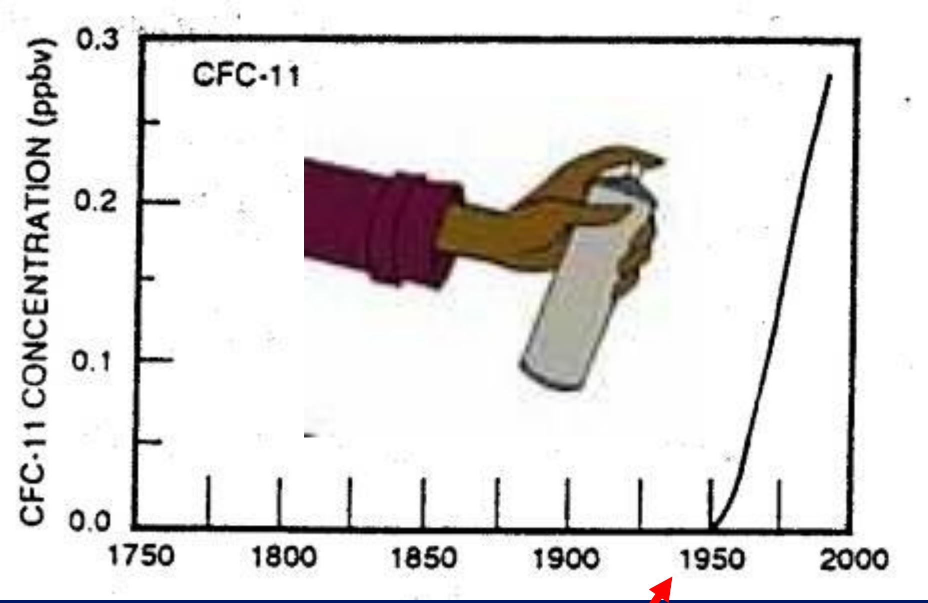
Greenhouse Gassers

GROUPS #16, 17, 18, 19, 20

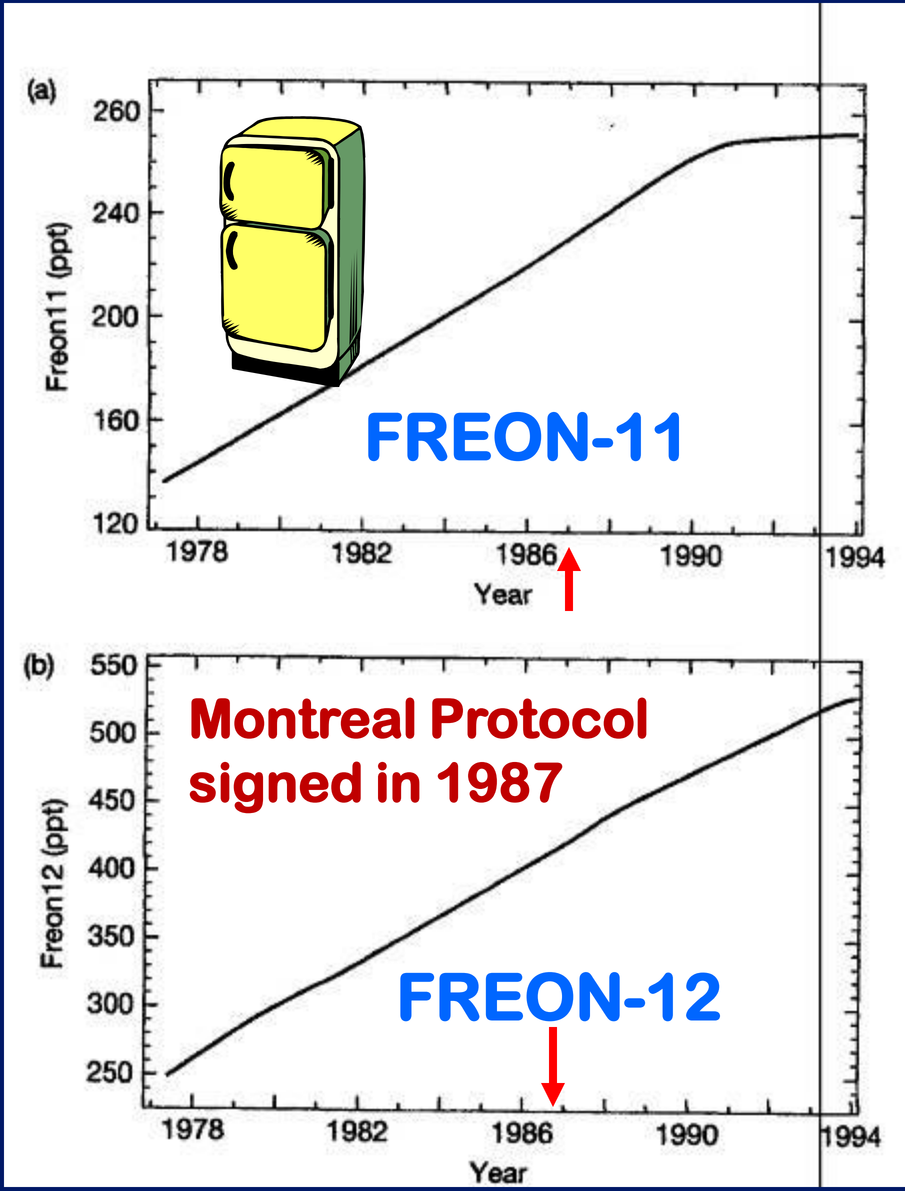
Name that GAS!!!

MYSTERY
GHG # 4

CFCs: Trends



Human-made -- didn't exist before 1950!



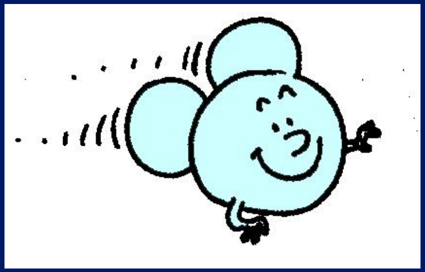
☺

Blue Sky Diffusers

GROUPS: # 21, 22, 23, 24, 25

Name that GAS!!!

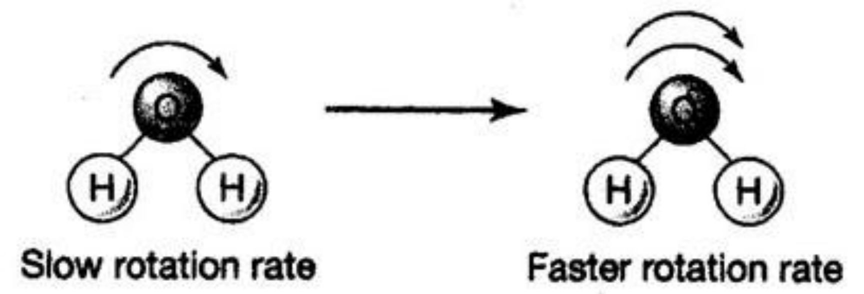
MYSTERY GHG # 6



WATER VAPOR

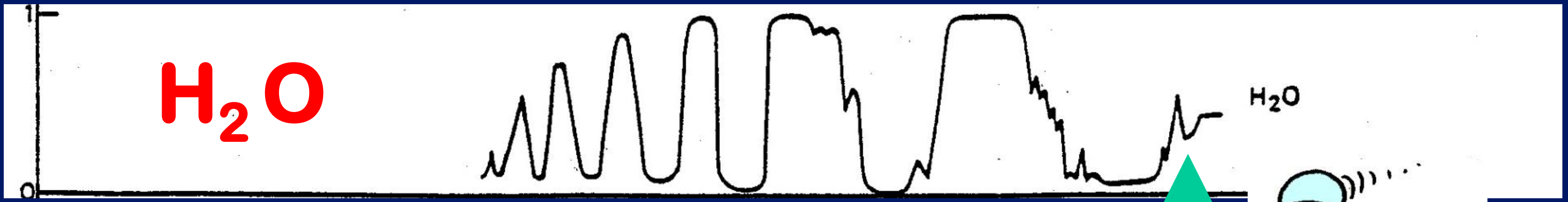
* Arrives in atmosphere naturally through evaporation & transpiration

* Due to unique quantum rotation frequency, H_2O molecules are excellent absorbers of IR wavelengths of **12 μm and longer**;

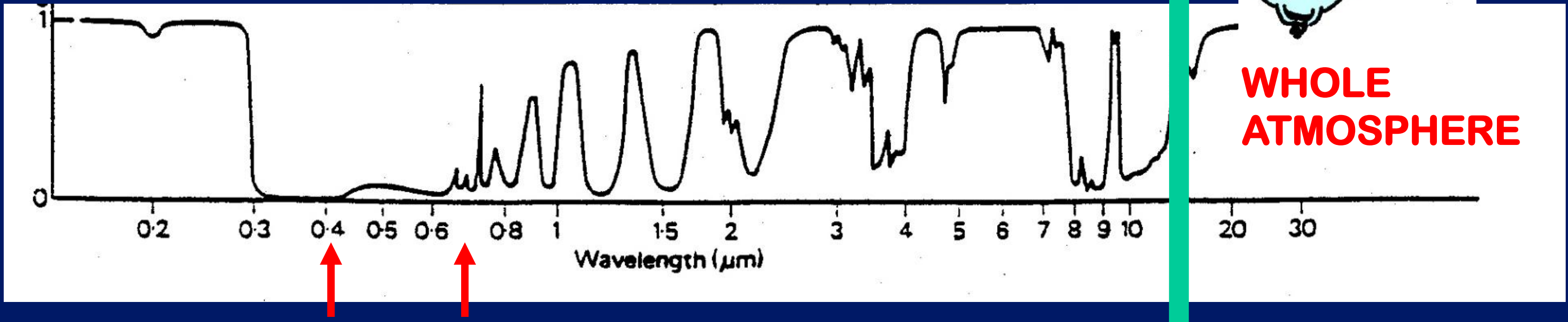


GAS Table on p 34

Virtually 100% of IR longer than 12 μm is absorbed by H_2O vapor and CO_2



Graphs on p 38 Class Notes



IR at 12 μm absorbed

(12 μm close to the radiation wavelength of 10 μm, at which most of Earth's terrestrial radiation is emitted.)

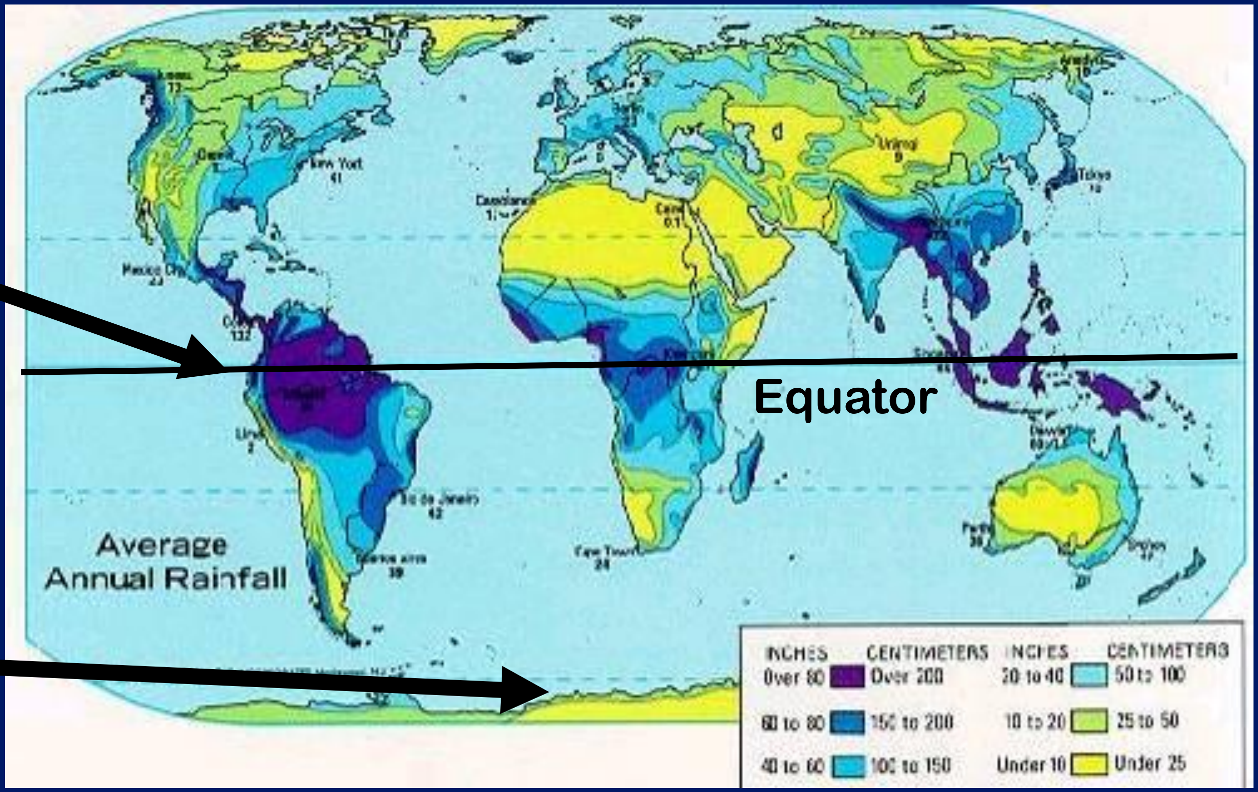
☺

WATER VAPOR (cont):

* H_2O has variable concentration and residence time in the atmosphere depending on location and atmospheric circulation

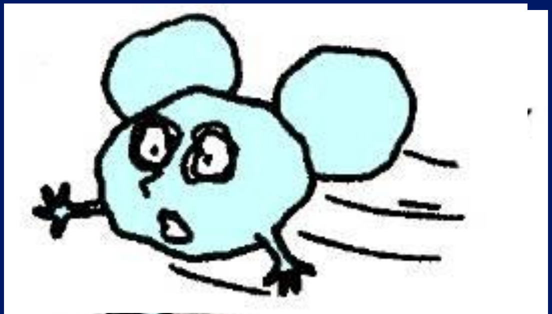
Blue = wettest climates, lots of humidity & water vapor

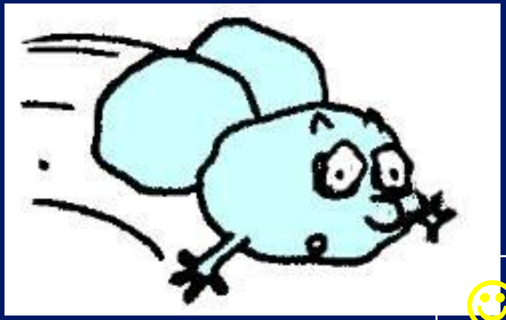
Yellow = driest climates, less atmospheric water vapor



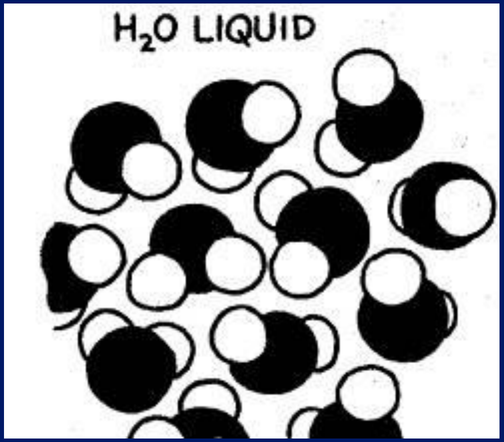
At higher air temperatures, H_2O molecules collide & rebound more frequently, leading to expansion of the air & the water vapor in the air.

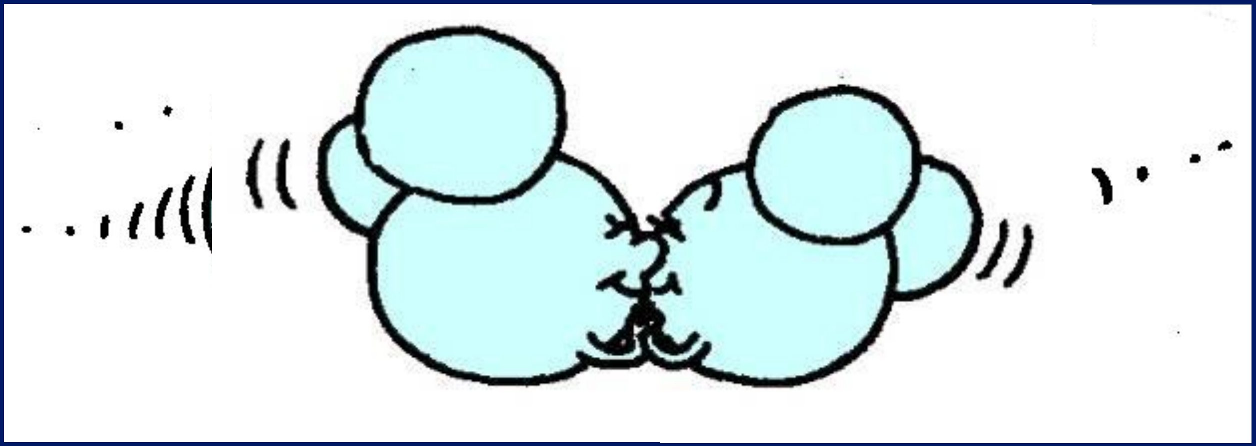
Hence hot climates can hold more water vapor in the air





At lower air temperatures as air gets more dense, H_2O molecules are more likely to bond so that a phase change to liquid water or even solid ice can occur.





Hence in cooler climates, more of the available H_2O is likely to be in the liquid or solid state on the Earth's surface

☺

WATER VAPOR (cont):

* H_2O is **NOT** globally increasing in <u>direct</u> response to human-induced factors, but if global temperatures get warmer, H_2O vapor in the atmosphere ***will* increase . . . .**

Why???

THINK ABOUT THIS!

. . . due to more evaporation in the warmer climate!

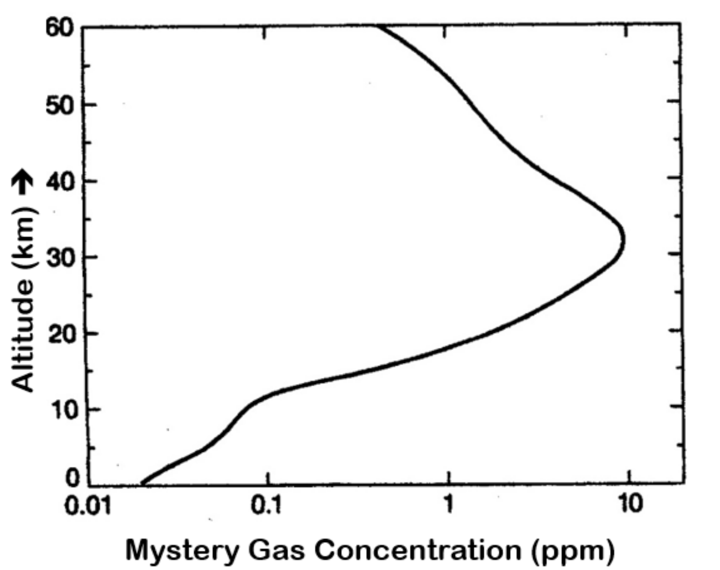
UltraViolet Zapper

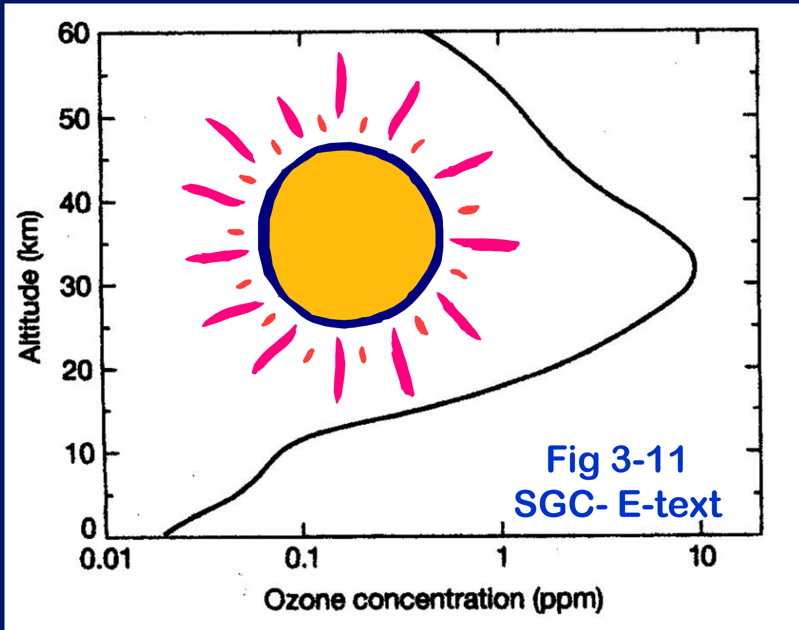
GROUPS: # 26, 27, 28

Name that GAS!!!

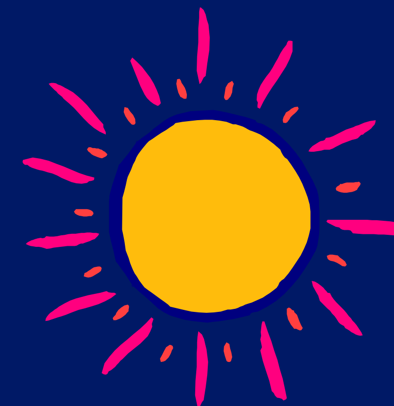
(this one's a visual hint only!)

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 34

OZONE
Time series trends

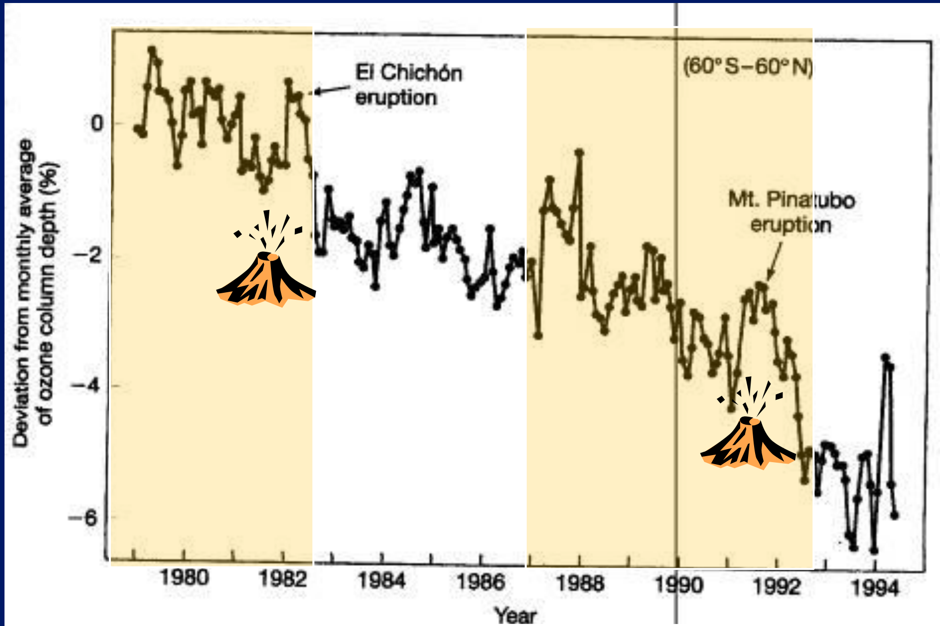
Overall, O3 is <u>decreasing</u> in the STRATOSPHERE ➔

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

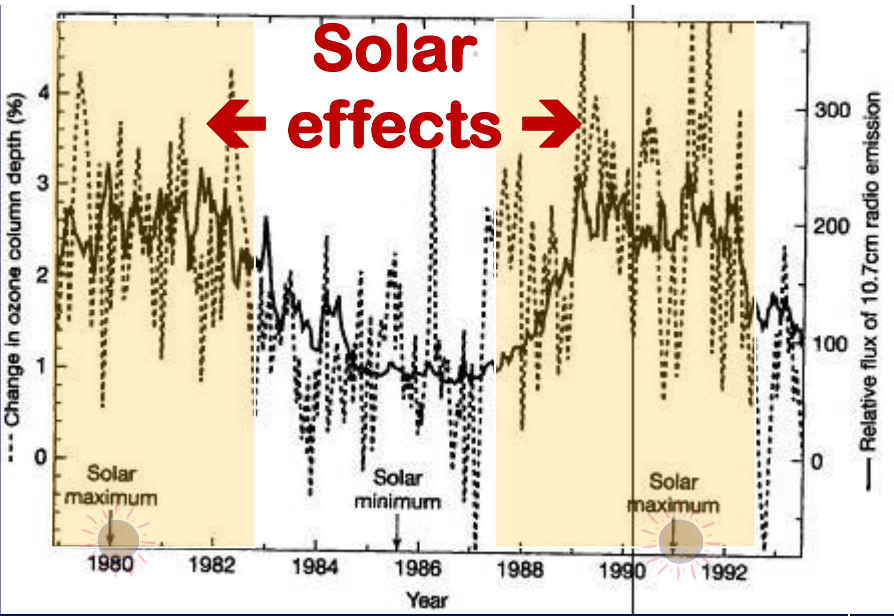
1. **SOLAR radiation**
(more sun ➔ more O3 production)

2. **VOLCANIC eruptions**

3. **Chemical reactions due to <u>CFCs</u>**



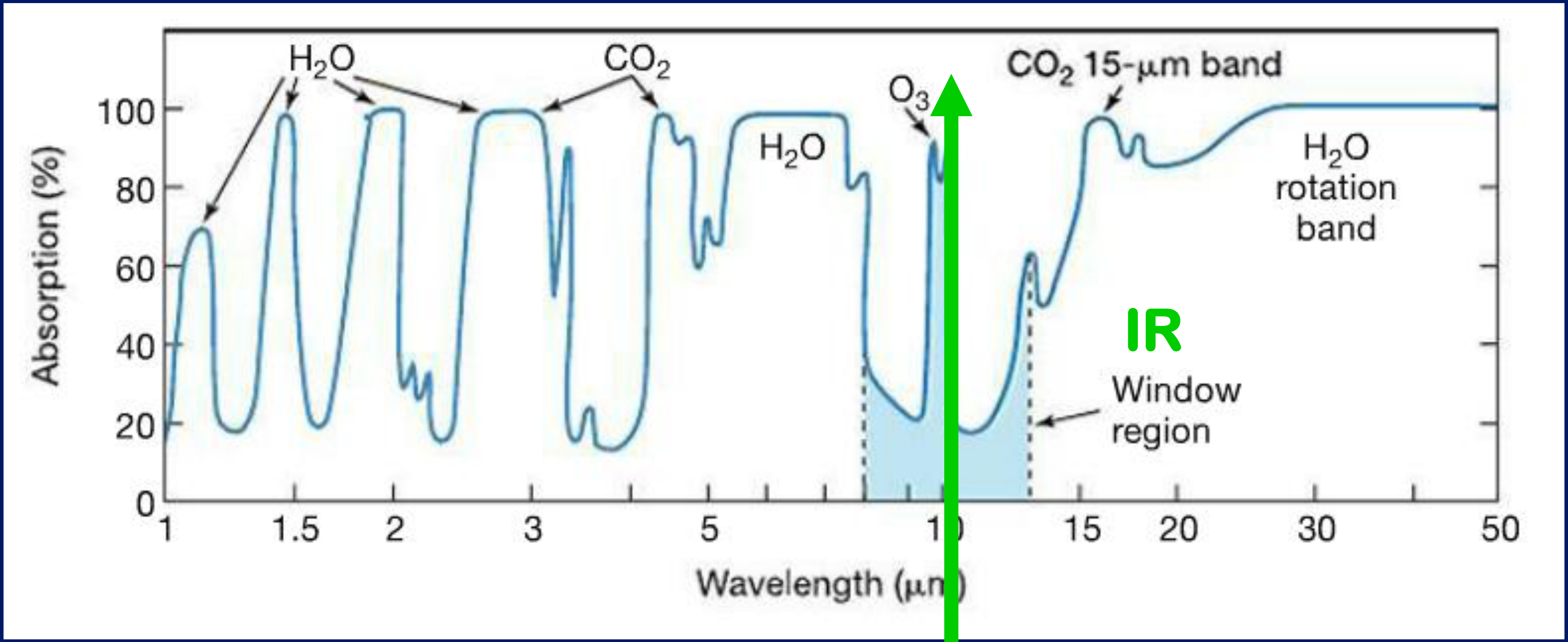
Trend in graph ↑ is removed in graph ↓ to show natural variability



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 <u>Global Warming Potential</u>

☺

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 ANTHROPOGENIC GREENHOUSE GASES

Gas	CO_2	CH_4	N_2O	CFC-11	HFC-134a	CF_4
Lifetime years	Multiple	12	121	45	13	50,000
Global warming potential of a pulse of this greenhouse gas compared to CO_2						
After 20 years	1	86	268	7,020	3,790	4,950
After100 years	1	34	298	5,350	1,550	7,350
After 500 years	1	8	153	1,620	435	11,200

"If you have an equal mass of CO_2 and CH_4, the methane will trap 86 times more heat than the carbon dioxide over the next 20 years"

See p 29 in *Dire Predictions*

☺

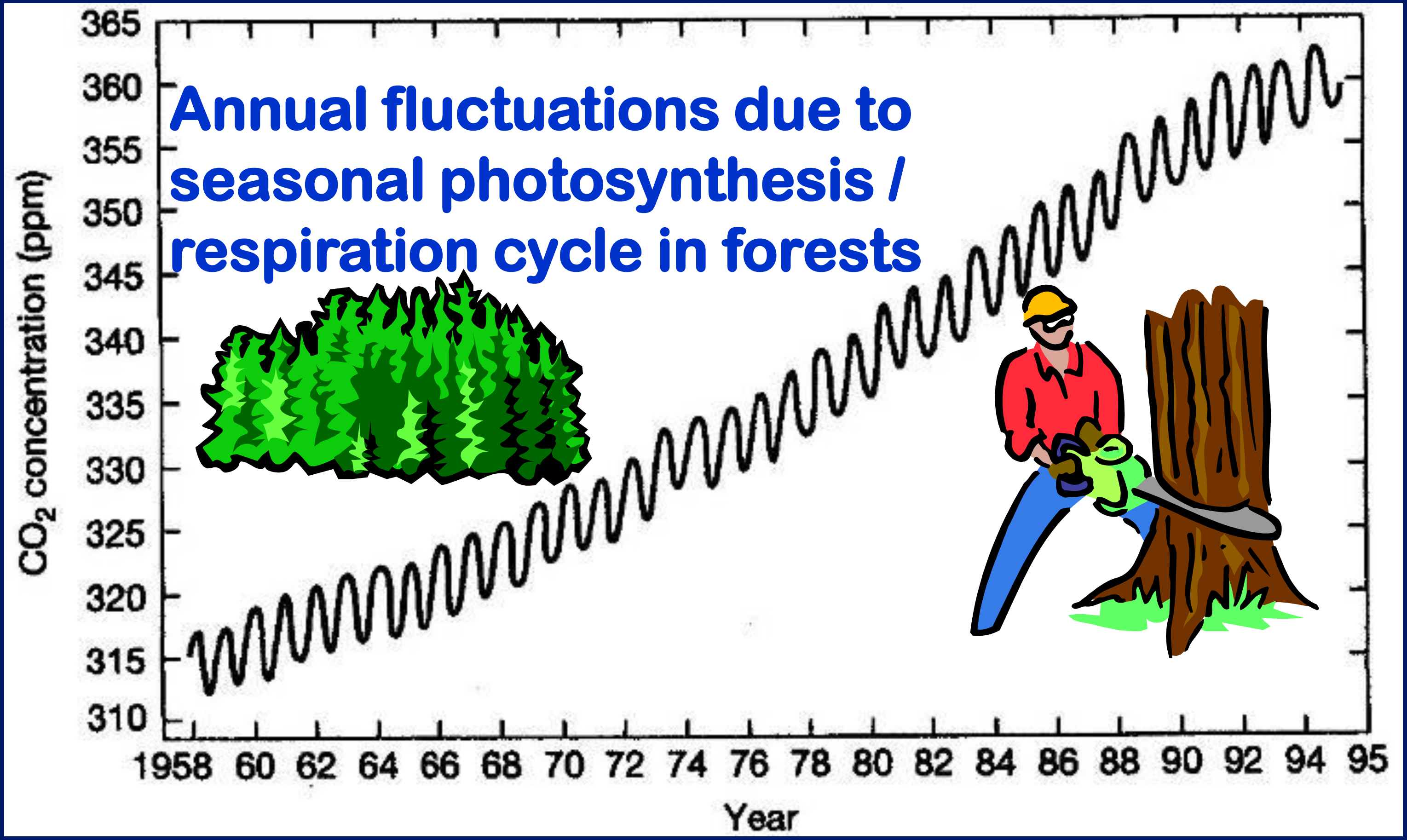
OPEN FLOOR

Name that GAS!!!

This one's a repeat of a previously guessed gas!

MYSTERY GHG #5

CARBON DIOXIDE --- Trends:



The Keeling Curve

CARBON DIOXIDE (cont.):

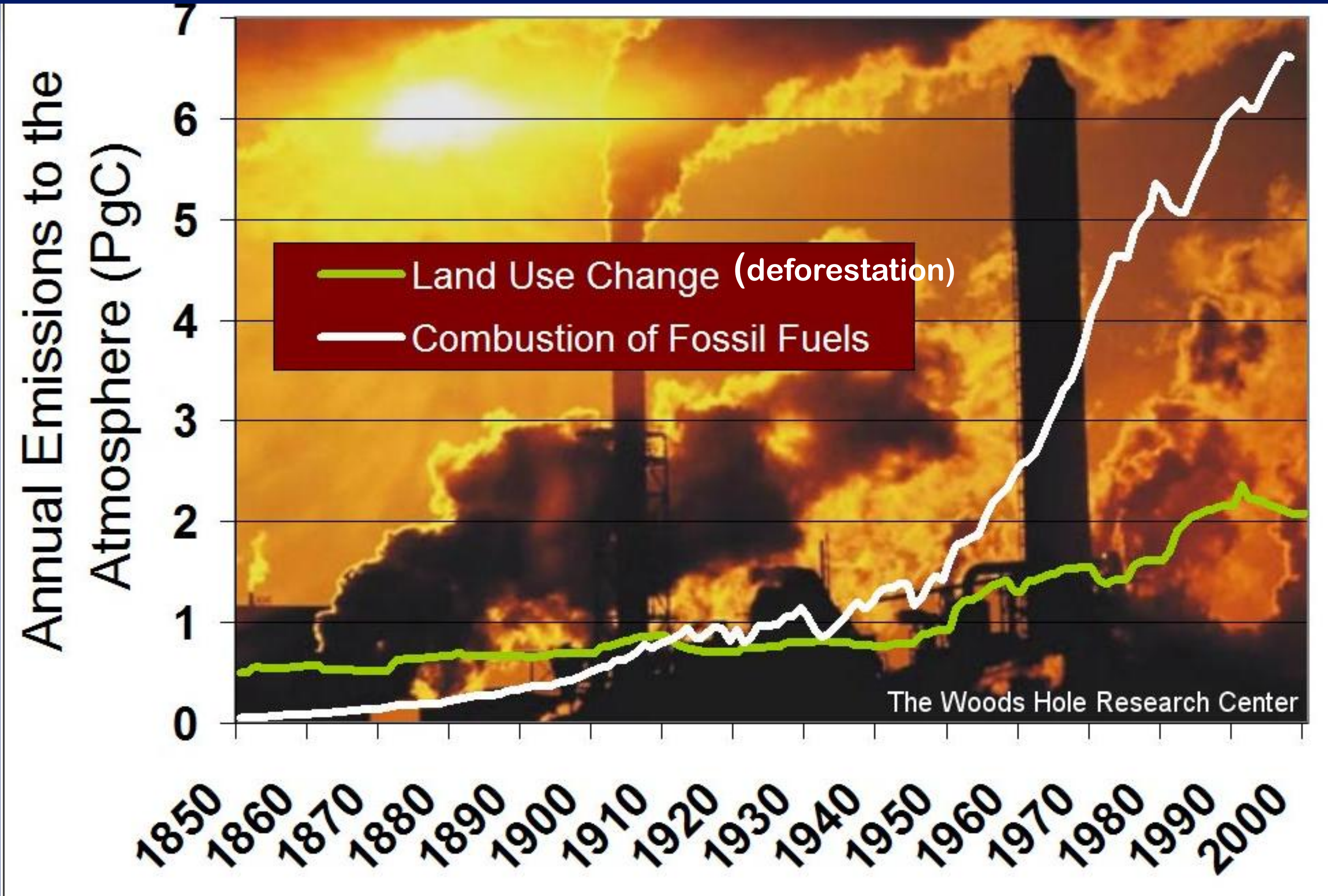
* Has increased dramatically since the 1800s due to:

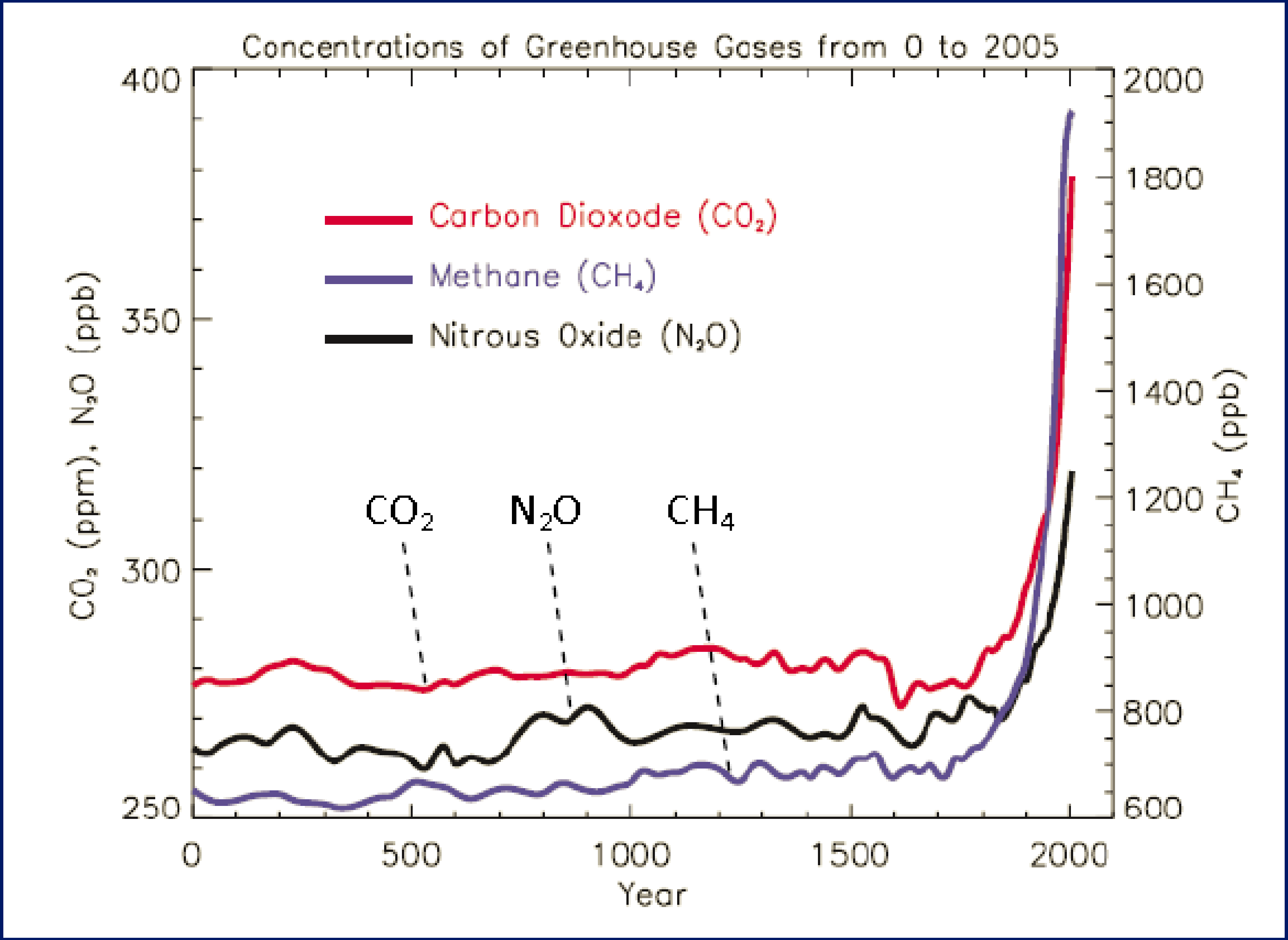
DEFORESTATION -- which has the effect of increasing the amount of carbon in the atmospheric “reservoir” by reducing the photosynthesis outflow and increasing the respiration inflow.

(Deforestation also accelerates forest decomposition, burning, etc. adding to the overall respiration inflow.)

☺ Table on p 34

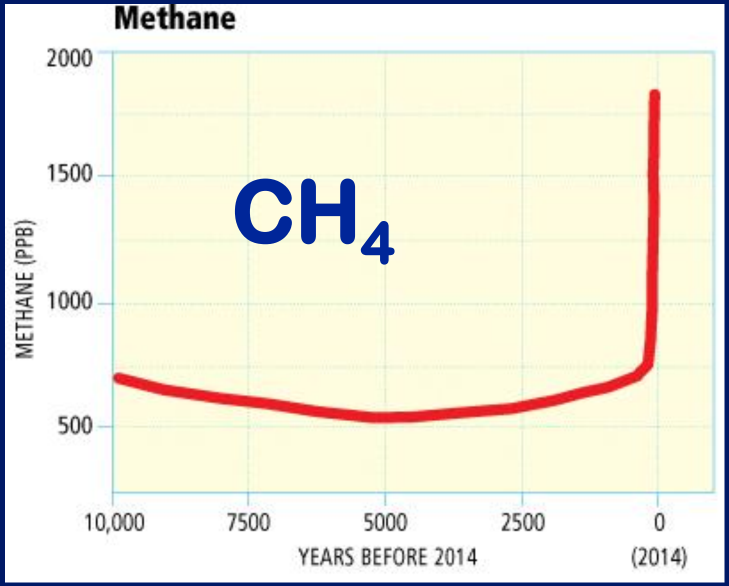
CARBON emissions into the atmosphere are increasing:

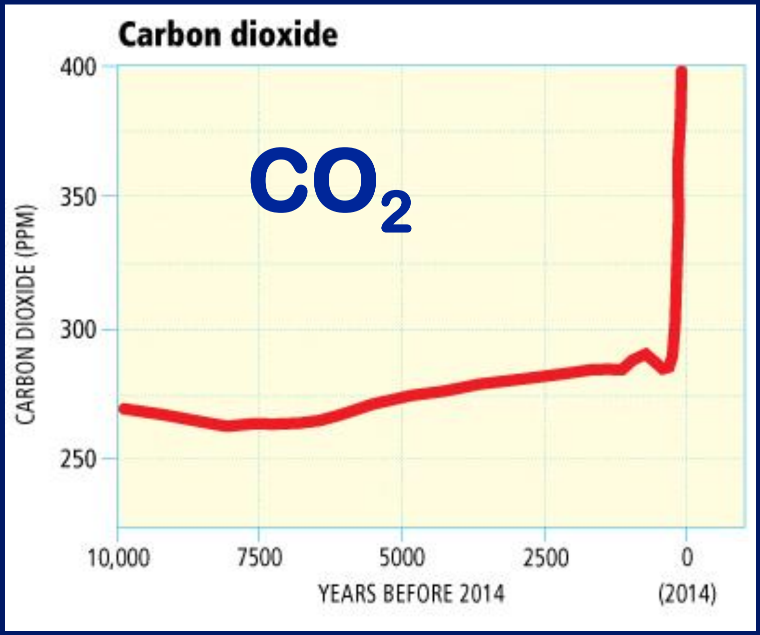


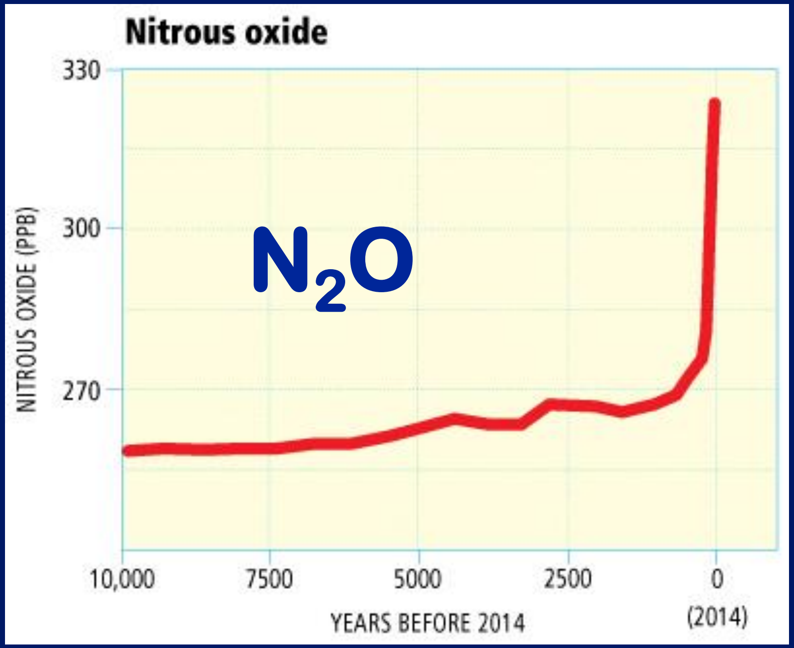


Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO_2)
Methane (CH_4)
Nitrous Oxide (N_2O)
CO_2
N_2O
CH_4
CO_2 (ppm), N_2O (ppb)
CH_4 (ppb)
Year
0
500
1000
1500
2000
250
300
350
400
600
800
1000
1200
1400
1600
1800
2000

Updated figures from **Dire Predictions** p 31

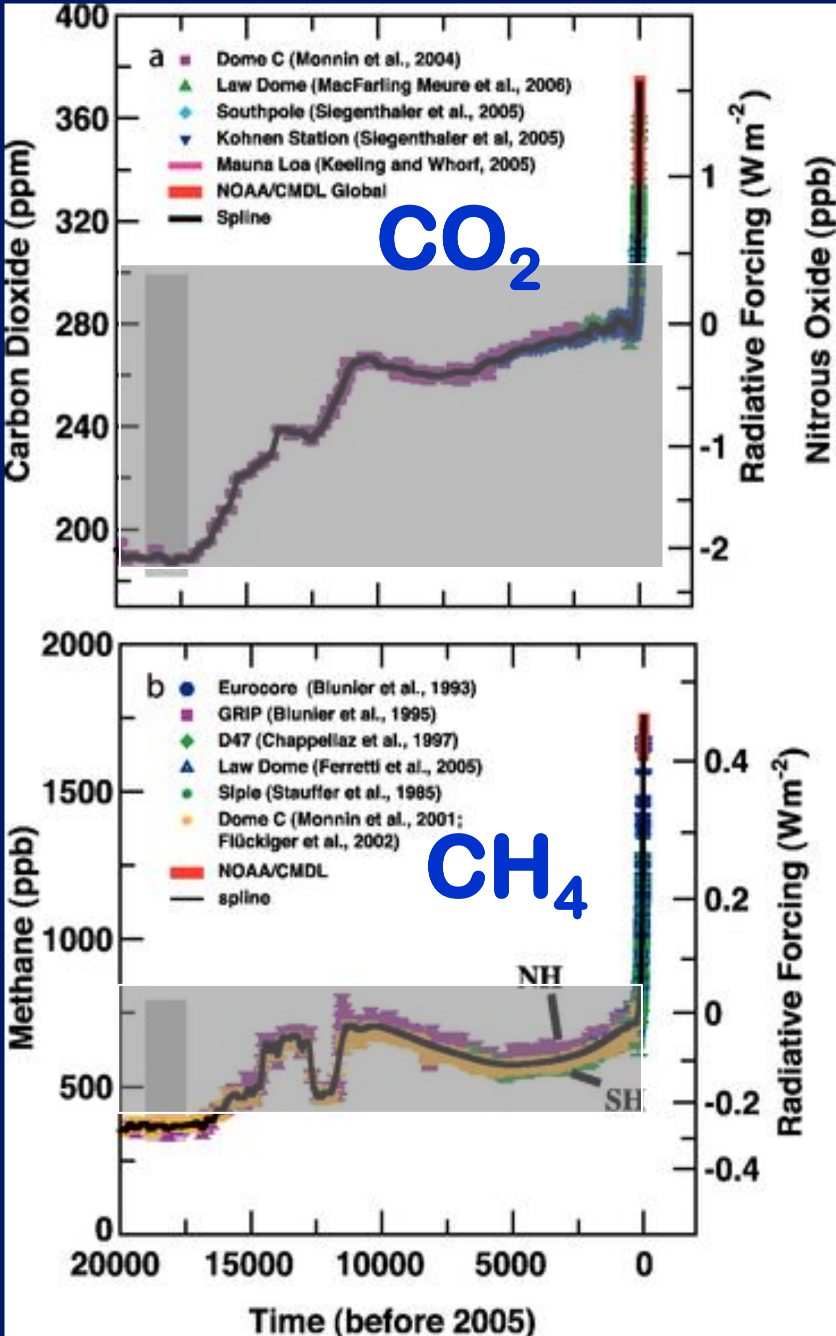


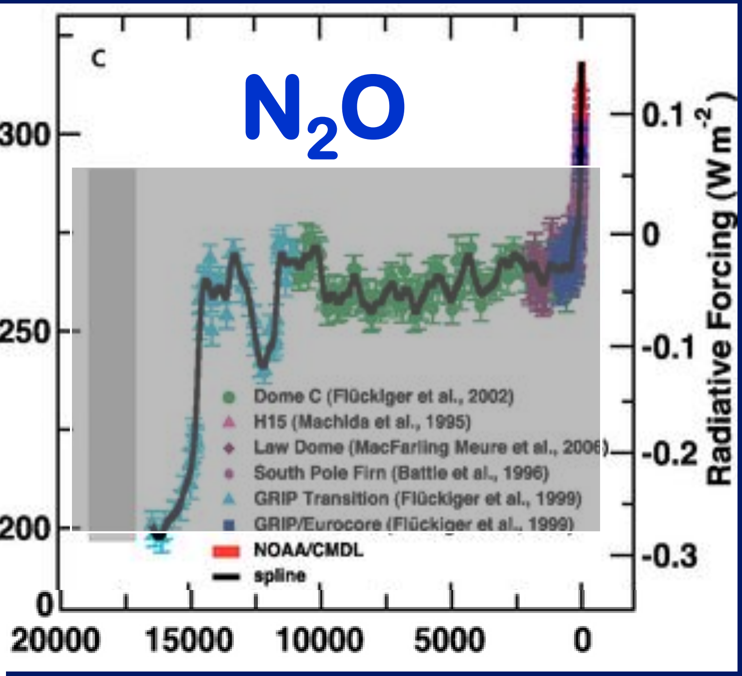




Natural vs Human-Influenced GHG Concentrations

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!

☺

Yay! Another
Sustainability Segment!
INTRO TO TOPIC #7 on Thermodynamics & Energy Efficiency

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

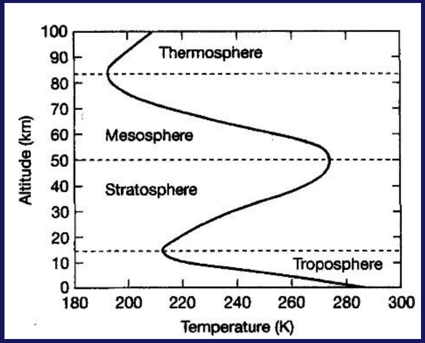
SUMMARY OF KEY CONCEPTS: short version

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:



SEE YOU ON WEDNESDAY !!