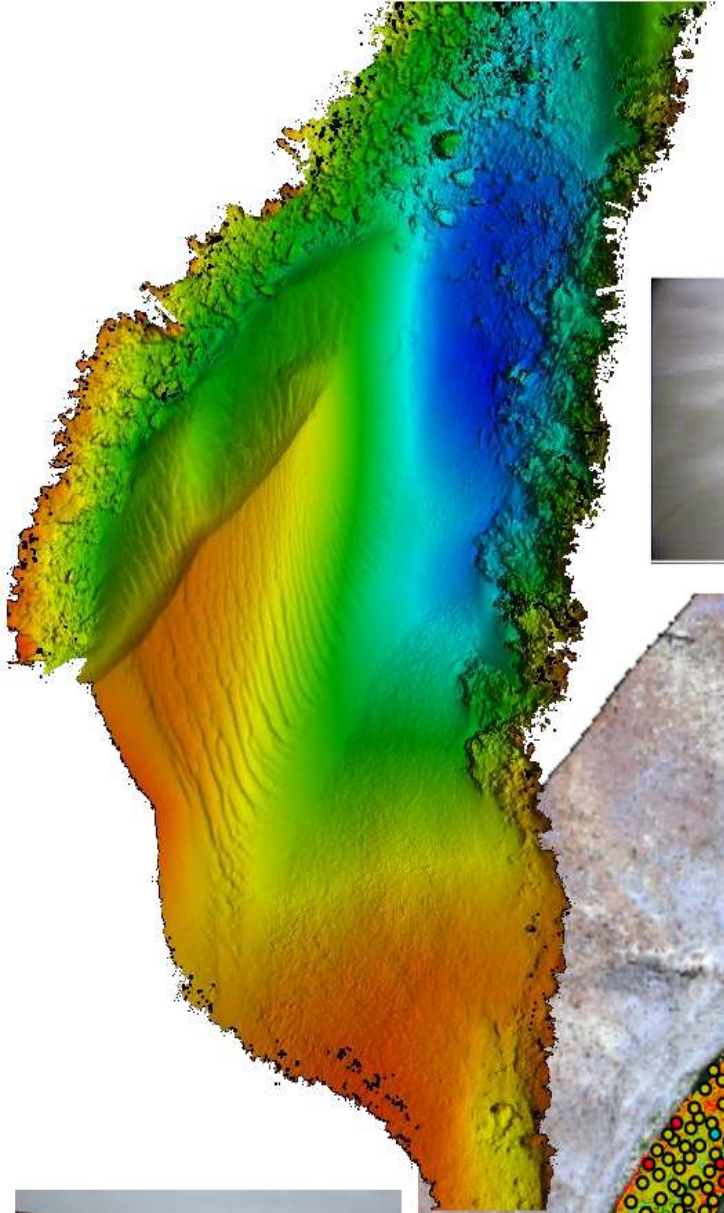
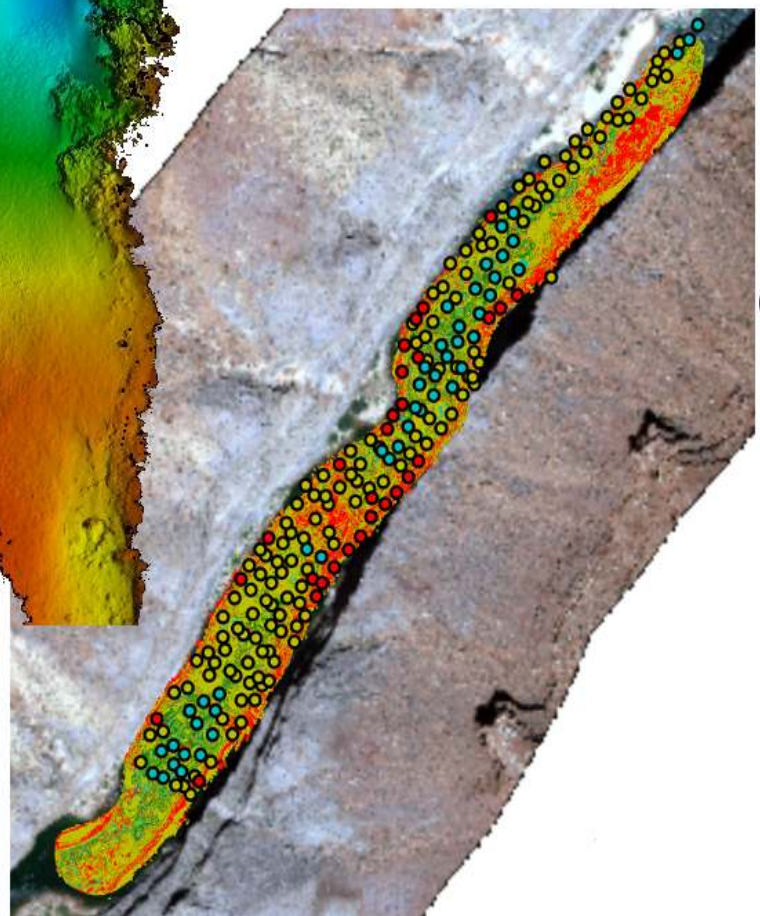




Acoustic Scattering by a Heterogeneous River Bed: Sediment Classification using Multibeam Echosounder.

Daniel Buscombe,
Paul E. Grams,
Grand Canyon Monitoring and Research Center, U.S. Geological Survey.

& Matthew A. Kaplinski
Northern Arizona University.

USGS science for a changing world

NORTHERN ARIZONA UNIVERSITY

Aim: mapping of Colorado River bed sediments.

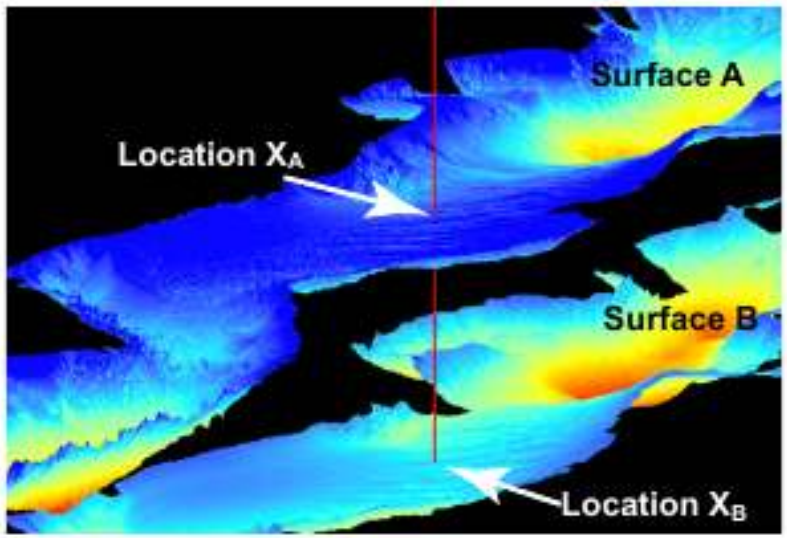
Why?

- Where is the sand?
  - Habitats
  - Geomorphology

Aim: mapping of Colorado River bed sediments.

Why?

- How much sand is there?
  - Budgets
  - Sediment transport models



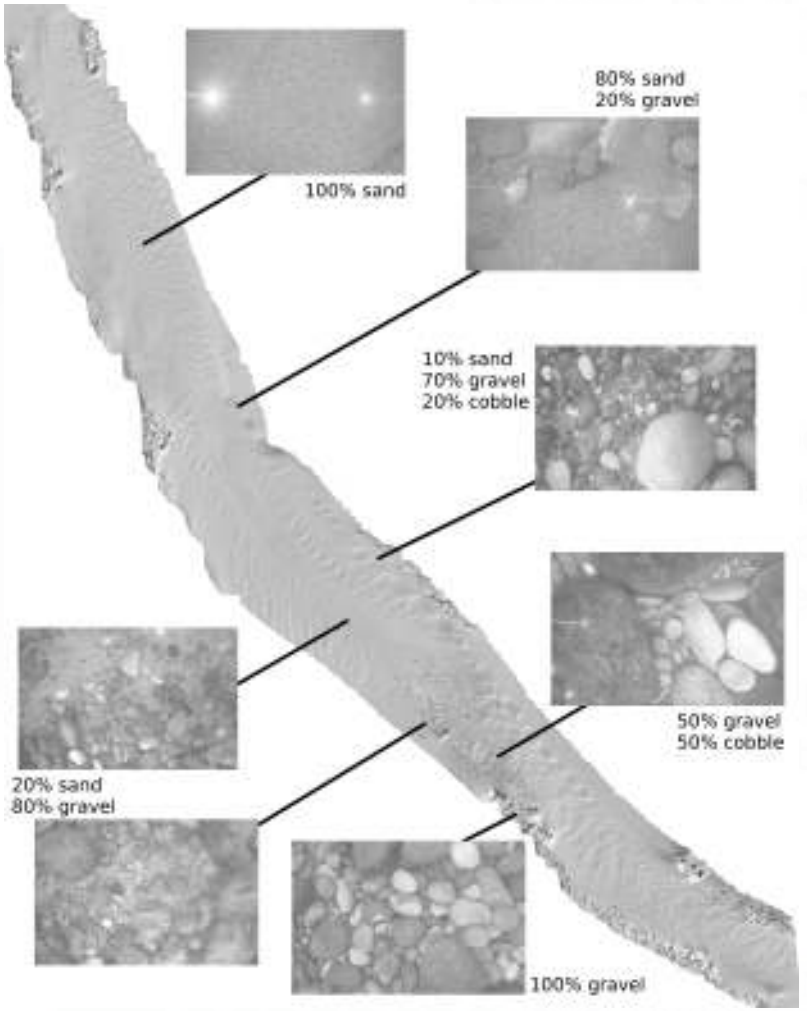
Aim: mapping of Colorado River bed sediments.

Why?

- How does that vary in time?
  - Dam operations
  - Experimental high flows

Objectives.

- Infer bed sediments using high-frequency backscatter
- Heterogeneous non-cohesive sediments
- Develop a data-driven approach using patches of known sediment type

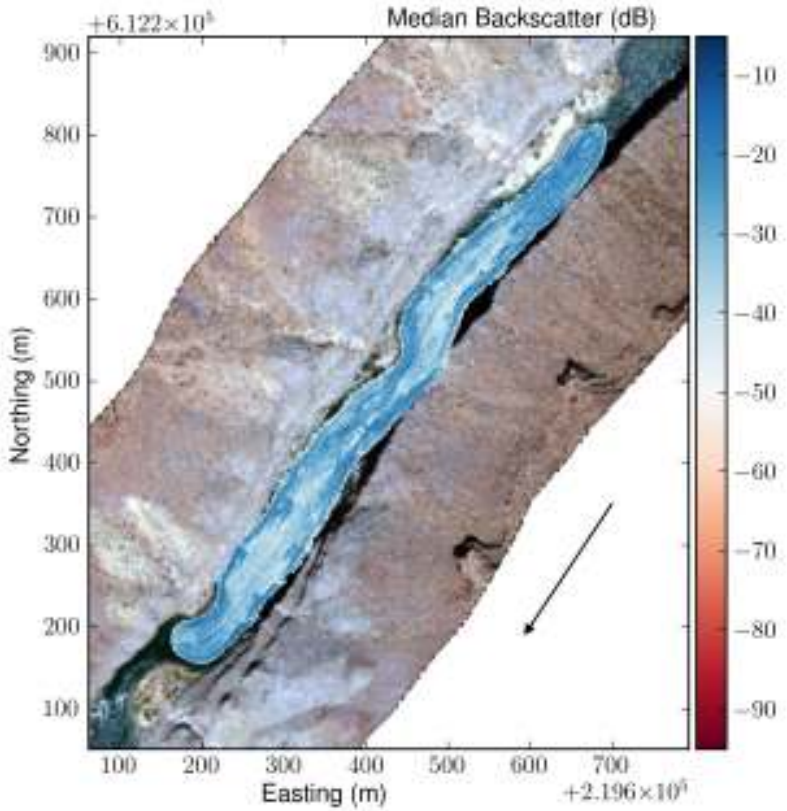


Talk outline.

- Multibeam and underwater video sampling
- Bed-sediment classification
  - Spectral analysis of backscatter
  - Statistical classification
- Preliminary results

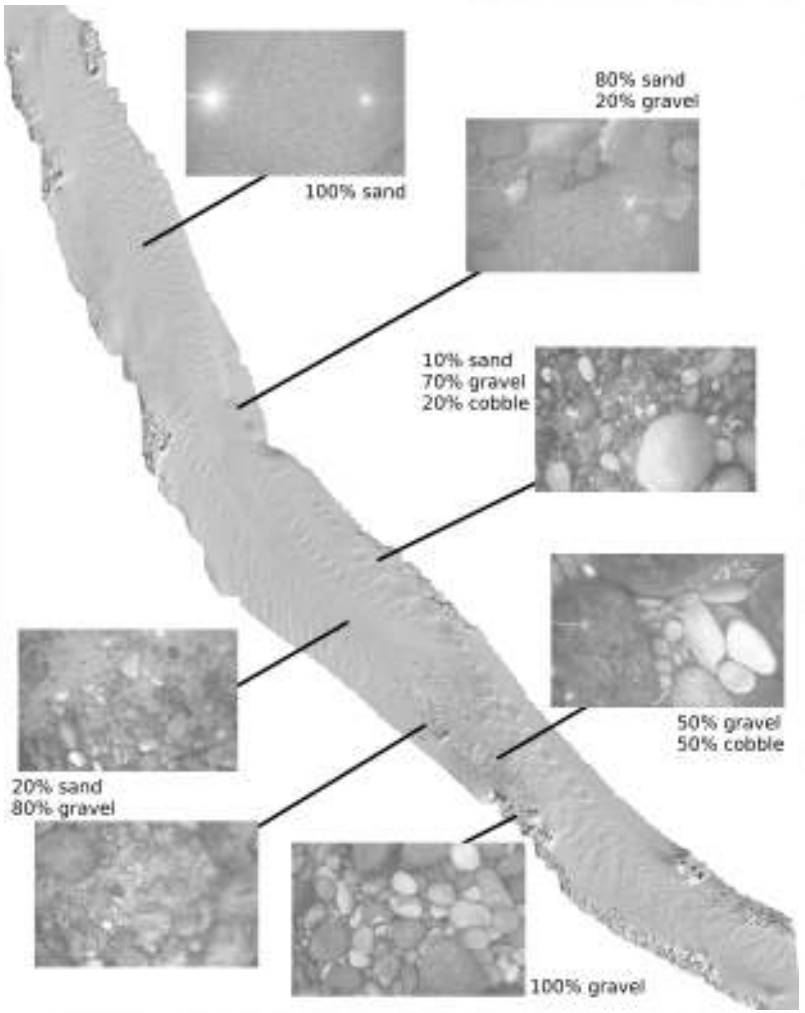
Talk outline.

- Multibeam and underwater video sampling
- Bed-sediment classification
  - Spectral analysis of backscatter
  - Statistical classification
- Preliminary results



Talk outline.

- Multibeam and underwater video sampling
- Bed-sediment classification
- Preliminary results



Riverbed bathymetry is mapped using multibeam ...

... using a Reson 7125 system

- 400 kHz
- 512 beams across 130^o swath
- 0.5^o x 1^o
- one uncorrected echo per sounding

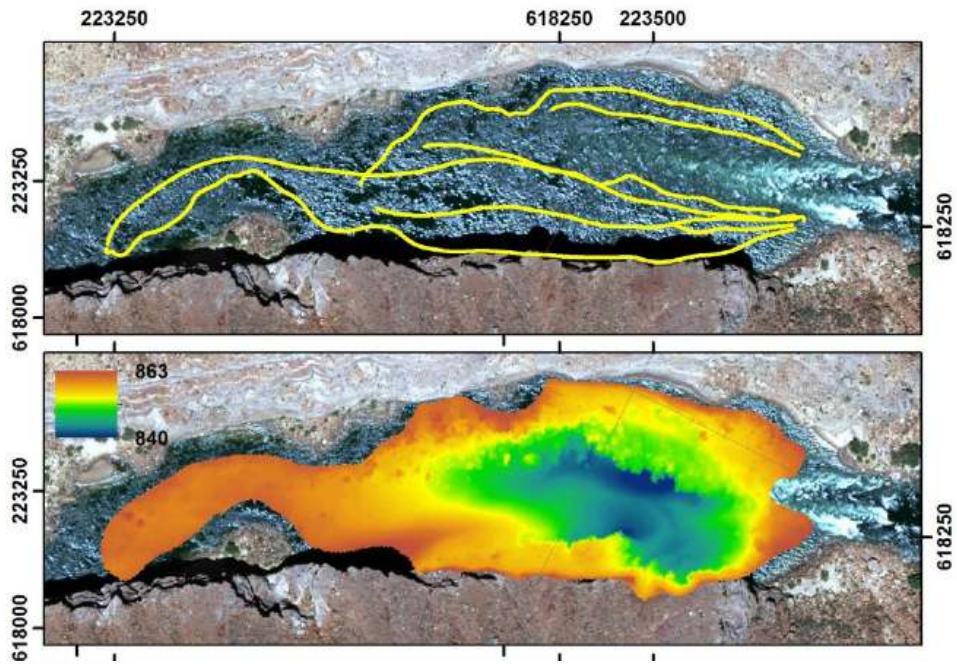
Bed sediments sampled using video ...

... which has revealed enormous bed sediment heterogeneity

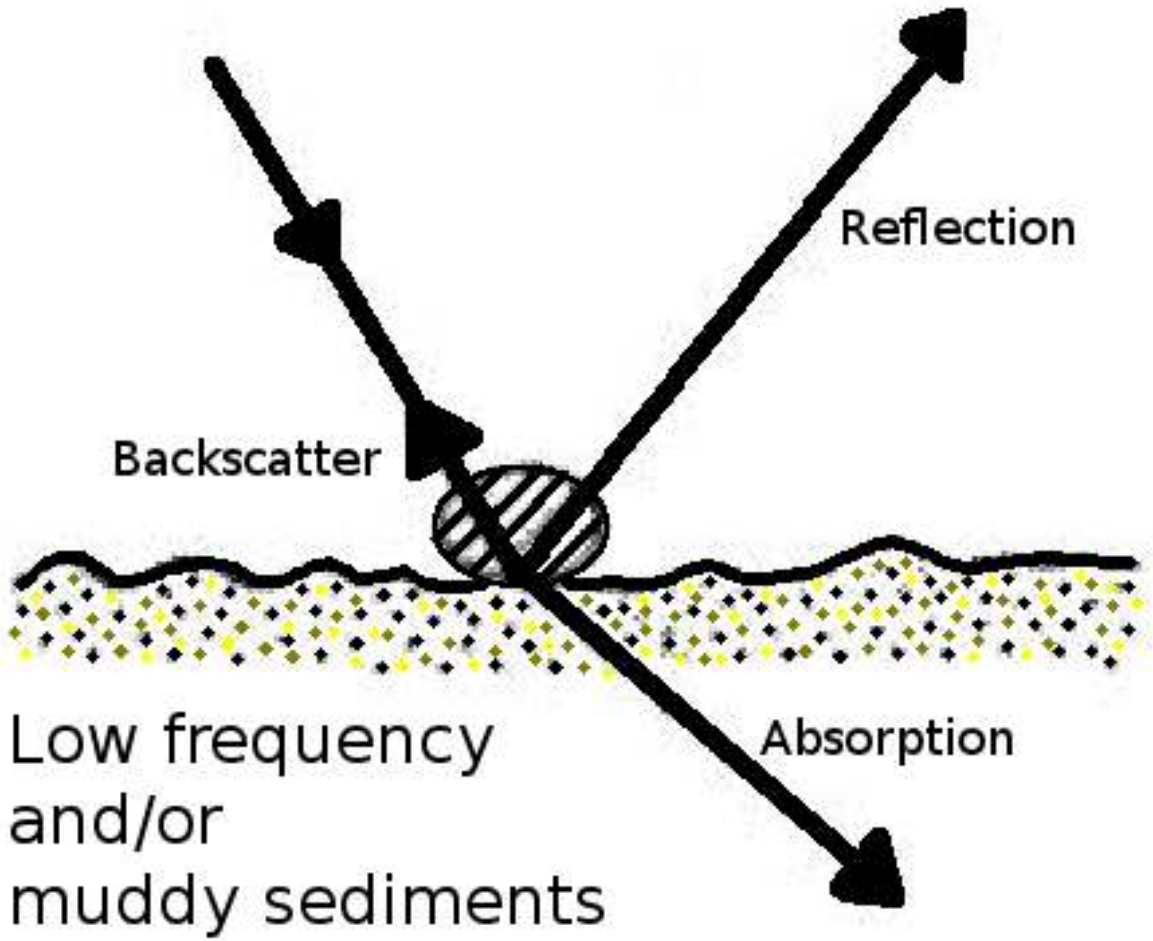
- Fine sand through to boulders
- Abrupt transitions

Why use acoustics for bed sediment?

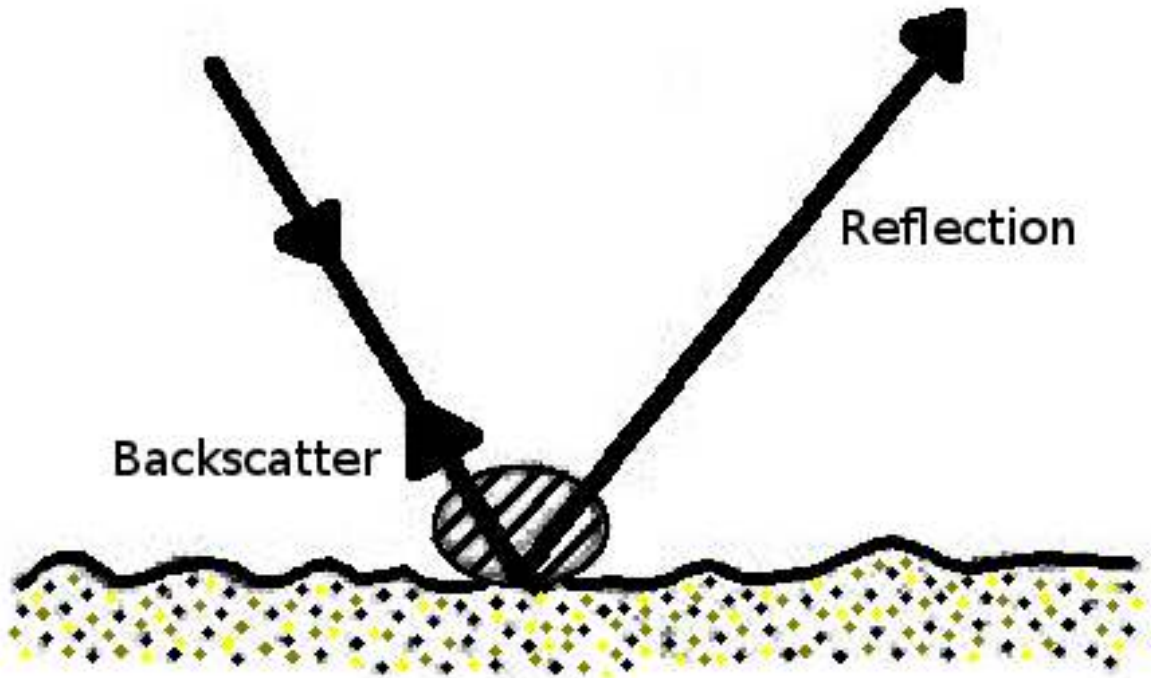
- Conventional sampling limited
- High resolution, large coverage
- Applied retroactively back to (at least) 2009
- Backscatter depends *in part* on grain size



Backscatter to infer grain size

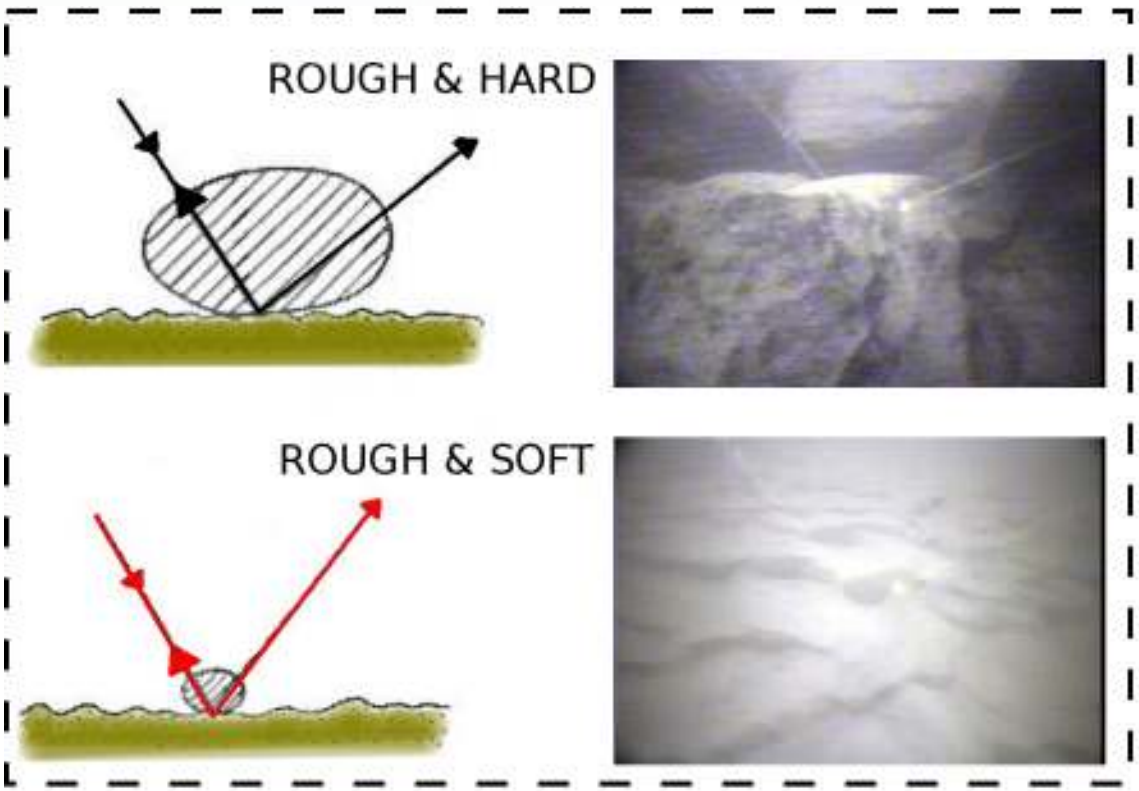


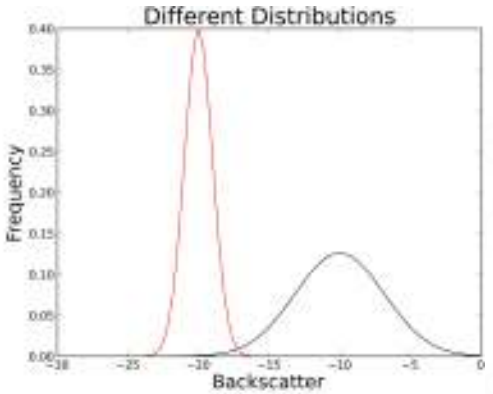
Backscatter to infer grain size

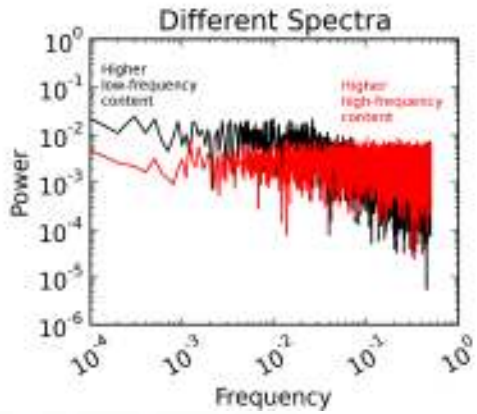


High frequency
and/or
non-cohesive sediments

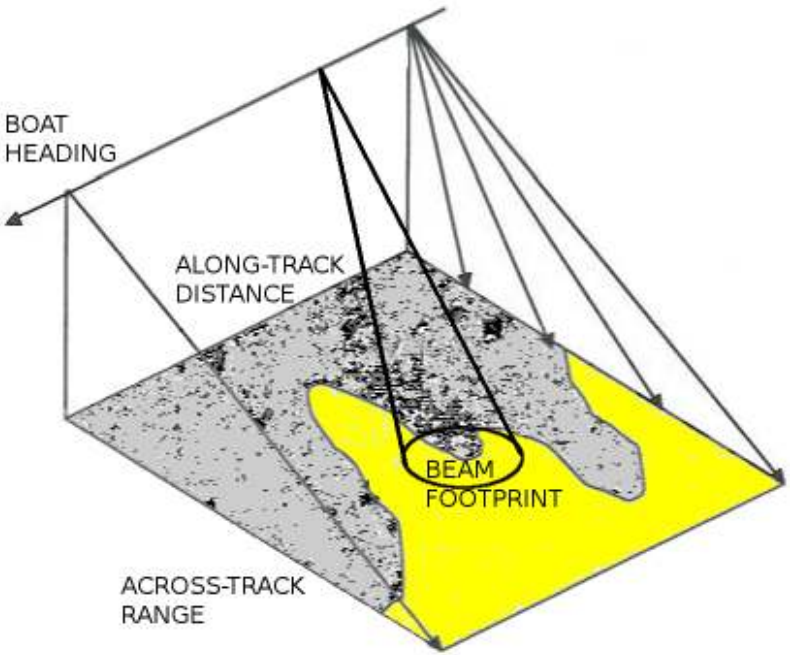
Backscatter to infer grain size



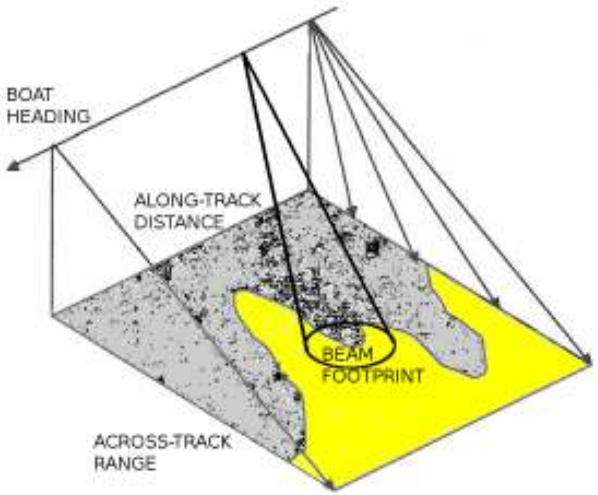


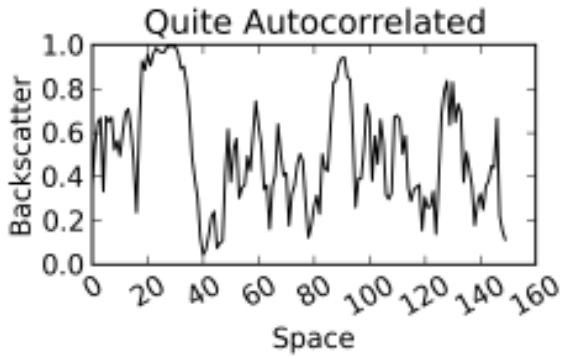


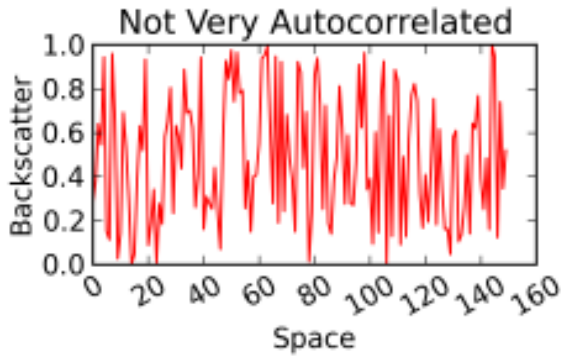
Acoustics of a heterogeneous river bed

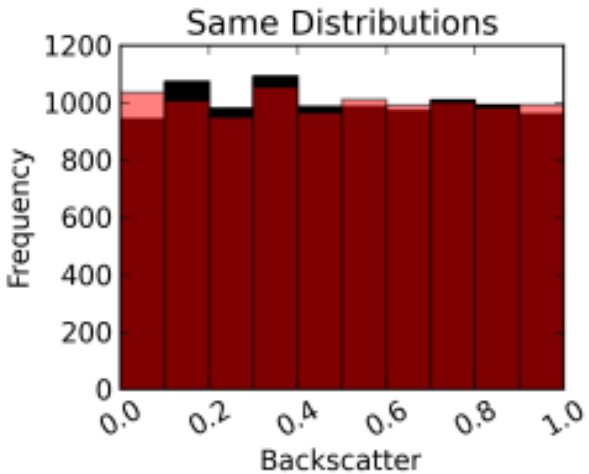


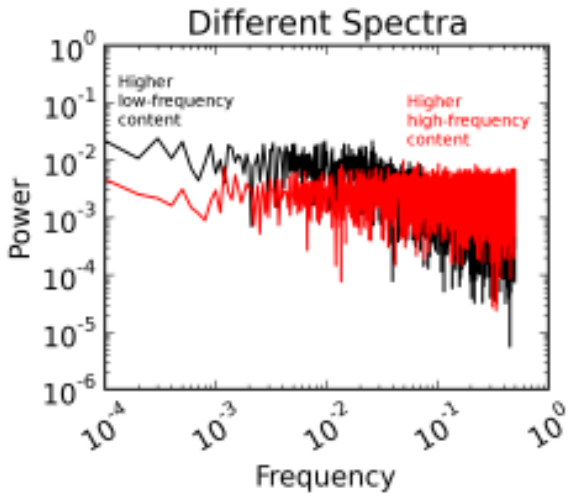
Acoustics of a heterogeneous river bed



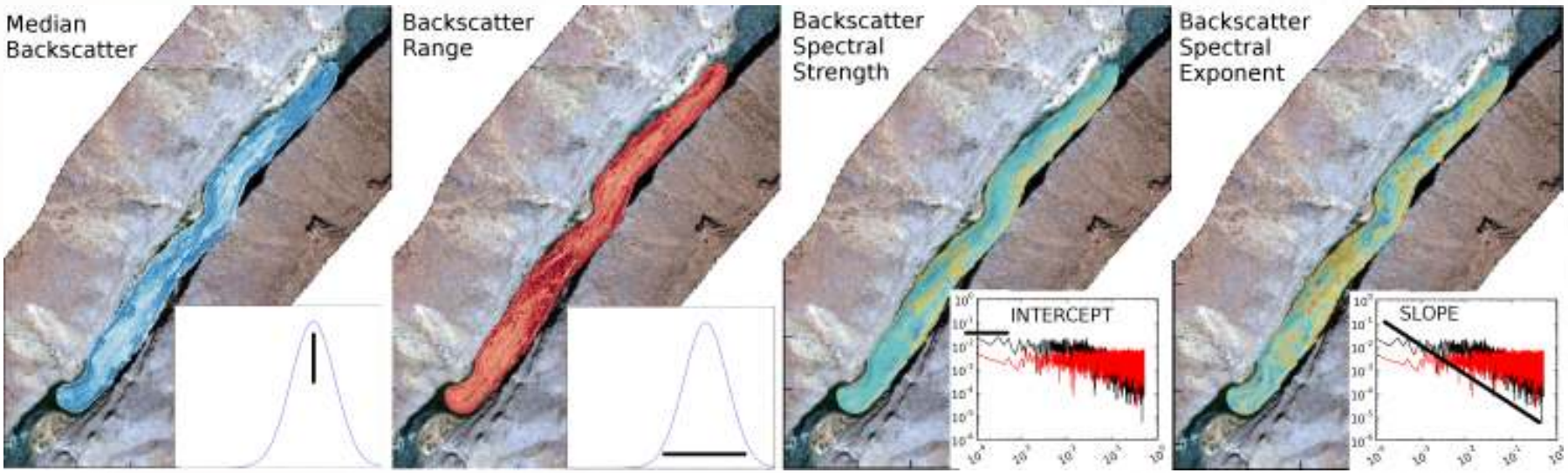




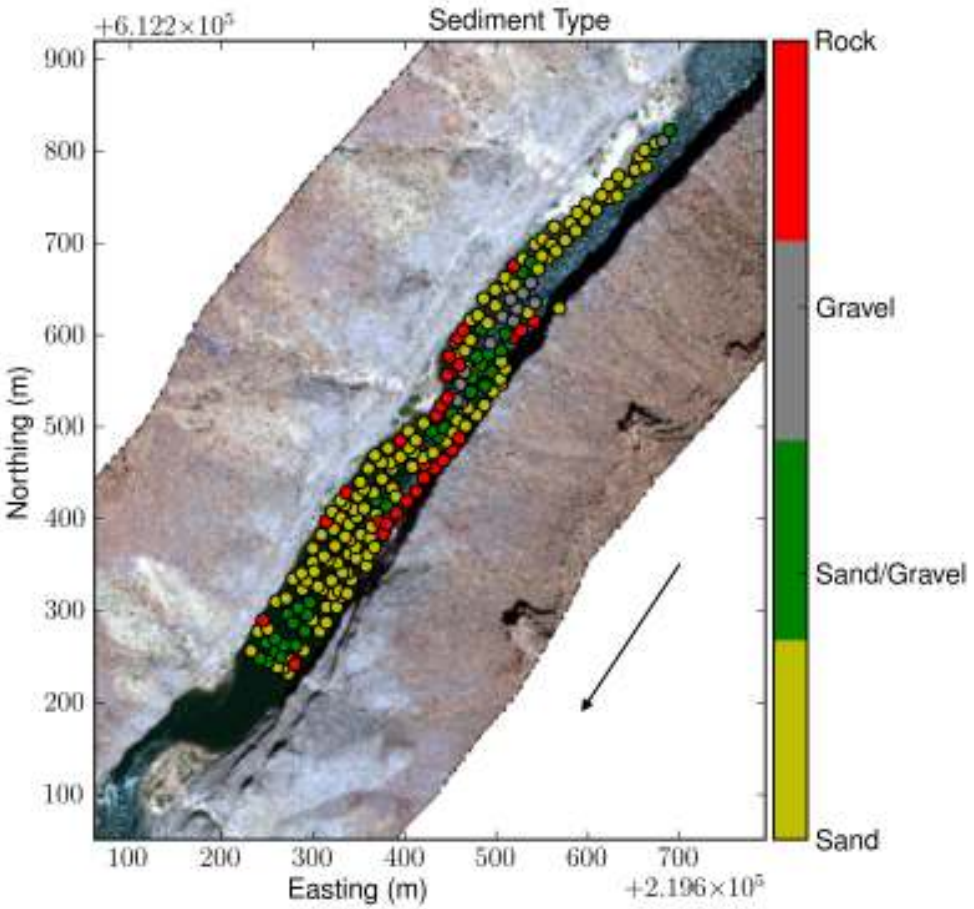


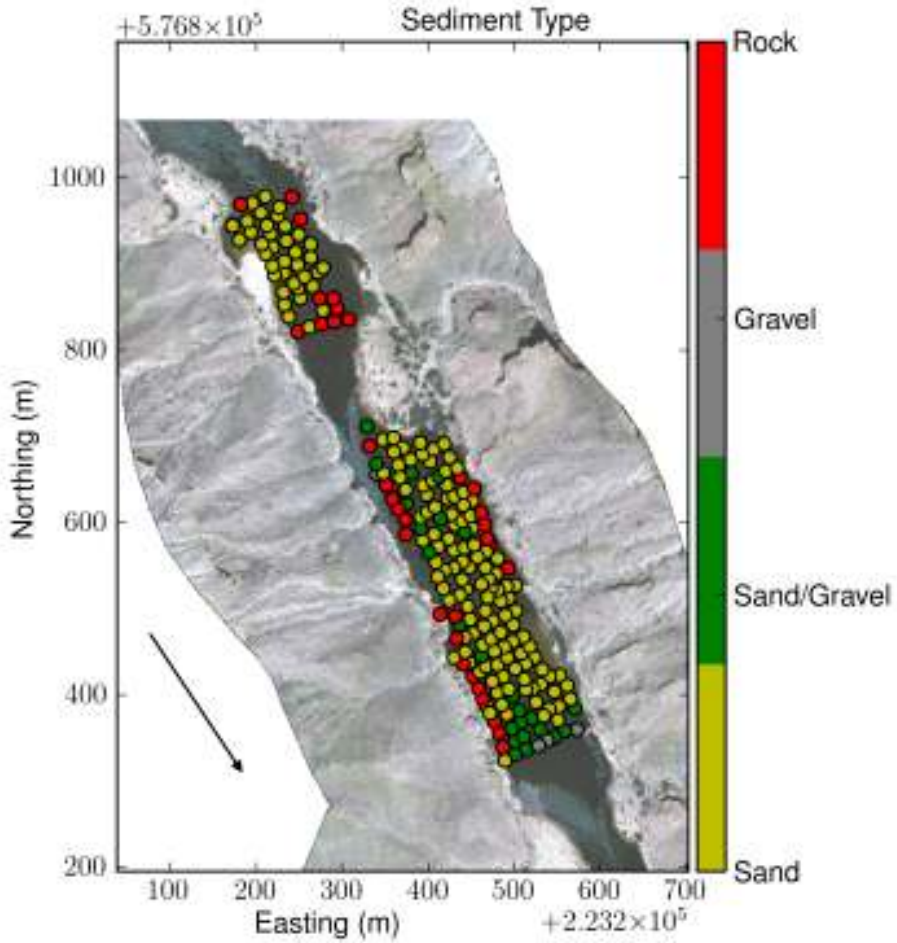


Backscatter statistics

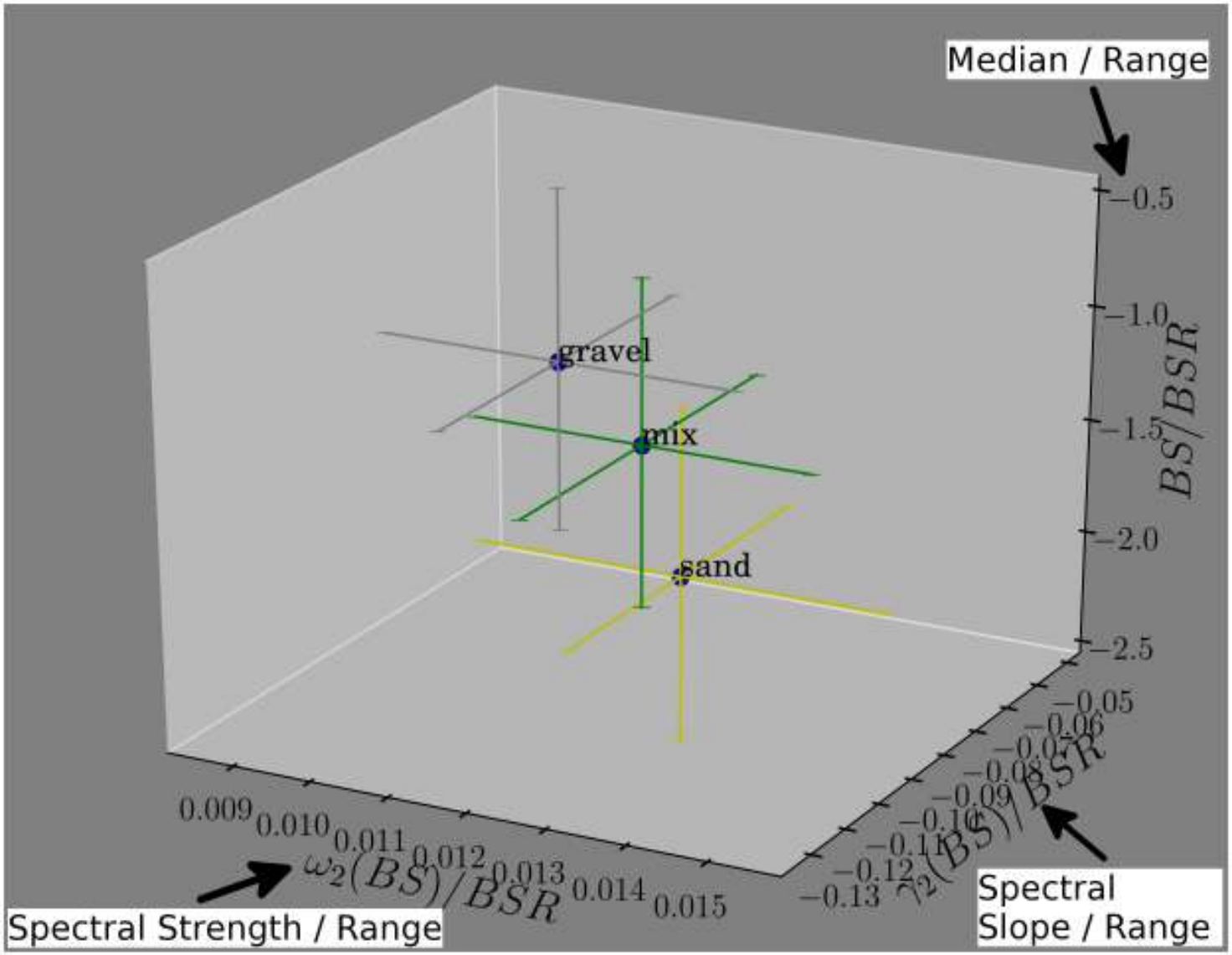


Backscatter statistics over known substrates

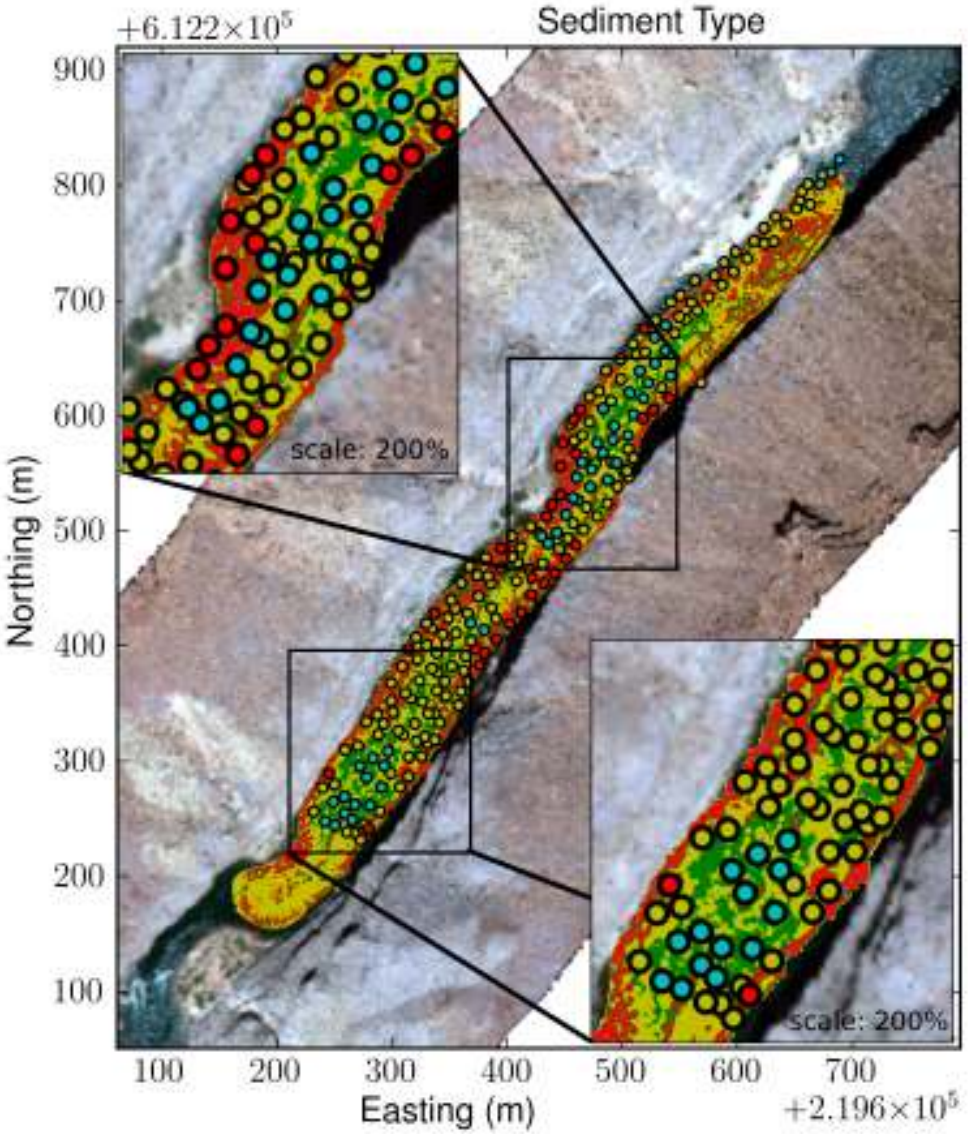


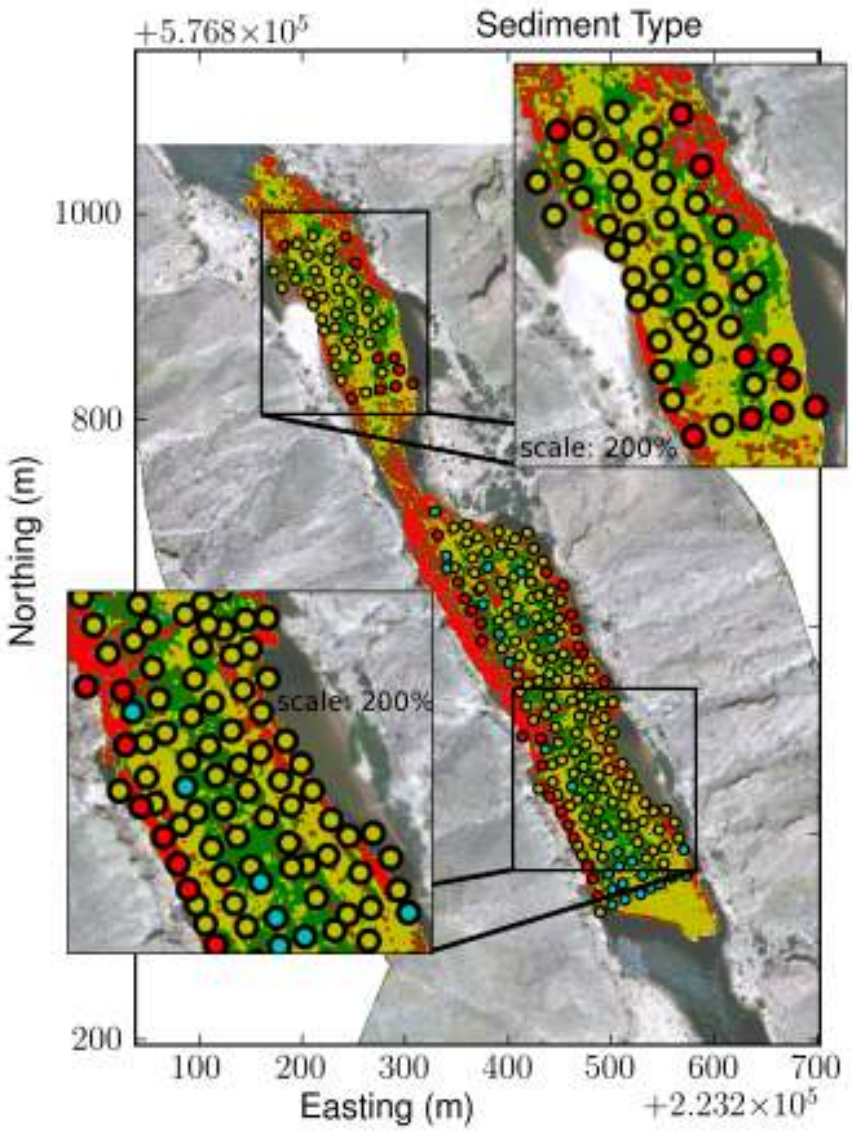


Classification



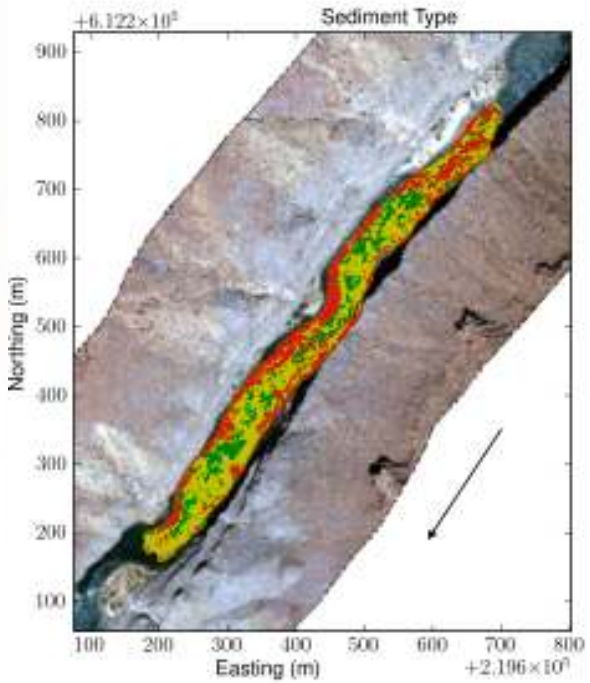
Sediment classification: different sites





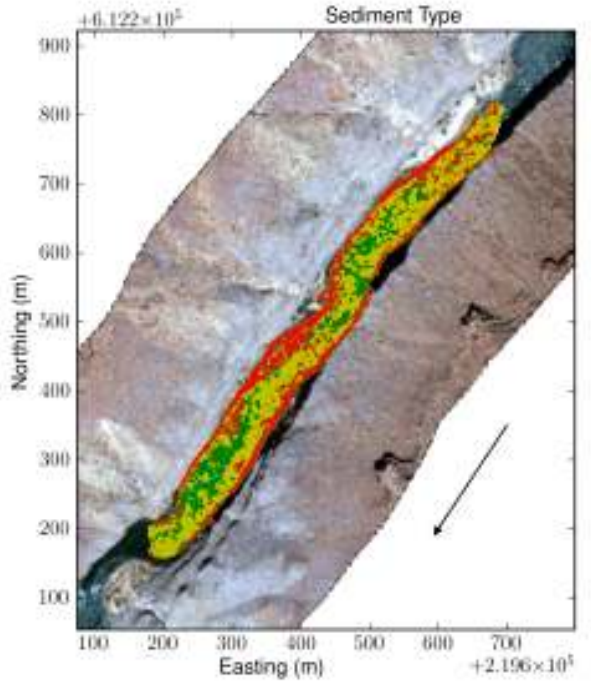
Sediment classification: same site, different times

MAY 2012



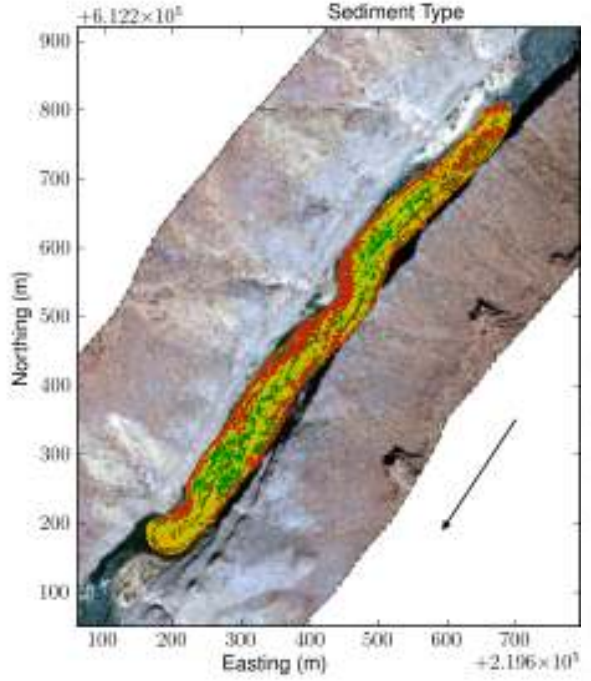
0.25%	unclassified
47.0%	sand
23.6%	sand/gravel mix
2.8%	gravel
26.4%	rock

MAY 2013



0.56%	unclassified
48.1%	sand
22.5%	sand/gravel mix
2.8%	gravel
26%	rock

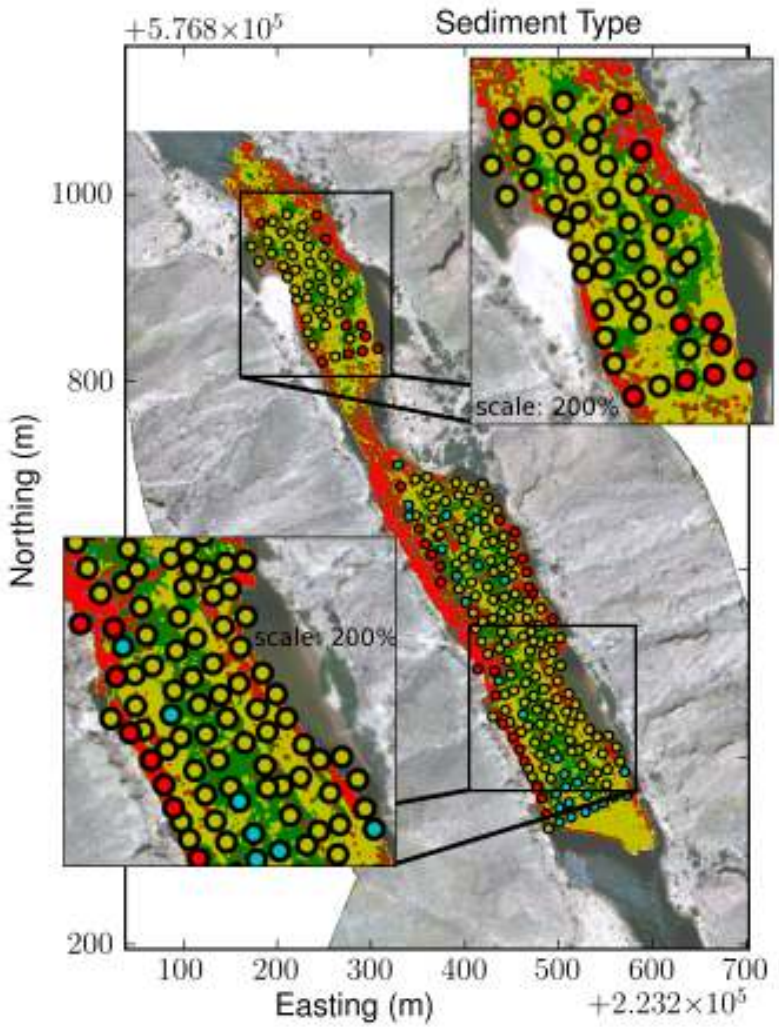
AUG 2013



0.28%	unclassified
46.3%	sand
25.1%	sand/gravel mix
2.0%	gravel
26.3%	rock

Summary

- Progress towards bed sediment classification using backscatter
- Statistical approach using both spectral and distribution properties
- Further refinements. More/better validation
- Apply to previous MB systems
- How well does it apply to 225 miles of river??



Summary

- Progress towards bed sediment classification using backscatter
- Statistical approach using both spectral and distribution properties
- Further refinements. More/better validation
- Apply to previous MB systems
- How well does it apply to 225 miles of river??

Thanks for listening

dbuscombe@usgs.gov | pgrams@usgs.gov | matt.kaplinski@nau.edu

MB SYSTEM

scikit learn

python

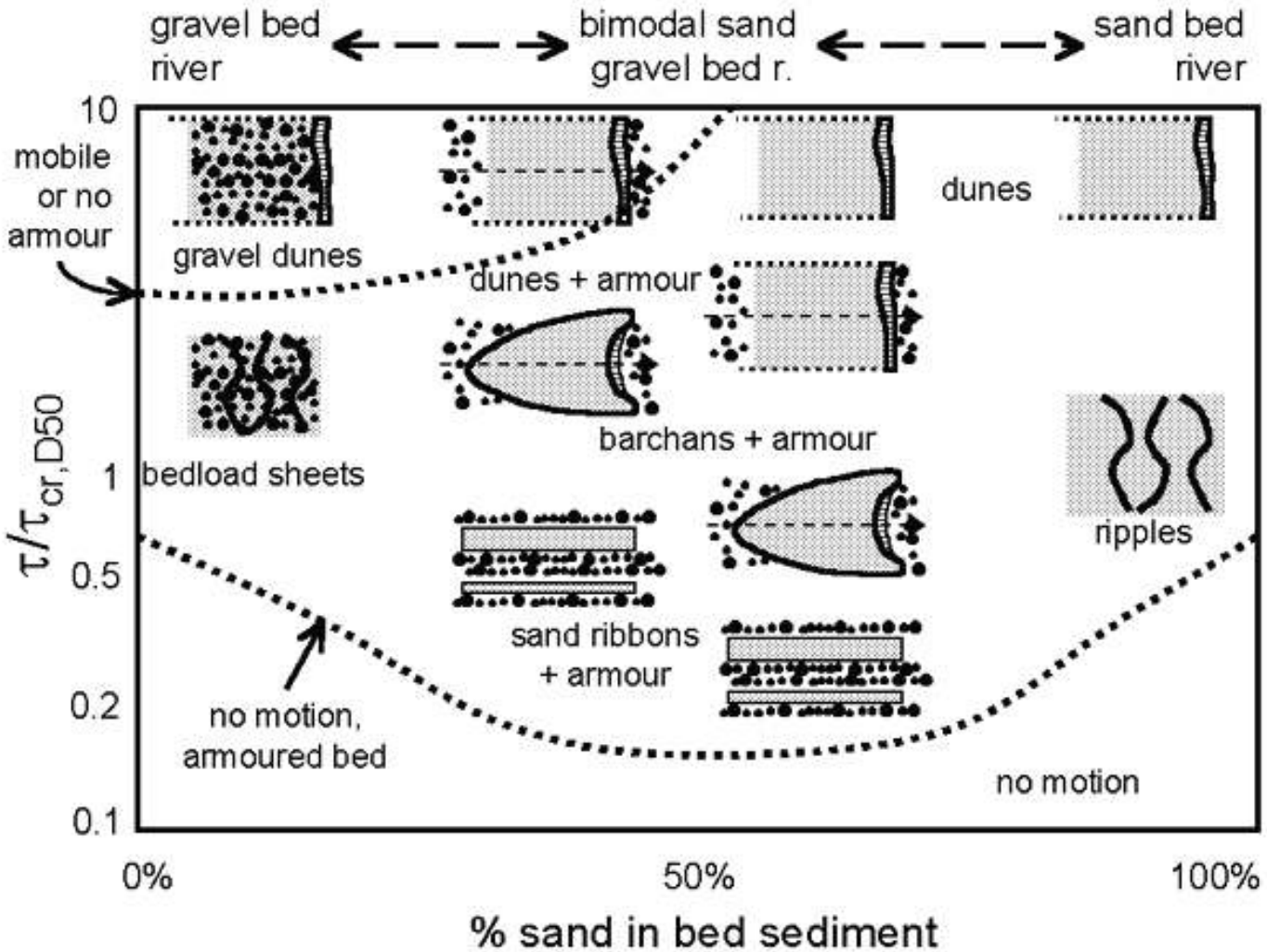
IP[y]: IPython Interactive Computing

matplotlib

github SOCIAL CODING

This slide is intentionally blank.

Non-uniqueness of backscatter

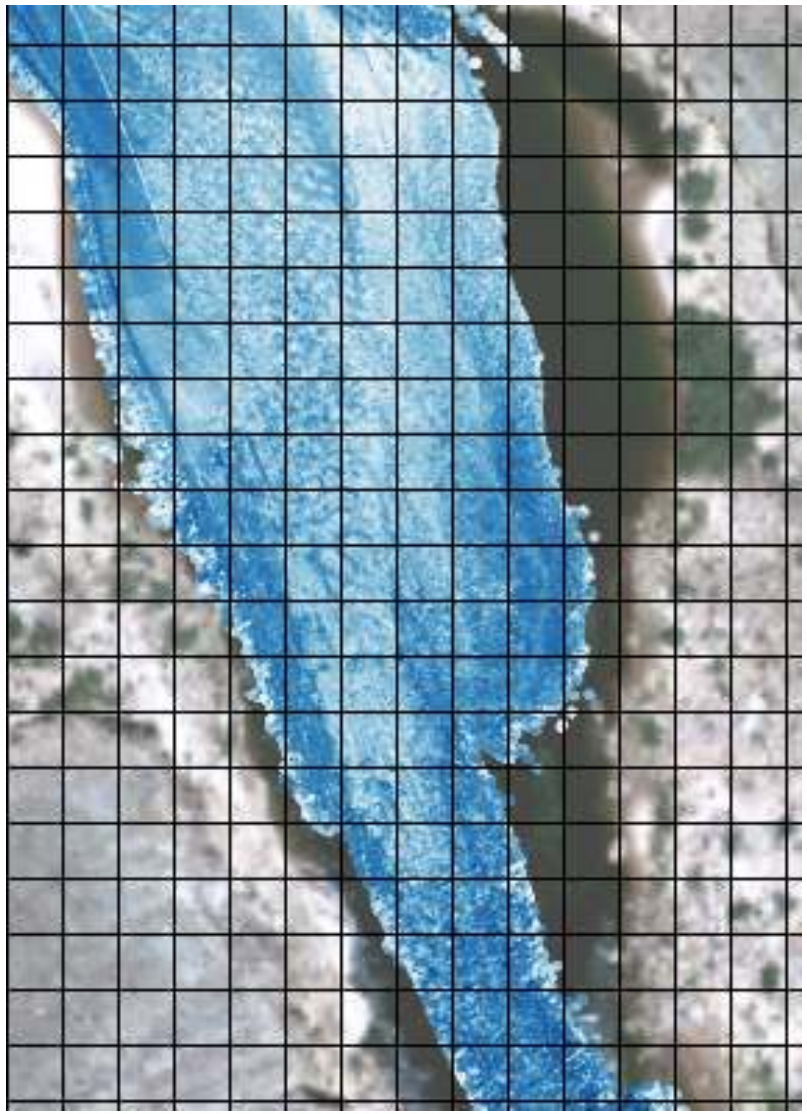


Kleinhans et al. Journal of Sedimentary Research, 2002

Acoustic ‘Roughness’

2D Power spectra

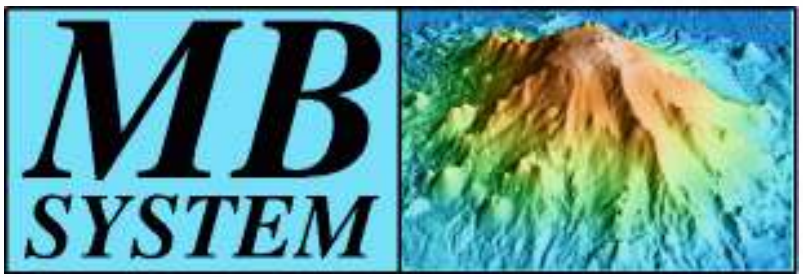
- Detrended DEM and BS
- Hann tapered 2D periodogram
- Normalised by background spectra
- 2D to 1D for power law fit
- Thousands of overlapping windows (25×25m) shifted 0.25m (ensemble averaging)
- Continuous maps of stochastic geometries



Pre-Processing

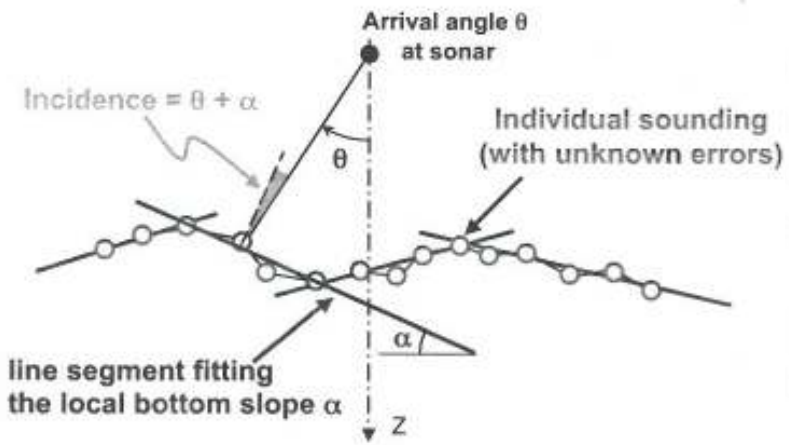
MB-System

- Generic
- Command line. *nix environments
- Scientific user community
- Control and reproducibility



Caress and Chayes. Proceedings of the IEEE Oceans 95 Conference, 1995.
Caress and Chayes. Marine Geophysical Research, 2006.

Pre-Processing



Corrections

- Roll and pitch bias, offset depths
- Slopes
- Slope ‘spikes’
- Remove “rails”

Balancing the Acoustic Budget

- Raw echo

$$BS(\theta_c) = EL(\theta_c) - SL(\theta_c) + 2TL(\theta_c) - 10 \log A_f(\theta_c)$$

- Source level [MEASURED]
- Transmission losses [ESTIMATED]
- True area of beam footprint [ESTIMATED]

Amiri-Simkooei et al., Journal of the Acoustic Society of America, 2009

Balancing the Acoustic Budget

- Raw echo

$$BS(\theta_c) = EL(\theta_c) - SL(\theta_c) + 2TL(\theta_c) - 10 \log A_f(\theta_c)$$

- Source level [MEASURED]
- Transmission losses [ESTIMATED]
- True area of beam footprint [ESTIMATED]

Amiri-Simkooei et al., Journal of the Acoustic Society of America, 2009

Balancing the Acoustic Budget

- Raw echo

$$BS(\theta_c) = EL(\theta_c) - SL(\theta_c) + 2TL(\theta_c) - 10 \log A_f(\theta_c)$$

- Source level [MEASURED]
- Transmission losses [ESTIMATED]
- True area of beam footprint [ESTIMATED]

Amiri-Simkooei et al., Journal of the Acoustic Society of America, 2009

Balancing the Acoustic Budget

- Raw echo

$$BS(\theta_c) = EL(\theta_c) - SL(\theta_c) + 2TL(\theta_c) - 10 \log A_f(\theta_c)$$

- Source level [MEASURED]
- Transmission losses [ESTIMATED]
- True area of beam footprint [ESTIMATED]

Amiri-Simkooei et al., Journal of the Acoustic Society of America, 2009

Transmission, Amplification & Sampling

$$BS(\theta_c) = EL(\theta_c) - SL(\theta_c) + 2TL(\theta_c) - 10\log A_f(\theta_c)$$

- Function of:
  - Output power [MEASURED]
  - Input amplification [MEASURED]
  - Ping rate [MEASURED]
  - Pulse length [MEASURED]

Water & Sediment Attenuation

$$BS(\theta_c) = EL(\theta_c) - SL(\theta_c) + 2TL(\theta_c) - 10\log A_f(\theta_c)$$

- Sediment attenuation [ESTIMATED] using Urick (1948):
  - Particle size and concentration [MEASURED]
  - Particle density [ESTIMATED]
  - Homogeneous mixing [ASSUMED]

- Water attenuation [ESTIMATED] using Fisher & Simmons (1977):
  - Temperature [MEASURED]
  - Salinity & pH [ESTIMATED]
  - Homogeneous mixing [ASSUMED]

Fisher and Simmons. Journal of the Acoustic Society of America, 1977.

Urick. Journal of the Acoustic Society of America, 1948.

Beam Footprint

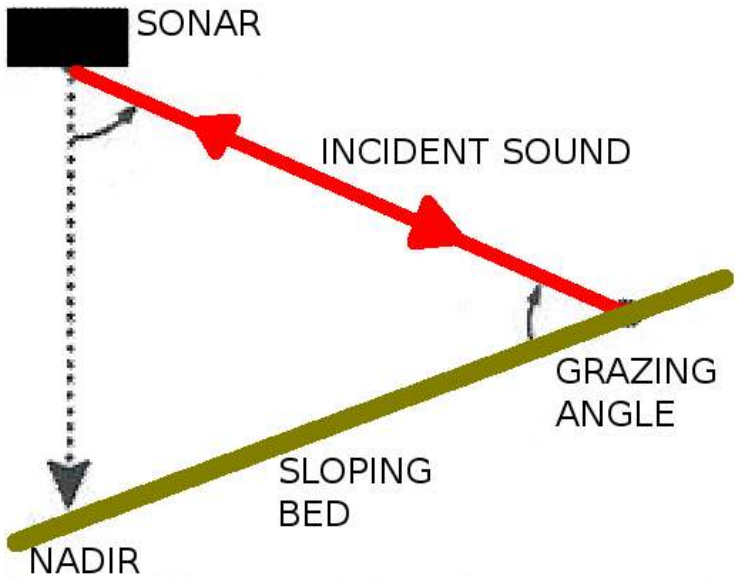
$$BS(\theta_c) = EL(\theta_c) - SL(\theta_c) + 2TL(\theta_c) - 10\log A_f(\theta_c)$$

- Function of:
  - Across- & along-track slopes [ESTIMATED]
  - Angular range [ESTIMATED]
  - Ping rate [MEASURED]
  - Grazing angle (ψ_c) [ESTIMATED]

Acoustics of a Heterogeneous River Bed

Shallow & Steep

- Few ‘scatter pixels’ (small beams)
- Large slopes = large grazing angles
- Backscatter at large angles = poor sediment discriminator



Backscatter "snippets"

Backscatter

- No processing on the fly
- Pseudo-sidescan
- "Snippets" - one uncorrected echo per sounding
- We use snippets = bed surface