

# HydroLight and EcoLight Lab 2 Exercises

Curtis Mobley, Maine 2021

Now we want to learn how to model more complex water bodies, input depth profiles of Chl or mineral particle concentrations, input measured absorption and scattering data, put bottoms at finite depths, etc., and examine the various kinds of output.

**Closure:** A common use of H is to check closure (internal consistency) between IOPs and radiometric variables or AOPs. For example, you read in your ac-s absorption and scattering data, let H predict  $E_d$  and  $K_d$  and  $R_{rs}$  and such, and then compare H's  $E_d$  and  $K_d$  and  $R_{rs}$  with the  $E_d$  and  $K_d$  and  $R_{rs}$  that you measured. Then try to figure out why the predicted and measured values disagree, which they almost always do.

## Exercise 1: Inputting measured $Chl(z)$ data.

**What you learn:** How to input measured  $Chl(z)$  data and then use an IOP model to define the IOPs for Case 1 water. Investigate how sky conditions effect irradiances,  $K$ 's,  $R_{rs}$ , etc.

There is a "HydroLight Standard Format" (HSF) for any type of data file to be read by HydroLight, e.g. for files containing Chl profiles, ac-s data, or measured sky irradiances. Example data files of various types are found in the HE60\data\Examples directory. We'll look at these during the lab and I'll point out what is important in putting your data into the HSF.

The "Classic Case 1" IOP model uses *The Ocean Optics Book* Eqs (6.12) – (6.14) to convert a Chl concentration to the absorption coef  $a$  and the scattering coef  $b$ , as functions of depth and wavelength. You still have to pick a scattering phase function. The "New Case 1" IOP model determines everything from the Chl value.

**Create a file with depth vs. Chl data, and use it to input a  $Chl(z)$  profile.** Start with the example file HE60\data\Examples\Chlzdata.txt and modify it as you desire (use values typical of Harpswell Sound, say  $Chl = 0.5$  to  $10 \text{ mg/m}^3$  over 0 to 50 m). Save your file as an ASCII text file (not a Word, RTF, CSV, or Excel file, and not a DOS Unicode file) with a new name, like Curt\_Chlz.txt. The recommended place for such files is the HE60\data\user directory.

Note: Notepad or Wordpad are what I used for this kind of work. In Notepad use "save as text, \*.txt"; in Wordpad use "Save as Plain Text Document". If converting data from Excel, you need to remove any tabs or other "hidden" characters.

**Run 1.** Pick the Classic Case 1 IOP model and browse for this file in the concentration profile box option "comes from a standard format user-supplied data file". Pick a  $bb/b$  value of 0.01 or 0.02, and other typical values for sun angle, etc. Run from 400-700 nm by 10 nm. Do the run to 25 or 50 m, say, and save the output every 5 m, with an infinitely deep bottom.

**Run 2.** Use the same Chl(z) data file and do a run with the New Case 1 IOP model, and all else the same. Compare the two sets of output for things like  $E_d(z)$ ,  $R_{rs}$ , Secchi depth, etc. For these runs, you can use the Excel files (on output\Hydrolight\excel\M\*.xlsx, etc.) to look at and plot the results.

Notice how the various  $K$  functions ( $K_d$ ,  $K_u$ ,  $K_{Lu}$ , etc) depend on depth and wavelength. Ditto for  $R = E_u/E_d$  and the mean cosines. Plot the  $R_{rs}$  spectra for these two runs.

Repeat one of your runs with the IOPs the same, but change the sky conditions. Put the sun at 0, 30, 60, and heavy overcast (100% cloud cover). How do the different sky conditions affect the irradiances,  $K$  functions, reflectances, and mean cosines? Comment on why irradiances are not AOPs.

## **Exercise 2: Inputting IOPs from $a$ , $c$ , and $b_b$ sensors.**

**What you learn:** How to input measured IOPs, rather than using an IOP model to define the IOPs.

You are always better off measuring the IOPs than trying to estimate them from Chl or mineral concentrations and a bio-geo-optical model to obtain the IOPs from the concentrations. The most common way to do this is with ac-s data (or corresponding data from other instruments). File HE60/data/examples/ac9data.txt contains some ac-9 data on the HSF for  $a$  and  $c$  data. Take a look at this file to see the format for this type of data. Note that if you have ac-s data, the format is the same, but then you would have 80 wavelengths instead of 9. **Note that ac-9 and ac-s data are assumed to have had water  $a$  and  $c$  values subtracted out; H will automatically add pure water values to the  $a$  and  $c$  values in the file.**

File HE60/data/examples/Hydroscat6.txt contains some Hydroscat-6 data on the HSF for  $b_b$  data. Take a look at this file to see the format for this type of data. **Note that  $b_b$  data usually include the water  $b_b$  values. However, H asks you whether or not the pure water  $b_b$  values are included in the  $b_b$  data.**

Use these files and the “MEASURED IOPs” IOP option to do some runs with measured data. If you have your own ac9 or backscatter data, put it on files of the same format, and use your own data.

**WARNING on ac-s data.** The ac-a has the same *number* of wavelengths for the  $a$  and  $c$  spectra, but the wavelengths are not exactly the same for  $a$  as for  $c$ . Therefore, spline the  $a$  and  $c$  spectra to a common set of wavelengths (say at 5 nm resolution) before inputting into HydroLight. Otherwise, the  $a$  and  $c$  values won't match for a given wavelength.

### **Exercise 3: Simulating Case 2 water.**

**What you learn:** How to build up a water body with Chl, extra CDOM, or mineral components.

Now use the “CASE 2” IOP model to do a series of runs to simulate the transition in  $R_{rs}$  as you go from Case 1 to Case 2 water with increasing mineral and/or CDOM concentrations. For example, you might: set  $\text{Chl} = 1 \text{ mg/m}^3$ , let the CDOM be a function of Chl like in Case 1 water, and then do runs with a mineral concentration of 0, 0.25, 0.50, 1.0, 2.0, 5.0, 10.0  $\text{g/m}^3$ , with all else being held constant. Maybe use a phase function with 1% backscatter fraction for Chl-bearing particles and 3% for the mineral particles. Then plot  $R_{rs}$  as a function of wavelength and mineral concentration.

Alternatively, you might hold the mineral concentration fixed at 1  $\text{g/m}^3$ , but vary the type of mineral (from the selection of calcareous sand, red clay, yellow clay, and brown earth).

Note: if you want, save these  $R_{rs}$  spectra for later, when you can run them through an inversion model that obtains Chl from  $R_{rs}$ , to see how well the inversion does. In principle, you would retrieve the same Chl value for each spectrum, but that won't happen.

### **Exercise 4: Simulating optically shallow water.**

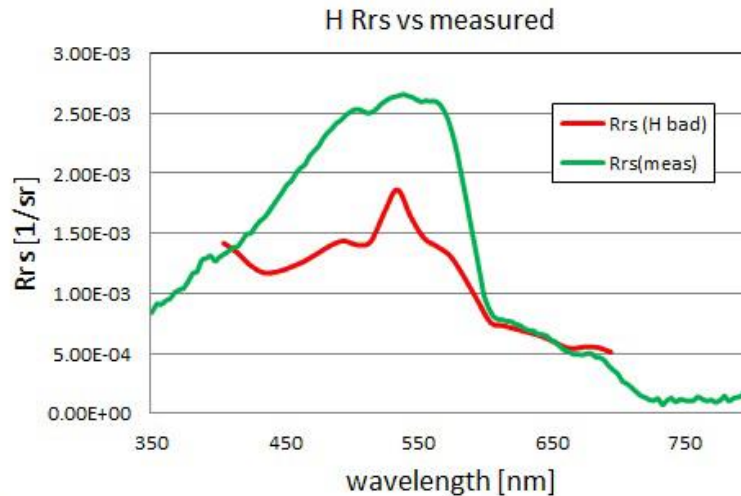
**What you learn:** How to put a finite-depth bottom in H, and see the effect of bottom reflectance on  $R_{rs}$  and  $K$  functions.

File HE60/data/user/AC9\_Bahamas.txt has ac9 data that were measured in very clear water in the Bahamas. Use the IOP DATA option to read in this ac9 data. Do a run from 400 to 700 by 10 nm. On the Bottom Boundary Condition form, pick the options for a finite depth, and bottom reflectance dependent on wavelength, and then pick the coral sand bottom reflectance file. Do runs with the bottom placed at 5, 10, 20, and 30 m, and infinitely deep water run down to 30 m. Save the output at 1 m intervals. Plot  $R_{rs}$  for the different bottom depths to see how deep the water has to be before you don't “see” the bottom in  $R_{rs}$ . Now plot  $K_{Lu}$  at 550 nm vs depth to see how the bottom reflectance affects  $K_{Lu}$  as you get near the bottom. How is  $K_d(550)$  affected by the bottom?

## Exercise 5: Providing HydroLight User Support

The most common HydroLight user support question is something like, “I used H to compute  $R_{rs}$  (or whatever) and compare with what I measured, and they don’t agree. What is wrong with H?”

The figure below shows an actual example of this. The user had the ac-9 data contained on file HE60/data/user/AC9\_Lab2.txt. The user used this ac-9 data in H with the IOP DATA option, and used a backscatter fraction of 0.01 to determine the phase function. Use this IOP input, with the sun at 30 deg in a clear sky, infinitely deep water, run down to 20 m, 400 to 700 nm by 10 nm, and reproduce the user’s curve H, which is red. **Then figure out “what is wrong with HydroLight” and fix the problem.** Then do the run again and see if the H output gives a better fit to the measured  $R_{rs}$ , which is the green curve.



The first questions to ask yourself are, “Does the measured  $R_{rs}$  curve (green) look realistic?” and “Does the HydroLight-computed (red) curve look realistic?” OK, now you’re on your own. (BTW, it took me less than one minute to figure out and solve the problem.)

You get the idea. Play with HydroLight all you want for the rest of the course. Now is the time to get your questions answered. You have until August 31, 2021 to finish the runs for your Ph.D. dissertations.