Sediment flux through the Golden Gate

Maureen Downing-Kunz, Environmental Science Associates
Michael MacWilliams, Anchor QEA

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USGS science for a changing world

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Notes

- I conducted this work while working at USGS with David Schoellhamer, Paul Work, and others
- I no longer represent the USGS
- The content in these slides is from material approved for public release
- Further information can be found in our 2021 paper:

  Downing-Kunz, M.A., Work, P.A. & Schoellhamer, D.H. Tidal Asymmetry in Ocean-Boundary Flux and In-Estuary Trapping of Suspended Sediment Following Watershed Storms: San Francisco Estuary, California, USA. *Estuaries and Coasts* (2021).

  https://doi.org/10.1007/s12237-021-00937-y

Background

- Watershed and sediment discharge enter SF Bay from Sacramento and San Joaquin Rivers, and smaller local tributaries
- Sediment supply to SF Bay has changed over time
- One motivation for this work was to improve understanding of the SF Bay sediment budget
- Quantifying the SF Bay sediment budget aids in management of:
  - Navigation dredging
  - Contaminant transport
  - Shoreline resilience
  - Wetland restoration
  - Beach erosion
  - Aggregate mining

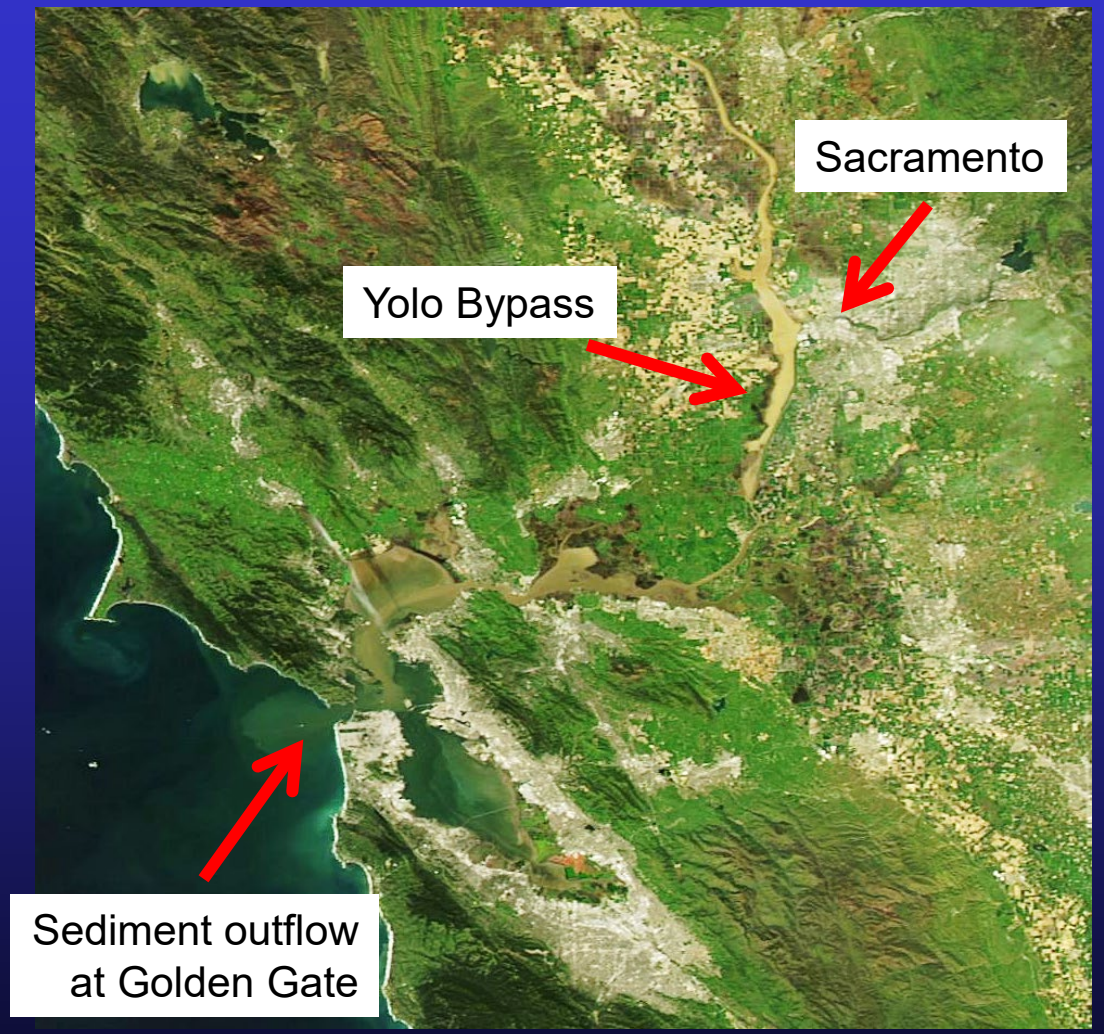

Image date: 3/16/16; worldview.earthdata.nasa.gov

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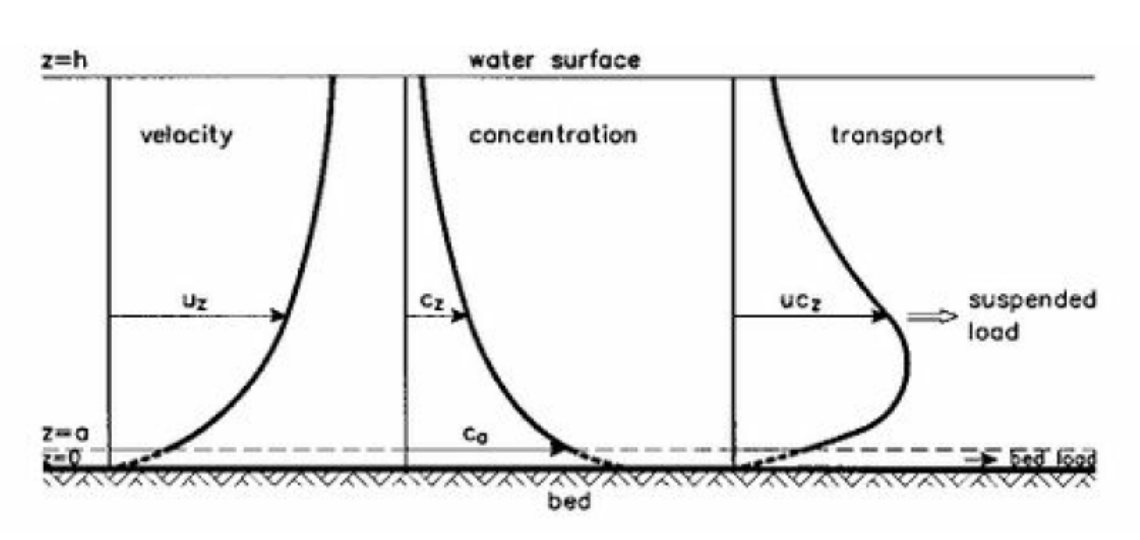
Sediment fluxes and budgets



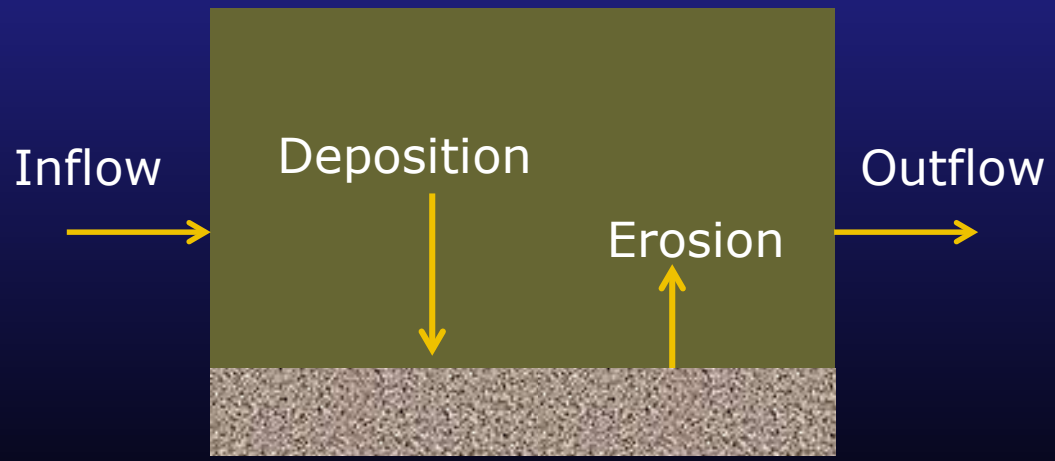
van Rijn 2006

Flux: rate of transport at a cross-section

*Flux = discharge * concentration*

Budget: a way to account for sediment gains and losses within a region of interest

Change in storage = inflow - outflow



Suspended-sediment flux at Golden Gate

- Sediment budgets show that suspended-sediment flux at the Golden Gate is *the largest and most uncertain term*
- **Objective:** Collect sediment flux measurements during high runoff, build upon existing work documented in Erikson et al. (2013)

Source	Years	Method	Sediment outflow (Mt/yr)
Gilbert (1917)	1849-1914	Arbitrary estimate	20.2
Ogden/Beeman/Krone (1992)	1955-1990	Mass conservation	1.3
Schoellhamer et al. (2005)	1955-1990	Mass conservation	5.0
Schoellhamer et al. (2005)	1995-2002	Mass conservation	4.2
Erikson et al. (2013)	2004-2011	Surrogate flux	5.0

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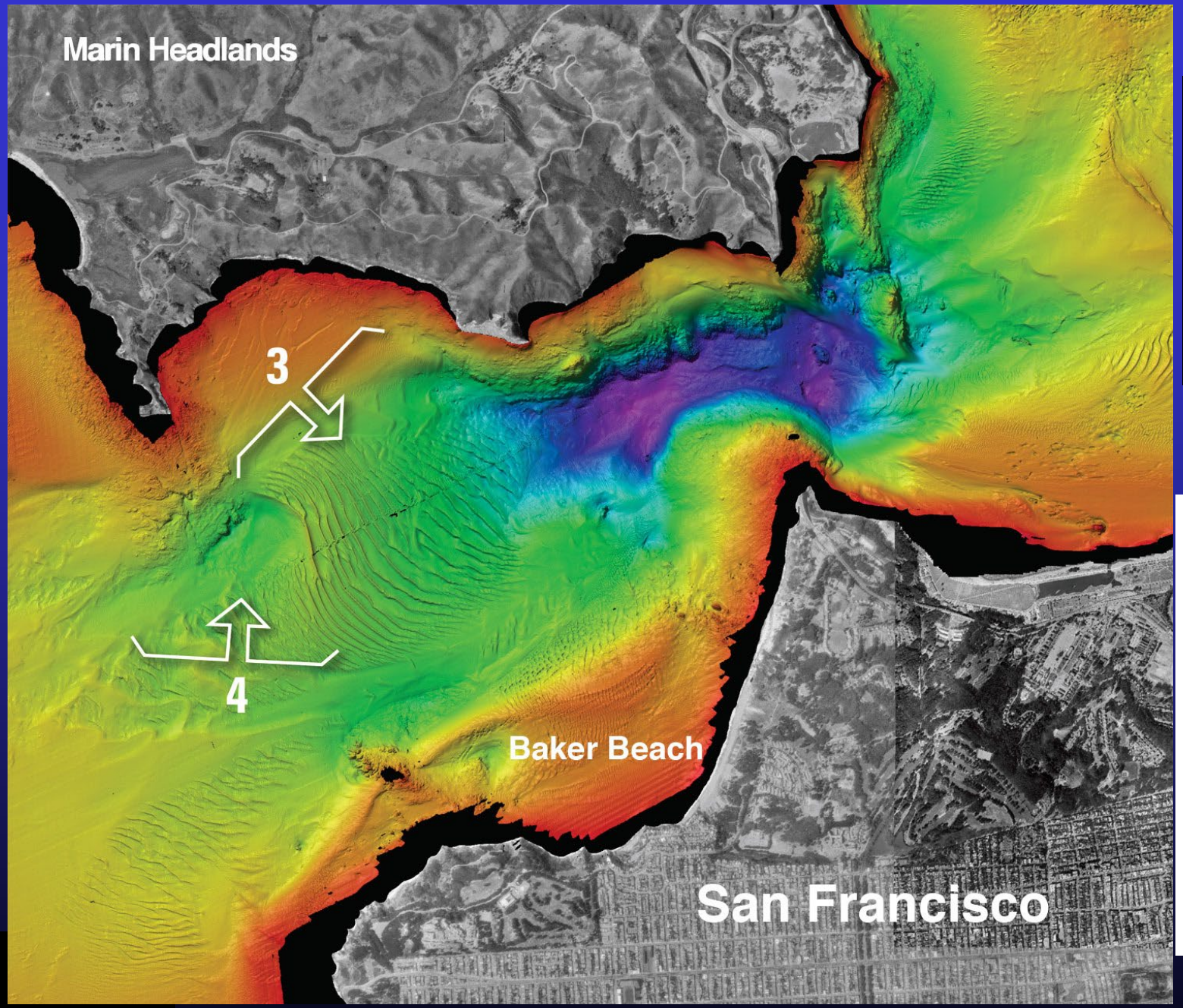


Golden Gate is extreme—great depths, fast currents

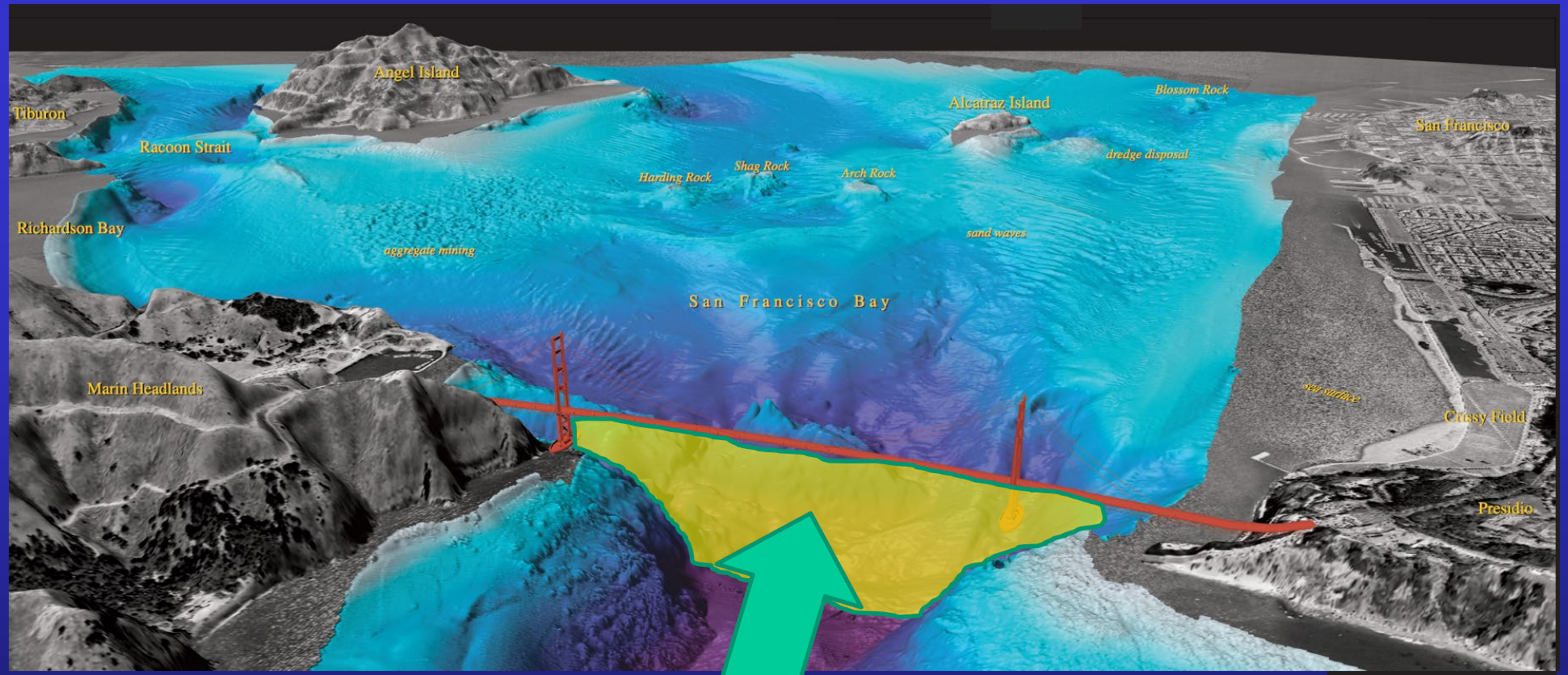
- 6 ft (1.8 m) tidal range
- ~25% of SF Bay volume exchanged per tide

Depth

m	ft
20	65
40	130
60	200
80	265
100	330

Cochrane, G. R. et al. 2015

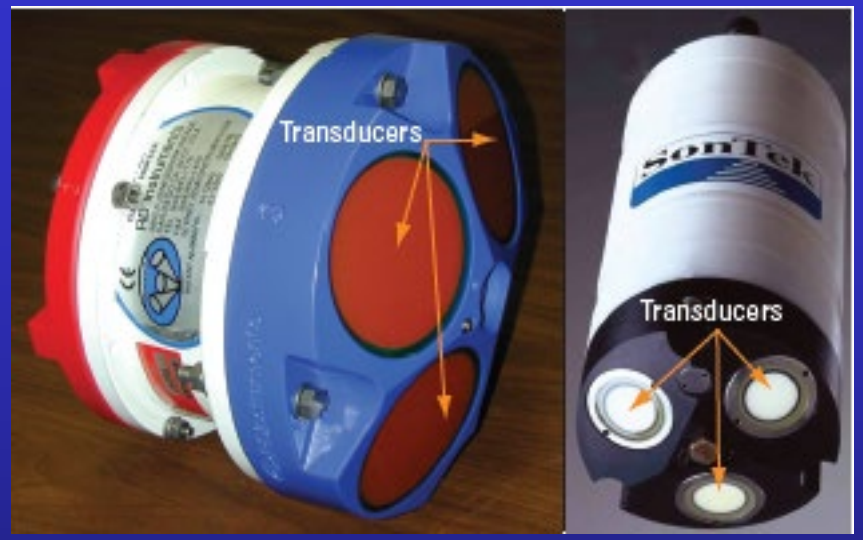
Cooler colors = greater depths

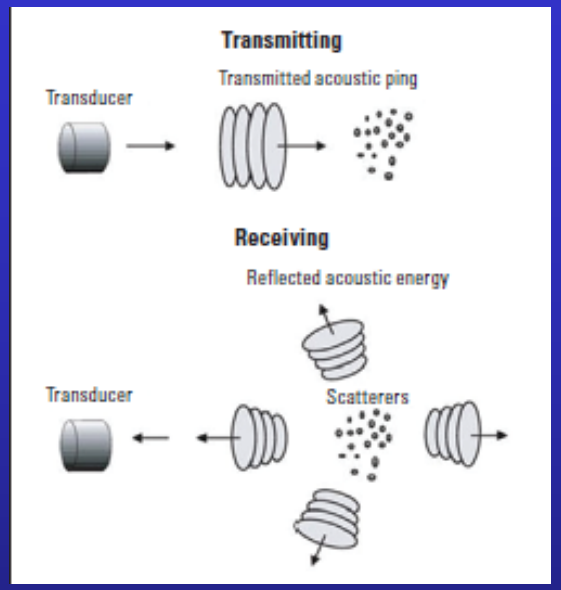


Dartnell et al. 2006

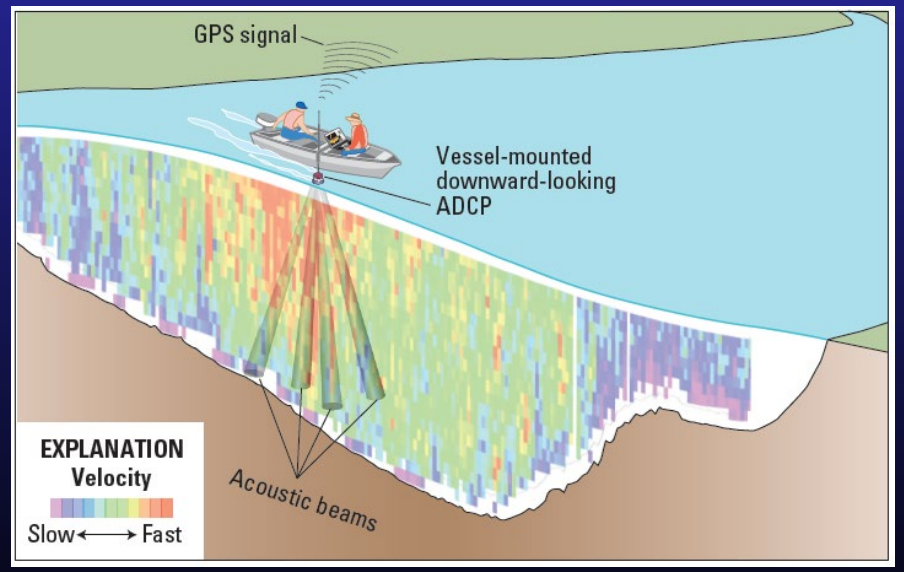
*Sediment flux = discharge * concentration*

Acoustic Doppler Current Profiler (ADCP): The sediment flux whisperer





Simpson 2001



Mueller et al. 2013

*Discharge = velocity * area*

*Sediment flux = discharge * concentration*

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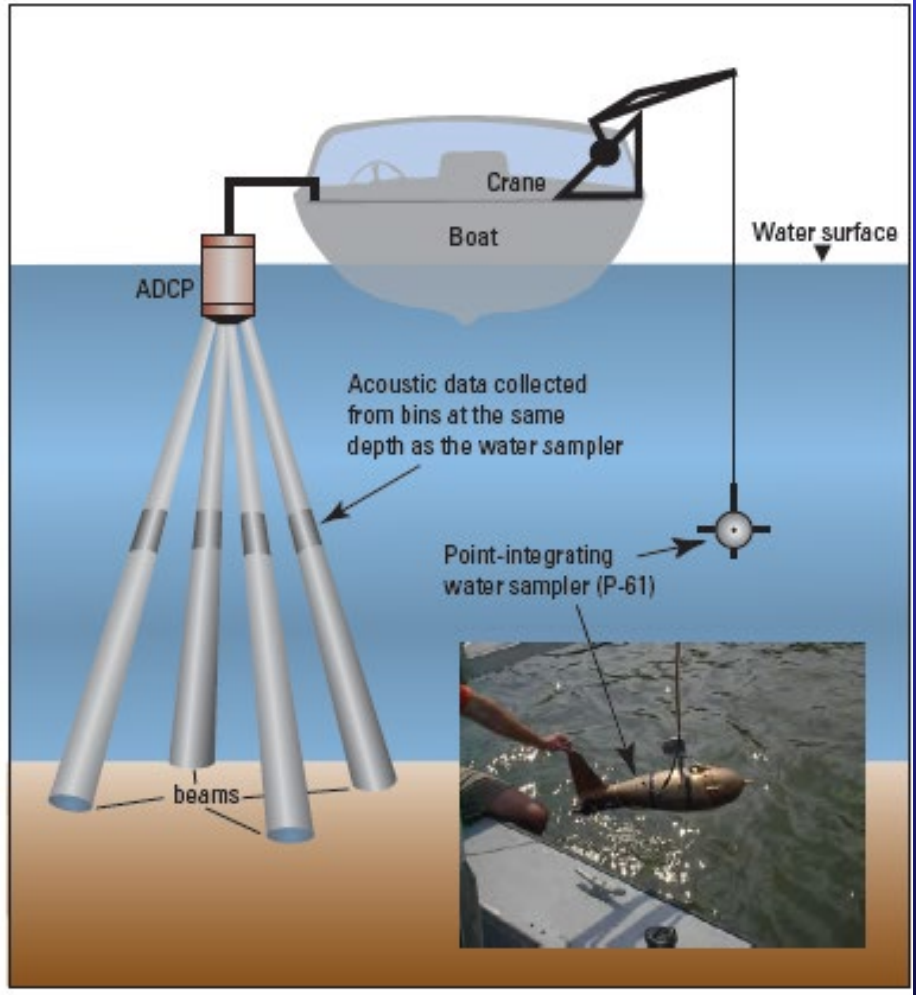
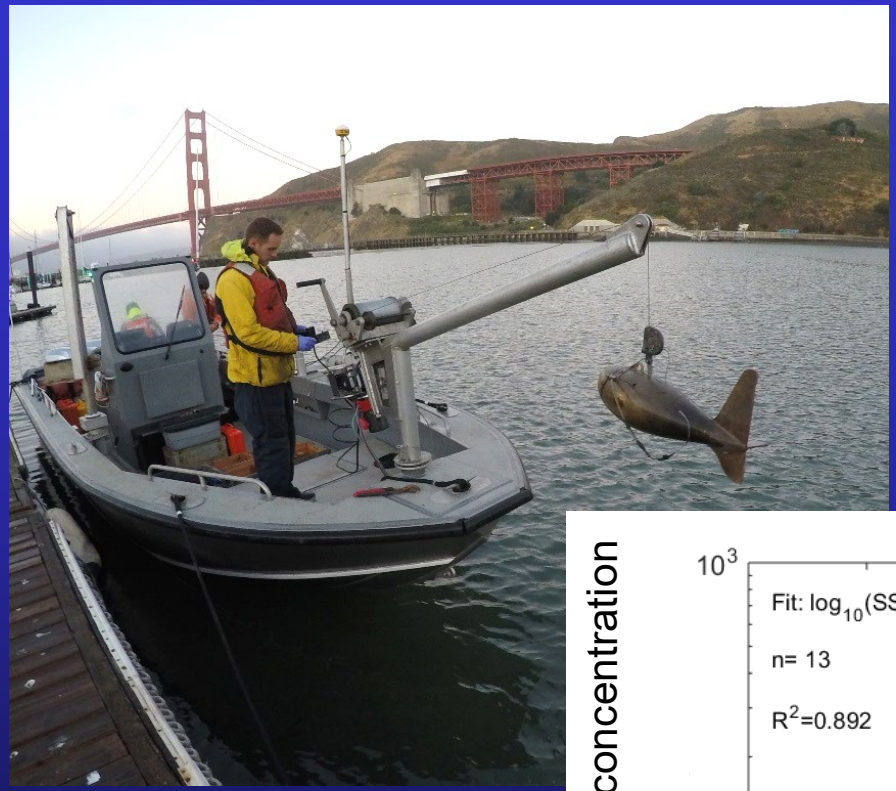
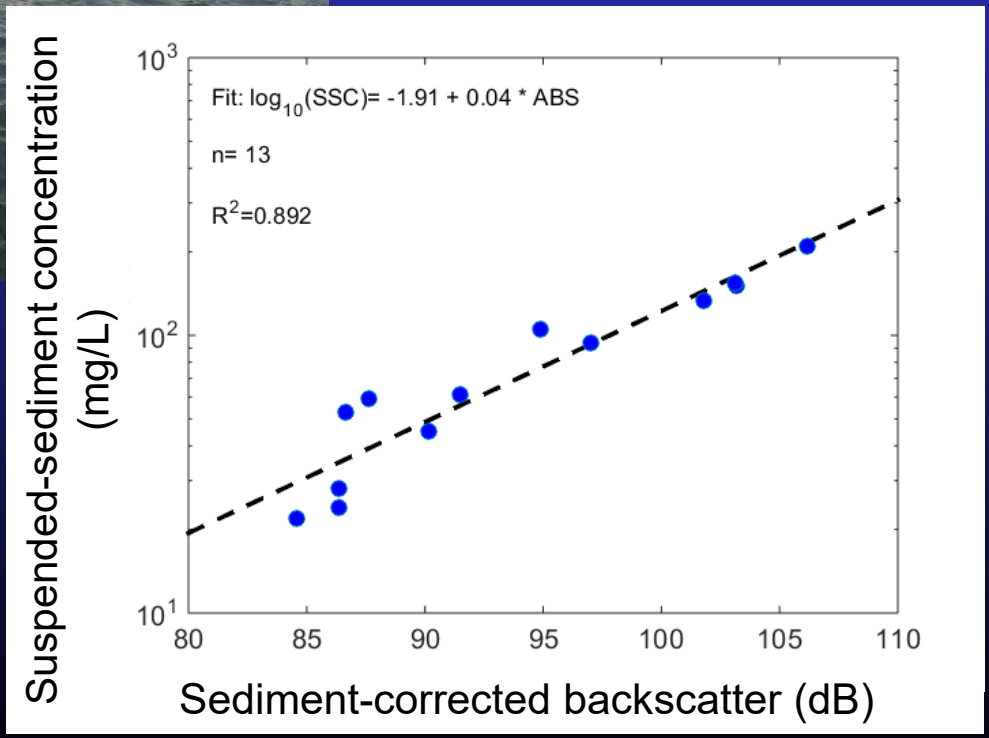
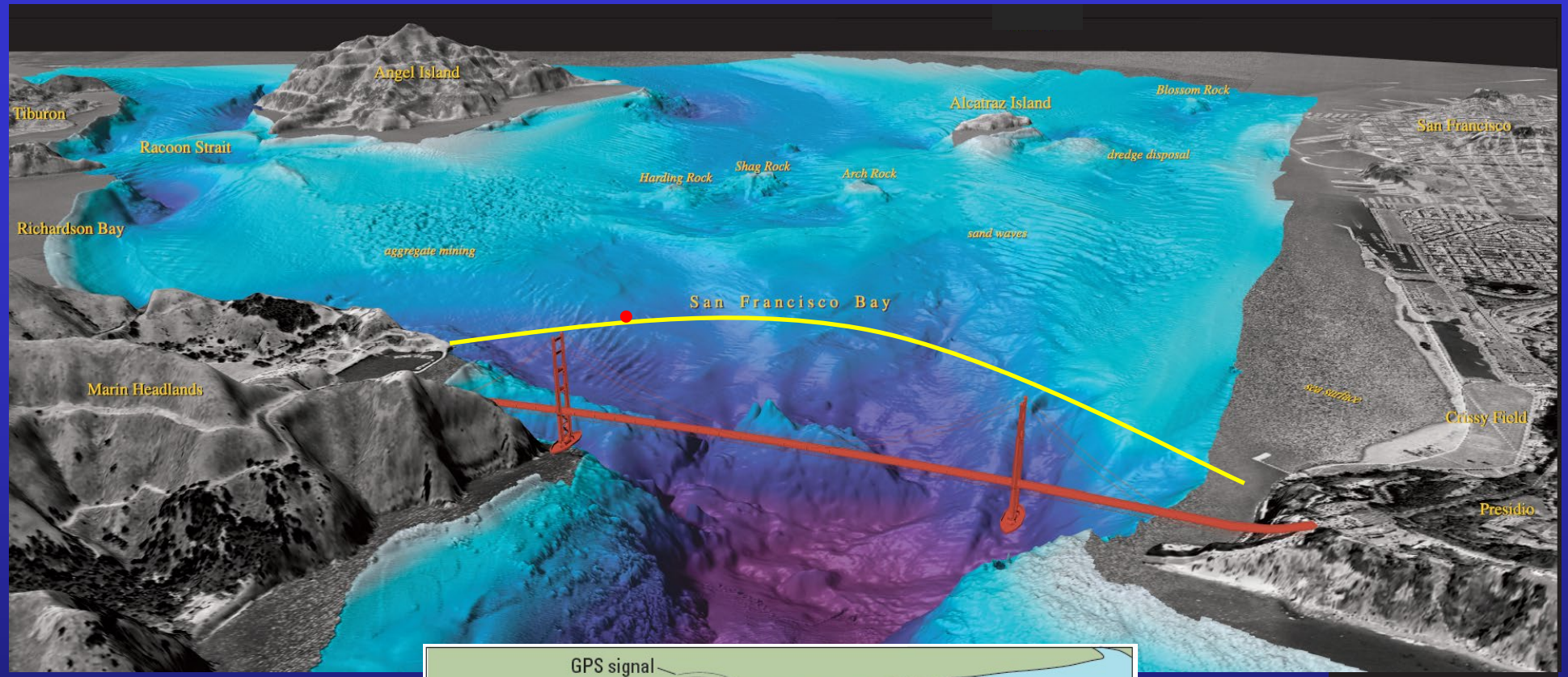
Calibration of backscatter to suspended-sediment concentration (SSC)



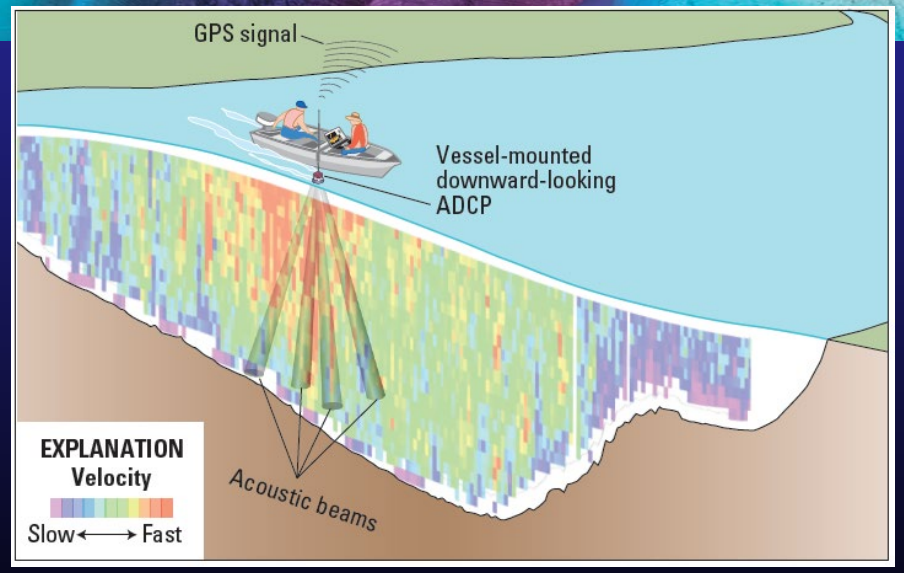
Wall et al. 2006

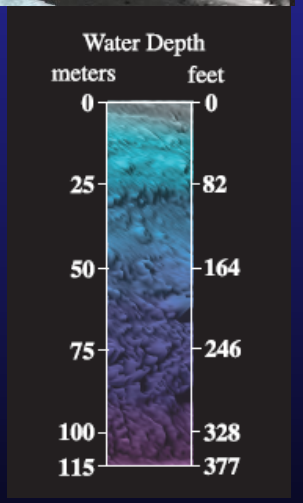






Dartnell et al. 2006





Mueller et al. 2013

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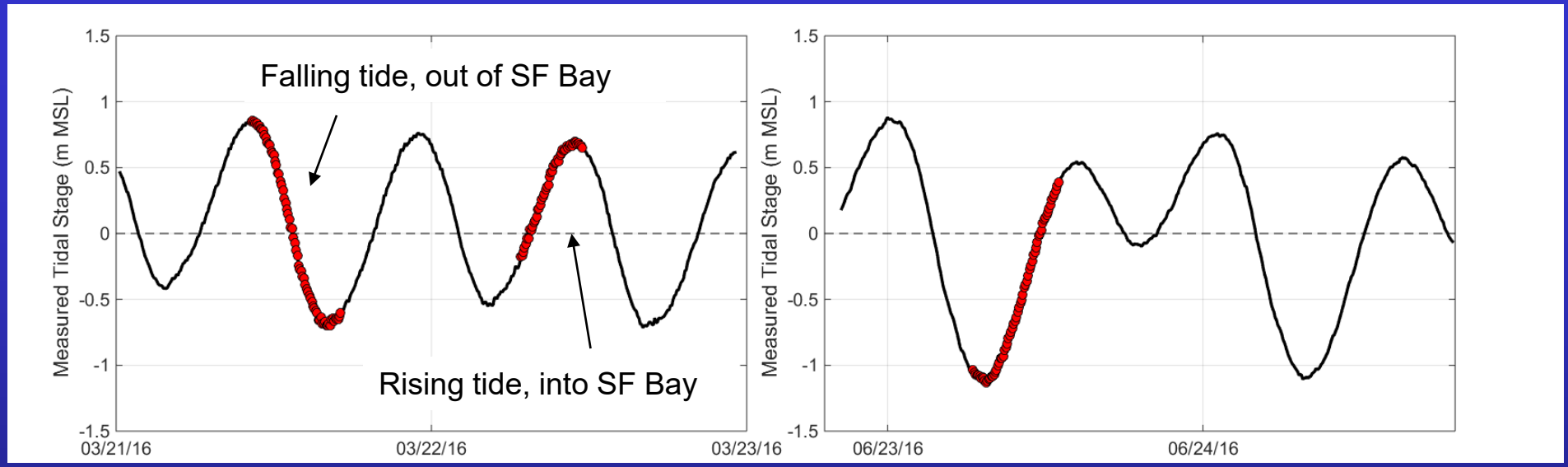
Underway aboard *R/V Questuary* on a calm day

Fairweather sediment sampling

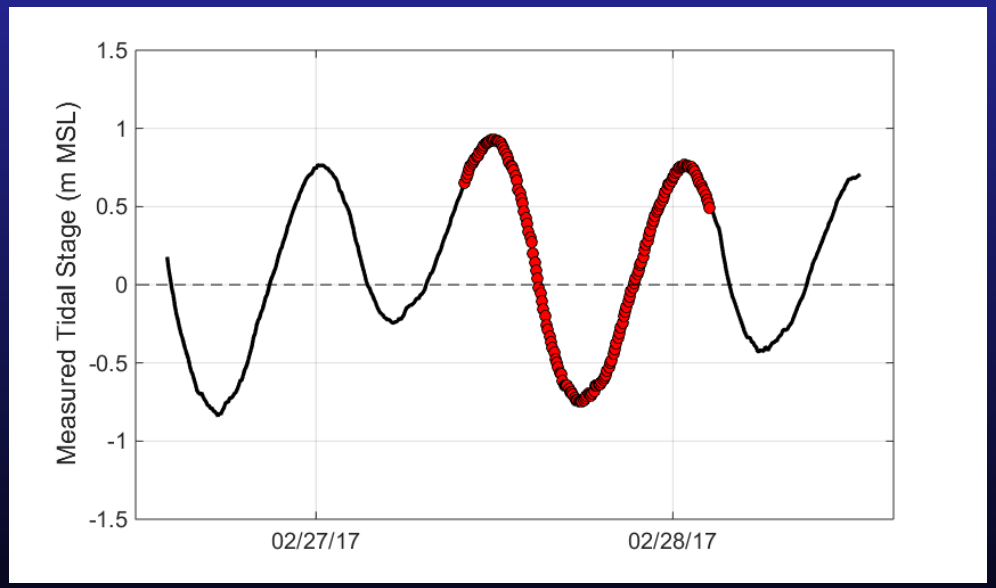
Views from the stormy day

ADCP transects by field campaign



March 2016, *n* = 18

June 2016, *n* = 7



February 2017, *n* = 32

High spatial resolution
but
Low temporal resolution

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Results

Field Date	Peak water flux ($1x10^5$ m^3/s)		Peak sediment flux ($1x10^5$ kg/min)		Peak transect-average SSC (mg/L)	
	Ebb	Flood	Ebb	Flood	Ebb	Flood
Mar 2016	1.3	1.0	1.6 <	2.0	25 <	33
Jun 2016	1.1	0.9	1.2 <	1.3	21 <	35
Feb 2017	1.3	1.1	3.0 <	4.6	62 <	68

Downing-Kunz et al., 2021

- Peak water flux on ebb
- Peak sediment flux on **flood**
- Peak cross-sectional average SSC on **flood**

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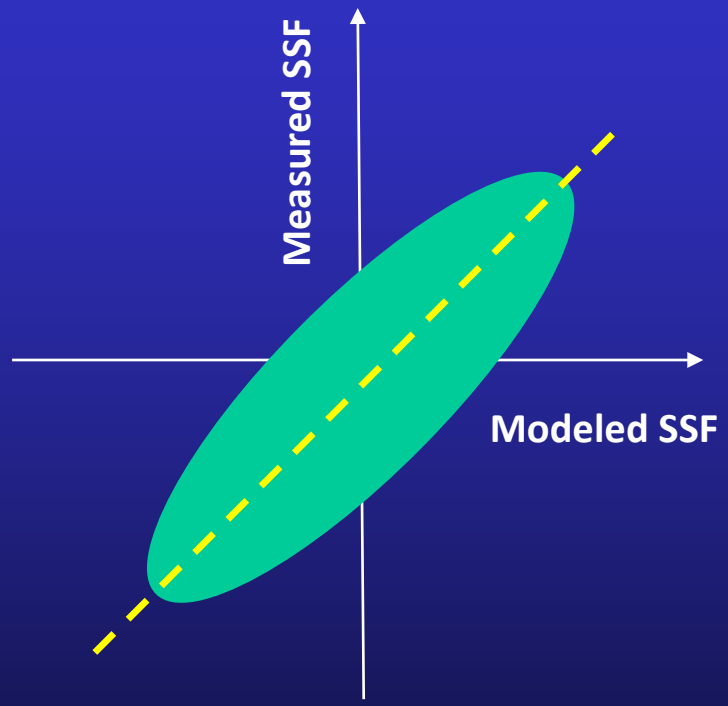
Challenges

- Getting the timing right
  - Physical factors are complex
  - Scheduling an appropriate vessel
- Labor intensive
  - Low temporal resolution
- ADCP frequency
  - Trade-off between range and sensitivity

Next step: Modeling suspended-sediment flux (SSF)



Acknowledgements

- San Francisco Bay Regional Monitoring Program
- San Francisco Bay Regional Water Quality Control Board
- San Francisco Estuary Institute
- San Francisco Estuary Partnership
- US Environmental Protection Agency, Region 9
- US Army Corps of Engineers, San Francisco District
- US Bureau of Reclamation
- National Water Quality Monitoring Network for U.S. Coastal Waters and their Tributaries
- Rachel Allen, David Bell, Paul Buchanan, Gwen Davies, Brian Downing, Darin Einhell, Li Erikson, Larry Freeman, Daniel Livsey, Scott Nagel, Mark Stacey, David Stevens, Kurt Weidich, and Scott Wright

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Sediment Flux through the Golden Gate

Presented by

Maureen Downing-Kunz, PhD

Michael MacWilliams, PhD, PE

ANCHOR QEA

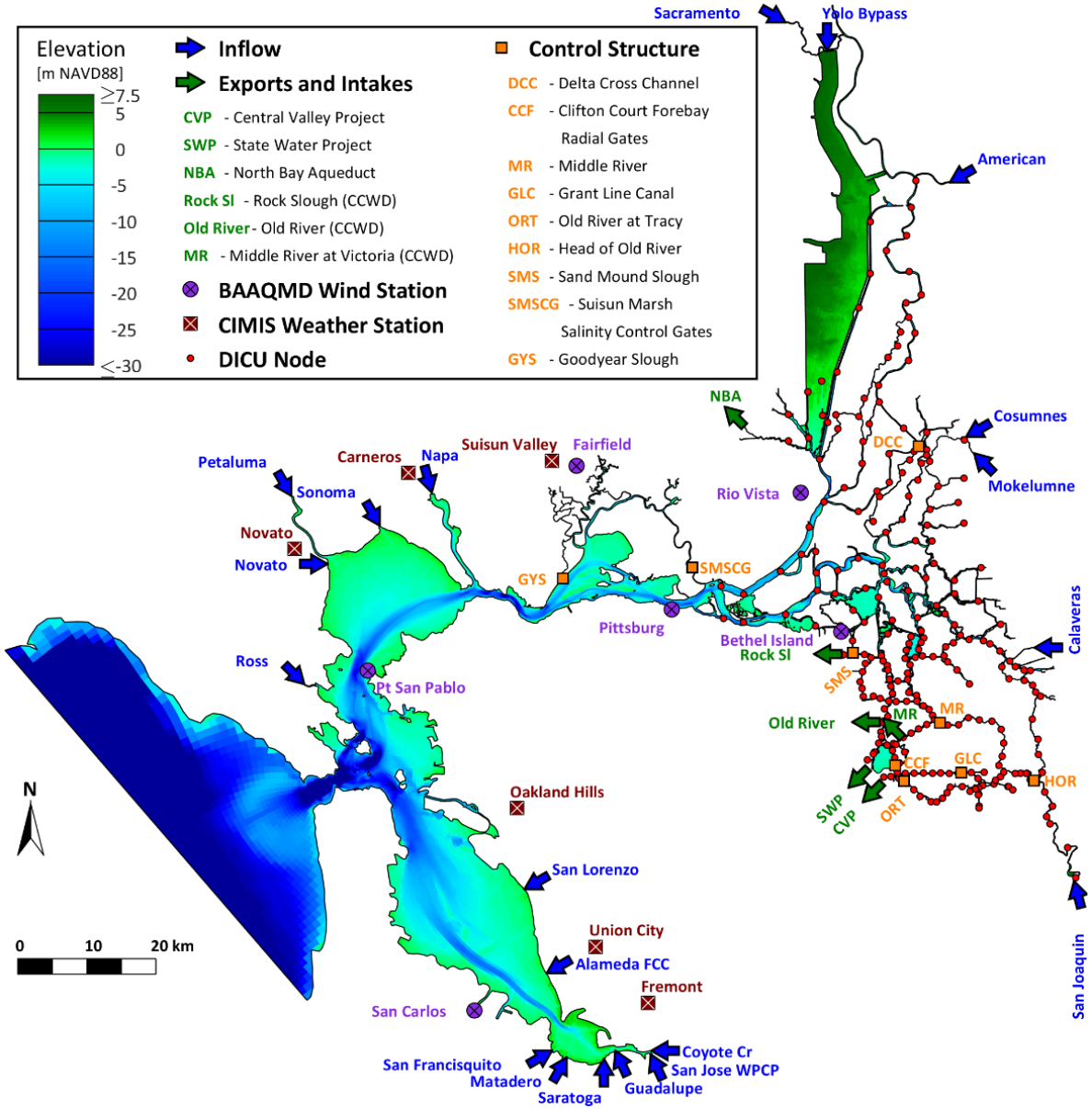
ESA

Focus of the Modeling Study

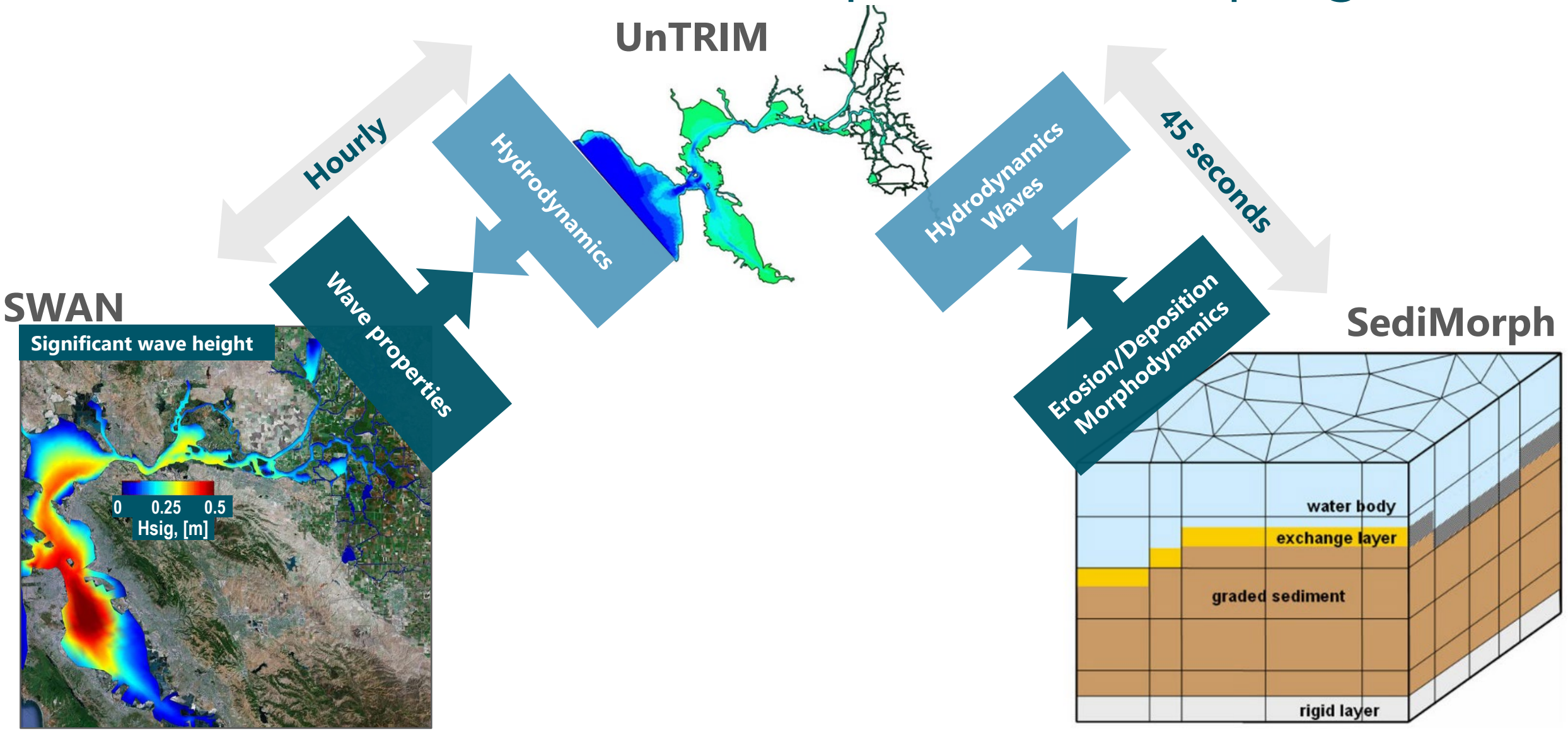
- Goal
  - Evaluate modeled sediment flux through the Golden Gate and compare to USGS data-based estimate of sediment flux
- Approach
  - Simulate hydrodynamics, waves, and sediment transport throughout the Bay-Delta
  - Validate predicted SSC
  - Compare USGS estimated sediment flux to modeled sediment flux and evaluate predicted sediment flux over a 4.5-month simulation period

Hydrodynamic Modeling

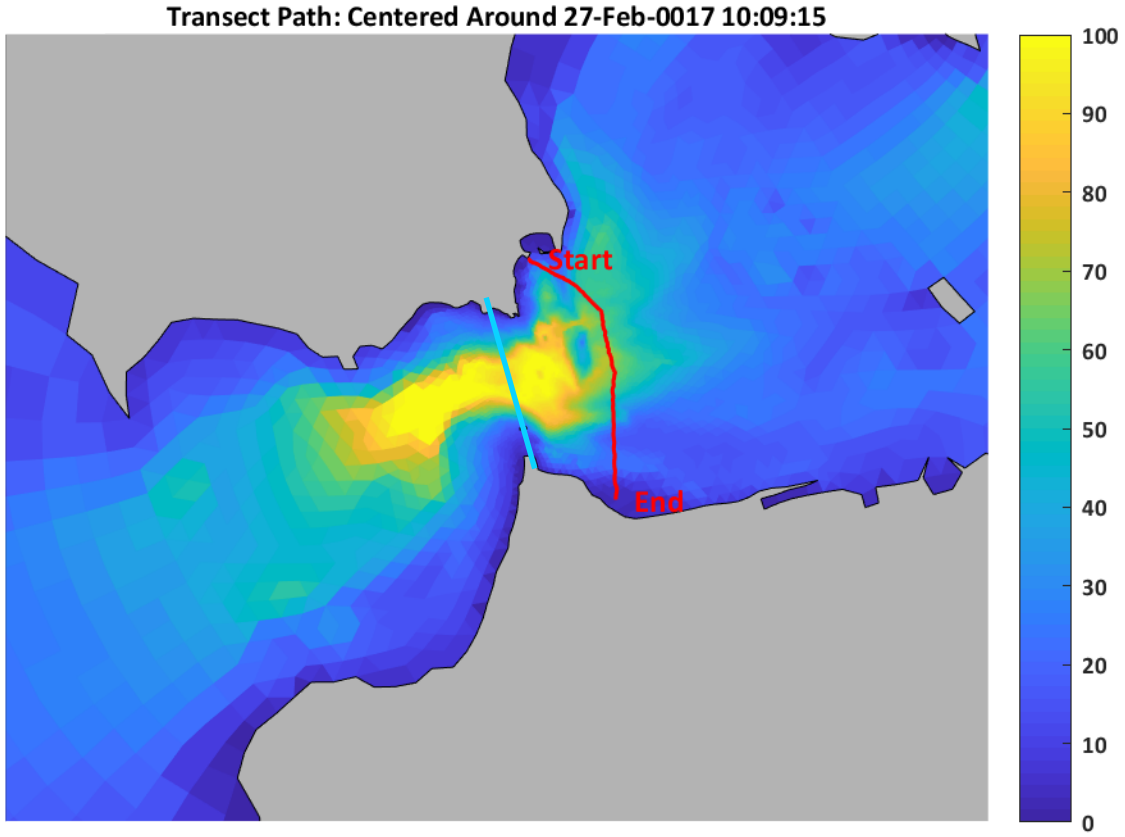
UnTRIM Bay-Delta Model



UnTRIM-SWAN-SediMorph Model Coupling



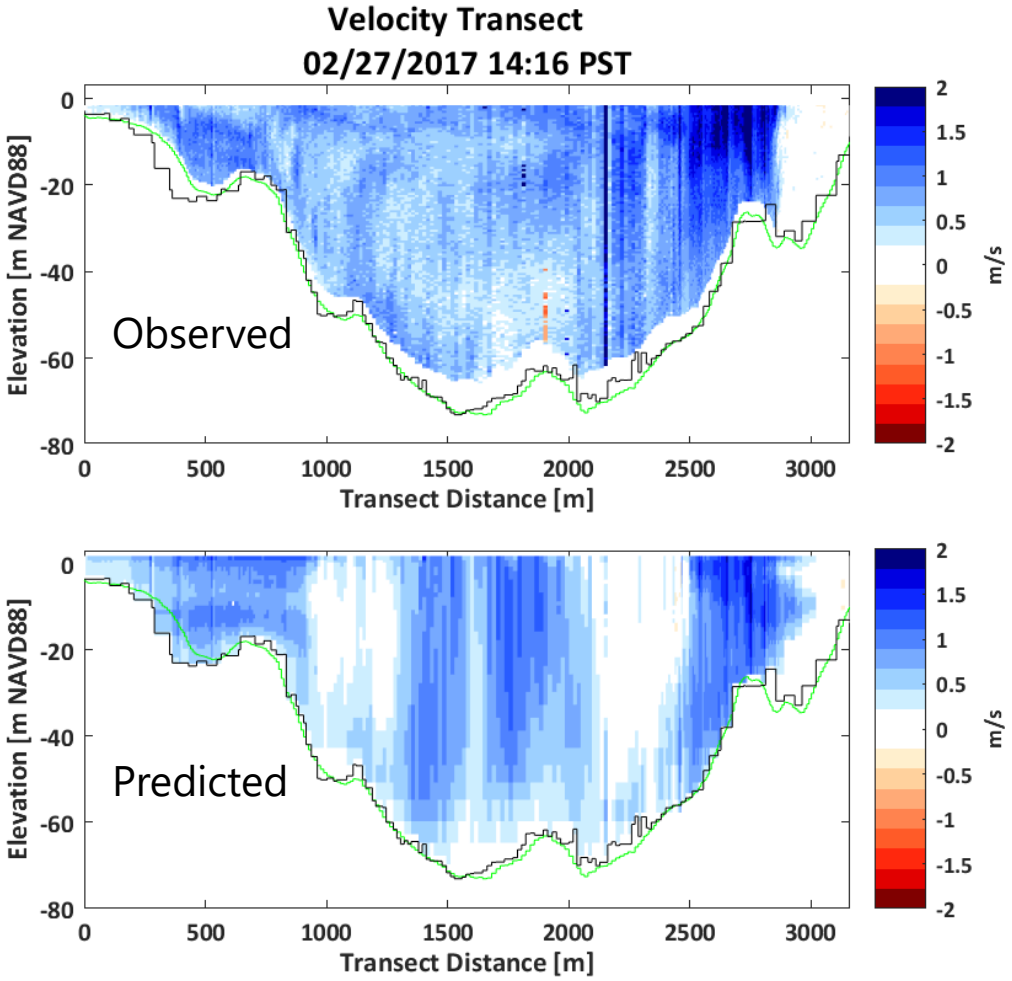
Sediment Flux Calculation

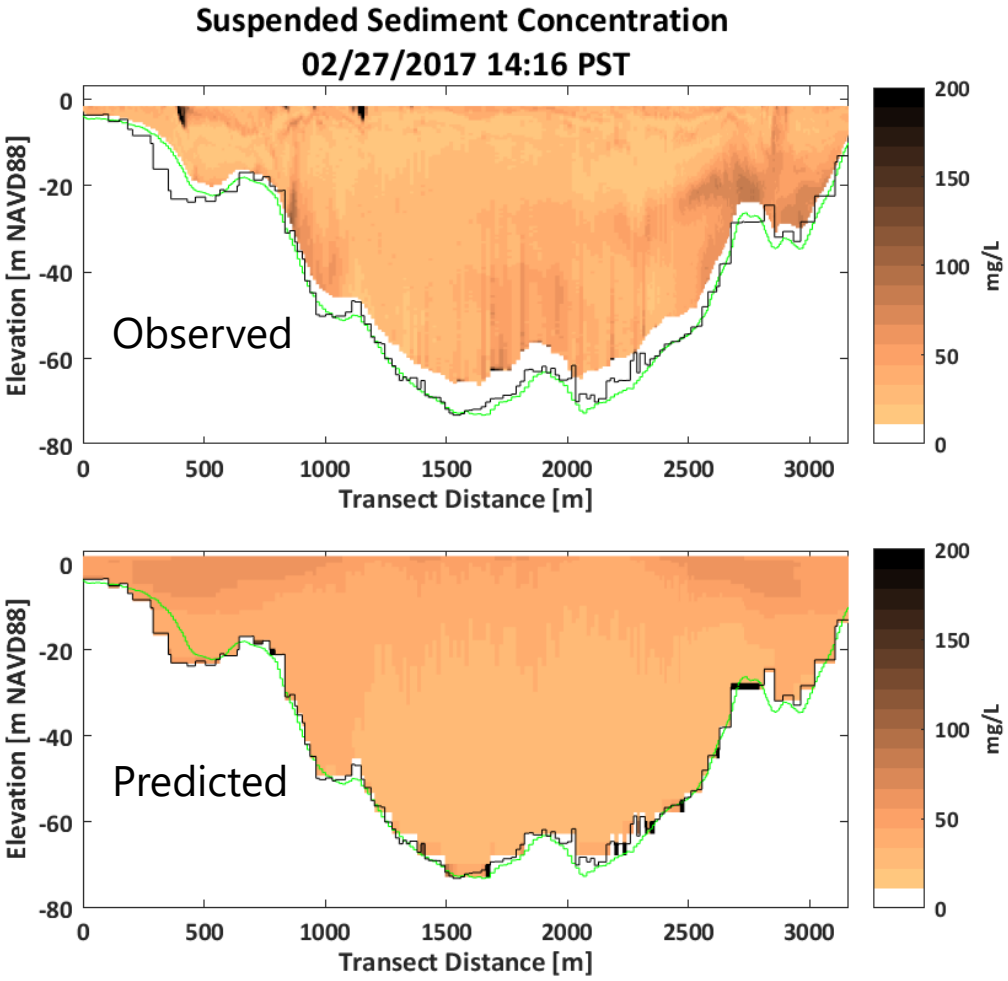


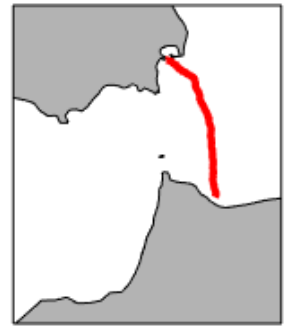
ADCP transect

Modeled cross section

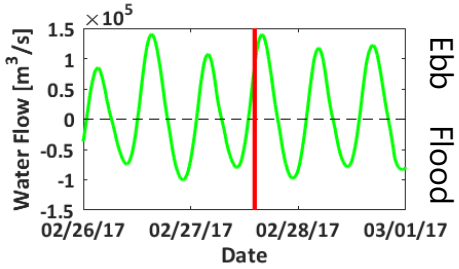
ADCP Transects: Increasing Ebb Flow



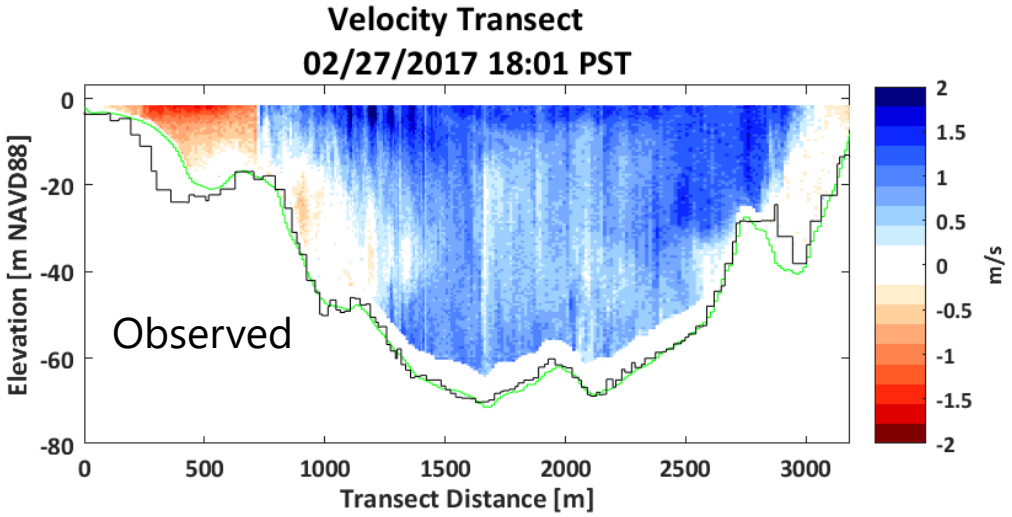


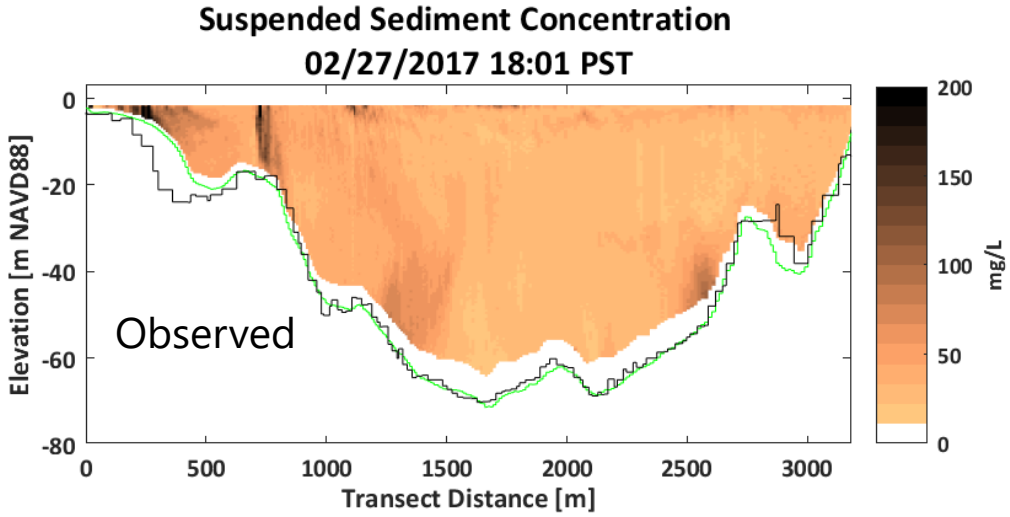


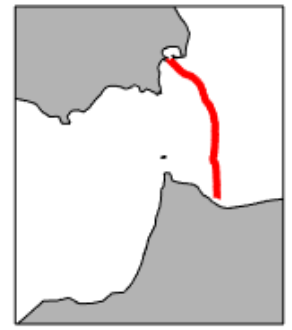
Transect Location

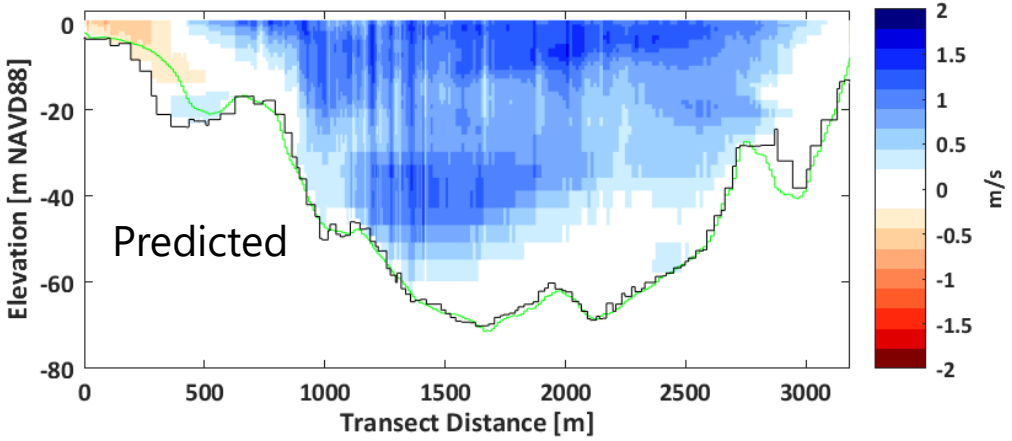


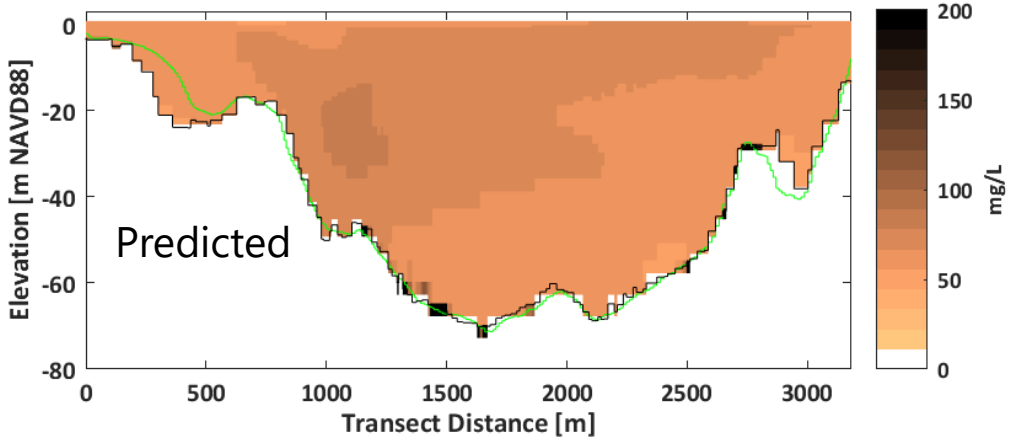
ADCP Transects: Decreasing Ebb Flow

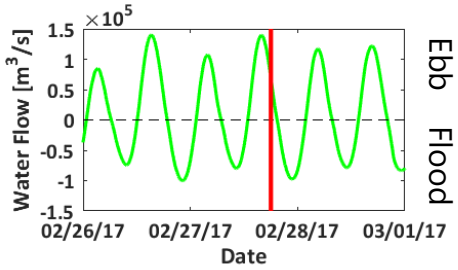




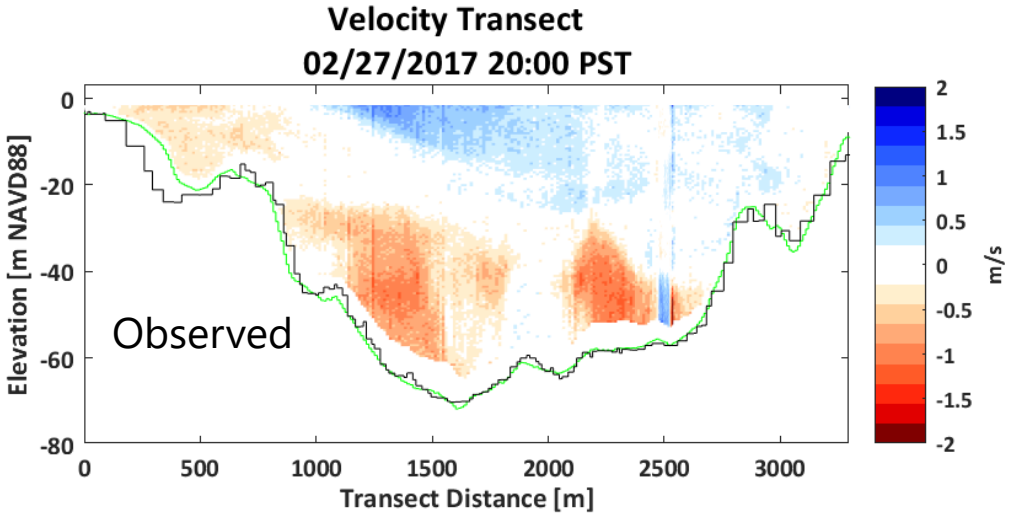


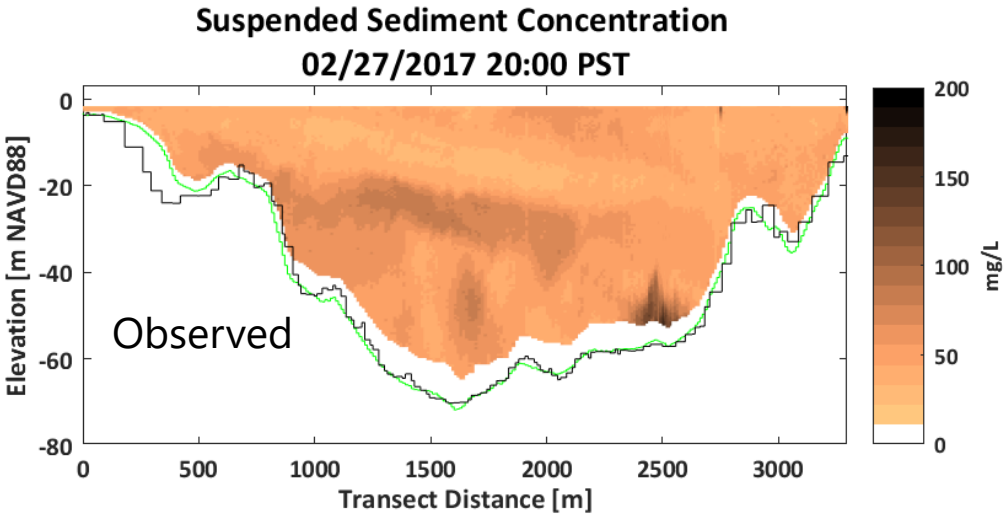


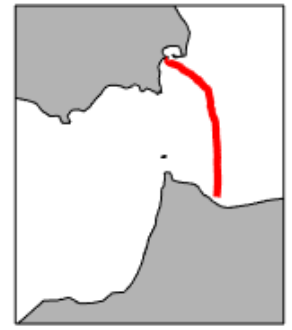


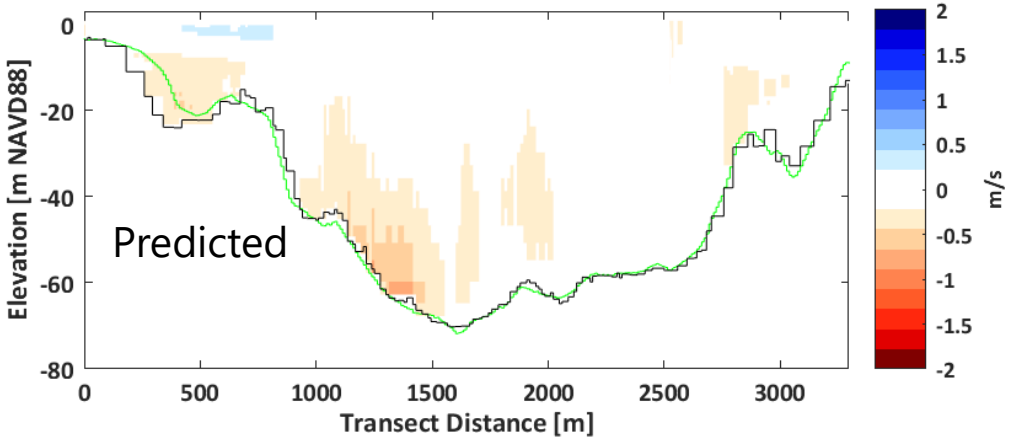


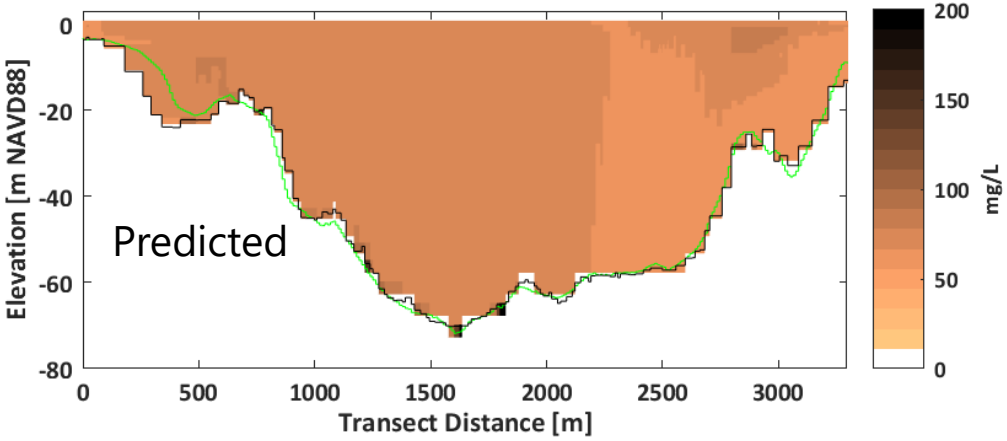
ADCP Transects: Near Slack Before Flood

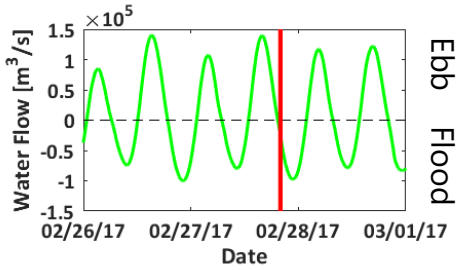




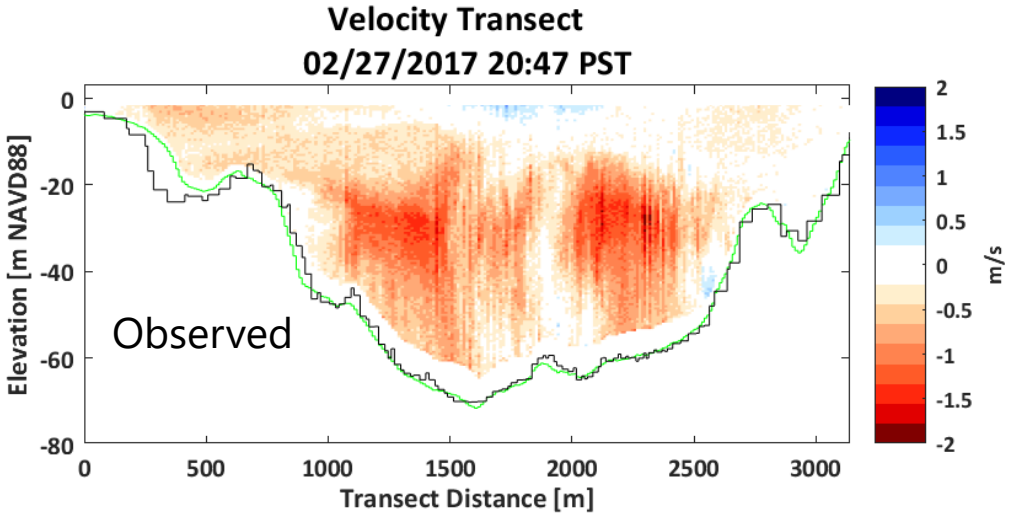


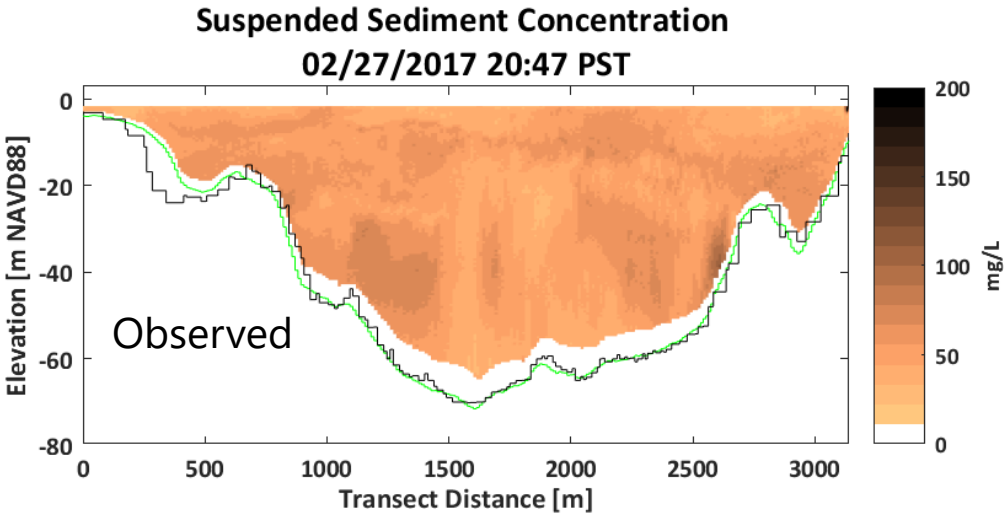


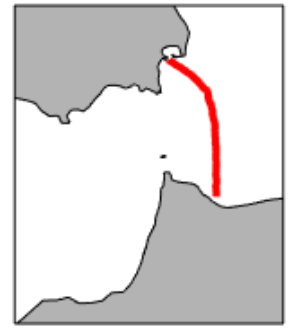


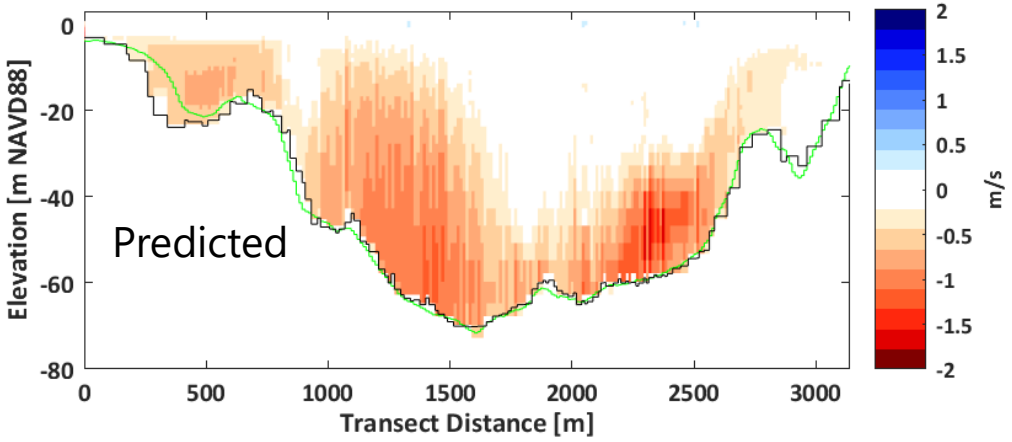


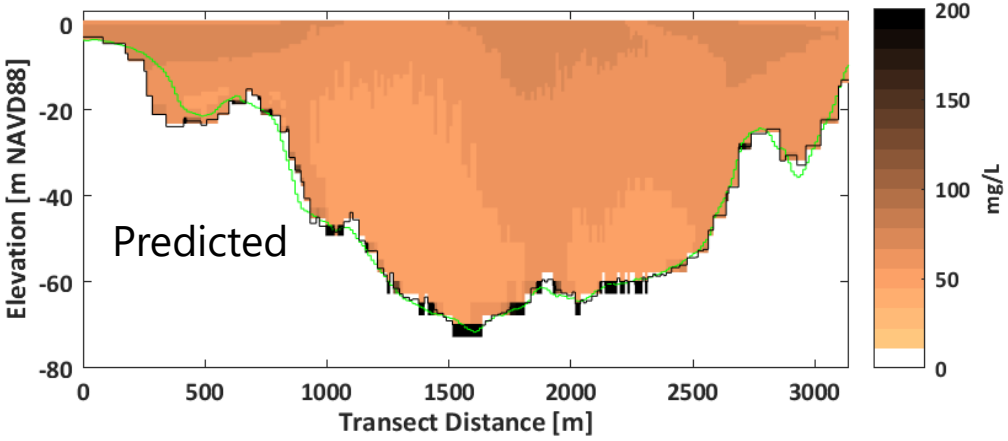
ADCP Transects: Increasing Flood Flow

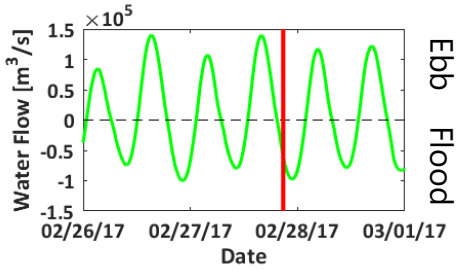






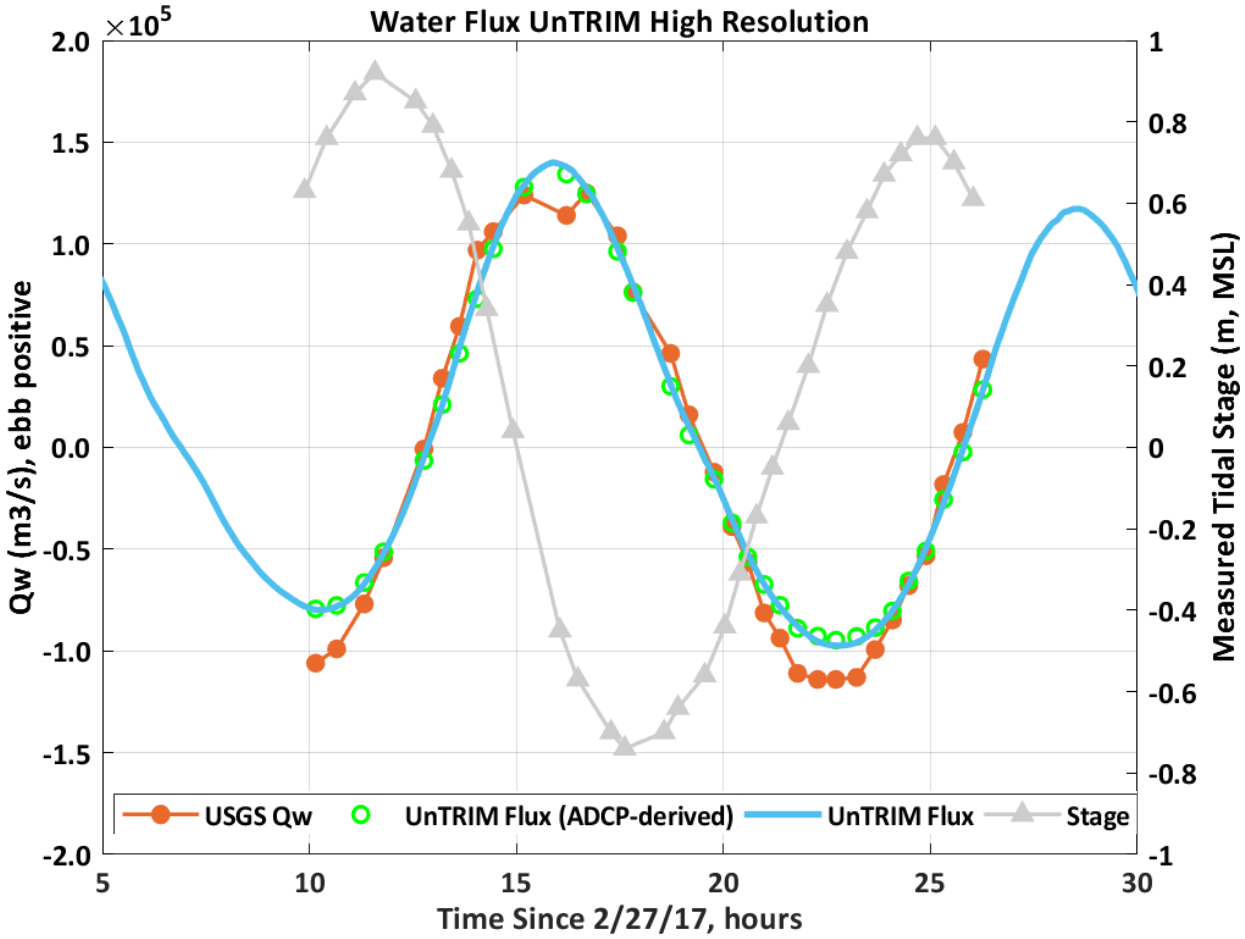






Water Flux Through the Golden Gate

- Measurements and predictions of water flux for 32 transects over 16.5 hours
- Compared to continuous model-predicted water flux at Golden Gate (blue)
- Model predicts slightly larger (+5%) ebb flow and smaller (-13%) flood flow



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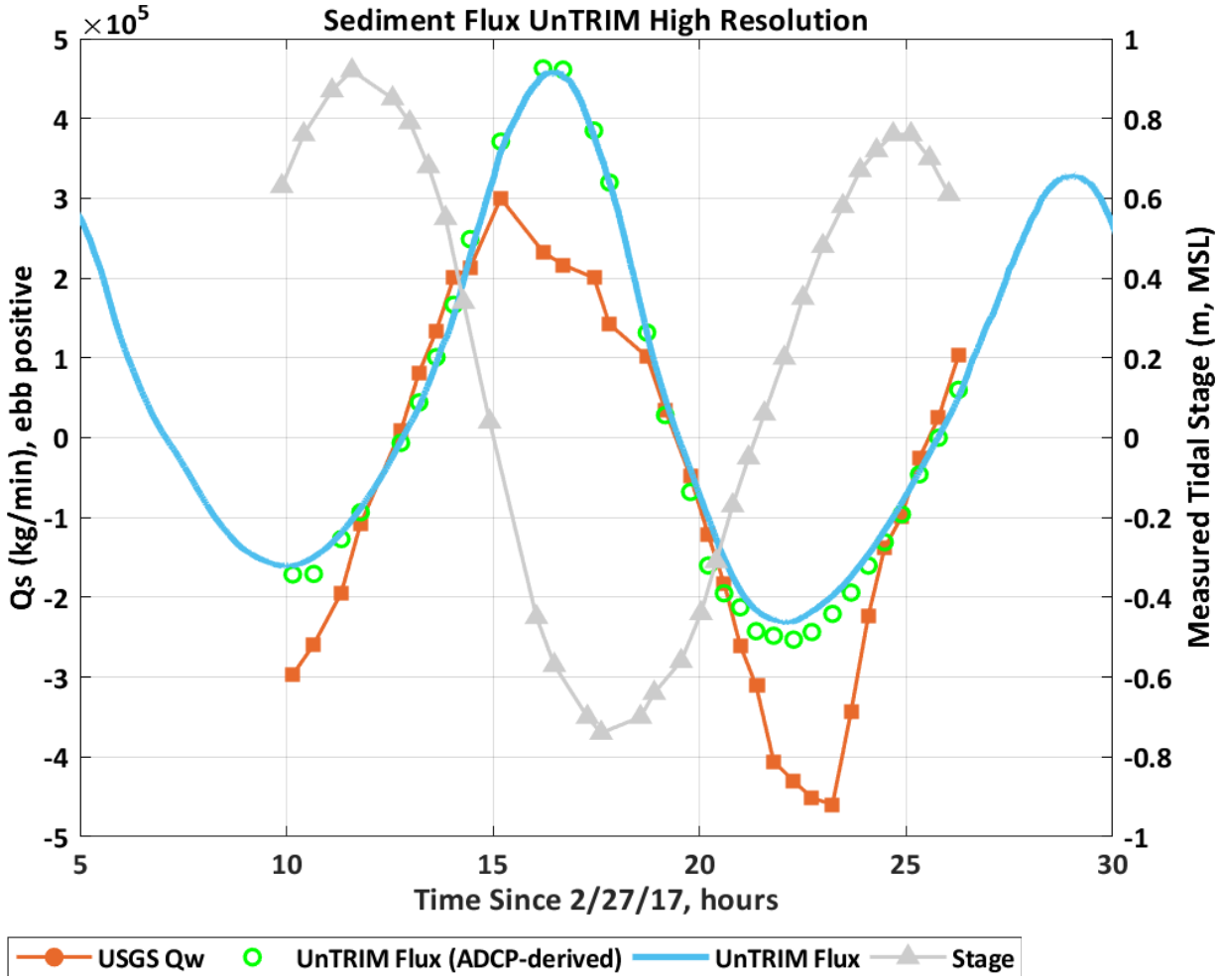
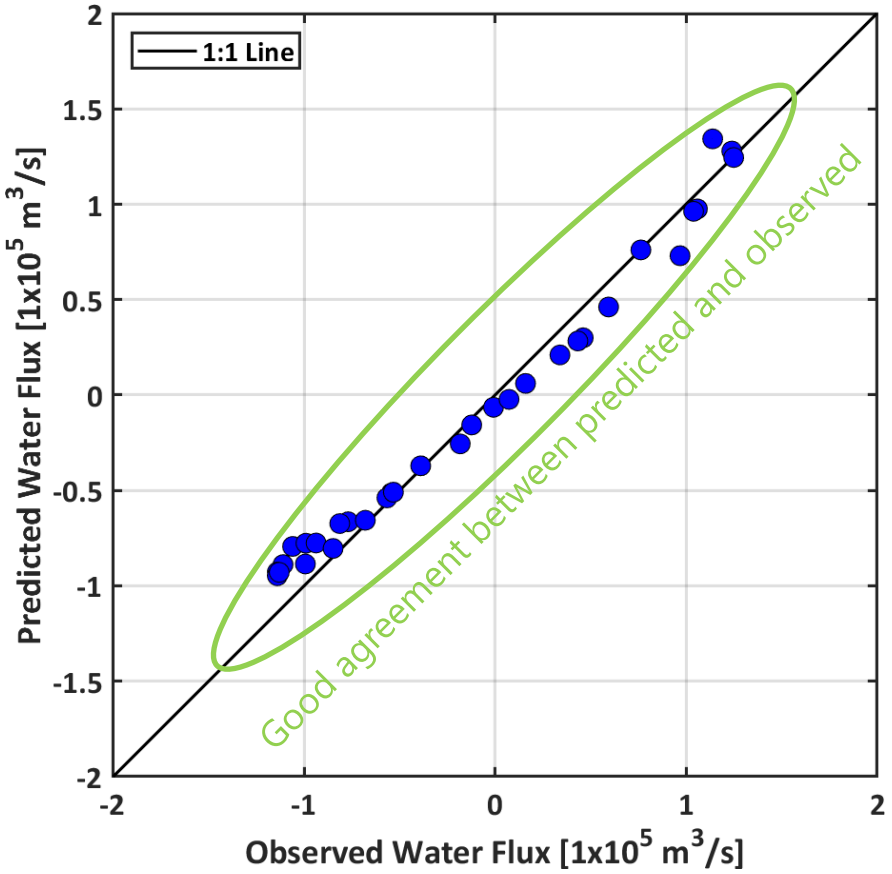
Sediment Flux Through the Golden Gate

- Measurements and predictions of sediment flux for 32 transects over 16.5 hours
- Compared to continuous model-predicted sediment flux at Golden Gate (blue)
- Model predicts larger ebb sediment flux and smaller flood sediment flux than measured

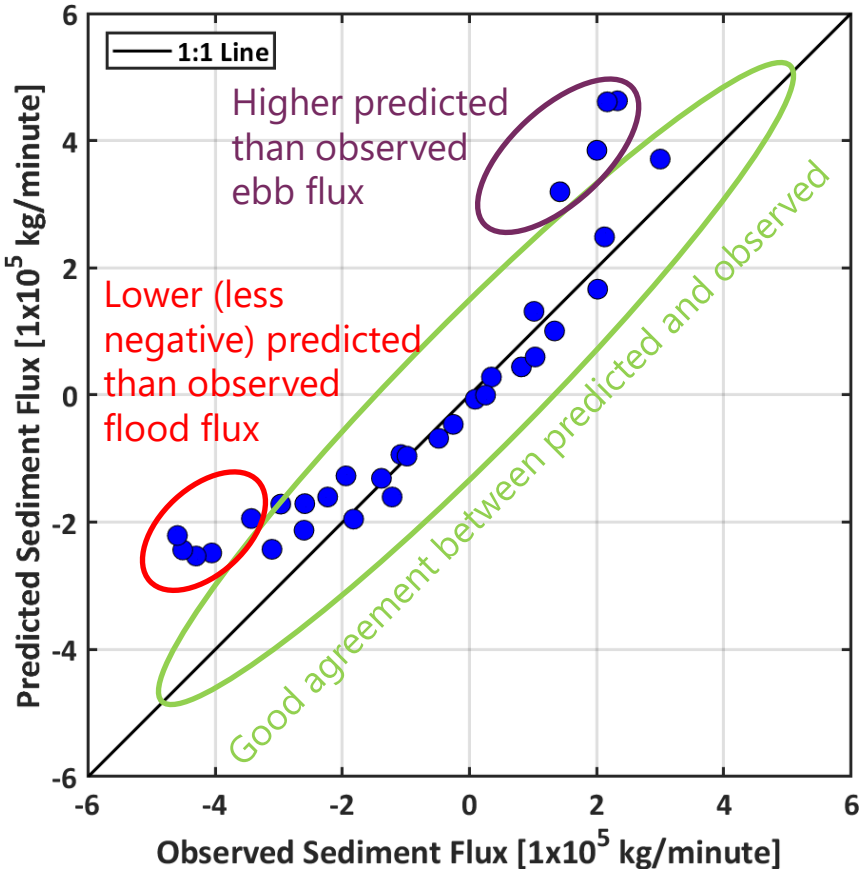


Water and Sediment Flux Through the Golden Gate

Water Flux



Sediment Flux



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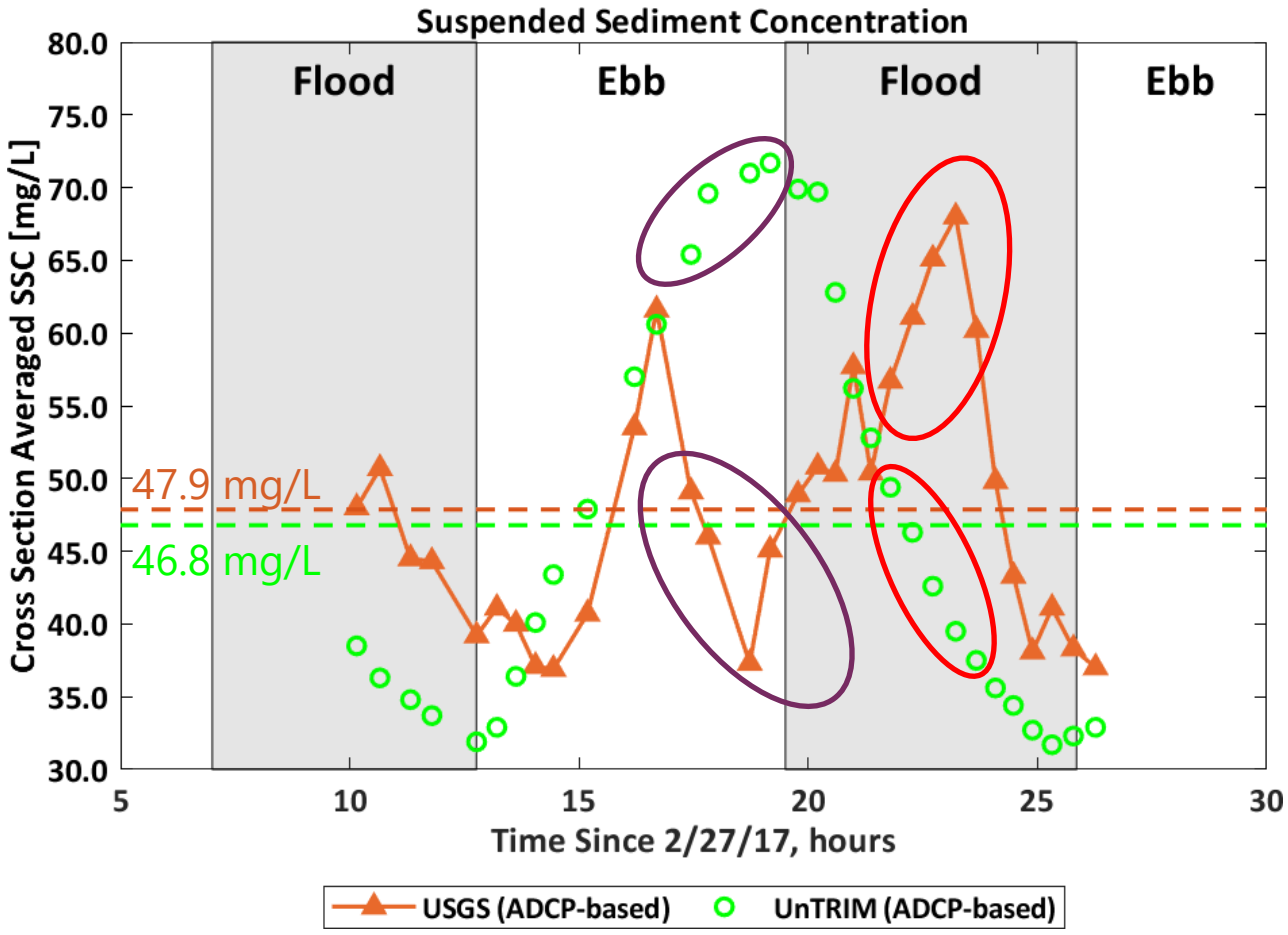
Sediment Flux Through the Golden Gate

- Sediment flux equals flow times concentration
- Model predicts similar average concentration (46.8 mg/L) to measurements (47.9 mg/L) over 32 transects
- Largest difference between modeled and measured sediment flux results from different pattern in average SSC over the tidal cycle



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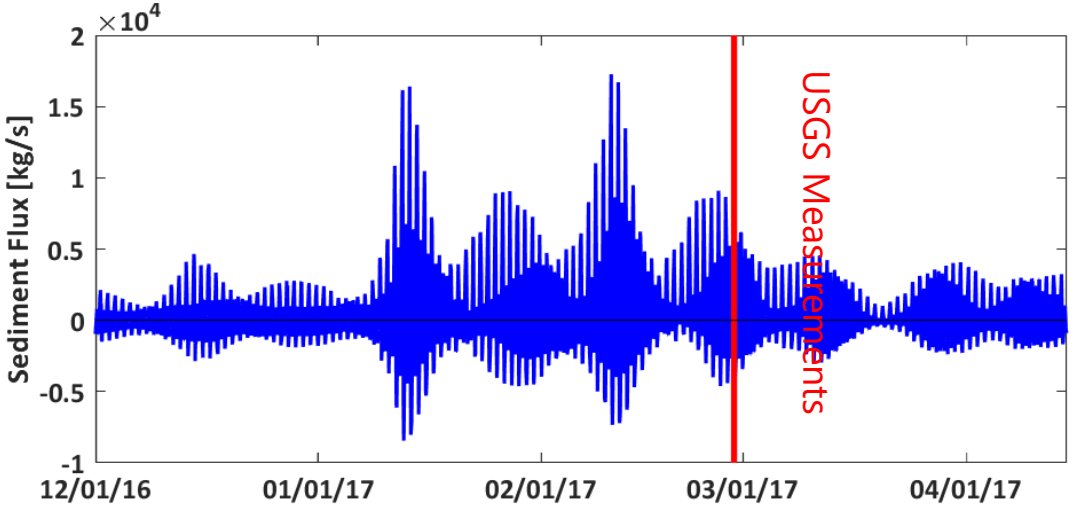
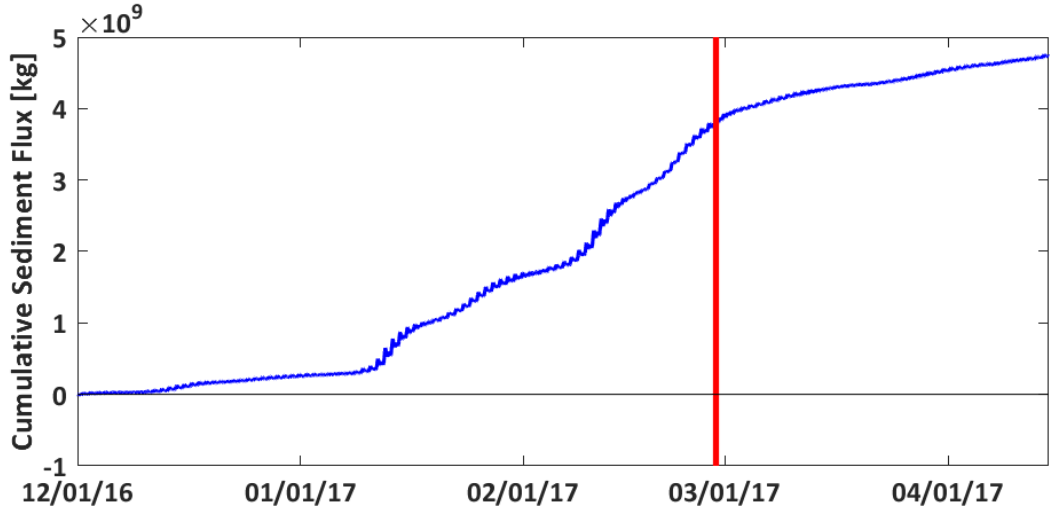
Predicted Sediment Flux at Golden Gate





- Model provides estimate of sediment flux over longer timescales
- USGS measurements provide estimate over partial day (16.5 hours)
- Observations necessary to validate model
- Uncertainty in both observations and model

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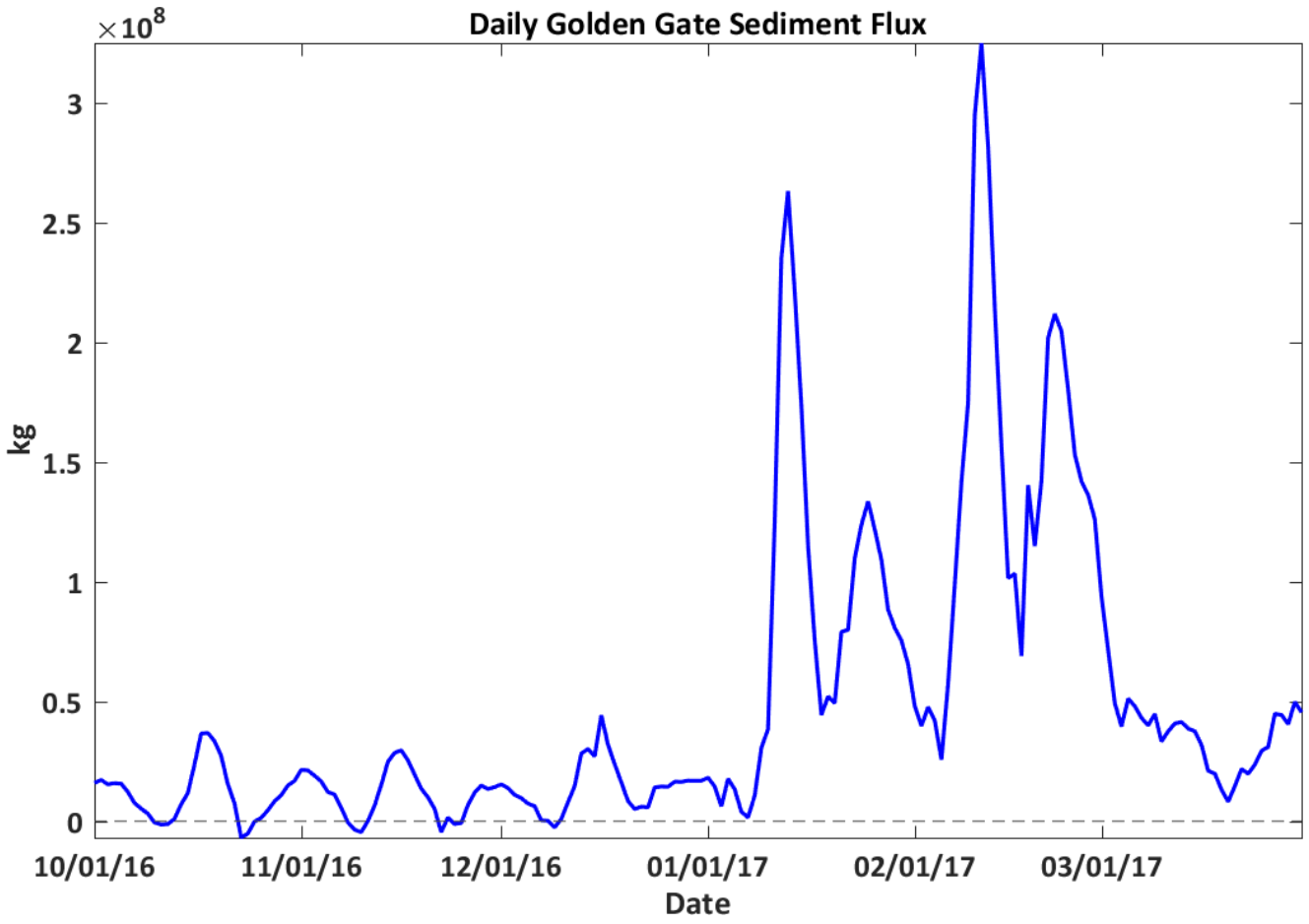
Predicted Daily Sediment Flux at Golden Gate



- Overall goal is to improve estimates of sediment flux at Golden Gate over longer timescales
- Combination of field data collection and modeling can improve our understanding of sediment flux
- Long-term sediment flux estimates are essential for sediment budgets

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What questions do you have?

Please use the chat box.