Hydrodynamic modeling using Anuga

Delta-X Workshop 2024
May 8th, Baton Rouge

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URS Clearance **CL#24-2353**

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Part 1:
Introduction


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Why modeling hydrodynamics?

Due to their many levels of complexity, understanding the *dynamics of coastal environments* is crucial for a variety of applications :

- **Environmental Management**
- **Floor Risk Mitigation**
- **Navigation and Infrastructure**
- **Conservation Efforts**
- **...**

The landscape of hydro-models

There exists a wide variety of models to simulate coastal dynamics:

- SWAN, Delft3D, XBeach
- Open Telemac Mascaret
- **Anuga**
- FVCOMS
- Mike 21/3
- ADCIRC
- ROMS
- SCHISM

Anuga: Strengths and limitations

Strengths

- Open Source
- Python
  - Executable on any OS able to run python code
- Lightweight
- Finite volumes
- Parallelizable
- QGIS supported (natively)

Limitations

- 2DH shallow waters only
- No waves
- No sediment transport
- No morpho-dynamics
- No chemistry

Delta-X hydro-model products

https://doi.org/10.3334/ORNLDAAC/2310

Version 1

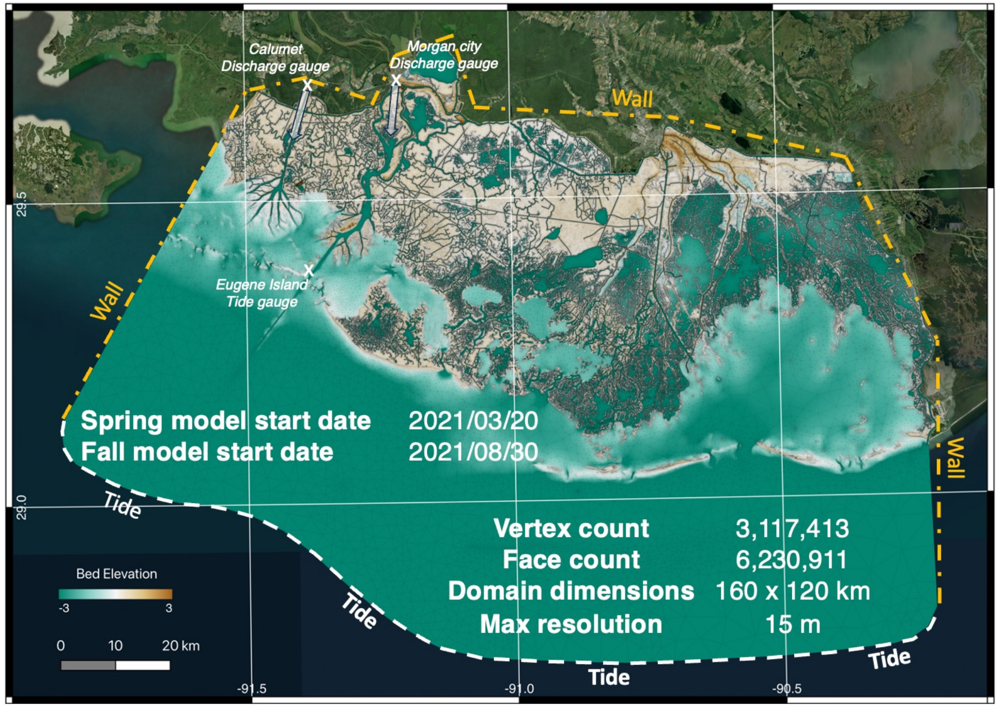
- Spring 2021

Version 2

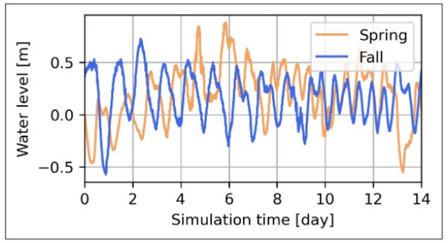
- Spring 2016
- Spring 2021
- Fall 2021

Delta-X hydro-model products

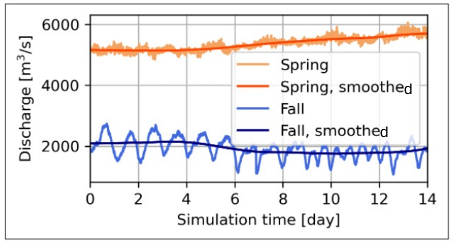
Hydrodynamic model setup



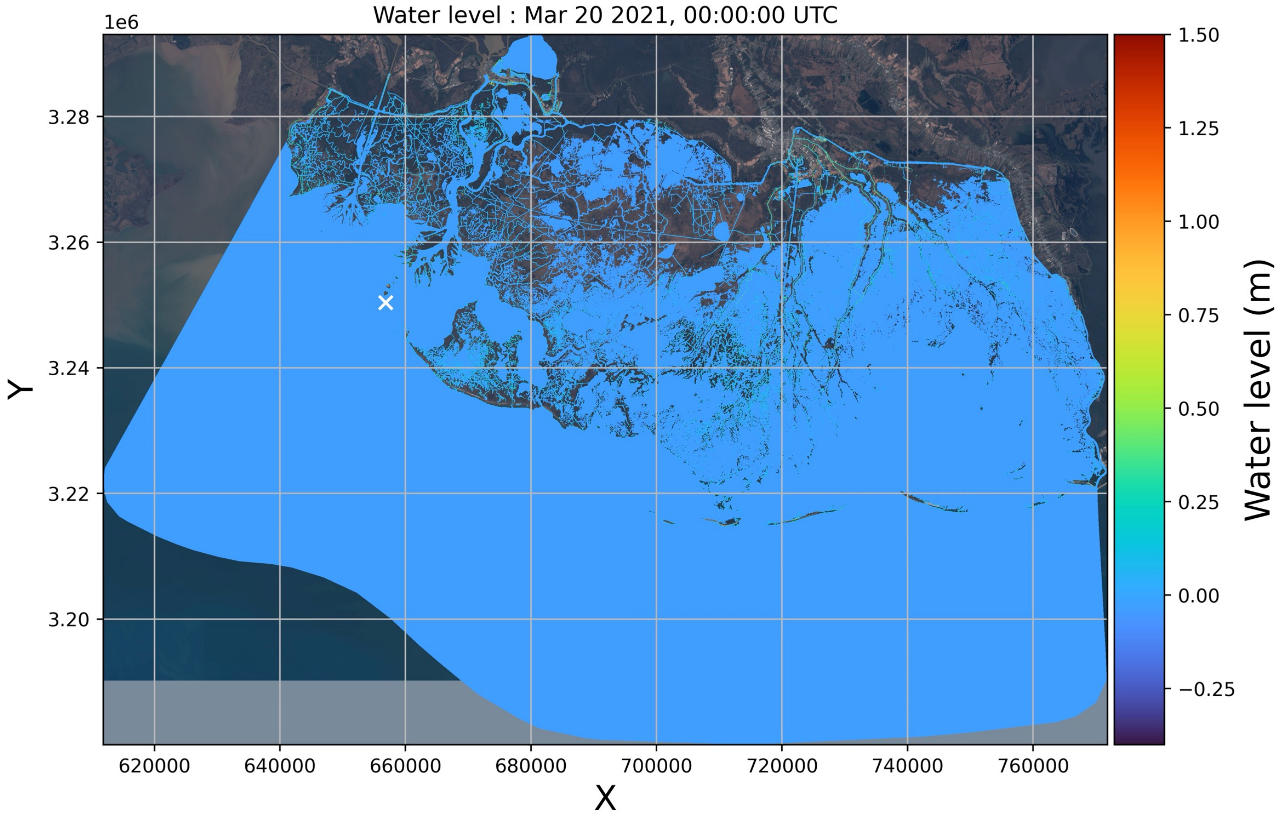
Model inputs

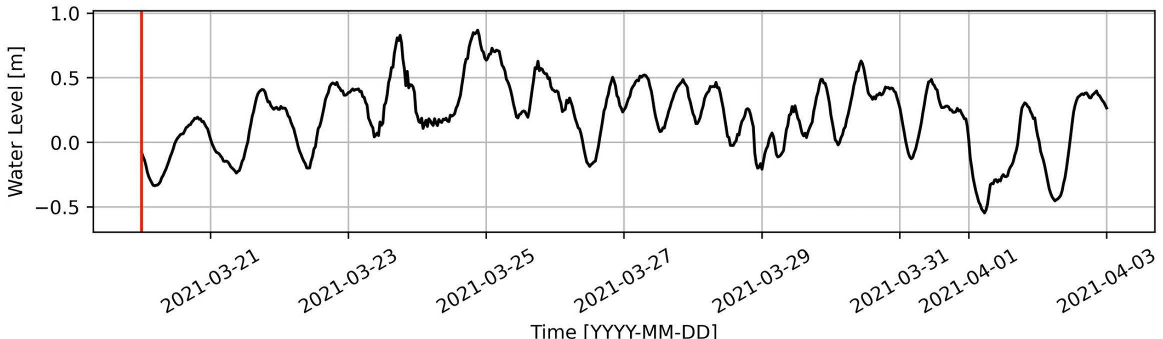


Tide at Eugene Island



River discharge at Calumet



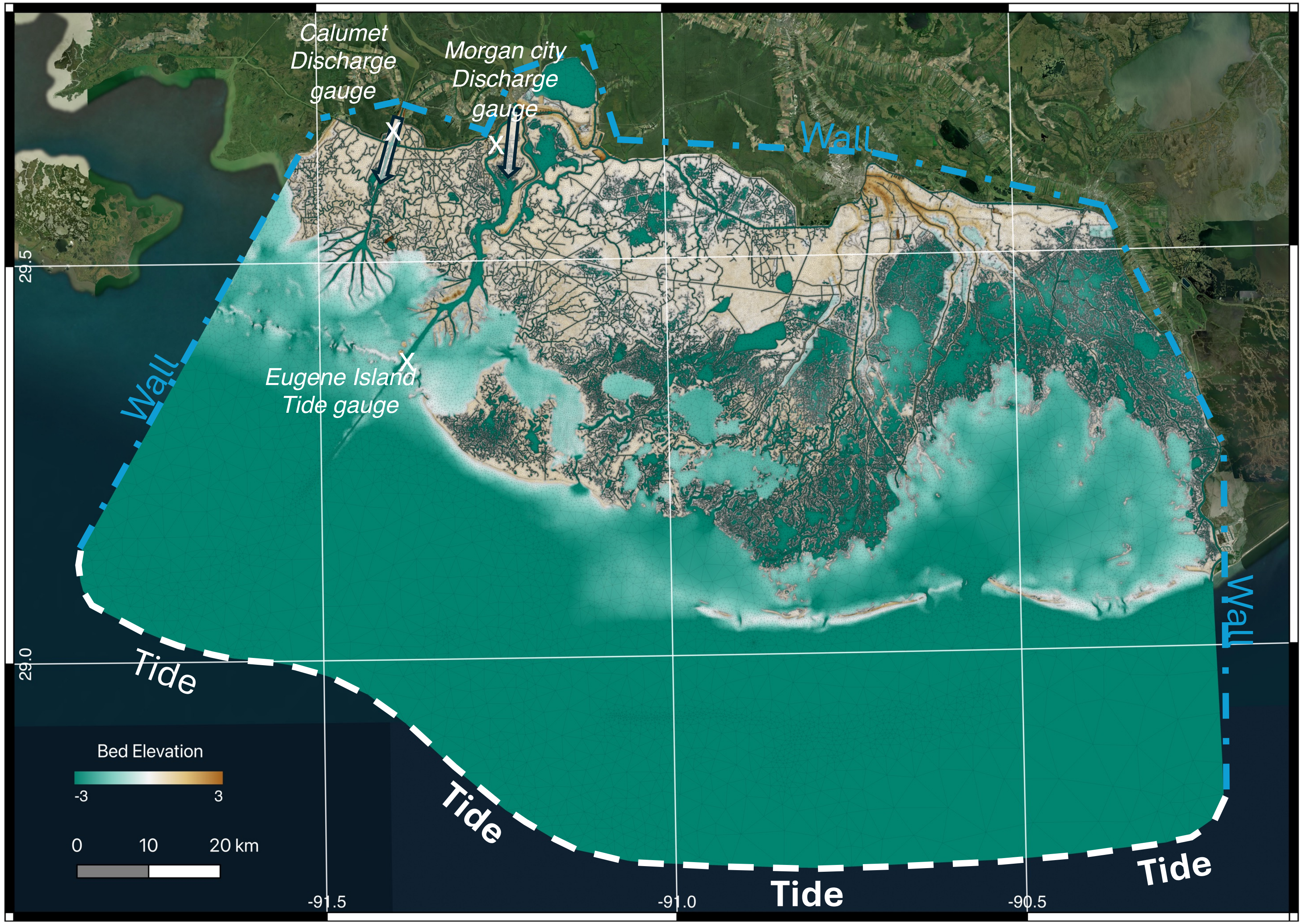


Part 2:
Modeling Workflow

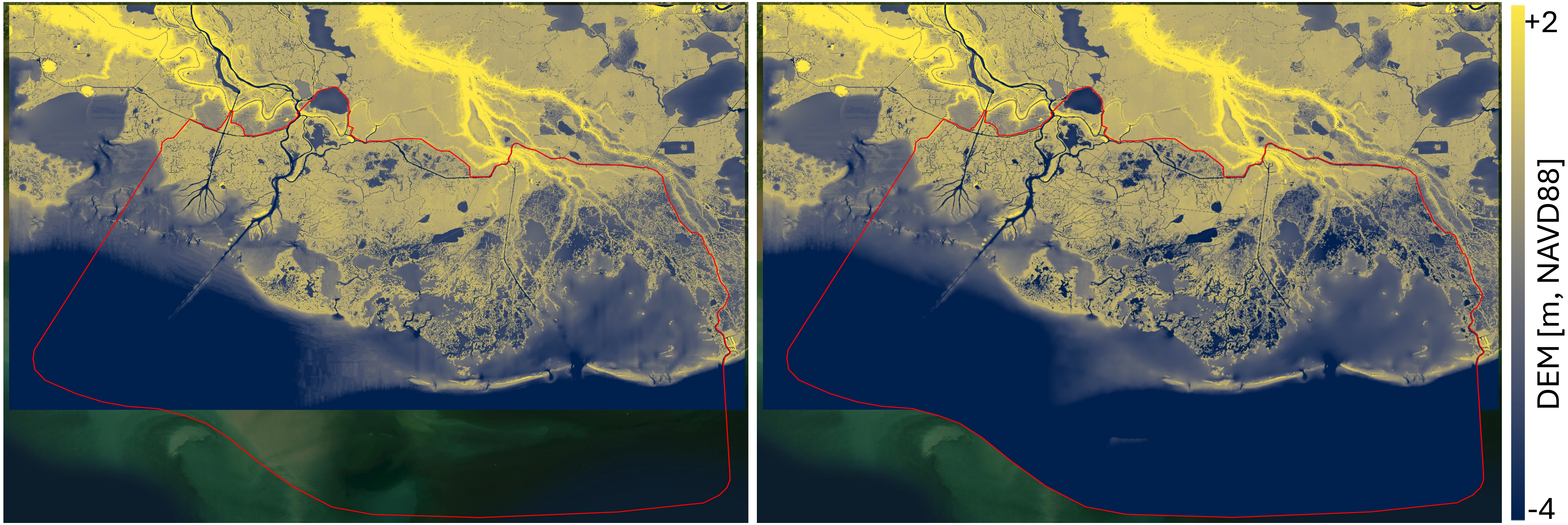
Domain Definition

<u>Important Parameters:</u>

- Watershed isolation
- Data availability
- Geomorphological setting
- Size and computational constrains



DEM adjustments



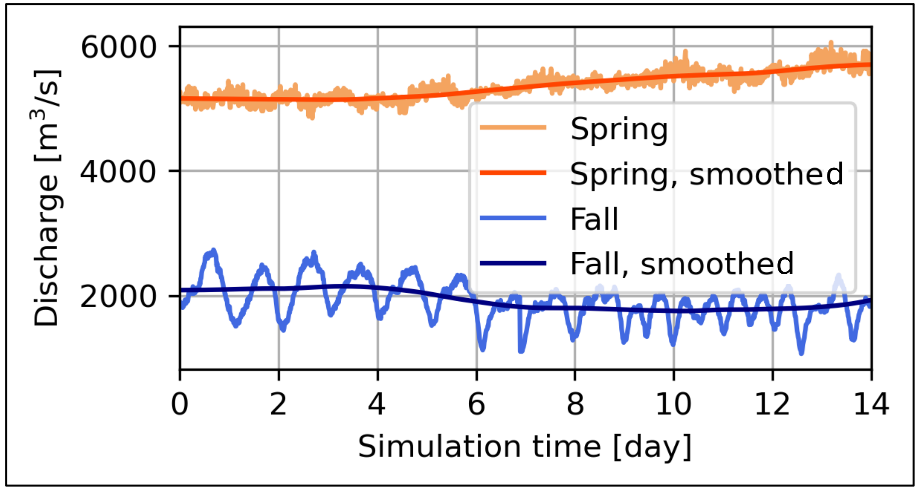
Original DEM (Christensen et al., 2023)

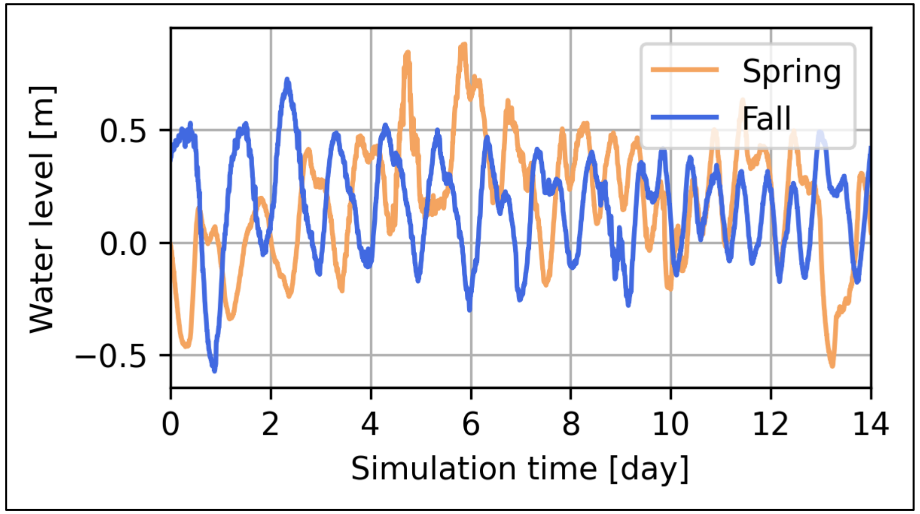
Modified DEM

Input Data Selection

<u>Common options:</u>

- Digital Elevation Model (DEM)
  - Local model
  - Gebco
- Tides
  - NOAA
  - Global models: FES2014, …
- River Discharges
  - Gauges
  - SWOT
- Waves
  - Buoys
  - Global models: WaveWatch3, …
- Wind
  - NOAA



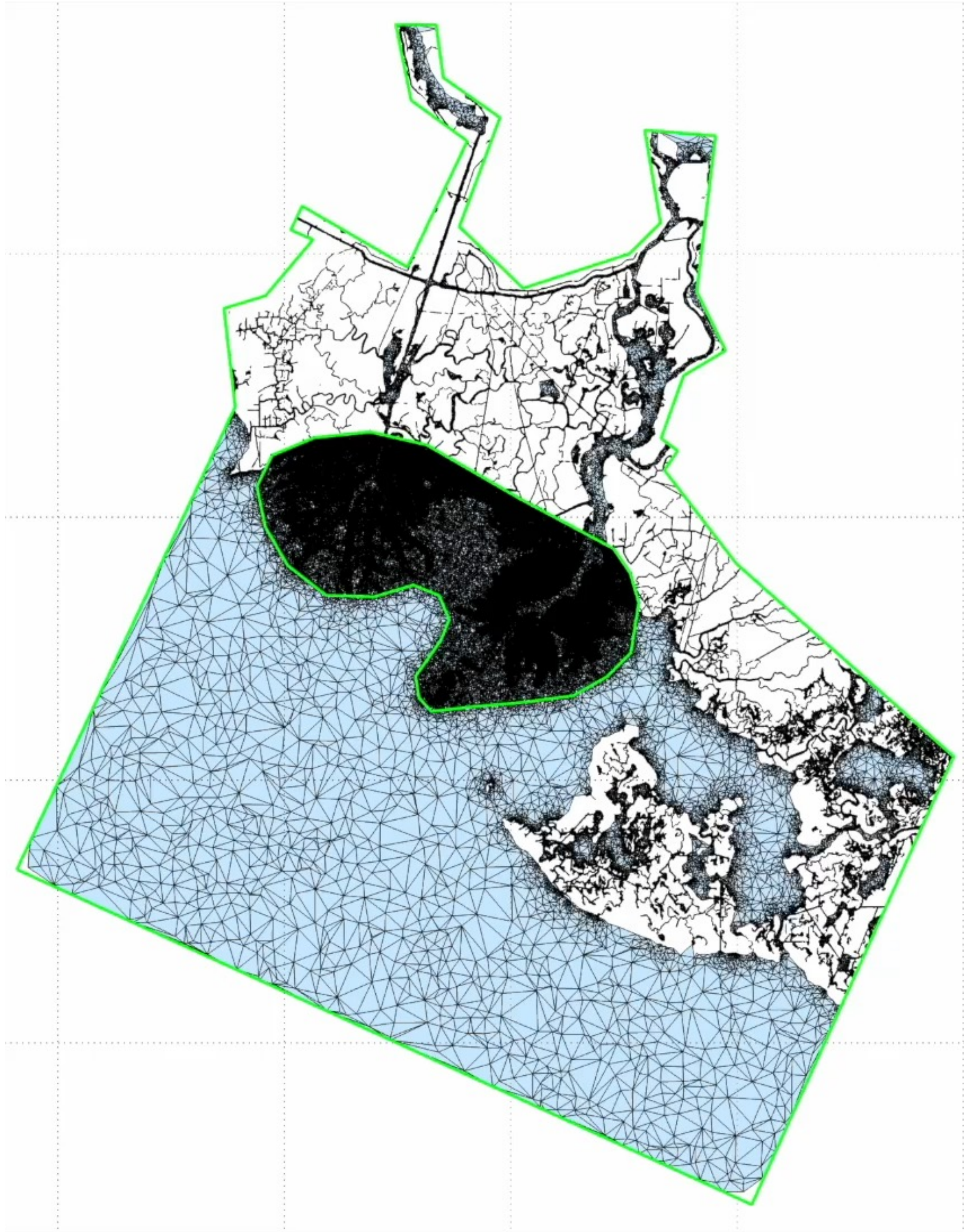


Input time series used in the Delta-X Anuga models

Domain Meshing

Common options:

- Structured
- Unstructured
  - Triangular (Anuga)
    - Model built in tools
    - OceanMesh2D (matlab)
    - Blue Kenue (windows only)
    - QGIS
  - Quadrilateral
- Hybrid



Example of resolution optimization of a triangular mesh using OM2D

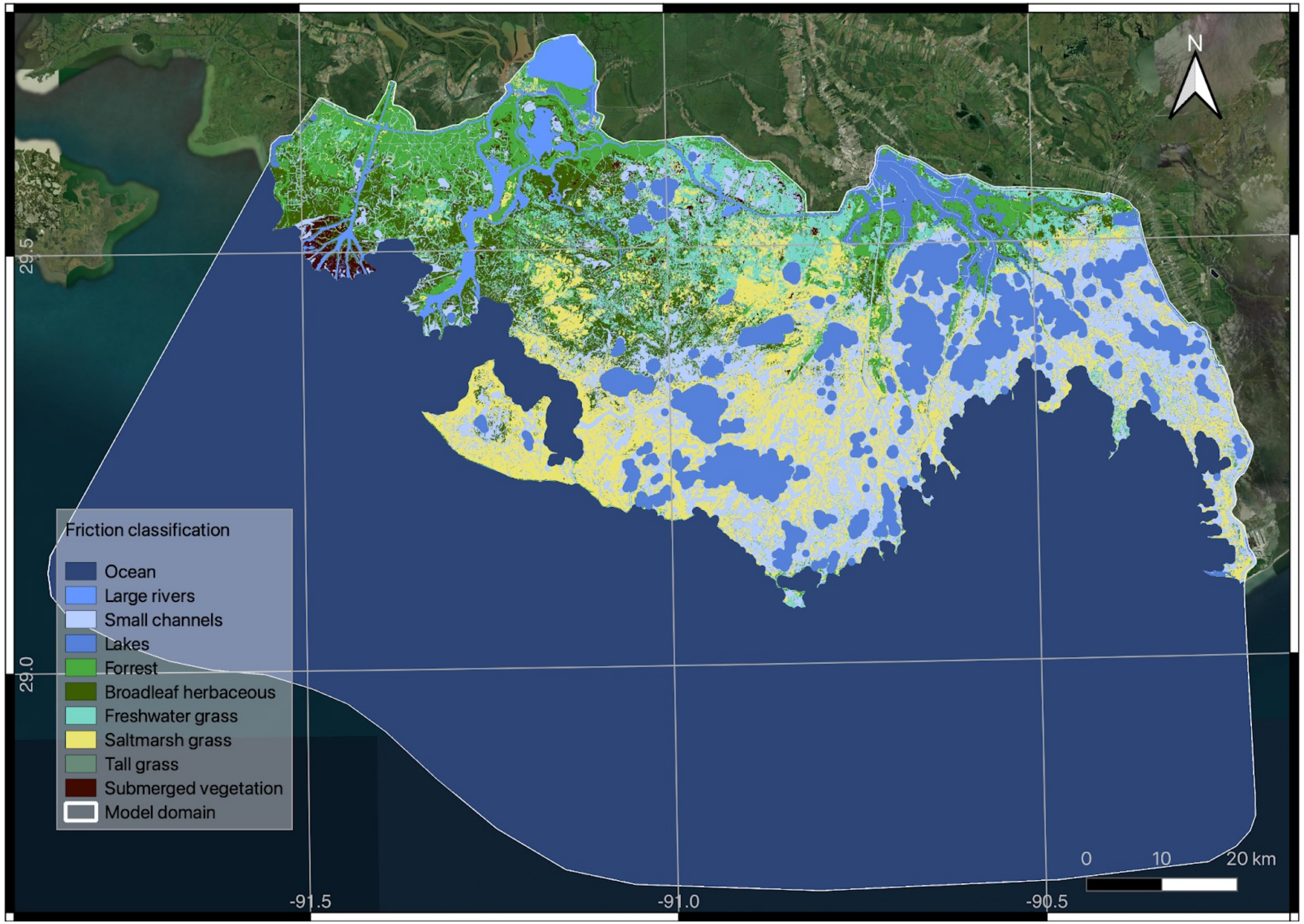
Step 4: Friction Calibration

Common options:

- Mapping Process
  - Water masks and land cover data
- Calibration process
  - Empirical tables
  - Try and Error approach

JPL Delta-X models:

- Mapping process
  - Vegetation classes
    - Aviris NG (Jensen et al. 2024)
    - Sentinel 2 (Christensen, pc)
  - Water classes
    - DEM dataset (Christensen et al. 2023)
- Calibration process
  - In situ biostatistics measurements (Castañeda-Moya and Solohin, 2021)
  - Weights to match with previous models from Wright et al. 2024
  - Try and error approach for finer calibration



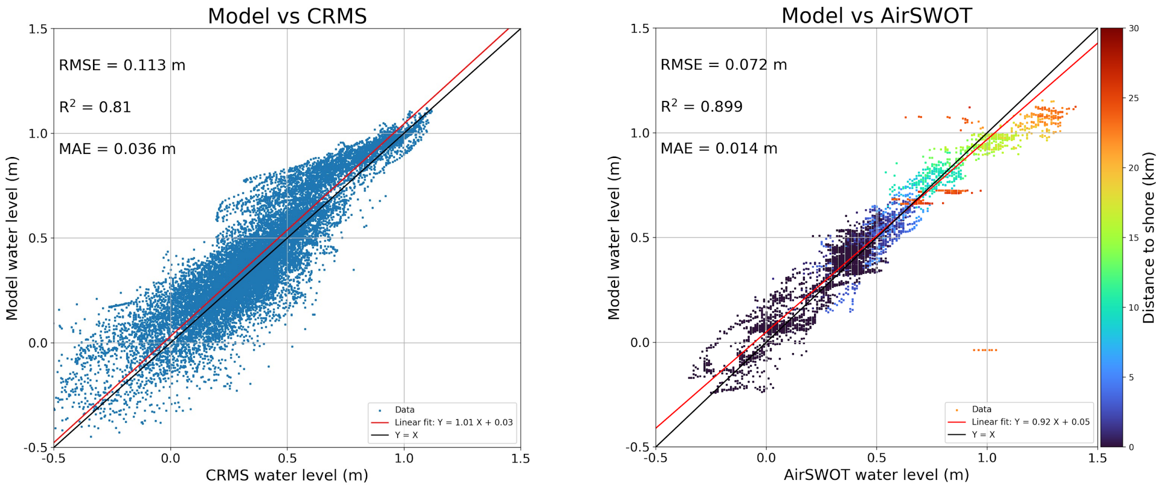
Model Validation

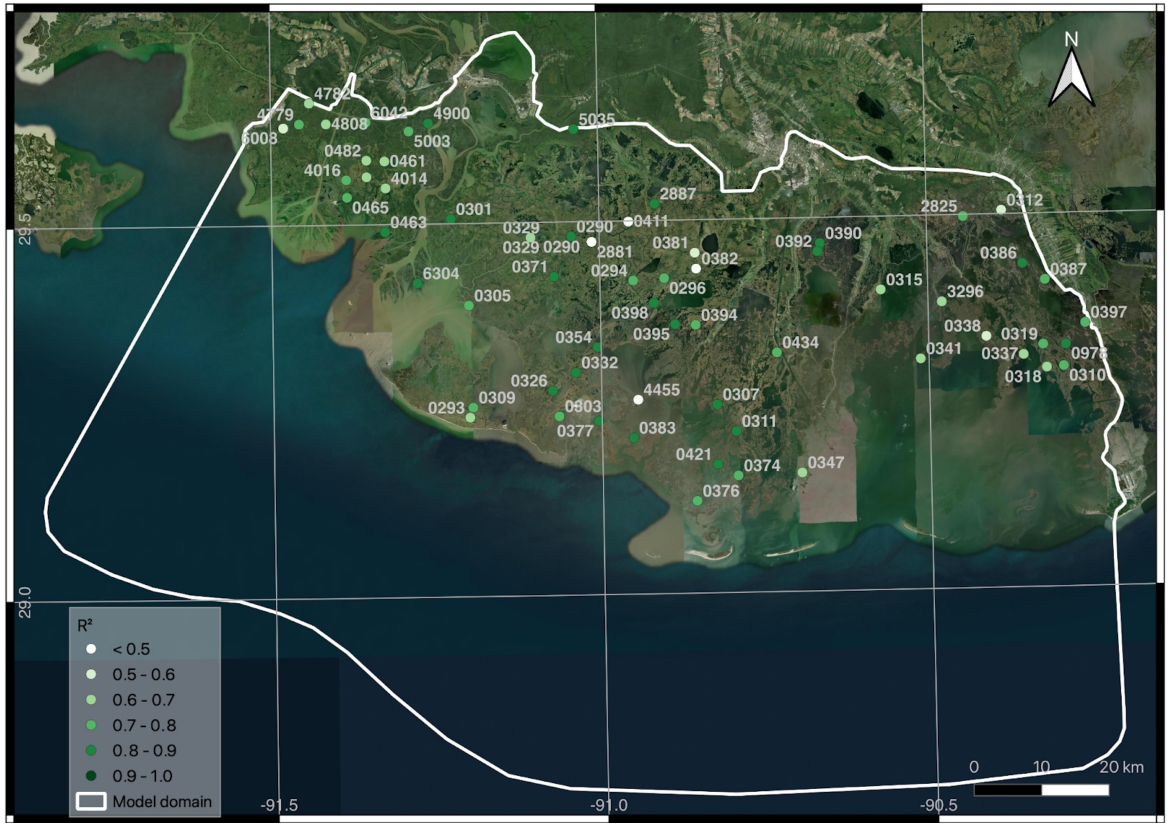
<u>Common options:</u>

- Local gauge stations
- Spaceborne radar altimetry data
- SWOT (since 2023)

<u>JPL Delta-X models:</u>

- AirSWOT data
- Delta-X JPL Gauges data
- CRMS Gauges data
- UAVSAR data

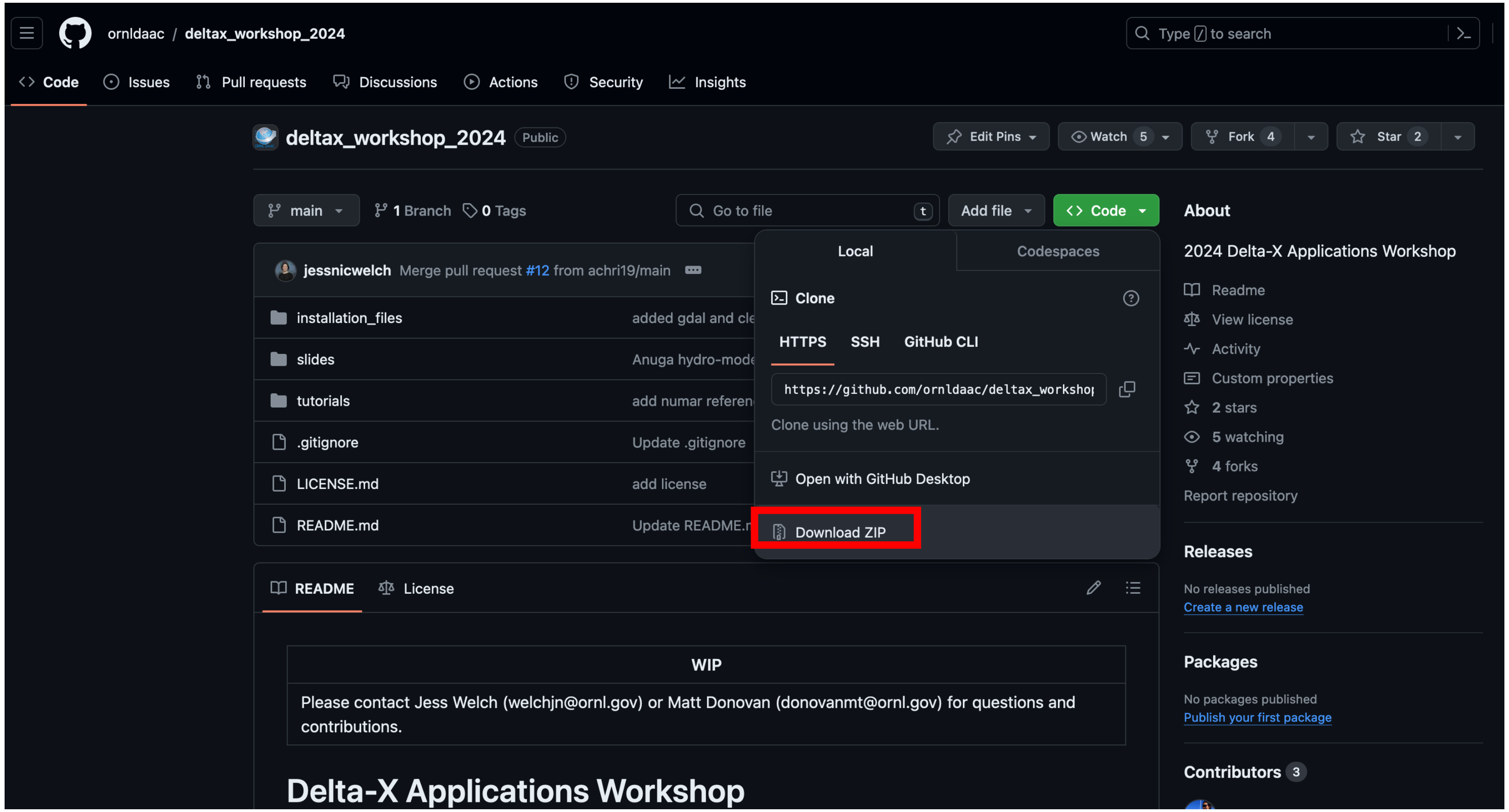




JPL Delta-X Model Validation using various datasets

Part 3:
Hands On Exercises

Download the Workshop Material



1. Download the workshop archive
2. Unzip it on your computer at your preferred location

https://github.com/ornldaac/deltax_workshop_2024

Install the python environment

1. Download and install Anaconda
2. Open a command prompt / terminal window
3. ANUGA and DORADO conda environment

Download *anuga_dorado.yml* and navigate to the folder where it is saved and run the following commands
conda env create --name anuga_dx --file=anuga_dorado.yml
conda activate anuga_dx
python -m ipykernel install --user --name=anuga_dorado

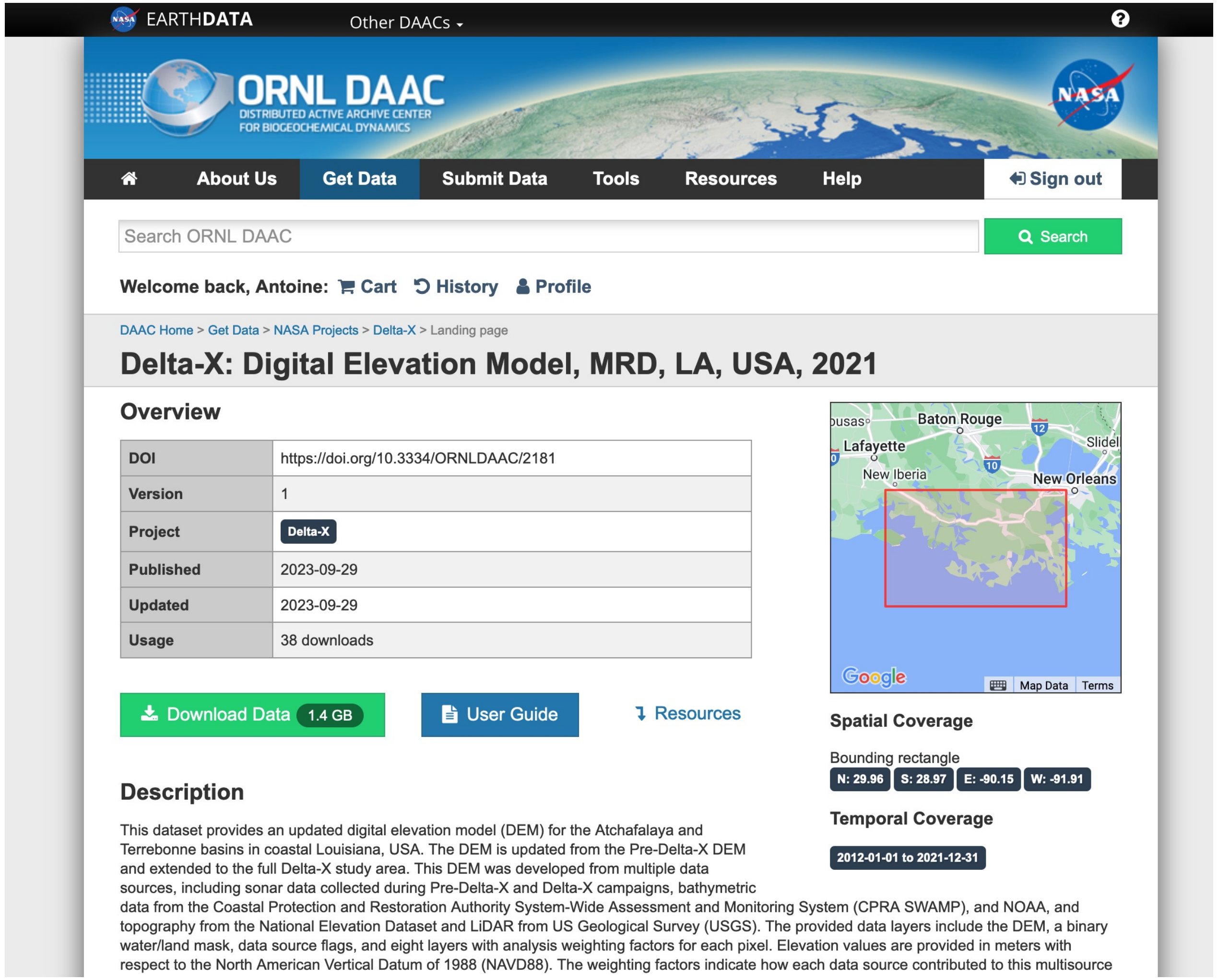
Test the installation of ANUGA and DORADO by running the following command:
Python

Wait a few seconds while python initializes. When “>>>” appears on the left side of the window, copy-paste the following lines and hit return:
import anuga
import dorado

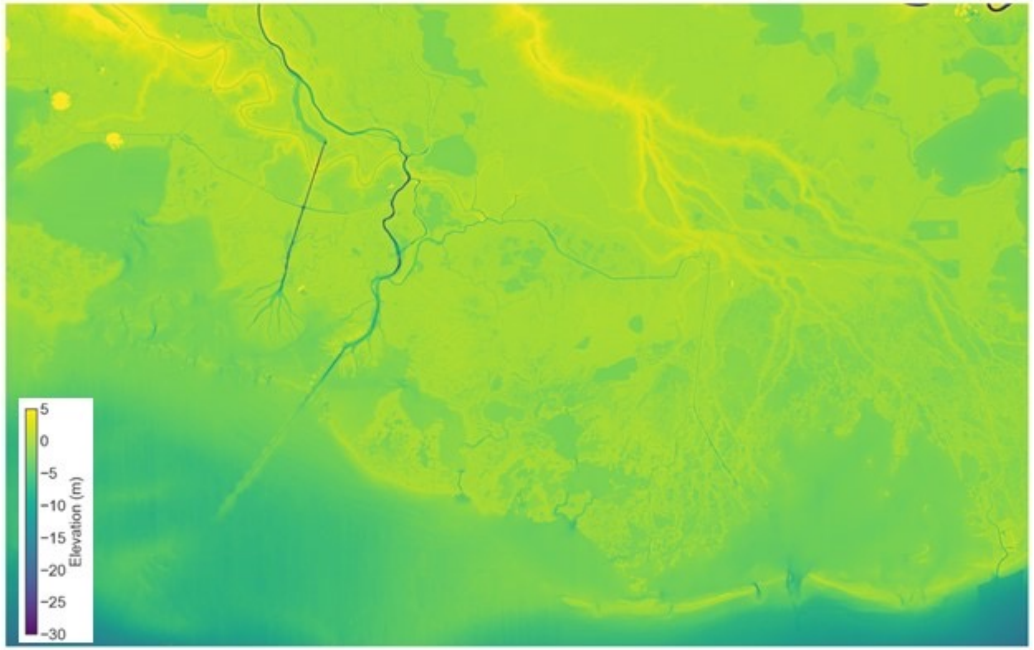
If for some reason something is not working, you will be prompted with an “Error” message (“Warnings” are not an issue). In such cases, please refer to Section 4: ANUGA and DORADO - Manual Installation.

https://docs.google.com/document/d/1vlykr5kp8t-2cXk17LA2tKUy97WKpe-J/

DEM download



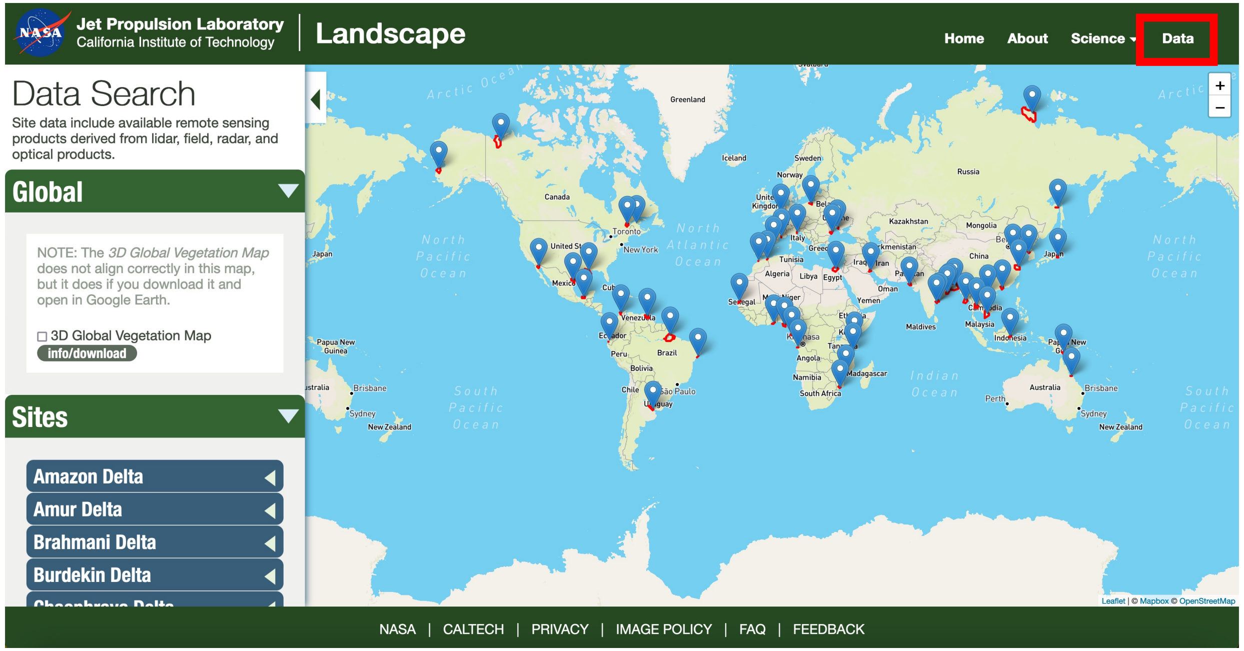
https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=2181

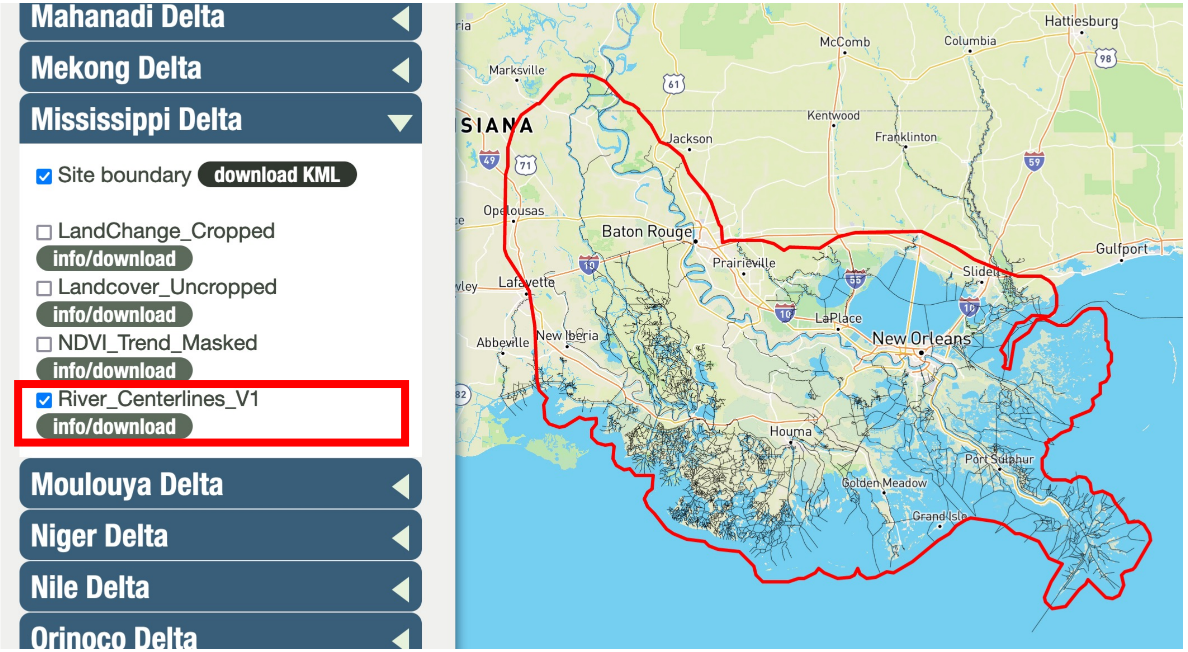


Filename	Units	Description	Flag value
DeltaX_MultiSource_DEM_Atchafalaya-Terrebonne_Basin_2021_V1.tif	m	Interpolated elevation of bed (waterbodies) or land relative to the NAVD88 in meters.	-
DeltaX_MultiSource_DEM_Data_Source_Flag_V1.tif	-	Flags denoting data source for raster cells; see Table 2.	-
DeltaX_MultiSource_DEM_watermask_V1.tif	-	Binary mask denoting water (1) or land (0).	-
adh_weight_V1.tif	1	Analysis weight for ADH bathymetry.	1
atcha_weight_V1.tif	1	Analysis weight for lake bathymetry in Atchafalaya Basin	9

Download and place the tif files in the subfolder called ***1_HydrodynamicModeling_ANUGA/data***

River Centerlines download





https://landscape.jpl.nasa.gov/cgi-bin/data-search.pl

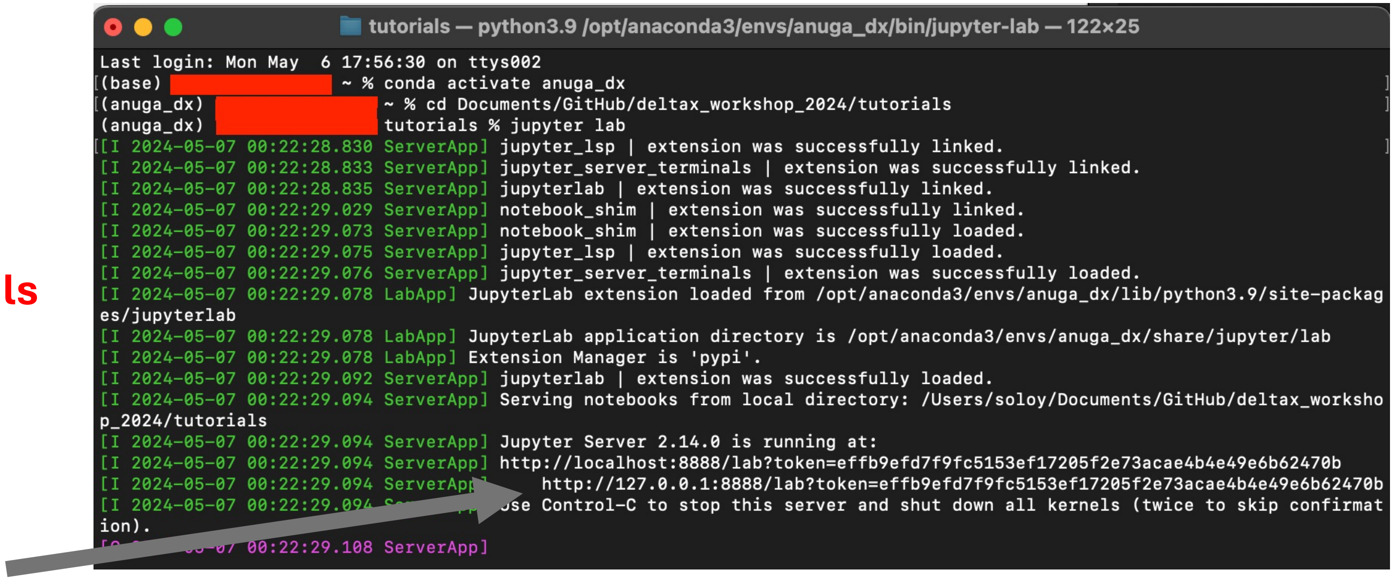
Download and place the unzipped centerlines folder in the subfolder called
1_HydrodynamicModeling_ANUGA/data

Other data download

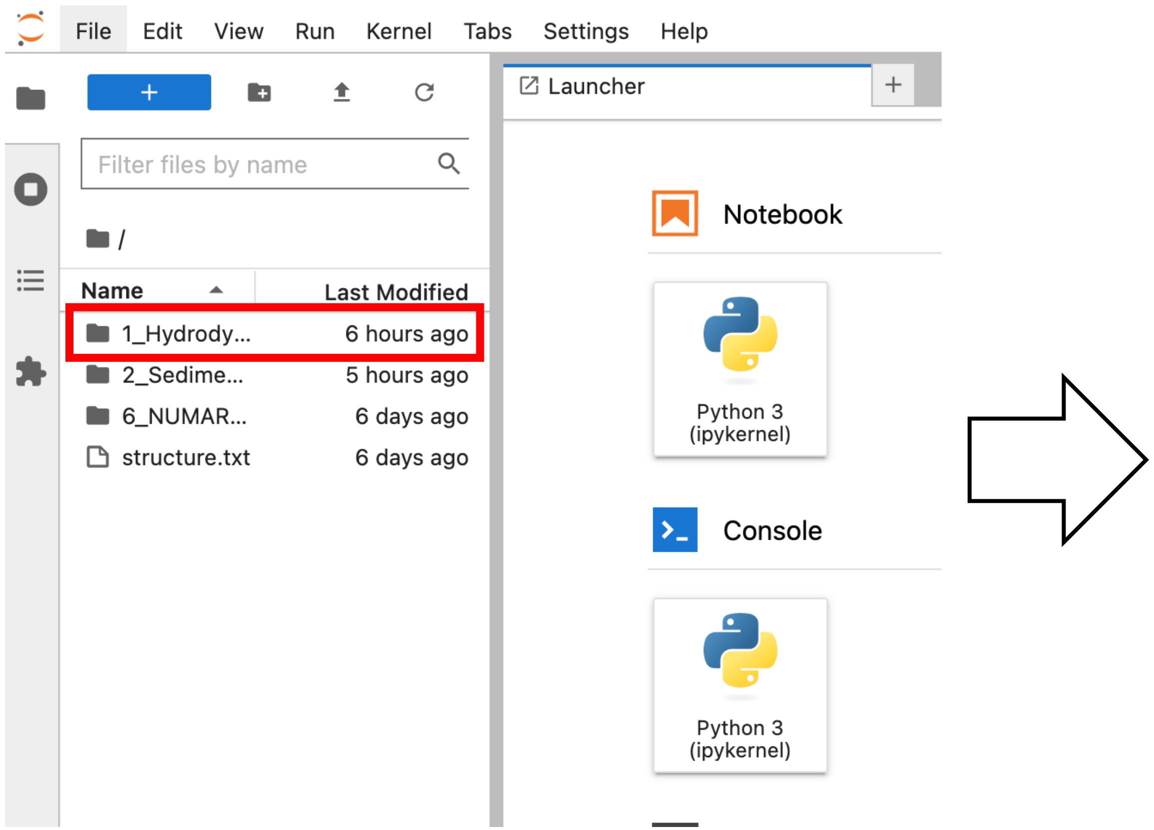
- **Delta-X Vegetation Classification Map**¶
  - Download link: https://drive.google.com/file/d/1OSyAWekAuXGFz3yLRz61PlLuQgj2FkGa/view?usp=drive_link
- **Delta-X AirSWOT L3 Water Surface Elevations**
  - Download link: https://doi.org/10.3334/ORNLDAAC/2349
- **CRMS water level gauges**
  - Download link: https://drive.google.com/file/d/1WjOSv8XcYZwkN_-oPdsdXH_5Lg2zcp5x/view?usp=drive_link (workshop sample)

Jupyter Notebook / Lab (1)

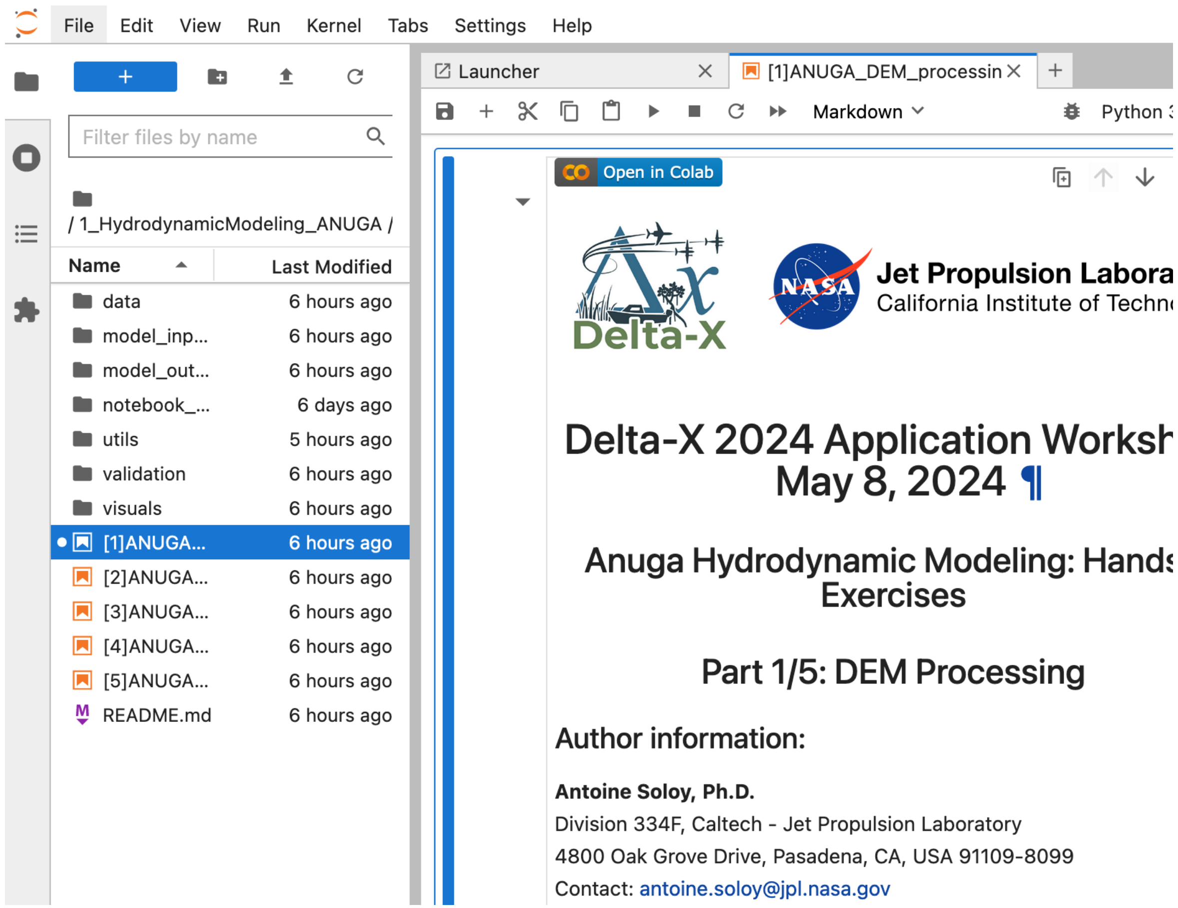
- Open a command prompt / terminal window
- Activate the new environment using
  conda activate anuga_dx
- Navigate to the unzipped archive
  cd path/to/deltax_workshop_2024/tutorials
- Open Jupyter Lab (equivalent to Jupyter Notebook)
  jupyter lab
- Wait for your web browser to open.
- **<u>If nothing happens</u>**, copy one of the url addresses from your command prompt/terminal window into a new browser page.



Jupyter Notebook / Lab (2)



When Jupyter Lab opens, navigate in the first subdirectory

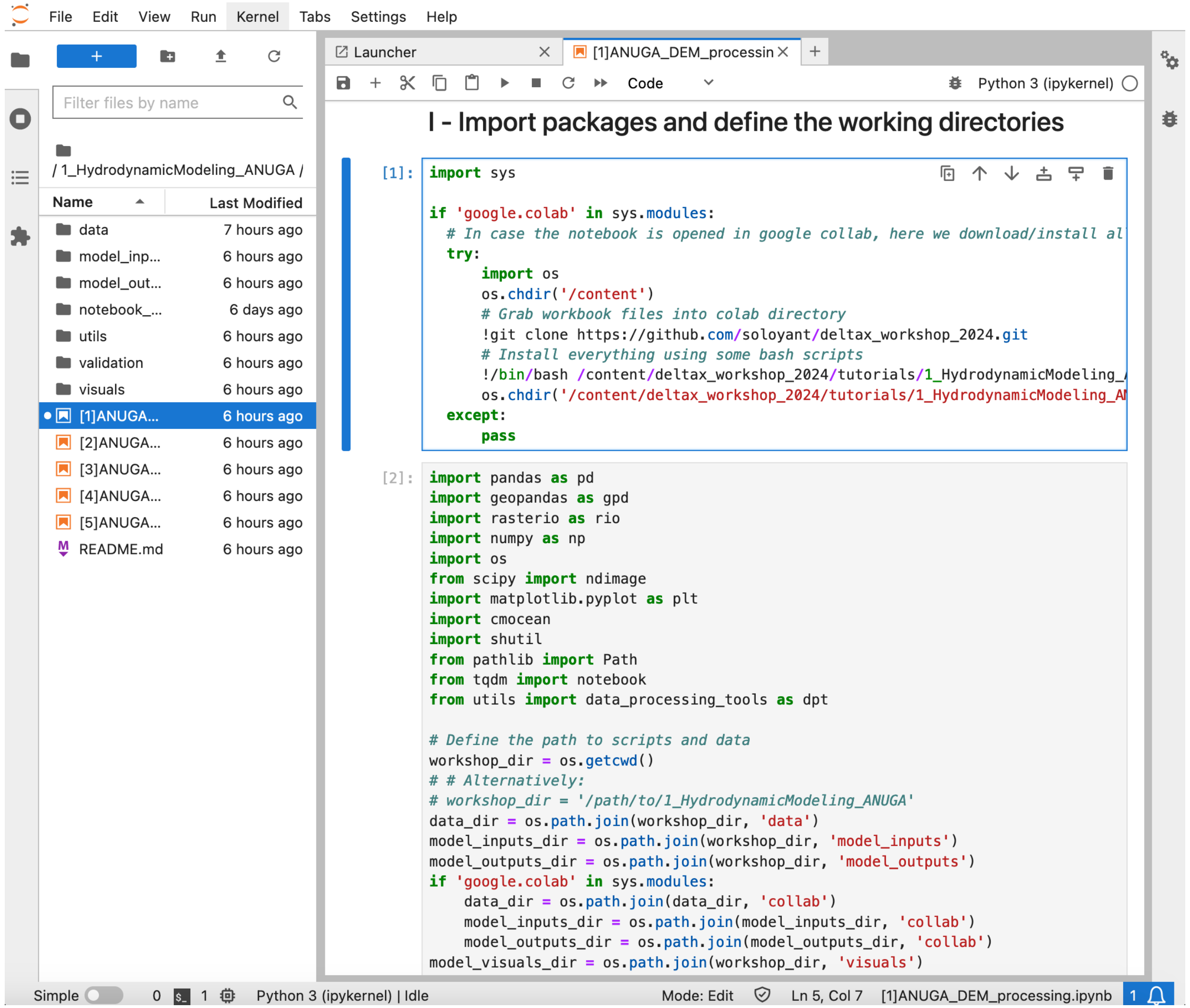


Then open the first Notebook

Jupyter Notebook / Lab (3)

How does it work ?

- Jupyter works in sequences of code cells.
- The content of one cell is read all at once, but cells can be read one by one.
- Reading a cell is done by using the “play” button at the top of the page.
- Most changes initiated by previously read instructions (i.e. created variables, imported packages, etc.) remain effective until the kernel is killed
- The script of the first workshop segment is a sequence of instructions to modify the Digital Elevation Model. Some parameters can be modified at will to customize the type/magnitude of changes
- The outputs of notebook 1 are the inputs of notebook 2, etc.



Google Collab

Alternatively, one can run the notebooks in a Collab environment:

1. On the workshop's github page, navigate to tutorials, then to 1_HydrodynamicModeling_ANUGA
2. Locate the list of 5 "Open in Collab" buttons, and hit the first one
3. Run cells as if it was a local Jupyter Notebook
   - Nb: Google Colab is an online service, it is less easy to customize the script and save results, and all modifications are erased once the page is closed.

We recommend the use a local environment with Jupyter Lab or Notebook to follow this workshop, if possible.

https://github.com/ornldaac/deltax_workshop_2024/tree/main/tutorials/1_HydrodynamicModeling_ANUGA