There are a variety of optical and physical properties of suspended solids that are needed by the Mie and T-matrix theory to generate the phase function of a particle in water. As summarized by Kim [12], the Oops program’s Mie scattering solution to the phase function makes use of the particle size and refractive index while the solution to the T-matrix makes use of the particle size, shape, refractive index and orientation. These are the main physical properties needed to model the suspended solid IOP’s for use in Hydrolight.

The refractive index requires that we know the composition of the suspended solids as well as the refractive index for each type of solid. Some of the earliest research on composition focused on dissolved solids. A summary of this research can be found in Hem [8] and covers the origin, composition, and chemical controls for many ions in solution for a number of water areas in the United States. While Hem covers some chemical techniques for the composition determination of suspended solids, the techniques were too complicated to use for general sampling as done for the dissolved states.

More recent research has started to allow for a faster sampling of suspended solids. X-ray fluorescence and automated scanning electron microscope techniques introduced a new way to quickly analyze atmospheric particles (Hanna [7] and Johnson [11]) which eventually expanded to the study of suspended particles in water (Xhoffer [18]). Xhoffer [18] also introduced a laser microprobe mass analysis technique for studying the elemental composition of suspended matter though the method is destructive. One of the broadest techniques for the number of elements scanned is the instrumental neutron activation analysis method performed on suspended matter by Niedergesäss [15]. The requirements of a reactor to irradiate the sample and a 3 day processing time make this a seldom used method. Eisma [4] also briefly mentions atomic absorption spectrometry, inductively couples plasma analysis, emission spectrography, gas
chromatography, mass spectrometry, and Curie point-flash pyrolysis as some of the many ways researchers have tried to determine the composition of suspended solids.

Once the composition of the water to be modeled is measured (or just chosen if not trying to match a real water body) the appropriate refractive indices can be inputted into Oops. Eisma [4] lists some of the more common minerals found in suspended solids. These include quartz; the feldspars orthoclase, albite, and anorthite; the clays kaolinite, chlorite, illite, and montmorillonite; calcite; and opal. There are a host of other minerals that can be found in waters depending on the local sources for those minerals. Some examples of suspended solids content with analysis of possible particle origins can be seen in Jambers 1997 [9], Dekov [1], Jambers 1999 [10], and Xhoffer [18]

The refractive index of minerals often found in suspended solids is still being investigated as researchers working in various fields discover a need for more accurate data. For most general minerals, a basic refractive index at one wavelength is listed in Lide [13]. More detailed coverage covering multiple wavelengths can be found for specific minerals though. Covering mostly metals, semiconductors, and insulators, Palik [16] does comprehensively cover calcium carbonate (also called calcite) from 0.1-400 µm. Quartz has coverage from 0.185-0.795 µm in Gifford [5]. The clays illite, kaolinite, and montmorillonite all have some coverage over the visible and near infrared wavelength regions in Egan and Hilgeman [2].

The next step in generating the suspended solid IOPs is specifying the particle size distribution that will be modeled. There are a variety of ways to measure this property. Among these are laboratory methods for visible or electron microscopy and electrical resistance methods (Mobley [14]), fractionation (Niedergesäss [15]), pipette analysis (Eisma [4]), flow cytometry (Green [6]),

The particle size research that has been conducted so far (using the methods mentioned above) draw a somewhat confusing picture of the state of suspended solids in water. Simpson [17] summarises some early research and shows the early general view that particle size of suspended solids in water was similar to that of aerosol suspended solids and followed a Junge power-law relation for ocean waters. Some other more complicated relations are also shown that can improve this basic fit, but a majority of research seems to take this basic relation as accurate enough given the difficulties and errors incurred when using most measurement sampling procedures.

Newer research has started to show how inadequate this assumption might be, especially when examining particles that are in rivers or lakes instead of the ocean. Research by Eisma [3] sampled a number of European estuaries with both laboratory type particle sampling techniques and some in situ sampling techniques. The analysis from this large collection show that while the lab techniques give a maximum size of 125 µm the in situ analysis reaches upwards of 1000 µm. In fact, almost 80% was present in conglomerated particles (called flocs) that were larger than the maximum reported laboratory size. These in situ flocs also seem to follow a different distribution according to the results shown by Eisma [3]. A number of the sampling points show distributions that resemble gaussian or skewed gaussian distributions instead of the open ocean's Junge distribution. Thus, there are now two very different distributions that can be tested when modeling suspended solid IOP's. This offers the opportunity to model conditions of both the open ocean and the far more complex and interesting coastal regions, rivers, lakes, and estuaries.

The application of the above particle size distributions to the different ele-
ments that compose the suspended solids is not necessarily a straightforward process. Strong local sources of particular particle types could lead to radically different distributions for those types of particles. Research by Niedergész [15] suggests that these differences are not normal for inland waters though. Elemental composition is uniform for different settling velocities (roughly equivalent to different particle sizes based on Stokes’ Law) for most sites sampled by Niedergész. The main abnormal case where the distribution of particle sizes changed for different particle types arose during a flood event. While this should be kept in mind when trying to model a real scene that might have undergone an event like this, in general the much simpler equal distribution assumption can be used for the modeling that will be done for this research.

Now that particle composition, refractive index, and particle size distribution ranges are known, the effect that varying these parameters has on the reflectance of the water’s surface or on the radiance leaving the water’s surface can be calculated. First Oops generates the IOP’s of the suspended solids component of the water column. These IOP’s are then used as inputs by Hydrolight to determine the propagation of light through the water body.

References


