HYDROLIGHT TECHNICAL NOTE 3

ADVICE ON CHOOSING OUTPUT DEPTHS IN HYDROLIGHT RUNS

Hydrolight solves the radiative transfer equation at a given wavelength by numerically integrating a set of hundreds of coupled nonlinear ordinary differential equations (ODEs), which are given by Eqs. (8.74) to (8.85) of *Light and Water*. These equations are functions of the nondimensional optical depth ζ, which is related to the geometric depth z (in meters) and the beam attenuation coefficient $c(z)$ by $\zeta = \int_0^\infty c(z)\, dz$.

When running Hydrolight, the user interface asks for the depths where output is to be saved for later analysis. If you ask for output to be saved at $z = 30$ m, for example, you get the same answer at 30 m whether or not you also asked for output to be saved at $z = 5$, 10, and 20 m. Although that is what the mathematics says, in practice things are not quite so simple. The ODEs are integrated in depth using a sophisticated algorithm and code that generally works very well. However, sometimes the ODE solver gets lost when integrating over tens of optical depths, with disastrous consequences. [This is not a subtle loss of accuracy with increasing depth. Hydrolight will either give good results or the run will blow up completely, with obviously bad results such as negative or wildly oscillation radiances.]

A situation in which this might occur is the following. You are interested only in the light field at 100 m depth. You thus tell Hydrolight to save the output only at depth 0 (always an output depth) and 100 m. The run at wavelength 700 nm then blows up for no apparent reason. However, if you resubmit the run and ask for output at depths 0, 20, 40, 60, and 100 m, Hydrolight runs without problems. This is what is happening. At 700 nm, pure water absorption is 0.65 m^{-1}, so 100 m depth is at least 65 optical depths. The light field (radiance or irradiance) at 100 m is then at most $e^{-65} \approx 10^{-29}$ of the surface value. The ODE solver is not able to start with numbers of order 1 and then keep accurate track of numbers as small as 10^{-29}. However, if you ask for output every 20 m, which is every 13 optical depths in this example, the light field from one output depth to the next decreases by $e^{-13} \approx 10^{-6}$. The ODE solver can keep track of part-per-million changes from the starting depth to the ending depth. By asking for output every 20 m, the ODE solver was able to restart itself at each output depth after accurately finding the solution at a given depth, and then continue down to the next output depth.

A good rule of thumb to follow when running Hydrolight is then

Request output at depths spaced no more than about 10 optical depths apart.

To get a quick estimate of what geometric depth z corresponds to 10 optical depths, just eyeball the beam attenuation profile and get an estimate from $z \approx 10/\langle c \rangle$, where $\langle c \rangle$ is the depthaveraged $c(z)$. Thus if you look at your $c(z)$ data and see that $c(z)$ varies from 3 to 4 m^{-1}, you can estimate that $z \approx 10/3.5 \approx 3$ m is about 10 optical depths. Thus you might ask Hydrolight for output every 3 m (or some other interval, such as 2 or 2.5 or 5 if that is convenient). Just don't try to go to 30 m ($\zeta \geq 90$) in this water without intermediate output. If you cannot easily estimate an output depth interval before making a run (e.g., because you are running an IOP model that uses constituent concentrations as input, and you do not know c until after the model runs), then make a preliminary run and look at the output to seen what are the greatest optical depths between given geometric depths. You can then adjust the output depths for the subsequent runs to give you enough depths to avoid numerical problems without having many more depths (and larger output files) than necessary.

Finally, use a bit of common sense. I have had users try to run Hydrolight to 5,000 m depth and then ask why the output looked bad. Even in pure water at the clearest wavelengths, 5,000 m is 100 optical depths and the light is 10^{-44} of the surface values. Take a look at *Light and Water* Problem 3.3 before getting too carried away with running Hydrolight to the bottom of the ocean.

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