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ATMS 749 FINAL EXAM
UNR SPRING 2004

Each question is worth 20 points each.

1. A laser beam has an output power of 5 mW and is passing through an artificial cloud layer 10 m in thickness. The beam is directed at 30 from the normal to the layer.

a) Neglecting the effect of multiple scattering, calculate the extinction coefficients (per length) if the measured power exiting the cloud are (i) 1.57576 mW and (ii) 0.01554 mW. Also calculate the normal optical depths in these cases.

Hint: Use the Beer-Bouguer-Lambert Law.

b) Which component of the total radiation field does this calculation refer to? (Direct, Diffuse, or Total)?

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2. Sketch the extinction efficiency factor, Q_{ext}, as a function of the size parameter $x=2\pi a/\lambda$ where a is the radius of the water droplet and λ is the wavelength of light. Identify the Rayleigh regime in your sketch as well as the geometrical optics regime. Show the limiting value of Q_{ext} for large x. Explain the oscillations and ripples in the curve. Show the Q_{ext} curve for various imaginary part of the refractive index.

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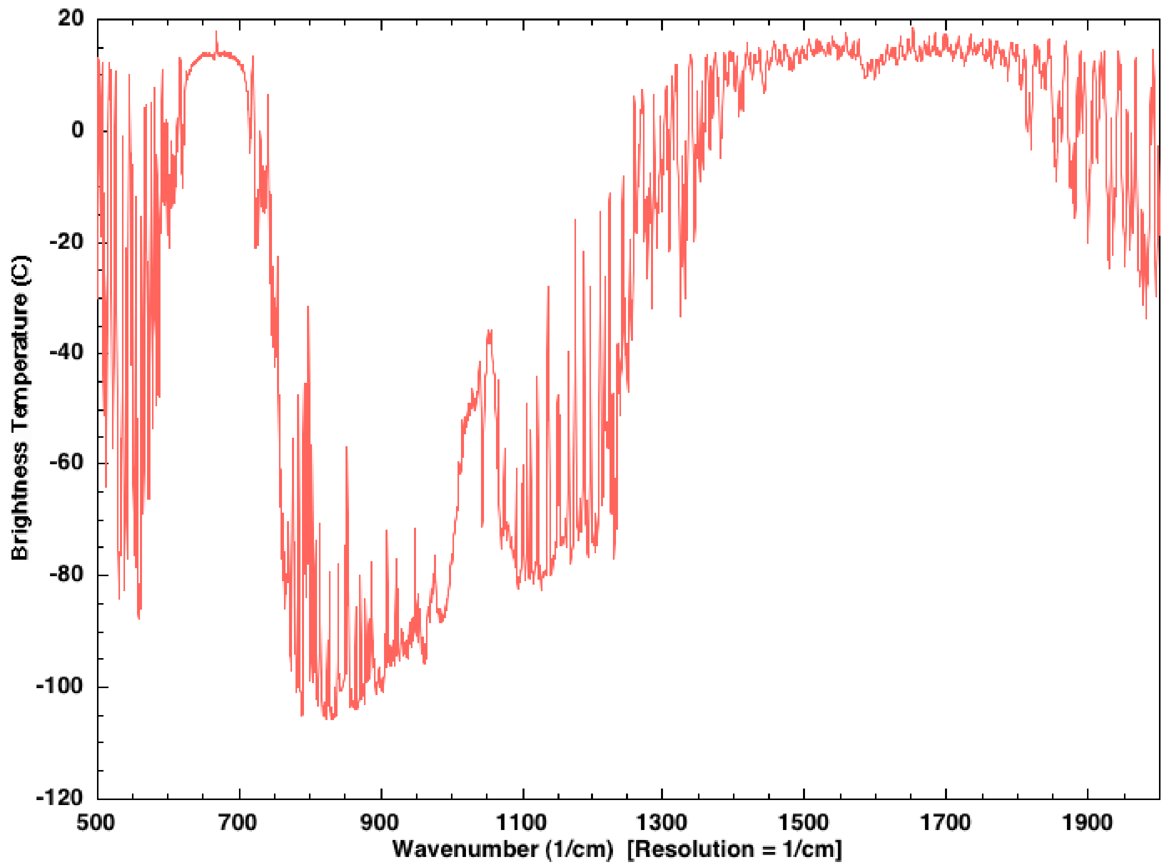

3. The above figure shows the brightness temperature of radiance observed at the ground with a spectrometer looking straight up.

(a) What is the relationship used to obtain the brightness temperature? You can give the basic idea without explicitly doing the calculation if you don't remember an equation.

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(b) What is the significance of the brightness temperature in relation to the atmosphere composition and thermodynamic profile? For example, why is the brightness temperature at 700 cm^{-1} higher than at 900 cm^{-1}?

(c) The wavenumber range from about 750 cm^{-1} to about 1250 cm^{-1} is sometimes described as the atmospheric window range. In what ways does the figure above suggest this description? (It might be helpful to make the connection between surface radiance, and outgoing radiance).

(d) Give the wavenumber ranges where strong contributions to downward radiance occur for:

i. H_20,

ii. CO_2,

iii. O_3.

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4. Consider an isothermal, isobaric atmosphere characterized by a temperature T and a pressure P [units of Kelvin and atm, respectively]. This artificial atmosphere extends a distance L above the surface of the planet. The surface temperature is T_s. Let the atmosphere be composed of only 1 absorbing gas having a relative concentration of C [units of ppmv], and absorption efficiency Babs(ν) [units cm^2 / molecule]. The units are only given as a memory aid, or as a guide to make sure you have the correct relation through unit analysis.

Use constants where you need to without giving explicit values. Use the symbol B(T) to refer to blackbody radiance at temperature T.

(a) What is the number of absorbing molecules per unit volume?

(b) What is the relationship for the absorption optical depth?

(c) What is the monochromatic transmission through the atmosphere?

(d) What is the emissivity of the atmosphere?

(e) What is the downward radiance from the atmosphere?

(f) What is the upward radiance from the atmosphere alone, from the planet alone, and from the combination of planet and atmosphere?

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5. Consider the following equation:

$$R = \frac{\omega}{4(\mu + \mu_o)} P(\mu, \phi, -\mu_{0,} \phi_0) \{1 - \exp[-\tau (\frac{1}{\mu} + \frac{1}{\mu_o})]\}$$

(a) Describe the physical meaning of this expression and define the terms.

(b) Discuss how you would use this equation in a remote sensing application.

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6. In a homework exercise, the SBDART multiple scattering radiative transfer model was utilized to calculate radiances in narrow visible and near-infrared wavebands for a cloud layer of varying optical depth. Consider now a thin cirrus (ice cloud) layer in the upper troposphere. List and discuss how the cloud microphysical properties, the atmospheric structure (temperature and humidity profiles) and the surface characteristics (albedo and emissivity) can influence the radiances of a thin cirrus cloud layer that would be observed by a satellite above the top of the atmosphere. Particularly mention the reasons for differences between observed visible (0.64 μm) and near-infrared (3.7 μm) radiances.

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7. Cloud Radiative Forcing

(a) Using the appropriate equation from those provided below, and the figures of mean annual upwelling radiation components provided on the following page, estimate the longwave cloud radiative forcing for the southern tip of South America.

$$C_{LW} = F_{LW}^{\uparrow\,clear} - F_{LW}^{\uparrow observed}$$

$$Csw = Q\ \left(r^{\,clear} - r^{\,observed} \right)$$

(b) Using the equations and result from (a) above, a value for Q of S/4 (where S is the Solar Constant) and an observed reflectivity of 0.28, determine what value of clear-sky (surface) reflectivity would allow a net cloud radiative forcing of zero.

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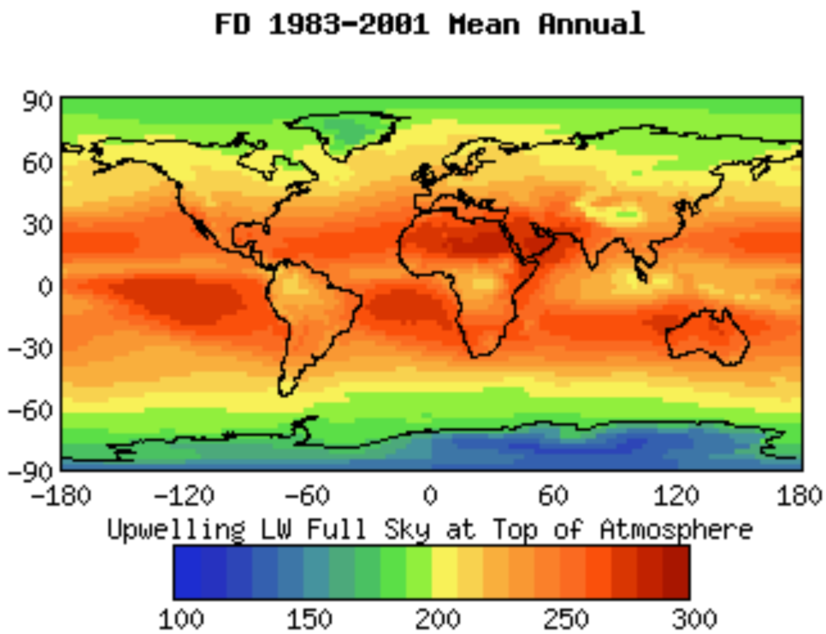
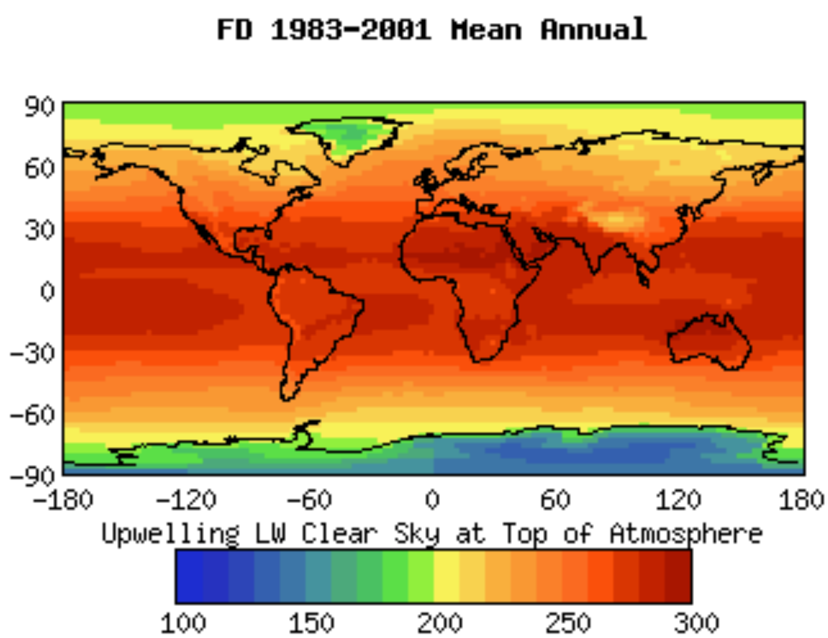
Figures for Problem 7(a):





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8. Surface Energy Budget

(a) Draw a diagram that shows this surface energy budget:

$$S_s = F_{SW}{}^{\downarrow}{}_{z=0} (1 - r_s) - \varepsilon_s \sigma T_s^4 + \varepsilon_s F_{LW}{}^{\downarrow}{}_{z=0} - LF_e - F_h$$

note: subscript s denotes "surface" (z=0)

Also, define the components of the above equation.

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(b) Using the equation in (a) and assuming a balanced energy budget at the surface (S_s = 0), and a dry (no evaporation) land surface with emissivity 0.6 and temperature 273 K, determine an expression for F_h as a function of downward longwave flux at the surface during night-time conditions. Determine the value of sensible heat flux required to equal the effect of $F_{LW}^{\downarrow}$ = 400 W m^{-2} under those conditions.