Estimating the Size-Dependent Settling Velocity of Suspended Particles Using the LISST-ST

SEQUOIA SCIENTIFIC, INC. ◆ *APPLICATION NOTE L007*

The aggregate nature of particles, non-spherical shapes or non-uniform density, can cause in-situ settling velocities of particles to not follow Stoke's Law. The ST is designed to measure the in-situ settling velocity for 8 size classes without making *a-priori* assumptions of a settling law.

In operation, a sample of water is drawn into the LISST-ST settling column, filling the column with the initially homogeneous (at least, mostly) natural sediment suspension. Near the bottom of the column, a laser illuminates a thin layer of the column, Figure 1.

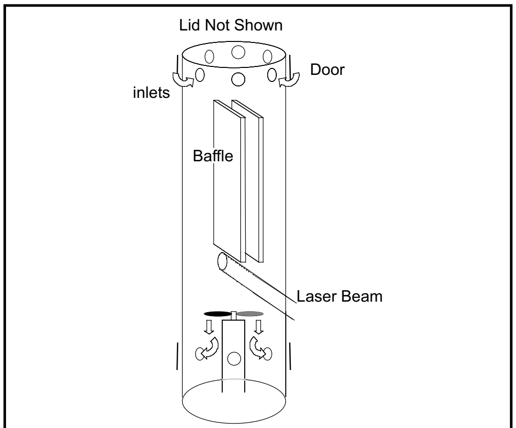

Figure 1: *The settling column*

The laser provides size distribution at this station in the settling column. At the beginning of a settling experiment, the laser measures a size distribution that is representative of the natural suspension. In the early stages of settling in the trapped column of water, the size distribution measured by the laser is depleted first of the fastest settling particles. Slower settling particles gradually become depleted until eventually, the settling column contains water from which particles have settled out.

The evolution of concentration of particles of any size as measured by the laser can be predicted as follows: at the start of the settling process, particles of all sizes are present throughout the column. Consider now, particles of size a and settling velocity w_f. Let the distance to fall from the top of the column to the laser beam be L. Then, at time $t_1 = L/w_f$, the last of the particles of size a (that started from the top of the water column) will have reached the laser beam. If the laser beam has a diameter L_B, then at a later time $t_2 = L_B/w_f$, this layer will have fallen through the laser beam. Thus the concentration evolution for this size class a will be constant for time t_1, declining to zero over time t_2, Figure 2. In reality, measurements in the settling column will show 'noise' from this ideal.

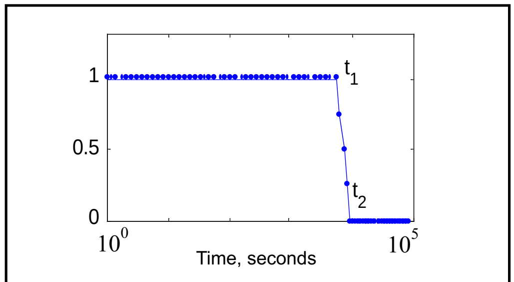

Figure 2: *Idealized history of concentration of a single size class of particles.*

The noise may be due to: (i) incomplete mixing of the initial sample at start, (ii) measurement noise, (iii) the presence of particles of different density; and (iv) the errors of inversion employed in estimating size distribution from the multi-angle scattering (see Application Note 001). For these reasons, settling times t_1 and t_2 are estimated by a fitting procedure that matches an ideal concentration history to the measured history in a least squares sense. This algorithm is built into the software provided with the LISST-ST.

The settling velocity estimates deduced from the history of the complete size distribution are presented only at 8 size classes with the LISST-ST. This means that each size class contains particles of a broad size range - approximately 72% of the mean size. Finer resolution is generally not possible unless the data are exceptionally noise-free, which means not only that the measurement be *clean*, but also that the initial sample be uniformly mixed.

In examining field data from the LISST-ST, we recommend that the user first view the optical transmission. In a good experiment, the optical transmission should show continuous clearing of water. Any large oscillations may be hints of leaks in the settling column doors. Such difficulties may occur due to corrosion or fouling of the mechanisms over long deployments.

For processing data obtained with the LISST-ST, Windows software is provided. In addition to this Windows software, MATLAB software is available by request. This MATLAB software permits treatment of unusual circumstances, such as the use of non-standard sampling times during settling. Other variations may use short or prolonged settling experiments, depending on whether the settling velocities of the full size-range of particles are of interest. A particular advantage of the LISST-ST is that the last measurement in a long settling experiment can be used as the *zscat* itself, providing an excellent measure of the *in-situ* background scattering.

In figure 3, we display the output of the standard MATLAB program. The concentration histories of the 8 size classes are displayed. Also, displayed in the adjacent figure are the settling velocity estimates vs. size. The settling velocities are output in an ASCII file.

For processing LISST-ST data using MATLAB, the functions *proc_st.m* and *find_sv.m* are provided upon request. The MATLAB help command will guide a user on how to use this function. Please also consult Application Note L006 on the use of MATLAB with LISST data. To use, type:

[scat,tau,ad,ferror,lastscan,d]=proc_st(filename,zscfile,n_tsteps,i_expt,i_type).

Type *help proc_st* for an explanation of variable names.

The transmission history is the variable *tau* for the settling experiment numbered *i_expt*. The size-distribution is in the array named *ad*.

To compute settling velocities, type:

sv = find_sv(ad, i_type);

If it is desired to use the last scan in a settling experiment as a *zscat*, simply save the output variable *lastscan* (see left hand side of command line above) as the zscat; e.g.

zsc = lastscan;
save zscat.asc zsc -ascii

and reexecute the *proc_st* command with the new *zscat.asc* as background file name.

As a final remark, it should be noted that particles of all sizes are not necessarily present in every experiment. In the event that a size class is empty, the concentration estimates will be dominated by noise. For this reason, the interpretation of the settling velocity distribution requires careful attention to the initial size distribution in the settling column.

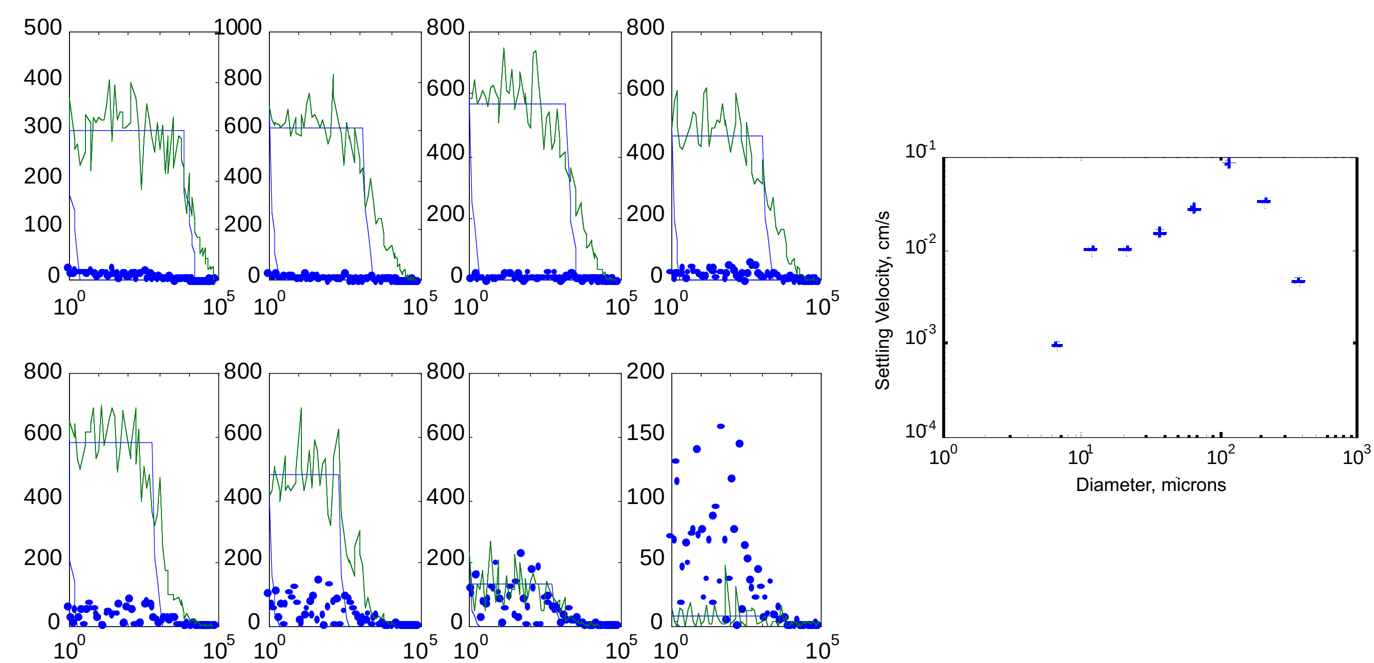

Figure 3: *History of the 8 size classes (left to right, from top), and the estimated settling velocity spectrum from a field experiment off the New Jersey coast. The dots on the history plots (left) are estimated error in concentration. Note that the errors are of the same order as the concentration for the 2 largest size classes making estimates of settling velocity at the two largest sizes unreliable in this case.*

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