HydroLight and EcoLight Lab 1 Exercises

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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 ζ corresponding to geometric depth z (in m) is defined as

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

where $c(z,\lambda)$ is the beam attenuation coefficient. For homogeneous water, this reduces to $\zeta(\lambda) = c(\lambda)z$. (Note: optical depth is *not* $K_d z$, as Kirk uses, which should be called something like "nondimensional diffuse attenuation depth".) If you contemplate the radiative transfer equation long enough to achieve enlightenment, you will see that any two water bodies that have the same $\omega_o = b/c$, same phase function, and same boundary conditions will have the same radiance as a function of optical depth (see the discussion of Eq. 12 at https://www.oceanopticsbook.info/view/radiative-transfer-theory/the-srte-heuristic-development). 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_o as before; for example, let $a = 1$ and $b = 4$. Make another run to 20 optical depths.

Compare the two printouts (files in the HE60/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 correspond to 20 optical depths in your runs? Did the runs take about the same amount of computer time, even though the geometric depths were much different?

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-s 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-S absorption is accurate to ±20%. Do two more runs (Run4 and Run5) with everything the same, but let $a = 0.24$ and then $a = 0.36\ m^{-1}$, 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 HE60\output\HydroLight\excel directory, and open the SRun4.xlsx and SRun5.xlsx files created by the runs, and then look at the IRRAD page of each spreadsheet, where the various irradiances are tabulated.

Exercise 3: R_{rs} dependence on backscatter.

What you learn: R_{rs} is roughly proportional to $b_b/(a + b_b) \approx b_b/a$.

Do a run (Run6) using the CLASSIC CASE1 IOP model and enter a Chl concentration, say 2.3 mg Chl m^{-3} (a typical value for Harpswell Sound), for homogeneous water. Pick a Fournier-Forand (FF) 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 depth, 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 FF particle phase function with $B_p = 0.02$.

Note: You can easily look at $R_{rs}(\lambda)$ using the Excel multi-wavelength files, e.g., MRun7.xlsx. How did doubling the backscatter fraction affect $R_{rs}(\lambda)$? Is the percent change in $R_{rs}(\lambda)$ 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?
The "classic" and "new" Case 1 IOP models are described in detail in the Ocean Optics Web Book starting at
https://www.oceanopticsbook.info/view/optical-constituents-of-the-ocean/level-2/classic-iop-model-case-1-water
and in The Ocean Optics Book Sections 6.8 and 6.9.

Exercise 5: Comparison of HydroLight and EcoLight outputs.

Run9: Repeat the last run (Run8) using EcoLight (just hit the "run EcoLight" button; you don't need to work through the GUI again.) Check to see if the computed irradiances, R_{rs}, etc. are the same as for HydroLight. How much faster was EcoLight? Why?

Exercise 6: Keep running H and/or E as your curiosity requires.

We'll do more in HydroLight Lab 2, when we learn things like how to input measured IOP data.