Applications with the Newest Multi-spectral Environmental Satellites

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Homework Assignment (Due 11 June 2007)

1. What is the ratio of blackbody radiances at B(10 μm, 300 K) and B(0.5 μm, 6000 K)? Estimate this without calculating the radiances explicitly.

2. If the 4 μm brightness temperature is 310 K and the 11 μm brightness temperature is 290 K, what fraction of the radiance at 4 μm is due to reflected solar radiation? Use the fact that B(4 μm, T) is proportional to T^X where x ~ 12.

3. If the effective temperature of Earth is 255 K (defined as blackbody temperature at which solar energy received is equal to infrared energy released) and the surface temperature is 285 K, what is the average absorptance of the atmosphere of Earth to infrared radiation? Assume that the surface behaves like a blackbody and the atmosphere is transparent to solar radiation; use conservation of energy at the top of the atmosphere and at the surface to derive your answer.

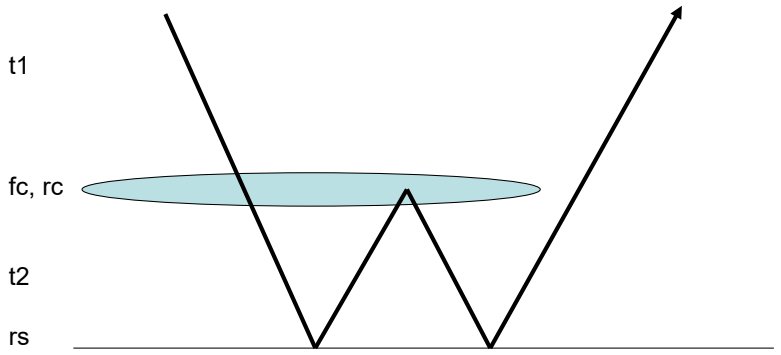
4. Measurements of outgoing radiation from the earth-atmosphere system in a nadir viewing radiometer yield brightness temperatures of 310 K in the infrared window at 900 cm-1, 220 K in the CO2 band at 660 cm-1, and 280 K in the O3 band at 1040 cm-1. What is the transmission of the ozone layer at 1040 cm-1? Assume the earth surface radiates as a blackbody, the stratosphere is opaque at 660 cm-1, and the ozone resides exclusively in the stratosphere. Note that Planck radiances B(1040 cm-1, T) = 14.8, 64.1, and 107.9 mW/m2/ster/cm-1 for T = 220 K, 280 K, and 310 K respectively.

5. Two window channels (11 and 12 μm) are viewing the ocean in cloud free conditions. The observed brightness temperatures are 297 K and 294 K. The respective atmospheric transmittances are .98 and .95. (a) What is the ratio of the absorbing powers kw11/kw12? (b) What is the SST?

6a. The ocean surface at 300 K is covered by a layer of water vapor at 280 K with an optical depth of 0.05 in the infrared window (IRW) at 11 microns. The MODIS IRW measurement will be less than 300 K due to atmospheric water vapor absorption; what correction must be made to the measured brightness temperature to arrive at the correct SST? Assume the ocean surface behaves like a blackbody, express the transmittance of the water vapor $\tau = 1-\sigma$, and use the fact that at 11 microns the Planck radiance is proportional to T^4.

6b. If the earth surface is not a blackbody but has an emissivity of 0.9, what is your answer?

7. A model atmosphere consists of an upper layer with transmittance t1, a partial cloud layer with fractional area fc covered by clouds with reflectance rc in either direction, and a lower layer with transmittance t2. The earth surface has an average reflectance rs. (a) Ignoring scattering in the layers and absorption in the clouds, derive an expression for F, the fraction of solar radiation making it out of earth-atmosphere via the indicated path. (b) If t2 decreases by 1% (due to low level pollution), what is the corresponding percentage change in F?



8. Consider an atmosphere where the temperature profile is given by $T(p) = 200 + 100\ (p/ps)$ in degrees K. The transmittance for a microwave spectral band is given by $\tau(p) = 1.0 - 0.7\ (p/ps)$. Assuming reflection is negligible at the earth surface, what is the brightness temperature observed by the microwave sensor in this spectral band? Start with the RTE to develop your answer.