An improved energy balance model:
Atmosphere and Greenhouse gases

1) Absorption by atmosphere;
2) Greenhouse gases;

Summary: Earth Energy Balance Equation

$P_{in} = P_{out}$

$P_{in} = (1-A)\, S\, \pi\, R_{Earth}^2$, $P_{out} = 4\pi\, R_{Earth}^2\, \sigma\, T_{Earth}^4$

$T_{earth} =$ 255K

Q0

The solar constant is 1kW/m^2 and the radius of the earth is 6400km, the incoming radiation power absorbed by the earth is approximately

1) 1000 kW;
2) 1,000,000 kW;
3) 1,000,000,000 kW;
4) 10^{14} kW.

Earth Energy Budget Sheet

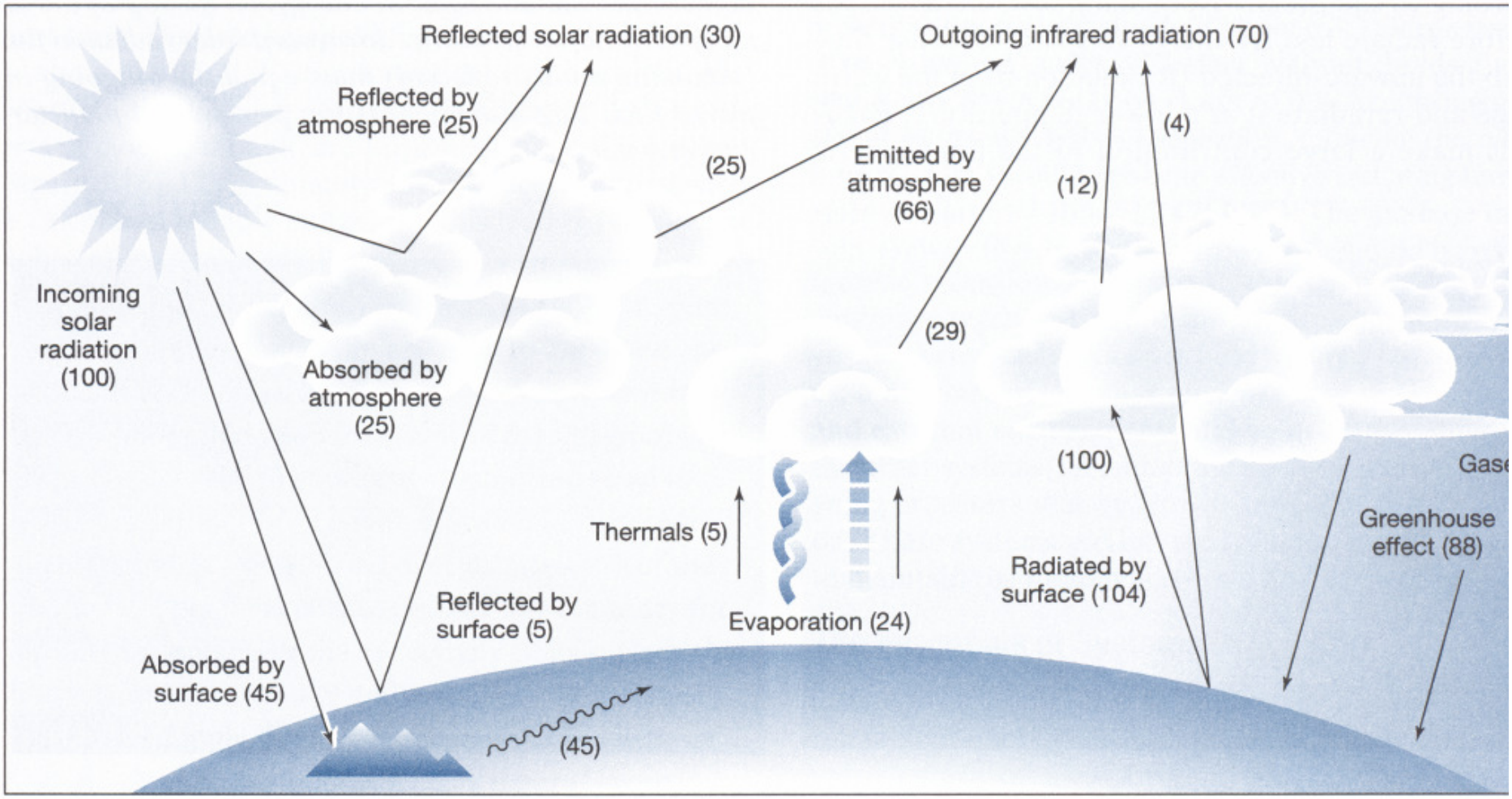
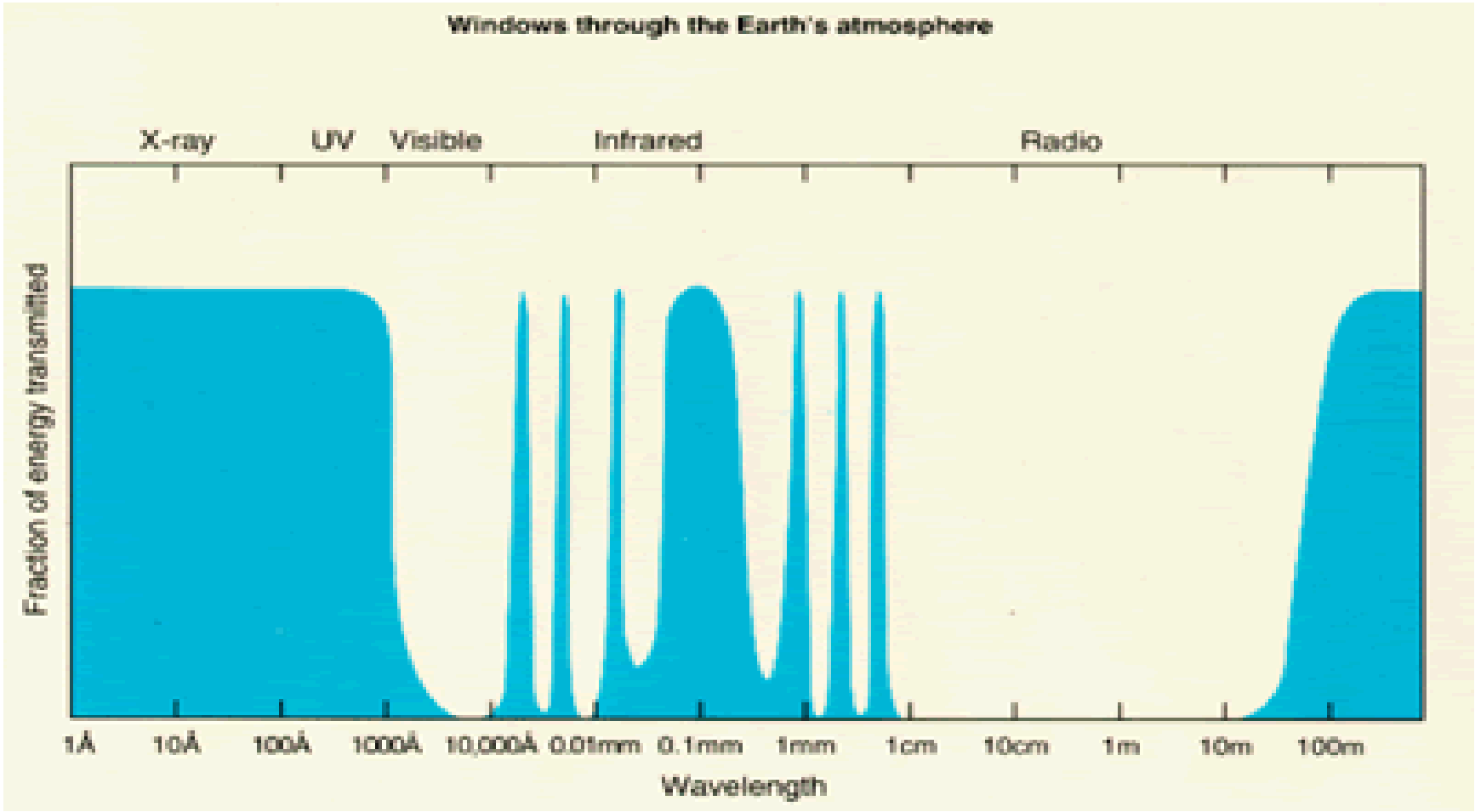


FIGURE 3-19

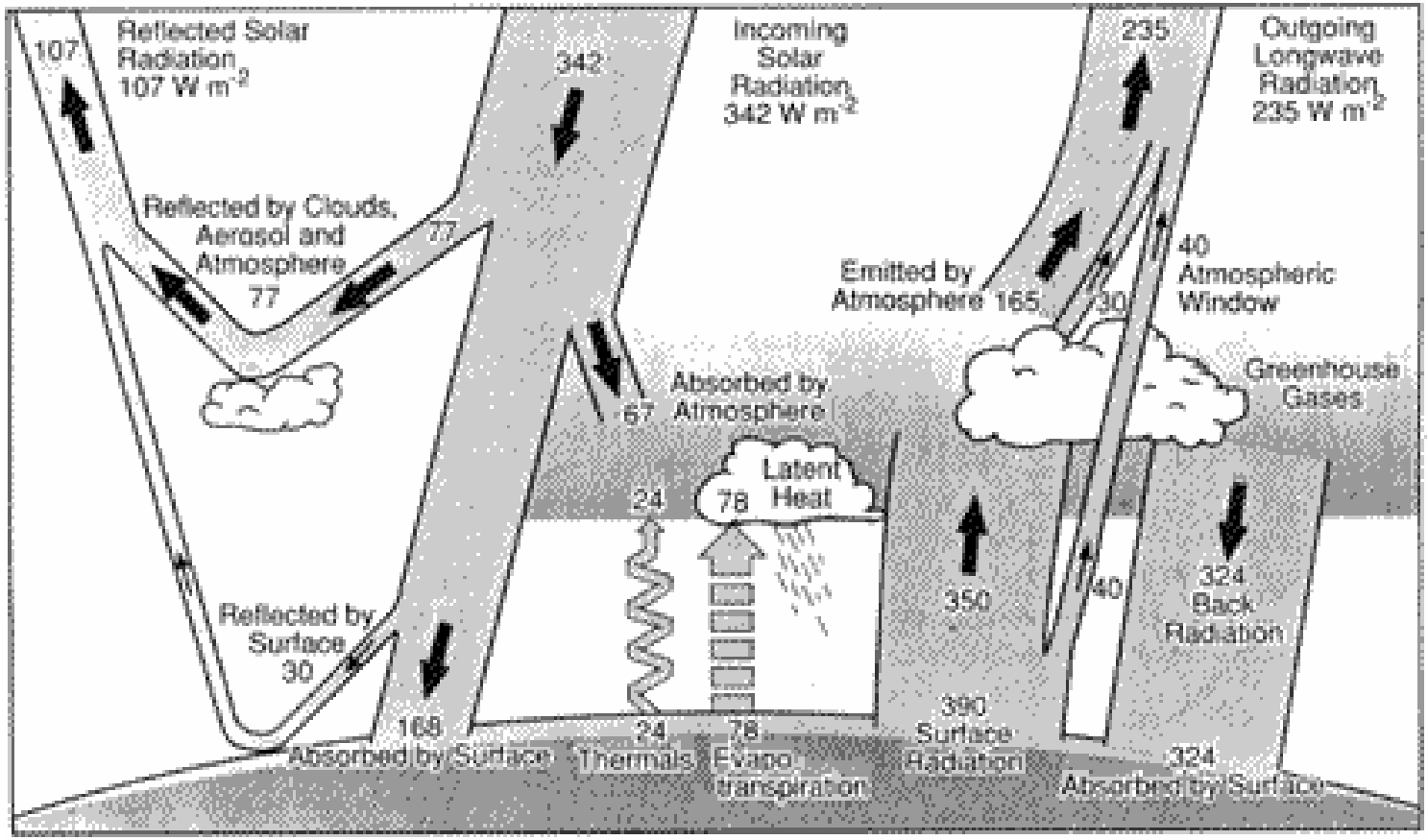
Earth's globally averaged atmospheric energy budget. All fluxes are normalized relative to 100 arbitrary units of incident radiation. (From Schneider, *Climate Modeling*, Scientific American, 256:5, 72–80, 1987.)

Atmospheric Absorption



- From: http://www.everythingweather.com/atmospheric-radiation/absorption.shtml

Atmospheric Absorption



- From: http://www.everythingweather.com/atmospheric-radiation/absorption.shtml

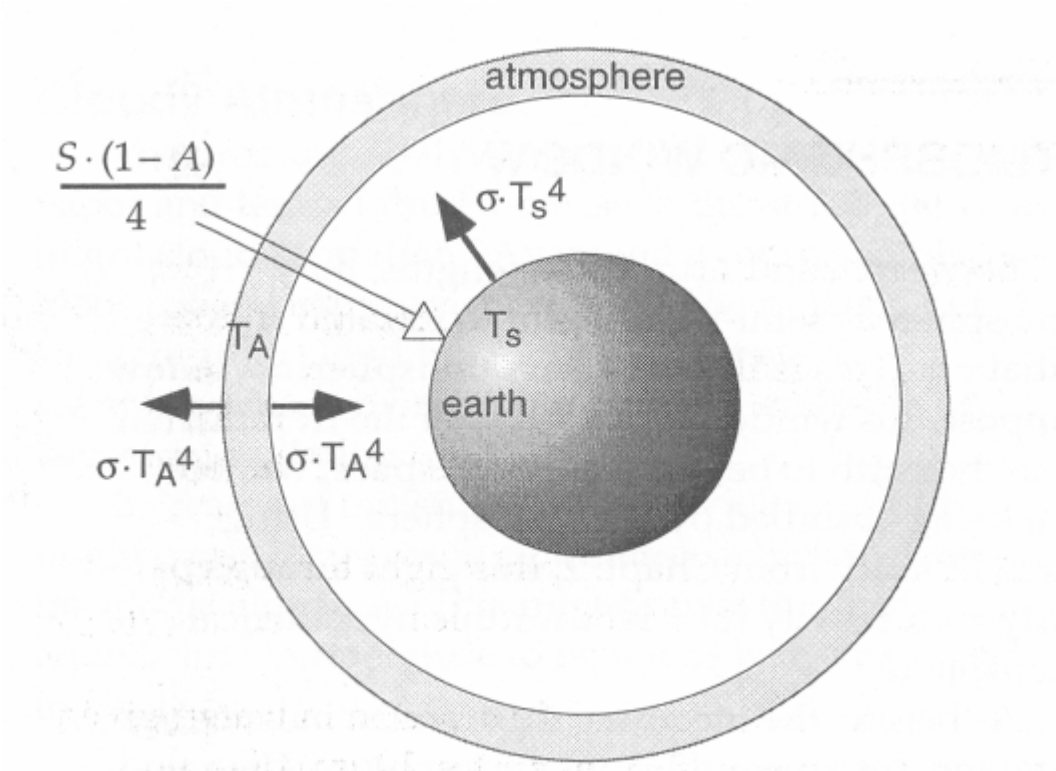
Green house effect

1) **Model one: Glass layer effects on the earth temperature;**

2) **An atmospheric model with Green house effect (with Green house gases).**

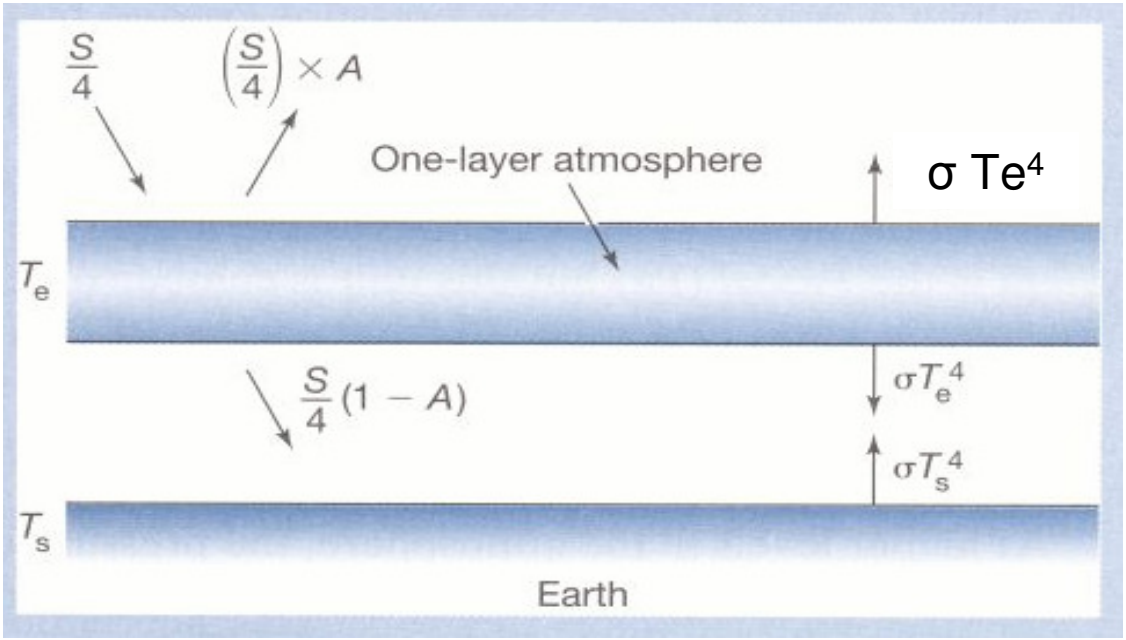
Earth Energy Balance

We will again make a very simple model but one which includes atmosphere



Now the energy balance for the surface of the Earth is:

- $P_{in} = (1\text{-}A)\ S\ \pi\ R_{Earth}^2 + \sigma\ T_e^4\ 4\pi\ R_{Earth}^2$
- $P_{out} = \sigma\ T_s^4\ 4\pi\ R_{Earth}^2$



Now the energy balance for the surface of the Earth is:

$$(1\text{-}A)\, S\, \pi\, R_{Earth}^2 + \sigma\, T_e^4\, 4\, \pi\, R_{Earth}^2 =$$

$$\sigma\, T_s^4\, 4\pi\, R_{Earth}^2$$

- $T_s^4 = (1\text{-}A)\, S\, /\, 4\sigma + T_e^4 = 2\, T_e^4$

(Assuming $T_e = 255$ K)

Q1

Using the improved climate model, I find that the surface temperature of the earth is

1) 0C
2) 15 C
3) 30C
4) 60 C

You should get

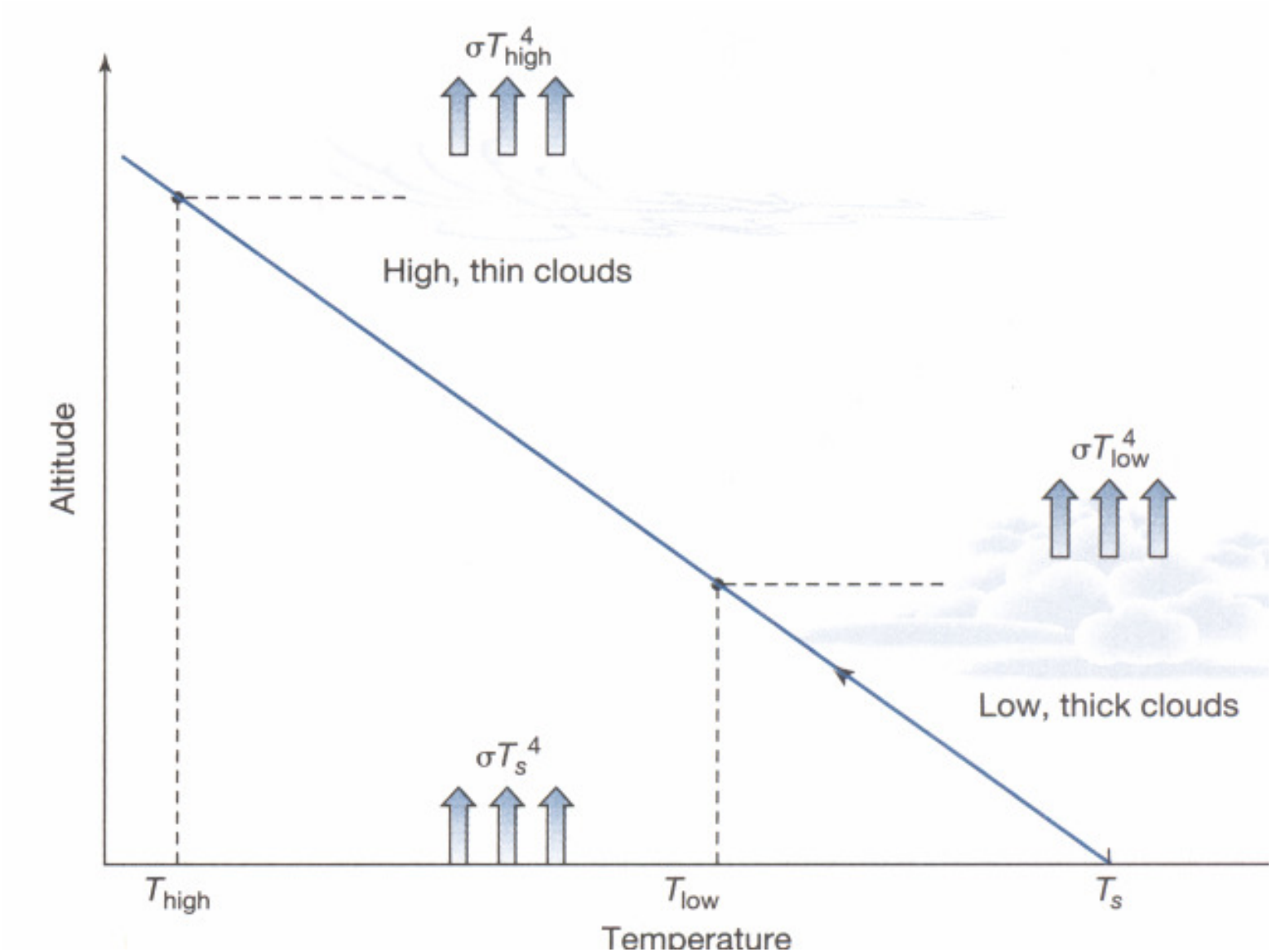
$$T_s = T_e \sqrt{2} = 303 \text{ K} = 30 \text{ ºC}$$

- Not really – too hot!

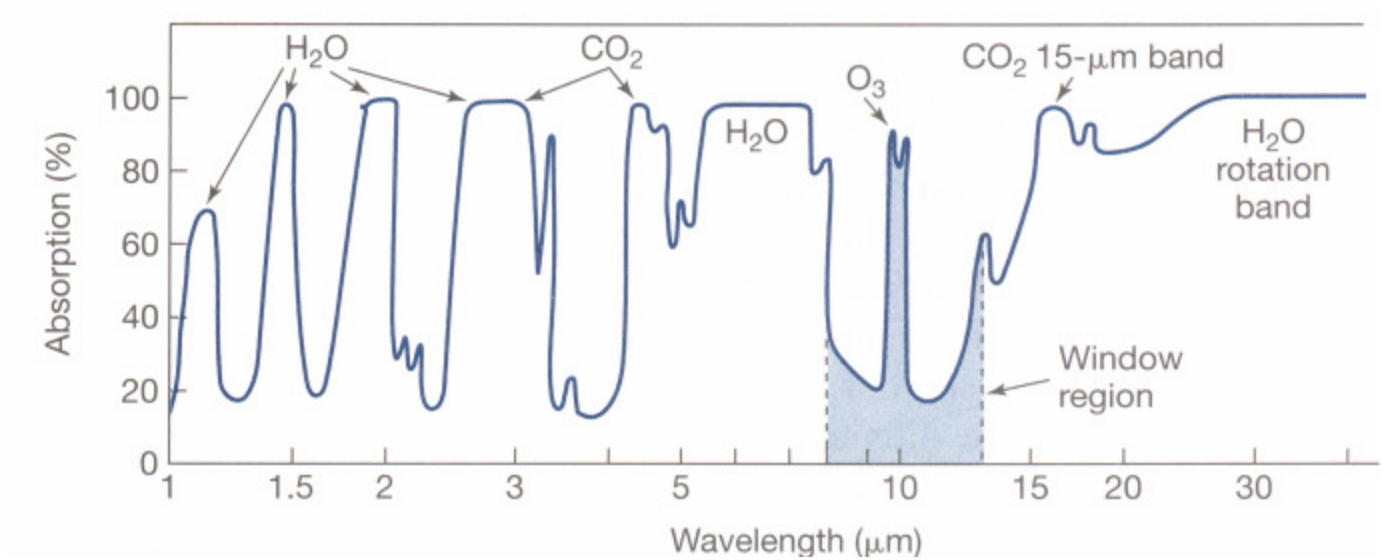
Issues:

- Is atmosphere a thin layer?
- Is it totally absorbing in infrared?

Different layers of the atmosphere



Lets have a closer look in infrared region.



We see plenty of “holes”.

Earth Energy Balance

- The more complex models involving multilayer atmosphere partially transparent in infrared come up with better estimates of temperatures of the surface of the Earth – about 15 ºC