Understanding hydrodynamics in the Western Scheldt Estuary

OCS 4001 FINAL PROJECT

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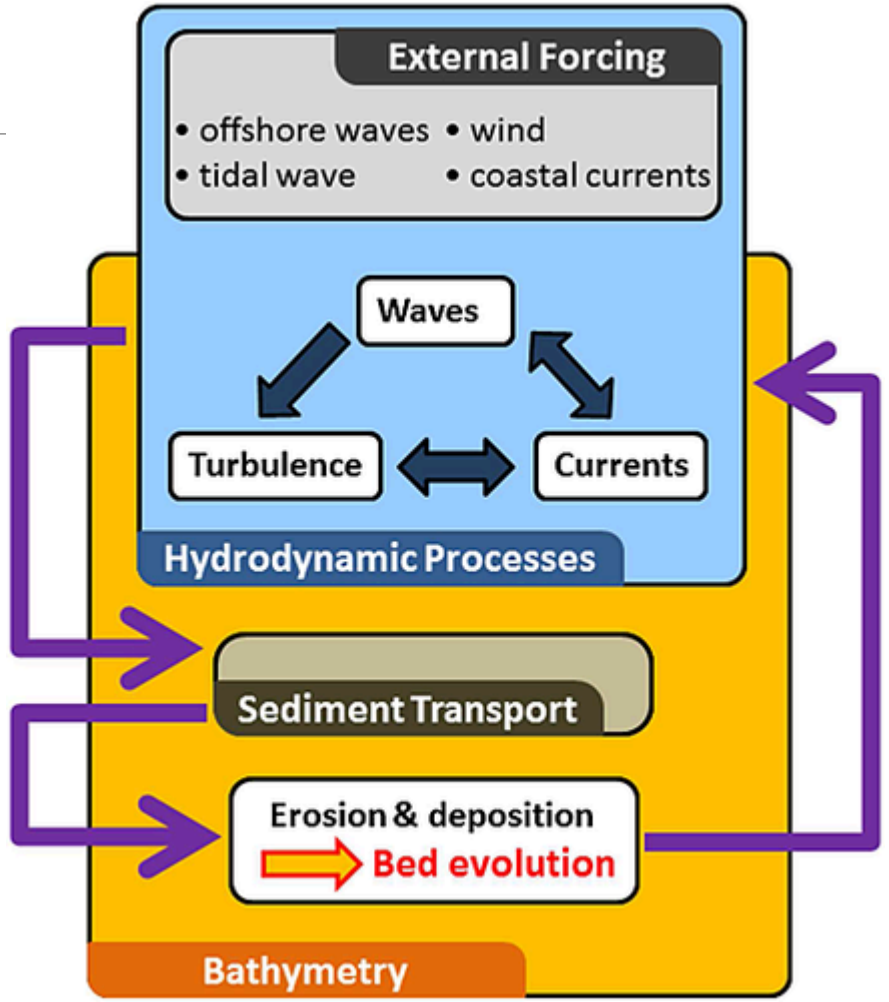
Background

- Coastal environments have many different hydrologic forcings impacting water volume and movement
  - Tides, waves, rivers, currents, rain….
- Hydrodynamics in estuarine environments have important implications for…
  - Coastal infrastructure – 25% of Earth's population is on the coast (Komar et al. 1998)
  - Ecosystem
  - Pollution transport
  - Sediment transport

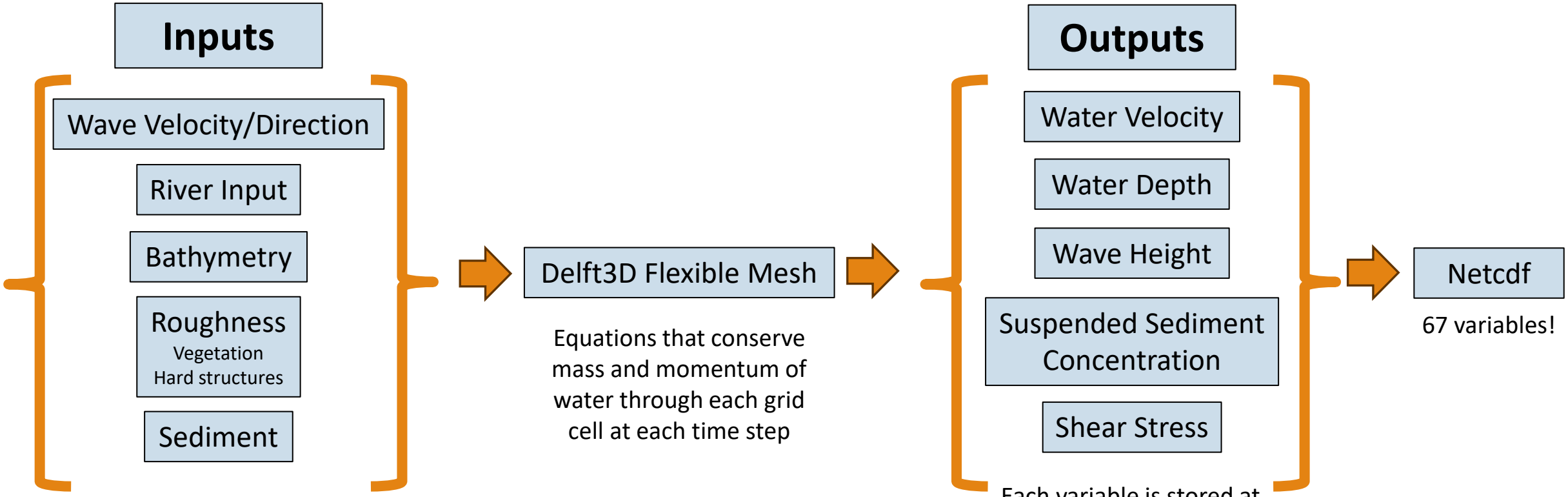


(Ribas et al. 2015)

Objectives

1. Use a Delft3D-FM hydro-morphodynamic model to understand how water moves throughout the Western Scheldt Estuary
   - Focus on water height and velocity fluctuations
2. Make clear and effective figures in Python to convey valuable information
   - Figures primarily focused on presentation quality, but also figures for papers

What is Delft3D?



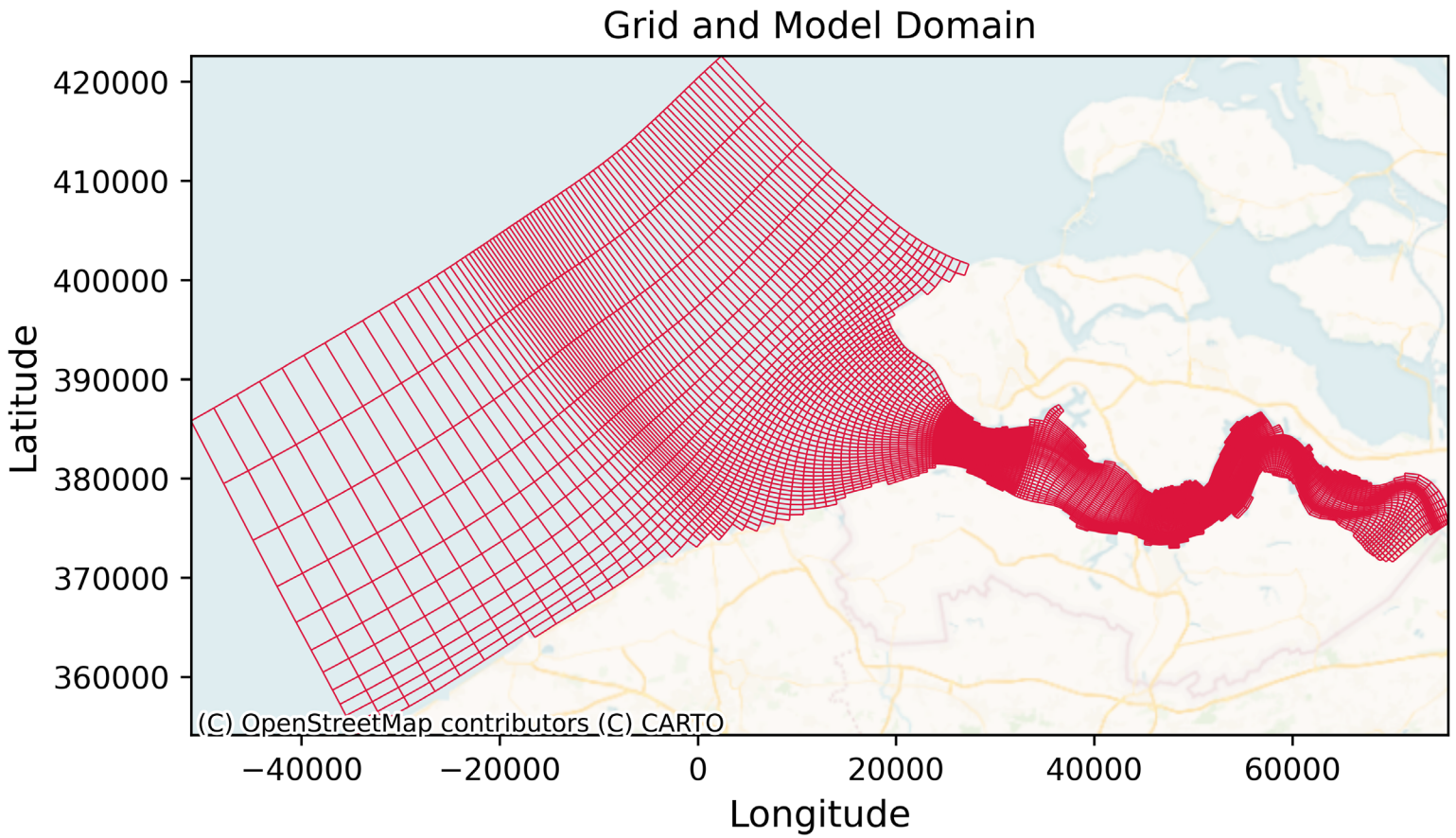
*Note: very much oversimplified

(Lesser et al. 2004)

Model Grid

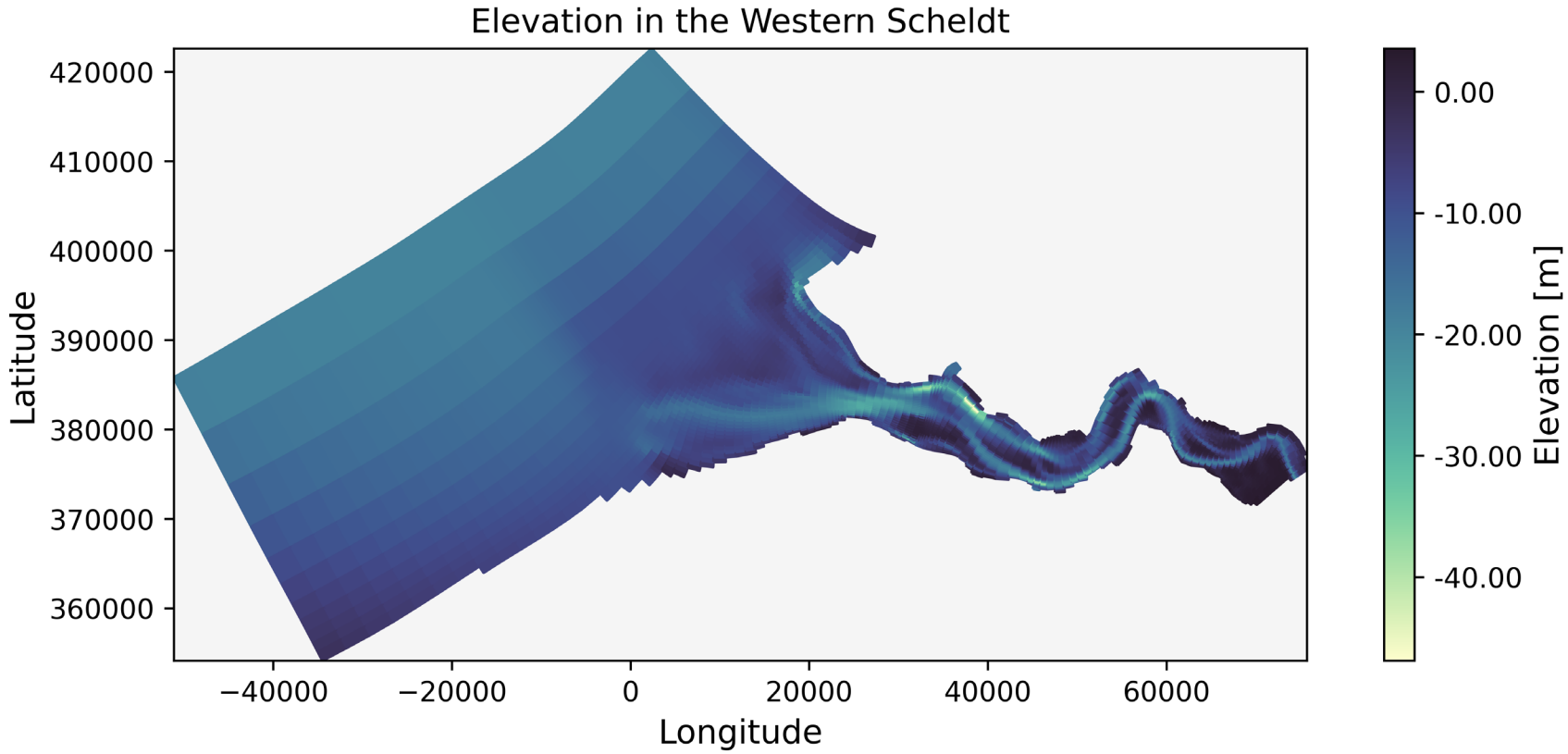
- Unstructured grid with 36,942,084 cells

- 3-day simulation with hourly output for total of 72 output files
  - Semi-diurnal system (2 high tides and 2 low tides each day)



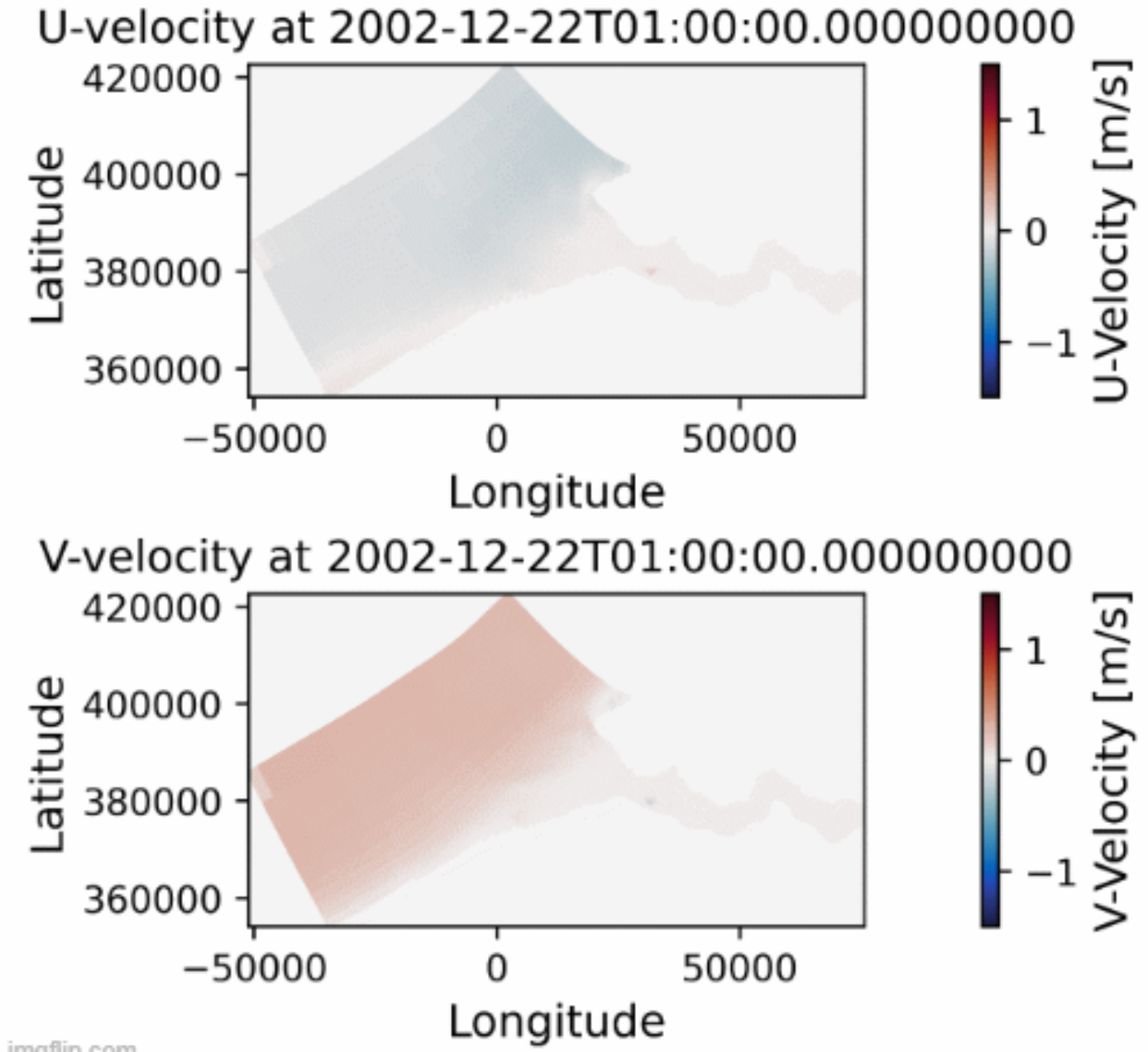
Bathymetry

- Maximum elevation:
  - 3.54 m above MSL
- Minimum elevation:
  - 46.89 m below MSL
- Dredged navigation channel to access the port of Antwerp, Belgium



Velocity through the estuary

Note! Check the quality of the gifmaker!

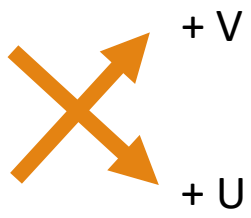


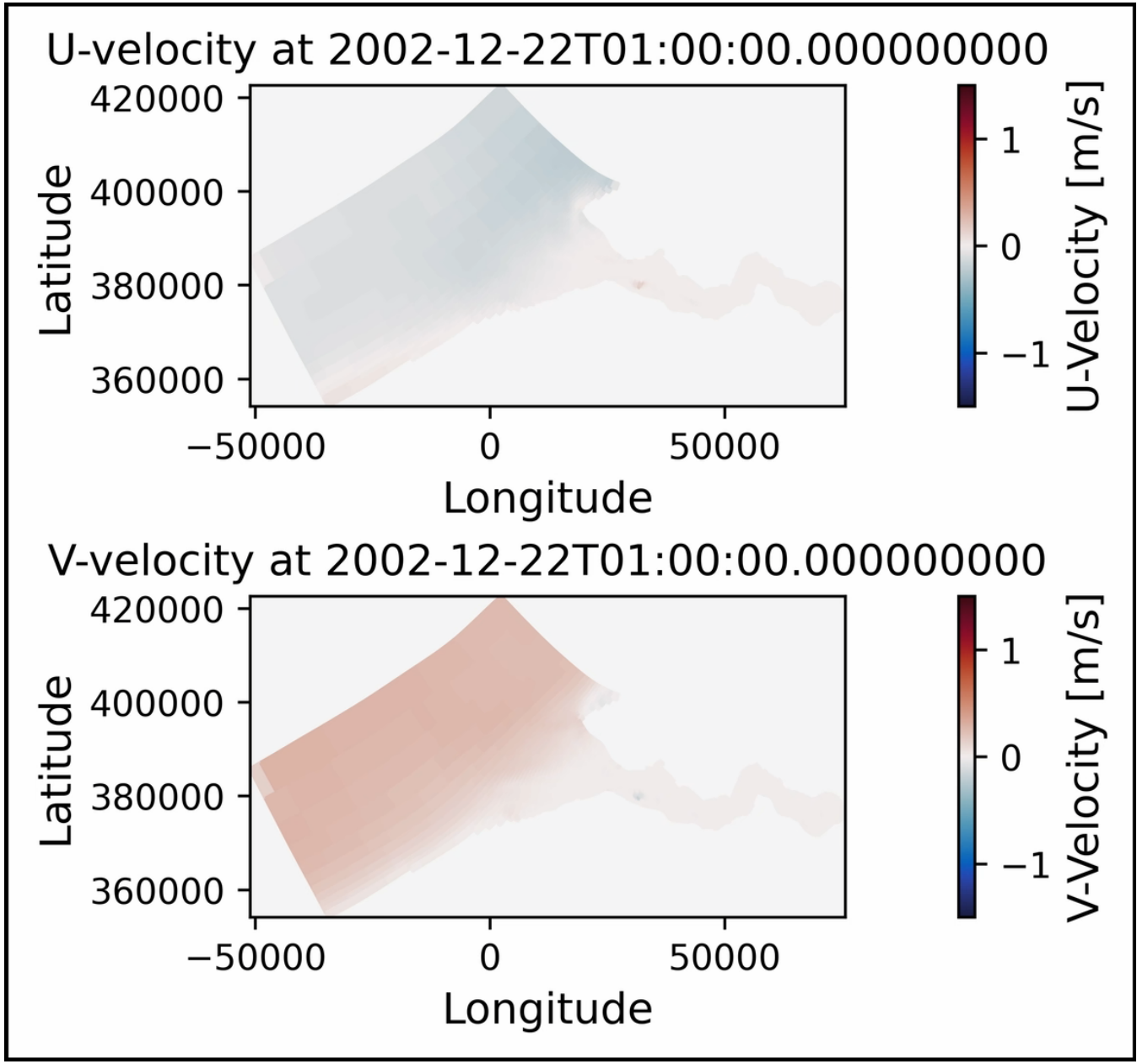
Velocity in U- and V- directions

- Direction of positive and negative velocities are based on how grid is defined in model set-up

- U velocity magnitudes are much higher than V velocity due to the shape of the estuary

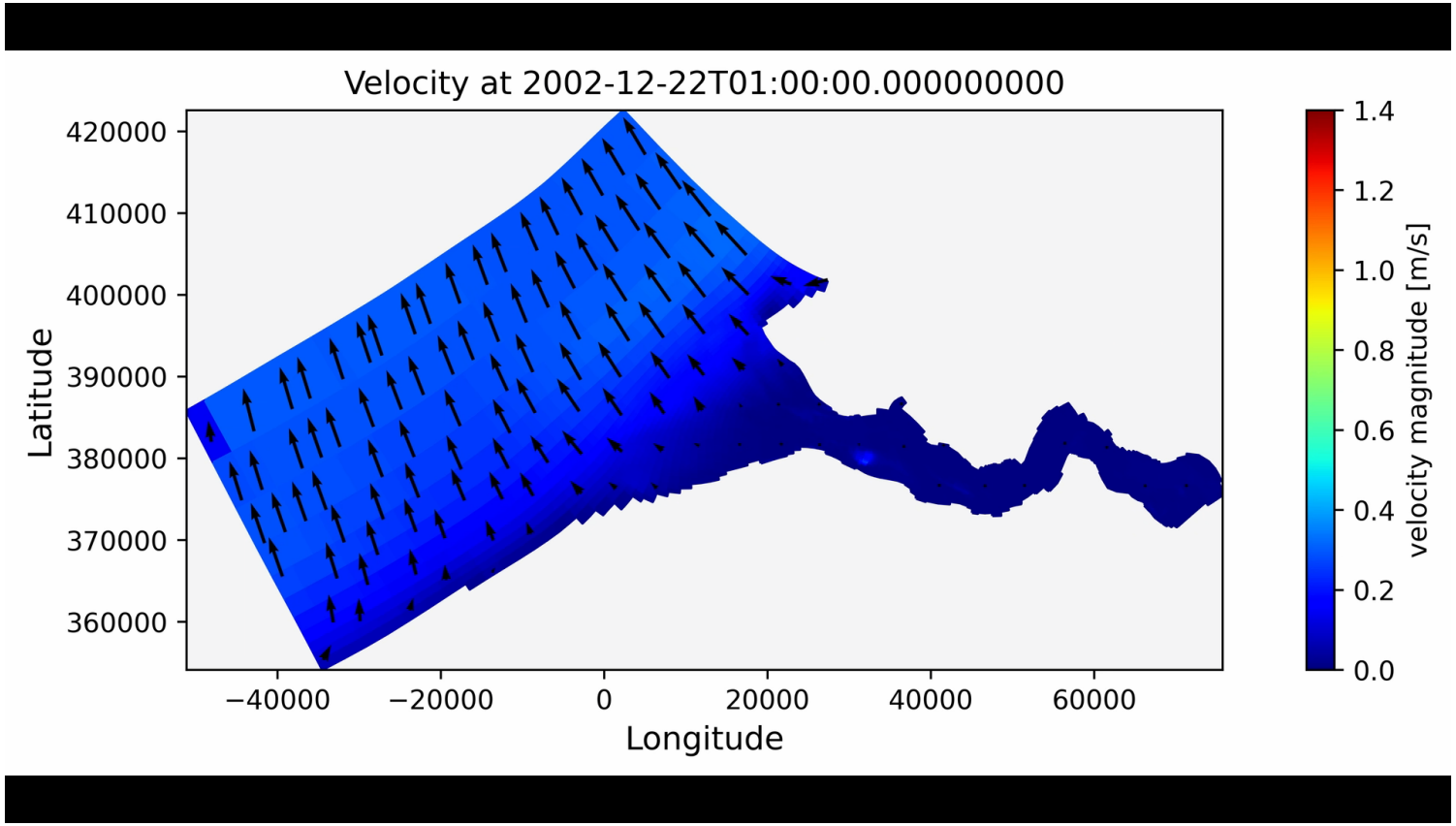
- U velocities are positive as the tide comes into the estuary, and negative as the tide leaves



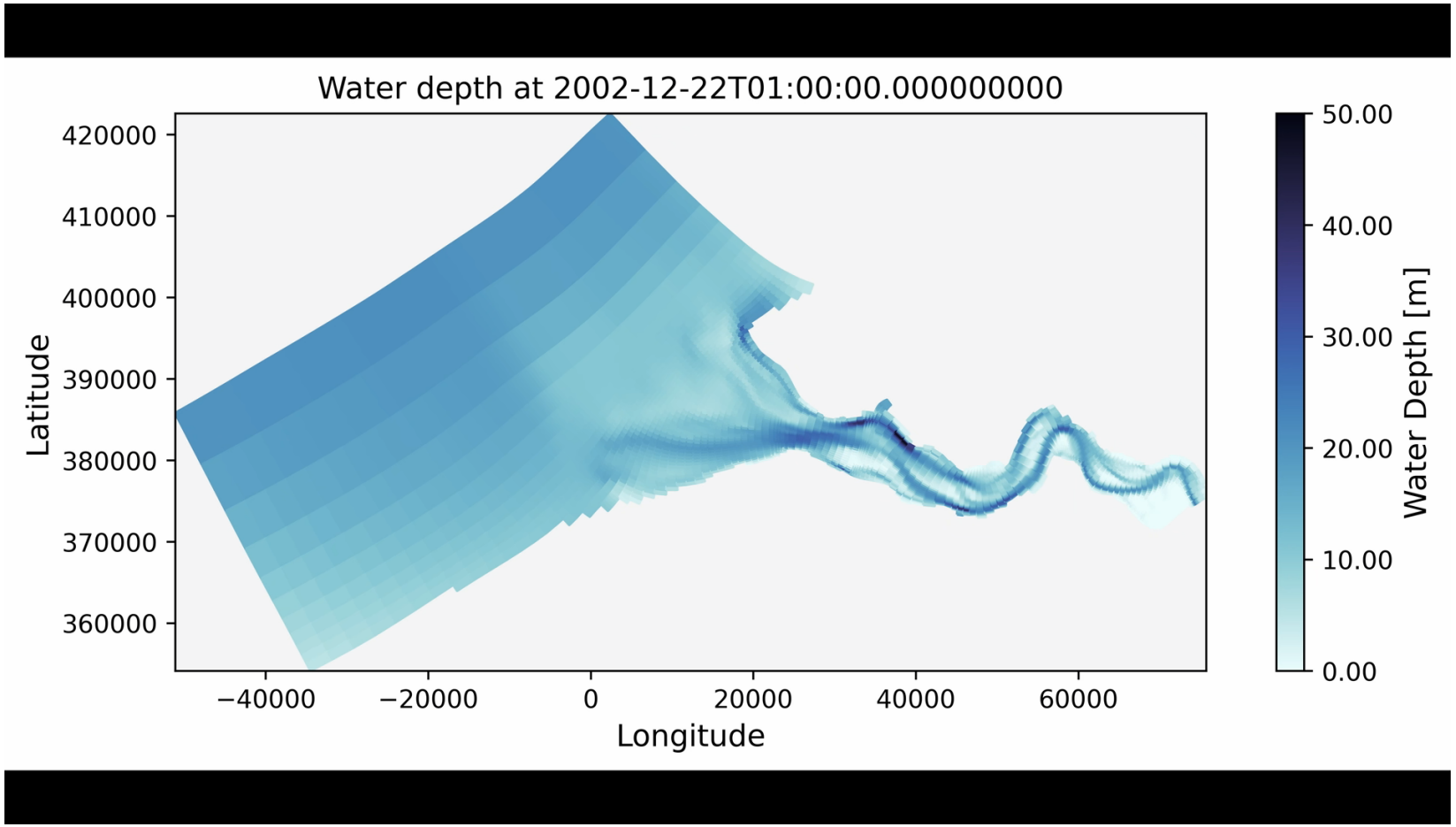


Velocity magnitude and vectors

- Quiver plot better shows velocity in 2D space



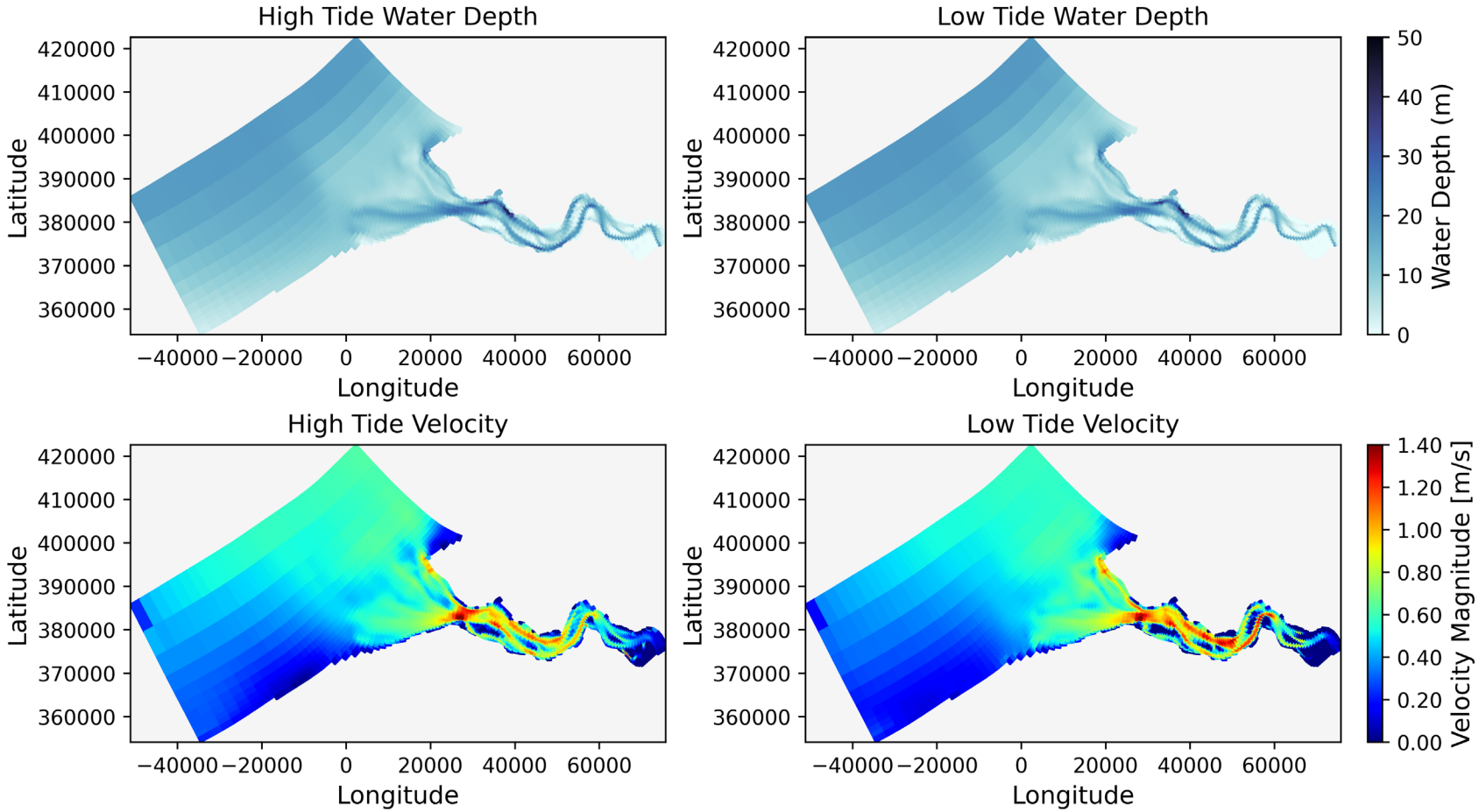
Water Depth


Water depth at 2002-12-22T01:00:00.000000000
Latitude
420000
410000
400000
390000
380000
370000
360000
−40000
−20000
0
20000
40000
60000
Longitude
50.00
40.00
30.00
20.00
10.00
0.00
Water Depth [m]

How are water level and velocity related?

- Scaling of water depth makes smaller patterns in water depth difficult to discern

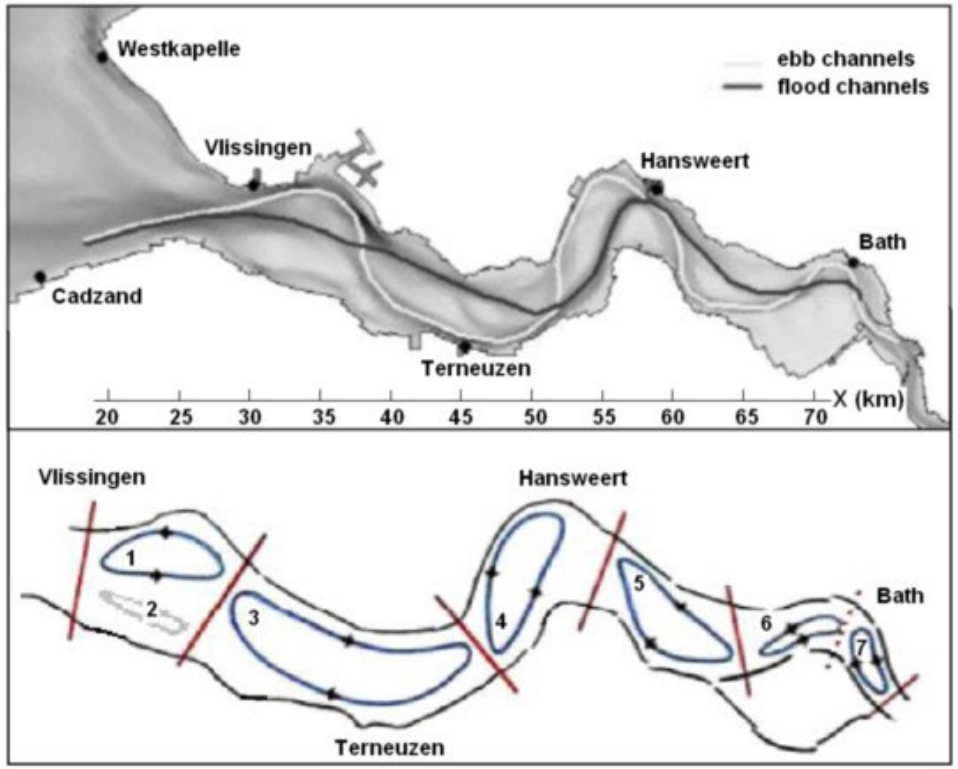
- Difference in water velocity at high versus low tide

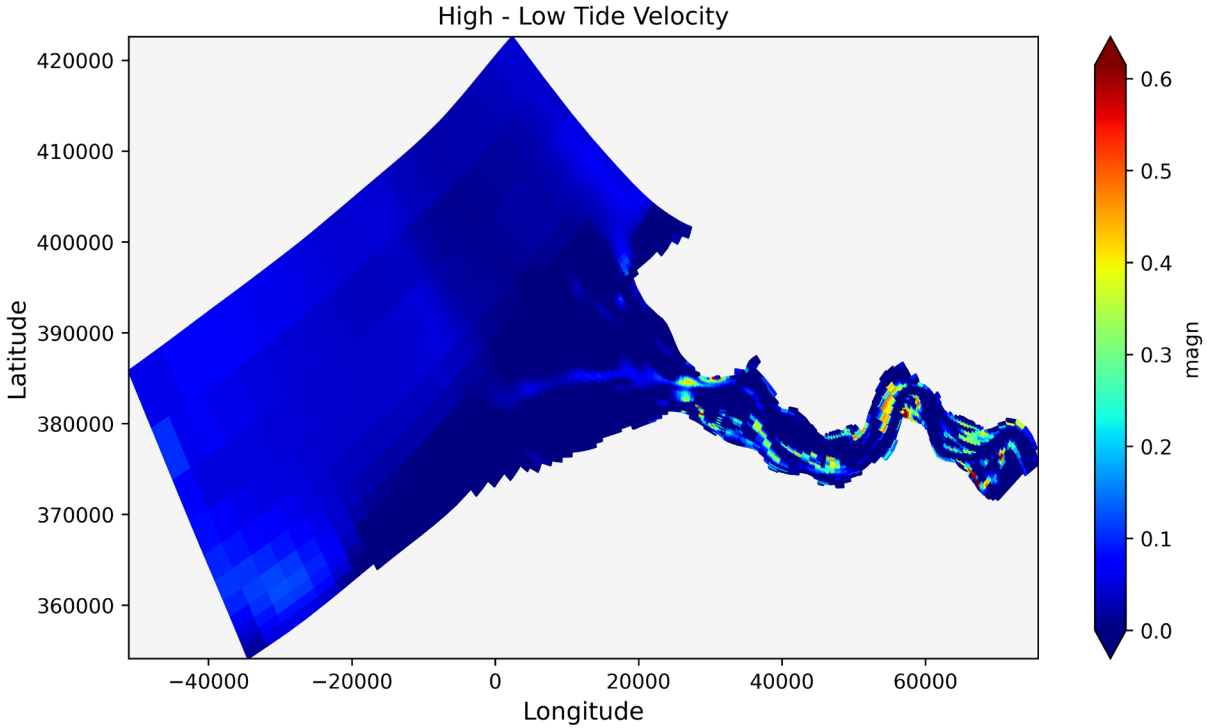


Spatial Velocity Variation

Flood tide = flood coming **in**

Ebb tide = flood going **out**



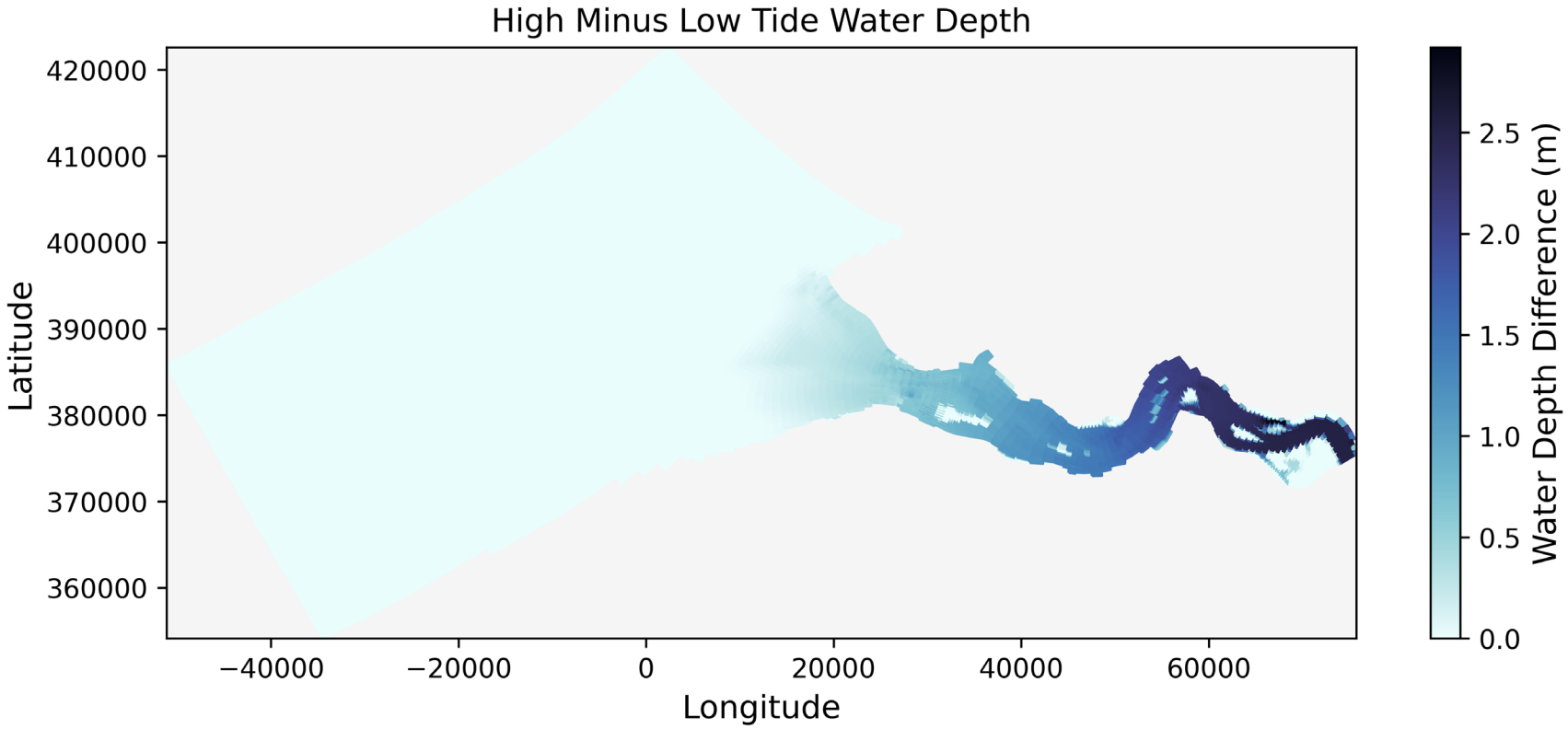


Highest difference is in the shallower regions instead of the dredged channel

Tidal Range

- Tidal range: the vertical difference in water height between high and low tide

- Tidal range up to 3 meters in the upper reaches of the Western Scheldt



Conclusions

1. The deepest parts of the estuary that correspond to dredging channels to the port have the highest water velocity magnitude

2. Water velocity at high and low tide differ, which shows tidal asymmetry
   - Biggest differences are located on the shallower platform versus the dredged channel
   - Supported by Bolle et al. 2010

3. The Western Scheldt has a tidal range of up to 3 meters that increases moving away from the ocean
   - Tidal funneling!

A. Make sure any gif rendering programs keep image quality
   - Want to make gif in python in the future

B. matplotlib is HARD

Sources

- Bolle, A., Bing Wang, Z., Amos, C., & De Ronde, J. (2010). The influence of changes in tidal asymmetry on residual sediment transport in the Western scheldt. *Continental Shelf Research*, *30*(8), 871–882. https://doi.org/10.1016/j.csr.2010.03.001
- Komar, P. D. (1998), *Beach Processes and Sedimentation*, 2nd ed., Prentice Hall, Englewood Cliffs, N. J.
- Lesser, G., Roelvink, J. v., Van Kester, J., & Stelling, G. (2004). Development and validation of a three-dimensional morphological model. *Coastal engineering*, 51(8-9), 883–915.
- Ribas, F., Falqués, A., de Swart, H. E., Dodd, N., Garnier, R., & Calvete, D. (2015). Understanding coastal morphodynamic patterns from depth-averaged sediment concentration. *Reviews of Geophysics,* 53(2), 362–410. https://doi.org/10.1002/2014rg000457