IN-STREAM LASER DIFFRACTION FOR MEASUREMENT OF SUSPENDED-SEDIMENT CONCENTRATION AND PARTICLE-SIZE DISTRIBUTION IN RIVERS

EXTENDED ABSTRACT

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Laser-diffraction technology has recently been adapted for in-stream measurement of fluvial suspended sediment concentrations (SSCs) and particle-size distributions (PSDs) as a streamlined (SL), isokinetic version of the Laser In-Situ Scattering and Transmissometry (LISST). The LISST-SL instrument is capable of at-a-point measurements of volumetric SSC and PSD ranging from 1.8–415 µm in 32 log-spaced size classes at a temporal resolution of 2 seconds.

As with any new sediment-measurement or sediment-surrogate technology, the LISST-SL must be rigorously tested with respect to accuracy and reliability in different physiographic environments, and its performance must be compared to concurrent measurements using traditional methods to identify and minimize bias and changes in precision between the old and new technologies (Gray and Gartner, 2009). To this end, we have collected 22 datasets of sediment and streamflow measured concurrently by using a physical sampler, LISST-SL, and acoustic Doppler current profiler (262 samples in all) during 2010–2012 at 16 U.S. Geological Survey streamflow-gaging stations in Washington and Illinois with basin areas ranging from 38 to 69,264 km². A detailed description of the methods, results, and discussion of this comparative study has been published by Czuba et al. (2015); herein the major findings are summarized and potential future work is discussed.

As laser diffraction measures volumetric SSC, these measurements must be converted to mass SSC measurements before they can be compared to the data from physical measurements. The conversion from volumetric SSC to mass SSC requires a measurement or assumption of the sample effective density. For fully dispersed quartz grains, the effective density is typically around 2.65 g/mL and for 23 of the physical samples, the effective density varied from 2.56–2.87 g/mL with an average of 2.67 g/mL. In contrast, an unrealistically low computed effective density (mass SSC/volumetric SSC) of 1.24 g/mL (95% confidence interval: 1.05–1.45 g/mL) provided the best-fit value (R² = 0.95; RMSE = 143 mg/L) for accurately converting volumetric
SSC to mass SSC for over two orders of magnitude of SSC (12–2,170 mg/L measured by the physical sampler; covering a substantial range of SSC that can be measured by the LISST-SL). These unrealistically low values for the computed effective density suggest something systemic is happening where the LISST-SL is overestimating the volumetric SSC. Explanations for such a low computed effective density have typically pointed to flocculation. However, PSD measured by the LISST-SL and in physical samples (which are dispersed before analysis) were similar, thus ruling out particle flocculation as a major factor.

For now, obtaining accurate mass SSC measurements with a LISST-SL in the fluvial environment requires applying an effective density much less than the density of the sediment particles. Either a best-fit effective density of 1.24 g/mL can be applied, or mass SSC measurements can be made to compute a site-specific effective density for converting volumetric SSC to mass SSC.

The results (Czuba et al., 2015) suggest that the most likely issue is the shortcoming of the laser-diffraction method in only being able to account for irregular particles through the irregular particle kernel matrix (Agrawal et al., 2008). Irregular particles are defined here, following the definition by Agrawal et al. (2008), as rounded or angular particles with particle axes approximately equal. The term “irregular” is used to denote a difference in particle shape from that of spheres but this definition does not include particles that are elongated or flaky. This definition is used because these were the shapes of particles used by Agrawal et al. (2008) in developing the irregular particle kernel matrix. The irregular particle kernel matrix is used to convert “raw” laser-diffraction measurements into concentrations of particles in different size classes. Any elongated (e.g., feldspar) or flaky (e.g., mica) particles present in suspension can create a strong bias in SSC without such an effect on PSD when applying the irregular particle kernel matrix to these particles (Felix et al., 2013). This suggests that a new “fluvial particle kernel matrix” may need to be developed that can account for elongated and flaky particles that may be present in suspension, although more research is needed to confirm that this is the causative factor.

Future work should focus on assessing the suitability of the irregular particle kernel matrix (Agrawal et al., 2008) for actual suspended fluvial material by obtaining suspended material directly from the river and considering the full distribution of fine and coarse material to assess if a different particle kernel matrix would better represent what the LISST-SL is measuring in the fluvial environment. More detailed analysis of the suspended material should be performed using a microscope to assess particle shape and surface characteristics. The characteristics of any organic material should also be assessed as well as the water chemistry affecting potential flocculation. These more detailed measurements at a few sites should provide further insight into the causative factor or factors responsible for the unrealistically low computed effective densities. If this is the case then it will be possible to reprocess all 262 LISST-SL measurements from this study to verify that any new kernel matrix is suitable for the fluvial environment.
REFERENCES


