
APRIL 3, 2006
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SPECIAL REPORT GLOBAL WARMING
TIME
BE WORRIED. BE VERY WORRIED.
Climate change isn't some vague future problem—it's already damaging the planet at an alarming pace. Here's how it affects you, your kids and their kids as well
EARTH AT THE TIPPING POINT
HOW IT THREATENS YOUR HEALTH
HOW CHINA & INDIA CAN HELP SAVE THE WORLD—OR DESTROY IT
THE CLIMATE CRUSADERS


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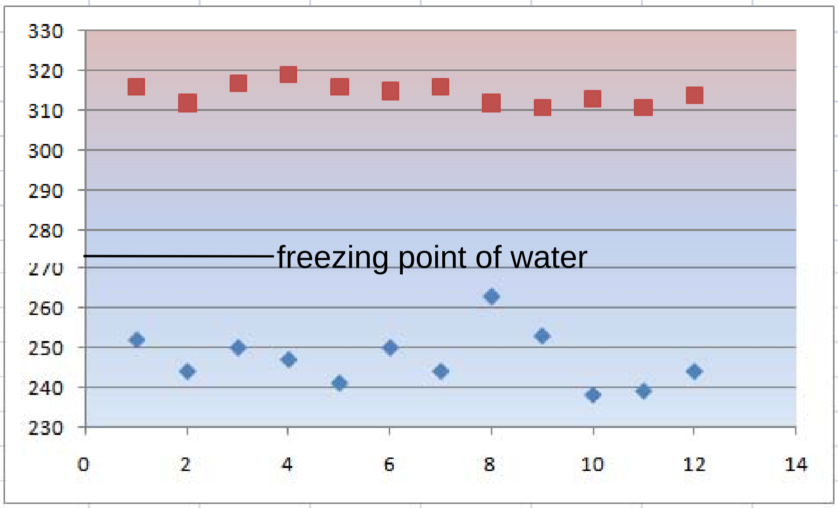
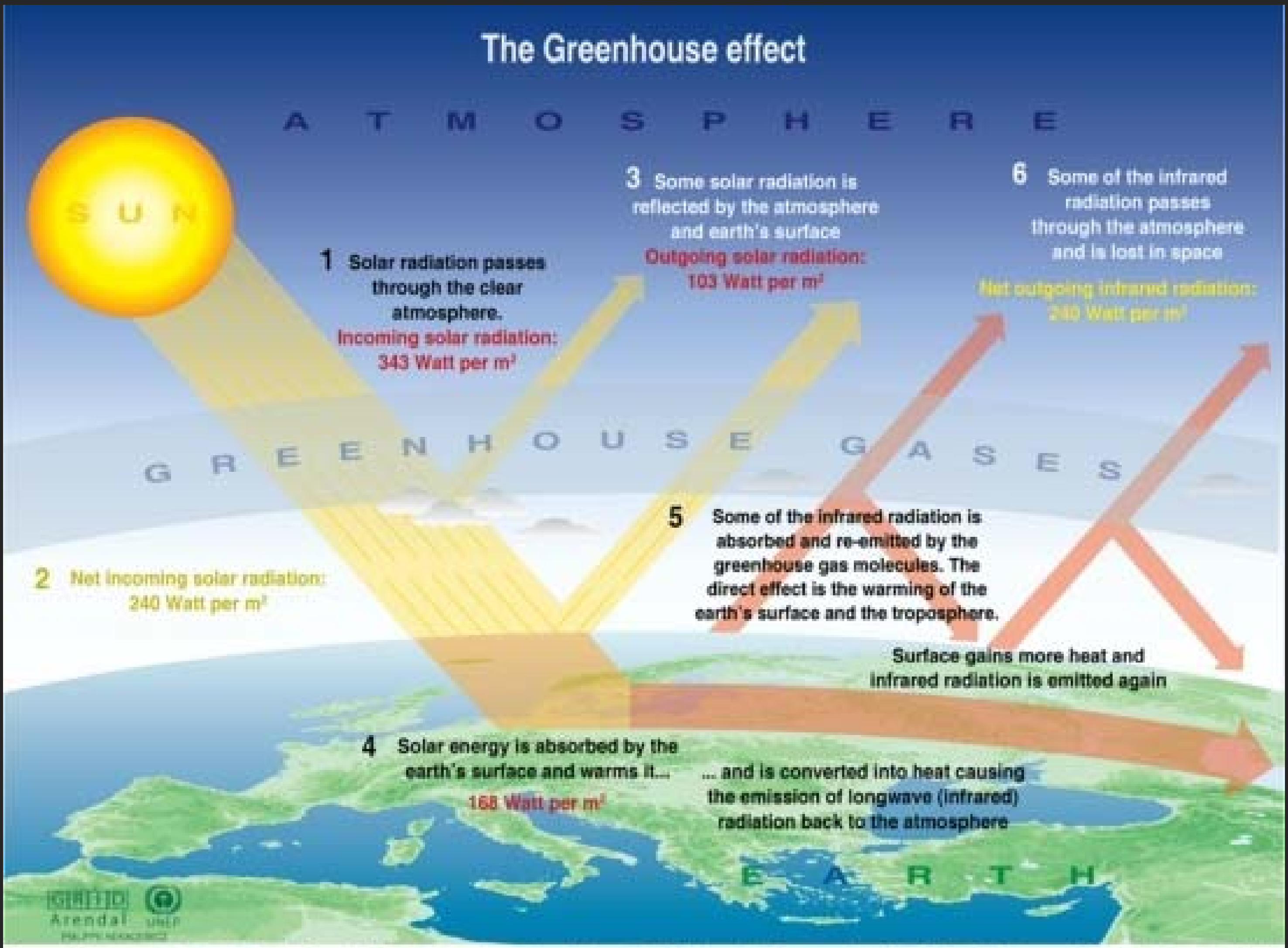
THE BRIDGE TRAGEDY • MURDOCH'S WAR PLAN
Newsweek
Global Warming Is A Hoax.*
* Or so claim well-funded naysayers who still reject the overwhelming evidence of climate change. Inside the denial machine. By Sharon Begley
NASA image of the Sun

HotNCold.xlsx - Microsoft Excel

B15 =AVERAGE(B2:B13)

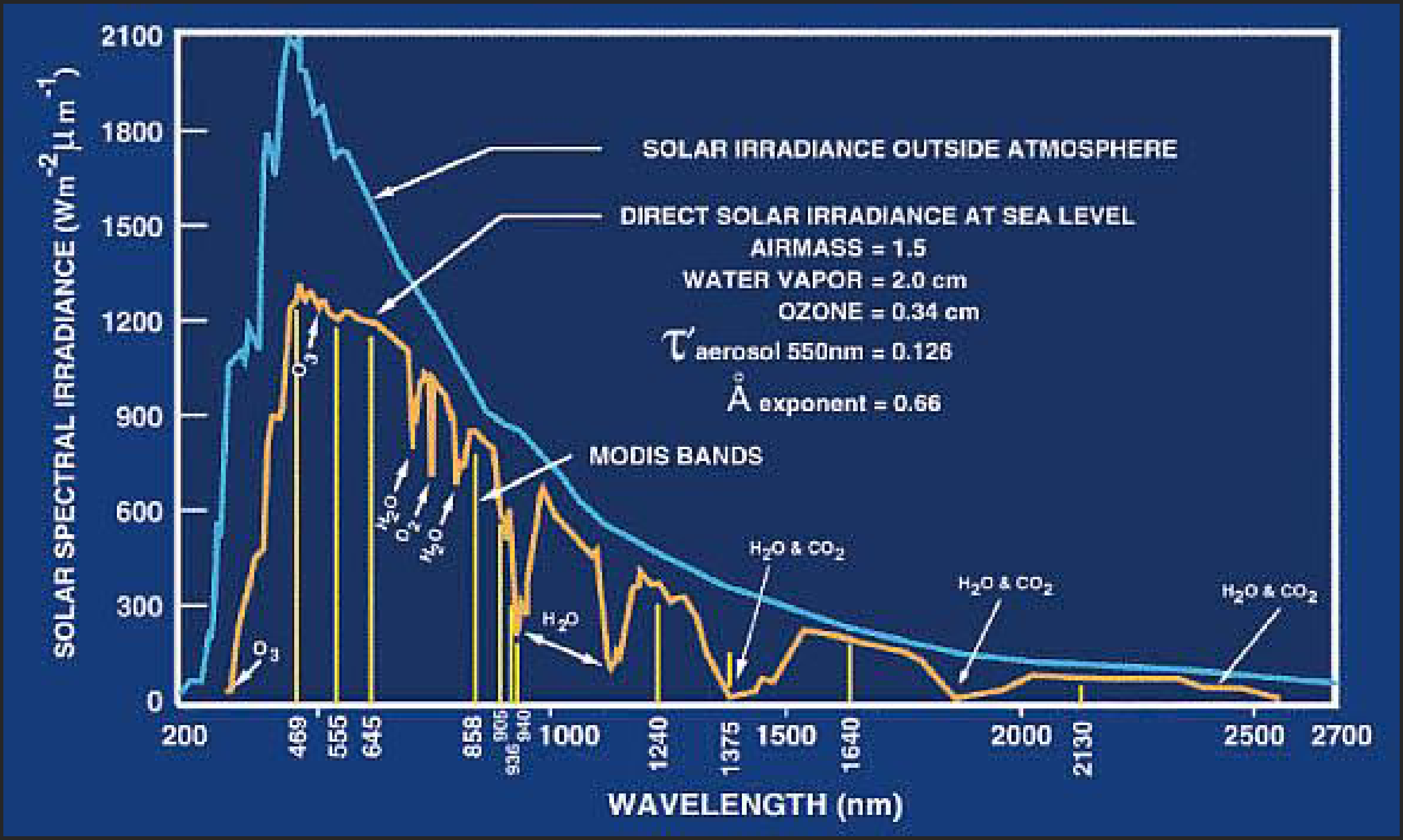
	A	B	C
1		coldest	hottest
2	1	252	316
3	2	244	312
4	3	250	317
5	4	247	319
6	5	241	316
7	6	250	315
8	7	244	316
9	8	263	312
10	9	253	311
11	10	238	313
12	11	239	311
13	12	244	314
14			
15		247.08	314.33
16		7.03	2.57

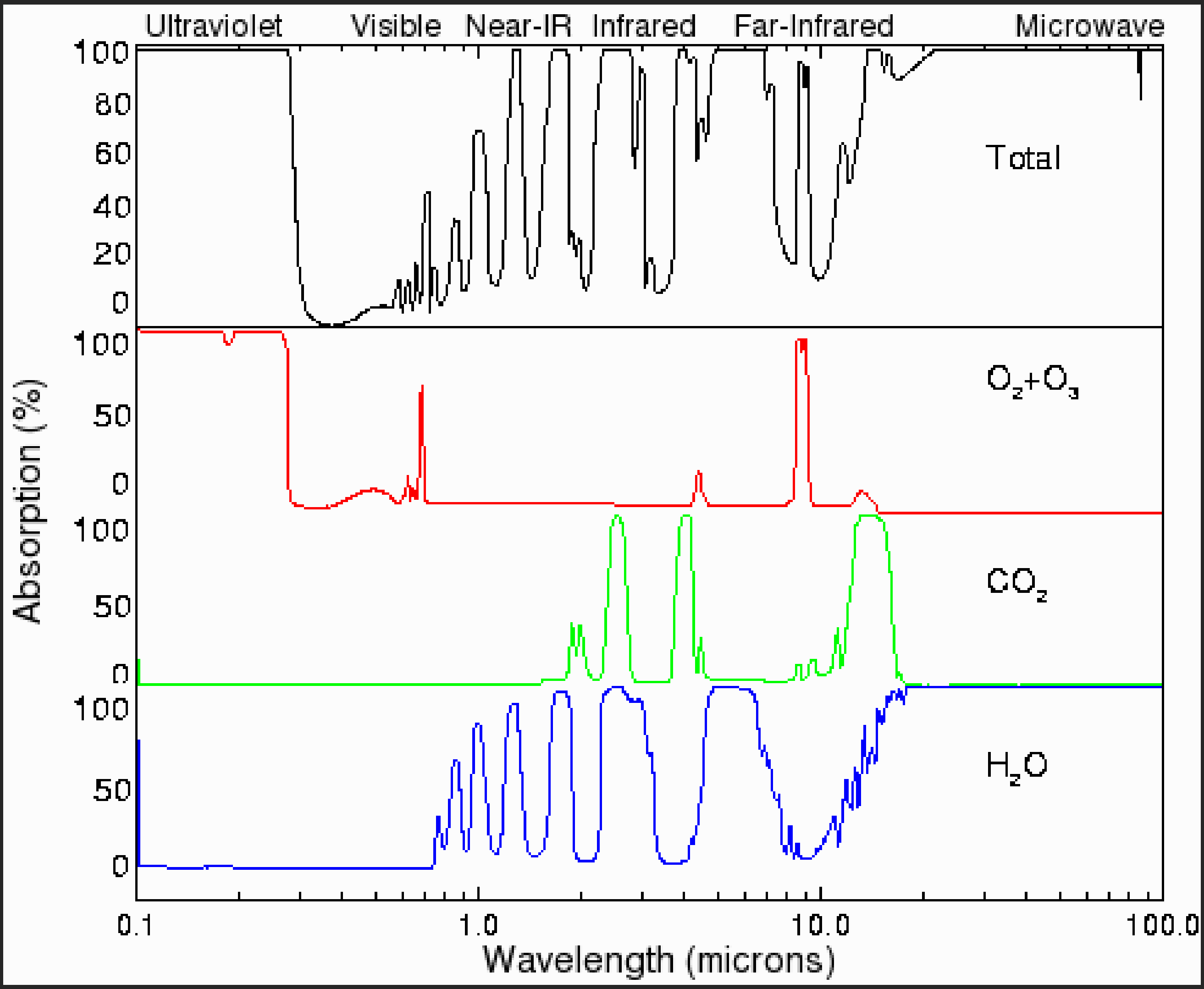




Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Absorption of incoming sunlight




Ultraviolet
Visible
Near-IR
Infrared
Far-Infrared
Microwave
Total
O_2+O_3
CO_2
H_2O
Absorption (%)
100
80
60
40
20
0
100
50
0
100
50
0
100
50
0
0.1
1.0
10.0
100.0
Wavelength (microns)

- Wikipedia, the free encyclopedia - Windows Internet Explorer

http://en.wikipedia.org/wiki/Infrared#The_Earth_as_an_infrared_emitter

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Infrared

From Wikipedia, the free encyclopedia

For other uses, see Infrared (disambiguation).

Infrared (IR) radiation is electromagnetic radiation whose wavelength is longer than that of visible light (400–700 nm), but shorter than that of terahertz radiation (100 μm – 1 mm) and microwaves. Infrared radiation spans more than three orders of magnitude (roughly 700 nm to 300 μm).[1]

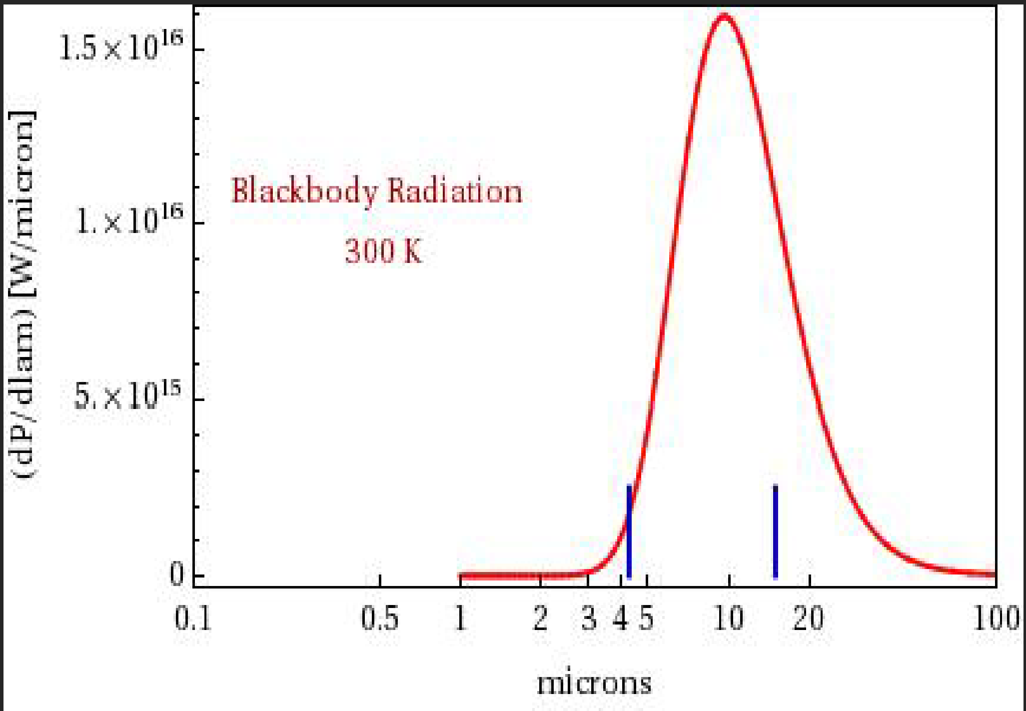
Direct sunlight has a luminous efficacy of about 93 lumens per watt of radiant flux, which includes infrared (47% share of the spectrum), visible (46%), and ultra-violet (only 6%) light. Bright sunlight provides luminance of approximately 100,000 candela per square meter at the Earth's surface.

Image of two human bodies
("thermal") light (false-color)

Contents [hide]

Adobe Illustrator | Topic6 | Infrared - Wikipedia, ...

Outgoing IR radiation from the surface of the Earth



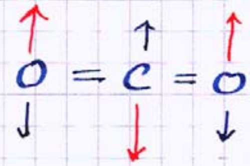
CO_2 absorption lines:
4.26 microns = antisymmetric stretch
14.99 microns = bending mode

The vibrational states of a carbon dioxide molecule E4/1

$O = C = O$ a linear molecule

Modes of Vibration

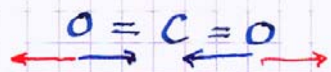
(1) Bending mode



- $\frac{\nu}{c} = 667 \ cm^{-1}$
- $\Delta E = \hbar\omega = \frac{h}{2\pi} 2\pi\nu = h\nu = hc\frac{\nu}{c} = 2\pi\hbar c\frac{\nu}{c}$

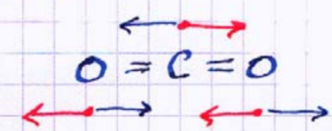
  $\Delta E = 2\pi \times 197 \ eV.nm \times \frac{667}{10^7 \ nm} = 0.0826 \ eV$
- The electric dipole moment is not 0
  $\Rightarrow$ there are strong electromagnetic transitions between the vibrational states. → i.e. emission or absorption of photons

(2) Symmetric stretch



- $\frac{\nu}{c} = 1388 \ cm^{-1}$
- $\Delta E = \hbar\omega = 0.172 \ eV$
- The electric dipole moment is 0, so there are only weak electromagnetic transitions between vibrational states; not active in the atmosphere.

(3) Antisymmetric stretch



- $\frac{\nu}{c} = 2349 \ cm^{-1}$
- $\Delta E = \hbar\omega = 0.291 \ eV$
- The electric dipole moment $\neq 0$, so there will be strong electromagnetic transitions between these vibrational states.

CO2 vibrations

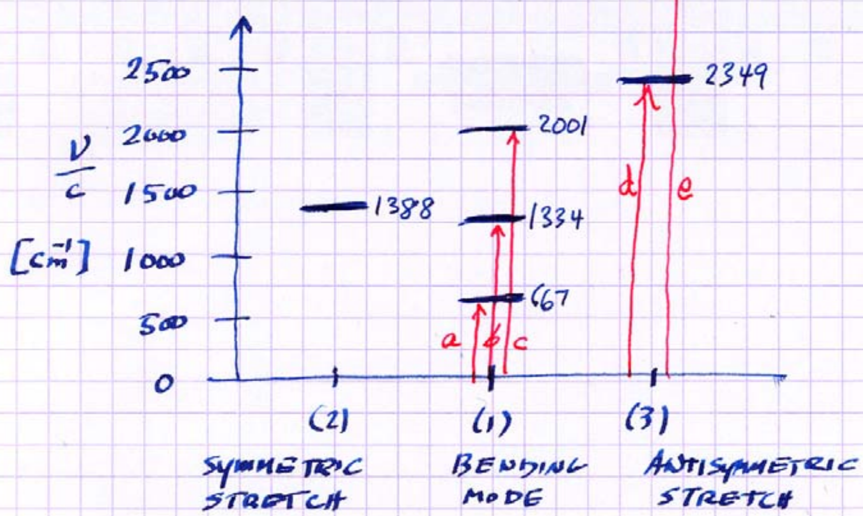
Bending Mode : $h\nu = 0.0826$ eV

$\lambda_\gamma = 14.99$ microns

Asymmetric Stretch : $h\nu = 0.291$ eV

$\lambda_\gamma = 4.26$ microns

Energy level diagram for vibrational states E4/2



$E_n = \hbar\omega\, n$

$n = 1, 2, 3, \ldots$

Absorption of I.R. photons by CO_2 in the atmosphere

$$E_\gamma = \Delta E = h\nu\,(n_2 - n_1) = h\nu\, n_2$$

(a) $E_\gamma = 0.0826$ eV $\quad \lambda_\gamma = \frac{hc}{E_\gamma} = \frac{c}{\nu} = 14.99 \times 10^3$ nm

(b) $E_\gamma = 0.165$ eV $\quad \lambda_\gamma = 7.50 \times 10^3$ nm

(c) $E_\gamma = 0.248$ eV $\quad \lambda_\gamma = 5.00 \times 10^3$ nm

(d) $E_\gamma = 0.291$ eV $\quad \lambda_\gamma = 4.26 \times 10^3$ nm

(e) $E_\gamma = 0.582$ eV $\quad \lambda_\gamma = 2.13 \times 10^3$ nm

10^3 nm = 1 micron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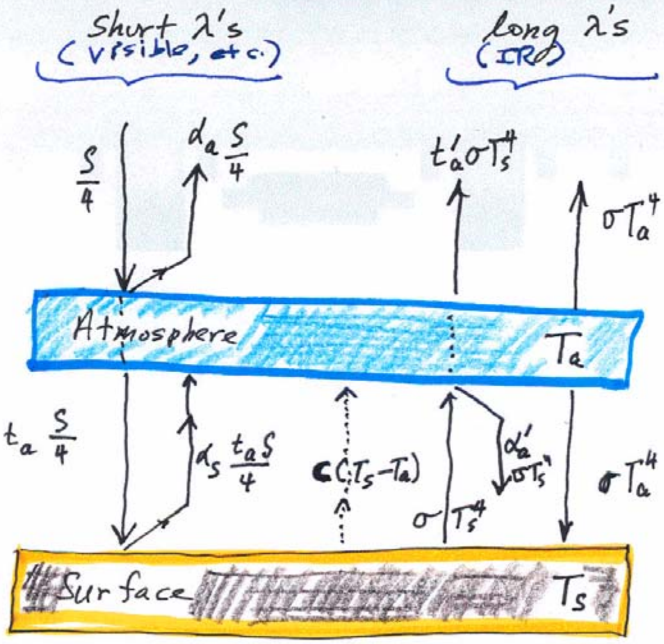

Energy Flux Diagra

"first order terms"

t_a, t'_a = transmissi coefficients

$\alpha_a, \alpha_s, \alpha'_a$ =
= albedo's
= reflection coeffici

C: convection coefficie

- Energy Balance for the Atmosphere ...

$$\text{flux in} = \frac{S}{4} + \alpha_s t_a \frac{S}{4} + c(T_s - T_a) + \sigma T_s^4$$

$$\text{flux out} = \alpha_a \frac{S}{4} + t_a \frac{S}{4} + \alpha'_a \sigma T_s^4 + t'_a \sigma T_s^4 + 2\sigma T_a^4$$

(Read about this model in Boeker & Grondelle)

$$= \left[1 - \alpha_a - t_a(1-\alpha_s)\right]\frac{S}{4} + c(T_s - T_a) + (1 - \alpha'_a - t'_a)\sigma T_s^4 - 2\sigma T_a^4$$

- Energy Balance for the Surface ...

$$\text{flux in} = t_a \frac{S}{4} + \alpha'_a \sigma T_s^4 + \sigma T_a^4$$

$$\text{flux out} = \alpha_s t_a \frac{S}{4} + c(T_s - T_a) + \sigma T_s^4$$

$$S_{in} - S_{out} = 0 \qquad \text{Eq. (3.1)}$$

$$= t_a(1-\alpha_s)\frac{S}{4} - c(T_s - T_a) + \sigma T_a^4 - (1-\alpha'_a)\sigma T_s^4$$

- Energy flux for the whole earth (atmos. + surface)

Add equations (3.1) and (3.2) ⇒

$$0 = (1-\alpha_a)\frac{S}{4} - t'_a \sigma T_s^4 - \sigma T_a^4 \qquad (*)$$

Do you see why it makes sense?

Dimensional Analysis of the Equations

Note $\frac{S}{4} = \sigma T_o^4$ where $T_o = \left(\frac{S}{4\sigma}\right)^{1/4} = 278.8$ K

Write $T_a = G T_o$ and $T_s = H T_o$

where G and H are pure numbers.

(*) $0 = (1-\alpha_a)\frac{S}{4} - t_a' \sigma T_s^4 - \sigma T_a^4$

$0 = 1-\alpha_a - t_a' H^4 - G^4$ (dimensionless)

$$G = \{ 1 - \alpha_a - t_a' H^4 \}^{1/4} \quad \text{(A)}$$

Eq. (3,1) and (*)

$$0 = t_a(1-\alpha_s)\frac{S}{4} - c(T_s - T_a) - (1-\alpha_a')\sigma T_s^4$$
$$+ (1-\alpha_a)\frac{S}{4} - t_a' \sigma T_s^4 \quad \leftarrow [\text{that is } \sigma T_a^4 \text{ by } (*)]$$

$$0 = [t_a(1-\alpha_s) + 1 - \alpha_a]T_o^4 - \frac{cT_o}{\sigma}(H-G) - (1-\alpha_a' + t_a')H^4 T_o^4$$

Define $\frac{cT_o}{\sigma} = \gamma T_o^4$ i.e., $\gamma = \frac{c}{\sigma T_o^3}$

Dimensions of γ are $\frac{W/m^2/K}{W/m^2/K^4 \cdot K^3} = 1$

$$0 = [t_a(1-\alpha_s) + 1 - \alpha_a] + \gamma(G-H) - (1-\alpha_a' + t_a')H^4$$

$$H = \left\{ \frac{[t_a(1-\alpha_s) + 1 - \alpha_a] + \gamma(G-H)}{1-\alpha_a' + t_a'} \right\}^{1/4} \quad \text{(B)}$$

Solve (A) and (B) by iteration using a computer.

Given the parameter values $(\alpha_a, t_a ; \alpha_s', \alpha_a', t_a' ; \gamma)$

Calculate $T_{atmos.} = G T_o$ and $T_{surf.} = H T_o$.