

Name: \_\_\_\_\_

## ATOC/ASTR 5560 Radiative Processes — Lab 9

November 9, 2001

The purpose of this lab is to learn how to use a multistream polarized radiative transfer code and investigate some issues that influence the radiance field. Log in to nit and copy the following files to your directory:

/home/rt/multistream/multi.pro	IDL file for the lab
/home/rt/multistream/readrt3output.pro	IDL procedure to read rt3 output file
/home/rt/multistream/rt3	executable for the doubling-adding code
/home/rt/multistream/runrt3	script to run rt3
/home/rt/multistream/*.f	Fortran source code for the RT model

1. Look over the `runrt3` script that we will use to run the polarized multistream radiative transfer model `rt3`. You may wish to refer to the documentation at the beginning of files `rt3.f` and `radtran3.f` for more information. The RT code reads a *layer file* and a *scattering file*, and examples of each are in the script. You will need to change only the following parameters for this lab: `Nstokes`, `Nquad`, `Nazimuth`, `layerfile`, `deltaM`, `solarzenith`, `sfcalbedo`, `outfile`.

Look at the `DOUBLING_INTEGRATION` routine in the `radintg3.f` file. Compare with the doubling formulas in your notes. Note: the `rt3` sign convention for  $\mu$  is opposite the standard convention. Count the number of matrix multiplies and inversions for a solar source problem (the number of floating point operations for these matrix operations goes as  $N^3$  and dominates the computing time). How many of these matrix operations are done for a single layer of optical depth 1 (the initial  $\delta\tau = 10^{-6}$ )?

2. a) Calculate the upwelling radiance from a molecular Rayleigh scattering atmosphere with optical depth  $\tau = 1$ . Do two experiments: a polarized “vector” calculation with three Stokes parameters ( $I, Q, U$ ) and a “scalar” calculation with only the intensity ( $I$ ). Use a solar zenith angle of  $60^\circ$ , zero surface albedo, and  $N_{quad} = 20$ . Plot the upwelling radiances in the principle plane ( $\phi = 0$  and  $\phi = 180^\circ$ ) as a function of zenith angle using section `PlotPolRad` in the IDL file.

b) Do the same polarized vs. unpolarized experiment for the Mie scattering file from the Lab 7 mineral aerosol case. You will need to make a new layer file for the aerosol layer. Adjust the height in the layer file to give an optical depth of 1. You should use delta-M scaling and  $N_{azimuth} = 20$ . Plot the radiances as in a.

c) What can you conclude about when a polarized calculation is necessary to compute an accurate intensity? Explain why by looking at the phase matrix elements  $P_{11}$  and  $P_{12}$  for the Rayleigh and Mie phase functions at  $\Theta = 90^\circ$ .

d) Explain the differences between the Rayleigh and aerosol radiance patterns.

3. a) Calculate the radiances for a layer with the  $5 \mu\text{m}$  effective radius,  $\lambda = 1.64 \mu\text{m}$  cloud case from Lab 7. Do two experiments: i) 0.1 km thick layer ( $\tau = 1.3$ ) and ii) 1.0 km thick layer ( $\tau = 13$ ). Use  $N_{quad} = 40$  and  $N_{azimuth} = 40$  for good angular resolution and  $N_{stokes} = 1$  to make it faster. Again use a solar zenith angle of  $60^\circ$  and zero surface albedo. Plot the upwelling and downwelling radiances with section `PlotRadUpDown` in the IDL file.

b) Explain the angular pattern of upwelling and downwelling radiances for both optical depths. What is the maximum downwelling radiance for both cases?

4. Now consider overhead sun ( $\theta_0 = 0^\circ$ ) for the  $\tau = 13$  cloud case with a black surface.

a) How many azimuthal modes are needed ( $N_{azimuth}$ )? You can find out experimentally or theoretically.

b) What is the minimum number of quadrature angles per hemisphere needed to compute upwelling and downwelling *flux* to within 0.5%. The fluxes are in the `rt3` output file in the rows with  $\mu = +2$  (downwelling flux) and  $\mu = -2$  (upwelling flux).

c) Change the Lambertian surface albedo to 0.4. Using the same number of streams in part b, calculate the upwelling and downwelling flux.

How well does the simple adding formula for the combined surface+atmosphere reflectance work in this case? Get the atmosphere  $R$  and  $T$  from part b.

Add the upwelling and downwelling fluxes. Is energy conserved?! Explain.