Thermal Radiation



Absorption and Emission

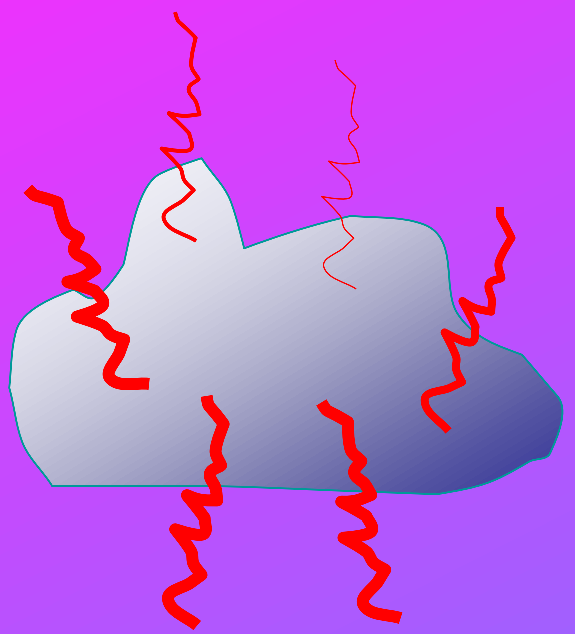
"A good absorber of radiation must also be a good emitter of thermal radiation."

Why?

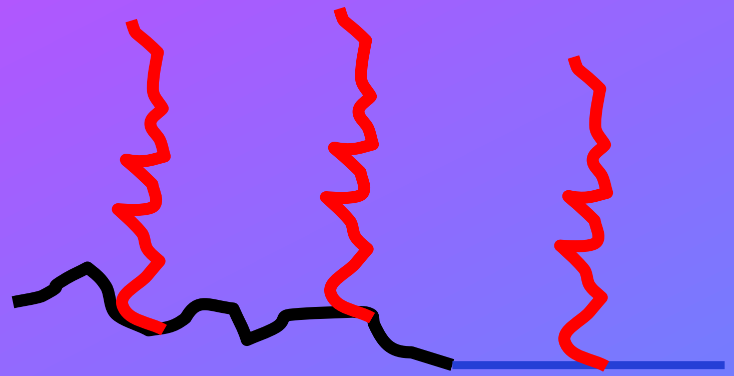
(what would happen if an object absorbs everything but emits nothing?)

An **ideal** absorber absorbs all EM radiation that falls on it, and will radiate energy away at the maximum possible efficiency.

Things that act like Thermal Blackbodies



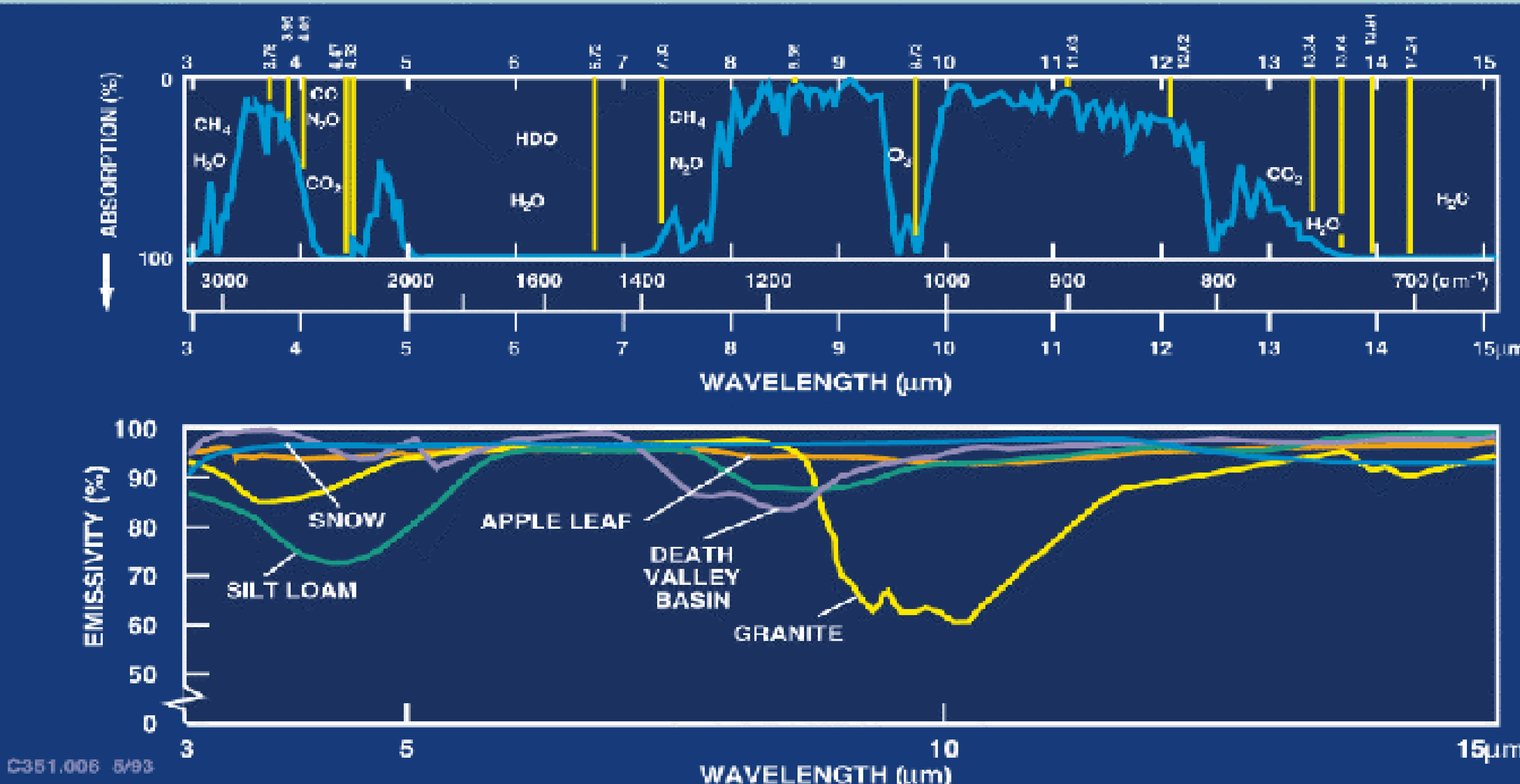
Since water absorbs IR, clouds can absorb and emit like blackbodies. But it may take several hundred meters for absorption to occur, so the emission will be from that same depth.



Land and water will also absorb and re-emit very well, usually in the top one or two mm.

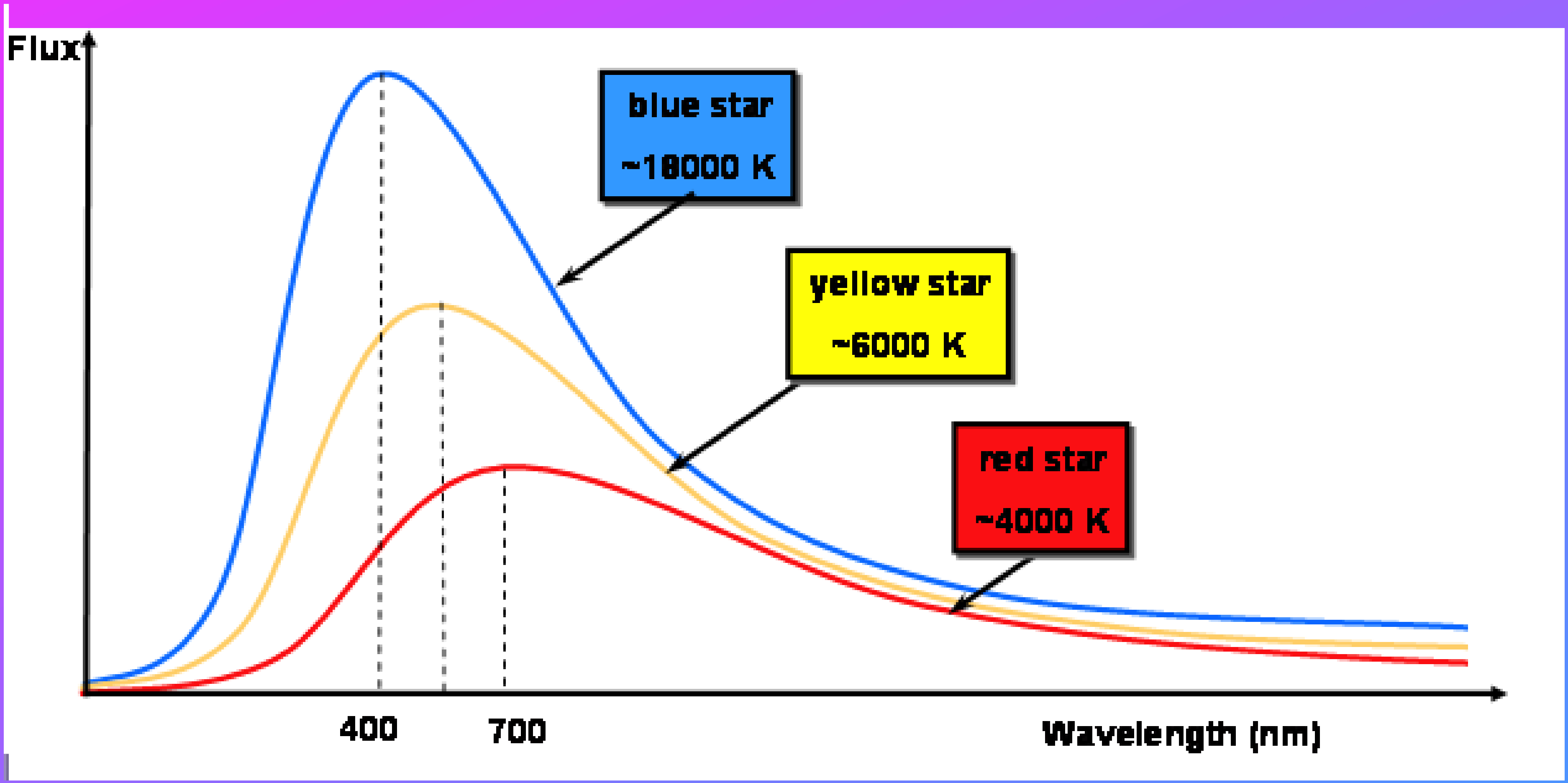
Atmospheric transmission at top….

LAND - THERMAL RADIATION



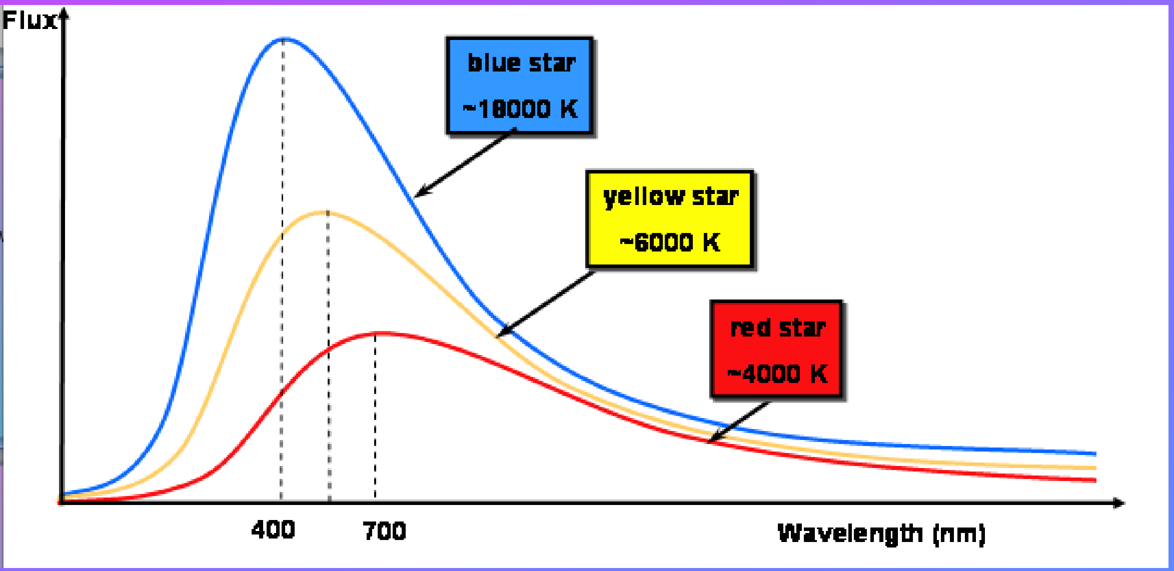
Emission from various surface types at bottom.

Ideal Thermal Radiation



Shift of Peak with Temperature
(Wien’s Displacement Law)

$$T\lambda_{max} = \text{constant} \quad (2897\ \mu mK)$$



Q1: if sunlight peaks in the yellow (0.5 μm), what is the temperature?

$T = \text{constant}/\lambda = (2.897\text{x}10^{3}\ \mu\text{mK})/(5\text{x}10^{-1}\ \mu\text{m})$
$= 0.58 \times 10^{4}\ \text{K} = 5.8 \times 10^{3}\ \text{K}$

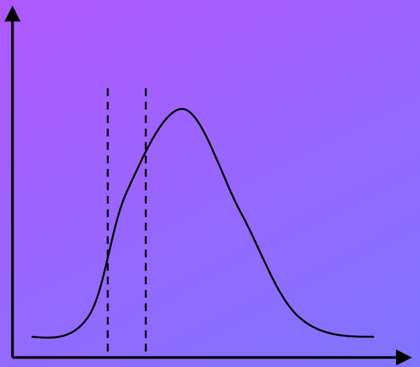
Q2: approximately at what wavelength does Earth's thermal radiation peak?

$\lambda = \text{constant}/T = (2.897\text{x}10^{3}\ \mu\text{mK})/(290\ \text{K})$
$= (2.897\text{x}10^{3})/(2.9\text{x}10^{2})\ \mu\text{m} = 10^{1}\ \mu\text{m}$

The Planck Function

Intensity around a single wavelength

$$I(\lambda, T) = \varepsilon \frac{A}{\lambda^5\left(\exp\left(\frac{B}{\lambda T}\right) - 1\right)}$$



I gives you the radiant intensity from an object per unit area at a given wavelength and temperature.

$A = 1.19 \times 10^8\ \mathrm{W\mu m^4/m^2}$

$B = 1.441 \times 10^4\ \mathrm{\mu m\ K}$

Emissivity ε ranges from 0 to 1, and depends on the material.

Note the result is in $(\mathrm{W/m^2})/\mathrm{\mu m}$, so represents a micron range of the spectrum around the wavelength.

Plug 'n Play

At typical Earth temperatures, how much radiation will be emitted per square meter within a 1 micron slice of spectrum centered on 10 microns?
(assume emissivity = 1)

$$I(10\mu m, 300K) = 1\frac{1.19x10^{8}\, W\mu m^{4}/m^{2}}{(10^{1}\mu m)^{5}\left(\exp\left(\frac{1.441x10^{4}\mu m K}{(10^{1}\mu m)(3x10^{2}K)}\right)-1\right)}$$

$$= \frac{1.19x10^{3}\, W/m^{2}\mu m}{\exp\left(\frac{1.441}{3}\frac{10^{4}}{10^{1}10^{2}}\right)-1} = 0.00984x10^{3}\, W/m^{2}\mu m = 9.84\, W/m^{2}\mu m$$

(14.41) / 3

Brightness Temperature

What if you have the satellite values of Intensity for thermal radiation, but want to know the temperature?

Solve the $I(\lambda,T)$ equation for temperature!

(the temperature you get this way is called "brightness Temperature" to remind us it's not a direct measurement.)

Brightness Temperature Calculation

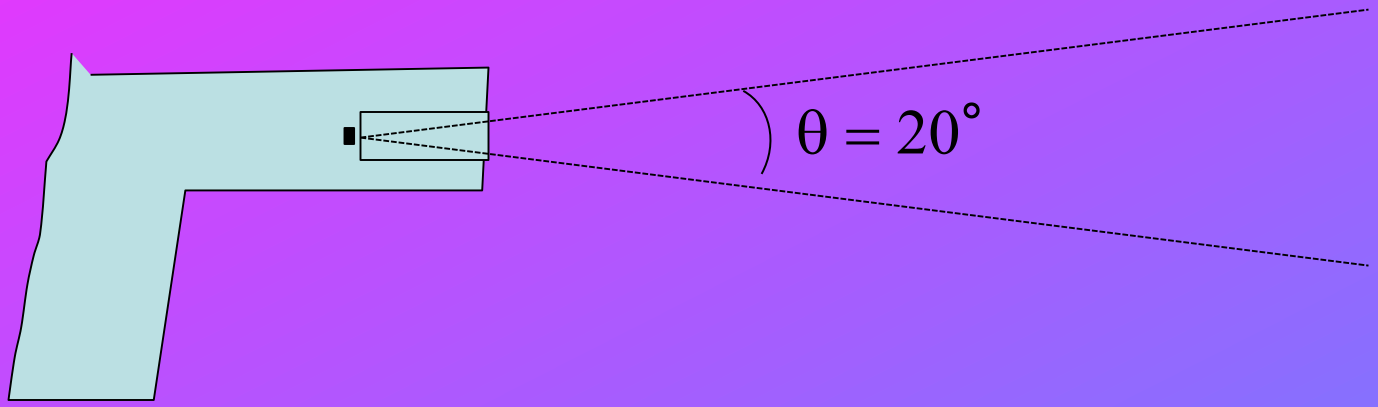
$$T_B = \frac{B}{/ \ln\left(1 + \frac{eA}{I/^5}\right)}$$

A = 1.19 x 10^8 Wμm^4/m^2

B = 1.441 x 10^4 μm K

Wavelength in microns, Intensity in W/m^2/μm

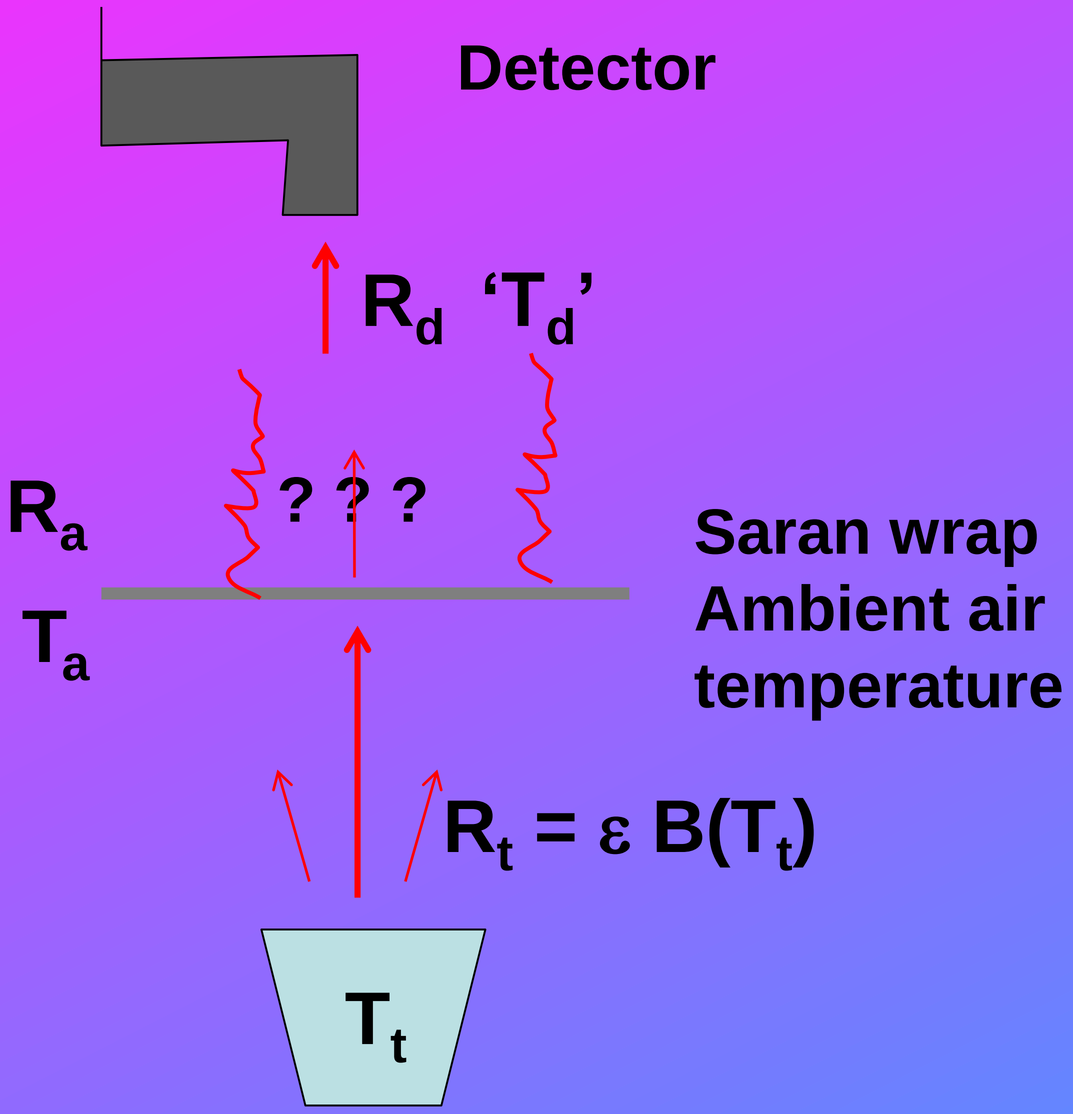
Our Temperature Guns



Collimation angle = 20˚

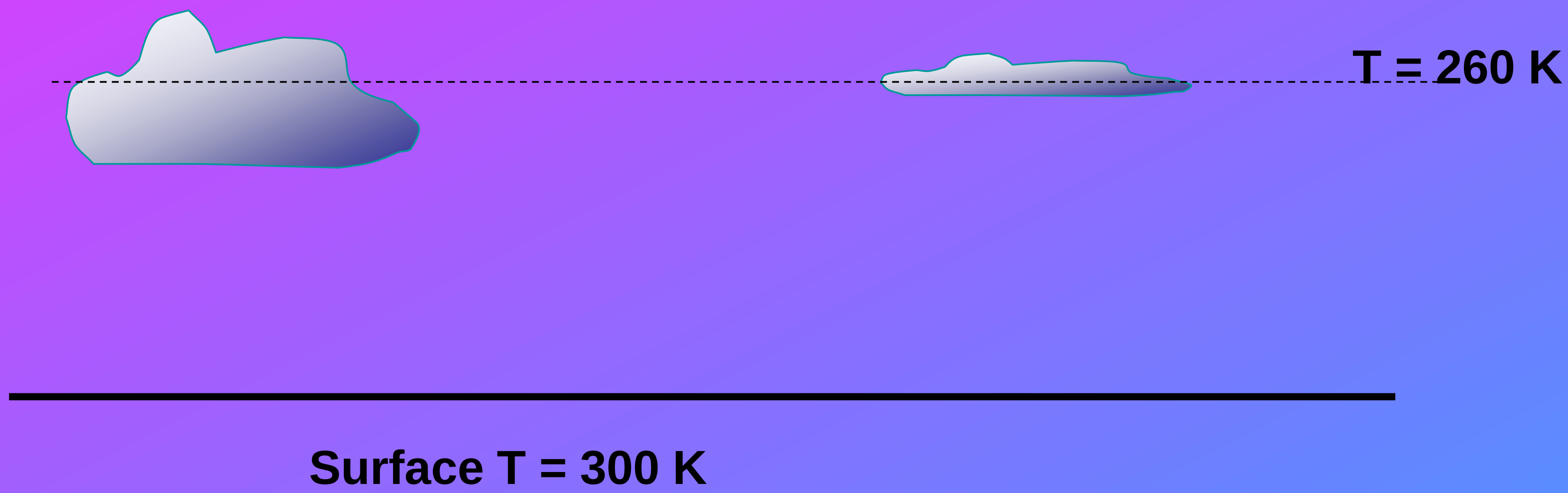
Wavelength = 10.3 μm

Assumed emissivity = 0.95



what does the saran wrap do so that at the radiance at the detector is not just R_t from the target?

Thought Problem: We have two clouds, one very thick, the other thin enough to have an emissivity of 0.5. The situation is shown below. Assume brightness temperature is calculated from the 10 um window channel.



What would be a good guess for the brightness temperature of each cloud measured from above and measured from below?

Today's Classwork :

Write a function that, given the wavelength in microns, observed intensity in $W/m^2/\mu m$, and the emissivity, will return the Brightness Temperature in Centigrade.

List your name in a comment at the top.

Test values:

IF I = 8 $W/m^2/\mu m$; wl = 10 μm, e = 0.9

Should Get BT = 20.7 C

Also IF: I = [8, 9; 7, 8.5]; BT = [20.7, 27.8; 12.9, 24.3]

Unit Project

Write a module that will do the following:

1. Make an RGB image of New York City (save the image, initial title)
2. Calculate the brightness temperature of every pixel on the map, display with colorbar scale. (save the image with initials in title)
3. Select the cloudy pixels based on temperature, (use a histogram) and calculate the scene's cloud fraction.
4. Make a scatter plot of reflectance (and/or optical depth!) versus temperature for these cloudy pixels. (save the image with initials)
5. Make a map of NDVI, green above your chosen threshold, black below this threshold. (save the image, initials in title)
6. for non-cloud pixels, scatter plot BT vs NDVI (save the image)

Include your name in the top line of the script, and include all functions used. Write a paragraph that explains why the scatter plots look the way they do. All files can be submitted via drop box.

To be turned in for Project

- A “master script” file that has all the commands used to produce the project output, in sequence. Functions at the end. Scored by Abdou.
- Image files: RGB image, Thermal image, Scatter plot, NDVI image.
- The paragraph that explains the scatter plots should be in the email.

On the top line of all files put your name