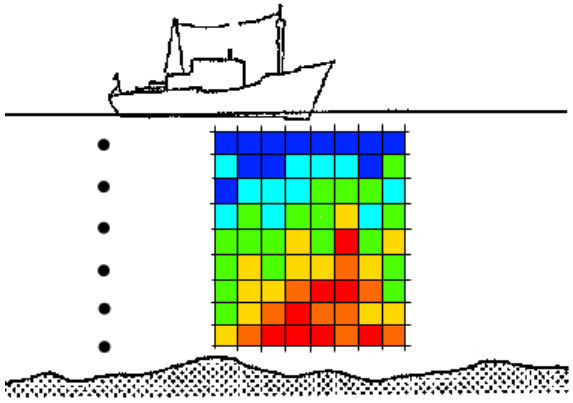
Updates to STA

Software for processing ADCP-SSC data

Justin Boldt

October 20, 2022



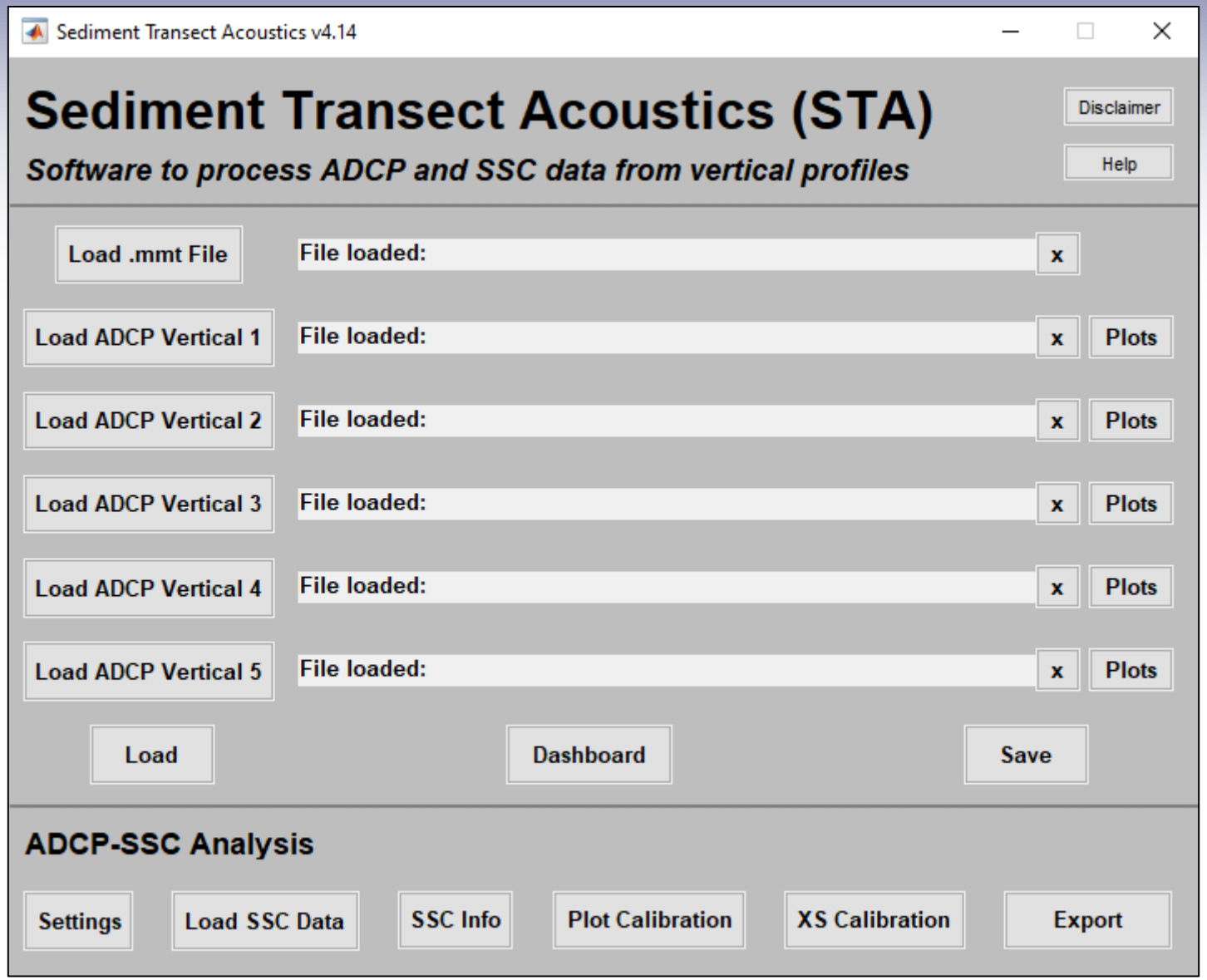
Disclaimer: This information is preliminary or provisional and is subject to revision. It is being provided to meet the need for timely best science. The information has not received final approval by the U.S. Geological Survey (USGS) and is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.

USGS
science for a changing world

What is STA?

- **S**ediment **T**ransect **A**coustics
  - Software to assist in processing ADCP and SSC data from vertical profiles
  - To develop a relationship between acoustic backscatter & suspended sediment concentration
  - For computing total SSC and sediment load
  - And high-spatial resolution visualizations

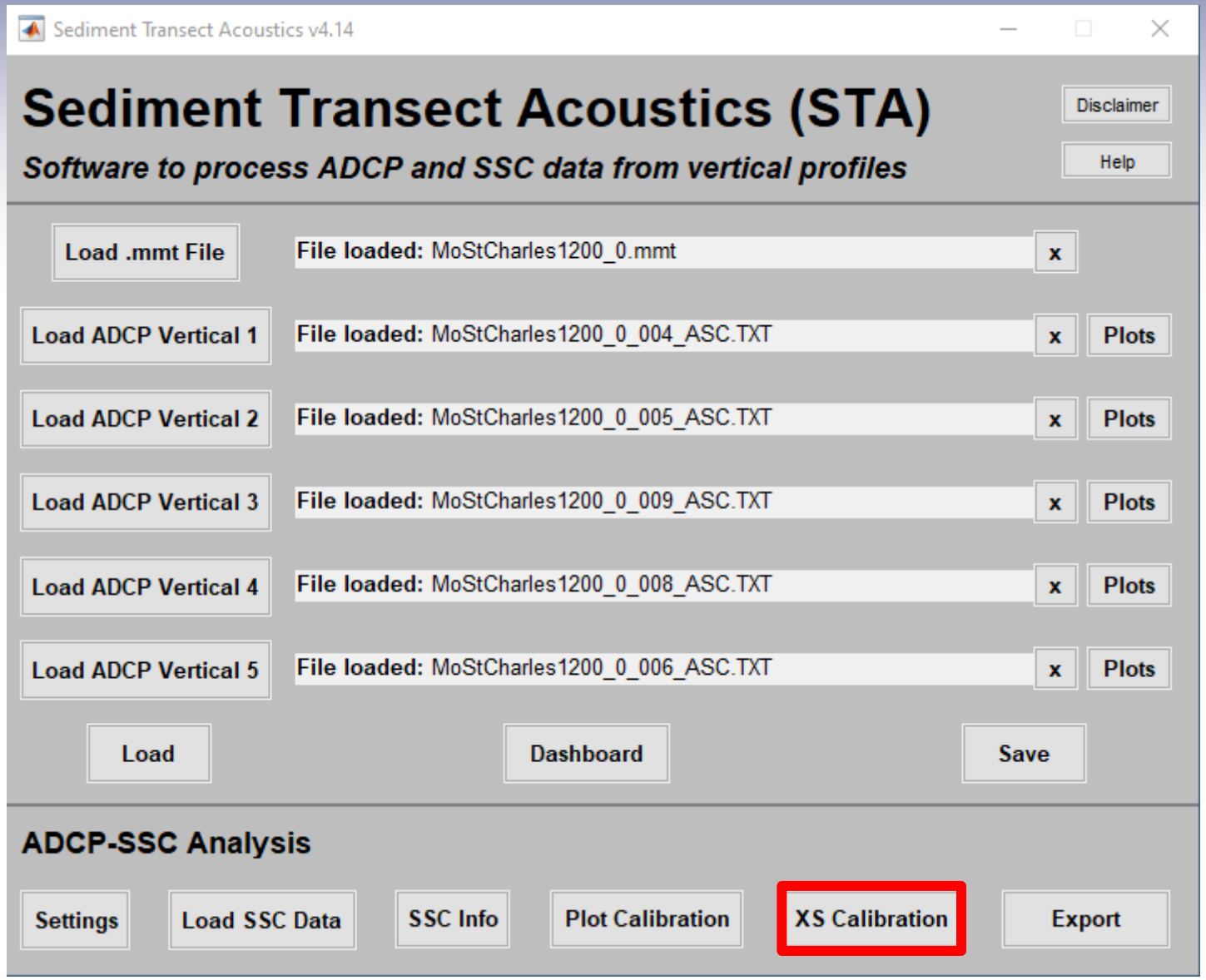
Current version: 4.14 (beta testing)



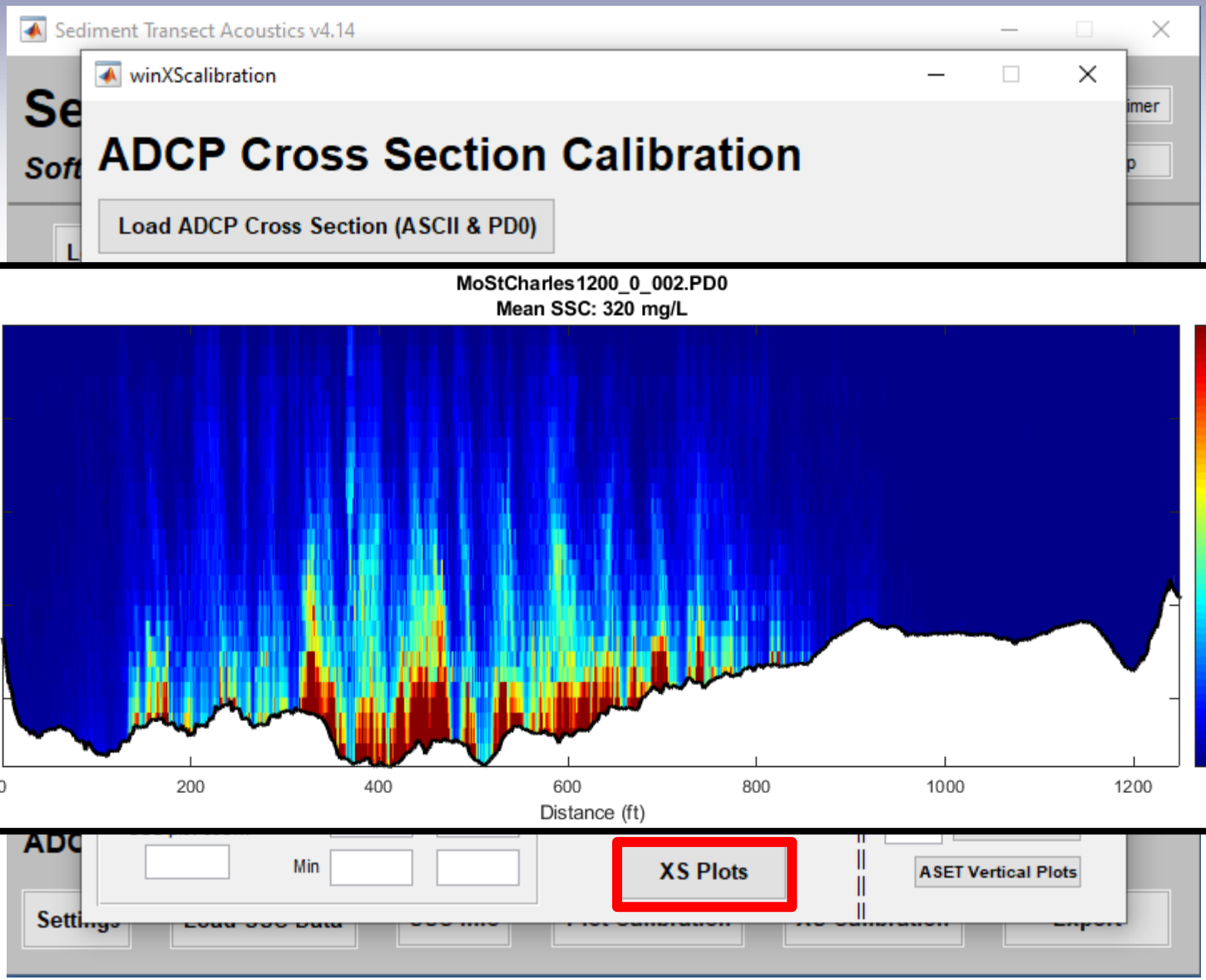
Recent updates/improvements

- Merged STA and ASET extrapolation methods and consistent load calculations
- Support for RiverPro/RioPro ADCPs
- Added functionality to allow for multiple .PD0 files at a vertical
- Ability to run historical datasets (“Apply a calibration” option)
- Numerous QA/QC checks and other usability improvements

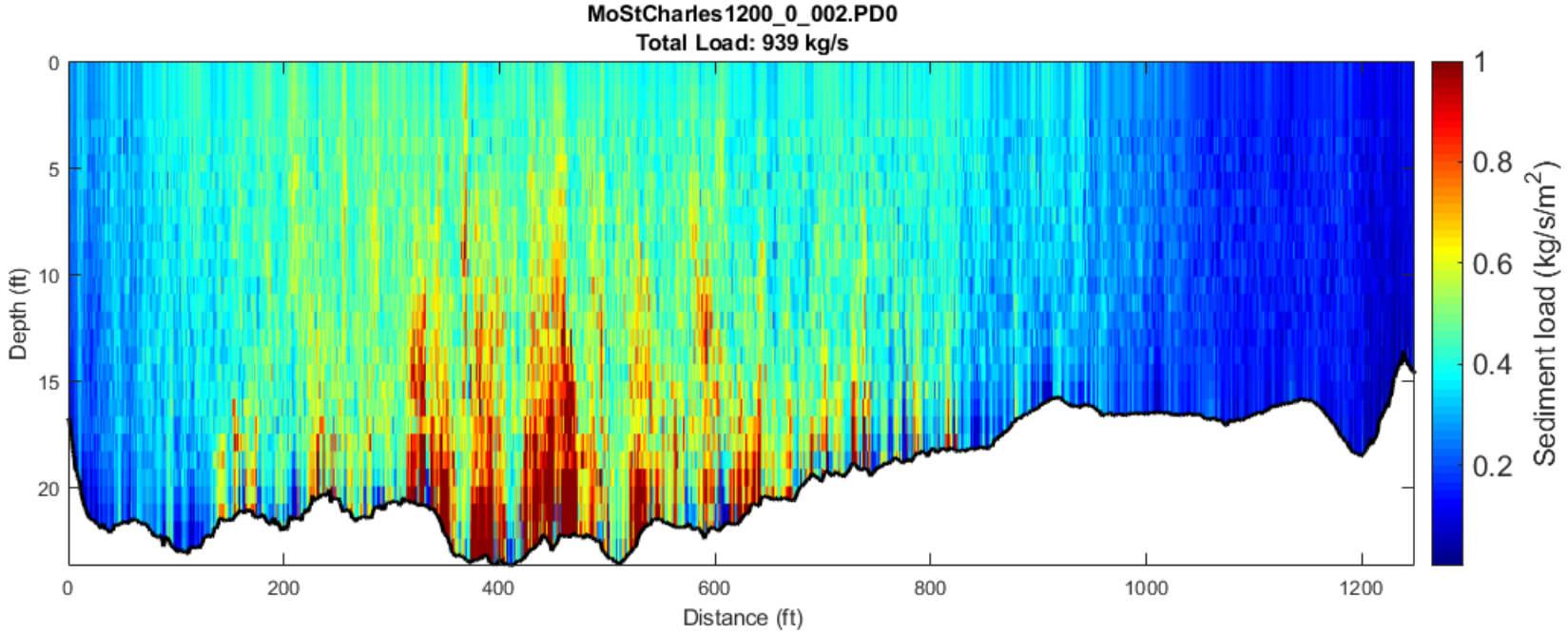
XS Calibration



XS Calibration



Output plot #3: Sediment Load

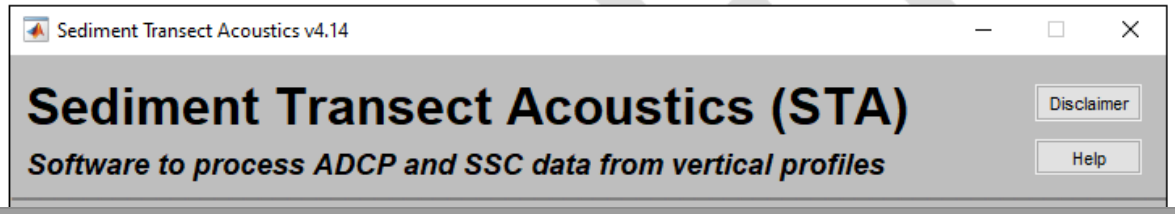


User's Guide

User's Guide for Sediment Transect Acoustics (STA) v. 4.14 beta

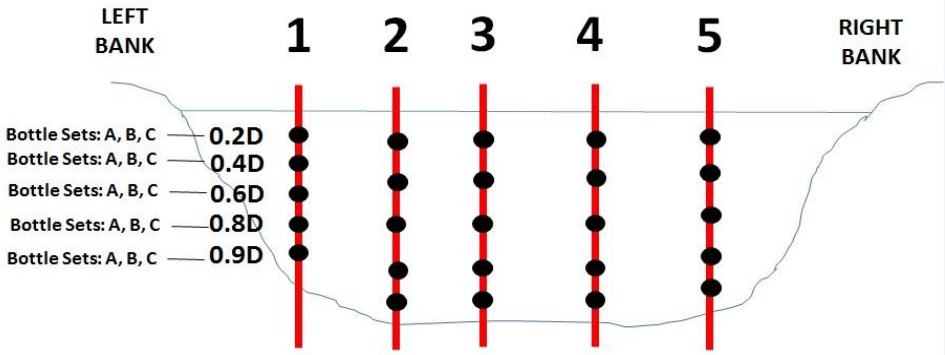
Justin A. Boldt, U.S. Geological Survey, 08/18/2022

Sediment Transect Acoustics (STA) is a stand-alone, MATLAB-based program developed by the U.S. Geological Survey to assist in processing acoustic Doppler current profiler (ADCP) and suspended sediment concentration (SSC) data from vertical profiles to calibrate acoustic backscatter with SSC (fig. 1). The ADCP-SSC calibration can then be applied to a cross section to compute total SSC and sediment load. STA was originally built on the structure of VMT but now contains components from other ADCP-related software including QRev and ASET. The sediment acoustics analysis requires data from a down-looking ADCP and SSC point samples from up to five verticals. This tool also provides an in-depth analysis and visualization of stationary (at-a-vertical) ADCP data. STA version 4.14 beta is for research (not operational) purposes only. All output should be considered provisional data and subject to revision.



Data Collection - Analysis and Results

- 2016–2018 data collection at:
  - Missouri River at St. Charles, MO
  - Sacramento River at Freeport, CA
  - Illinois River at Florence, IL
  - Missouri River at Nebraska City, NE
  - St. Joseph River at St. Joseph, MI
  - Cowlitz River near Castle Rock, WA (1 vertical, training class)

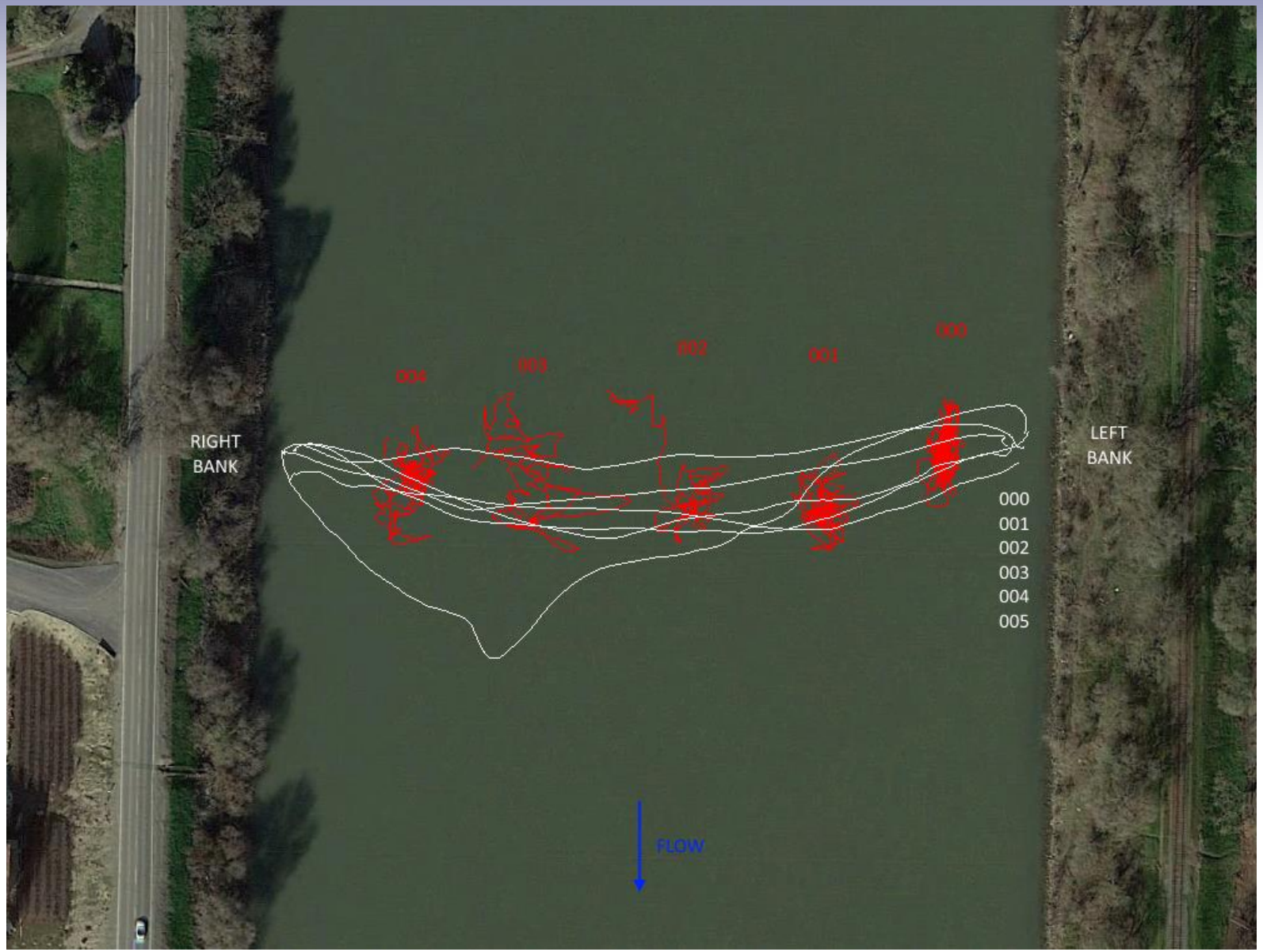


May 3, 2017

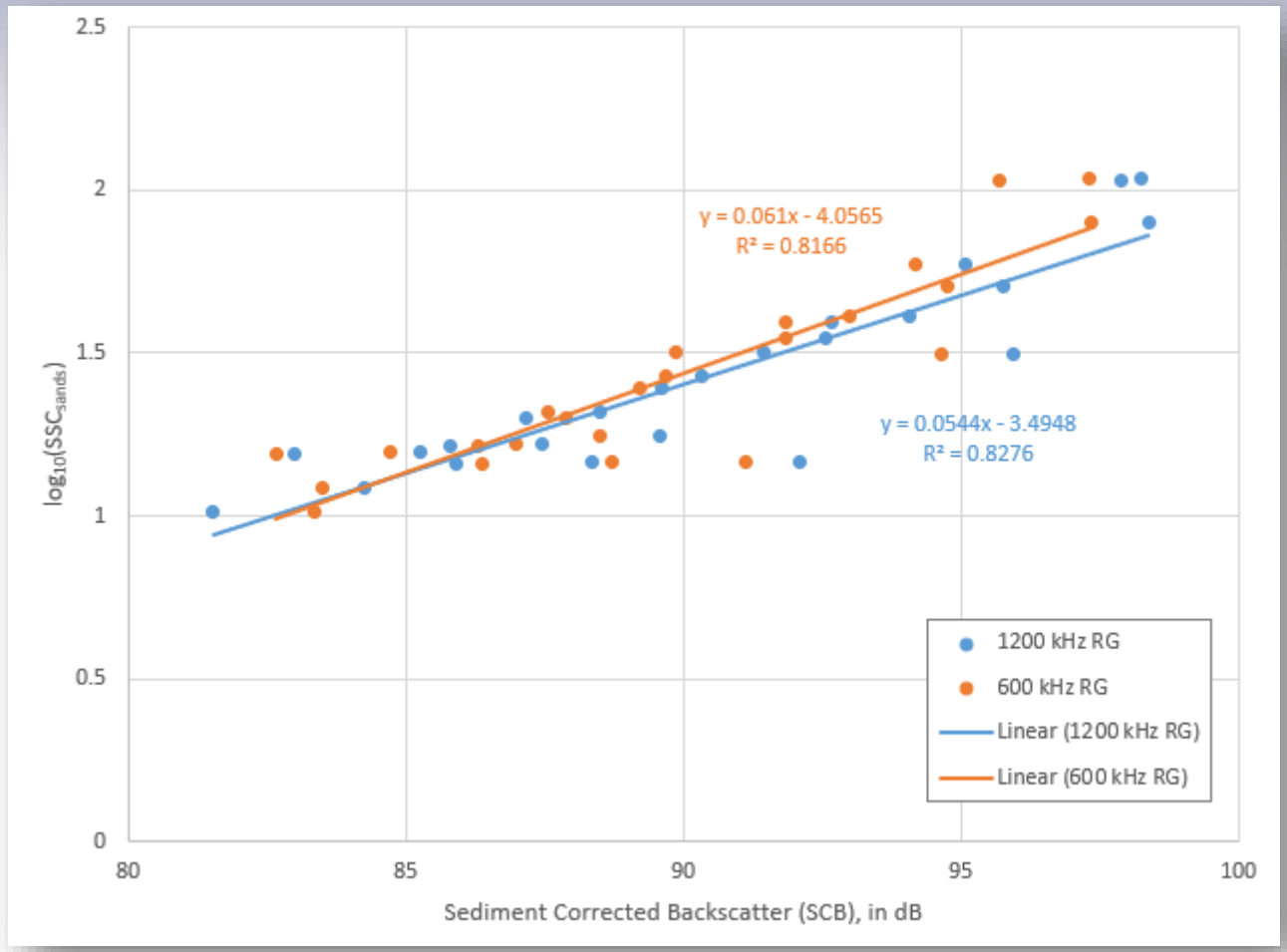
SACRAMENTO RIVER AT FREEPORT, CA

Conditions:
SSC = ~70 mg/L, 61% fines
Q = 69,000 cfs

Data Collection Locations



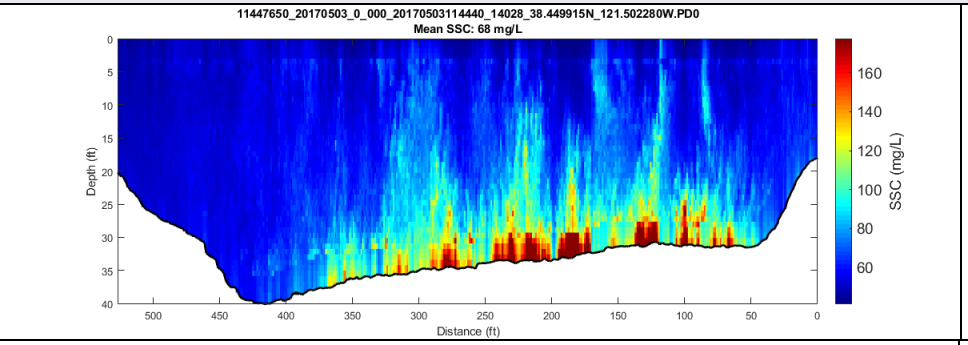
Calibration (sands)

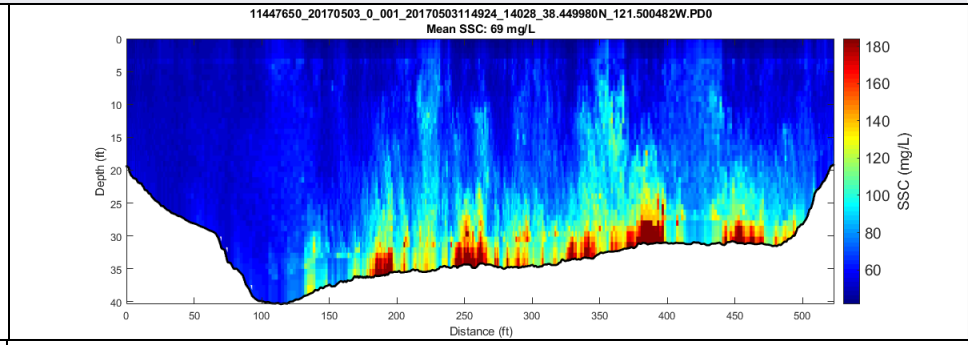


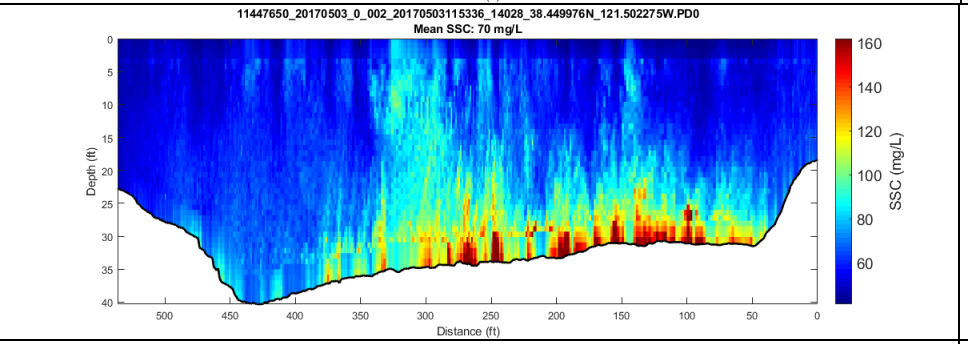
600 kHz and 1200 kHz calibrations match well. Slightly more scatter with 600 RG.

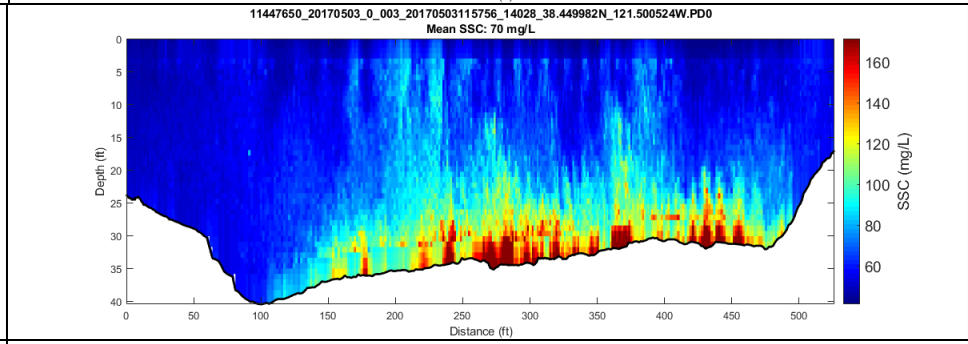
XS Calibration Results: SSC

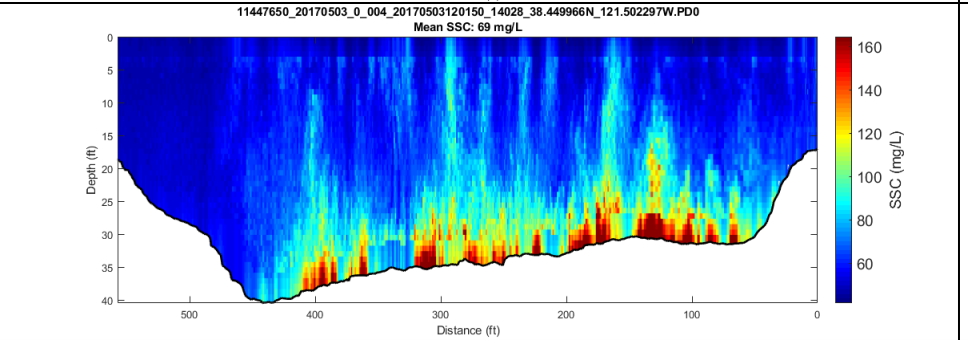
- 6 transects: Mean SSC range 67–70 mg/L

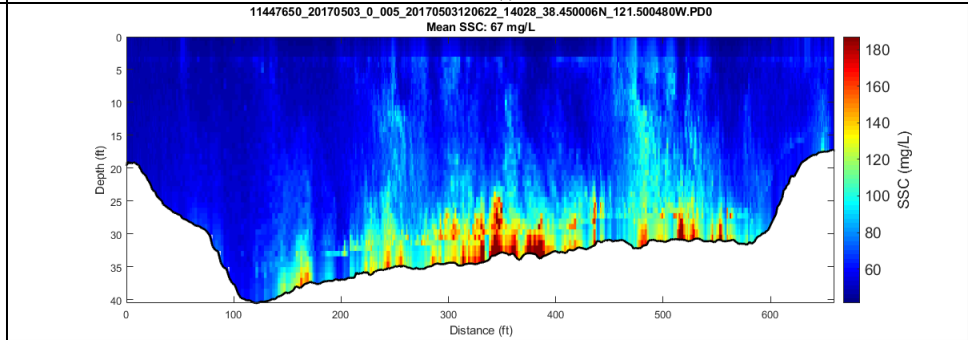






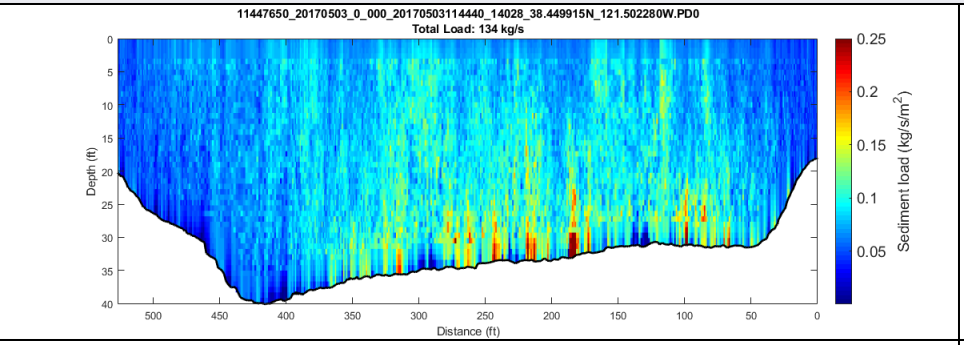


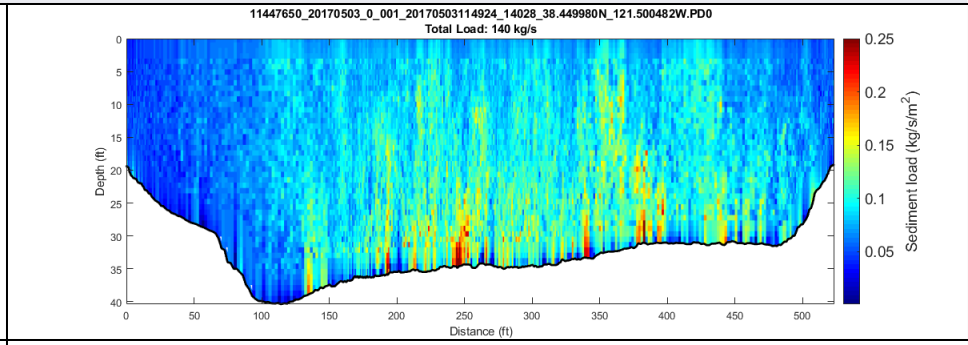


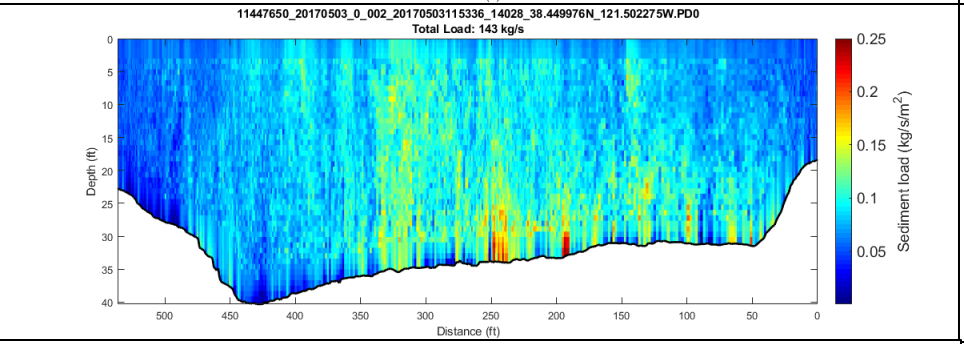


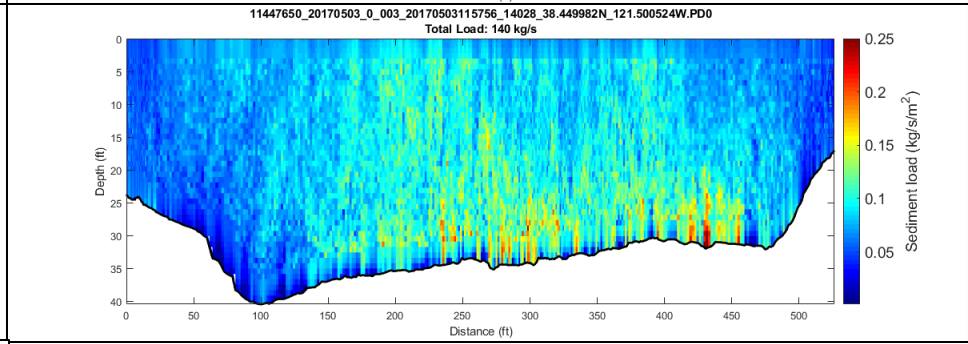
XS Calibration Results: SSL

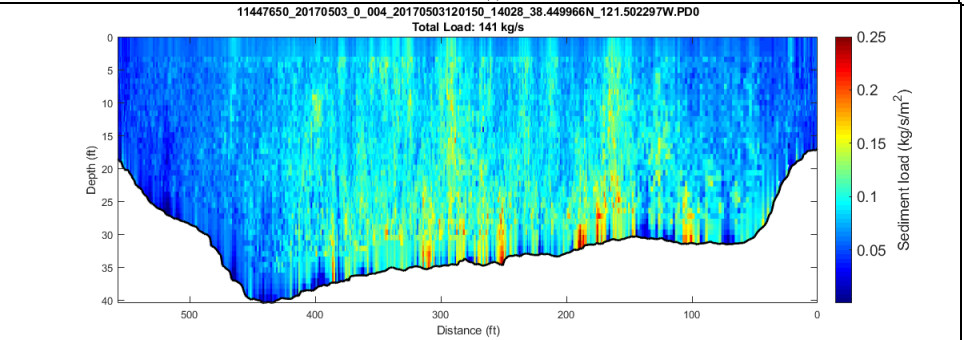
- 6 transects: Total Load range 134–157 kg/s

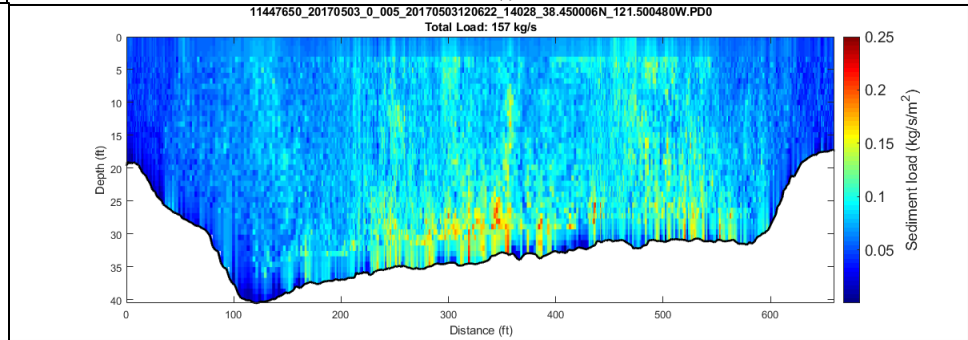




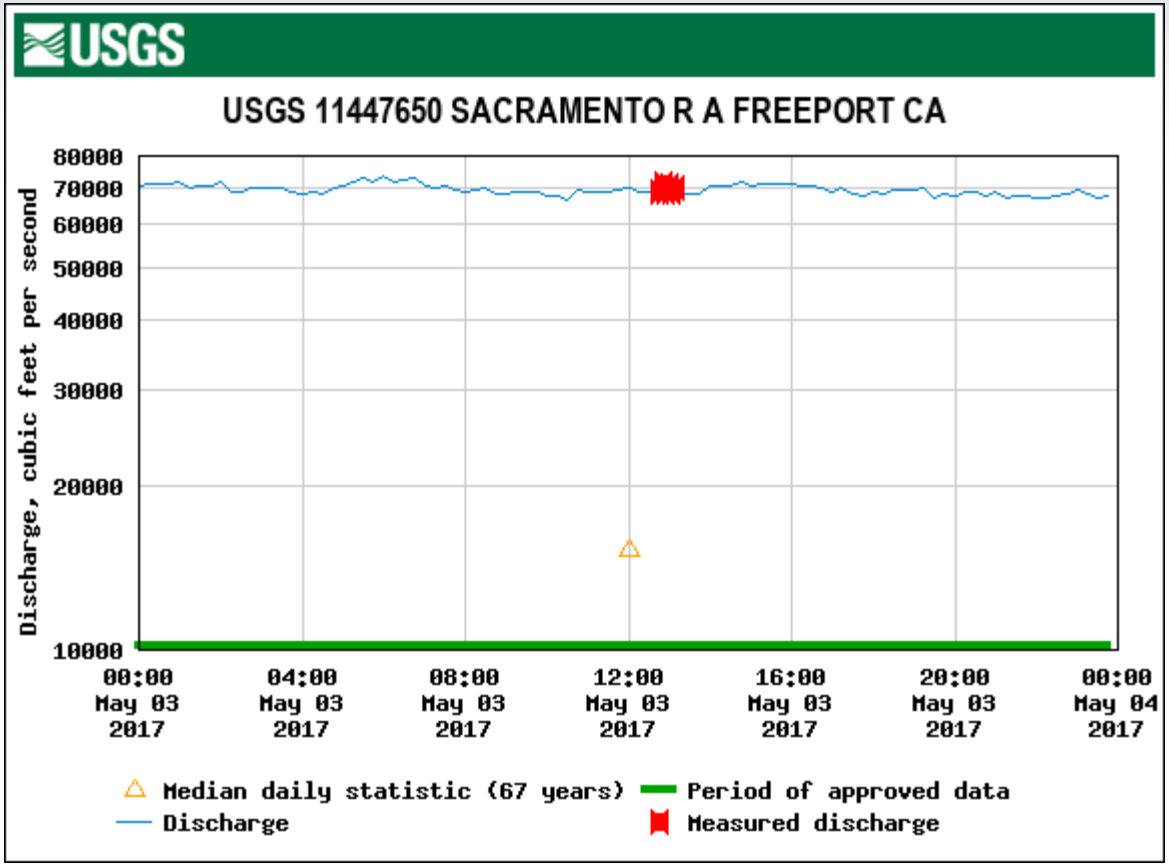


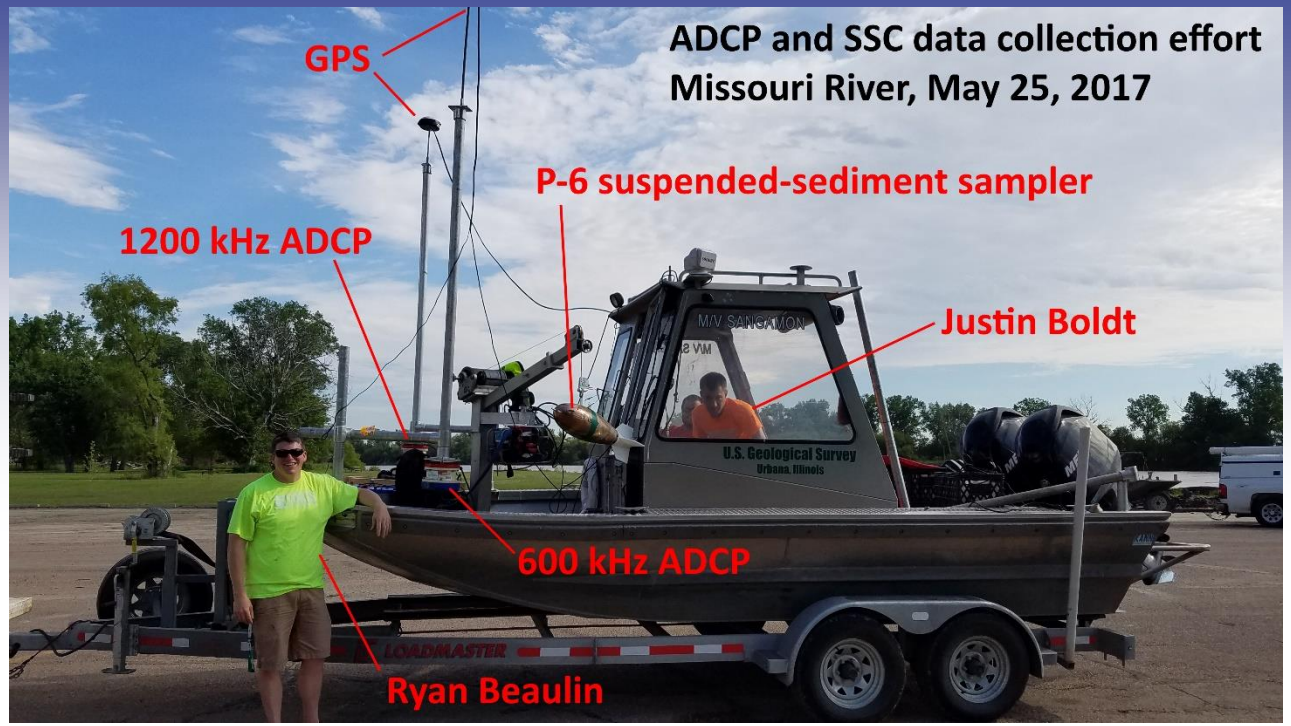






USGS 11447650 – Discharge



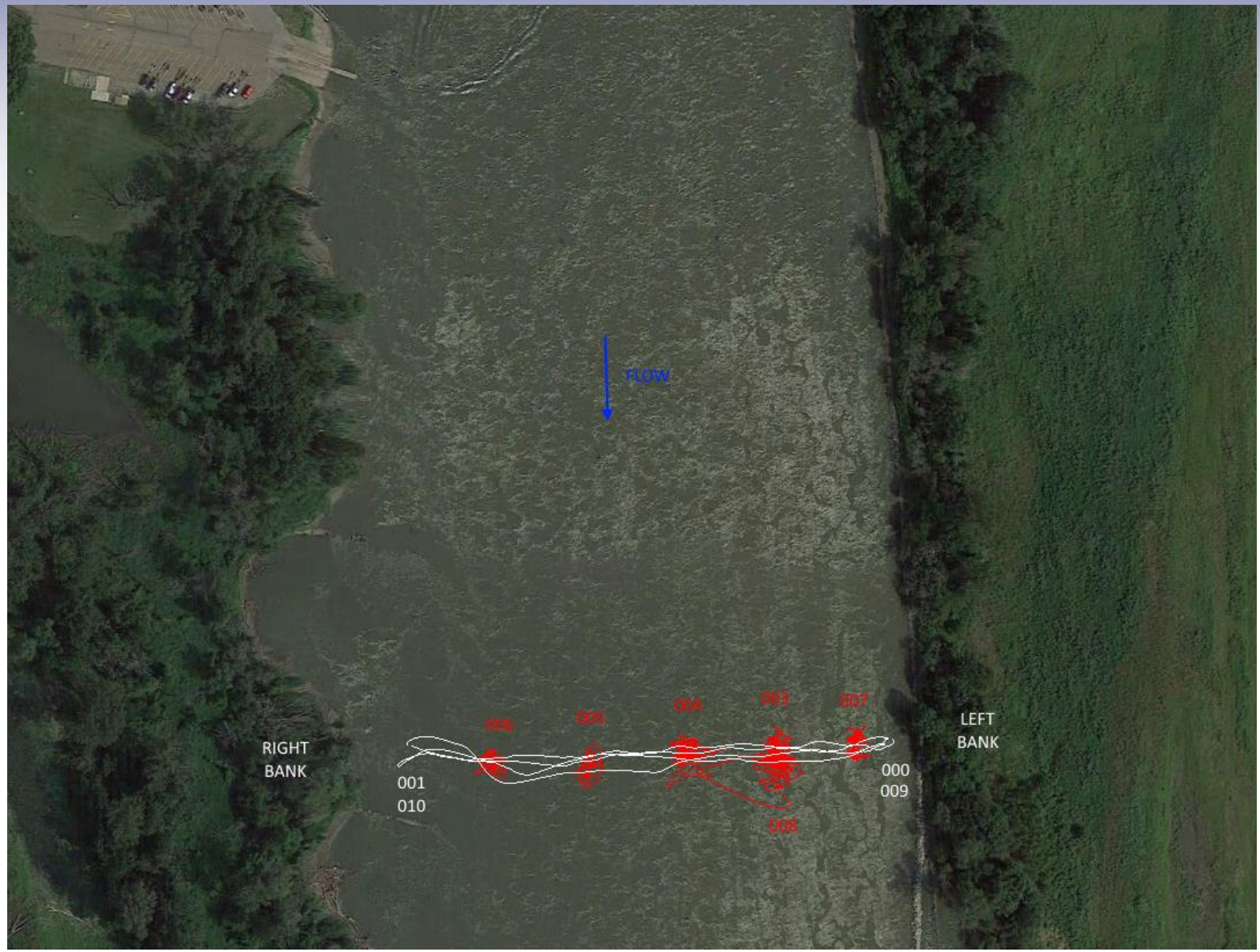


May 25, 2017

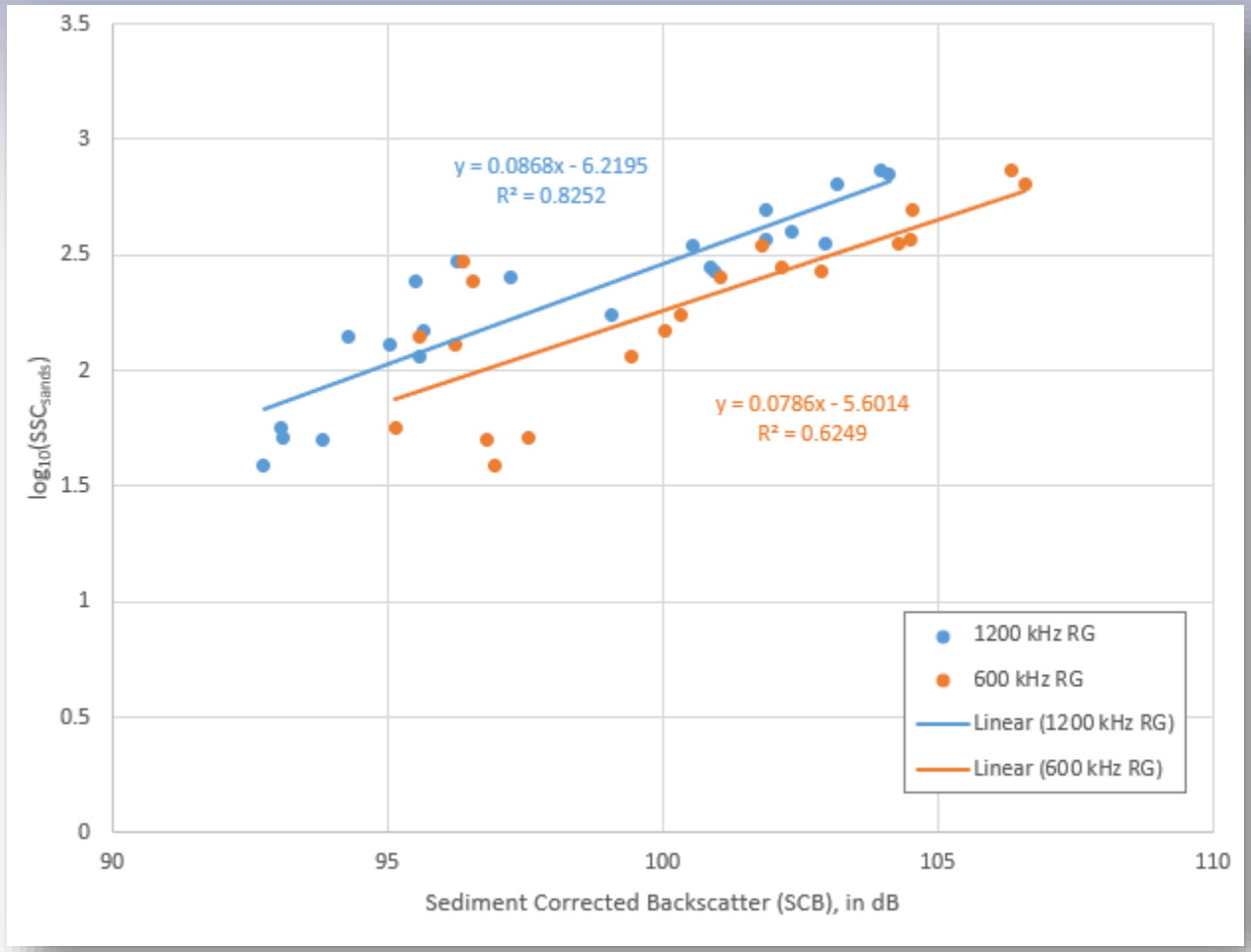
MISSOURI RIVER AT NEBRASKA CITY, NE

Conditions:
SSC = ~780 mg/L, 65% fines
Q = 75,000 cfs

Data Collection Locations



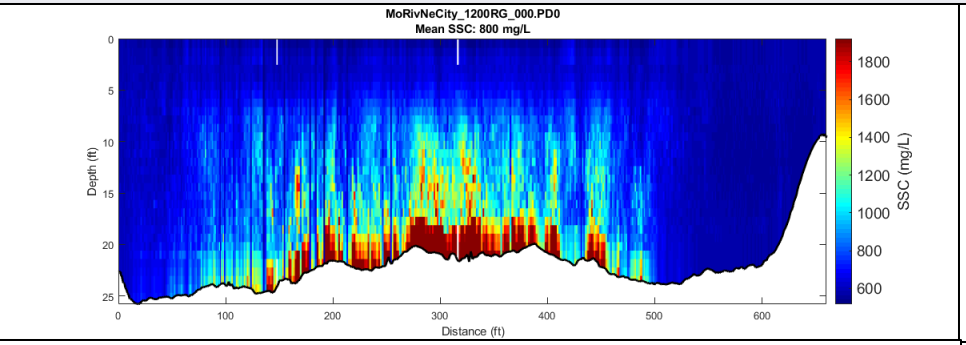
Calibration (sands)

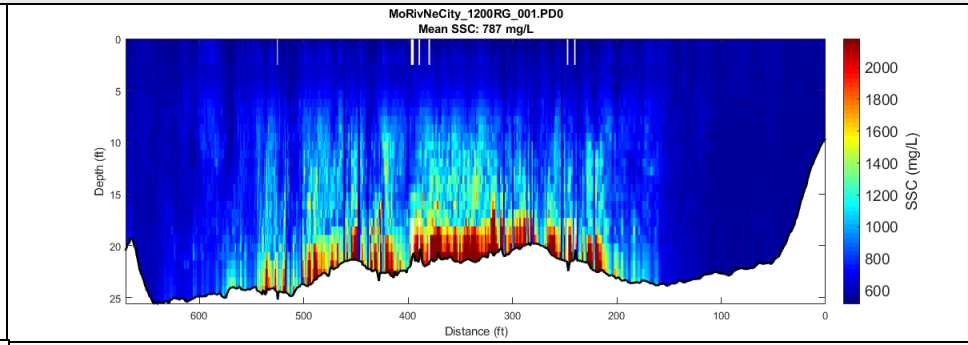


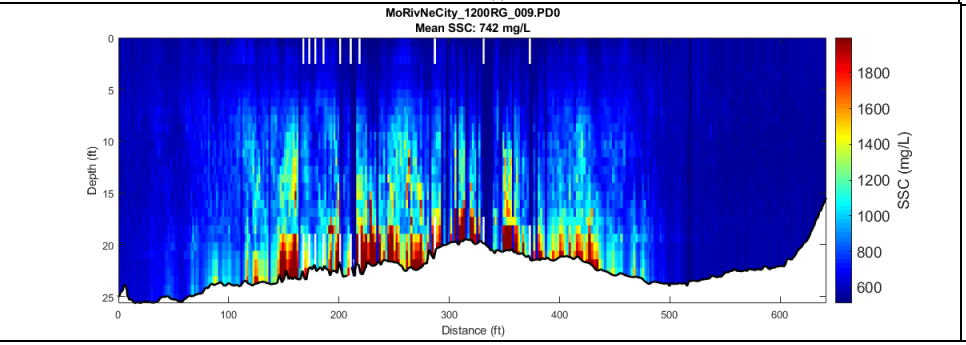
600 kHz and 1200 kHz calibrations offset slightly. More scatter with 600 RG.

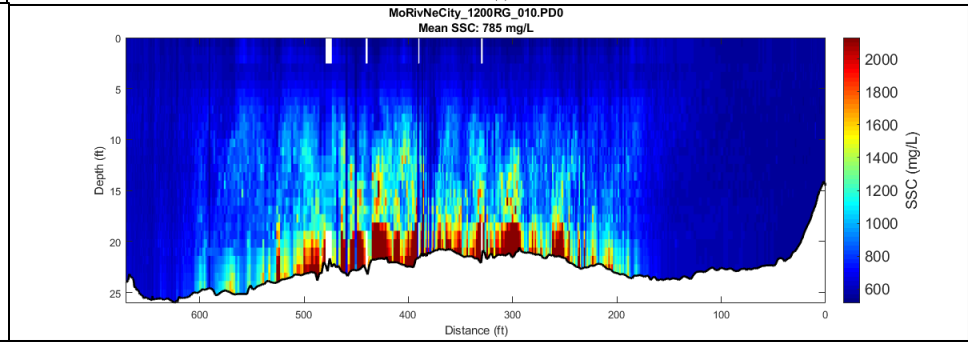
XS Calibration Results: SSC

- 4 transects: Mean SSC range 742–800 mg/L



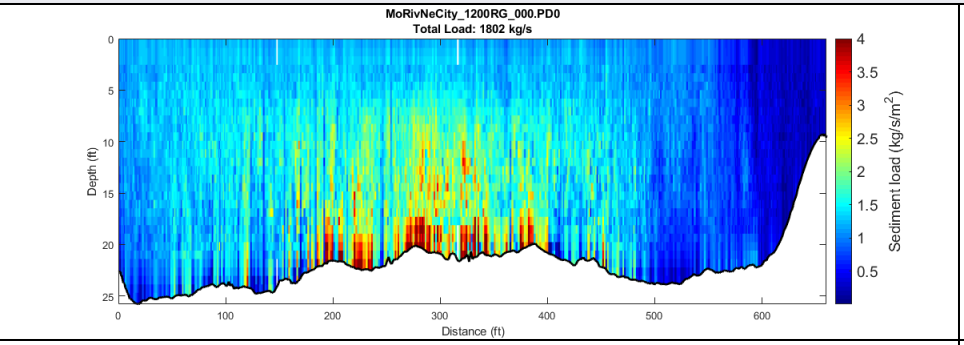


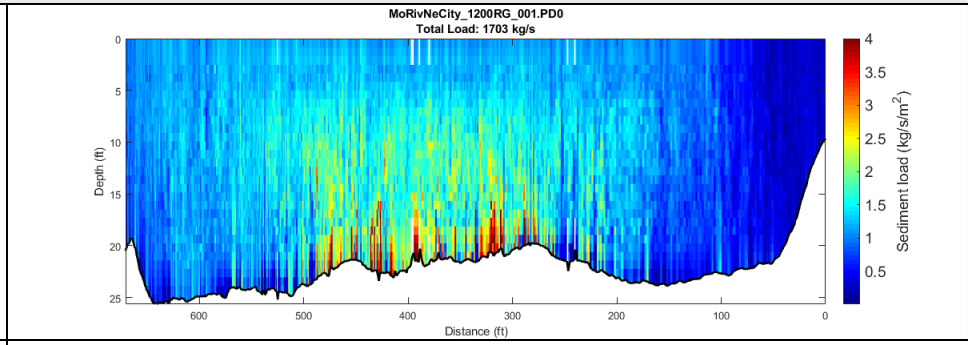


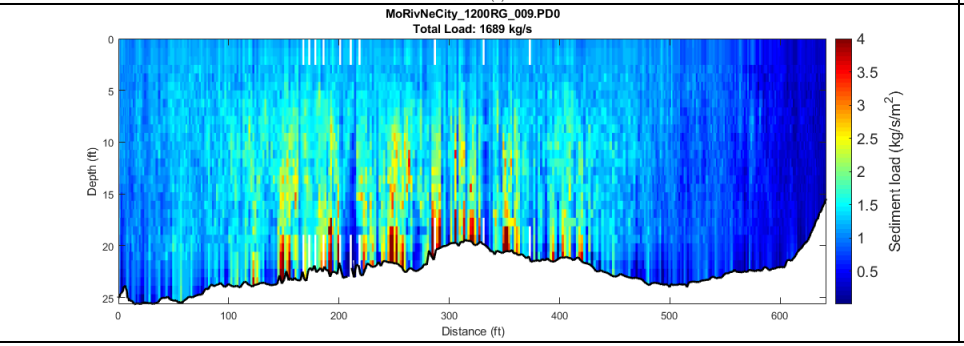


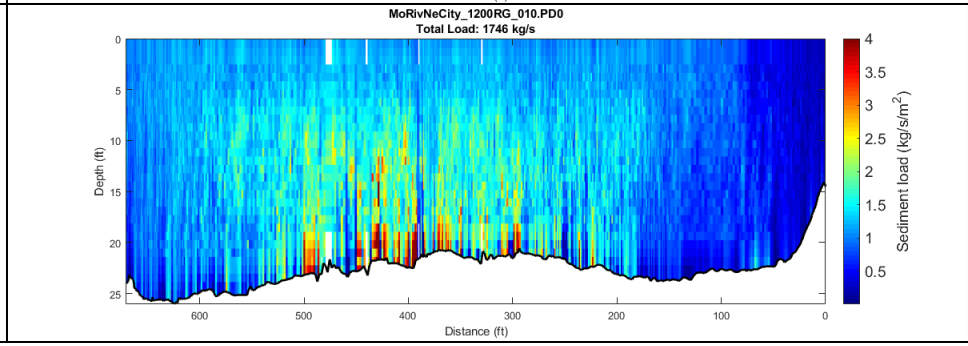
XS Calibration Results: SSL

- 4 transects: Total Load range 1689–1802 kg/s

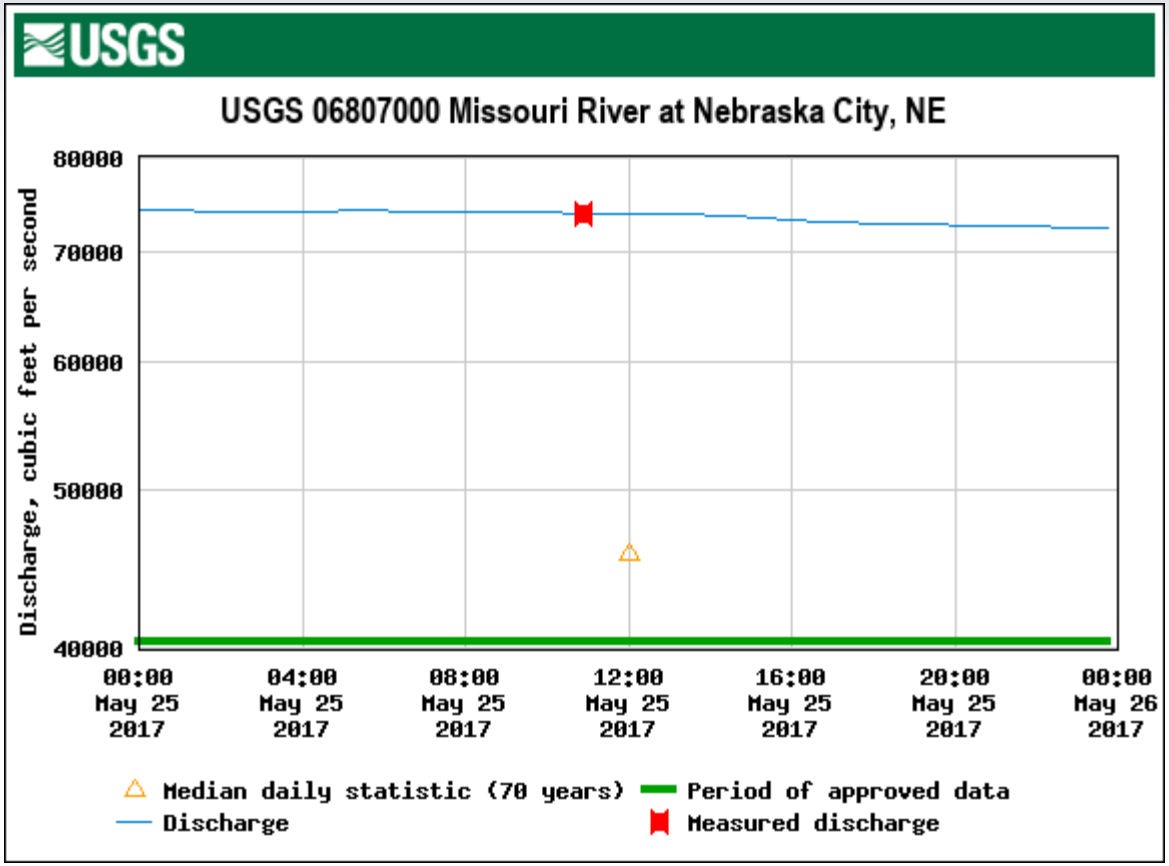






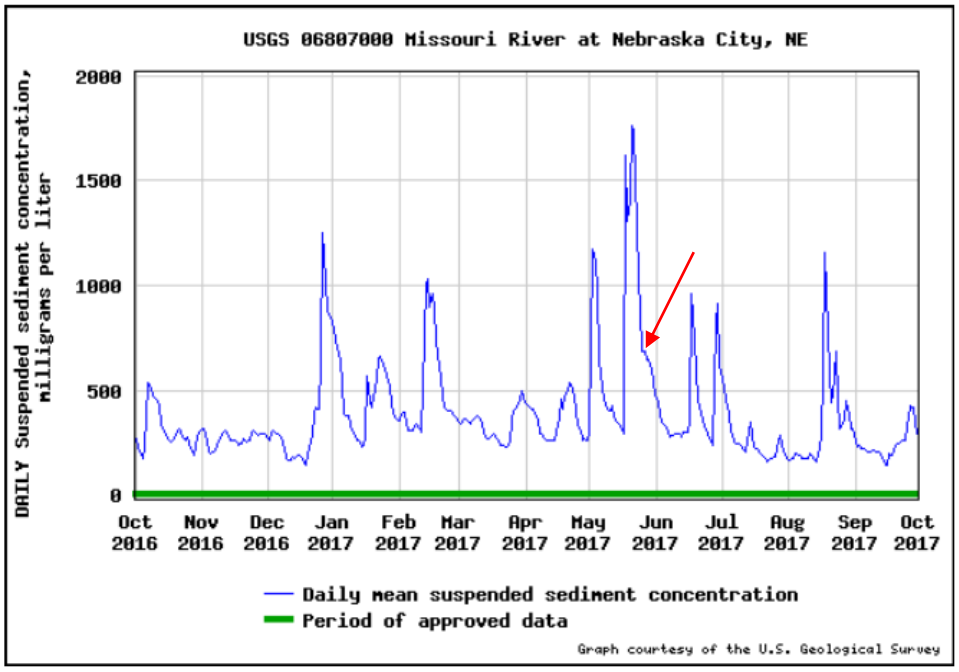


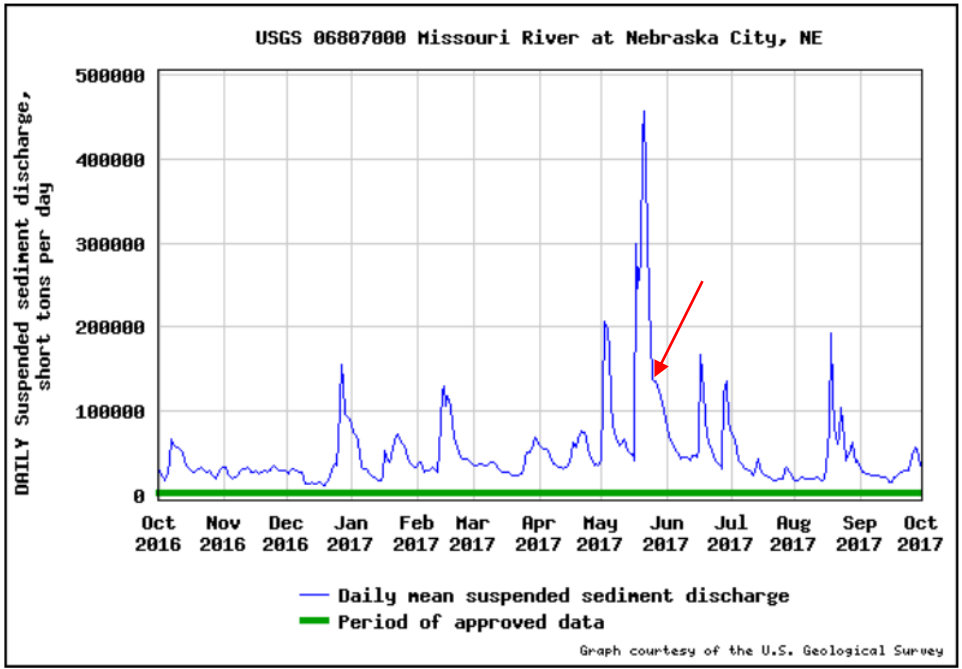
USGS 06807000 – Discharge

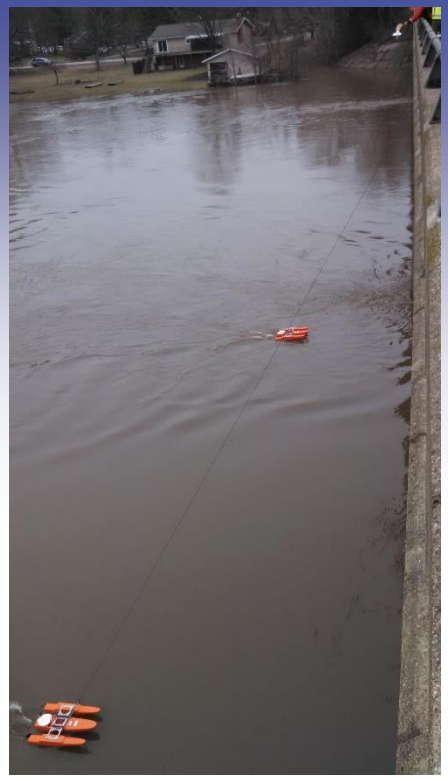


USGS Water-Year Summary 2017
06807000 Missouri River at Nebraska City, NE

- Published DAILY MEAN VALUES for May 25:
  - Suspended sediment concentration: 688 milligrams per liter
  - Suspended sediment discharge: 137,000 short tons per day
- STA (average): 780 mg/L and 165,000 tons/day





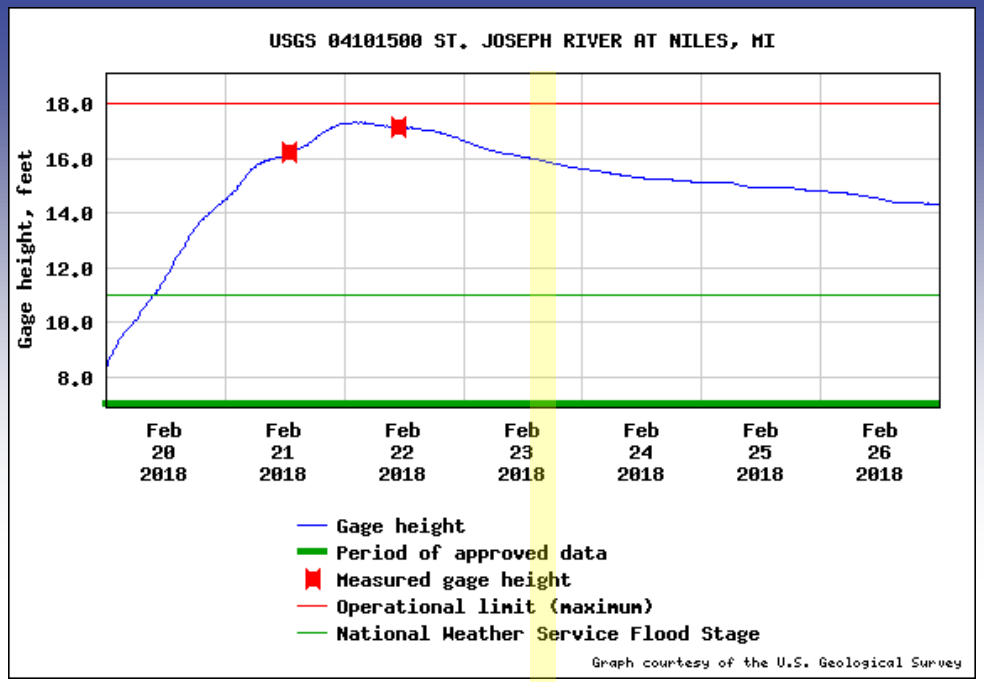


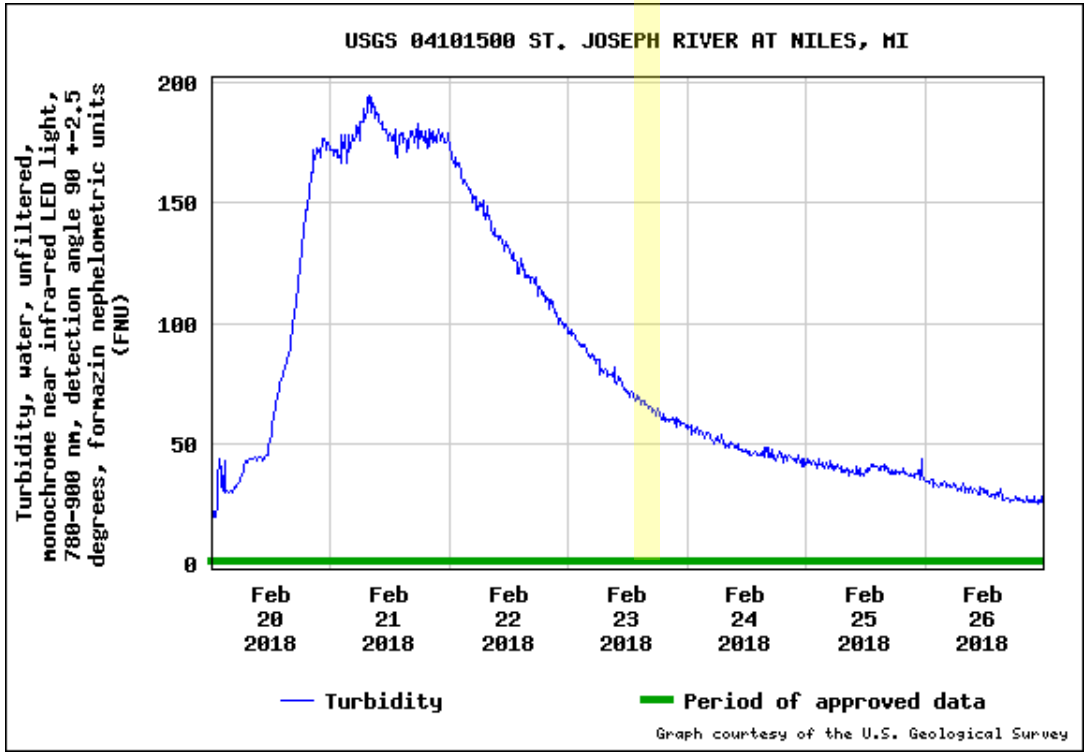
February 23, 2018

ST JOSEPH RIVER AT NAPIER AVE

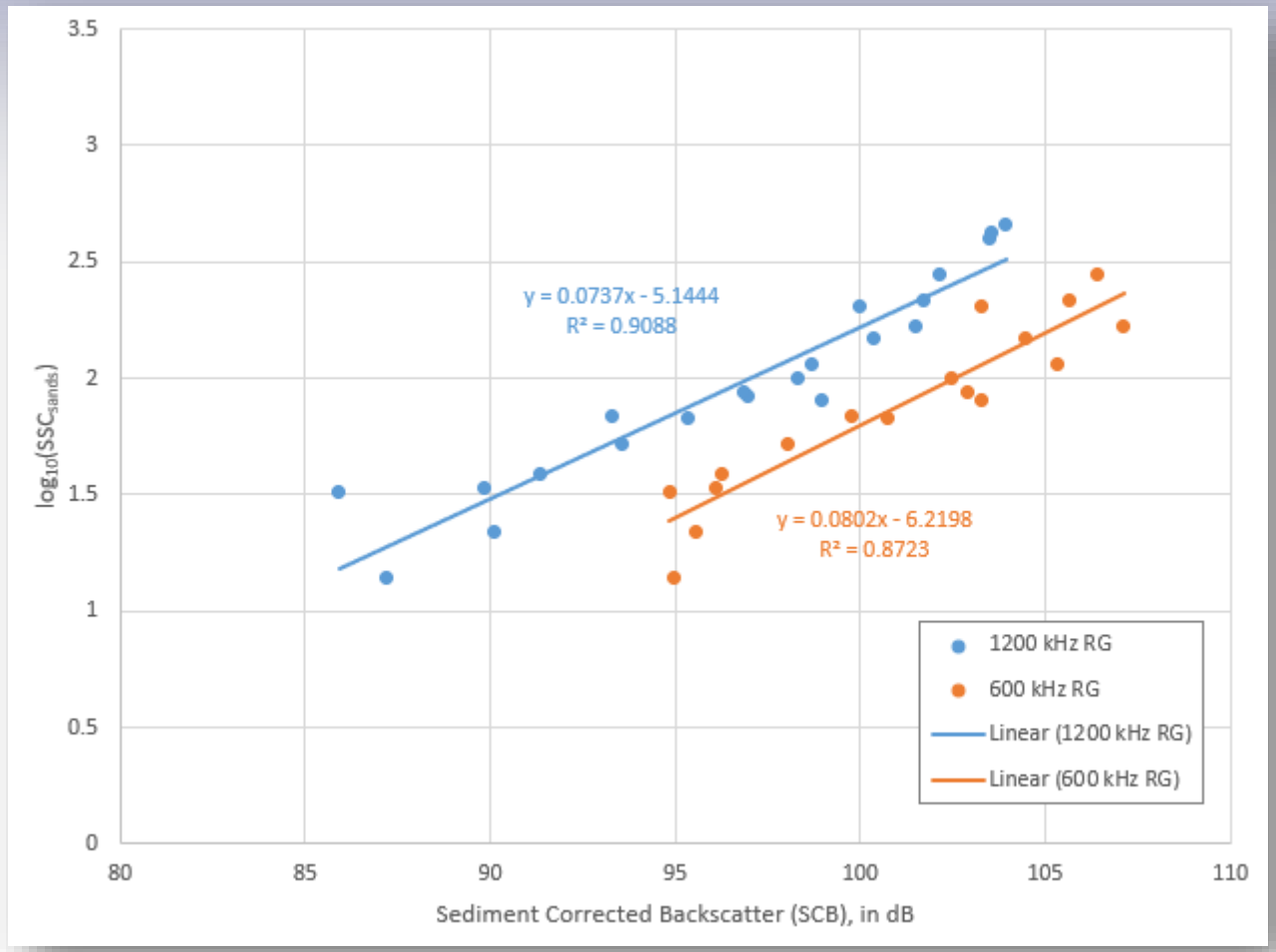
Conditions:
SSC = ~225 mg/L, 36% fines
Q = 25,000 cfs

Data Collection Locations


USGS 04101500 ST. JOSEPH RIVER AT NILES, MI
Gage height, feet
18.0
16.0
14.0
12.0
10.0
8.0
Feb 20 2018
Feb 21 2018
Feb 22 2018
Feb 23 2018
Feb 24 2018
Feb 25 2018
Feb 26 2018
Gage height
Period of approved data
Measured gage height
Operational limit (maximum)
National Weather Service Flood Stage
Graph courtesy of the U.S. Geological Survey


USGS 04101500 ST. JOSEPH RIVER AT NILES, MI
Turbidity, water, unfiltered, monochrome near infra-red LED light, 780-900 nm, detection angle 90 +-2.5 degrees, formazin nephelometric units (FNU)
200
150
100
50
0
Feb 20 2018
Feb 21 2018
Feb 22 2018
Feb 23 2018
Feb 24 2018
Feb 25 2018
Feb 26 2018
Turbidity
Period of approved data
Graph courtesy of the U.S. Geological Survey

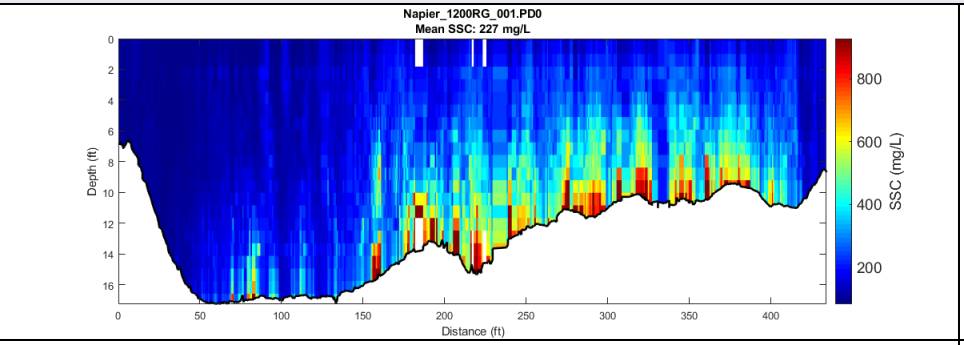
Calibration (sands)

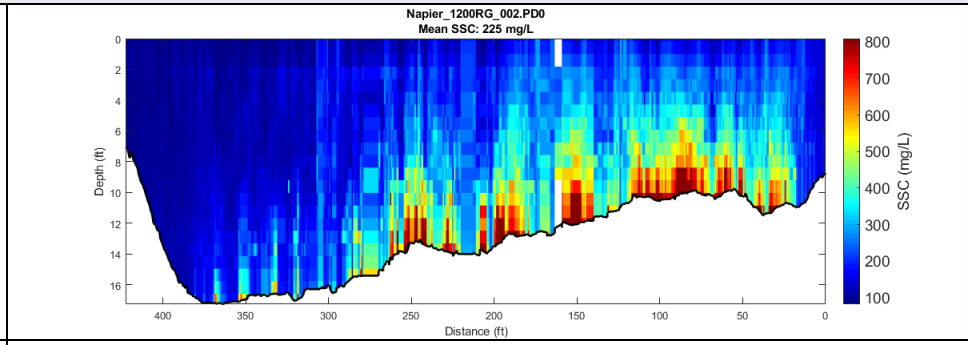


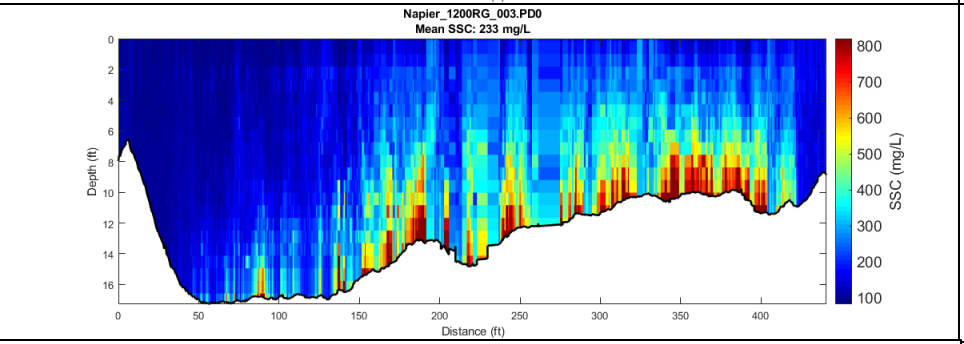
600 kHz and 1200 kHz calibrations offset slightly. More scatter with 600 RG.

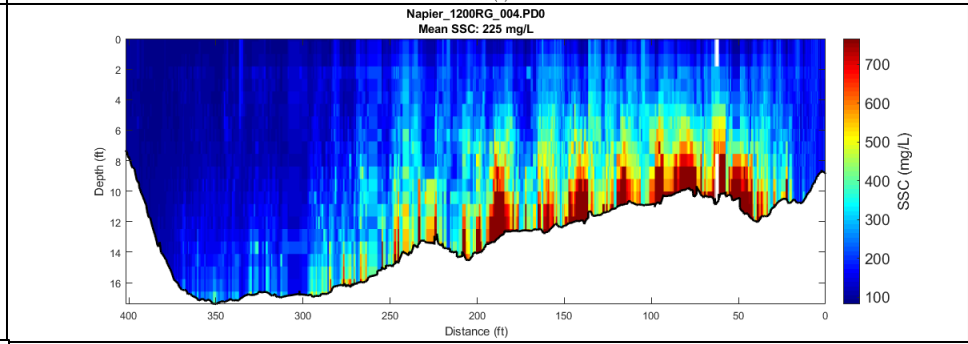
XS Calibration Results: SSC

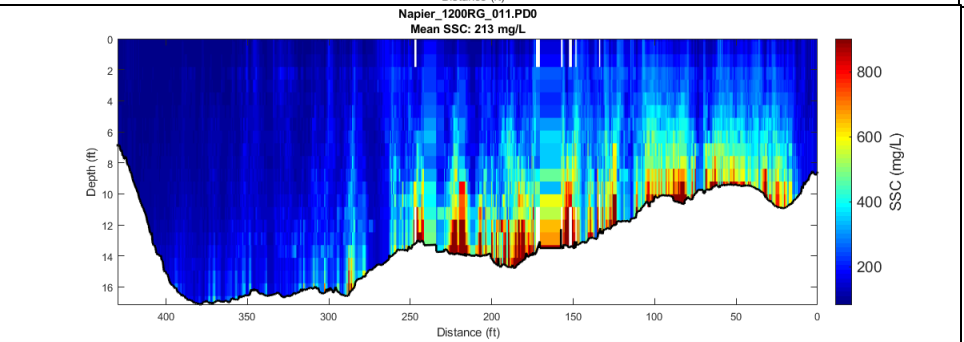
- 4 transects: Mean SSC range 213–233 mg/L

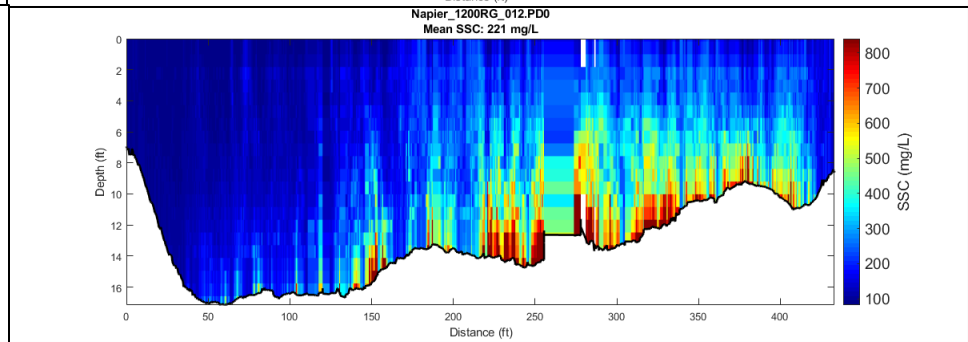






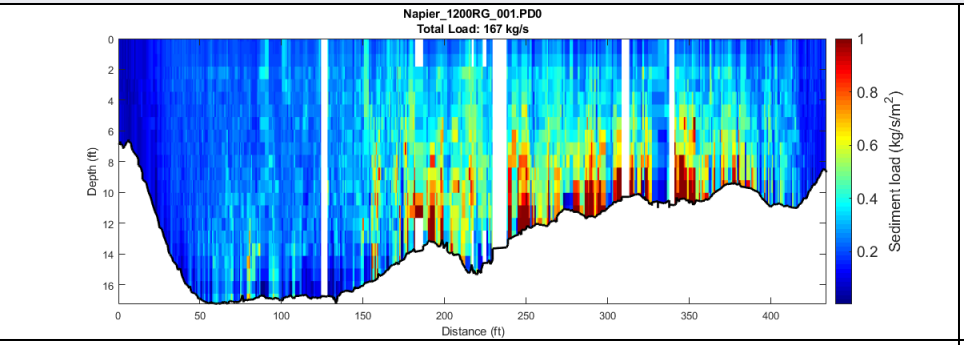


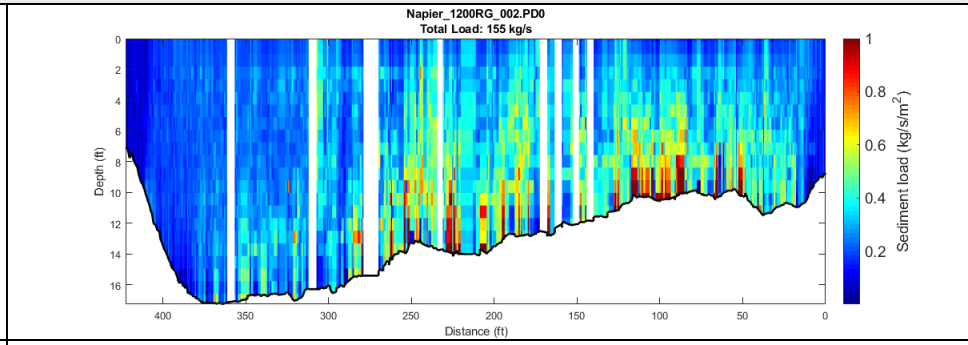


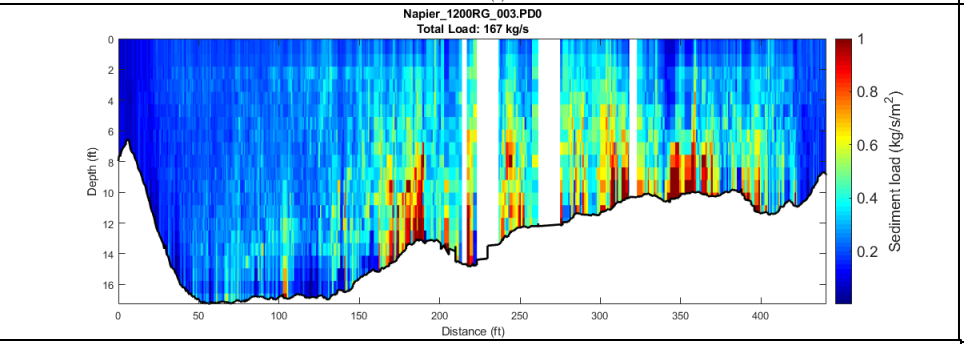


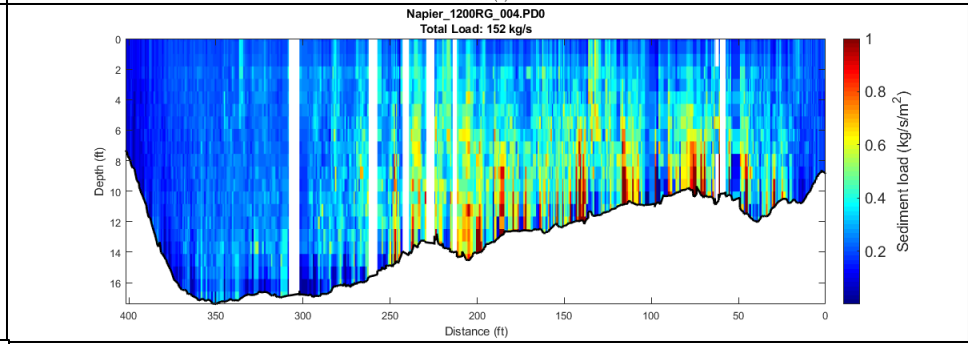
XS Calibration Results: SSL

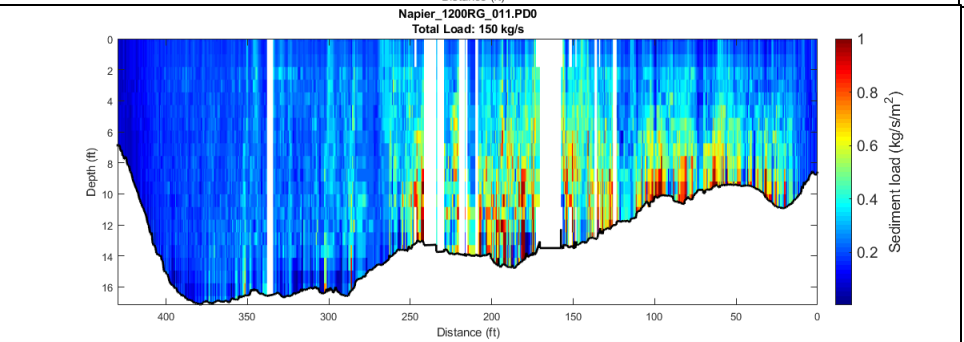
- 4 transects: Total Load range 150–167 kg/s

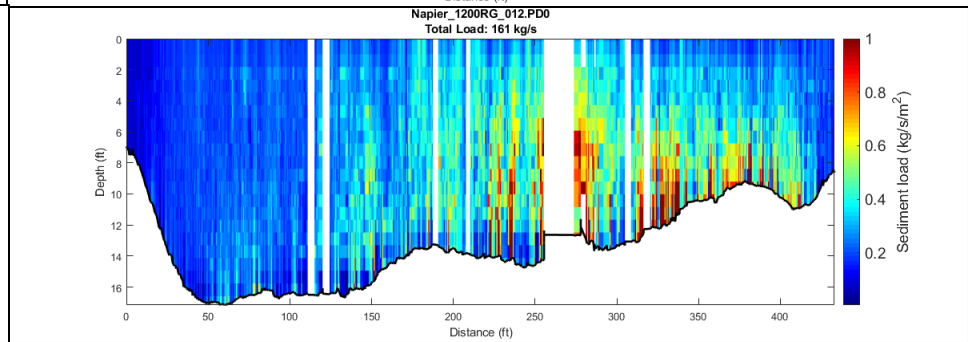










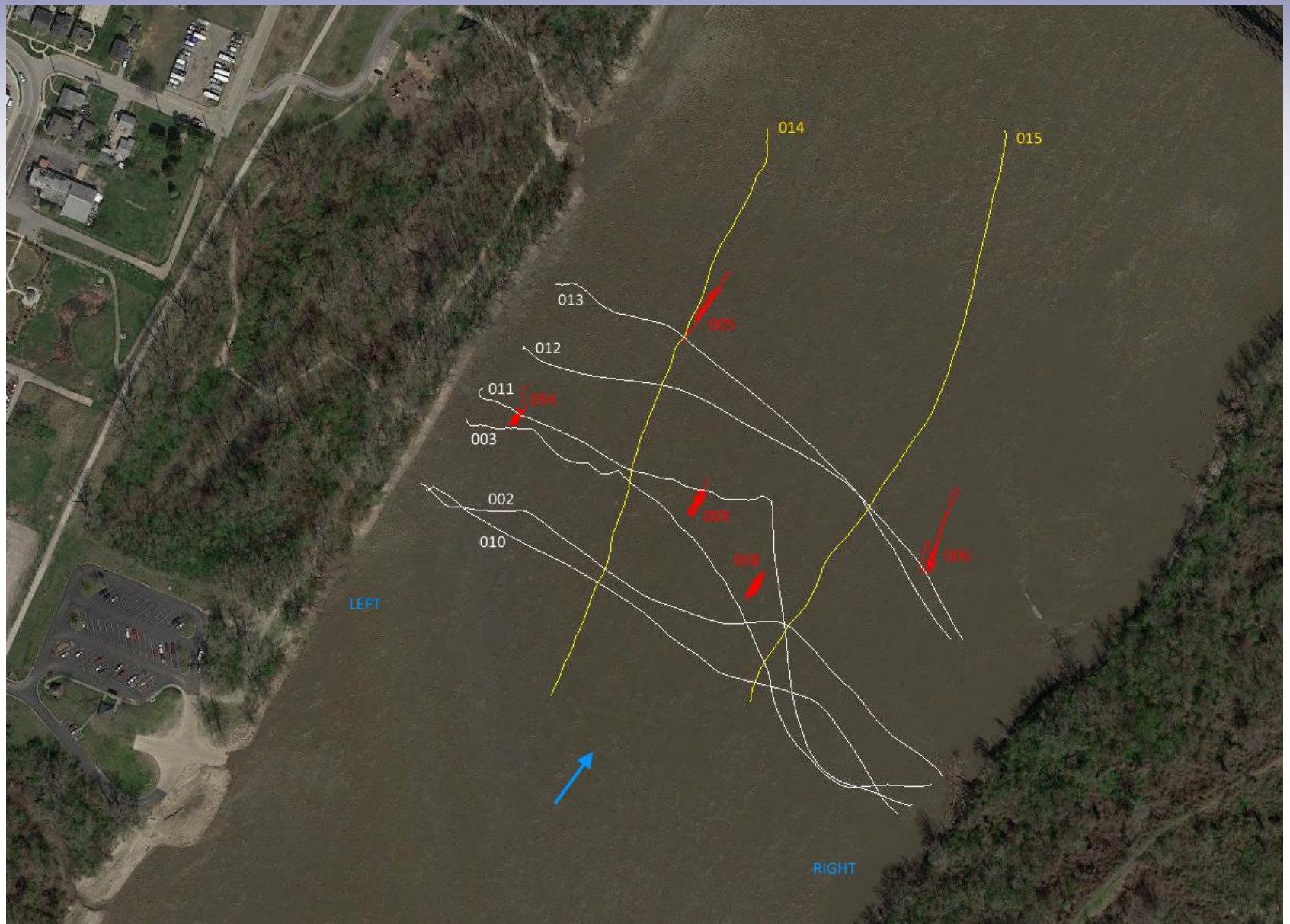


July 20, 2016

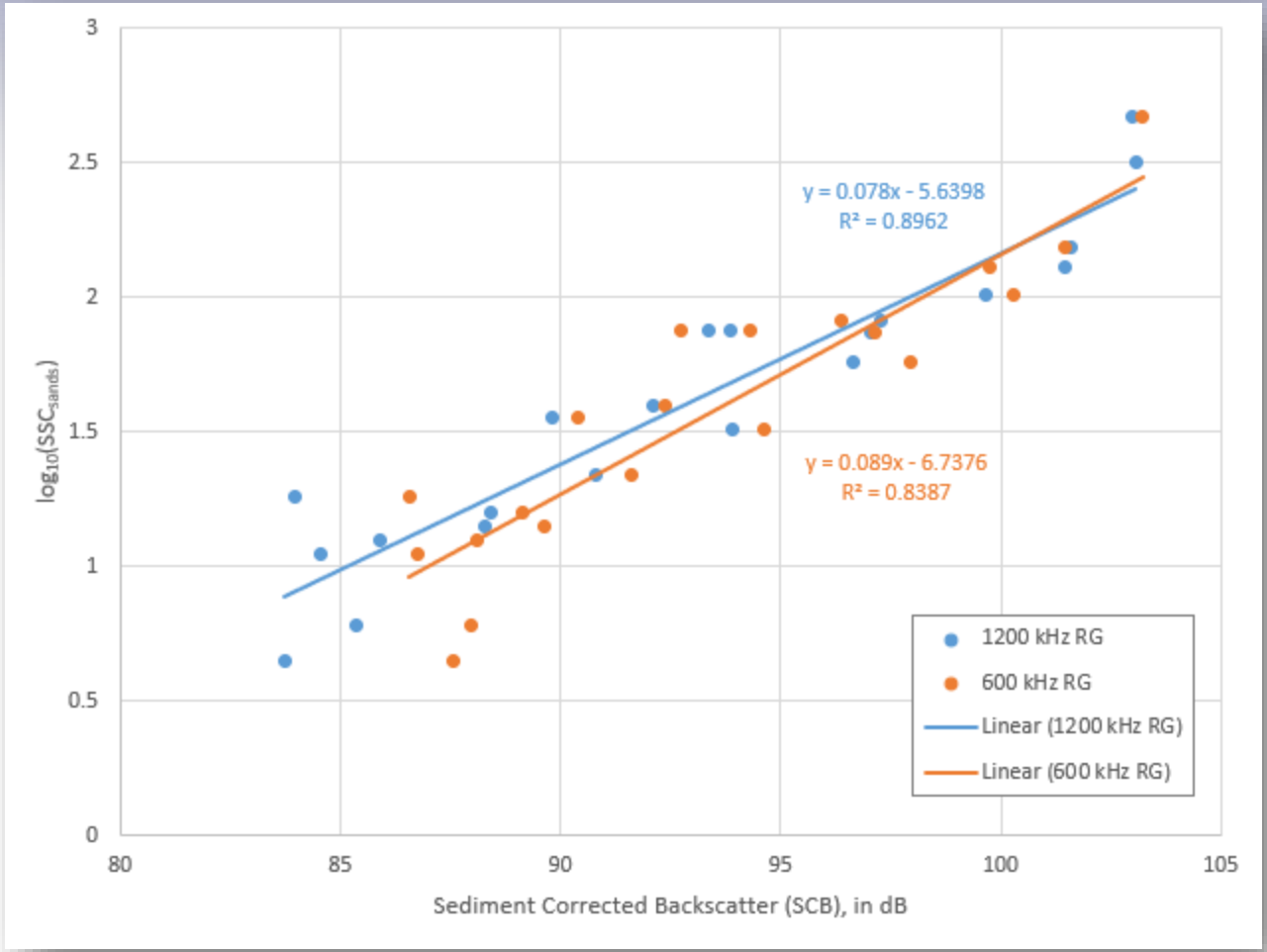
MISSOURI RIVER AT ST. CHARLES, MO

Conditions:
SSC = ~320 mg/L, 74% fines
Q = 100,000 cfs

Data Collection Locations



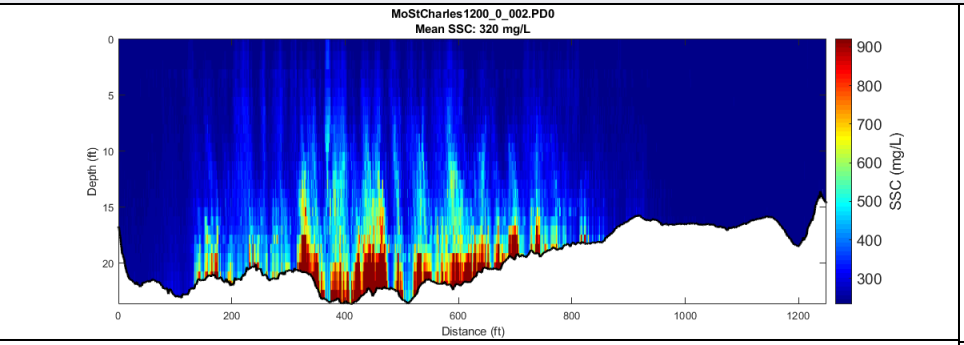
Calibration (sands)

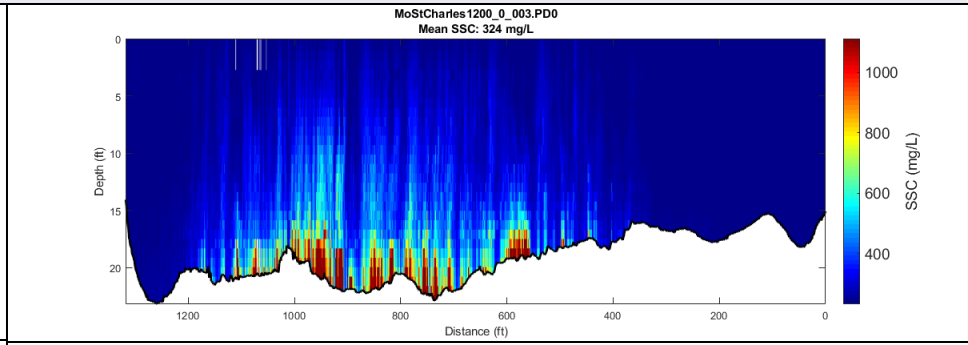


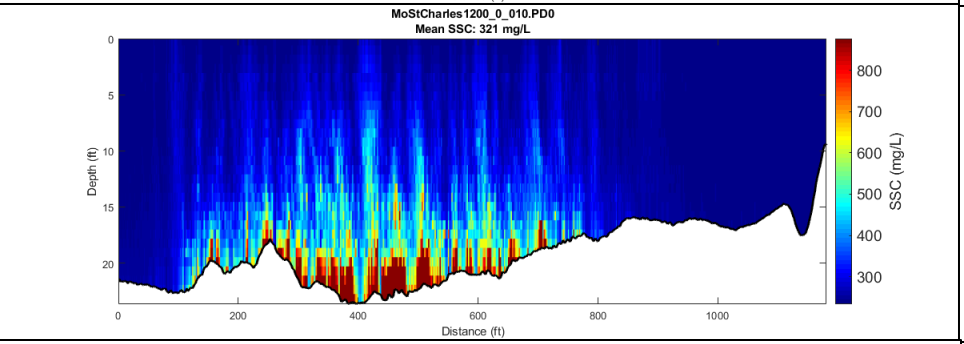
600 kHz and 1200 kHz calibrations match well. Slightly more scatter with 600 RG.

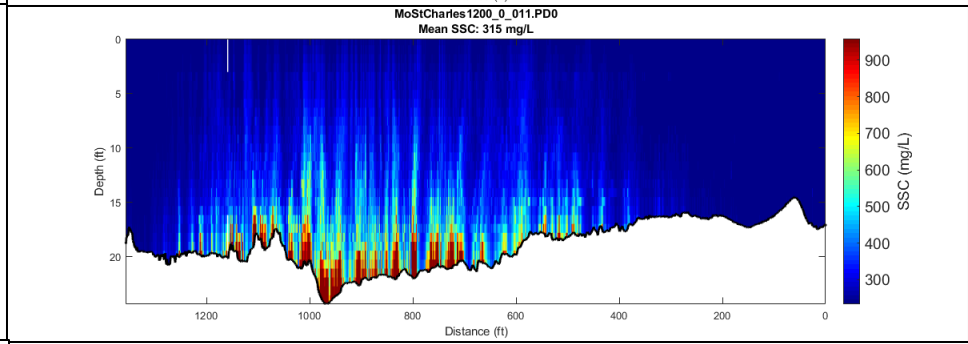
XS Calibration Results: SSC

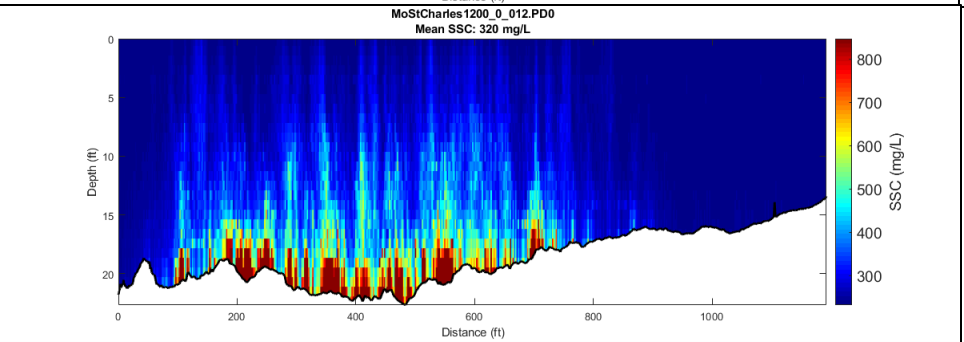
- 6 transects: Mean SSC range 315–324 mg/L

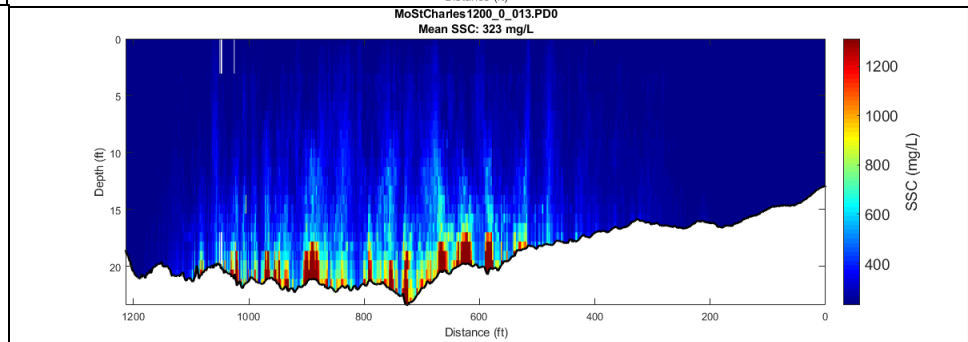






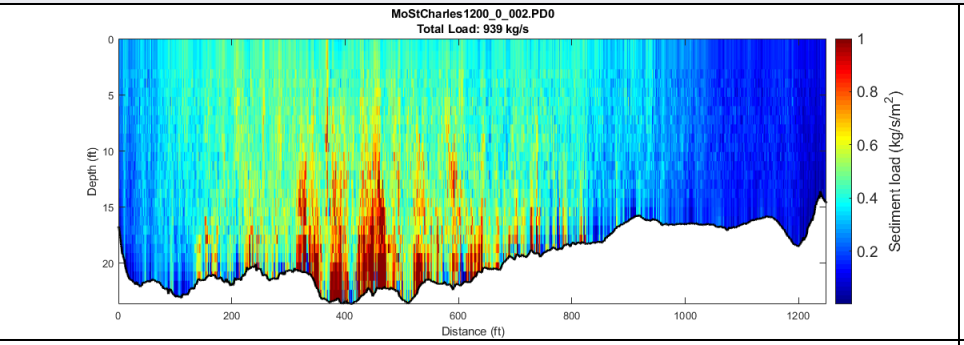


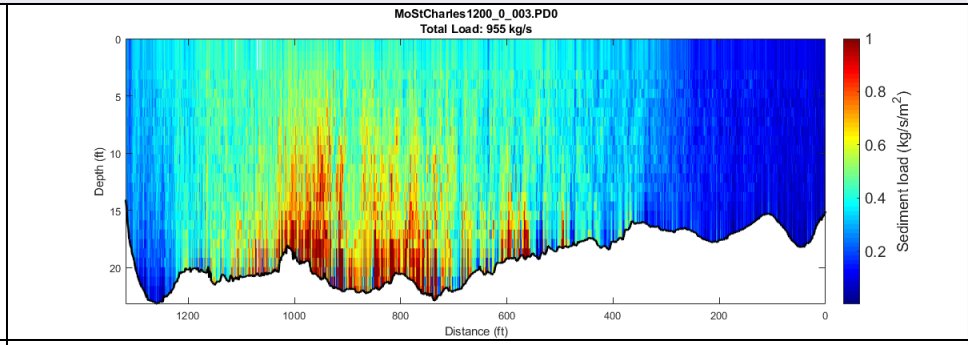


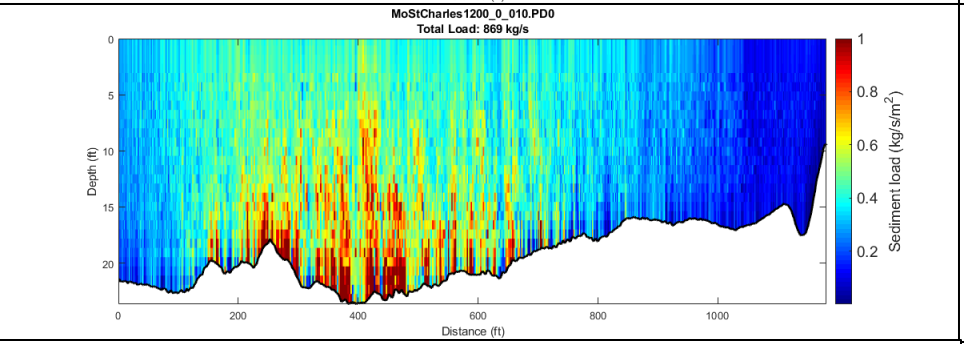


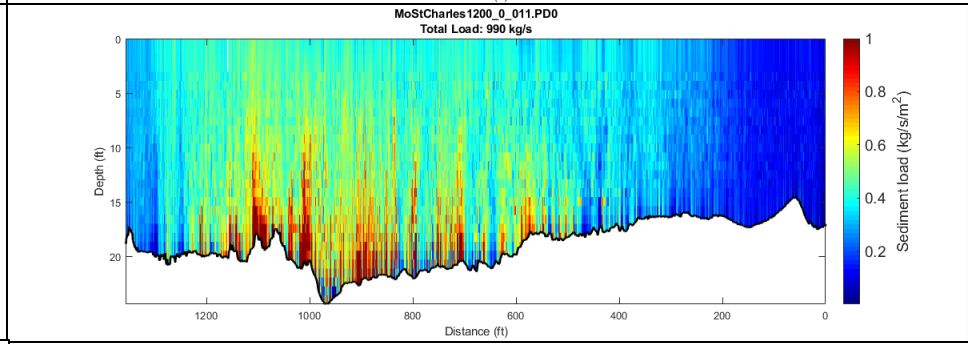
XS Calibration Results: SSL

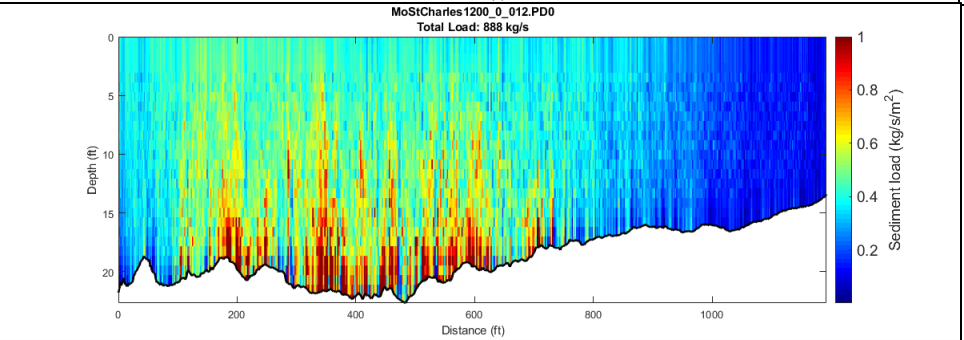
- 6 transects: Total Load range 869–990 kg/s

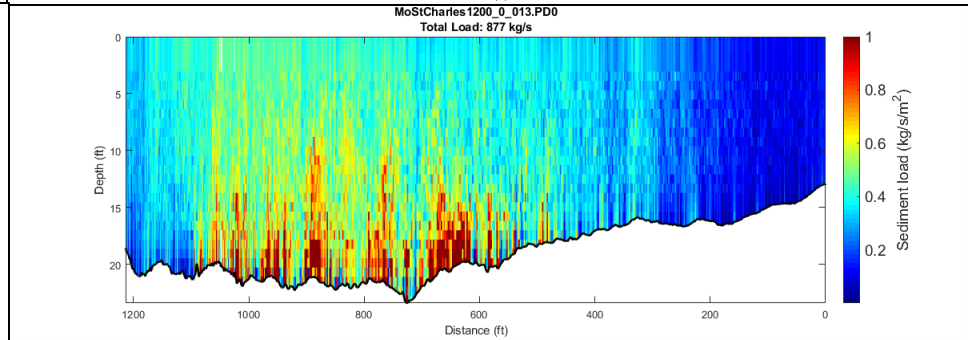




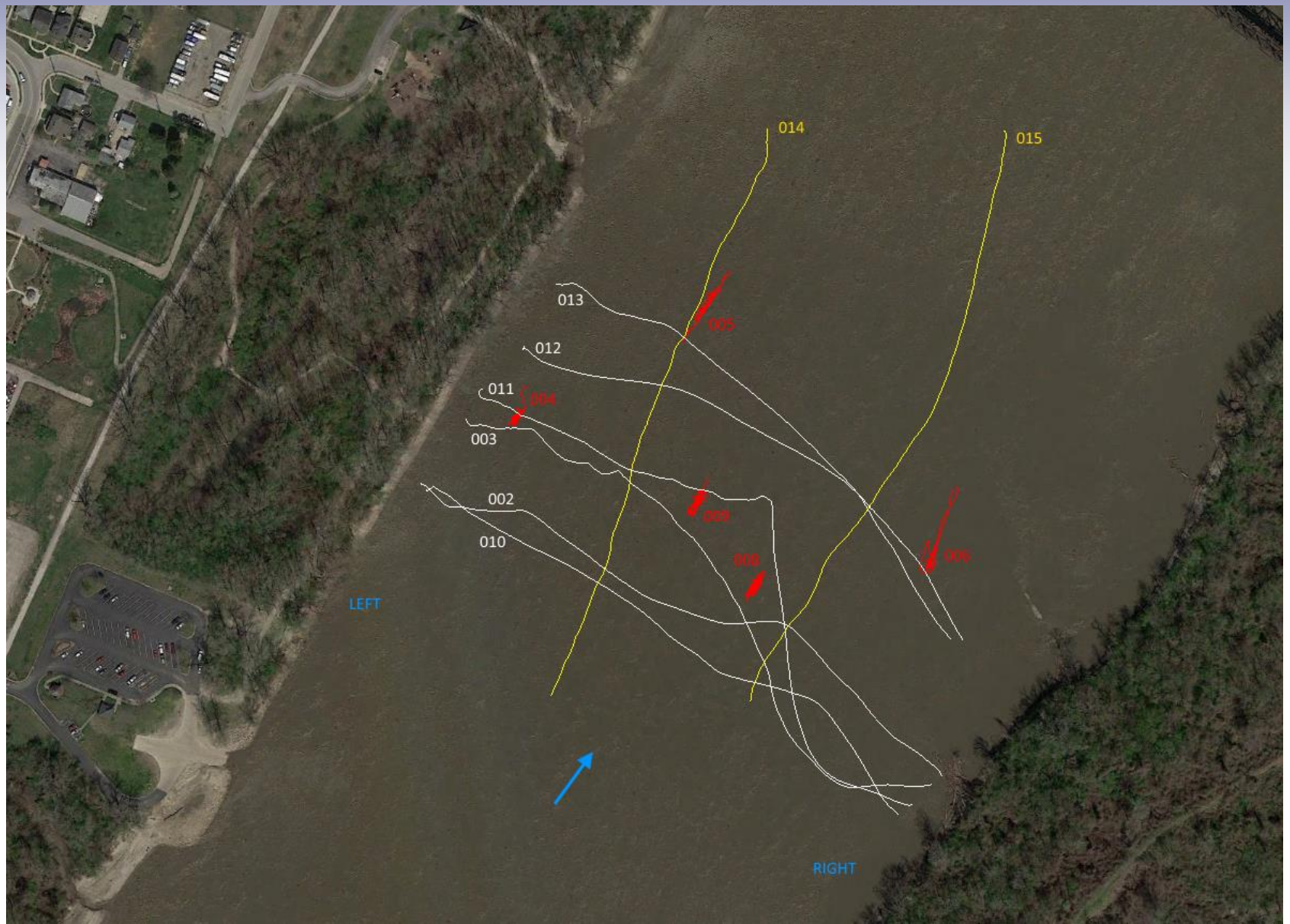




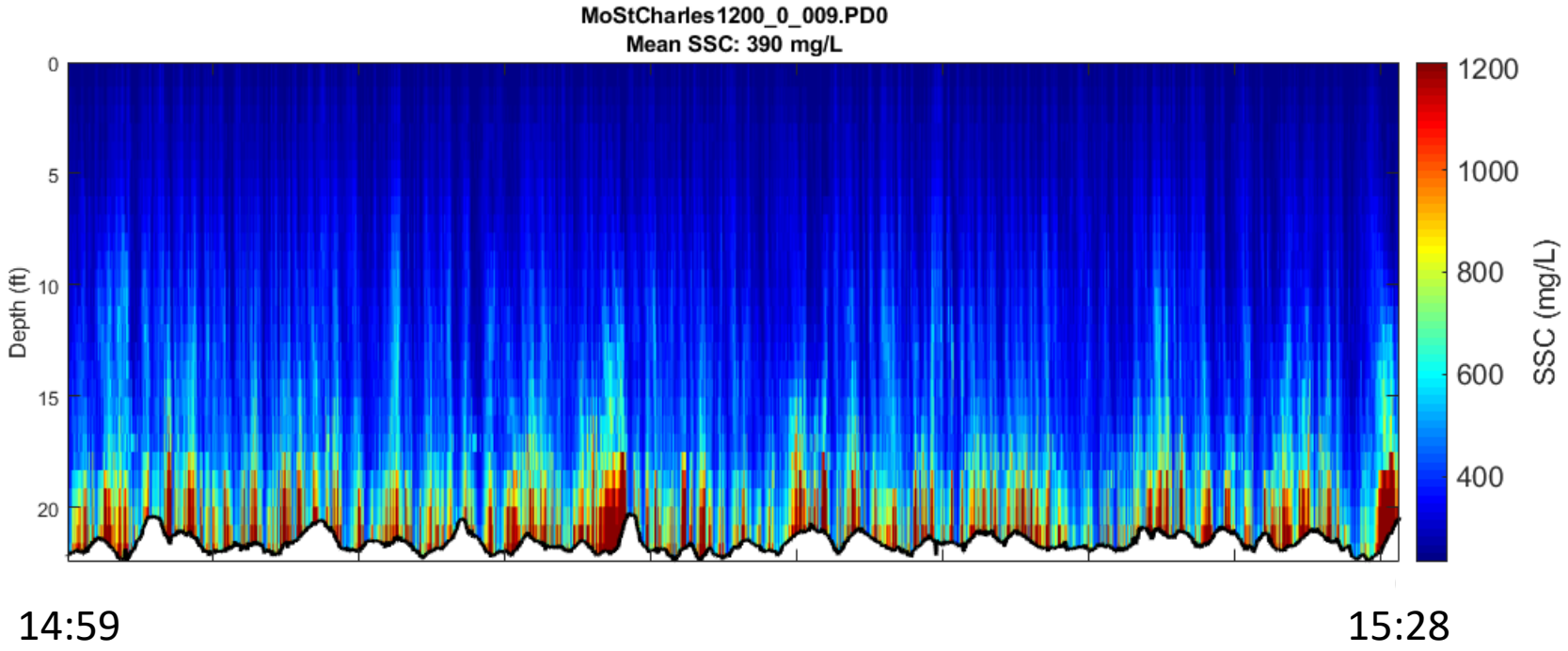




Data Collection Locations



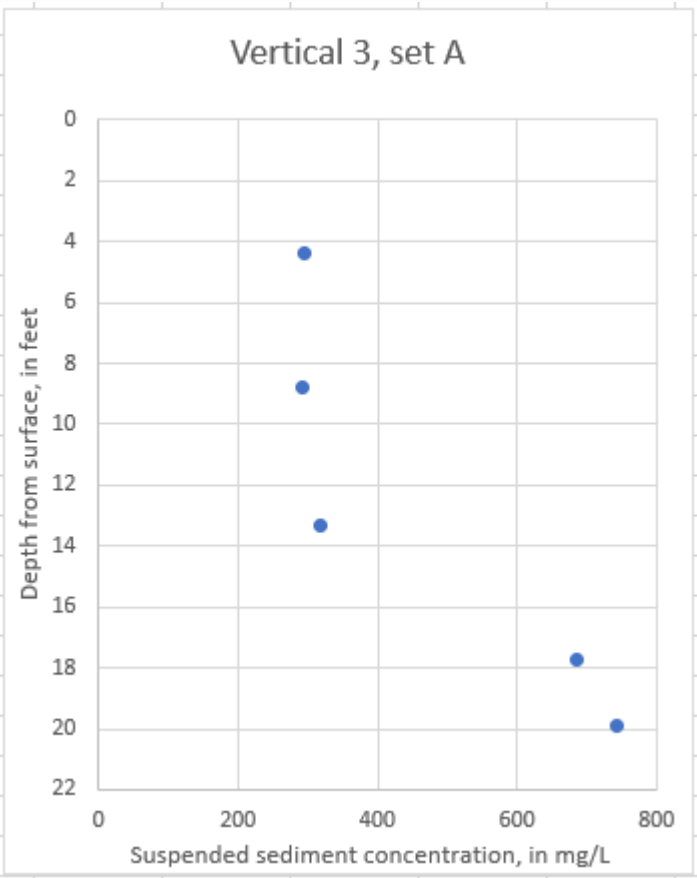
Apply Calibration to Vertical 3

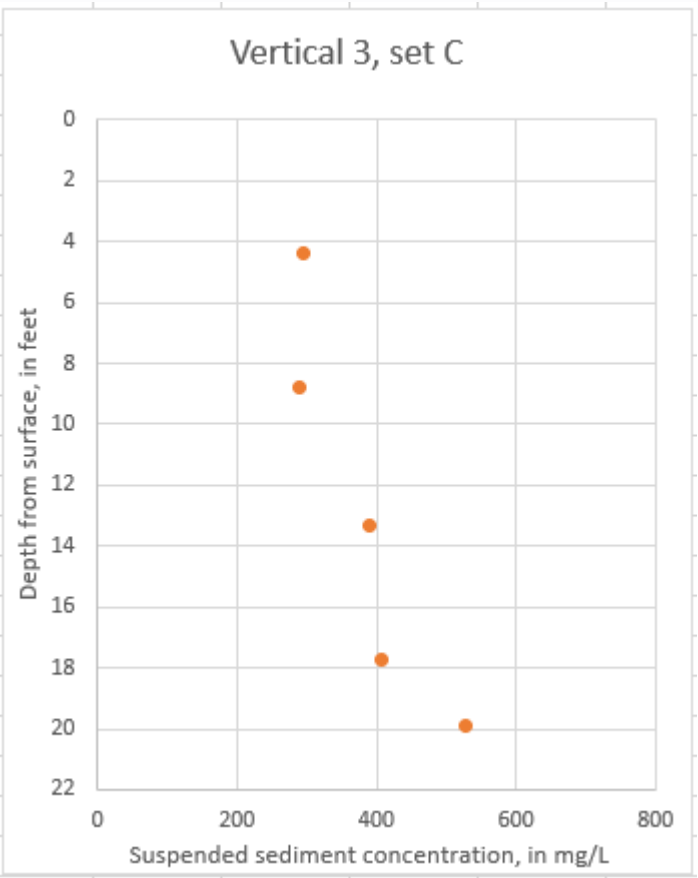


29 min * 60 sec/min * 19 bins = 33,060 “SSC samples” (from calibrated ADCP data)

SSC samples at Vertical 3

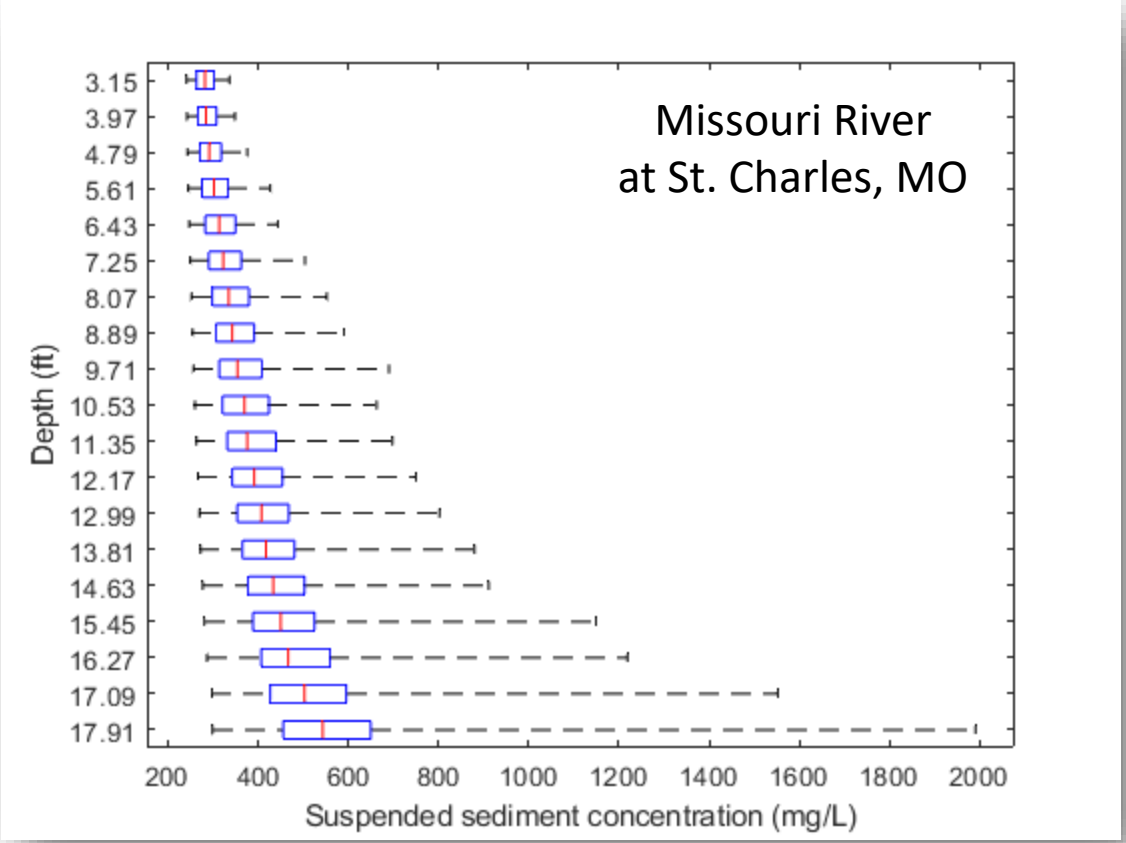
Station No	Station Name	Vertical	Depth Fraction	Depth_ft	Start Date Time Set A	Conc Set A mg/L	Conc Set C mg/L
06935965	Missouri River @ St. Charles, MO	3	0.2	4.4	07/20/2016 1500	294	294
06935965	Missouri River @ St. Charles, MO	3	0.4	8.8	07/20/2016 1505	292	289
06935965	Missouri River @ St. Charles, MO	3	0.6	13.3	07/20/2016 1508	317	389
06935965	Missouri River @ St. Charles, MO	3	0.8	17.7	07/20/2016 1519	686	407
06935965	Missouri River @ St. Charles, MO	3	0.9	19.9	07/20/2016 1524	742	527





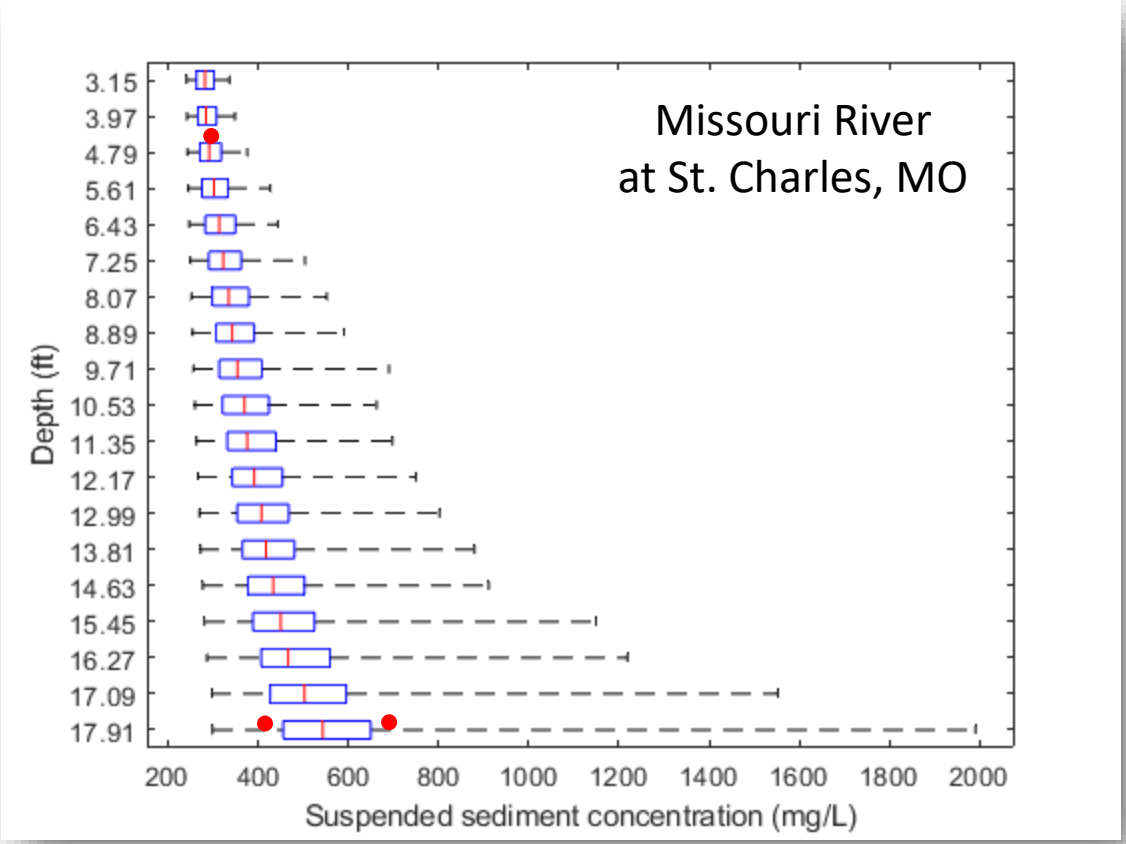
Stationary ADCP time-series SSC BOXPLOTS – Vertical 3

Station No	Station Name	Vertical	Depth Fraction	Depth_ft	Start Date Time Set A	Conc Set A mg/L	Conc Set C mg/L
06935965	Missouri River @ St. Charles, MO	3	0.2	4.4	07/20/2016 1500	294	294
06935965	Missouri River @ St. Charles, MO	3	0.4	8.8	07/20/2016 1505	292	289
06935965	Missouri River @ St. Charles, MO	3	0.6	13.3	07/20/2016 1508	317	389
06935965	Missouri River @ St. Charles, MO	3	0.8	17.7	07/20/2016 1519	686	407
06935965	Missouri River @ St. Charles, MO	3	0.9	19.9	07/20/2016 1524	742	527



Stationary ADCP time-series SSC BOXPLOTS – Vertical 3

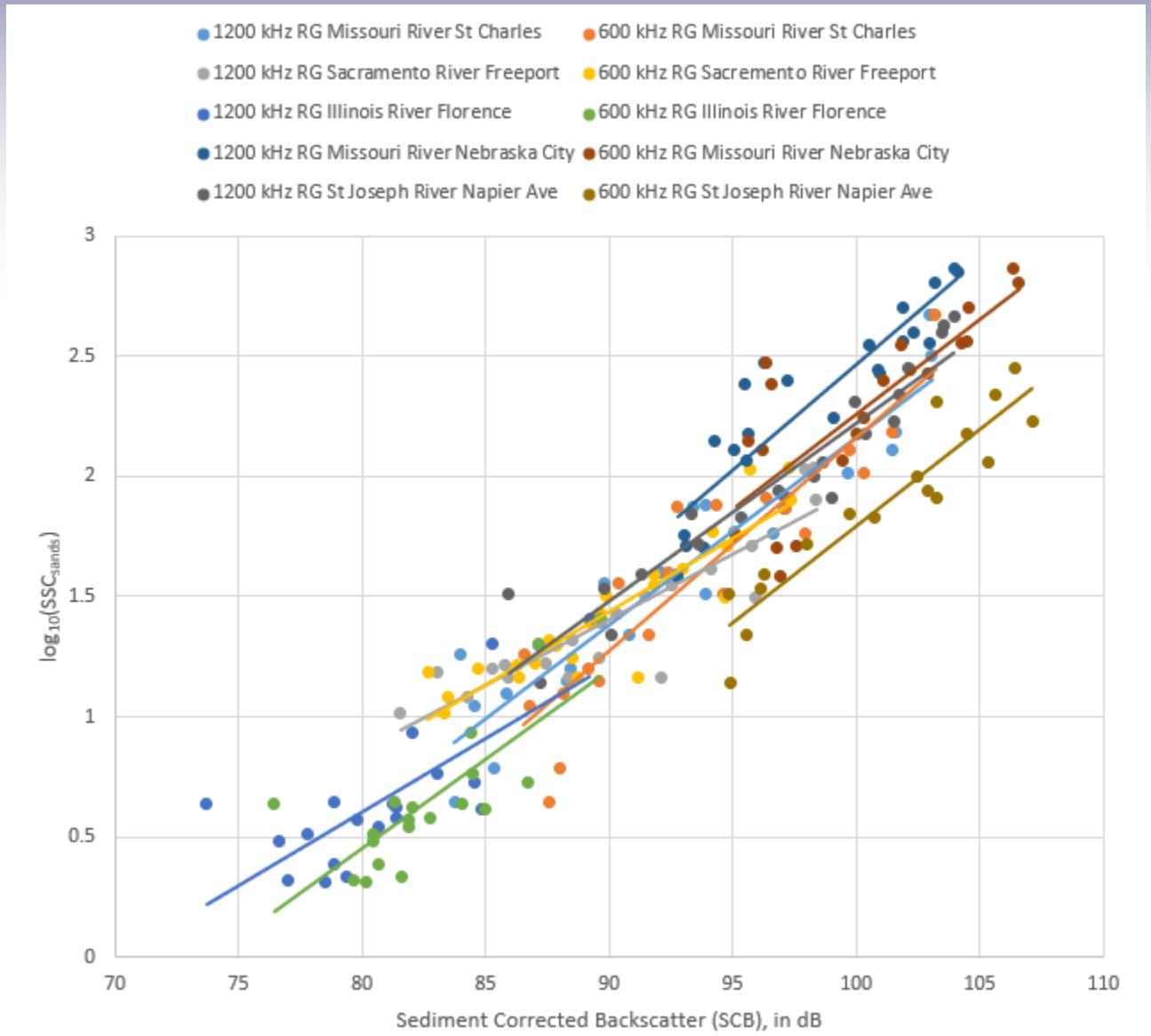
Station No	Station Name	Vertical	Depth Fraction	Depth_ft	Start Date Time Set A	Conc Set A mg/L	Conc Set C mg/L
06935965	Missouri River @ St. Charles, MO	3	0.2	4.4	07/20/2016 1500	294	294
06935965	Missouri River @ St. Charles, MO	3	0.4	8.8	07/20/2016 1505	292	289
06935965	Missouri River @ St. Charles, MO	3	0.6	13.3	07/20/2016 1508	317	389
06935965	Missouri River @ St. Charles, MO	3	0.8	17.7	07/20/2016 1519	686	407
06935965	Missouri River @ St. Charles, MO	3	0.9	19.9	07/20/2016 1524	742	527



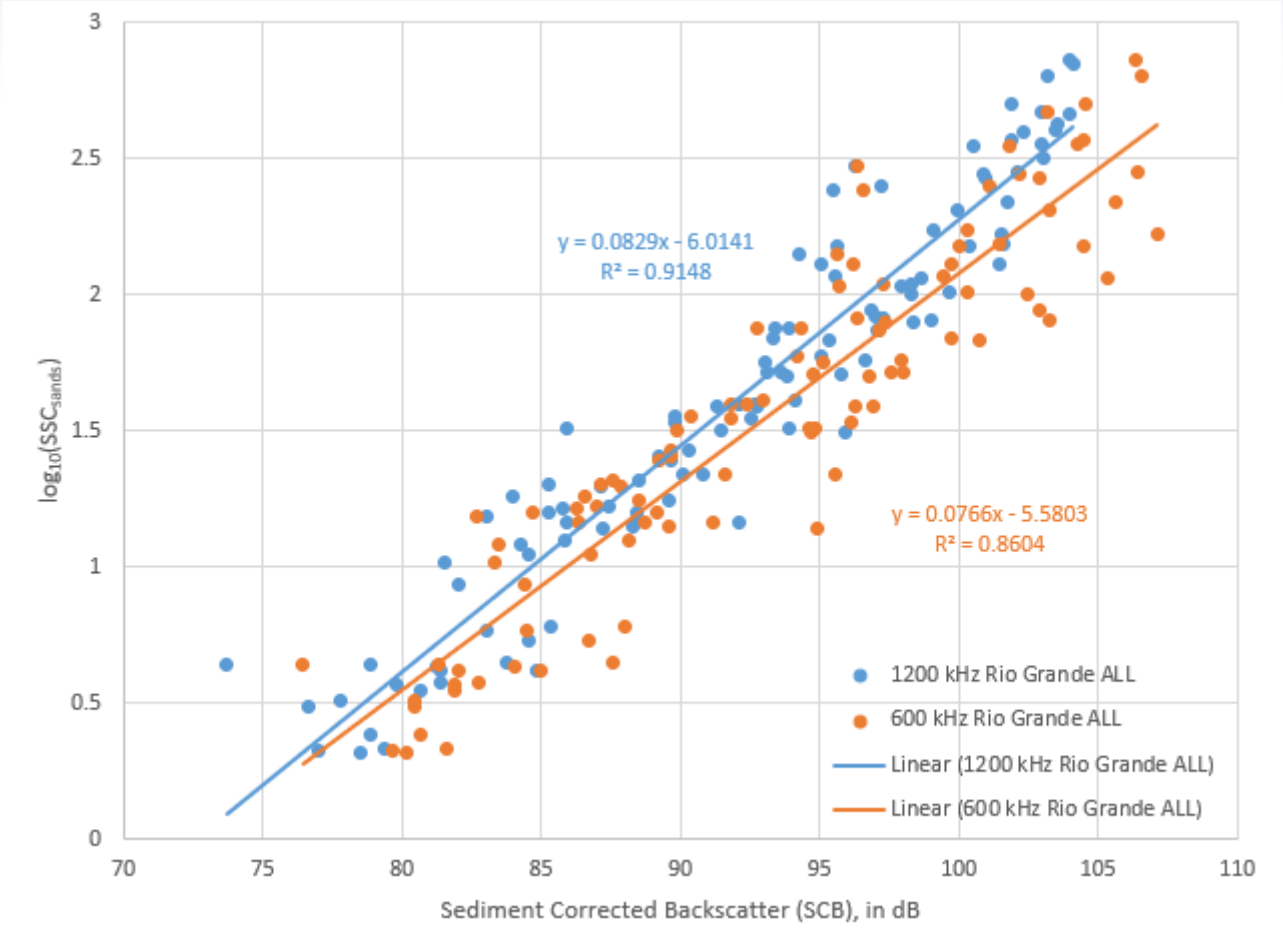
All 5 datasets from 2016–2018

Site Name	SSC (mg/L)	Sediment Load (kg/s)
Missouri River - St Charles	320	920
Sacramento River - Freeport	70	140
Illinois River - Florence	68	140
Missouri River - Nebraska City	780	1,740
St Joseph River - Napier Ave	225	160

All 5 datasets from 2016–2018



All 5 datasets from 2016–2018 1200 kHz vs 600 kHz

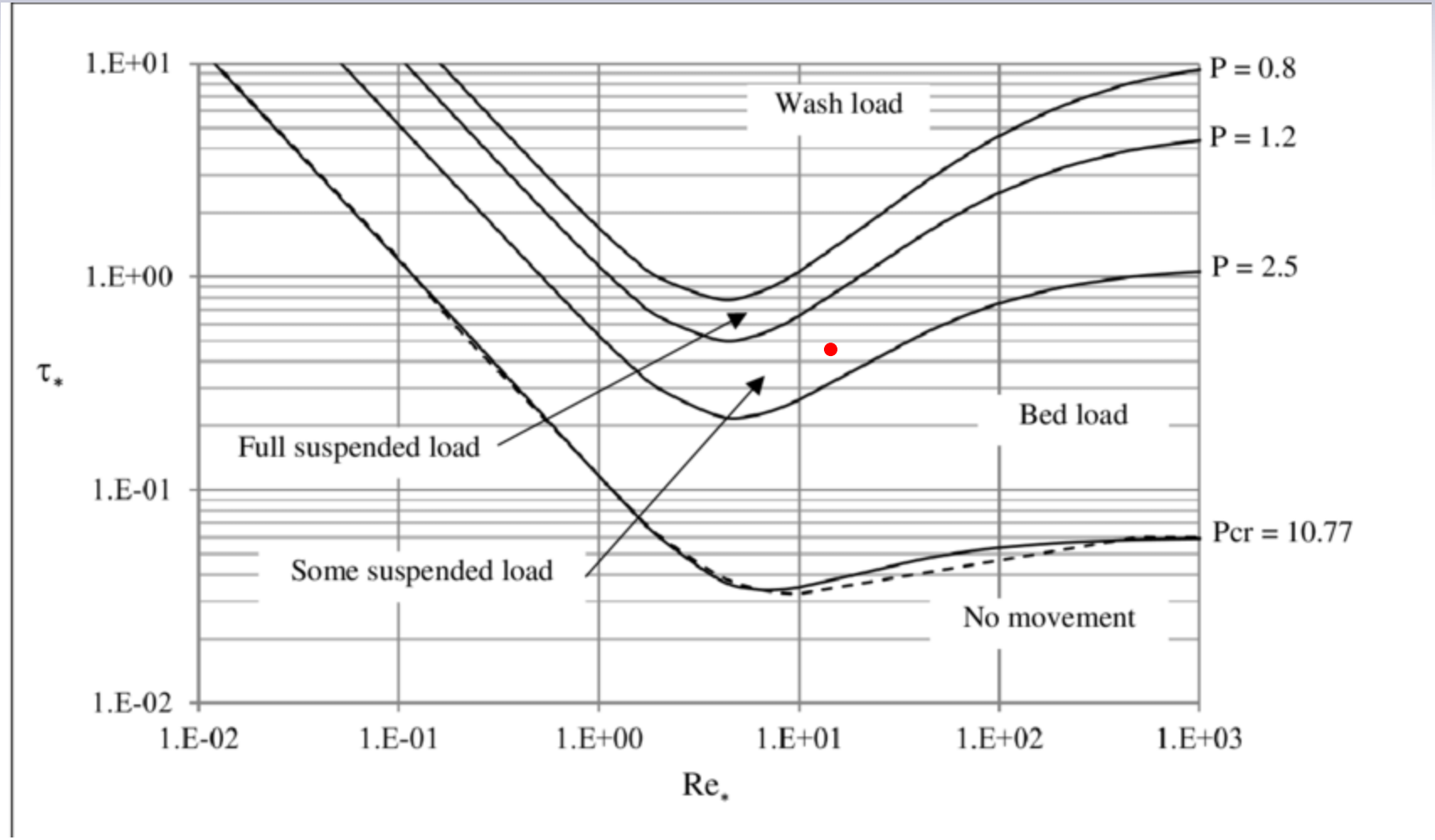


Next Steps

- Beta testing
- 2-year Water Resources Research Act (WRRA) Coordination Grant with Dr. Jonathan Czuba (Virginia Tech)
- Publish testing data sets and software

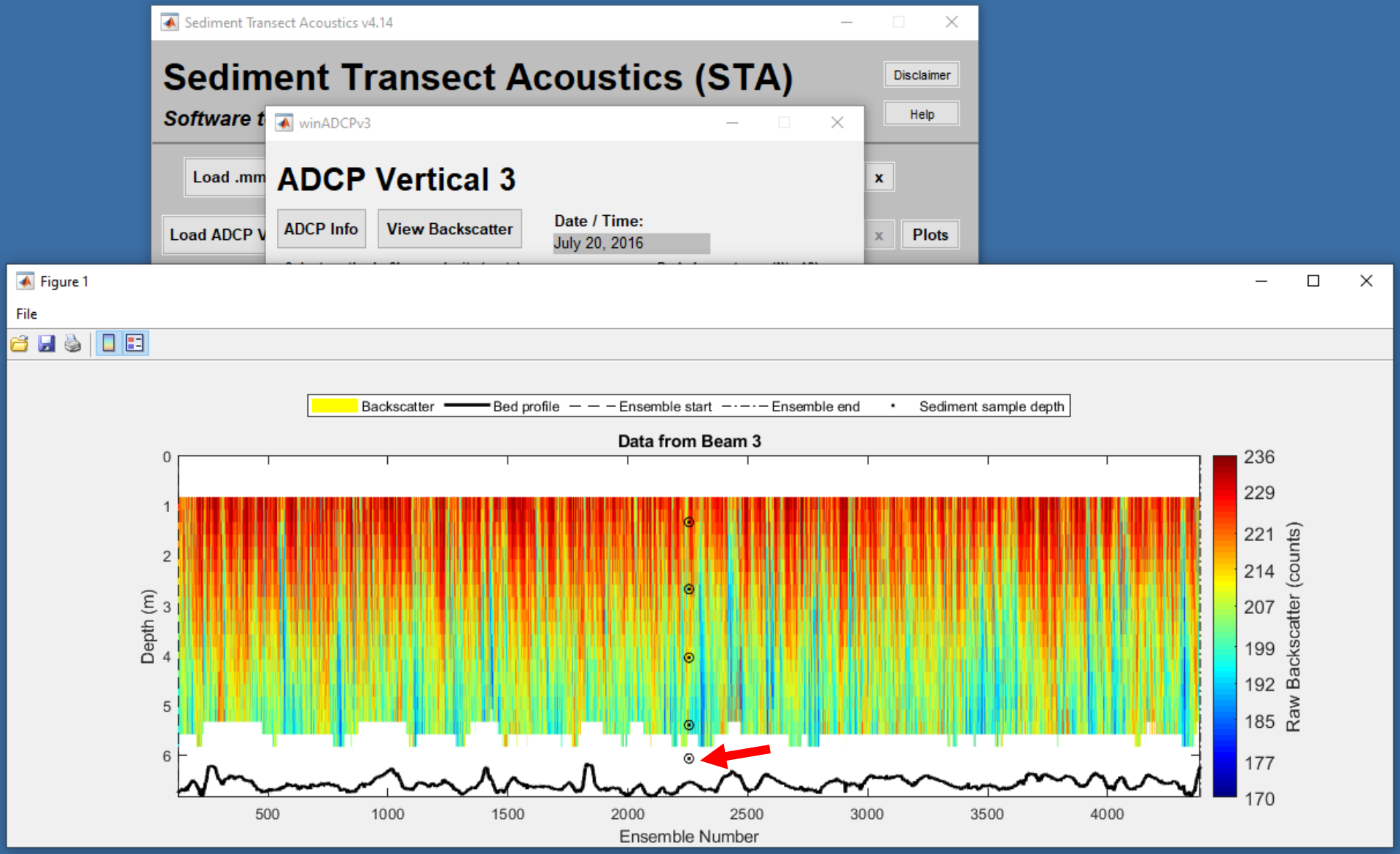
EXTRAS

Shields diagram and Rouse number

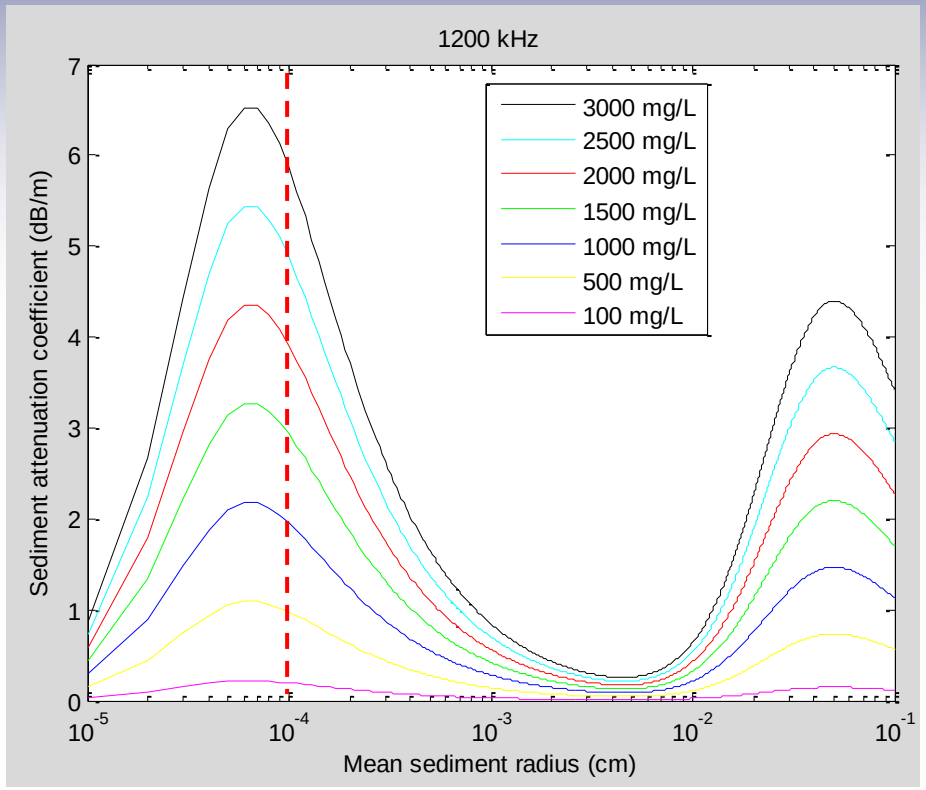


Reference: *Pekker, L., A calculator for sediment transport in microchannels based on the Rouse number, https://doi.org/10.48550/arxiv.1712.07073*

Sediment sample depths and ADCP



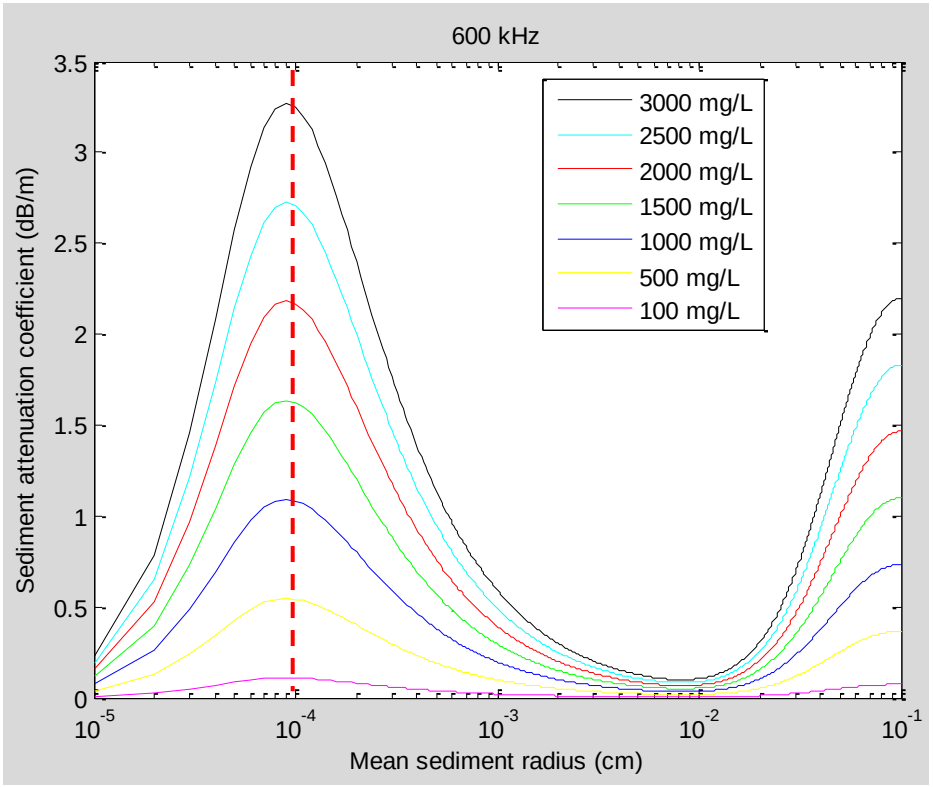
Plots of α_s vs. a_s for 1200 kHz & 600 kHz



$$\alpha_S = SSC_V \left[k(\gamma-1)^2 \left\{ \frac{s}{s^2+(\gamma+\tau)^2} \right\} + \left\{ \frac{k^4 {a_s}^3}{5(1+1.3k^2{a_s}^2+0.24k^4{a_s}^4)} \right\} \right] 4.34$$

Hybrid Urick-Sheng-Hay equation for the sediment attenuation coefficient (α_s)

(Urick, 1948), (Sheng and Hay, 1988), (Landers, 2010)



Questions:

- **How to determine mean sediment radius (a_s)?**
- **Use D_{50} or something else?**