HydroLight Lab
Curt Mobley's exercises with slight modification by E. Boss, Weizmann, 2008

Exercise 1: Optical Depth.
What you learn: it's optical depth, not geometric depth, that light cares about in radiative transfer theory, the nondimensional optical depth, ξ, corresponding to geometrical depth z (in m) is defined as

$$\zeta(z,\lambda) \;=\; \int_0^z c(z',\lambda)\, dz'$$

where $c(z,\lambda)$ is the beam attenuation coefficient. For homogeneous water, this reduces to $\xi(z, \lambda) = c(\lambda)dz$. (Note: *not K z*, as Kirk uses) If you stare at the radiative transfer equation long enough to achieve enlightenment, you will see that any two water bodies that have the same $\omega_0 = b/c$, same phase function, and same boundary conditions will have the same radiance as a function of optical depth (see *Light and Water*, page 252 in Chapter 5).

Make two HydroLight runs to verify this, as follows:
Run 1. Using the CONSTANT IOP model, enter a and b values and select a phase function. For example, let $a = 0.1$ m^{-1}, b $= 0.4$ m^{-1}, and pick the Petzold phase function. Pick reasonable values for the other inputs like sun angle (say 30 deg) and wind speed (say 5 m/s). Make a run to 20 OPTICAL depths and save the output every 1 optical depth.

Run 2. Go through the GUI again, and change *only* the a and b to values by some factor, so that you have the same ω_0 as before; for example let $a = 1$ and $b = 4$. Make another run to 20 optical depths. Compare the two printouts (files in the HE5/hydrolight/output/printout directory with names like PRun1.txt and PRun2.txt, for example). Are the irradiances and everything else the same at the same optical depths? What geometrical depths z corresponds to 20 optical depths in your runs? Did the runs take about the same amount of computer time, even though the geometrical depths were much different?

Since you have already done the run, let us look at another issue. Your IOPs are constant with depth. Does this imply that the diffuse attenuation coefficients are constant with depth? Check it? Is there a depth where they start to be more constant? You may need to increase the output resolution near the surface to see this phenomenon in its full glory. In short, a surface mixed layer may imply a layer mixed with respect to IOPs but does not imply a layer where the rate of attenuation of light is constant.

Exercise 2: IOP error effects on computed light fields
What you learn: a small error in an IOP can make a big difference in the light field at depth
Suppose your ac-9 gives $a = 0.30$ m-1 and $b = 1.0$ m-1 at 440 nm. Make a run (Run3) using the CONSTANT IOP model and these values. Go to 50 m GEOMETRIC depth and save the output every 5 m. Now suppose your ac-9 absorption is accurate to $\pm20\%$. Do two more runs (Run4 and Run5) with everything the same, but let $a = 0.24$ and $a = 0.36$ m-1, respectively. How much

difference do these 3 runs have in E_d or L_u near the surface? How much difference is there in E_d and L_u at 10 m depth, and at 50 m depth? Explain your results.

Note: An easy way to look at these outputs is via Excel. Go to the HE5\hydrolight\output\excel directory, and run the macro named SINGLEWL.xls or SINGLEWLwPlots.xls (includes automatic plotting) and open the SRun4.txt and SRun5.txt files created by the runs, and then look at the irrad page of each spreadsheet, where the various irradiances are tabulated and plotted.

Exercise 3: Rrs dependence on backscatter.
What you learn: $R_{rs}(\ )$ is roughly proportional to $b/(a+b) \sim b/a$
Do a run (Run6) using the "CLASSIC" CASE1 IOP model and enter a Chl concentration, say 2.3mg Chl m^{-3} (my value for our dock samples), for homogeneous water. Pick a phase function with a particle backscatter fraction of $B_p = b_{bp}/b_p = 0.01$. Do a run from 350 to 750 nm by 10 nm, down to 10 m, with output saved every 5 m. Use typical values for other inputs, e.g., put the sun at 30 deg in a clear sky, wind speed of 5 m/s. Include chlorophyll and CDOM fluorescence and Raman scatter in the run.

Now do another run (Run7) with everything the same except use a particle phase function with $B_p = 0.02$.

Note: You can easily look at $R_{rs}(\ )$ using the Excel MULTIWL.xls or MULTIWLwPlots.xls macro. How did doubling the backscatter fraction affect $R_{rs}(\ )$? Is the percent change in R_{rs} from Run6 to Run7 the same at every wavelength? Why did it take H longer to solve the RTE at 745 nm than at 445 nm?

Exercise 4: Comparison of the "classic" and "new" Case 1 IOP models.
What you learn: There's no such thing as the "correct" model for converting Chl to IOPs.
Run8: Use the "NEW" Case 1 IOP model and enter the same Chl value as in Exercise 3. Note that you don't get to select the phase function with this IOP model. Keep all other inputs the same. Compare the computed $R_{rs}(\ )$ spectra from the two IOP models. Which one is correct?

If you're interested, the "classic" and "new" Case 1 IOP models are described in detail in the writeup on HE5\documents\HE5_newCase1IOP.pdf.