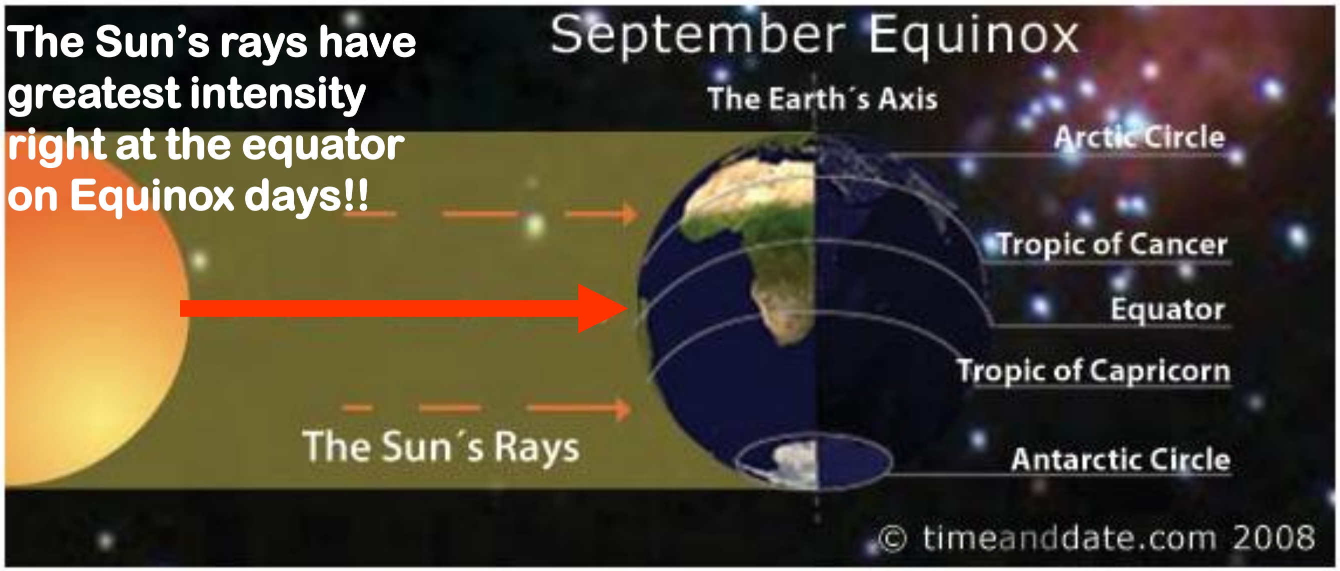
The **September Equinox** is today: Sep 23rd!

It's considered the "traditional" end of Summer and the beginning of Fall



This illustration, which shows an example of the September equinox, is not to scale.

For more see:
http://www.timeanddate.com/calendar/september-equinox.html

More coming up in Topic #11
(class notes p 61)

Topic # 7 – Part II
ATMOSPHERIC STRUCTURE
&
CHEMICAL COMPOSITION

All about the GASES IN THE ATMOSPHERE, esp. GREENHOUSE GASES!

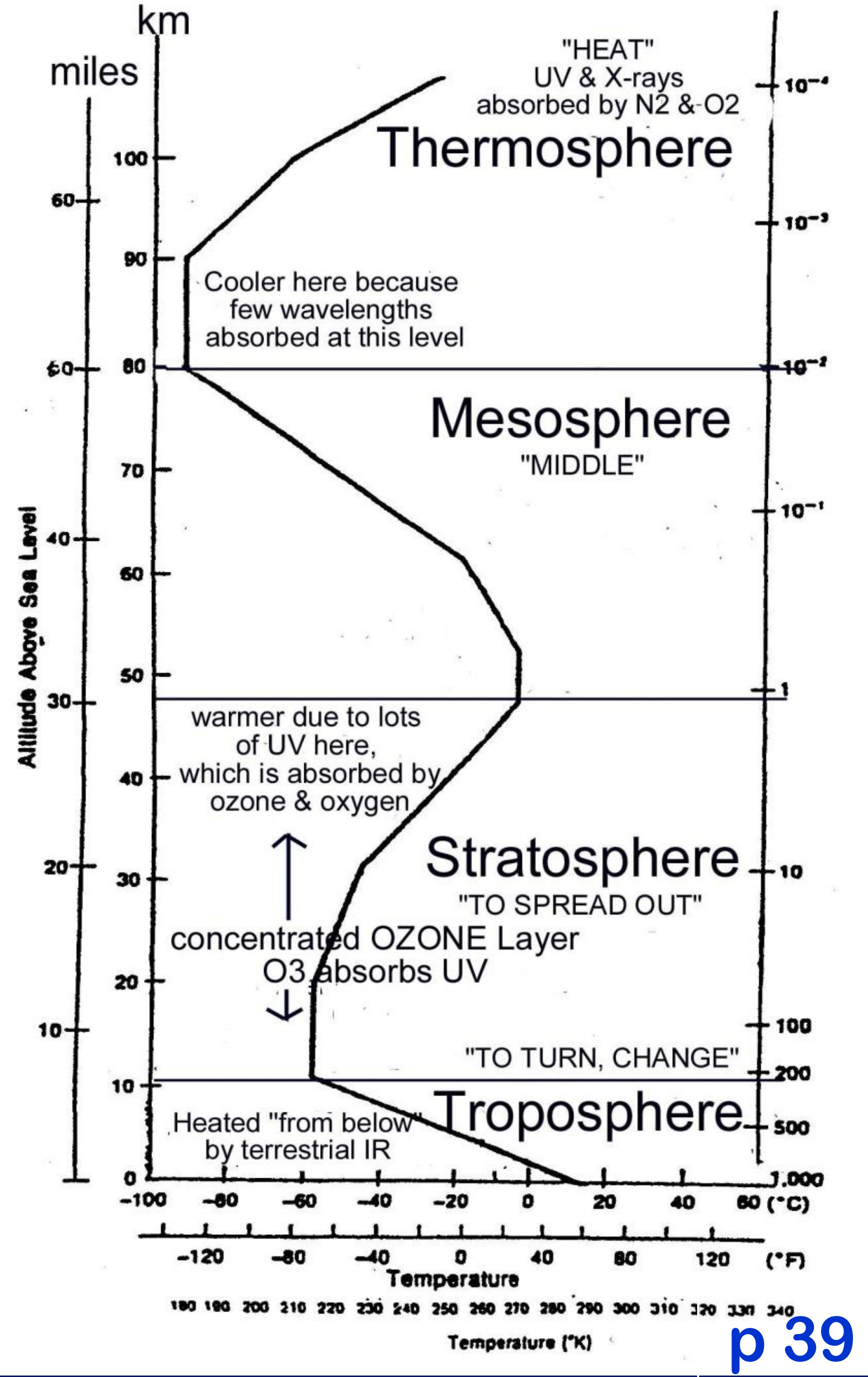
Class Notes pp 39- 44

ATMOSPHERIC STRUCTURE

The changes
in temperature
with height
are the result of:

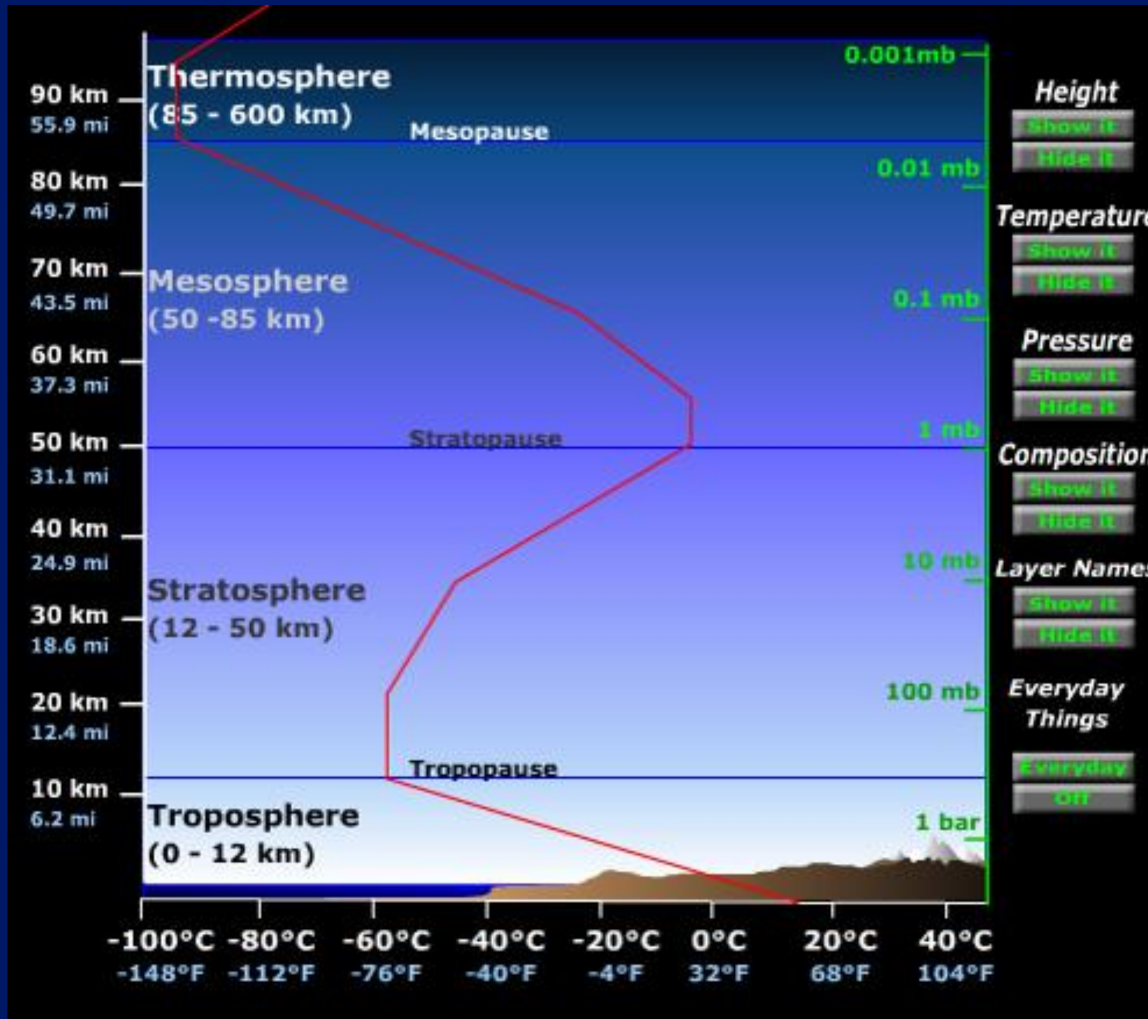
differential absorption
of shortwave (SW)
& longwave (LW)
radiation

by atmospheric GASES
concentrated at
various altitudes.



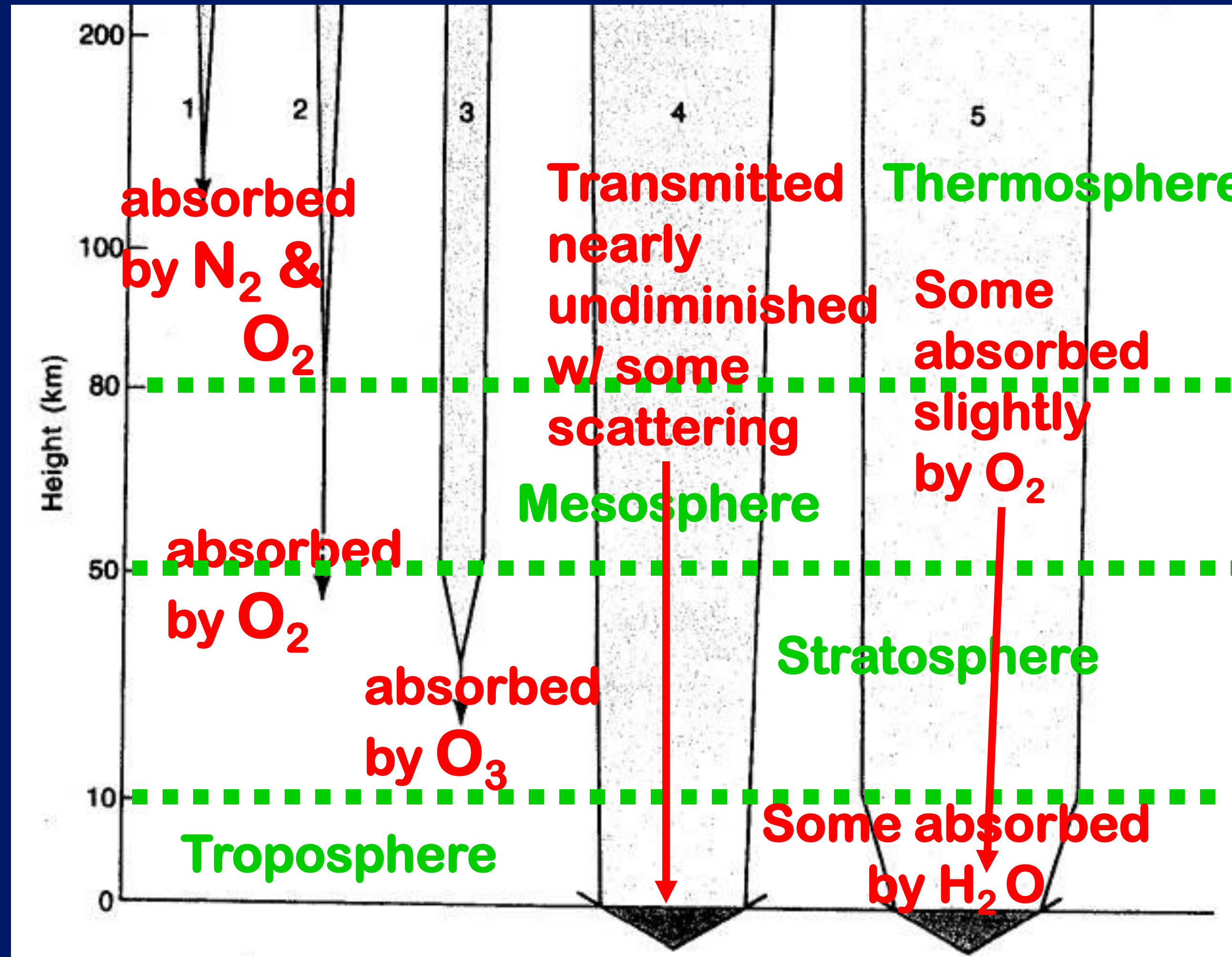
A nice online review . . .

http://earthguide.ucsd.edu/earthguide/diagrams/atmosphere/index.html



UV rays < .32 μm very harmful to life on Earth arrows 1, 2 + 3

How **incoming SOLAR radiation** of different wavelengths gets **TRANSMITTED** or **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

CLICKER QUIZ
on page 39:

Channel 41

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. UVA + Visible
5. Near IR
6. BOTH 4 + 5

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 $< 0.12\ \mu m$
2. UV $0.12 – 0.18\ \mu m$
3. UVC + UVB
4. UVA + Visible
5. Near IR
6. $\boxed{\text{BOTH 4 + 5}}$

Q 2. Why does ARROW #5's radiation get attenuated (thinner) below 10 km?

1. Because ozone (O_3) is abundant below 10 km and absorbs large amounts of incoming IR
2. Because this is the area of the troposphere where water vapor (H_2O) is abundant and (as a GHG) it absorbs IR
3. Because clouds in the troposphere block out some of the incoming visible light rays

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Q 3. Why does ARROW #3's radiation get attenuated below <u>50 km</u>?

1. Because this is the area of the **mesosphere** and there is very little absorption of radiation in this layer

2. Because **nitrogen (N_2)** and **oxygen (O_2)** are abundant at 50 km and act as GHG's to **absorb** the **UVC + UVB** rays

3. Because this is the area of the stratosphere where **ozone (O_3) is concentrated** and absorbs harmful **UVC + UVB** rays

Q 3. Why does ARROW #3's radiation get attenuated below 50 km?

1. Because this is the area of the **mesosphere** and there is very little absorption of radiation in this layer
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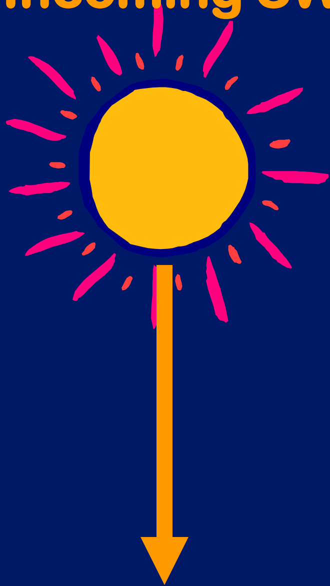
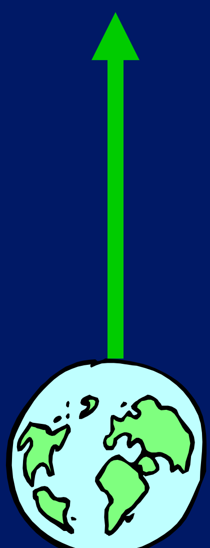
3. Because this is the area of the stratosphere where **ozone (O_3) is concentrated** and absorbs harmful **UVC + UVB** rays

Incoming SW



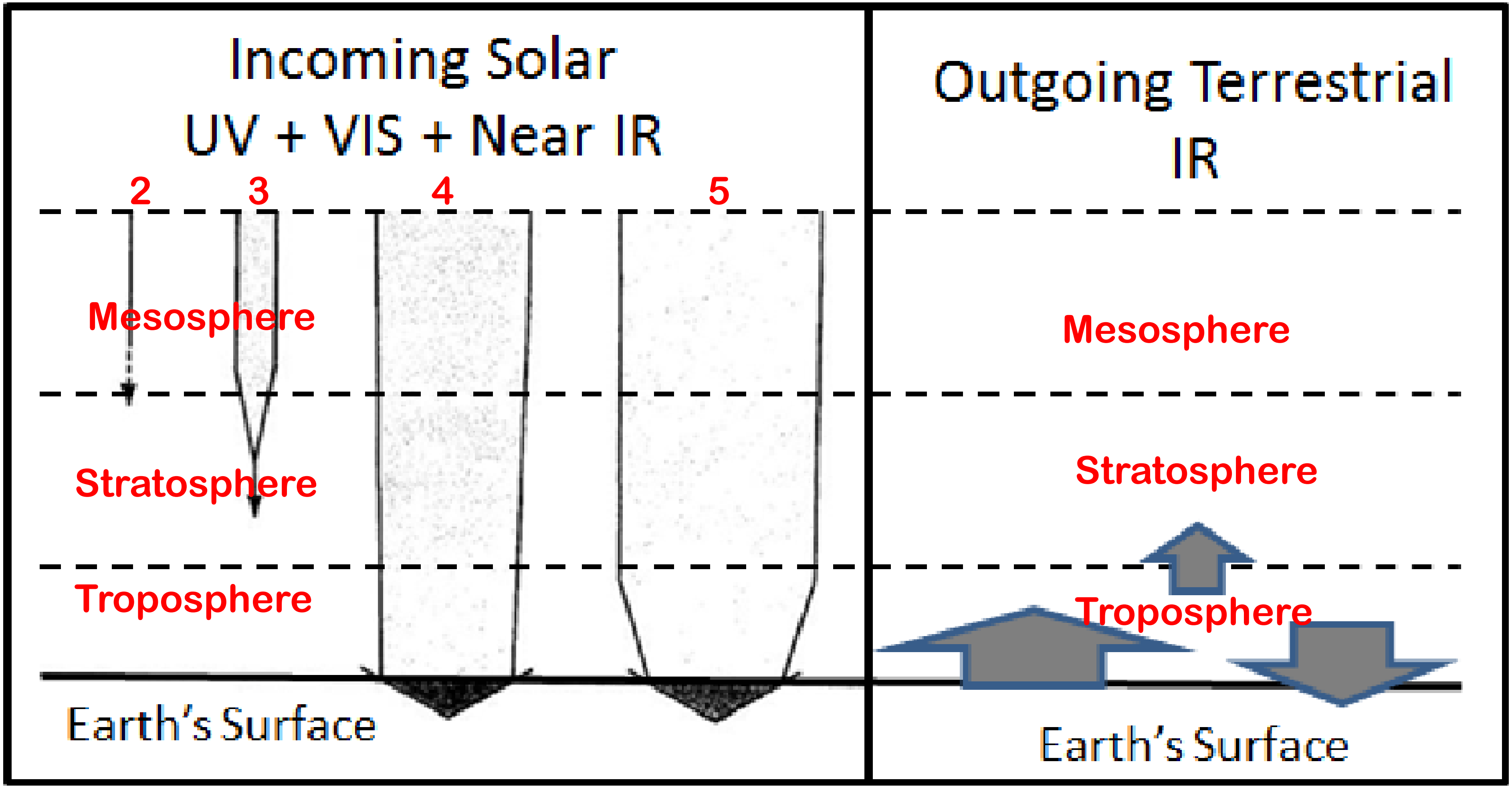
OK – so that explains what happens in different layers of the atmosphere to the **INCOMING SOLAR Shortwave (SW)** on its way down to the Earth's surface . . . .

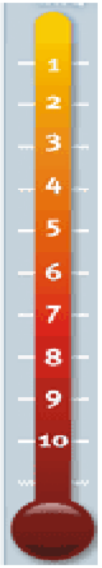
Outgoing LW



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

Write in the names of the layers:



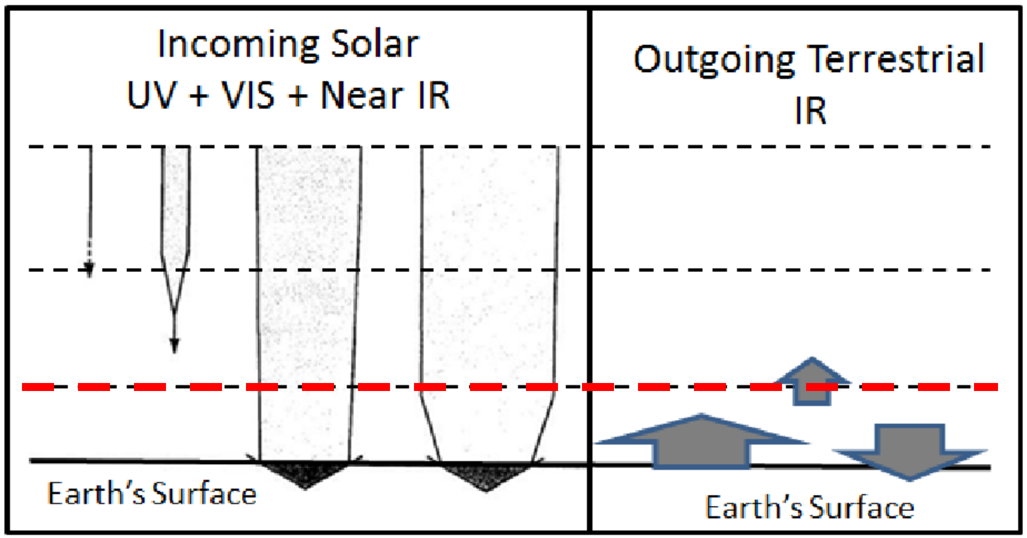


INDICATOR INTERLUDE . . .

The Greenhouse Warming Signature:
"Increasing CO_2 warms the Troposphere and cools the Stratosphere"

What would a <u>SOLAR</u> Warming Signature look like?

Radiative Forcing (RF) - Radiative forcing is the change in the net, downward (incoming) minus upward (outgoing), **irradiance** (expressed in W/m^2) at the *tropopause* due to a change in an external driver of *climate change*, such as, for example, a change in the concentration of *carbon dioxide* or the output of the Sun.



More on this later!!

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?

ATMOSPHERIC COMPOSITION

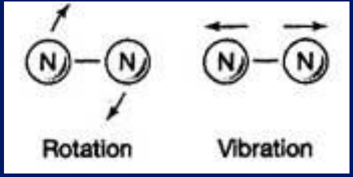
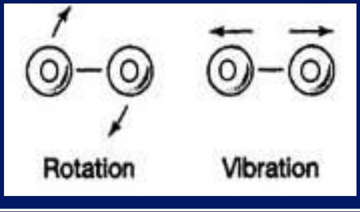
* = Greenhouse Gas (GHG) RF = Radiative Forcing of GHG's in Wm^{-1}

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 41

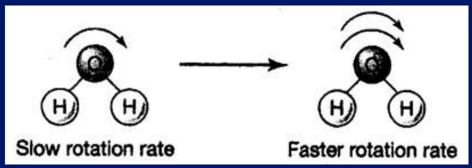
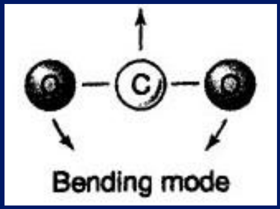
Most Abundant Gases in the Atmosphere

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%

p 41

Next Most Abundant Gases:

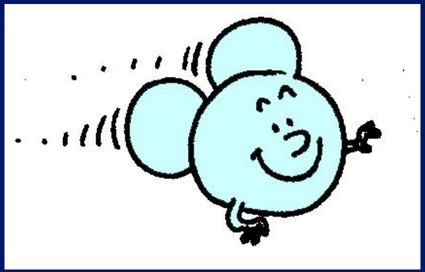
GAS	Sym bol	% by volume	% in ppm
Water Vapor 	H_2O	0.00001 (South Pole) to 4.0 (Tropics)	0.1 - 40,000
Carbon Dioxide 	CO_2	0.0390 (and rising!)	360 (in 1997) **390 !** (in May 2009)

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

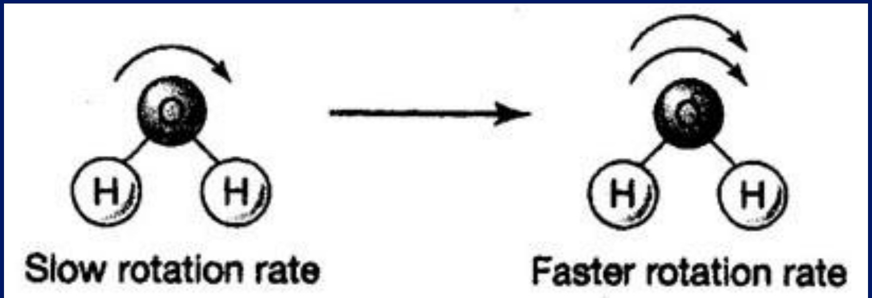
Greenhouse Gases!



WATER VAPOR

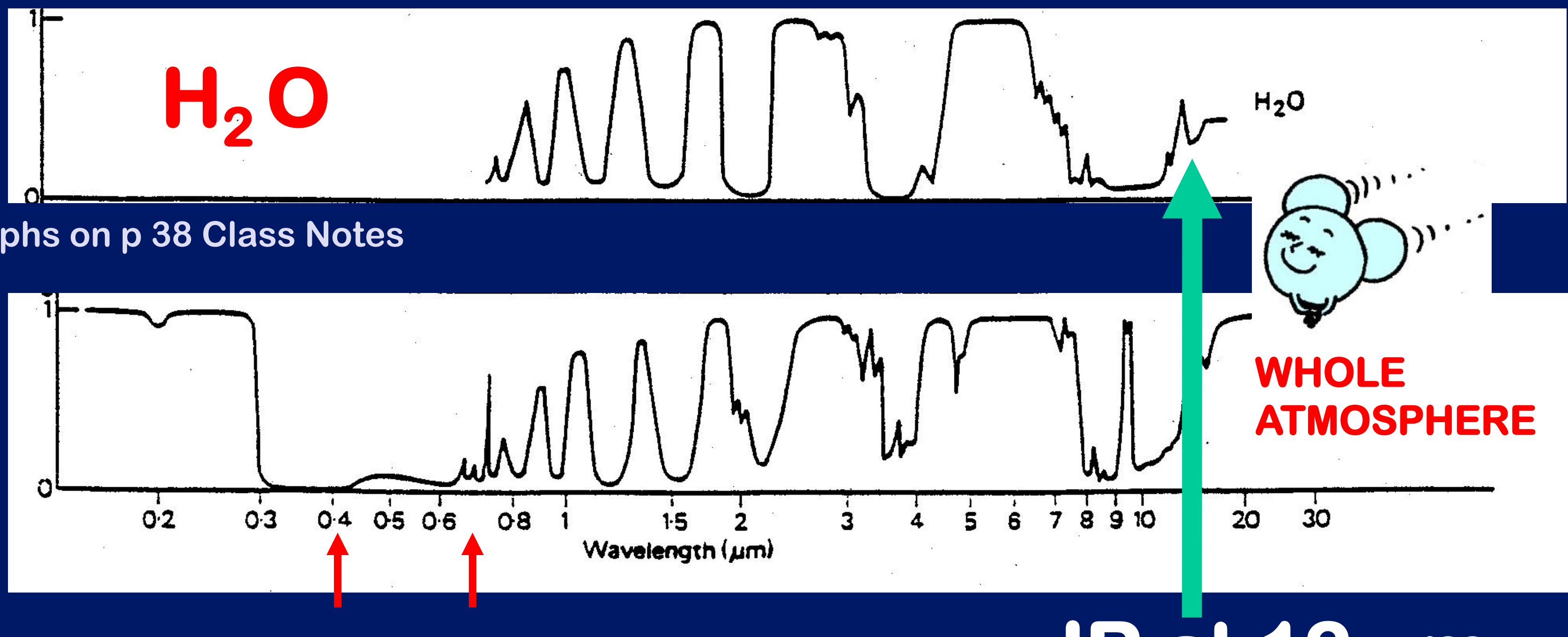
* Arrives in atmosphere naturally through evaporation & transpiration

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



Just listen!
This info is in Table on p 42

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



Graphs on p 38 Class Notes

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

Just listen!

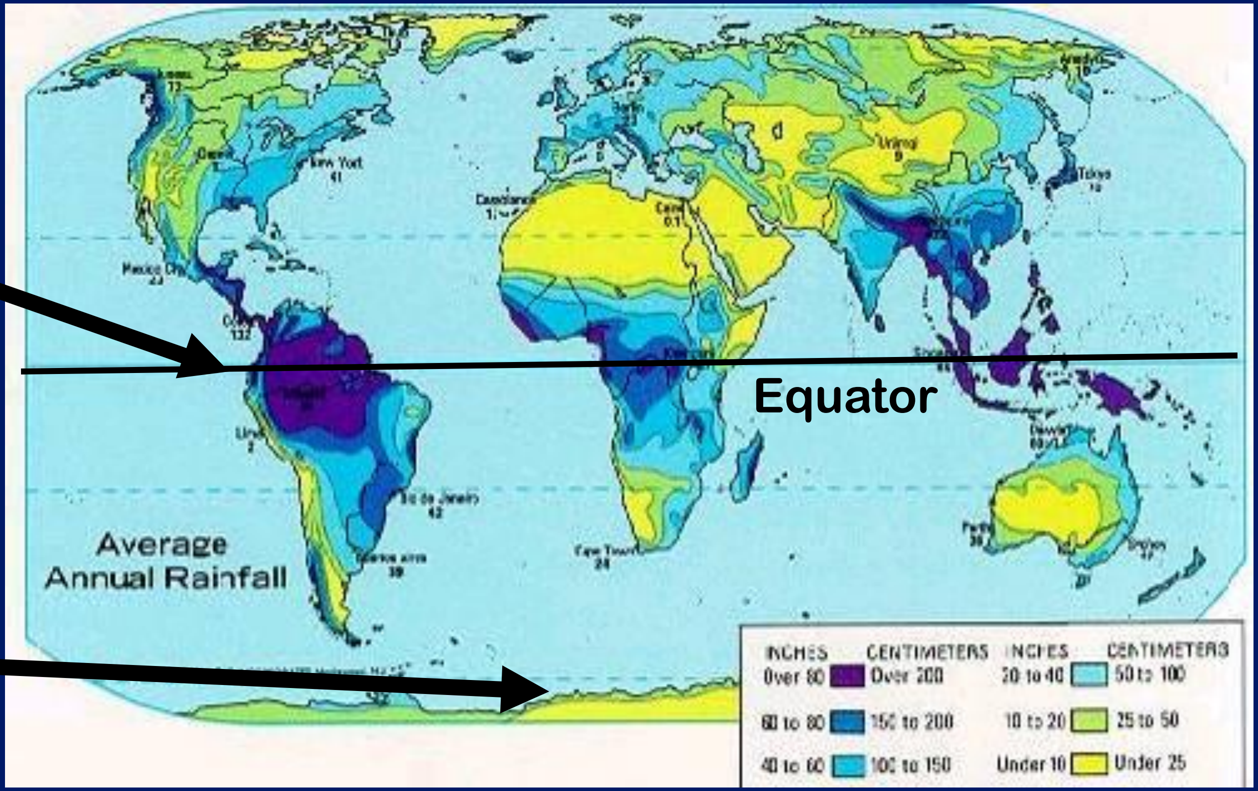
☺

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

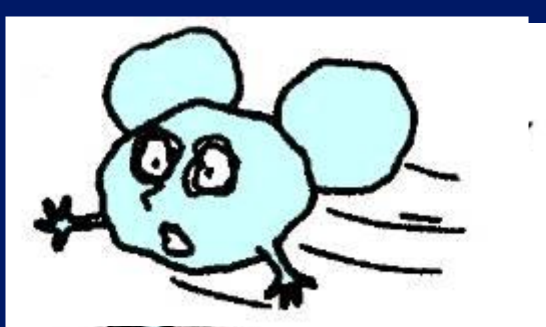


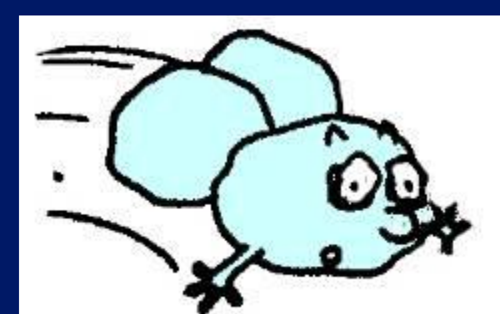
Just listen!

☺

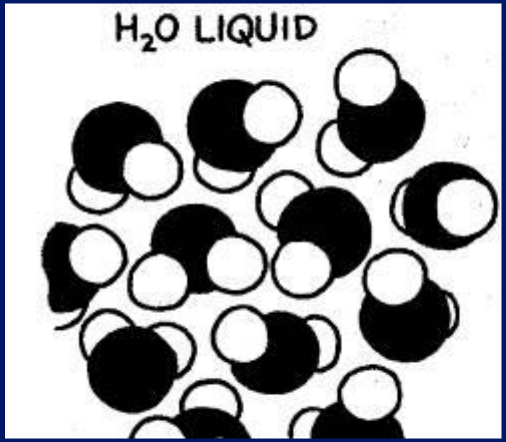
At higher air temperatures, H_2O molecules collide & rebound more frequently, leading to expansion of the air & the water vapor in the air.

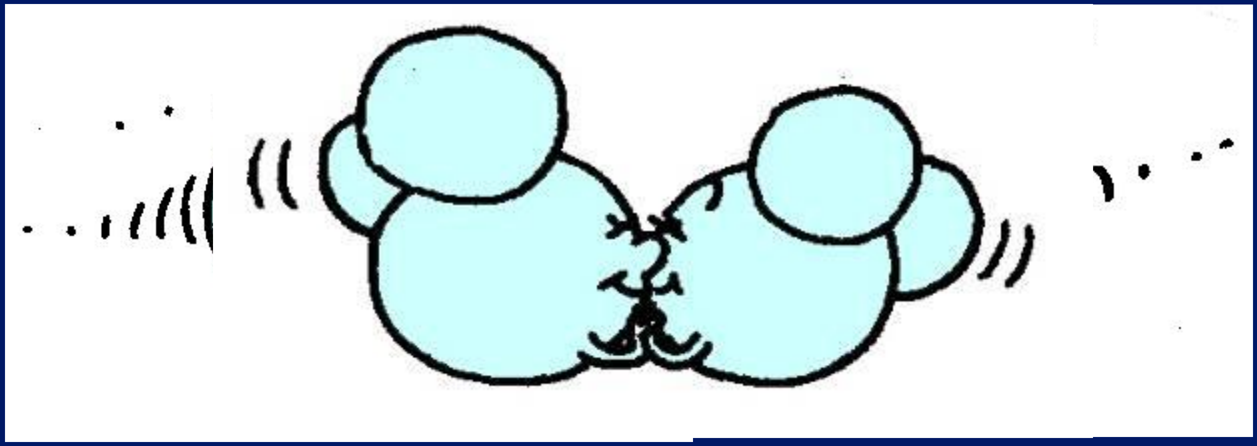
Hence hot climates can hold more water vapor in the air





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???

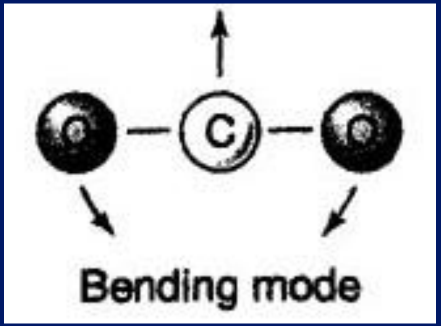
. . . due to more evaporation in the warmer climate!

THINK ABOUT THIS!

CARBON DIOXIDE:

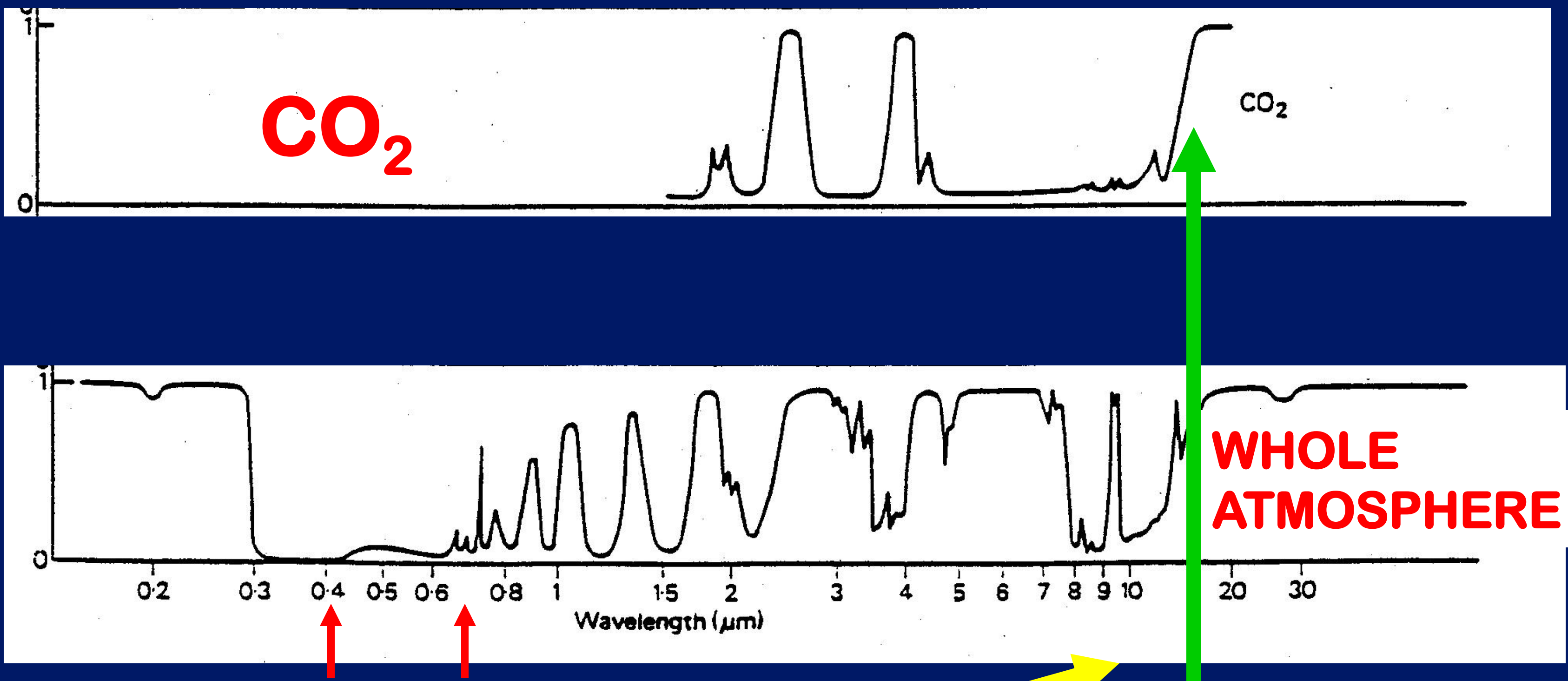
* Arrives in atmosphere naturally through the natural carbon cycle

* Due to unique quantum bending mode vibration behavior, CO_2 molecules are excellent absorbers of electromagnetic radiation of about 15 µm



Just listen! This info is in Table on p 42

CO_2 is excellent absorber of radiation of about 15 µm



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

IR at 15 µm absorbed

Review

CARBON DIOXIDE (cont.):

* Has increased dramatically since the 1800s due to:

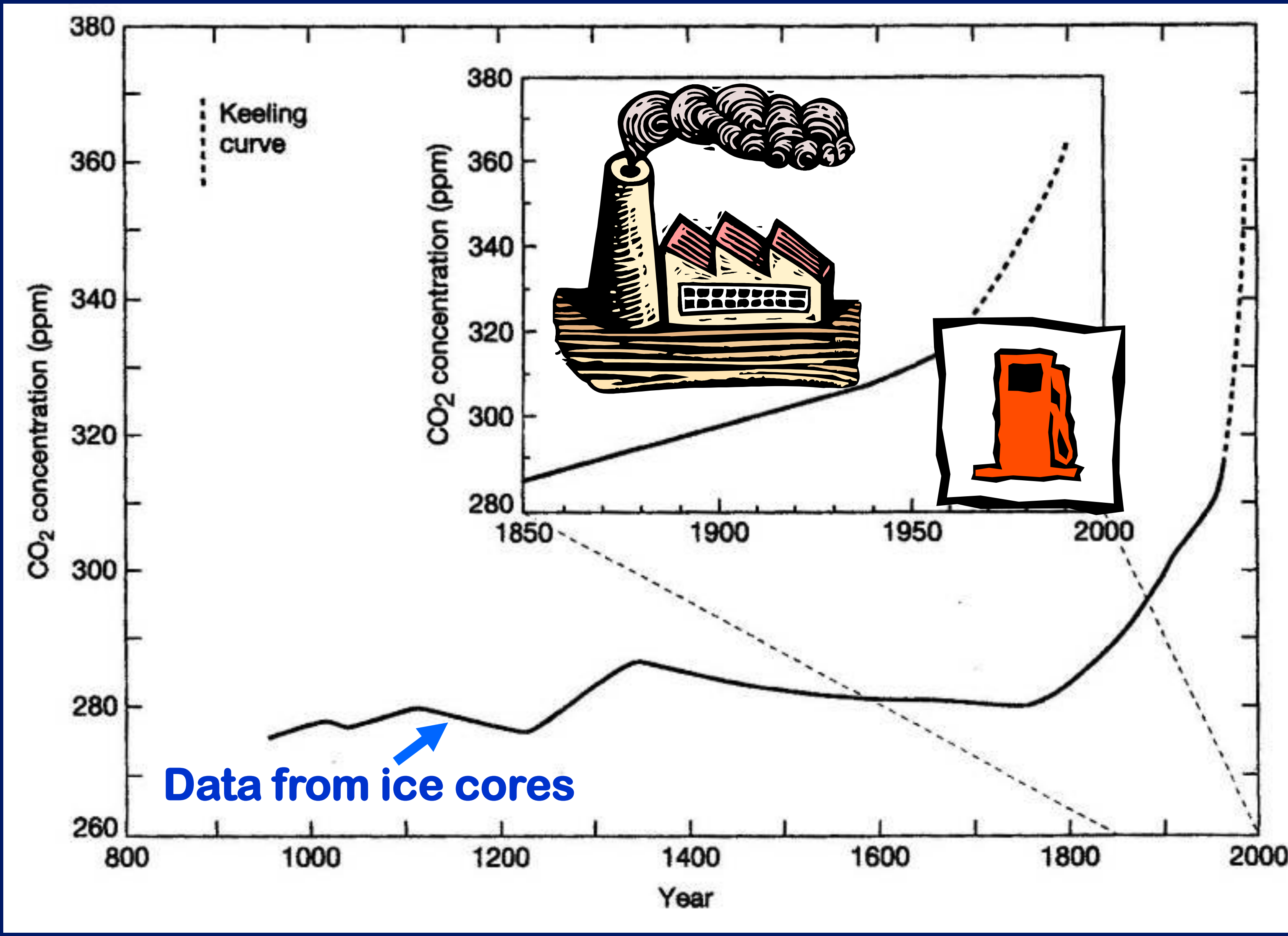
(1) fossil fuel combustion: oil, coal, gas -- especially coal, and

(2) 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.

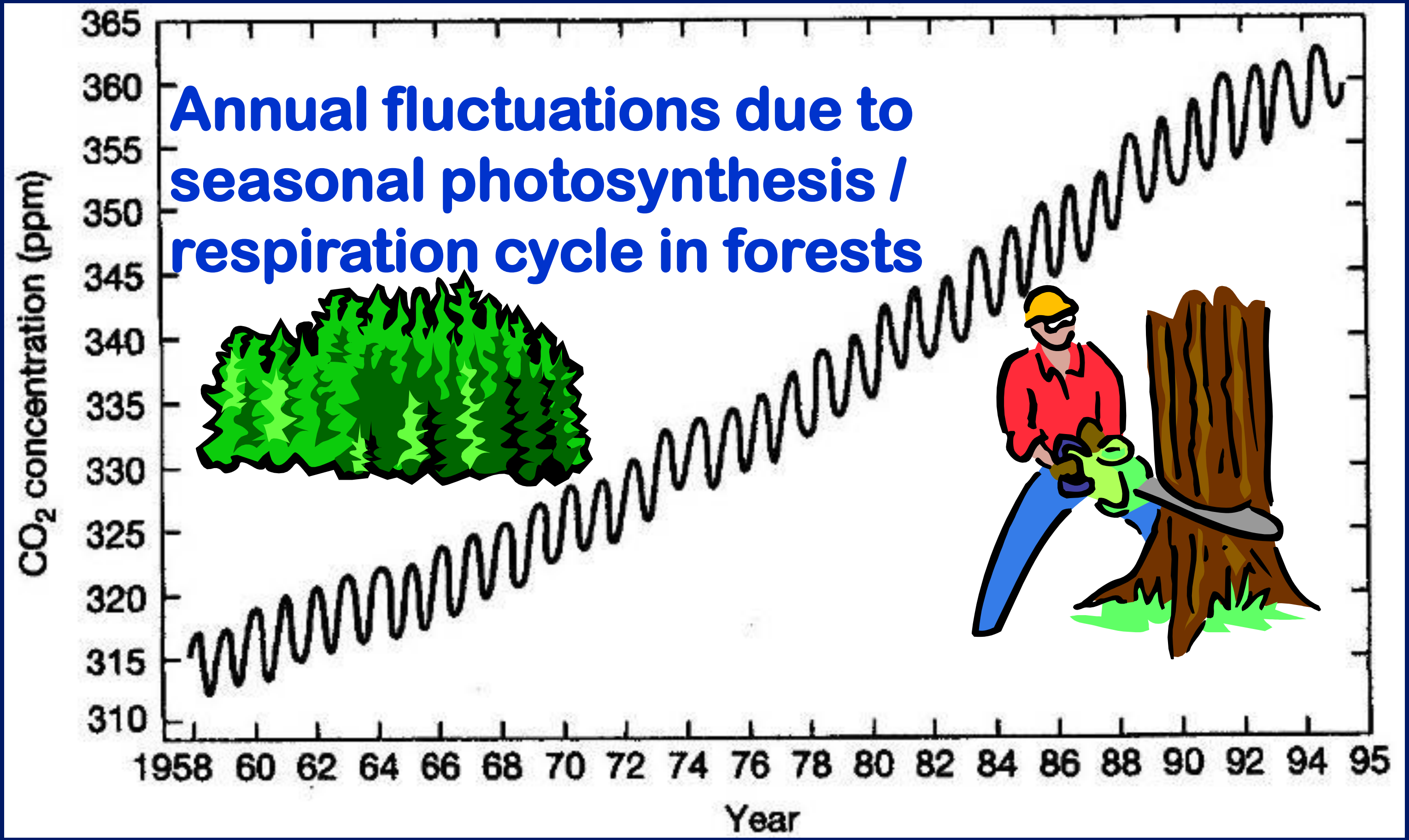
(Deforestation also accelerates forest decomposition, burning, etc. adding to the overall respiration inflow.)

This info is in Table on p 42

CARBON DIOXIDE: Trends

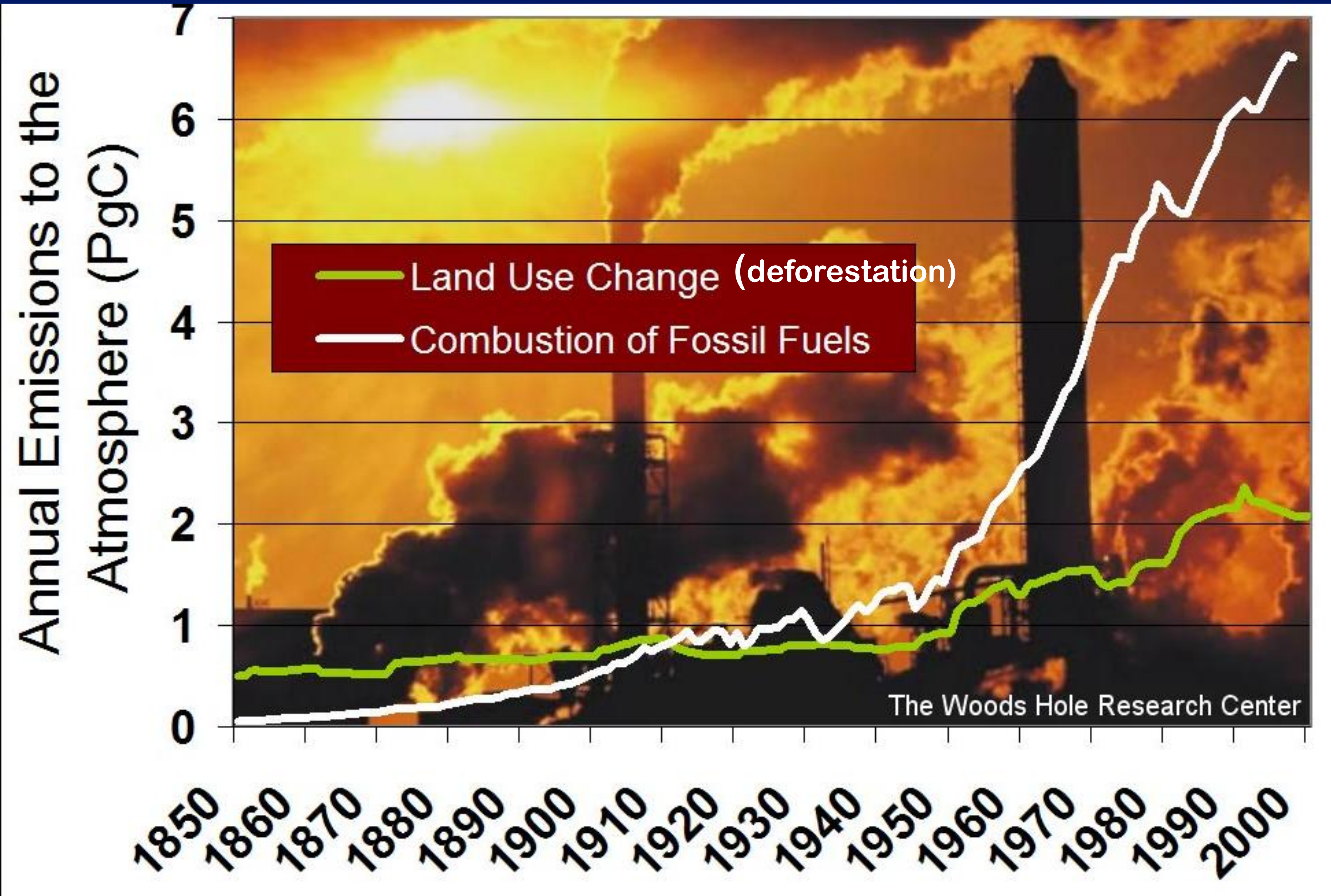


CARBON DIOXIDE --- Trends:



The Keeling Curve

CARBON emissions into the atmosphere are increasing:



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!

This info is in Table on p 42

METHANE (CH_4):
Sources

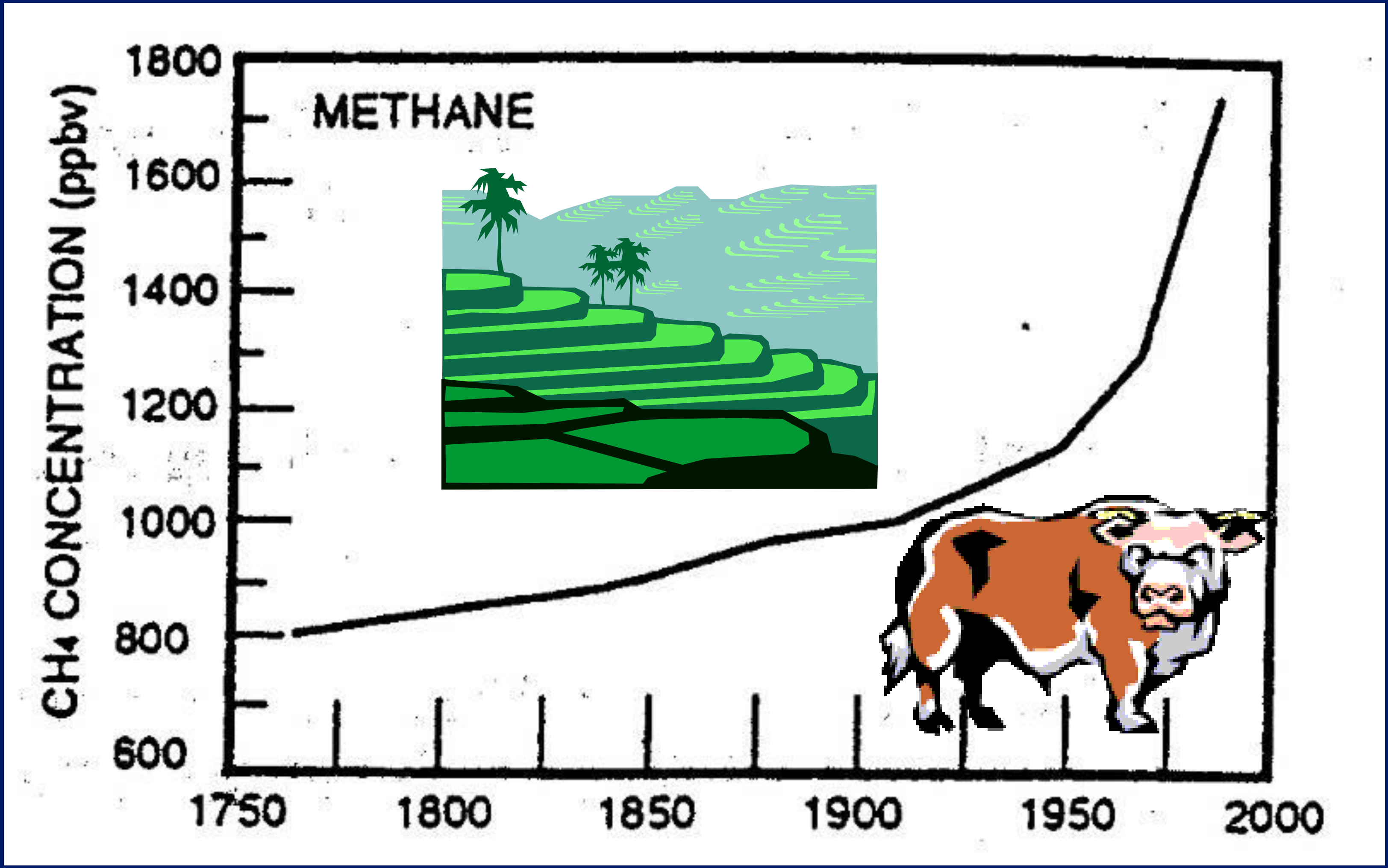
* Produced naturally in anaerobic processes (e.g., decomposition of plant material in swamps & bogs)

* **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)

This info is in Table on p 42

METHANE: Trends



NITROUS OXIDE (N_2O):
Sources

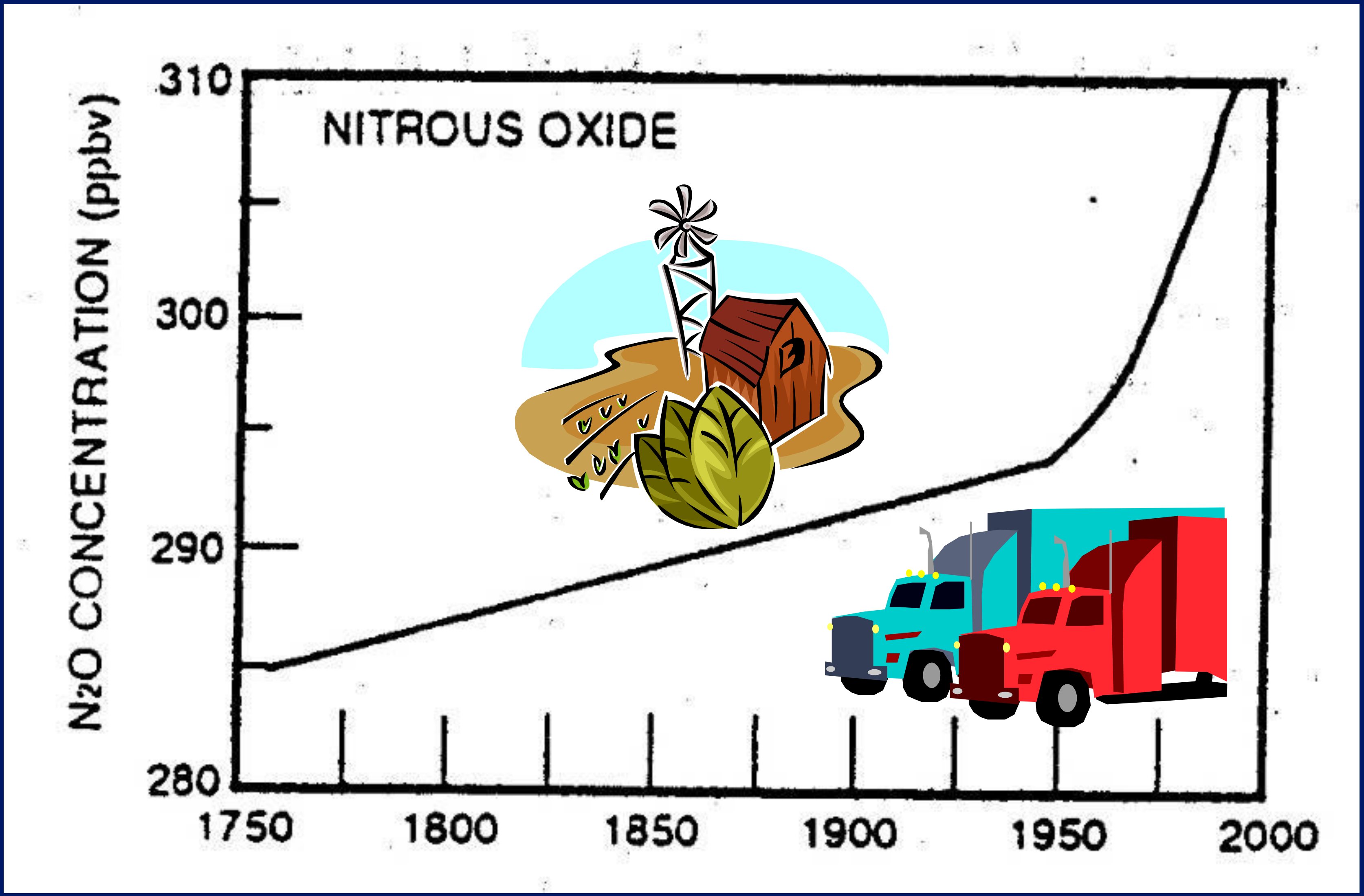
* Produced naturally in soils

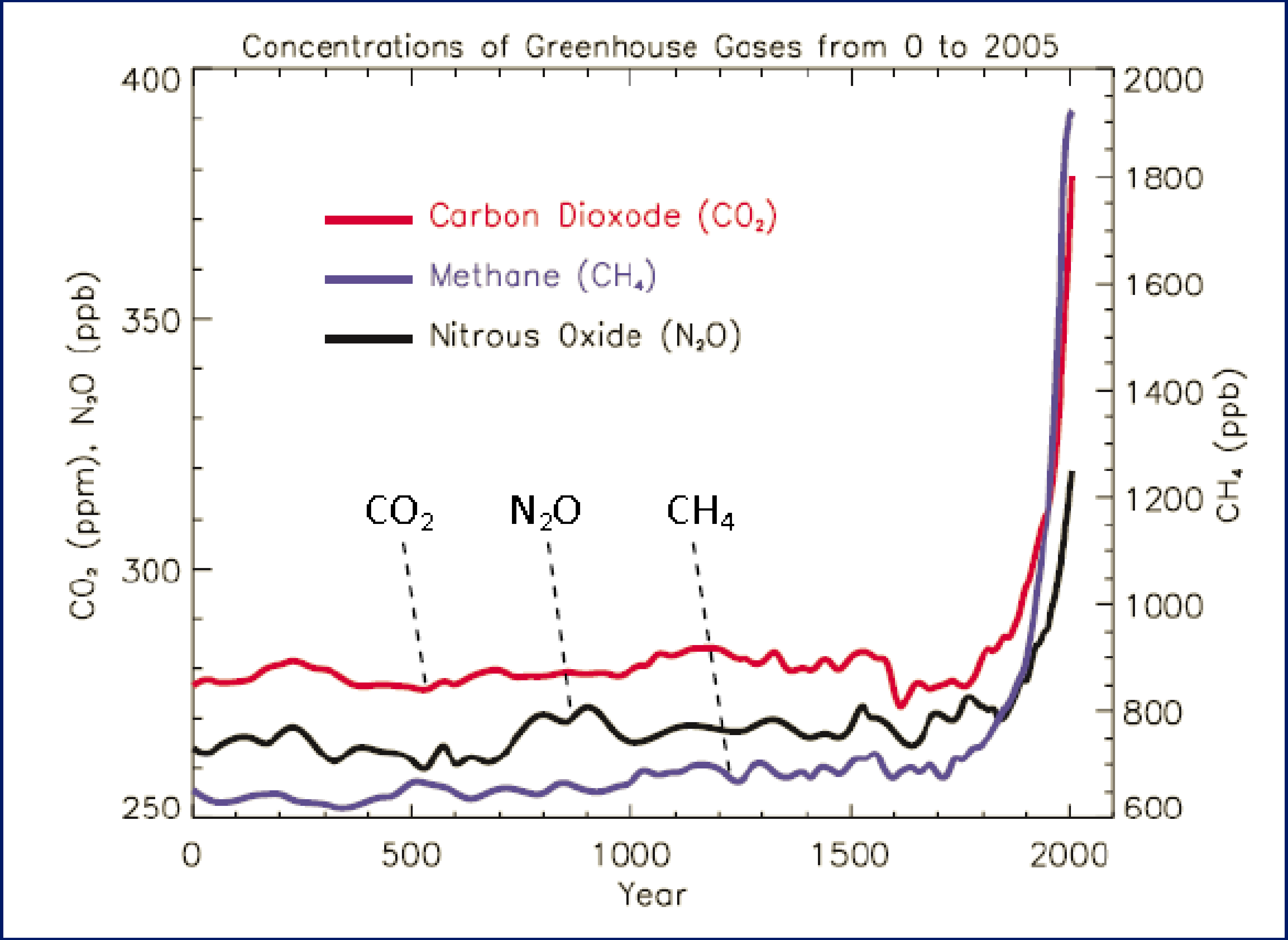
* Has increased due to fossil fuel combustion (esp. diesel), forest burning, use of nitrogen fertilizers

* Has long atmospheric residence time (~ 150 years)

This info is in Table on p 42

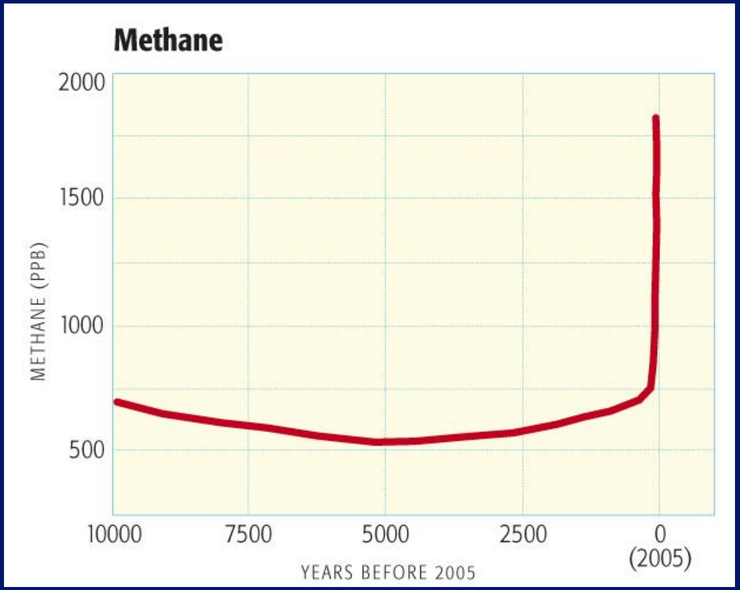
NITROUS OXIDE: Trends

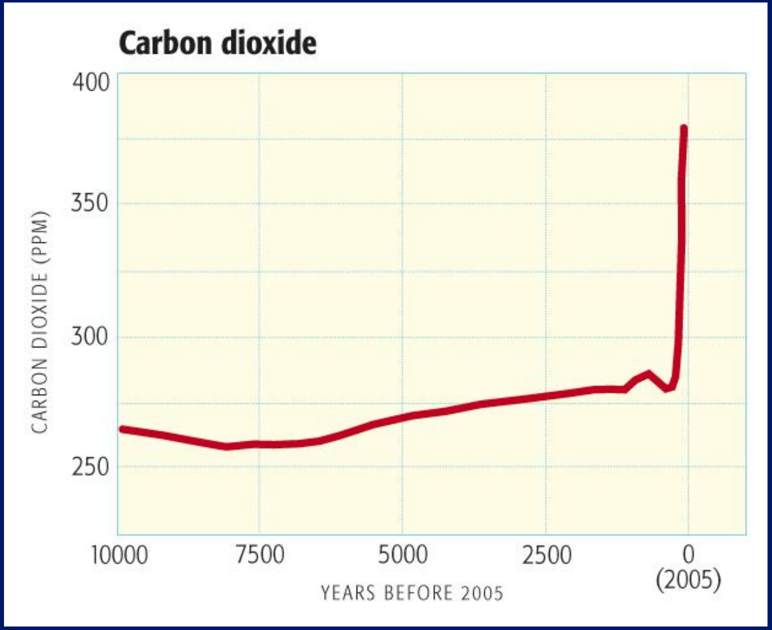


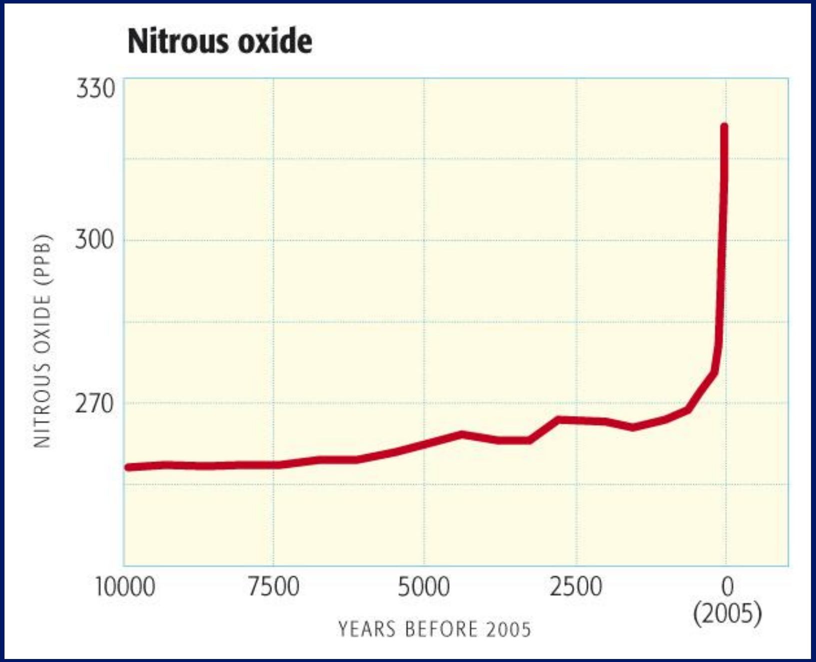


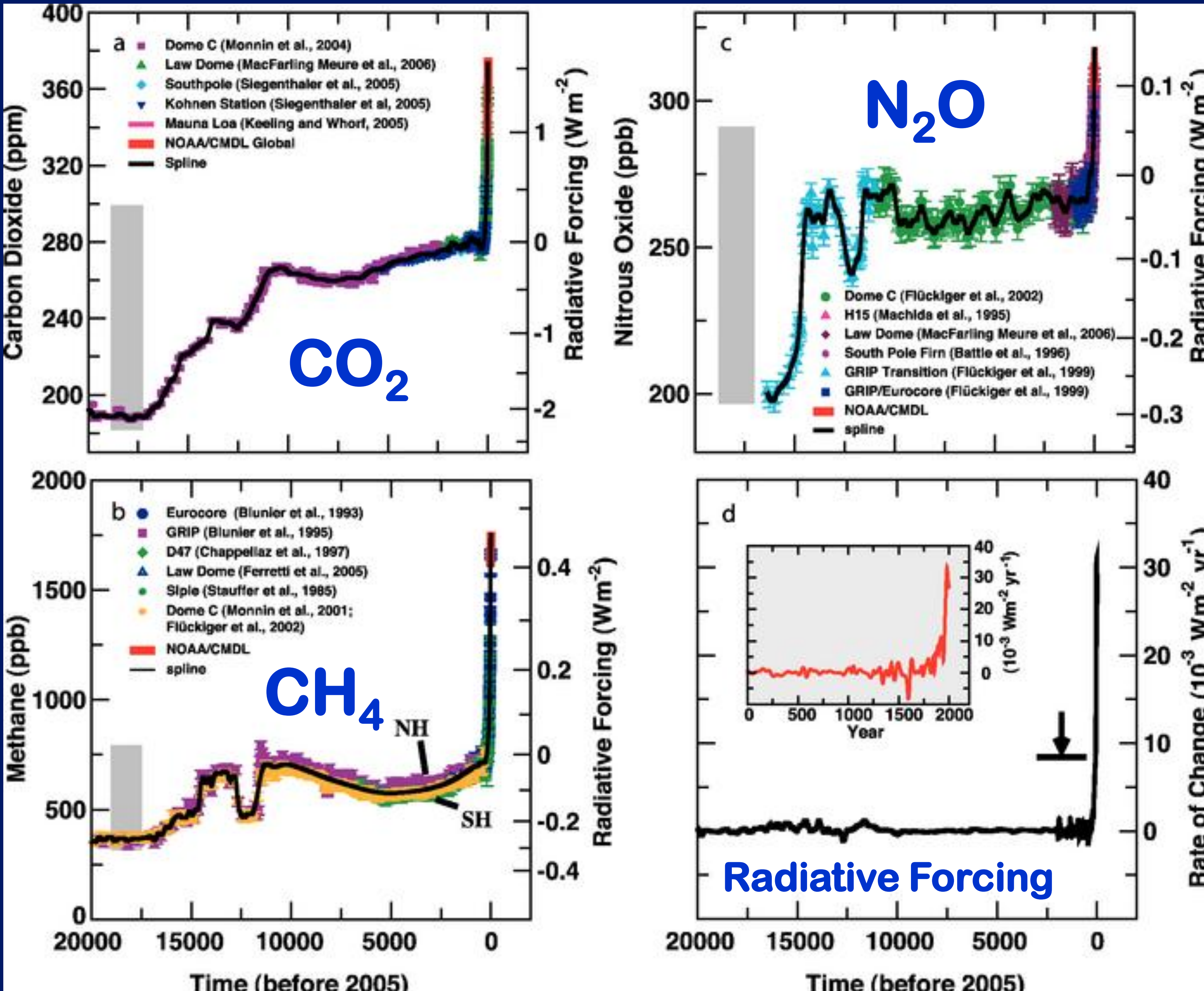
Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO₂)
Methane (CH₄)
Nitrous Oxide (N₂O)
CO₂
N₂O
CH₄
CO₂ (ppm), N₂O (ppb)
CH₄ (ppb)
Year
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000

Updated figures from **Dire Predictions** p 33









The grey bars show the reconstructed ranges of natural variability for the past 650 kyr

CFCs (Freon-11 & Freon-12)

* Human-made CFCs (didn't exist in atmosphere prior to 1950s)

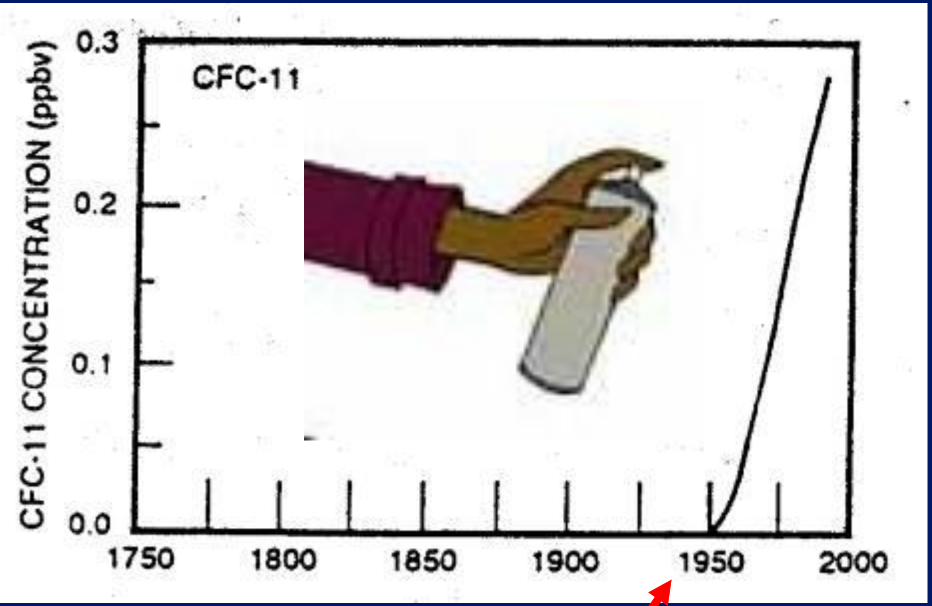
* Have increased at rates faster than any other greenhouse gas; used in refrigerants, fire retardants, some aerosol propellants & foam blowing agents

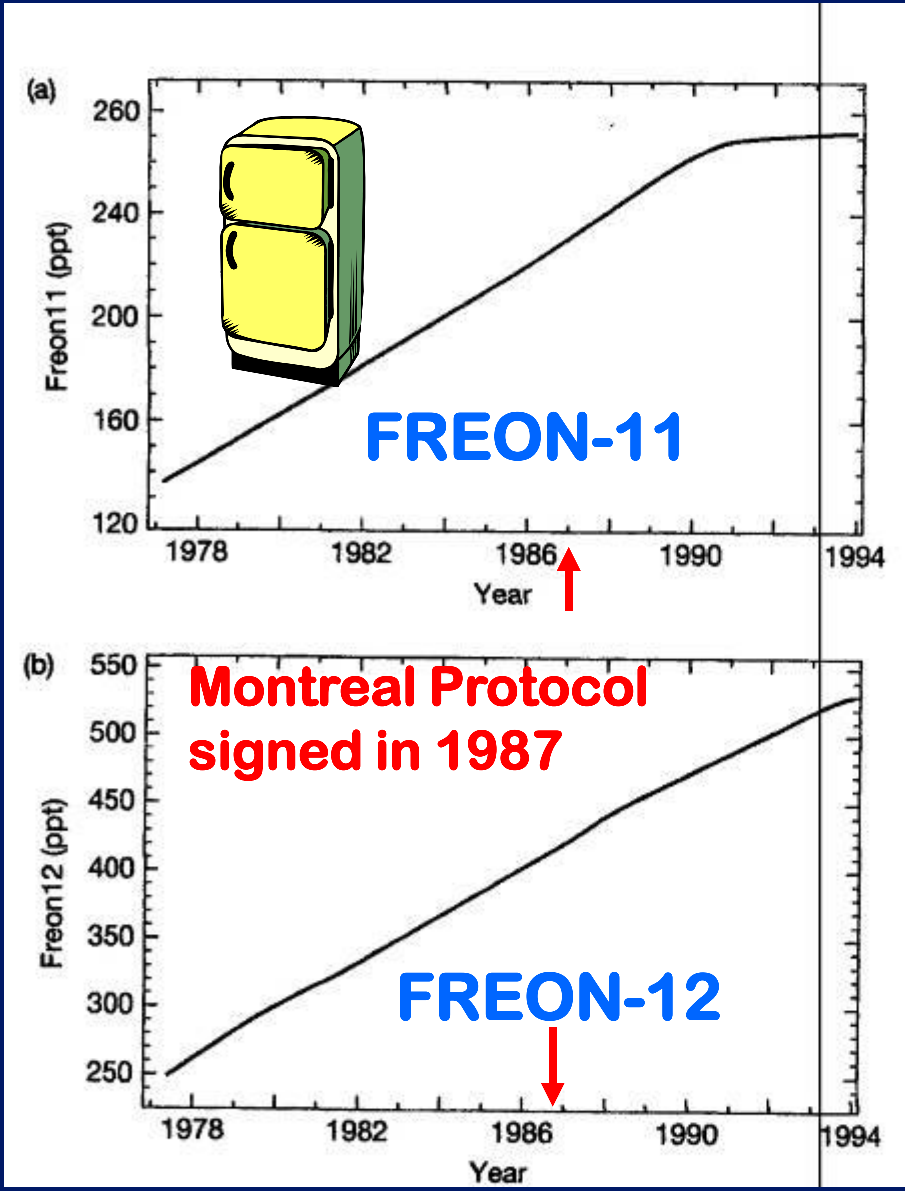
* Absorb at different wavelengths than H_2O and CO_2 (in 8 –12 µm "WINDOW" part of spectrum), hence a single molecule can have great effect

MONTREAL (and subsequent) PROTOCOLS have reduced CFCs!

This info is in Table on p 41

CFCs: Trends



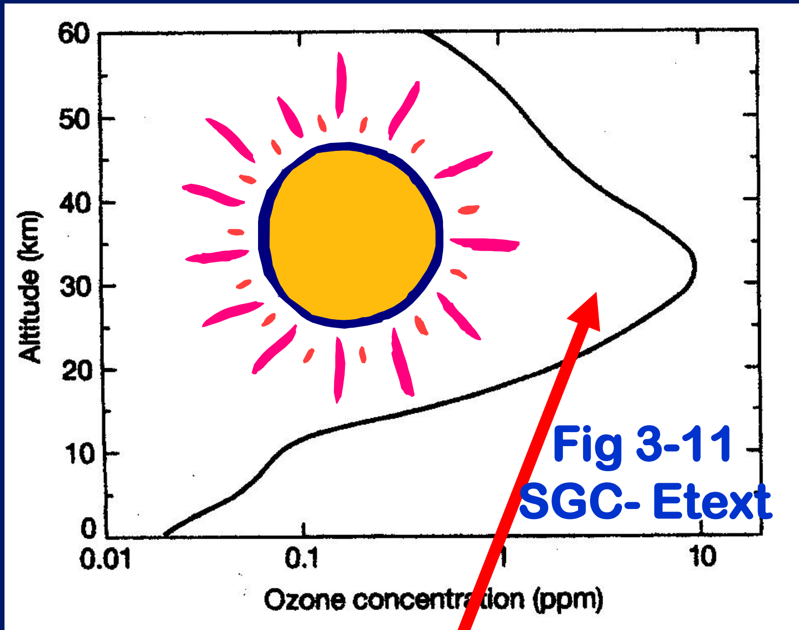


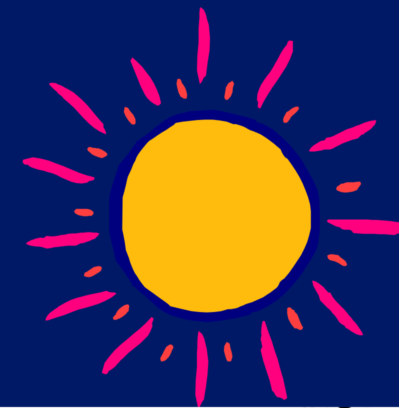
Human-made -- didn't exist before 1950!

Q10 – Why do you think the concentration of CFC's didn't begin dropping immediately after the Montreal Protocol in 1987?

1. Because it was an international "agreement only" and the nations of the world never followed through.
2. Because it called for only a 50% reduction of CFC's over 10 years and had to be followed by more stringent protocols later.
3. Because CFC's are very stable molecules and don't break down easily once they are in the atmosphere.

OZONE: Sources



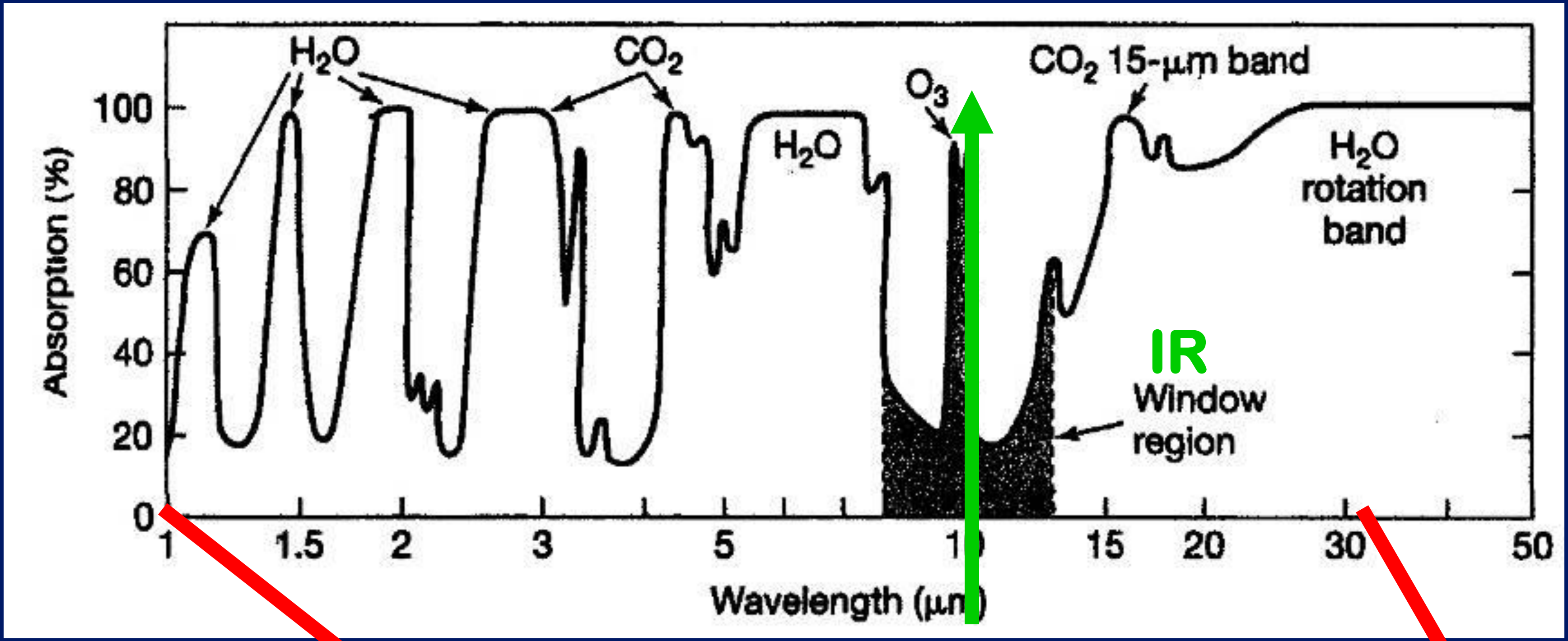


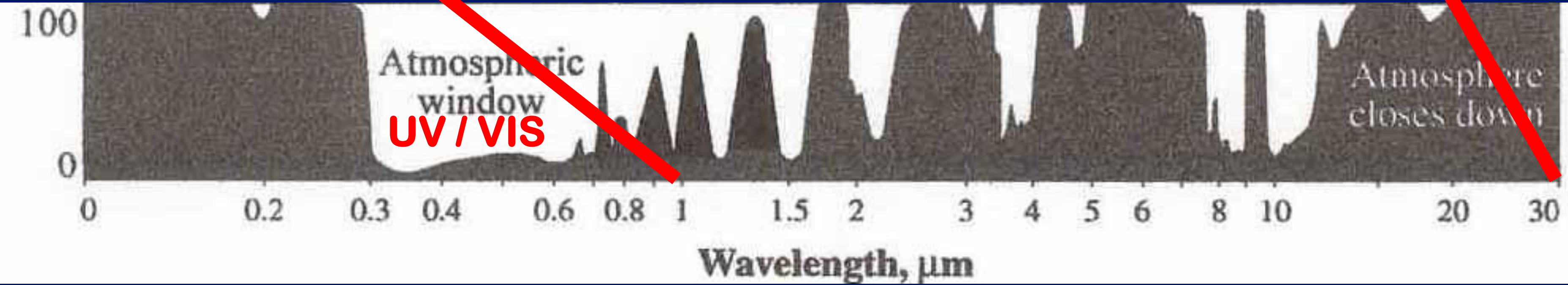
Produced naturally in photochemical reactions in STRATOSPHERIC ozone layer --"good ozone"

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

This info is in Table on p 42

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

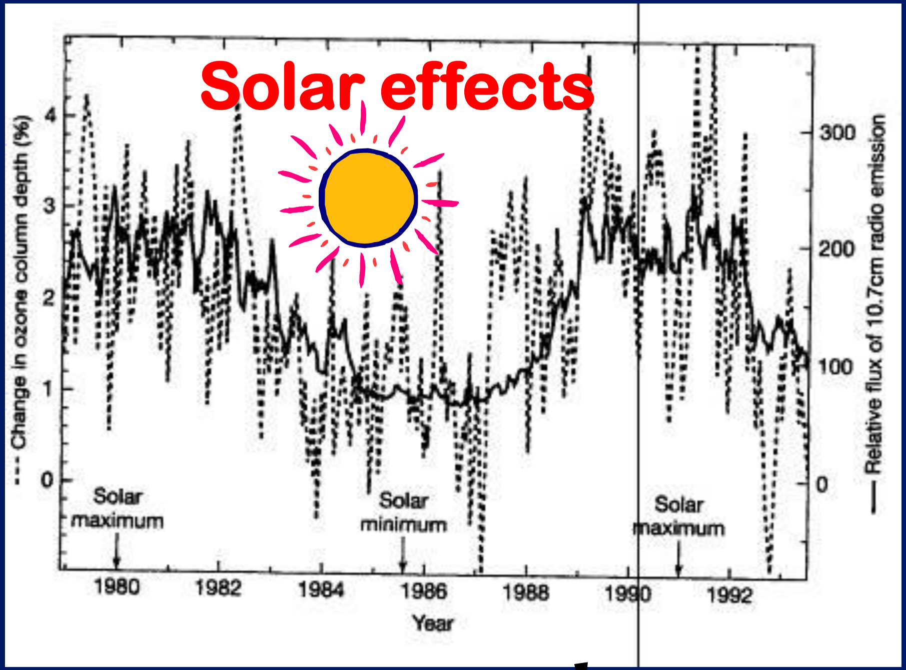




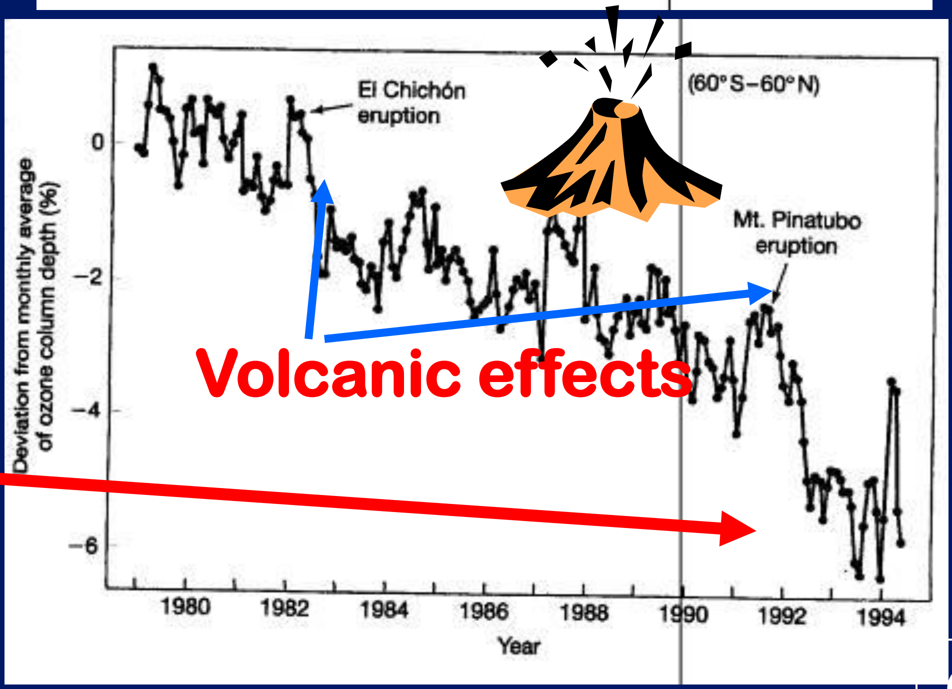
Review)

OZONE:
Trends

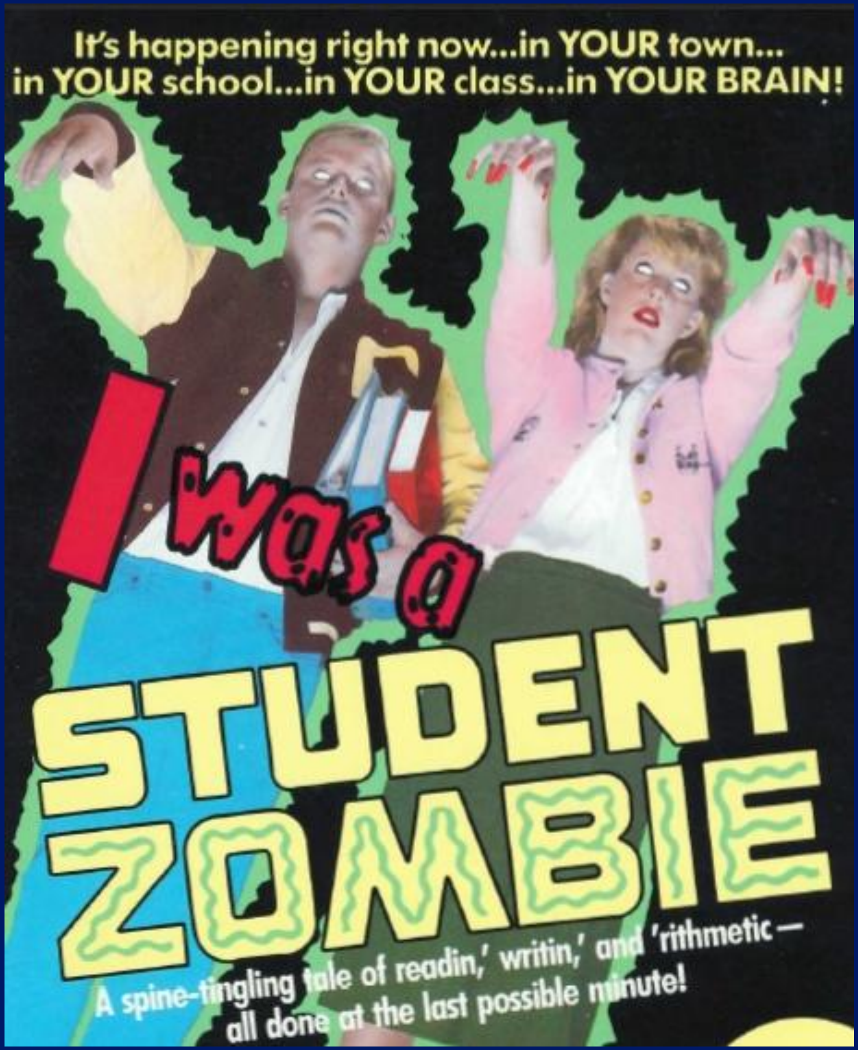
Stratospheric ozone varies by latitude and season -- is affected by solar radiation, volcanic eruptions & chemical reactions due to CFCs.



Overall, O3 is decreasing in the STRATOSPHERE



More on OZONE later on in the semester



ZOMBIE BREAK !

SHORT GROUP “Stretch” ACTIVITY!

1) Send someone up to get your Group Folder

2) REMOVE your graded TEST #1

3) PRINT YOUR FIRST & LAST NAME on a LABEL (preferred nicknames OK)

4) STICK the LABEL on your GROUP PHOTO (but NOT over your face!) and indicate which group member is YOU (with an arrow or pointer line)

5) Return the Group Folder to front of classroom

6) IF YOU are not in the photo, Dr H will take your photo today and photoshop you in!

THEN YOU MAY LEAVE!!

GO CATS!