Summary of USGS – Sequoia Scientific WebEx on LISST, Mon Jan 30, 12PM to 4pm

The development of LISST technology by Sequoia Scientific Inc for in-situ deployment has provided major advances in environmental particle size distribution (PSD) measurement (Andrews, et al, 2011). PSD and concentration data at high spatial and/or temporal resolution will open new doors for research on sediment transport mechanics and watershed processes. The USGS is particularly interested in this tool, and several LISST devices are now in use by USGS offices. However, several important issues were discovered or highlighted in the summer/fall of 2011. Guidance is needed soon for users of this equipment, and critical issues/questions need answers soon.

Purpose:

The purpose of this workshop is to obtain a clear statement of some issues in using the LISST-SL and LISST-Streamside that were discovered over the last 2 years, and especially summer of 2011. We would like to clearly show the manufacturer our results so they can address the issues, whether the fix involves software, firmware, hardware, or simply qualification of what is being measured. This is informal and generally confidential with USGS and Sequoia. The discussion will not be construed to necessarily represent vetted findings regarding LISST performance; but we do want to get to the nitty gritty of its performance and limitations.

Attending (14):

Mark Landers (OSW), John Gray (OSW), Johnny Wheat (HIF), Chris Ellison (MN WSC), Tim Straub (IL WSC), Chris Curran (WA WSC), Jon Czuba (WA WSC), Marinna Martini(USGS, Woods Hole), Chris Sherwood(USGS, Woods Hole), Patrick Dickhudt (USGS, Woods Hole), and from (Sequoia Sci): Yogi Agarwal, Chuck Pottsmith, Ole Mikkelsen, Randy Srnsky, Wayne Slade

Agenda

12:00 – Welcome, Intro, Presentation of Agenda and discussion of any modifications - Landers
12:10 – Sequoia Scientific

- Excellent, detailed presentation on technology for Laser Diffraction (LD) devices (*note especially clarification that any particle diffracts light at all angles, and inversion is empirically based for random shaped particles as described in 2008 JGR article)*
- Discussion of Limitations of LD in general and LISST Specifically
- Discussion of 'what can go wrong' in measurements

Presentation of Field Data Collection and Results

	Tim Straub
	Chris Curran
2:30-2:45	break
2:45	Mark Landers
3:30	Marinna Martini, Chris Sherwood, and Pat Dickhudt http://soundwaves.usgs.gov/2011/11/fieldwork2.html
3:45	Sequoia Sci – discussion / response
4:30-5:00	further discussion – possible test for flocculation

The contributions and ongoing research by USGS professionals and Sequoia Scientific Inc is acknowledged and appreciated. The following 'key comments and questions' summarize much of what was learned in the Web-Ex. The attached presentation files provide additional information and background. A few references are listed here; but much more extensive list is available in the 'Library' at Sequoia's web site: sequoiasci.com -mnl

Key Comments and Questions:

A) Laser Diffraction (LD) technology and limitations (see Sequoia Sci presentation for details)

a. Comment: In LD, a single particle diffracts light over all angles, non-uniformly. The diffraction pattern (i.e. profile of scattering on ring detectors) may be inverted to obtain particle size distributions (PSD) for (i) equivalent spheres, following Mie theory; or (ii) equivalent sieve size distribution of randomly shaped particles. The latter inversion is based on empirically determined light scattering properties of irregular particles following detailed research by Sequoia published in JGR (*Agrawal et al, 2008, Light scattering by random shaped particles… JGR 113, C04023*).

B) PSD comparisons by different Methods

a. Comment: PSD is a method-based definition, and one must qualify the method when discussing it. Gravimetric PSD by sieving and/or settling velocity would not be expected to be the same as laser-diffraction-based PSD. Furthermore, in-situ PSD would not be expected to be the same as laboratory PSD where sample is affected by handling and disaggregation due to sonic or chemical dispersants. None-the-less, for data continuity in sediment studies, the results need to be comparable quantitatively.

b. Comment (from Woods Hole): Flocculation is a complicated problem varying with concentration, turbulence, mineralogy, biological influence etc. From our experience in estuaries and continental shelf, we would not expect to be able to derive a quantitative relationship between an in situ PSD and a laboratory disaggregated PSD.

c. Comment (from Woods Hole): The recent OASIS experiment by USGS Woods Hole and collaborators may shed some light on this issue.

d. Questions: How can results by different PSD analyses, in different settings be compared? How should they be described (what metadata)? Who can they be qualitatively compared? How can they be quantitatively compared? This is a question we should ask USGS labs to weigh in on; as well, perhaps, as manufacturers of LD and related devices. (Note this question was a stated research focus for FISP for 2012., Also, Woods Hole notes that "Principles, Methods, and Application of Particle Size Analysis" by James Syvitski is a reliable reference.)

C) Measurement size limits of the LISST

a. Observations:

- Measurable in-situ particle Size range for LISST-SL and LISST-Streamside is 1.89 to 381 microns (minimum and maximum bin size limits). (*See size limits in instrument manual for each specific instrument.)*
- In data from 11 streams in IL, 30% to 50% of suspended sediment was less than 2 microns, based on laboratory analysis (after dispersion). In GA, about 30 percent of suspended sediment was less than 2 microns, and about 10 percent was larger than 381 microns.
- Clay sized particles in environment may flocculate producing larger flocs with lower densities.
- Woods Hole notes: Our experience has been that both silt and clay sized particles i.e. particles < 20 microns are likely to flocculate.

- If fraction of in-situ PSD larger than maximum measurement size and/or smaller than minimum is variable; then this would produce variation in VPC~SSC relation (of magnitude dependent on quantity and dynamics of unmeasured material).
- The influence of particles outside the instrument size range is described in the attached .ppt files from Sequoia, also at (http://sequoiasci.com/Articles/ArticlePage.aspx?pageId=221); also discussed in Andrews et al, WRR, 2011; and elsewhere. Sediment of sizes coarser than maximum measurable size produces scattering that drops of rapidly as sizes increase. Sediment finer than the minimum measurable size scatters ('leaks') light onto measured rings of LISST, producing a rising tail at the fine end of the PSD.
- Changing volumetric PSD measured by the LISST (within measureable size range) may provide indicator / quantitative measure of changing fraction of material outside the measurable range.
- The fraction of in-situ particles less than 2 microns is difficult (impossible?) to evaluate because of the uncertainty about flocculation, and difficulty of comparing laboratory PSD with LISST, in-situ PSD.
- Comment from Woods Hole: With particles this small, the particles making up a specific size class may be a combination of individual grains and flocs (e.g. you may have 100 micron sand as well as 100 micron flocs), and so far have been impossible to differentiate. Some research into the freshwater floc literature may provide some insight into maximum expected floc sizes but in saltwater flocs as large as 1 mm are not uncommon.
- Comment from Woods Hole: Flocculation has long been observed in both fluvial and marine waters, but generally considered an issue only in marine environments. Recent results where finer sediment is observed in lab techniques and does not show up in in-situ LISST measurements is considered a marker for the presence of flocs and may suggest that flocculation does occur under certain circumstances in fluvial environments.
- Note regarding maximum concentration from Sequoia web site: "The maximum working concentration for an instrument depends on the particle size and optical path length of the laser in instrument optics. As an example, the LISST-100 with its path length of 0.05 m, and for particles of 10 µm in diameter, the upper limit would be 200 mg/L (assumed density of 2.65g/mL). The limit changes to 1,000mg/L if an 80% PRM (0.01 m path length) is employed. For other instruments, the same 10 µm grains can be measured at concentrations up to 2,000 mg/L with the LISST-Portable and LISST-StreamSide (5mm path length) and up to 3,300 mg/L with the LISST-SL (3mm path length). … Note that the instruments do not suddenly stop functioning at these upper limits. These limits define an actually fuzzy boundary beyond which accuracy of measurement degrades due to multiple scattering of light (i.e. re-scattering of once scattered light). Measurements can continue with loss of accuracy (less than ~20%) down to optical transmission of 10%.

b. Questions:

- What is the effect of unmeasured size fractions smaller than minimum size?
- How can one test for the presence of and quantify the magnitude of this effect?
- For particles larger than max, can we simply compare volumetric and laboratory PSD to test and quantify this effect?

- Given the uncertainty due to potential, and potentially variable flocculation of small particles, can this issue be addressed for clay sizes? How? (Sequoia has presented a potential method to address influence of flocculation)

D) Measured ratio of SSC to VPC ("effective density")

a. Observations:

- If all in-situ particle sizes were measured, and there were no flocculation, then this ratio should equal particle specific gravity (2.65 for quartz)
- In results from streams in Idaho, 11 streams in IL (163 samples) the mean ratio of SSC/VPC ratio is 1.2; and from one stream in GA (194 samples) the mean ratio is 1.1.
- Unmeasured in-situ sediment (of sizes outside the LISST measured range) would cause this ratio to be larger. This result is occurring even though there may be unmeasured sediment that would drive the ratio upward.
- Sequoia Sci believes that in some / many / most systems, this could be entirely due to flocculation of fine particle in the in-situe environment, which flocs may have a density close to 1.
- Comment from Woods Hole: given our experience with these and other in situ particle size measurements, we feel that Sequoia's explanation is reasonable. Since SSC/VPC is an estimate of dry density, it is not unreasonable to have a density less than 1.

b. Questions:

- Overarching question is whether this issue renders the LISST VPC and PSD measurements incapable of producing data that can be quantitatively used to compute mass SSC and mass sediment flux? (The answer is no, based on extensive IL and GA and AZ, in which VPC is an excellent surrogate for SSC.)
- Does this issue require LISST VPC and PSD measurements to be calibrated concurrent SSC in order to be used for SSC and sediment flux?
- Comment from Woods Hole: Yes. You could also use cheaper (OBS, transmissometer) or pre-existing (ADCP backscatter) instruments to do the same. Does a LISST do a better job. Sequoia will say "yes". We would say "possibly". Note: the LISST is also a very good transmissometer. The % transmission (or attenuation) can also be calibrated to SSC.

E) Operational and other Observations and Questions

- An indicator is needed for LISST-SL to show when pump has stabilized to ambient velocity.
- Is an indicator also needed for LISST-SL and –SS to show when instrument temperature is stabilized to measured water temperature?
- What method does Sequoia recommend to dewater –SS for temporary storage?
- How close is Sequoia to having a working sonic cleanser in –SS so that weekly cleaning is not necessary (frequency depends on site, weather, etceteras)?
- Woods Hole: Why doesn't someone develop a multiwavelength optical + multifrequency acoustic sensor?

SEQUOIA SCIENTIFIC, INC. RESPONSES AND COMMENTS

C.b. These are questions with two part response.

i. There is a rigorous method to test the presence of significant amounts of particles finer than the lower limits of LISST size-range. This method tests the following idea: Is all the light removed from the laser beam by scattering accounted for as light sensed by ring detectors? If the answer is no, then significant material exists below LISST lower size limit. The test for this is coded into a Matlab function, bcratio_SL.m for LISST-SL, and similarly, bcratio_SS.m for the StreamSide instrument. In the above, b represents the *beam scattering coefficient*, and *c* represents the *beam attenuation coefficient.* [LISSTs only produce an estimate of b covering 0.05 to 10-degrees, i.e. not to 180^o, which we term b_f] When the b_f /c ratio is much lower than 0.7, (or lower than 0.2), significant fines are indicated. As an example, this ratio for the AC Coarse particles is 0.74.

ii. For particles larger than largest in LISST range, yes, a simple laboratory measure of this size range can be used as 'unmeasured large fraction'.

iii. Effect of flocculation: The state of flocculation in any river at any time depends on a lot of factors. Some of these are the biological content of water, strength of turbulence, nature of particles, etc.. Therefore, no general statement can be made about the state of flocculation in all rivers. However, it is possible to develop data on 'effective density' of flocculated particles that characterize rivers under various conditions.

D.b. (second bullet): Unless density of particles of different sizes in-situ are studied (e.g.. using LISST-ST settling tube), it is a good approach to use empirically determined mass densities. It would be helpful to characterize the range of applicable densities at any site, so as to put error bounds on VPC and SSC.

Similarly, attention should be paid to the amount of particles lost to small fractions due to flocculation (e.g. gravimetric/Sedigraph vs LISST, b_f /c ratio).

E. Operational Questions:

Sequoia is evaluating/implementing a method to indicate to the user when the pump has acquired isokinetic lock.

Sequoia is similarly evaluating/implementing a method to indicate when thermal equilibration of the LISST-SL has been reached.

Sequoia is evaluating how to dewater the LISST-SS for temporary storage under freezing conditions.

Sonicator in StreamSide: We are currently looking into the redesign. We hope to have an answer to this question shortly.