Jet Propulsion Laboratory
California Institute of Technology

Delta-X

Introduction to Delta-X Sediment Transport Module (Matlab)

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& Delta-X Project Team

Delta-X Applications Workshop, Baton Rouge, LA
May 8-9, 2024

Caltech

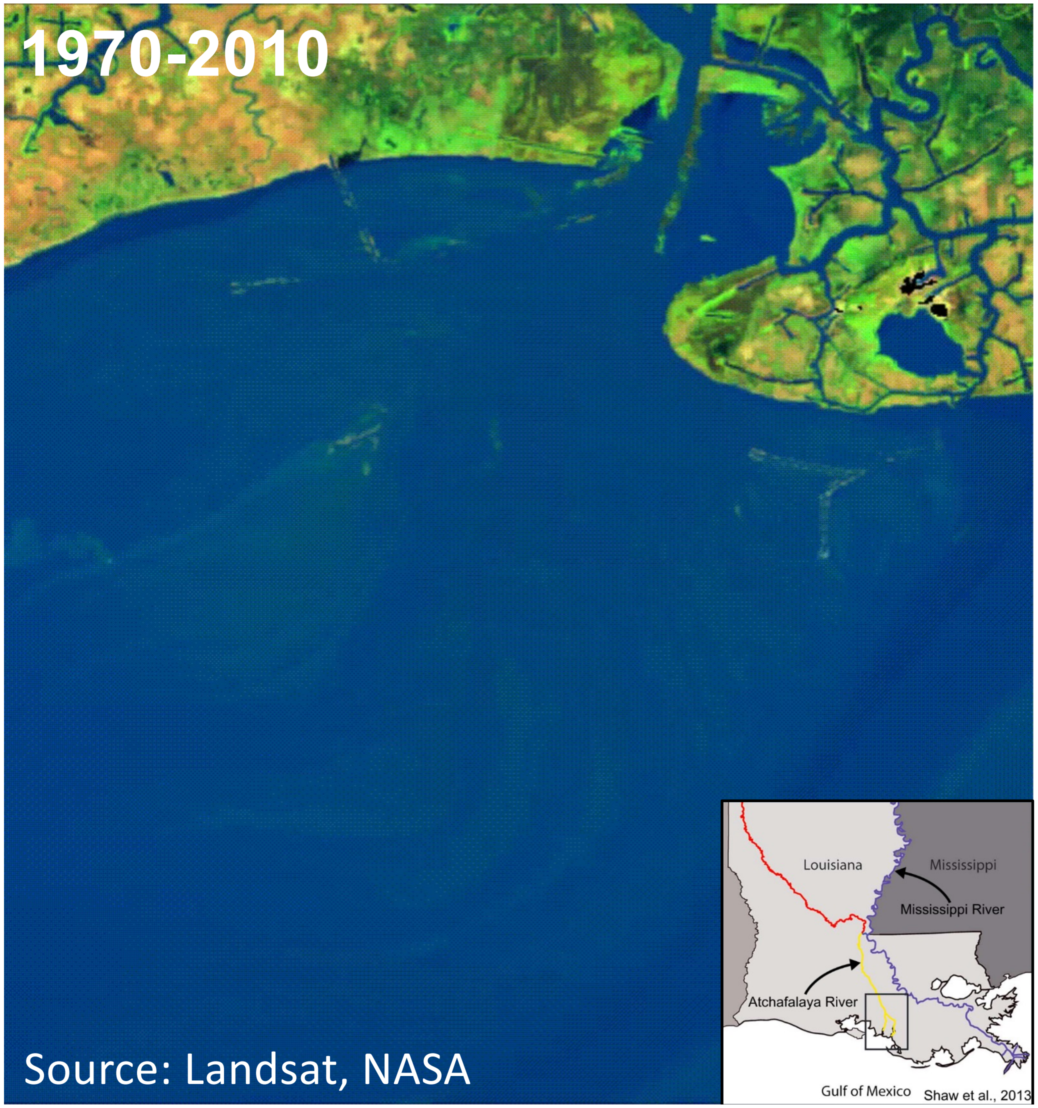
Agenda

- Background
- Implemented sediment transport theory and upscale strategy to estimate 1-yr land accretion rate
- Basic structure of the Sediment Transport Module

Hands-on

- Download the source code
- Prepare for model run (Preprocessing)
- Running an example case
- Post-processing of the model results
- Modifying the model parameters

- Q&A



Wax Lake Delta offers insight on delta growth

- Wax Lake Delta is one of the most actively growing delta in the world
- This is one of the few places that recorded net land growth in the past decades along the Lousiana coast
- Prediction the delta evolution requires accurate theory to describe sediment transport in this region

Sediment transport module

Governing equations | **Solved physical processes**

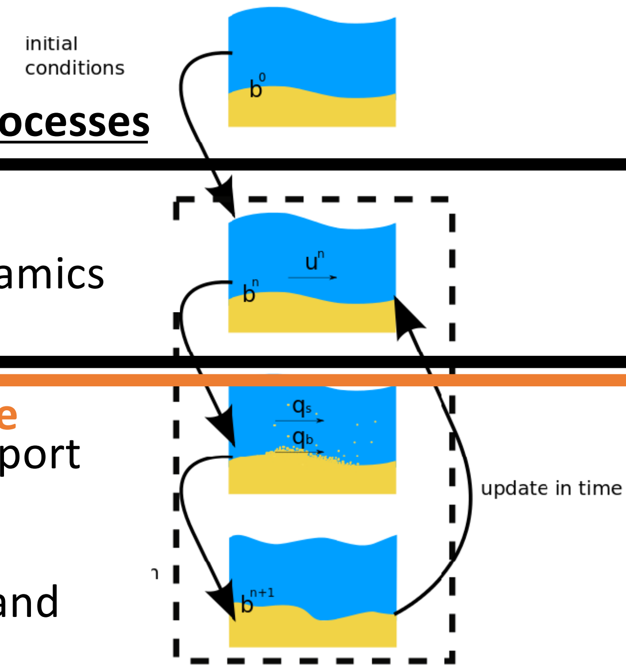
ANUGA Hydrodynamics model

Shallow water eqn. ⟺ Flow hydrodynamics

Matlab sediment transport module

Transport eqn. ⟺ Sediment transport

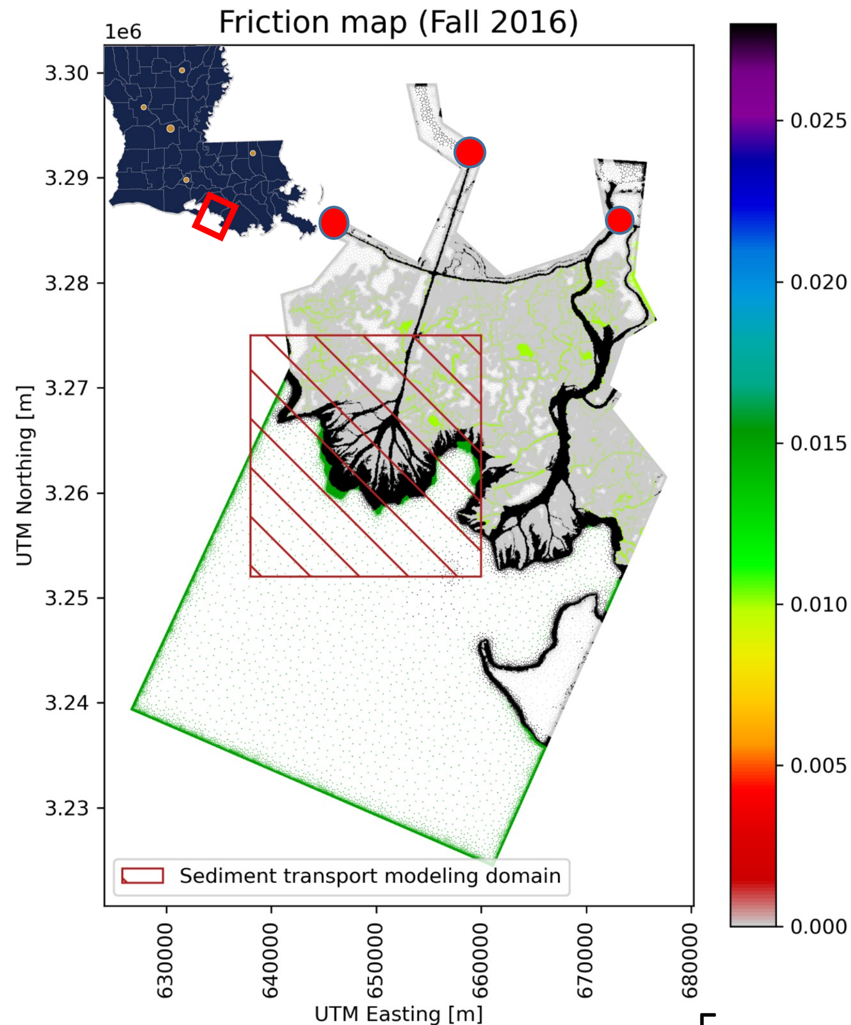
Exner eqn. ⟺ Bed evolution and stratigraphic



Source: Telemac manual

Hydrodynamics Model

- ANUGA hydrodynamics simulation results
  - $x, y, h, \eta, u, v, uh, vh, H, Chezy$ and n for every 15 min
- ANUGA Boundary conditions
  - Stage BC: NOAA (8764227), LAWMA at Amerada Pass
  - Discharge BC:
    - USGS (07381670) GIWW at Bayou Sale Ridge near Franklin
    - USGS (07381590) Wax Lake Outlet at Calumet
    - USGS (07381600) Lower Atchafalaya River at Morgan City



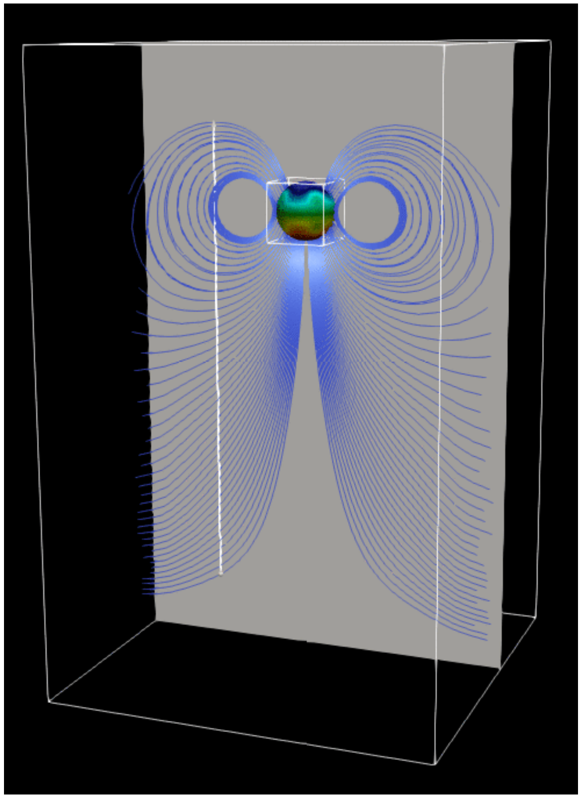
How are mud particles transported?

There are three hypothesis:

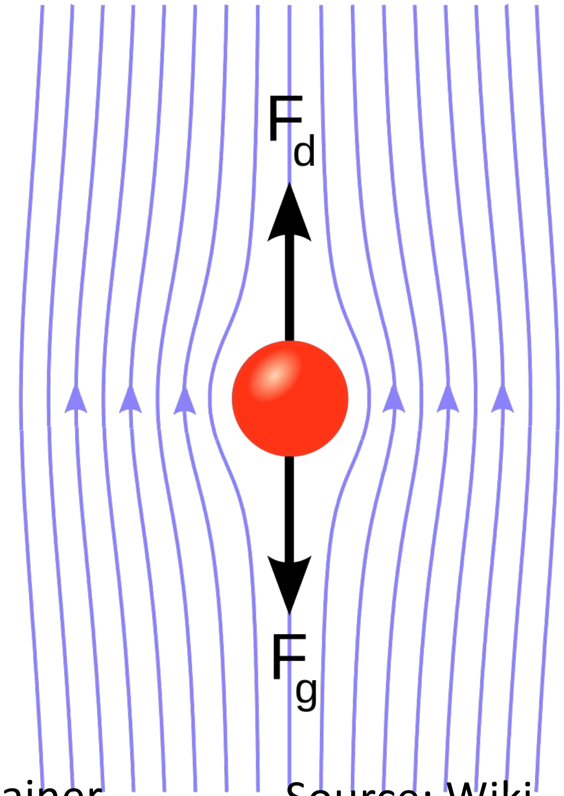
- Flocculated particles
- Individual grains
- Washload hypothesis

→ **What is particle settling velocity?**

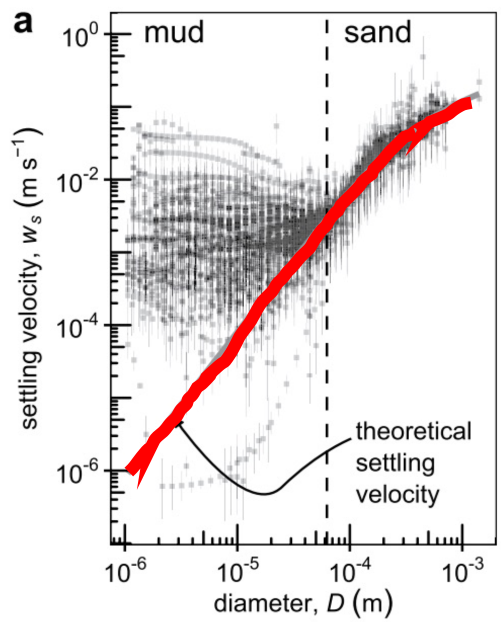
The particle settling velocity and the Stokes' law



Particle settles in a finite volume container



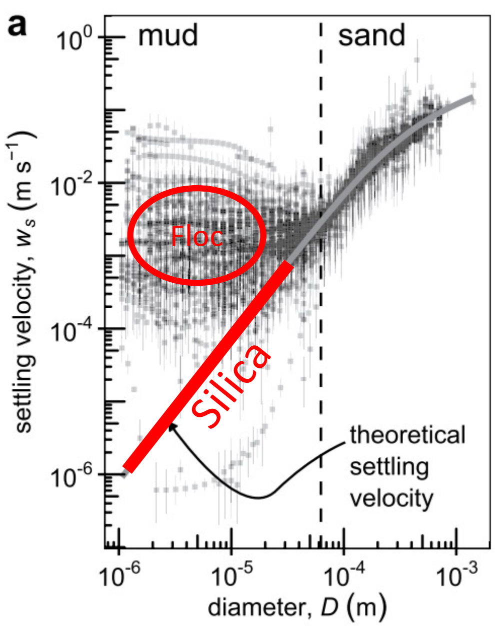
Source: Wiki



Nghiem et. al. (2022)

Mud particle settles much faster than Stokes' law predicted due to flocculation

- At Wax Lake Delta, 90% of the suspended sediment is mud (particle diameter < 62.5 microns)!



Nghiem et. al. (2022)

Credit: Dr. K. Miller

Implemented suspended sediment transport theory

$$(1-\lambda)\frac{\partial \eta}{\partial t} = \sum_i (D_i - f_i E_i)\,, \qquad \frac{Dhc_i}{Dt} = \nabla \cdot (h\nu_t \nabla c_i) - (D_i - f_i E_i)$$

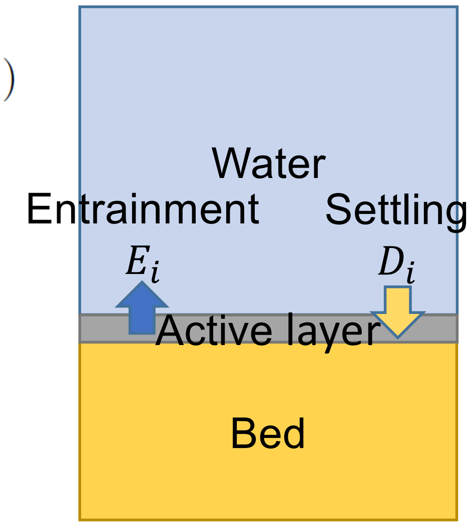
Where η is bed elevation; c_i is suspended sediment concentration; f_i the bed fraction, and

$$E_i = w_{si}\, f\left(\frac{u_*}{w_{si}}, Fr, \ldots\right)$$ the entrainment flux

e.g., $E_i = A\, w_{si} \left(\frac{u_*}{w_{si}}\right)^{\alpha} Fr^{\beta}$ where A, α, β are constants. (De Leeuw et al., 2020)

$$D_i = w_{si} c_{bi}$$ the settling flux

Here w_{si} is class-specific sediment particle settling velocity; u_* is shear velocity, c_{bi} is near-bed sediment concentration.

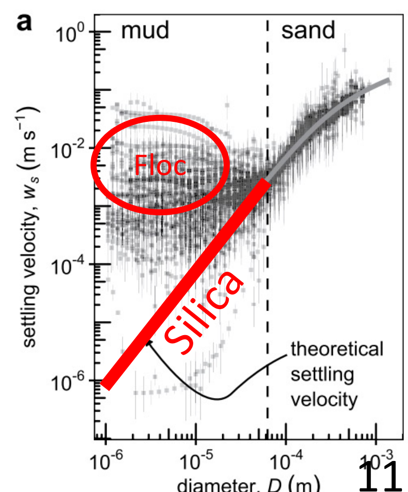


Objectives

- Build a sediment transport model to capture sediment transport pattern of Wax Lake Delta
- Test different mud transport hypothesis on delta land evolution model
- Develop an upscale strategy to estimate 1-yr land accretion rate at Wax Lake Delta

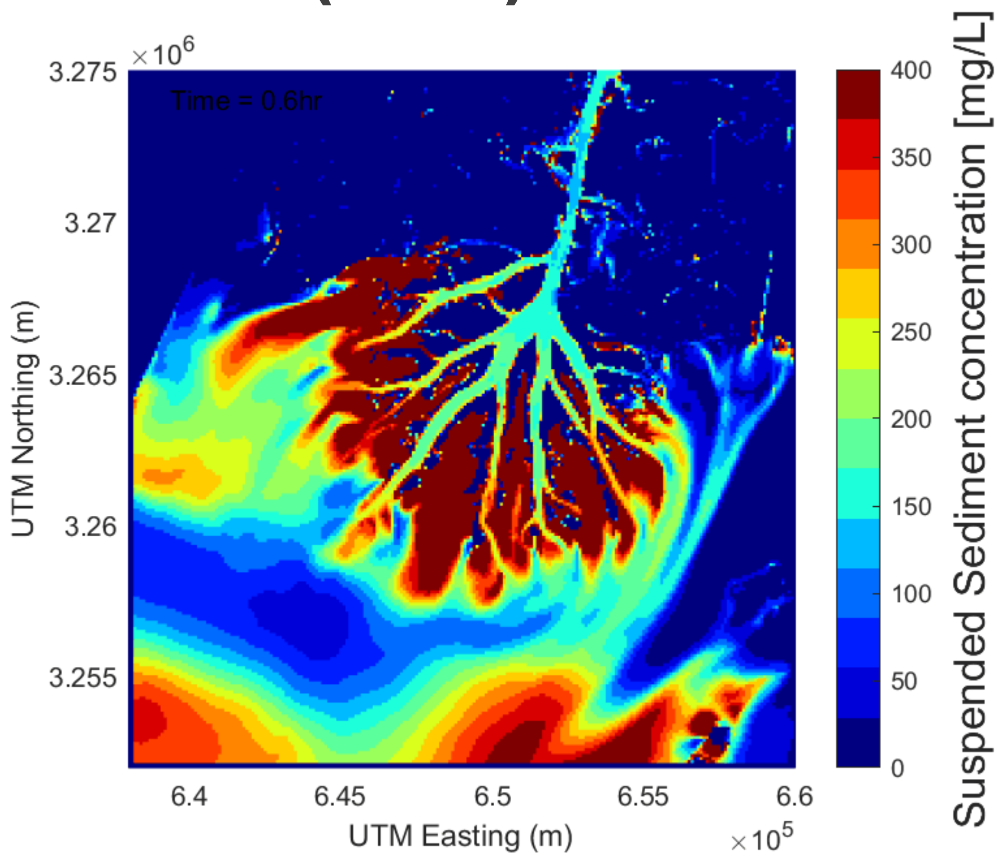
Implement the mud settling velocity predicted using different hypothesis

- **Case 1:** Effective floc settling velocity – allow fast settling of mud
- **Case 2:** Stokes settling velocity – allow slow settling of mud
- **Case 3:** Classic cohesive theory (Washload) – no settling of mud in erosional environment; no erosion in settling environment



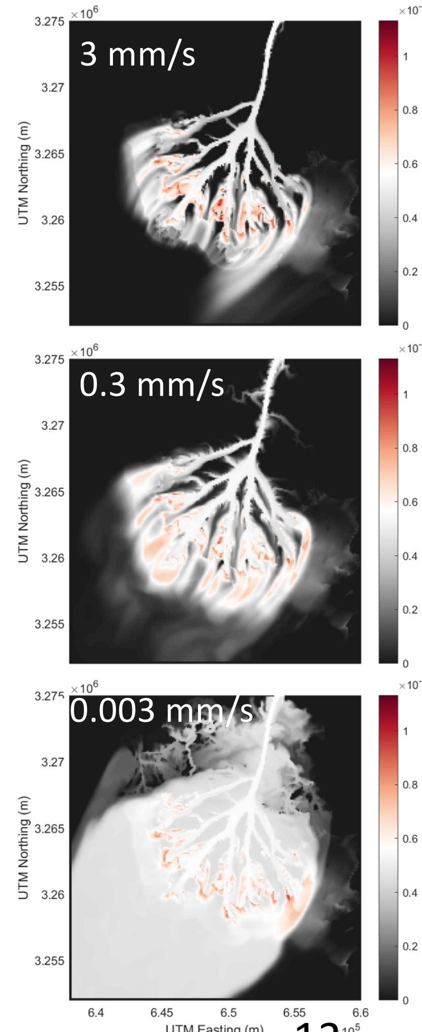
Nghiem et. al. (2022)

Modeled total suspended sediment concentration (TSS)



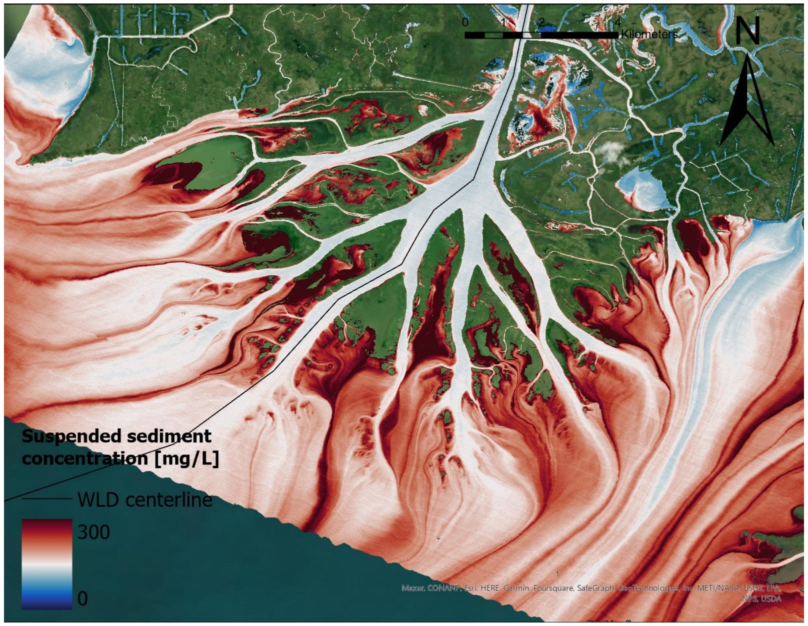
Model results validation against AVIRIS-NG L3 TSS product

AVIRIS, 04/01/2021



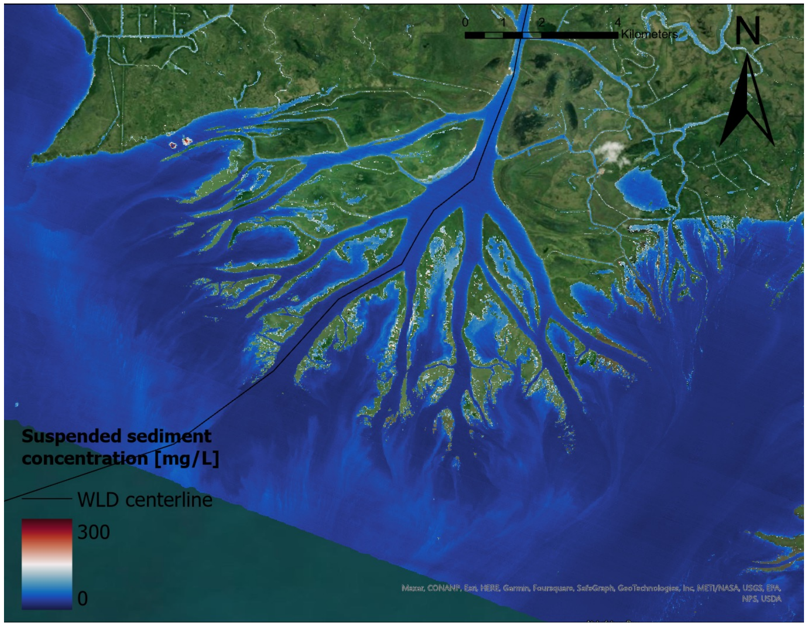
Modeled Delta-X campaigns

Spring 2021 campaign



AVIRIS-NG Derived TSS, 04/01/2021

Fall 2021 campaign

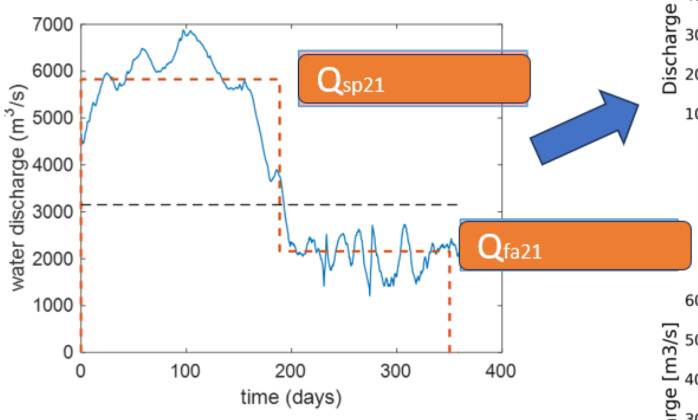


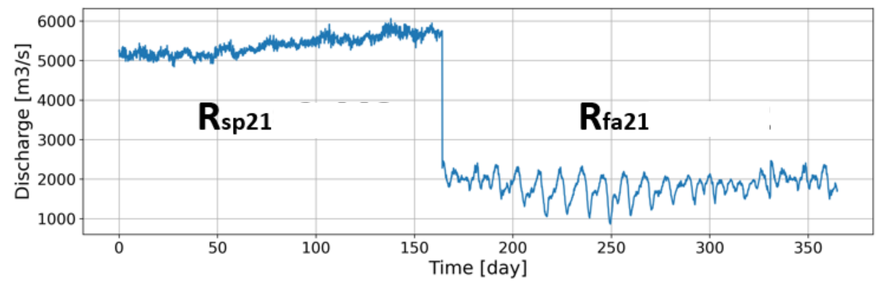
AVIRIS-NG Derived TSS, 08/2/2021

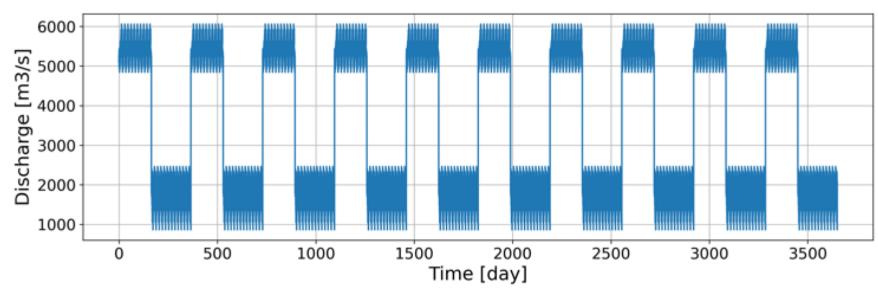
Future flow and sediment conditions? The synthetic time-series method

Use calibrated high-flow event (Spring 2021, SP21) and low-flow event (Fall 2021, FA2) to represent the full time series

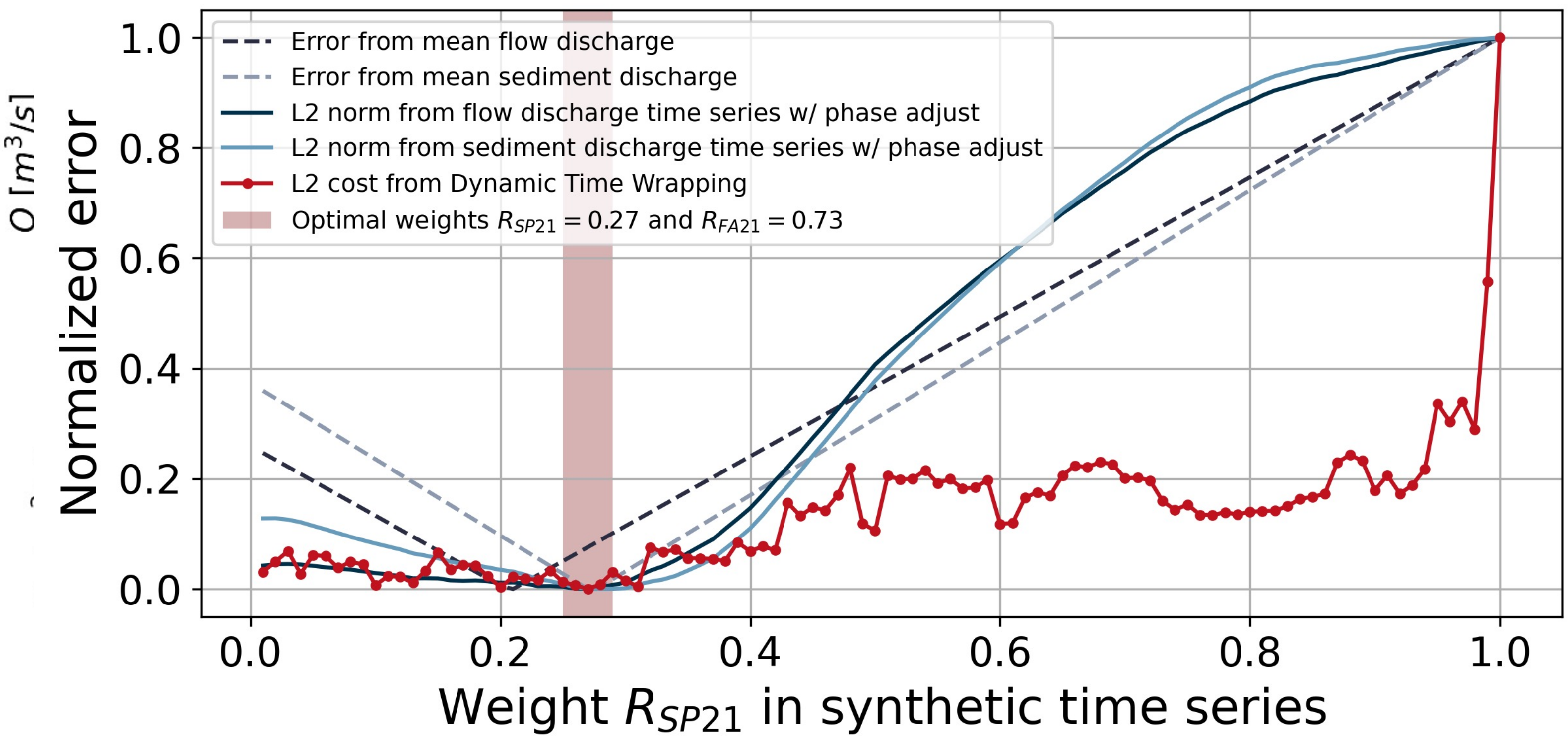
$$Q = R_{FA21} Q_{FA21} + R_{SP21} Q_{SP21}$$
$$Q_s = R_{FA21} Q_{s,FA21} + R_{SP21} Q_{s,SP21}$$



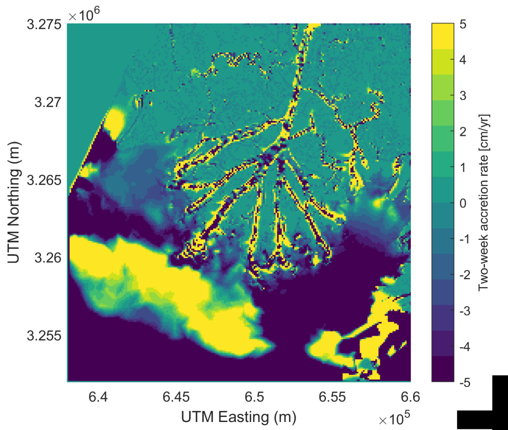




Future flow and sediment conditions? The synthetic time-series method

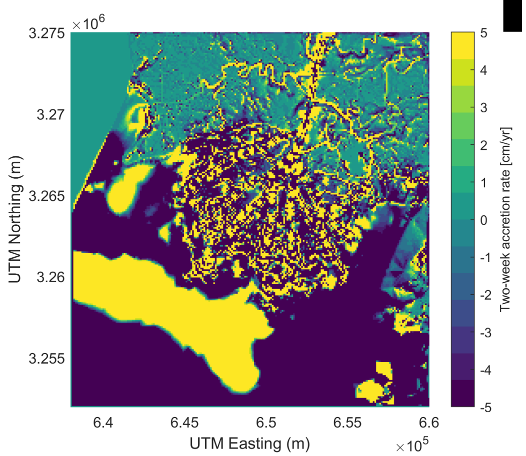


1-yr land accretion estimation



*0.73

+



*0.27

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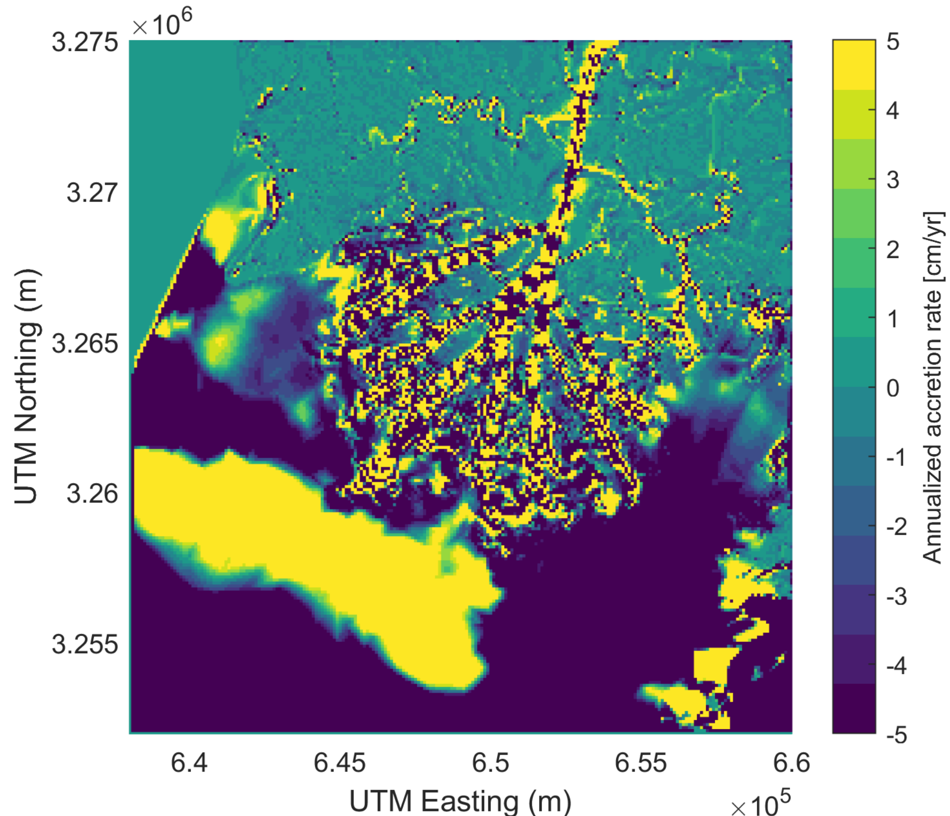
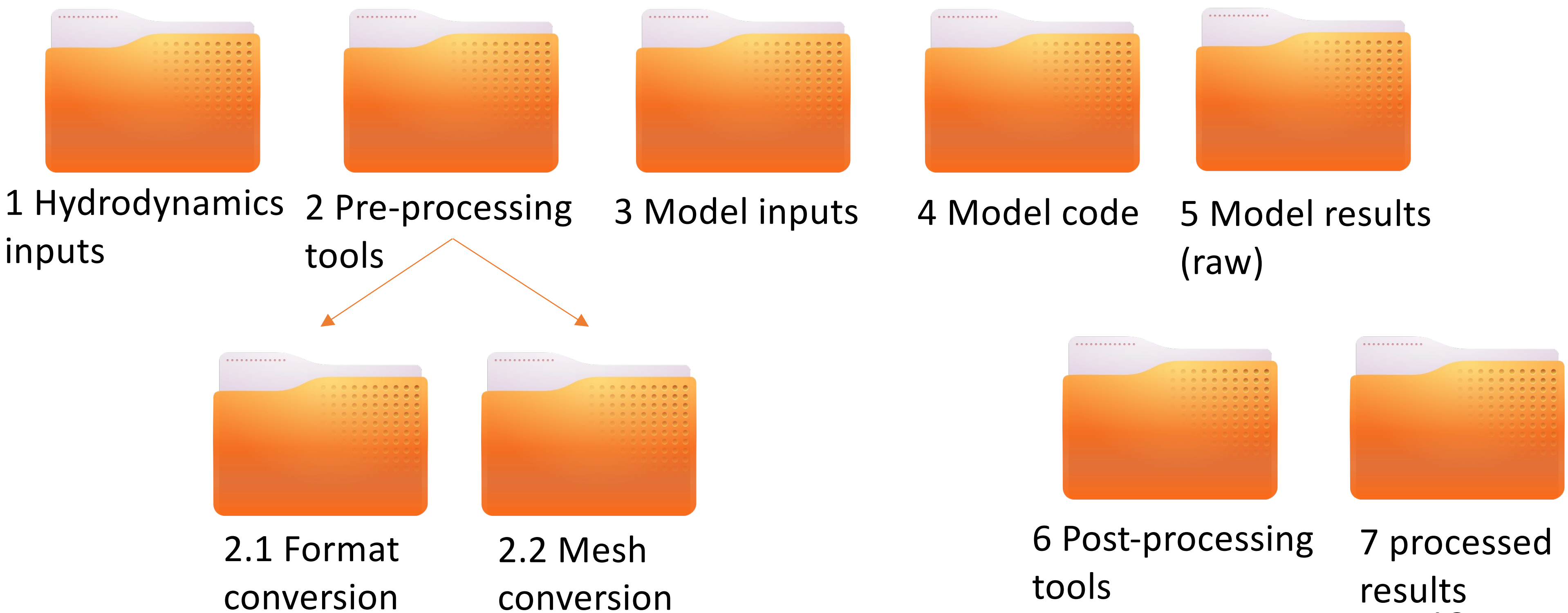


Structure of the Sediment transport module



Hands-on session

Download the Sediment Transport module source code

Wang, D., G. Salter, and M.P. Lamb. 2023. Delta-X: Matlab Model for Wax Lake Delta Land Accretion. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/2309

Data File (Granule)	Size
sediment_transport_land_accr...model_code_Wax_Lake_Delta.zip	1.8 MB

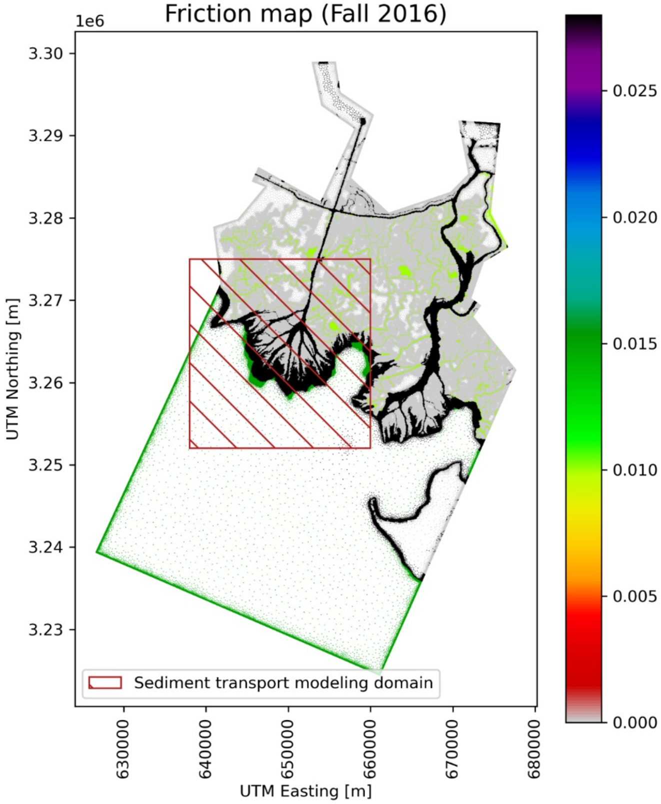
1 Hydrodynamics inputs

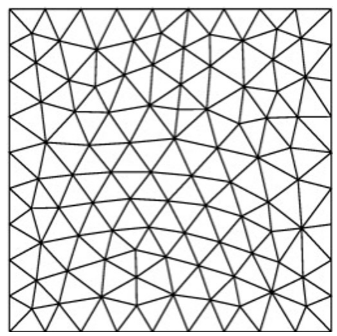
Wright, K.A., and P. Passalacqua. 2024. Delta-X: Calibrated ANUGA Hydrodynamic Outputs for the Atchafalaya Basin, MRD, LA. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/2306

Data File (Granule)	Size	Start Date	End Date	N Lat	S Lat	E Lon	W Lon
Hydro_WLAD_20161015_PDX.nc	2.6 GB	2016-10-15	2016-10-15	29.54	29.14	-88.30	-88.65
Hydro_WLAD_20161016_PDX.nc	2.5 GB	2016-10-16	2016-10-16	29.54	29.14	-88.30	-88.65
Hydro_WLAD_20161017_PDX.nc	2.5 GB	2016-10-17	2016-10-17	29.54	29.14	-88.30	-88.65
Hydro_WLAD_20161018_PDX.nc	2.6 GB	2016-10-18	2016-10-18	29.54	29.14	-88.30	-88.65

2 Pre-processing tools
Mesh and format conversion

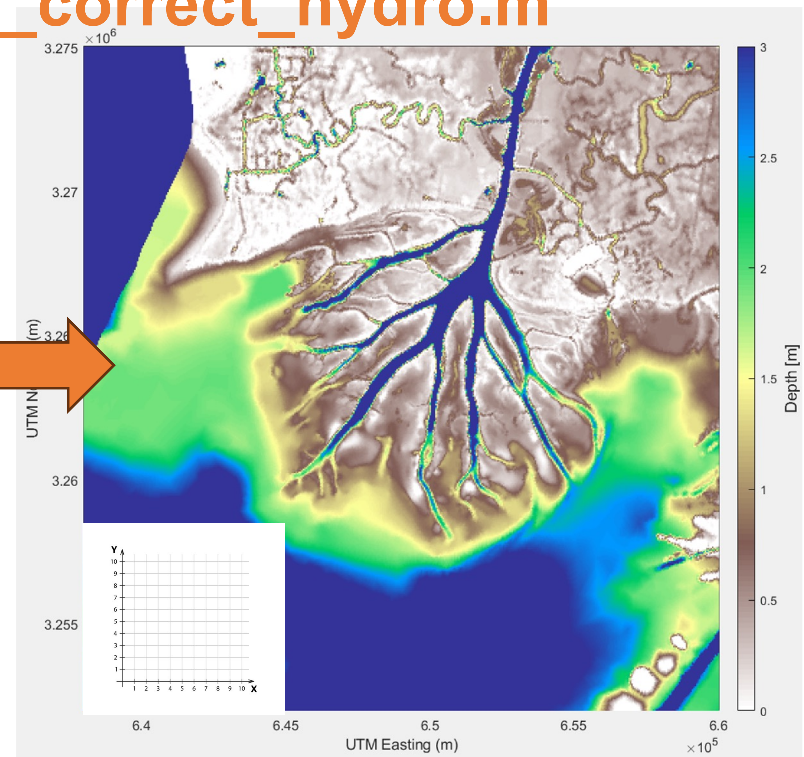
Load_anuga_NC.m





Unstructured mesh in hydrodynamics model

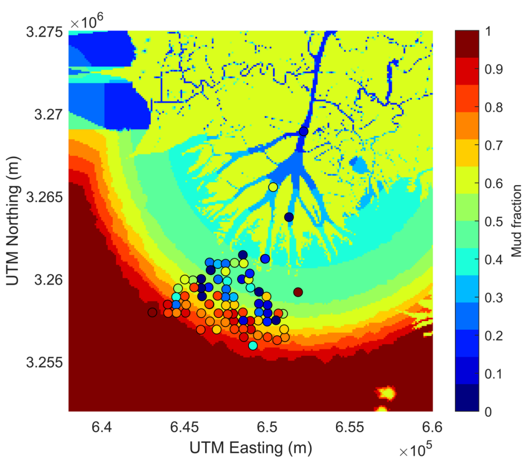
grid_and_correct_hydro.m

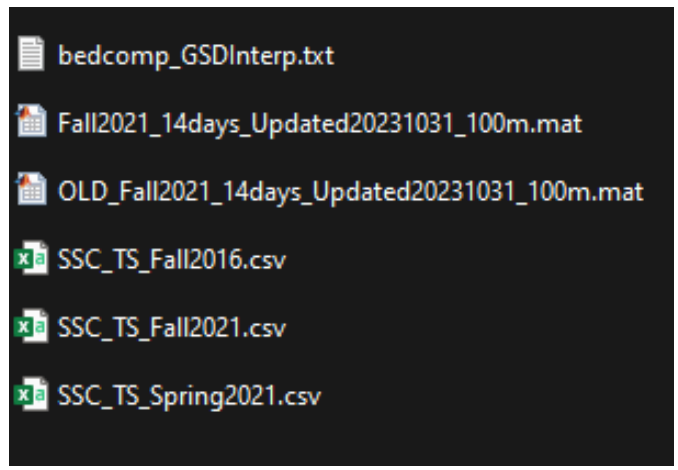


3 Model inputs

https://dropbox.caltech.edu/cgi-bin/dropbox.cgi?get=1&key=f3f5ee843927e1ddea372986c013ee4e

- Bed grain size distribution (*.txt)
- Hydrodynamics results (*.mat)
- Boundary conditions (*.csv)

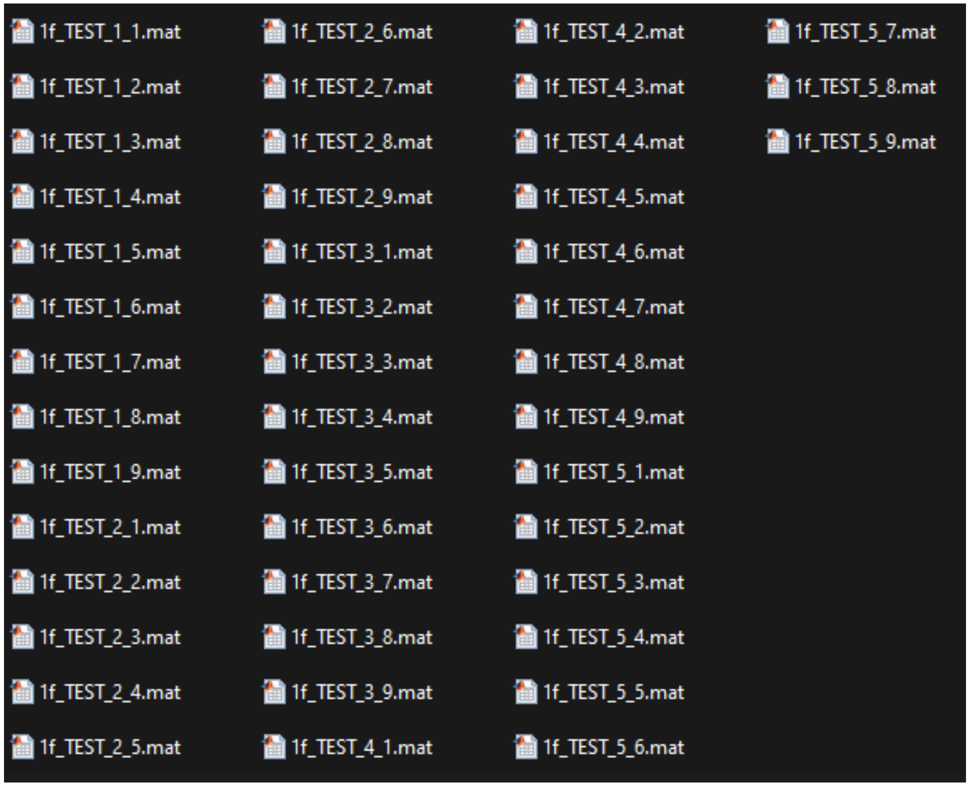




4 Model code

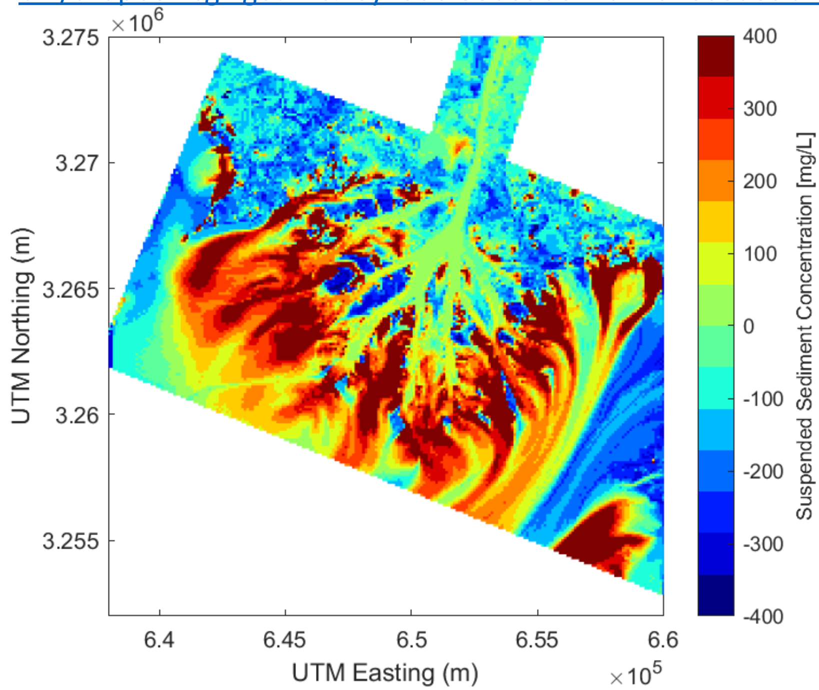
advection_SSC.m
compute_entrainment_deLueew_orign.m
polycrops.mat
rouse_submodel_beta_V3.m
SSC_2D_Model_WLD_1f_deLueew_orign_aggrWs_Run2.m

5 Model results (Raw)

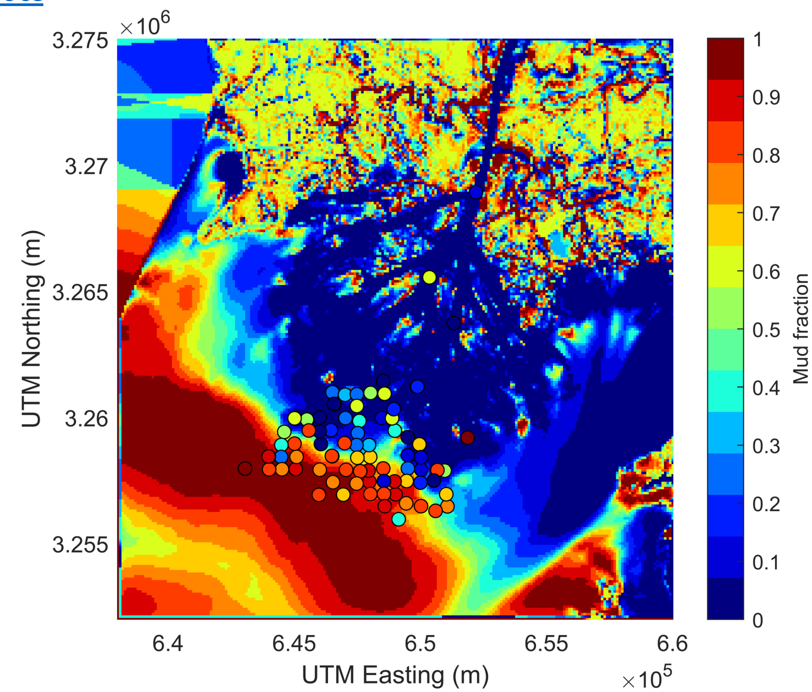


6 Post-processing tools & 7 Processed model results

https://dropbox.caltech.edu/cgi-bin/dropbox.cgi?get=1&key=3dcf866696e11a42a4cb6d89b46286c9



Example: Difference between AVIRIS-NG derived TSS and modeled TSS



Example: Modeled mud fraction

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