Measuring Suspended Sediments Using High Resolution Acoustic Velocimeters

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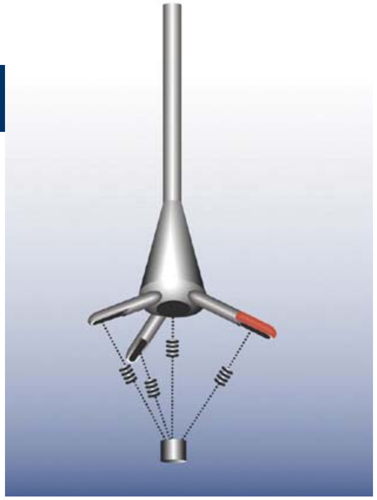
Benefits of Using Acoustics to Study Marine Particles

- In the MHz range, peak sensitivity to particles of O(100μm), where optics is not or may be affected by turbulence
- Less prone to biofouling
- Current meters can measure turbulent fluxes of particles, useful for sediment modeling
- Sound scattering depends upon the physical properties of sediments, different sensitivity to composition than optics

Acoustic Velocimeters for Mass Analysis



- Acoustic Velocimeter
  - Bistatic acoustic sensor
  - Doppler shift gives rise to velocity profile
- Make use of the Modus Operandi
  - Characterize the instrument response to concentrations of a given particle size distribution
  - Extrapolate a response to a broad range of particle sizes

The Sensors

- Nortek Vector
  - 6 MHz
  - Sampling volume located 15.7 cm from the transmitting transducer
  - Receives at 26^0 backward off acoustic axis

- Sontek MicroADV
  - 16 MHz
  - Sampling volume at 5 cm
  - Receives at 25^0 backward off acoustic axis

- Different transmit frequencies each respond to particles of a characteristic size

The Theory

- Acoustic pressure received at the transducer face is proportional to the mass concentration of scatterers,

  $$< P_b >= k_s k_t \sqrt{M} e^{-2r\alpha},$$

  sediment constant, $k_s = \frac{< f >}{\sqrt{\rho_s < a_s >}}$

  <f> is mean normalized form function, equivalent to VSF

  Instrument constant, k_t estimated through experiment

- Acoustic intensity related to pressure $I = \frac{1}{\rho c} P_b^2$

- Calculation of the form function

  Numerical method developed by Martin Anderson, 1996

  Solves the equations for a plane acoustic wave incident on a sphere with given physical parameters

  - Size, density, Poisson ratio, scattering angle

The Theory

- Acoustic Velocimeters
  - Logarithmic transform from instrument recorded units, "counts" to acoustic intensity

    $$Acounts = \log(\frac{I}{I_0})$$

  - Substituting for theoretical intensity, model equation

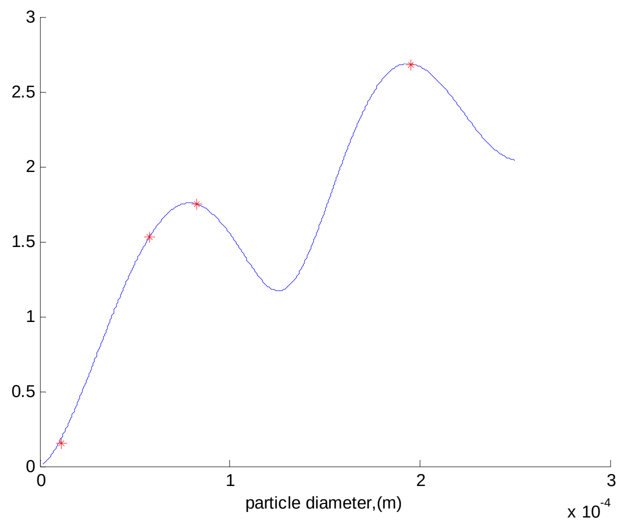
    $$Acounts = \log(\frac{1}{\rho c} k_s^2 k_n M)$$

- Conversion factor for each
  - Nortek
    - 0.45 counts = 1 dB
  - Sontek
    - 0.43 counts = 1 dB

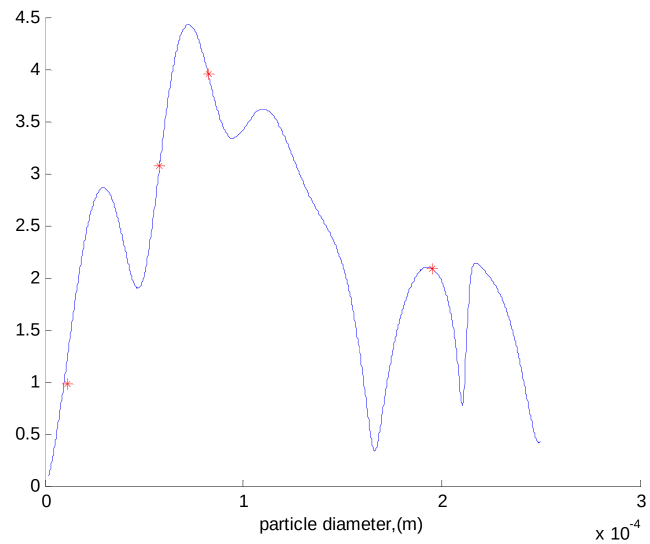
The Experiment

- Methods
  - Each sensor immersed in 7.5 L basin of DI water, water circulated with electric pump
  - Experiments performed with glass microspheres, sizes 3-30µm, 53-63µm,75-90µm, 180-212µm
  - Beads weighed dry in 0.2g parcels
  - Suspended sediment analysis to account for particle stratification
- Response to each concentration from each size measured and averaged from all 3 transducers, converted to acoustic intensity

Results



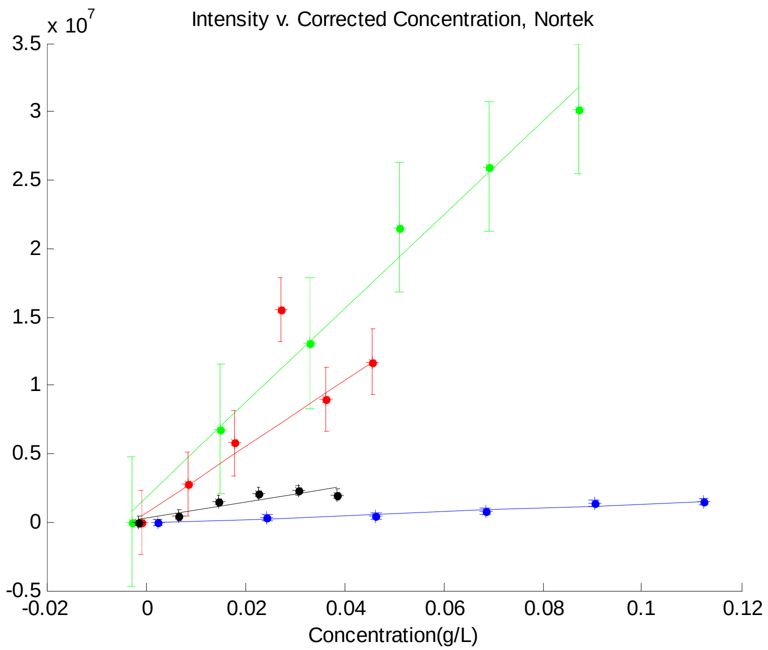
Nortek

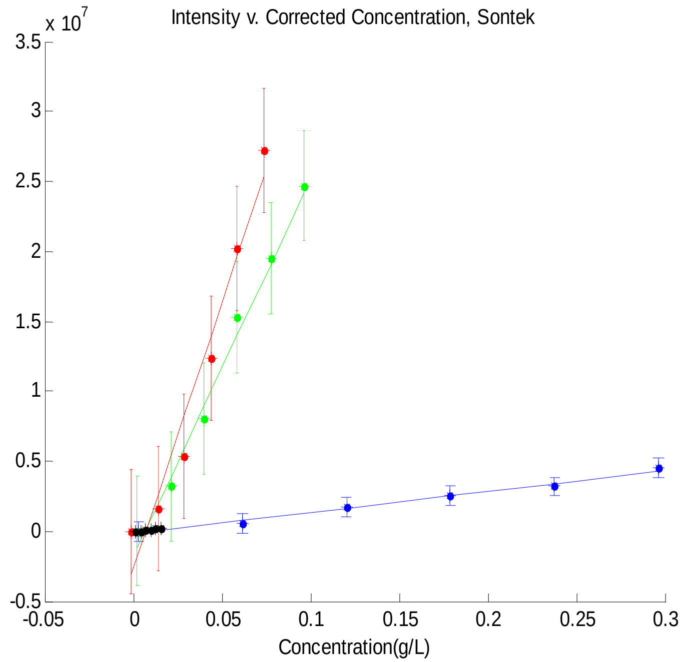


Sontek

Peak sensitivity predicted for particles of a characteristic size

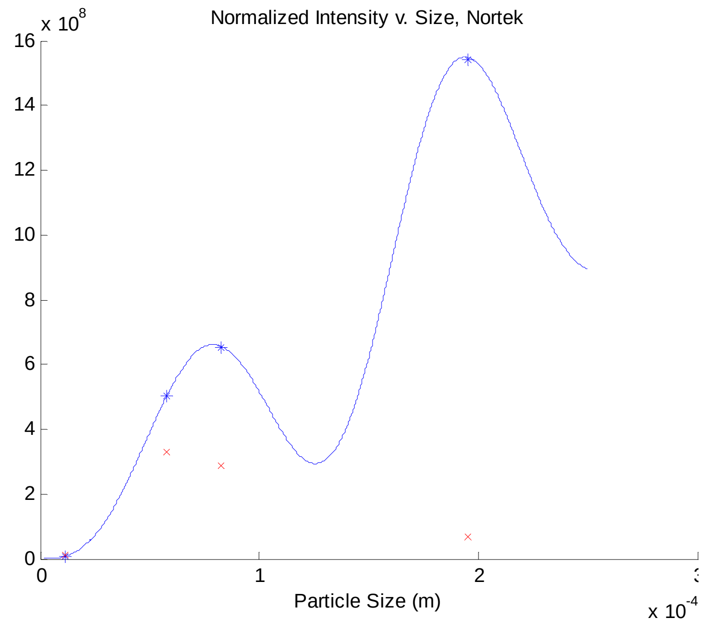
Results



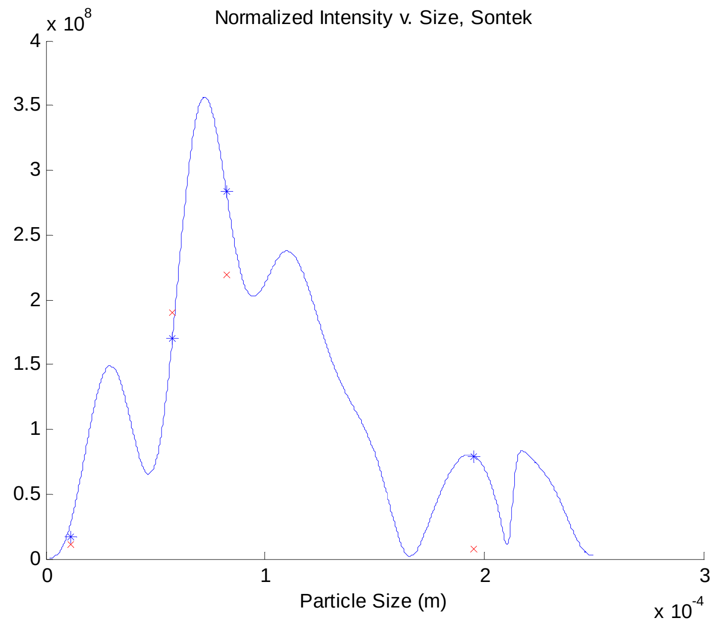


Linear response to mass!

Results



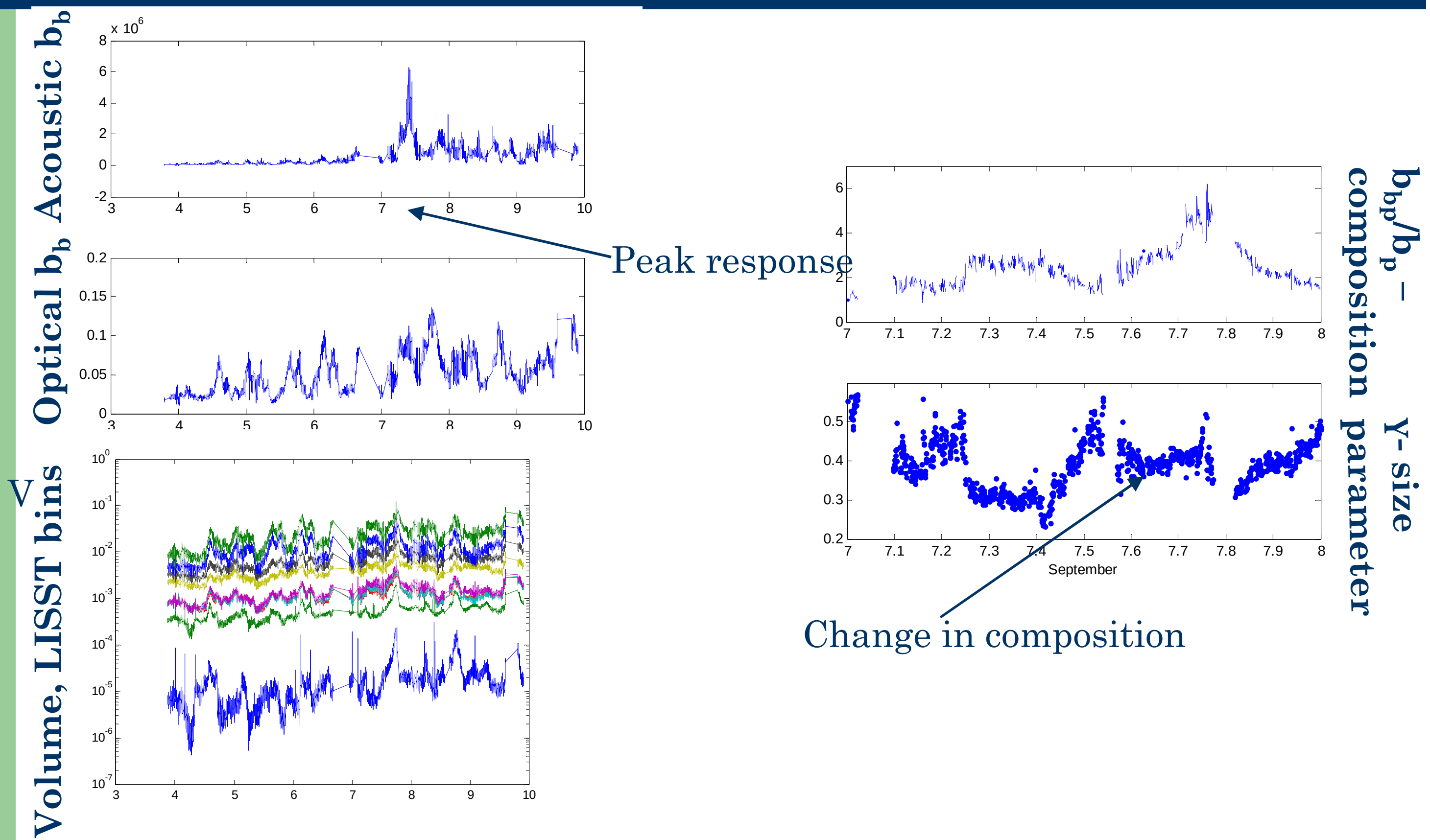
Nortek



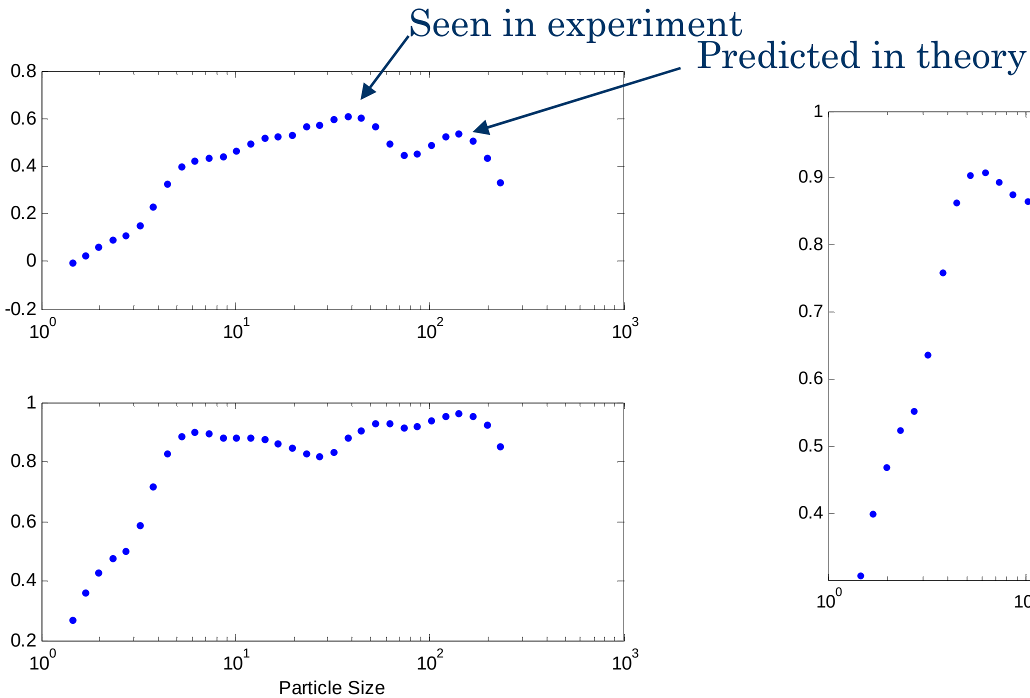
Sontek

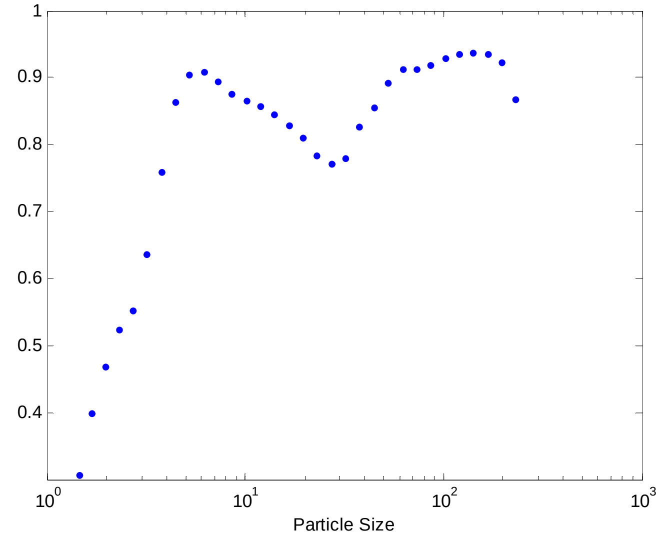
Sontek seems better behaved…

Contrasting Times Series, Acoustics & Optics (MVCO, 2005)



From the Field 2005…





Based on LISST inversion, acoustical backscatter correlates best with particles O(50μm).

Optical b_b and attenuation correlate better.

Summary

- Acoustics and optics contain different and complimentary information – useful to study particulates
- Correlation suggests the ability of using one to predict the other
- Future Work
  - Continue the characterization of sensors
  - Investigate composition effects on sensor response