Delta-X: Matlab Model for Wax Lake Delta Land Accretion

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Documentation Revision Date: 2024-10-31

Dataset Version: 1

Summary

This dataset provides the Matlab sediment transport and land accretion model at Wax Lake Delta (WLD), Atchafalaya Basin, in coastal Louisiana. The data include the Matlab scripts that solve the advection and Exner equations to simulate the suspended sediment transport and accretion at WLD. The model requires modeled flow information from a separate ANUGA hydrodynamic model as inputs. For this study, ANUGA modeled flow information from the Delta-X Spring and Fall 2021 campaigns were used as inputs. The ANUGA output files are converted to variables used by this Matlab model using pre-processing tools. The main code calculates suspended sediment fluxes and accretion rates of mud and sand as a function of space and time. The cumulative sediment accretion from each campaign was then used to estimate an annualized land accretion map using a weighted-average formula presented. The final product, the one-yr upscaled land accretion map, is archived as a separate dataset.

There is one compressed file (.zip) with this dataset which contains preprocessing and postprocessing tools.

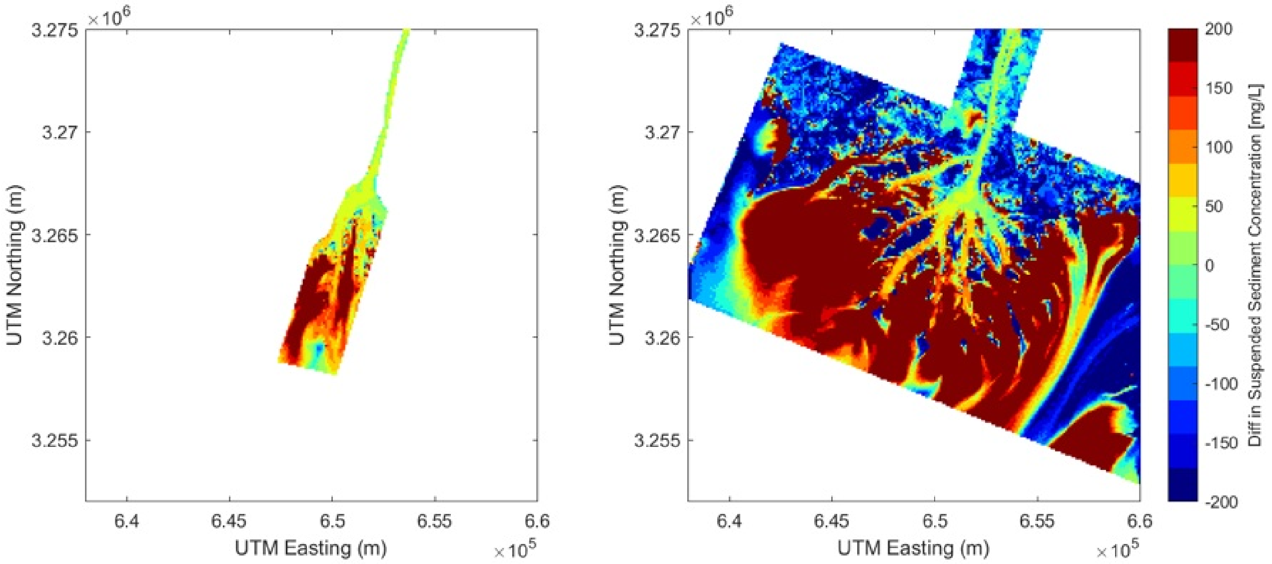

Figure 1. The difference between modeled depth-average suspended sediment concentration (SSC) and AVIRIS-NG inferred surface suspended sediment concentration at the two flyover times: 2021-04-02 (left) and 2021-04-01 (right). Modeled values may be slightly larger because they are the depth-averaged concentration, whereas the AVIRIS-NG data reflect the near surface concentration.

Citation

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

Table of Contents

1. Dataset Overview

This dataset provides the Matlab sediment transport and land accretion model at Wax Lake Delta (WLD), Atchafalaya Basin, in coastal Louisiana. The data include the Matlab scripts that solve the advection and Exner equations to simulate the suspended sediment transport and accretion at WLD. The model requires modeled flow information from a separate ANUGA hydrodynamic model as inputs. For this study, ANUGA modeled flow information from the Delta-X Spring and Fall 2021 campaigns were used as inputs. The ANUGA output files are converted to variables used by this Matlab model using pre-processing tools. The main code calculates suspended sediment fluxes and accretion rates of mud and sand as a function of space and time. The cumulative sediment accretion from each campaign was then used to estimate an annualized land accretion map using a weighted-average formula presented. The final product, the one-yr upscaled land accretion map, is archived as a separate dataset.

A summary of the model is provided in this documentation including a step by step guide to using the code, model governing equations, numerical methods, initial bed sediment composition, boundary condition for input suspended sediment concentration, and calibrations.

Project: Delta-X

The Delta-X mission is a 5-year NASA Earth Venture Suborbital-3 mission to study the Mississippi River Delta in the United States, which is growing and sinking in different areas. River deltas and their wetlands are drowning as a result of sea level rise and reduced sediment inputs. The Delta-X mission will determine which parts will survive and continue to grow, and which parts will be lost. Delta-X begins with airborne and in situ data acquisition and carries through data analysis, model integration, and validation to predict the extent and spatial patterns of future deltaic land loss or gain.

Related datasets

Wright, K.A., and P. Passalacqua. 2023. Delta-X: Calibrated ANUGA Hydrodynamic Outputs for the Atchafalaya Basin. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/2306

- This dataset provides the input data to the Matlab model in the current dataset.

Wang, D., G. Salter, and M.P. Lamb. 2023. Delta-X: Modeled 1-yr Upscale Land Accretion Map at Wax Lake Delta. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/2308

- This dataset holds the one-yr land accretion map generated with the Matlab model.

Fichot, C.G., and J. Harringmeyer. 2023. Delta-X: AVIRIS-NG L3-derived Water Quality, TSS, and Turbidity, MRD, V3. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/2152

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2. Data Characteristics

Spatial Coverage: Wax Lake Delta (WLD), the Atchafalaya River Basin, coastal Louisiana, U.S.

Spatial Resolution: N/A

Temporal Coverage: 2021-03-20 to 2021-08-27

Temporal Resolution: N/A

Site Boundaries: Latitude and longitude are given in decimal degrees.

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Atchafalaya Basin	-91.5704	-91.3287	29.59	29.39

Data File Information

This dataset includes one file **sediment_transport_land_accretion_Matlab_model_Wax_Lake_Delta.zip**, a zip archive that holds scripts and inputs for a Matlab model (Table 1).

The data include the Matlab scripts that solve the Exner equation and the advection equation to simulate the suspended sediment dynamics at WLD. ANUGA hydrodynamics modeling results (Wright and Passalacqua. 2023), which provide modeled flow information, are used by this Matlab model as model inputs.

The sediment transport model results were used to calculate the one-year upscale land accretion rate at WLD in post-processing. Both pre-processing and post-processing tools are included in this dataset.

Table 1. List of files in **sediment_transport_land_accretion_Matlab_model_Wax_Lake_Delta.zip.** There are seven directories in the .zip file. The directory contents are described below.

Directory Name	Directory Contents
1_HydroInput	The folder "1_HydroInput" should be created by the user to fill the ANUGA simulation result files (ANUGA input files (.npy files or .nc files)). There is one example empty text file in this directory

2_PreProcessing	There are two folders in this directory. Folder “2_PreProcessing\2_1_ConvertNumpyToMat” contains four files for preprocessing (preprocessing tool 2_1). The files can be used to convert the ANUGA files into .mat file (*.mat files). Depending on the ANUGA data format, the user can choose *load_anuga_NPY.m* or l*oad_anuga_NC.m* scripts to read and process the ANUGA result files in “.npy” or “.nc” formats, respectively. The folder “2_PreProcessing\2_2_ProjectHydrodynamicsResOnToMatlabMesh” contains three files. The script *grid_and_correct_hydro.m* should be run after step 2_1 to map the ANUGA results to the Matlab model mesh (*.mat files).
3_ModelInput	This folder is for the input files in three different formats (.txt, .csv, .mat files). The model input files (including the .mat file generated using pre-processing tool 2_2) need to be put into folder “3_ModelInput” . Other input files include: Bed composition map (*.txt files) and sediment concentration time series (*.csv files)
4_ModelCode (.m, .mat, .txt file)	There are six files in this folder (.m, .mat, .txt file). The main body of the sediment transport model is *SSC_2D_Model_WLD_MainCode.m*.
5_ModelResults	This folder contains one empty example placeholder file in .txt format. The model will generate output files (*.mat files) in this folder. This folder is left empty at the beginning of the model run.
6_PostProcessingCode	This folder contains 13 files (post-processing tools). • *TSRun_SinglePlot_Upscale.m* is a script that generates the cumulative sediment accretion maps for each campaign and an annualized total accretion using a weighted averaging approach. • *CompareAVIRIS_##.m* are scripts that generate Figure 2 shown in this document. • The *AVIRIS_##.txt* files represent AVIRIS-derived suspended sediment concentration maps that are archived on the ORNL DAAC but modified here by projecting onto the grid used in the sediment transport model. • *Generate_timeseries_spring2021.m* can be used to output the time series of the model variables at a user-specified location. Timeseries_plot.m plots the resulting time series output.
7_ProcessedResults (Output folder)	This folder contains two image files in .png format; the processed results from the post-processing tools are stored here.

3. Application and Derivation

The output of this Matlab model provides: the land accretion rate map for Fall 2021 campaign, Spring 2021 campaign and one-year upscale accretion rate at Wax Lake Delta.

4. Quality Assessment

The sediment transport model was validated using the comparison between the simulated suspended sediment concentration values and the AVIRIS-NG derived values for two flyovers during the Spring 2021 campaign. The model calibration and validation was performed by minimizing the error of suspended sediment concentration in the WLD delta channels. As shown in Figure 1, the misfit in the channels was smaller than 50 mg L^{-1}.

5. Data Acquisition, Materials, and Methods

Model governing equations

The Matlab sediment transport model equations are described in the figure below.

The Matlab sediment transport model solves the Exner equation and the transport equations for sediment flux for each sediment class i, with bedload transport being neglected, as shown in the equation below (e.g. van Rijn, 1984; Garcia and Parker, 1991):

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

where λ is bed porosity; η is the bed elevation; t is time; $D_i = w_{si} c_{bi}$ is the settling flux; w_{si} is settling velocity of sediment class i; f_i is fraction of the sediment class i in the bed materials; c_{bi} is the near-bed volumetric concentration of the sediment class i; E_i is the dimensionless sediment entrainment of sediment class i, and c_i is volumetric suspended sediment concentration for sediment class i averaged over the depth, h, and ν_t is the turbulent diffusivity. In our simulations we set $\nu_t = 0$. We used two sediment classes: sand and mud to approximate the full grain size distribution in this model.

The near-bed concentration c_{bi} of sediment class i is calculated using a shape factor r_0:

$$c_{bi} = r_0 c_i$$

The shape factor is determined using Rouse-Vanoni depth-profile for suspended sediment,

$$r_0 = h\left\{\int_{z_b}^{h}\left[\frac{(h-z)/z}{(h-z_b)/z_b}\right]^{P_i} dz\right\}^{-1}$$

where h is water depth; z is the height above the bed; $z_b = 0.1h$ is a reference height following the recommendation of de Leeuw et al. (2020); and the Rouse number $P_i = a\left(\frac{w_{si}}{u_*}\right)^b$, with $a = 0.991$ and $b = 0.453$ following de Leeuw et al. (2020), where u_* is the total bed shear velocity.

The entrainment of suspended sediment from the bed, E_i, is calculated using de Leeuw et al. (2020), as

$$E_i = 7.04 \times 10^{-4}\left(\frac{u_*}{w_{si}}\right)^{1.71} Fr^{1.81}$$

where Fr = $U/(gh)^{0.5}$ is the Froude number, U is the magnitude of the depth-averaged velocity and g is the acceleration due to gravity.

Figure 2. Model equations.

The model uses the active layer formulation in Garcia (2008) to simulate the bed sediment stratigraphy changes over time. The bed composition at each layer then changes at each time-step based on the relative depositional and entrainment flux of each of the two sediment classes. The active layer concept proposes that the sediment bed consists of an active layer sitting on top of the substrate, where the active layer is a thin mixed grain size layer that exchanges sediment with the water column. The bed elevation is then formulated as

$\eta = \eta_{sub} + L_\alpha$

where η_{sub} is the thickness of the substrate below the active layer and L_α is the active layer thickness. In our model, the thickness of the active layer was set to be a constant $L_\alpha = 1$ cm. The user can define the active layer thickness using the variable "L_active" in the model main code (*SSC_2D_Model_WLD_MainCode.m*). The underlying substrate can have multiple layers. In the model, only one layer below the active layer was used with thickness set to be $\eta_{sub} = 1$ m. The user can define the thickness using by setting the parameter "layerthick_initial" in the main code.

Numerical methods

The transport equation for sediment flux is solved using the Finite Volume Method with van-Leer flux limiter. Dirichlet boundary is set at channel inlets (upstream). Neumann boundary is set at downstream boundaries.

Model calibration

The only model parameters that were calibrated to field data in the sediment transport model were the settling velocities of the mud and sand fractions. Based on Lamb et al. (2020), the mud fraction was modeled as flocculated bed-material load using the same equations as for the sand fraction. Based on comparison to field data during the Delta-X campaigns, the effective settling velocity of flocculated mud was found to be best approximated as $w_{s,mud} = 0.33$ mm s^{-1}, which is similar to the value found by Lamb et al. (2020) from a global compilation. For the sand fraction, a value of $w_{s,sand} = 15$ mm s^{-1} was found to best match the field data.

Initial bed sediment composition

The initial condition needed to run the sediment transport model is a map of the fraction of the bed material that corresponds to each grain size class. For this case, it is the fraction of sand or mud. The sediment in the active layer and the bed layer were initially assigned in *bedcomp_GSDInterp.txt* file that contains initial guess of the bed composition in the "3_ModelInput" folder. The initial bed grain size map was based on interpolated unpublished measurements and expert knowledge. The map is provided in "3_ModelInput" folder. The authors make no claim about the reliability of this map. If the user runs the model using a different initial condition, the file format must match the example files provided.

During each model scenario, the bed composition changes to come into better equilibrium with the suspended sediment transport. Because the initial guess at the bed sediment mud and sand fractions may be in error, the model uses a spin-up phase where the scenario is run for four consecutive times, allowing the bed sediment size fractions to cumulatively adjust over these runs. Then, the model is run a fifth time which is taken as the main model result.

Boundary condition for input suspended sediment concentration

The boundary condition to drive the model is the suspended sediment concentration from upstream. Sediment is fed in from upstream where the northern model domain crosses the Wax Lake Outlet. If one wishes to run a larger domain, additional locations for sediment input can be added. For the Wax Lake Outlet, data were used from the USGS station at Calumet, Louisiana (Station 07381590). A time series of suspended sediment concentrations was generated by applying a rating curve relation to the measured discharge at Calumet. The best fit rating curve based on USGS observations are Calumet are shown in Figure 2. The resulting time series used for these model runs of the two campaigns are the two.csv files in "3_ModelInput".

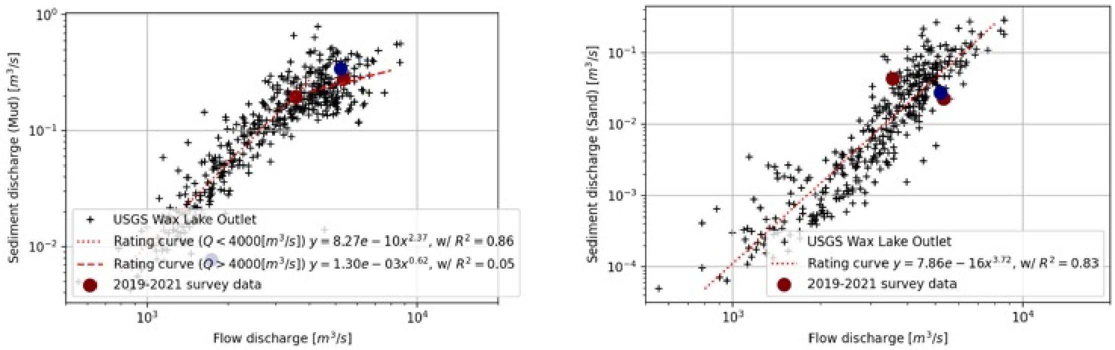

Figure 3. Flow discharge – sediment discharge rating curves derived using sediment data from USGS Calumet streamgage (07381590). (a) Rating curves for mud. (b) Rating curve for sand. The large filled symbols are data collected from Delta-X that are archived at the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC; Wright and Passalacqua, 2023).

Step-by-step guide for this code

- The user is responsible for placing the ANUGA hydrodynamics model results in the folder "1_HydroInput." The results from the Delta-X campaign ANUGA runs can be found on this archive.
- Next, the code in "2_PreProcessing\2_1_ConvertNumpyToMat" should be executed to convert the ANUGA hydrodynamic outputs into ".mat" formats. The hydrodynamic inputs that are needed for the sediment-transport model are the: x coordinate, y coordinate, time, x-direction momentum, y-direction momentum, water depth and bathymetry. This step depends on the format of the ANUGA results. The user can use *load_anuga_NPY.m* if the ANUGA files are in .npy format, or use *load_anuga_NC.m* if the files are in the netCDF (.nc) format.
- The sediment transport model requires a grid of flow resistance coefficients. For Delta-X, Manning's n was calibrated for channels as part of the ANUGA model producing a spatially variable but temporally fixed map of Manning's n values for channels. For the wetlands, the coefficients in the Baptist et al. (2007) model were calibrated for different ecogeomorphic zones as part of the ANUGA model. These friction coefficients are imported from the .nc input file and used in the sediment transport model function *load_anuga_NC.m* to calculate Chezy flow resistance coefficients in space and time.
- Next, the code in "2_PreProcessing\2_2_ProjectHydrodynamicsResOnToMatlabMesh" should be used to map all the hydrodynamic inputs onto a Cartesian grid. The sediment transport model runs in a Cartesian equally-spaced grid, while the ANUGA outputs used an unstructured triangular mesh. The resulting file is automatically saved in the folder "3_ModelInput."
- The boundary condition needed to run the model is the suspended sediment concentration time series that is applied at the upstream model boundary for the Wax Lake Outlet. The time series is found in the "3_ModelInput" folder. If the user runs the model using a different boundary condition time series, the file format must match with the example files provided.
- Now the user can perform the sediment transport calculations using the code located in the "4_ModelCode" folder. The example files were run using Matlab version 2022a. To run the calculations, execute the main code: *SSC_2D_Model_WLD_MainCode.m*. The rest of the files in this folder are functions that are called by the main code.
- The user can set parameters in the main code, *SSC_2D_Model_WLD_MainCode.m*, in lines 10 to 90. Details of all these parameters are provided in the comments following each line of code. Values are set to the best estimates for the Delta-X study.
- The code will output results to the folder "5_ModelResults". The output will be a series of .mat files that are ordered in time. Each mat file contains many variables and intermediate variables used throughout the calculations. The main outputs that are likely of most interest to the user include the suspended sediment concentration, bed material composition, and accretion/erosion amount. Each of these variables have values that change in space and time.
- The user can use the post-processing tools provided in the "6_PostProcessingCode" folder to process the raw data files. As described above, these tools produce outputs for land accretion, suspended sediment concentration, and a time series output at user-specified locations.
- The final products from the post-processing tools are output to the "7_ProcessedResults" folder.

6. Data Access

These data are available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

Delta-X: Matlab Model for Wax Lake Delta Land Accretion

Contact for Data Center Access Information:

- E-mail: uso@daac.ornl.gov
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7. References

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