hidrográfico marinha·portugal
3.as JORNADAS DE ENGENHARIA HIDROGRÁFICA
24, 25 e 26 de junho de 2014

Bathymetry interpolation for hydrodynamic modeling

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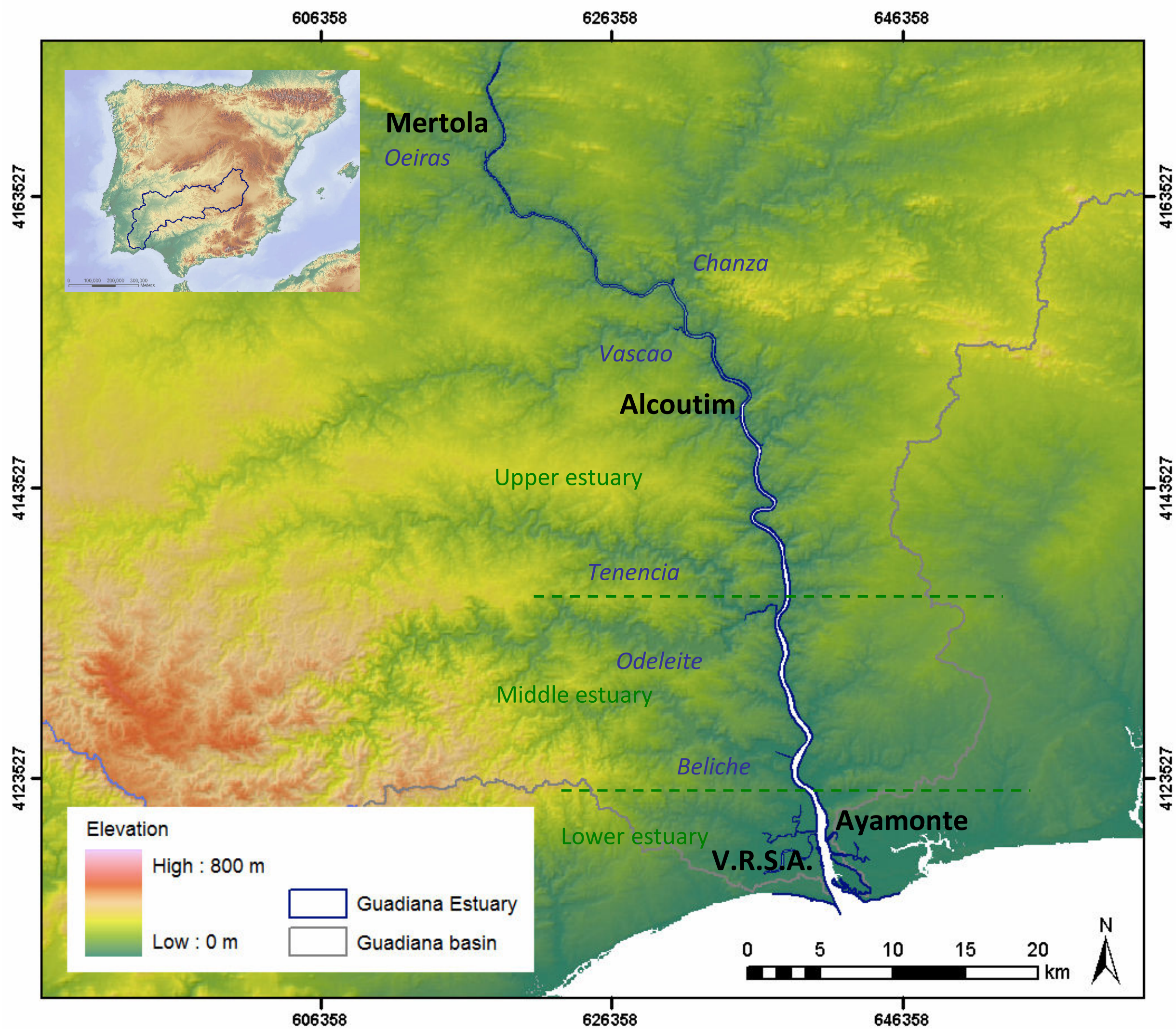
Contents

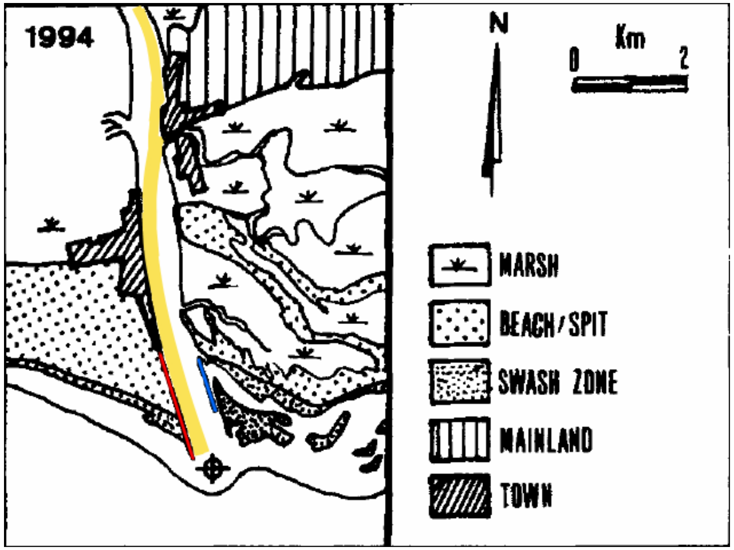
GIS and modeling in literature

- Integrating GIS and numerical models: a simple user-friendly GIS interface for visualization and basic necessary pre-processing
- Almost no works on using advanced GIS tools for improving model accuracy proved by real measurements
- There is a proposed method of advanced bathymetry interpolation for improving model accuracy but without real model runs

Guadiana Estuary



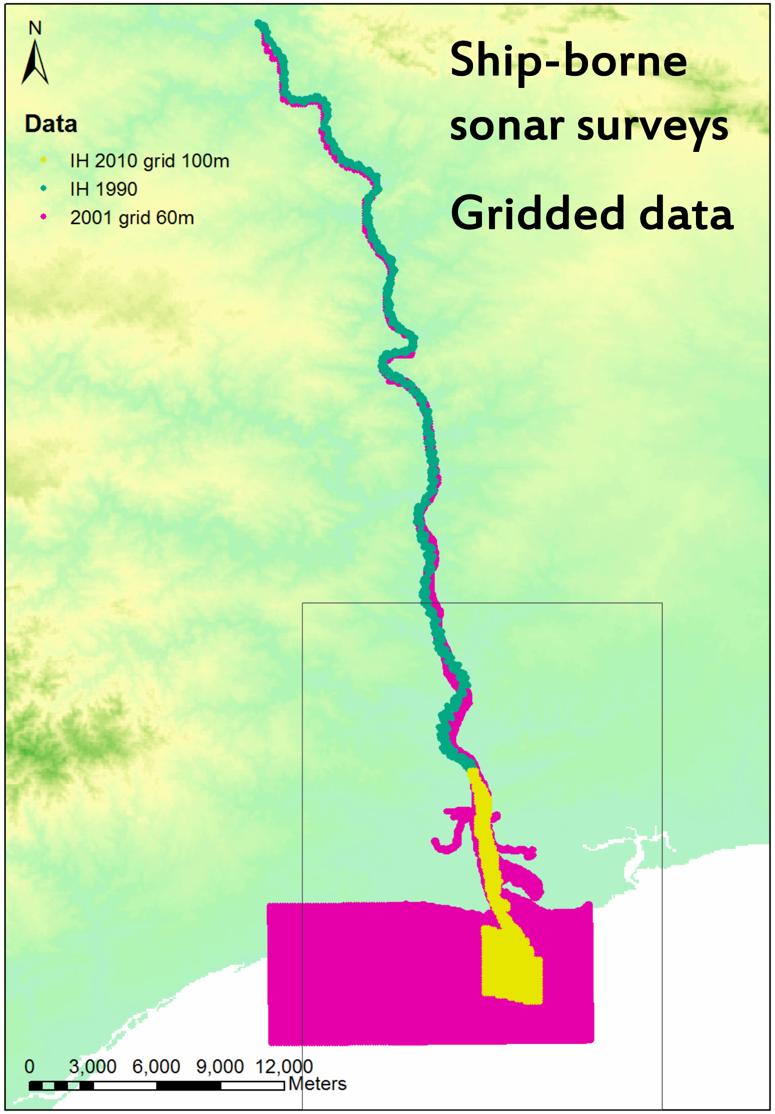
Guadiana Estuary characteristics

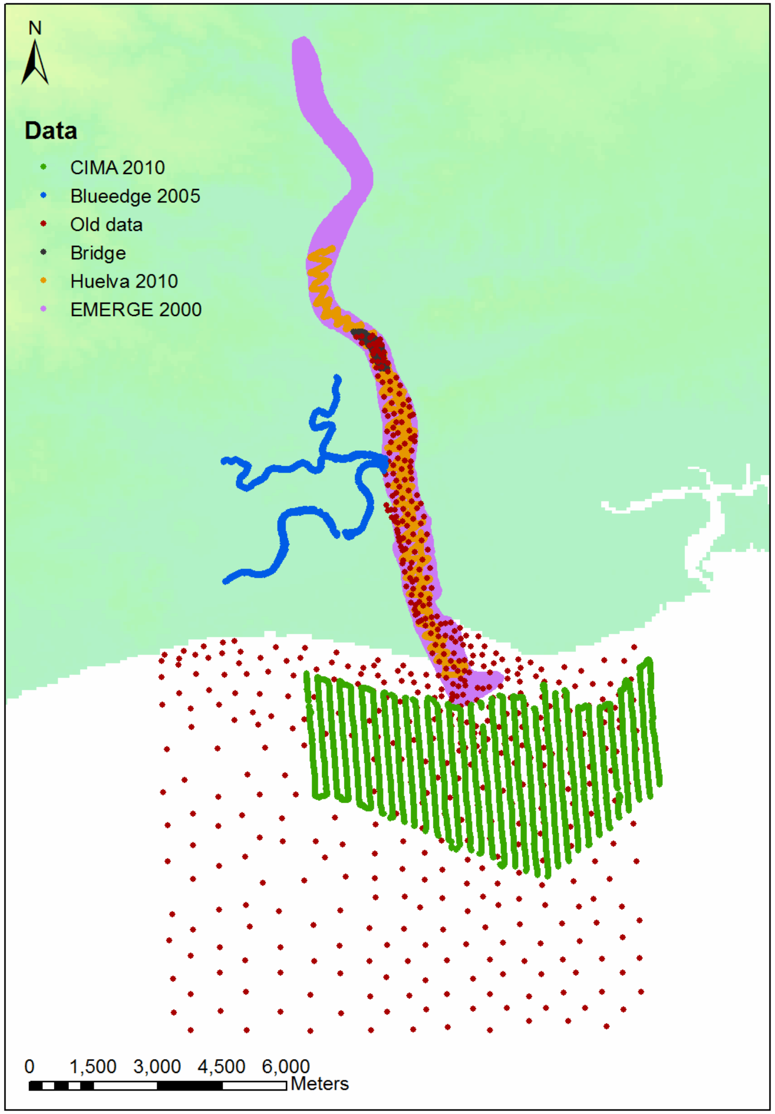


- Stratification conditions

	Spring tide	Neap tide
Low river discharge	well-mixed	partly stratified
High river discharge	highly stratified	highly stratified

Available bathymetry data





MOHID water modeling system

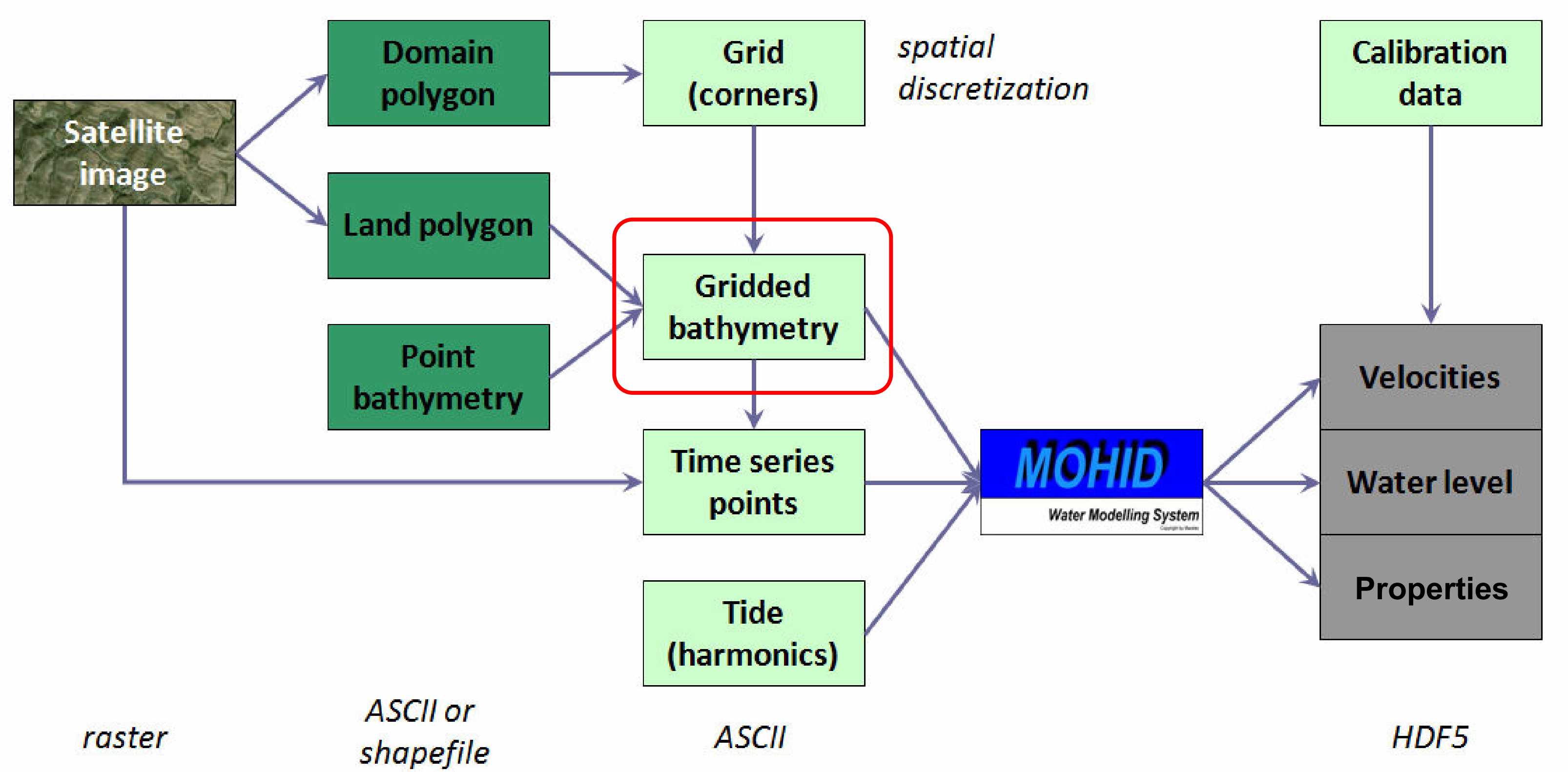
- Developed in Maretec, IST, Lisbon
- Finite volume discretization method
- Solves the transport equations in the integral form in the control volumes (the grid cells)
- Geometric parameters of the cells are included in the equations (the cell can have any shape)

MOHID GIS

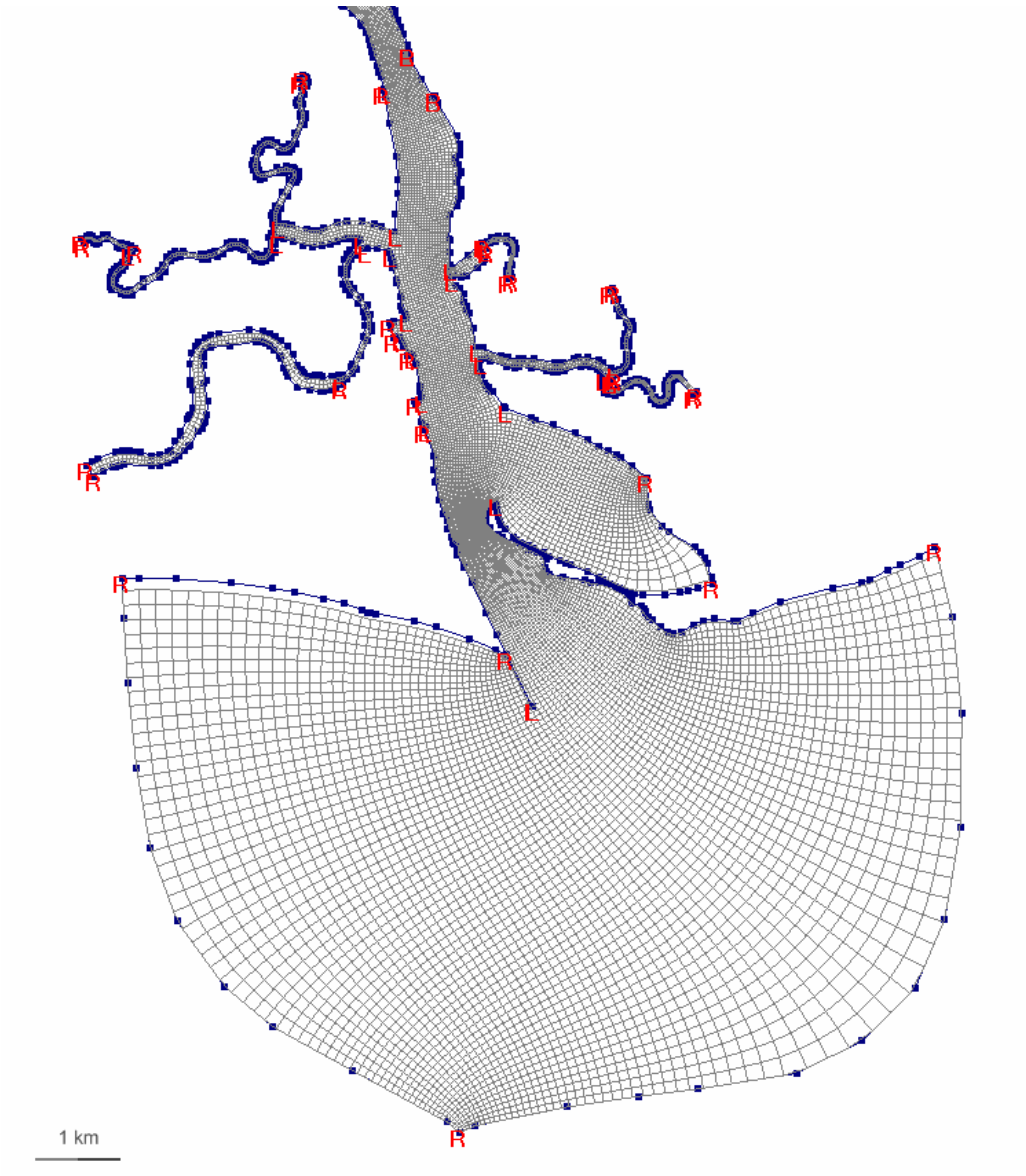
- GUI for simple basic pre- and post-processing
- It handles spatial and temporal data in specific MOHID format
  - generates curvilinear grids
  - visualizes spatio-temporal outputs
  - creates and edits vector data
  - displays georeferenced images
  - interpolates data into a grid (TIN)
- It requires all the data to be in the same coordinate system

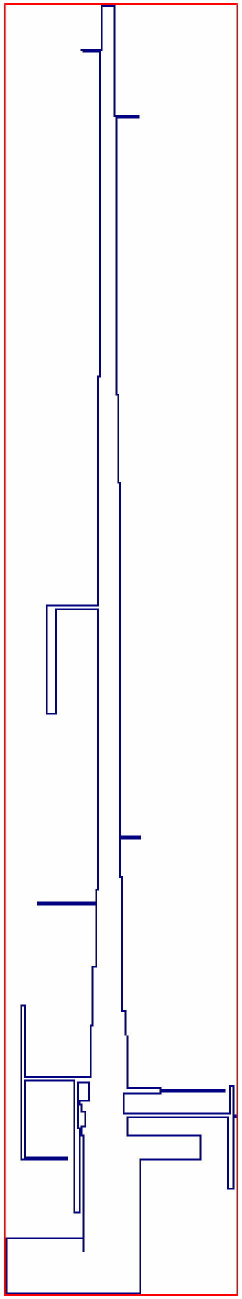
Model geospatial data

- The key input – gridded bathymetry – interpolation of points into the grid cells



Curvilinear grid



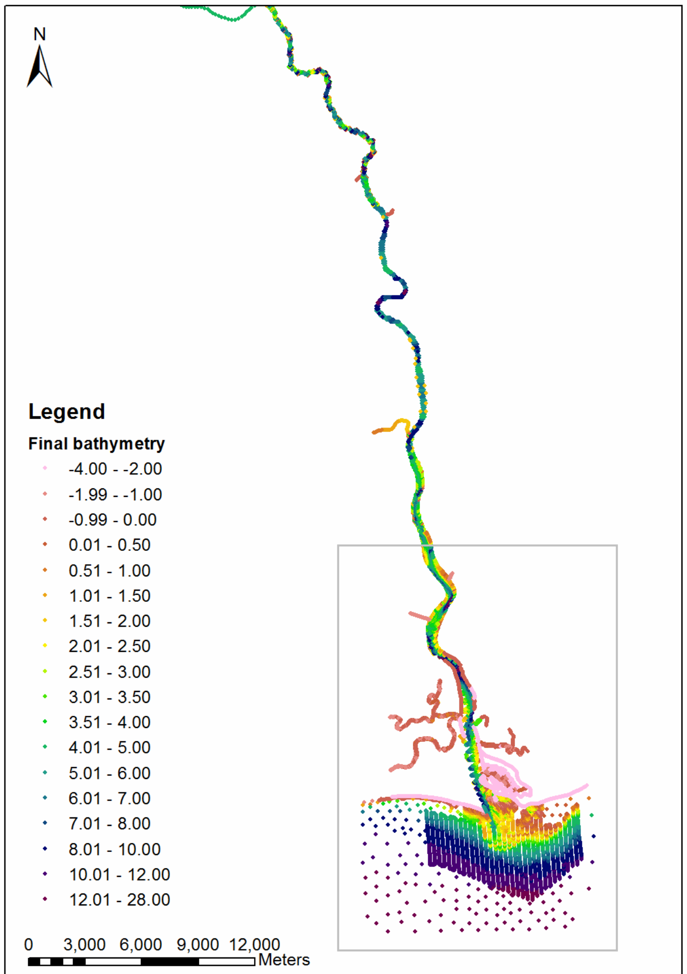


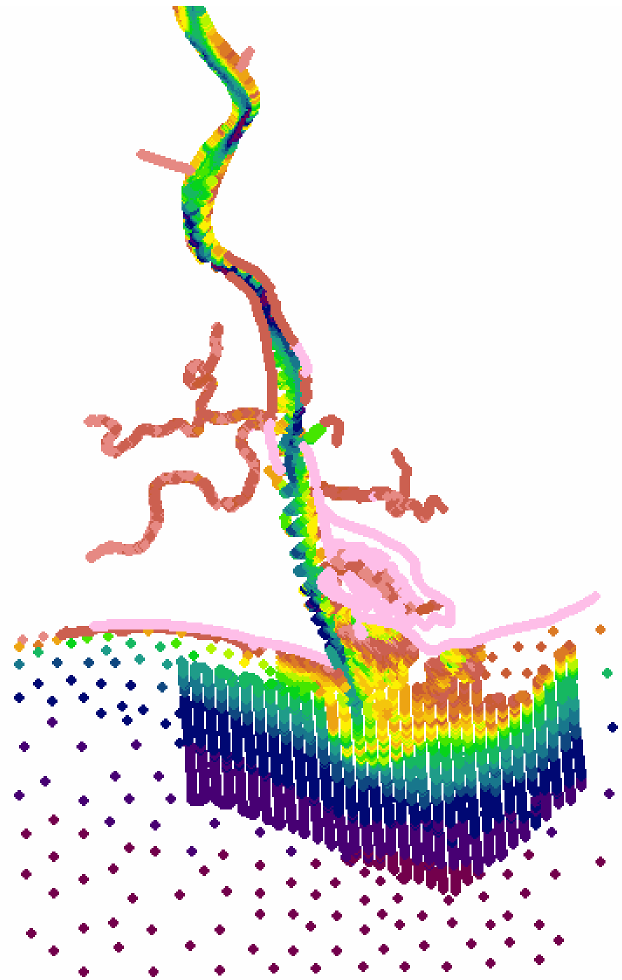
Preparing the model spatial inputs

- The data were transformed into one coordinate system and converted into shapefiles.
- Too dense data points were clustered and joined into one dataset
- The missing bathymetry data in shallow areas were estimated from an orthophoto
- The shoreline was extracted from the orthophoto by image classification based on PCA of the image bands
- The points along the shoreline at the lower estuary were added with 0 depth value

The final bathymetry dataset

- All data joined together



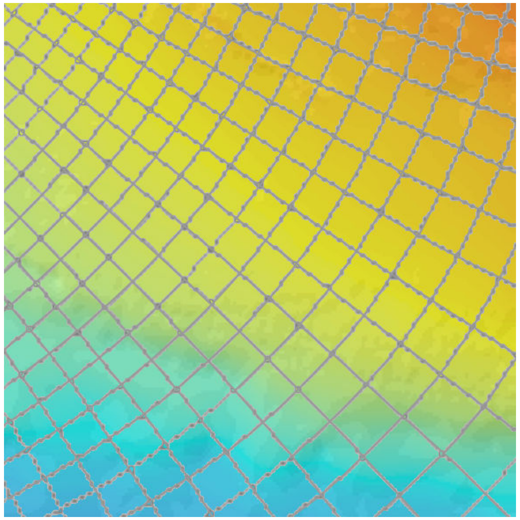


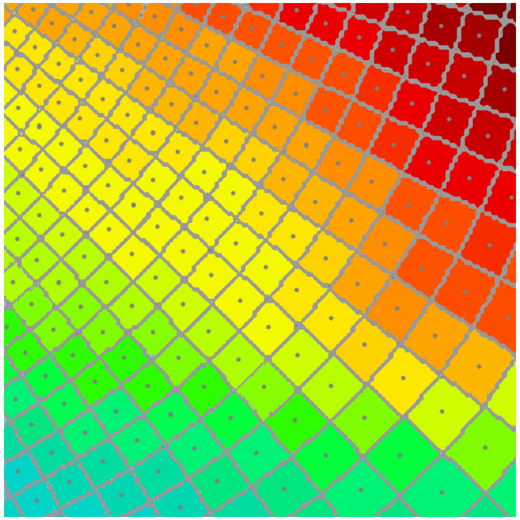
Bathymetry interpolation methods

- TIN (linear) – the most common
- Natural Neighbor
- IDW (Inverse distance weighting)
- Spline with tension (Minimum curvature)
- Kriging – geostatistical method, proved to be very accurate
- ANUDEM (included as Topo to Raster method in ArcGIS) – developed for real ground surfaces shaped by water

Bathymetry interpolation

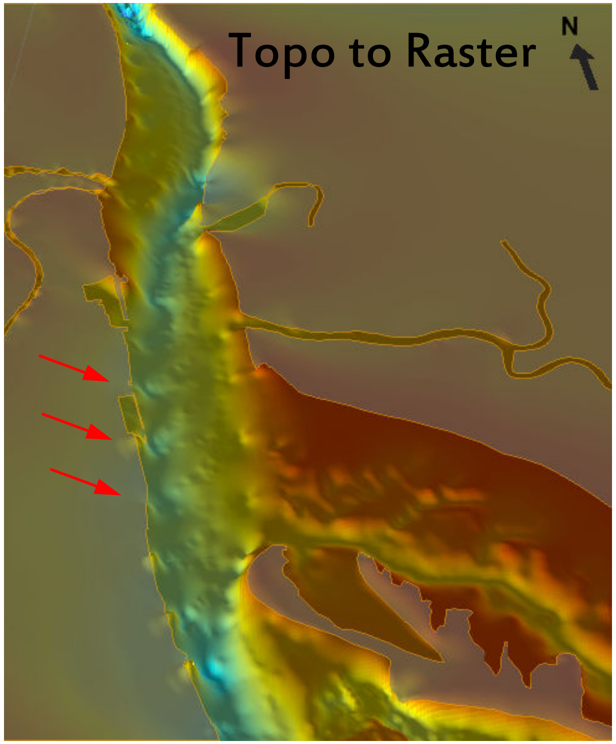
- Interpolated rasters (cell size 5 m) were overlaid by the curvilinear grid polygons
- Zonal statistics – average values of raster cells inside each curvilinear cell
- Averages attached to the curvilinear cell centers and imported into MOHID as model input bathymetries

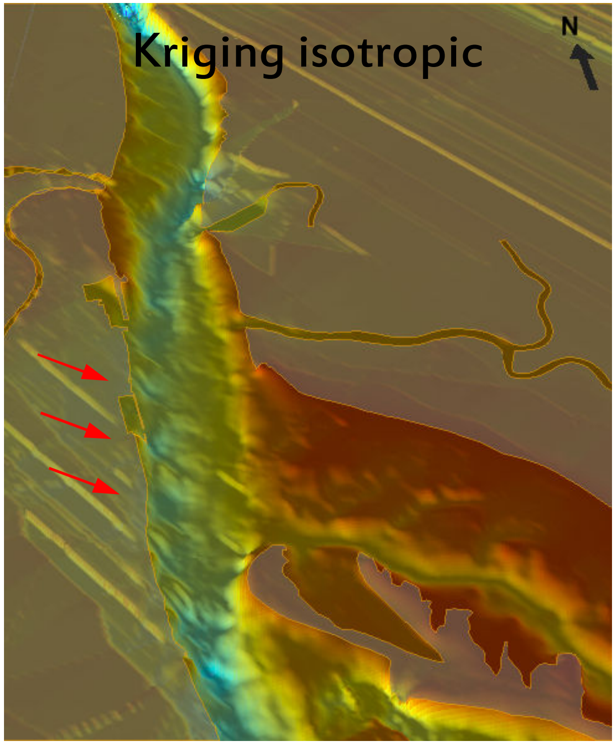




Bathymetry interpolation

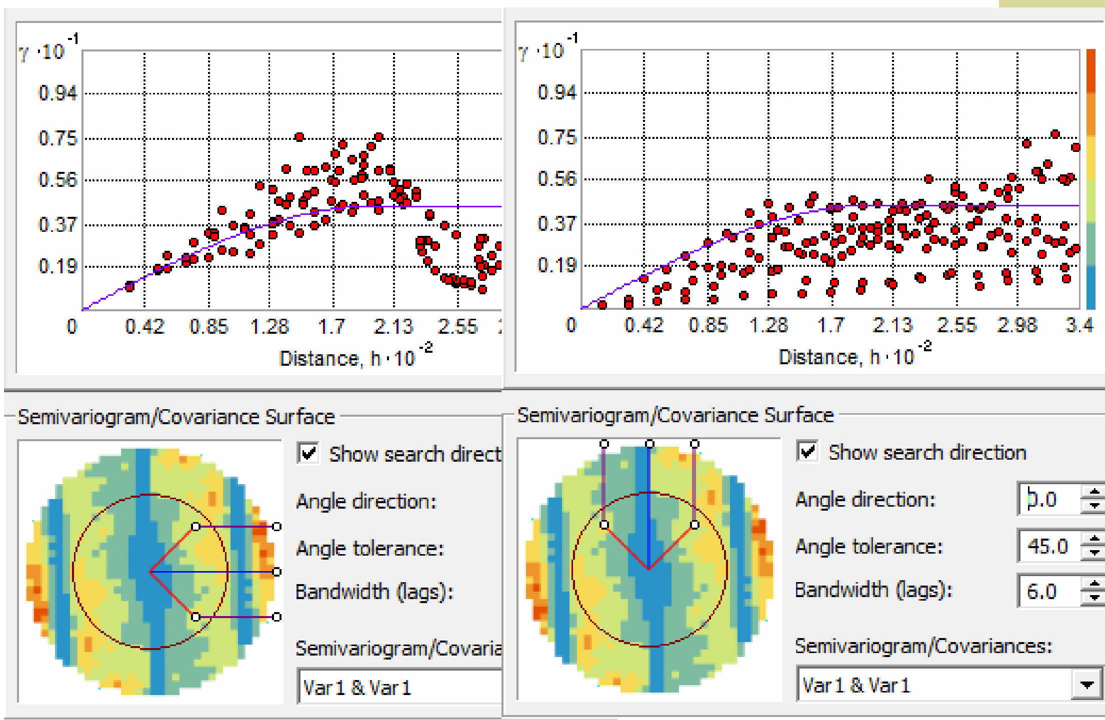
- IDW, TIN and Natural Neighbor interpolations showed unrealistic results.
- Minimum Curvature, Kriging, and Topo to Raster produced better results, but …

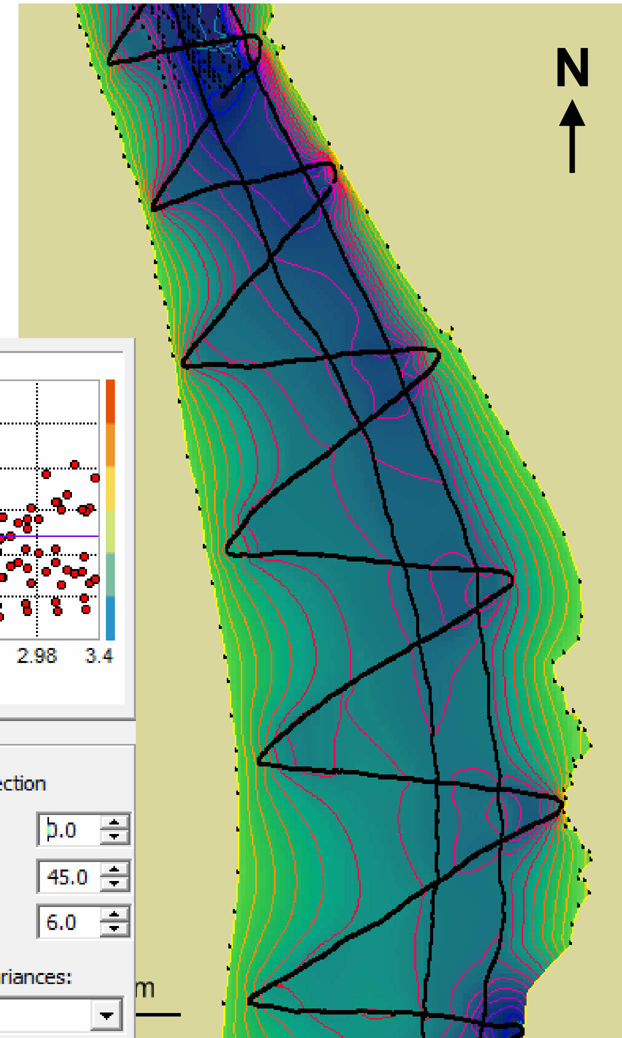




Anisotropy N-S

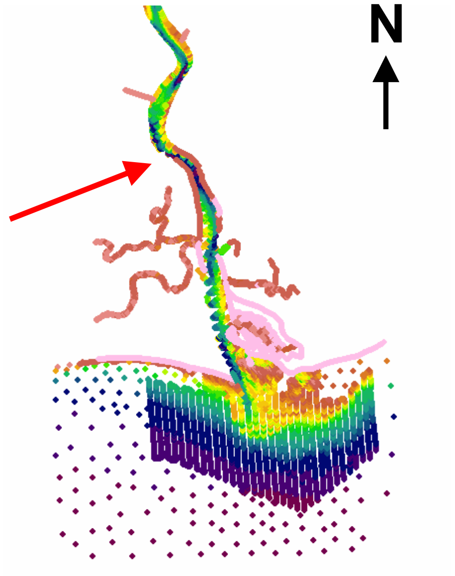
- Small gradient in along-channel direction, big gradient across

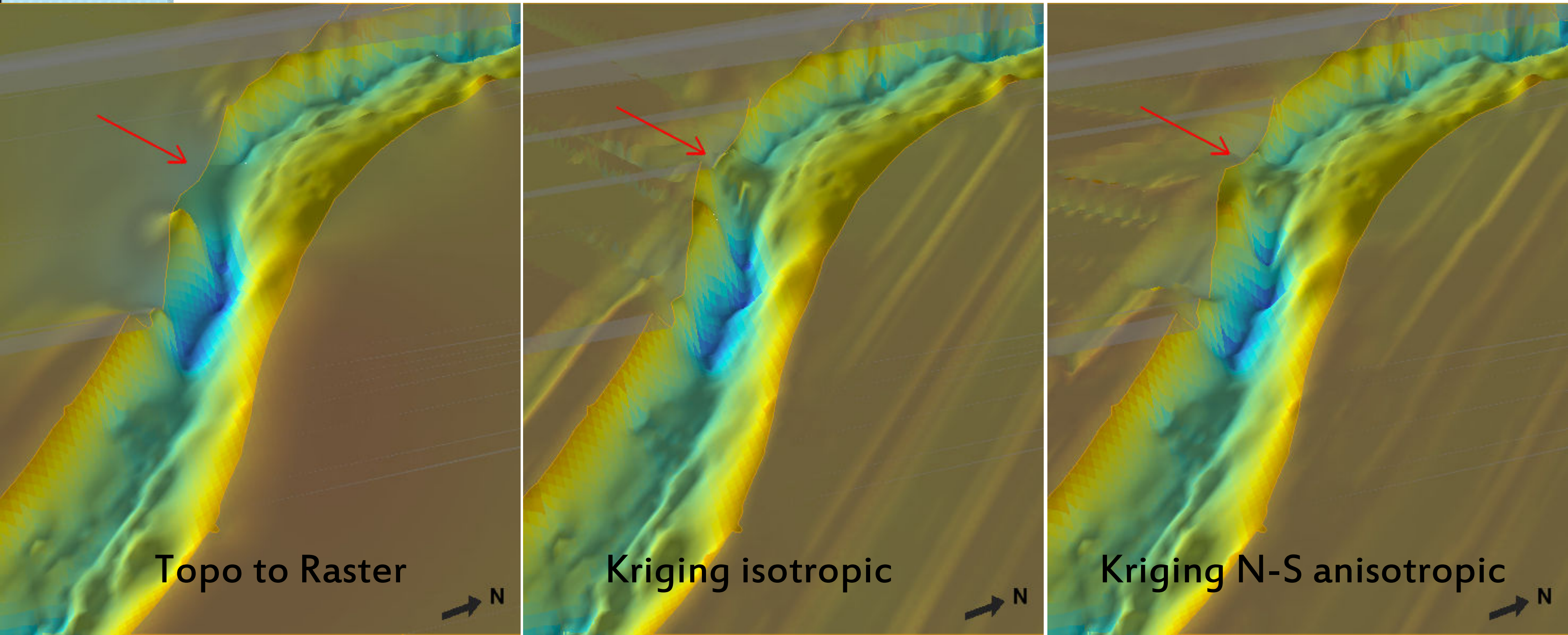




Variable anisotropy

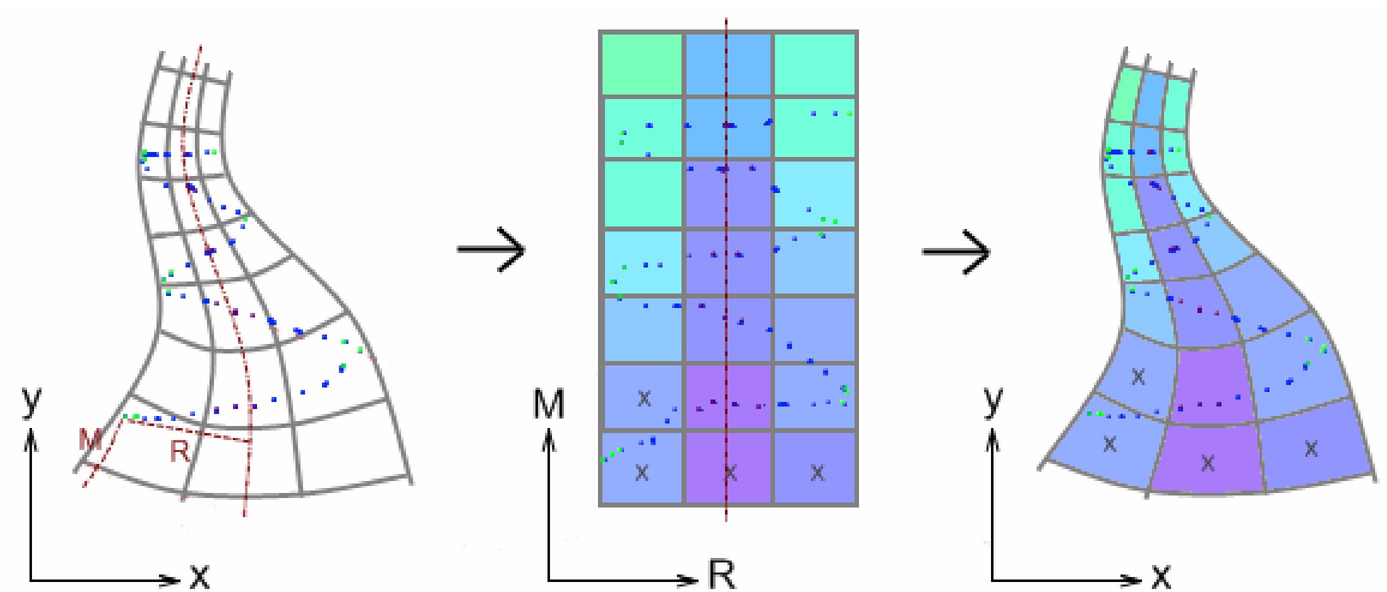
- Anisotropy of river bottom is variable and follows the river centerline (the thalweg)





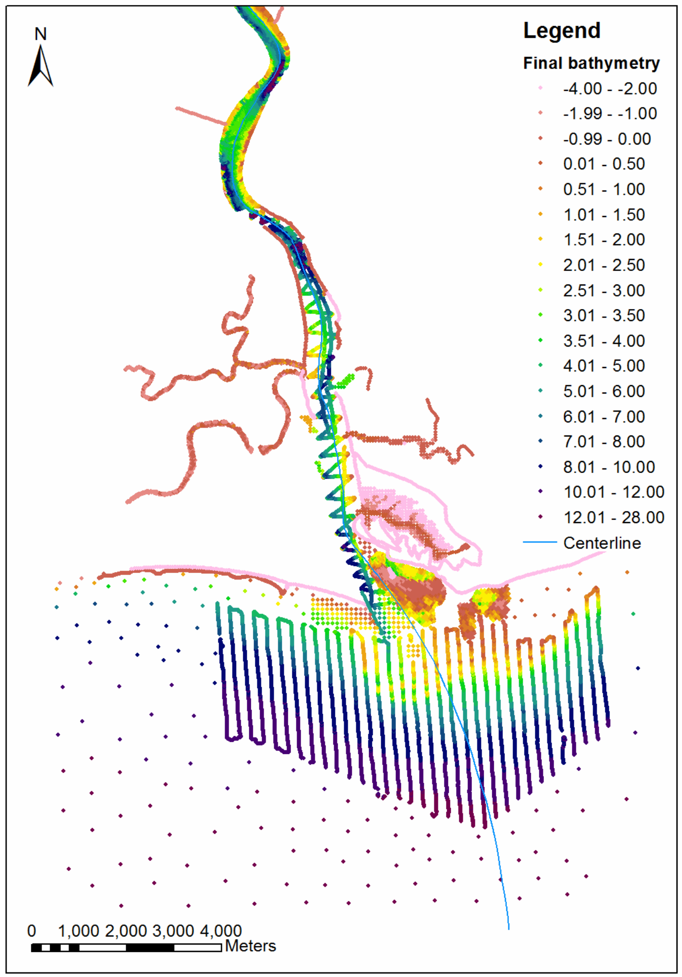
Along-channel coordinates

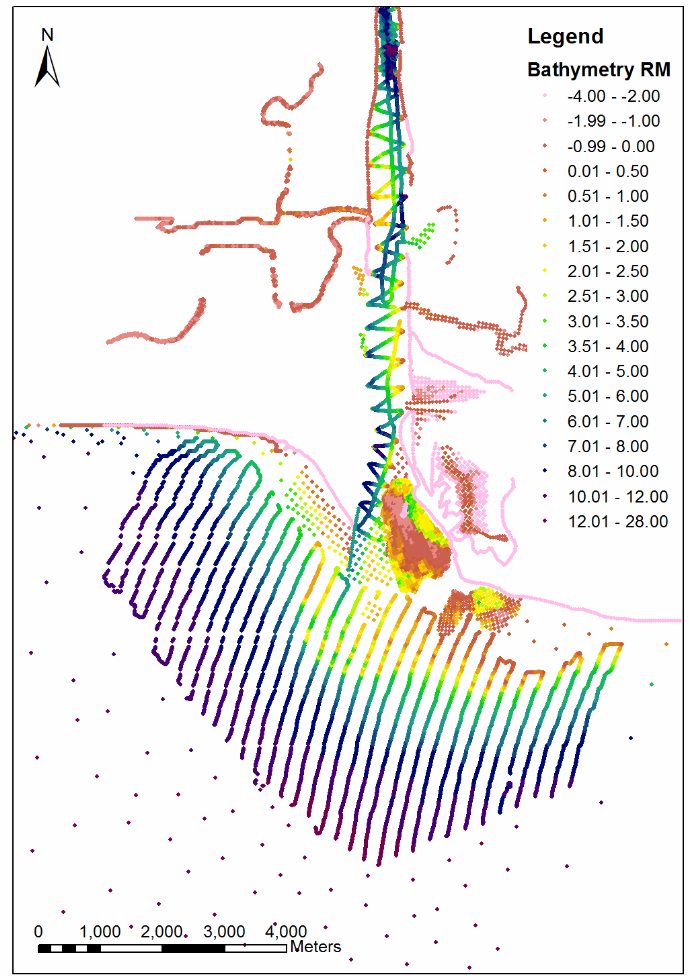
- Transforming the Cartesian coordinates (x,y) into R(x,y) and M(x,y) coordinates
- M is the distance along the river centerline, and R is the distance from the centerline
- Back-transformation is too complicated for GIS



Along-channel coordinates

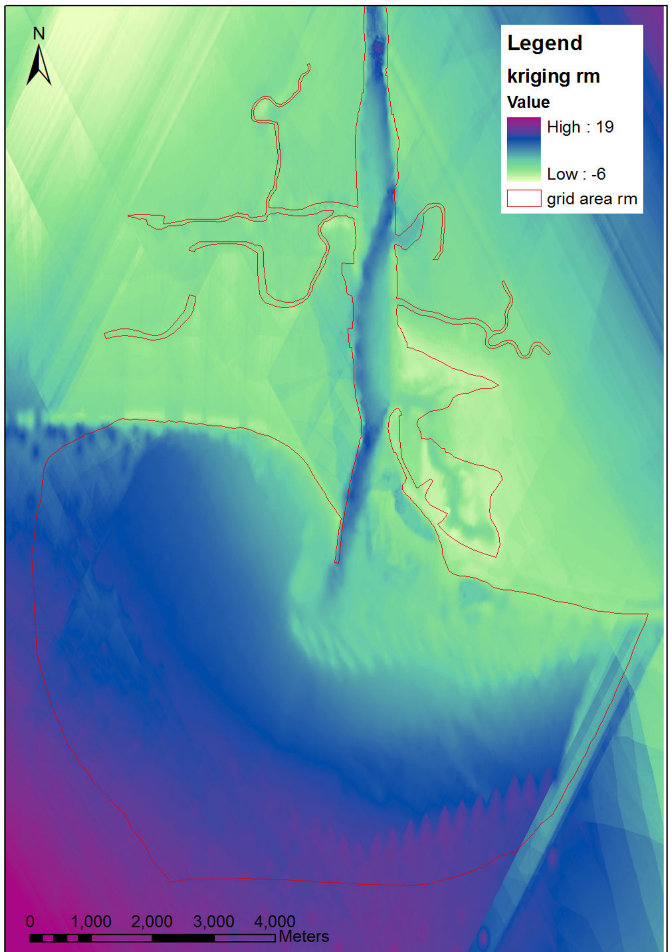
- Transforming bathymetry (linear referencing)

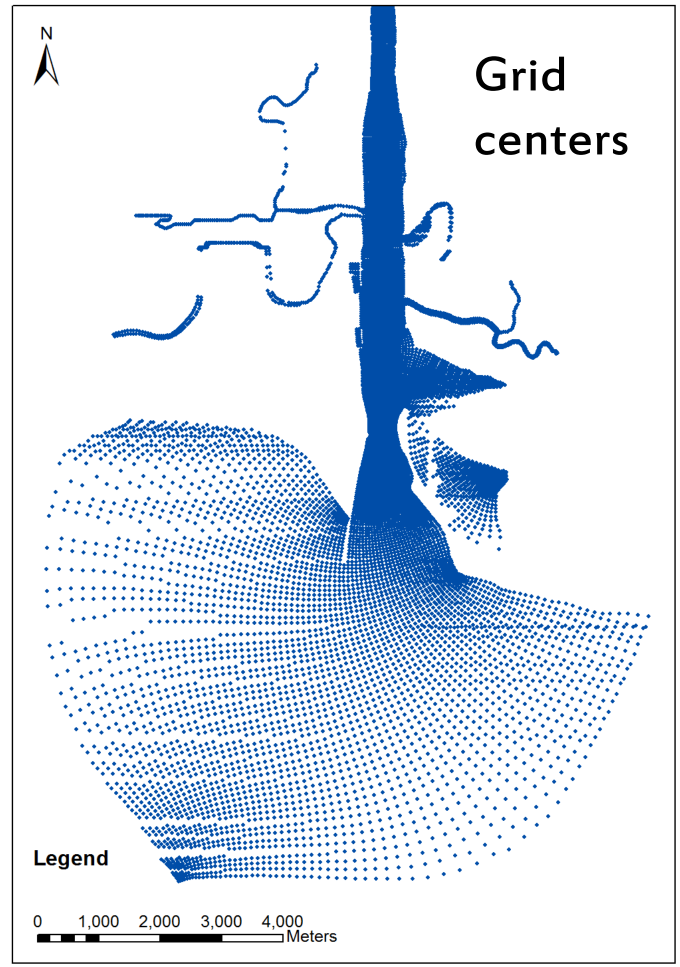




Along-channel coordinates

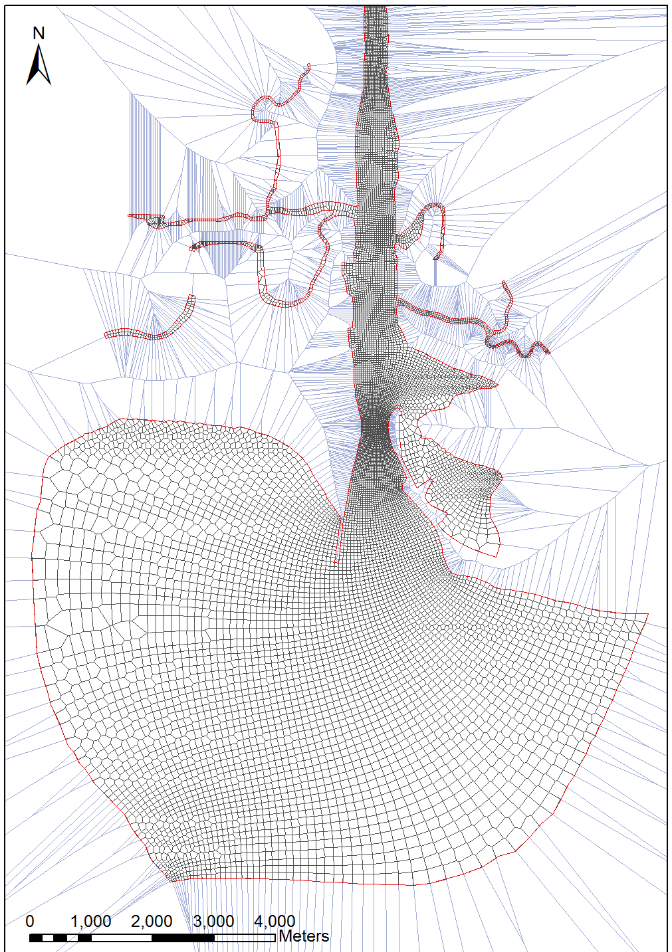
- Interpolation with anisotropy

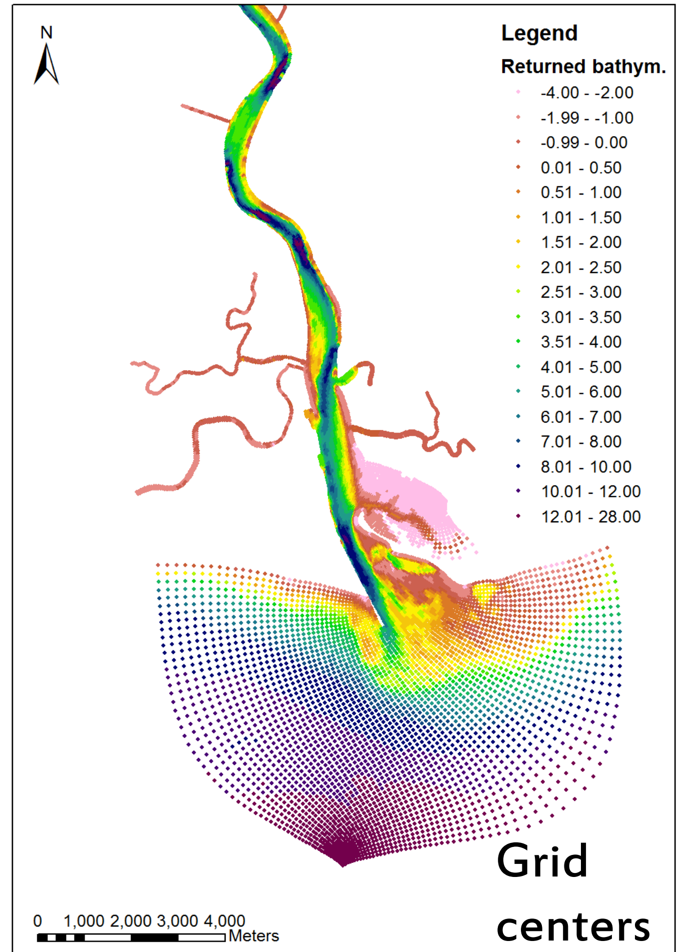




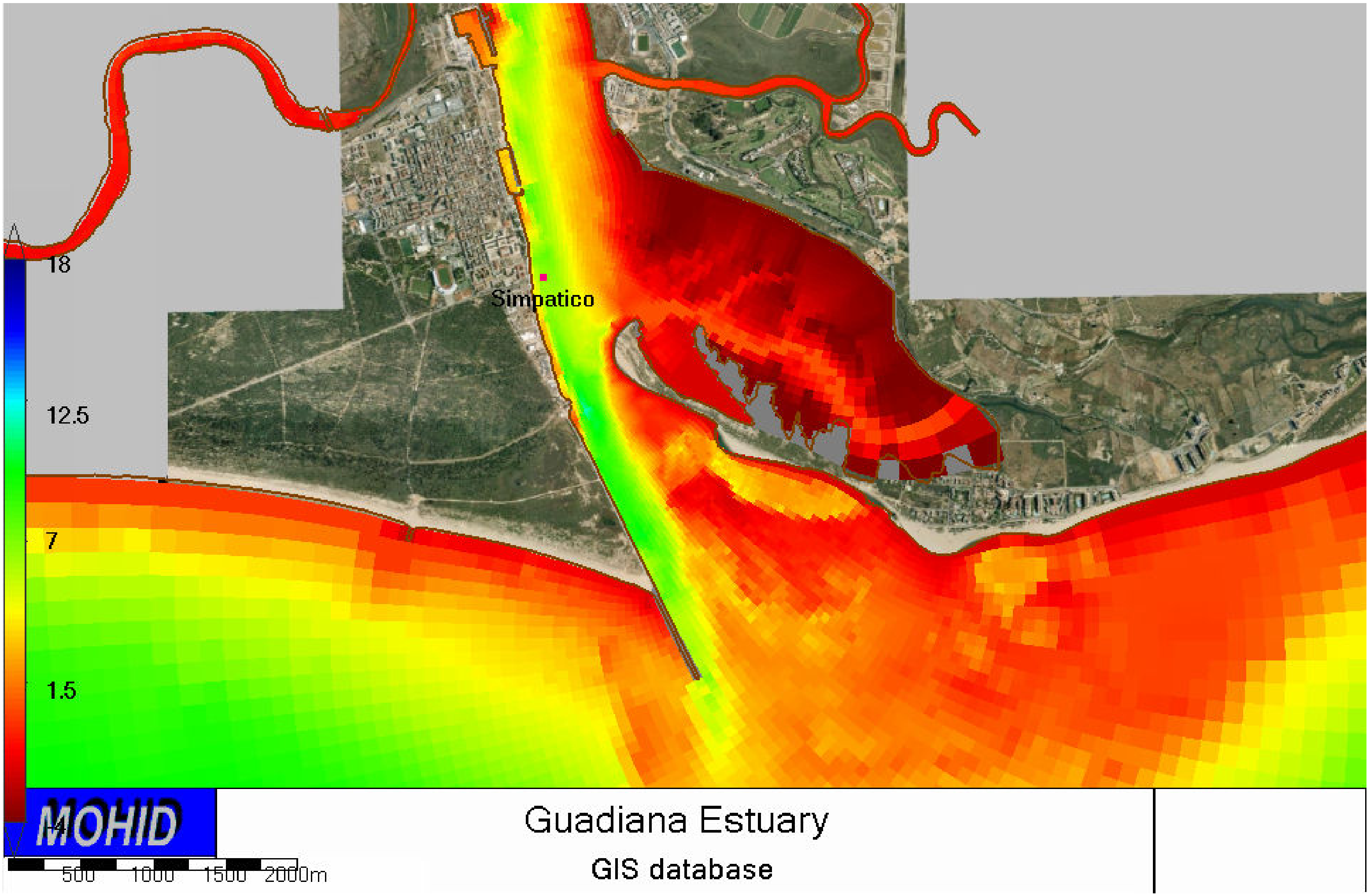
Simple back-transformation

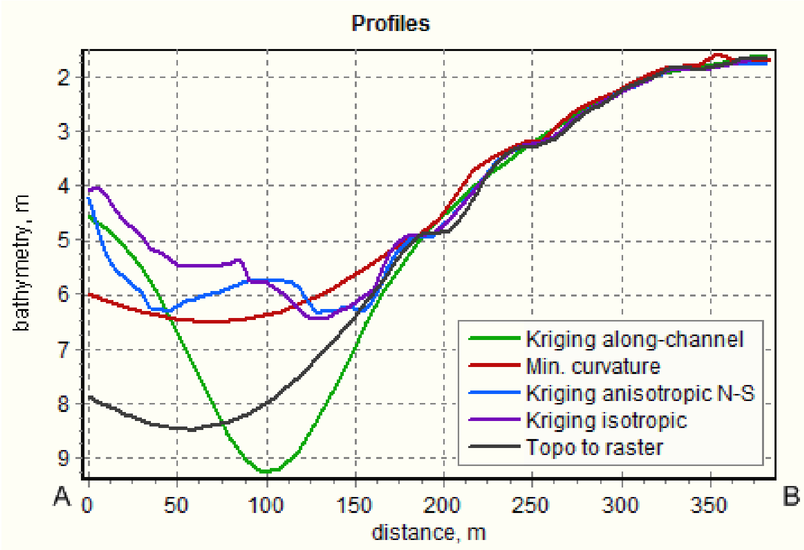
- Reconstructed grid (Voronoi), averages in cells

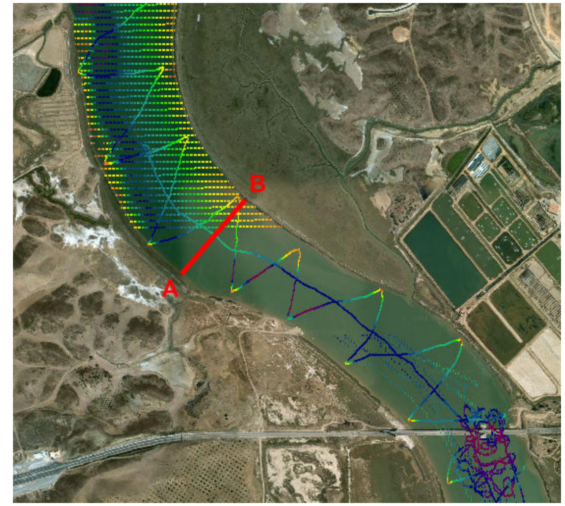


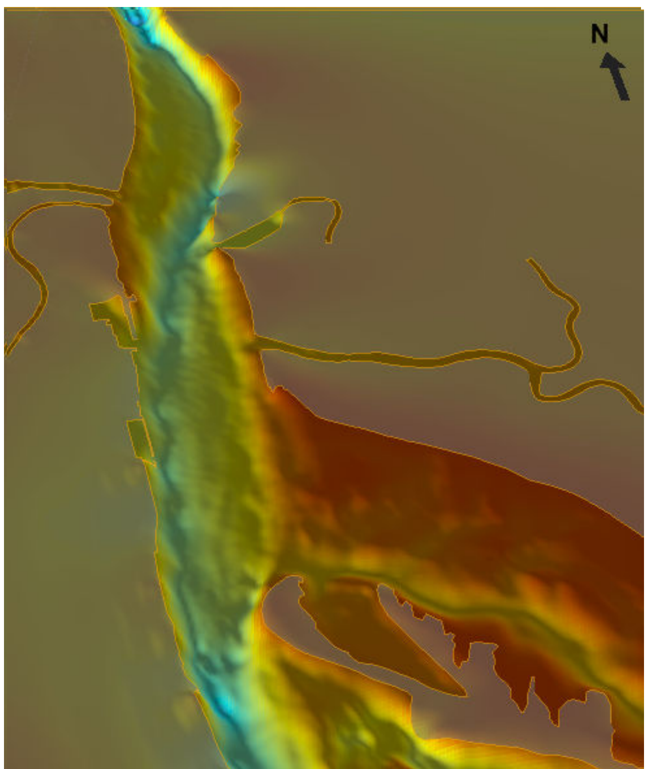


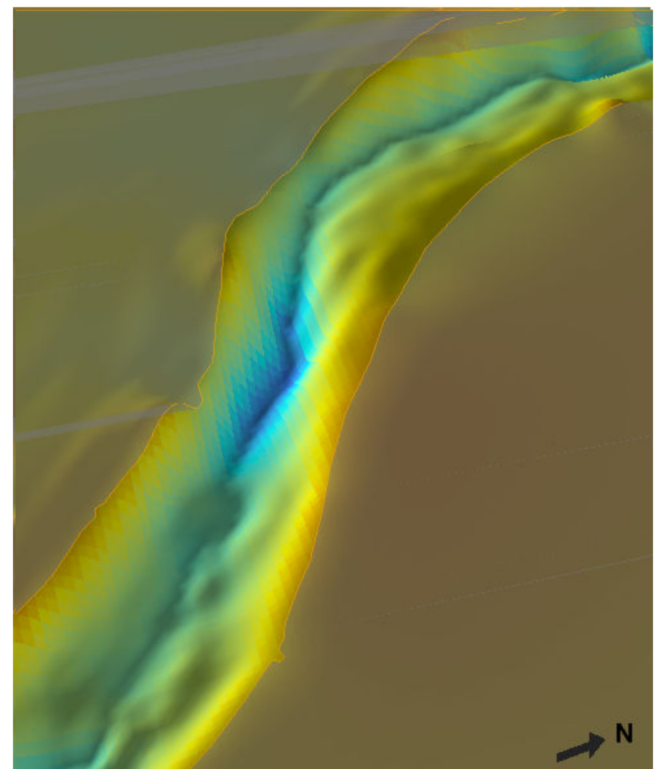
Gridded bathymetry




Profiles
bathymetry, m
2
3
4
5
6
7
8
9
A
0
50
100
150
200
250
300
350
B
distance, m
Kriging along-channel
Min. curvature
Kriging anisotropic N-S
Kriging isotropic
Topo to raster

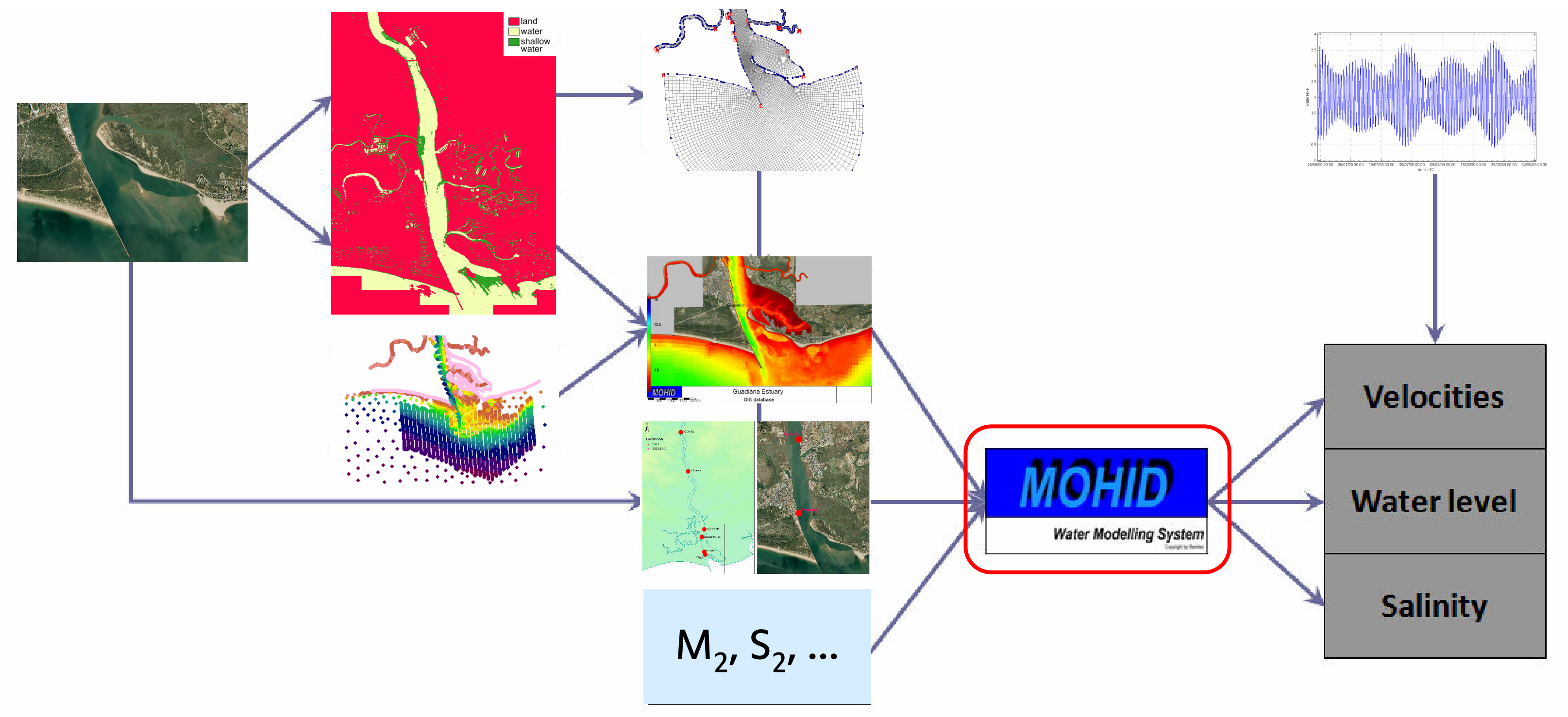

A
B


N


N

Model geospatial data

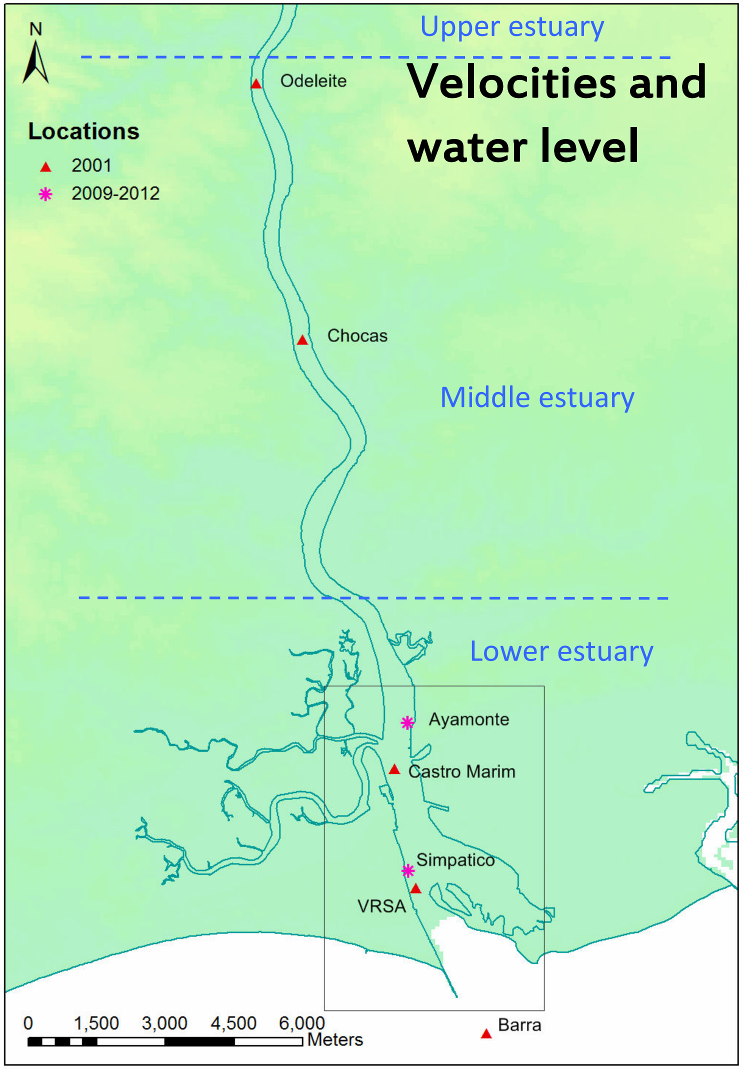
- Ready data

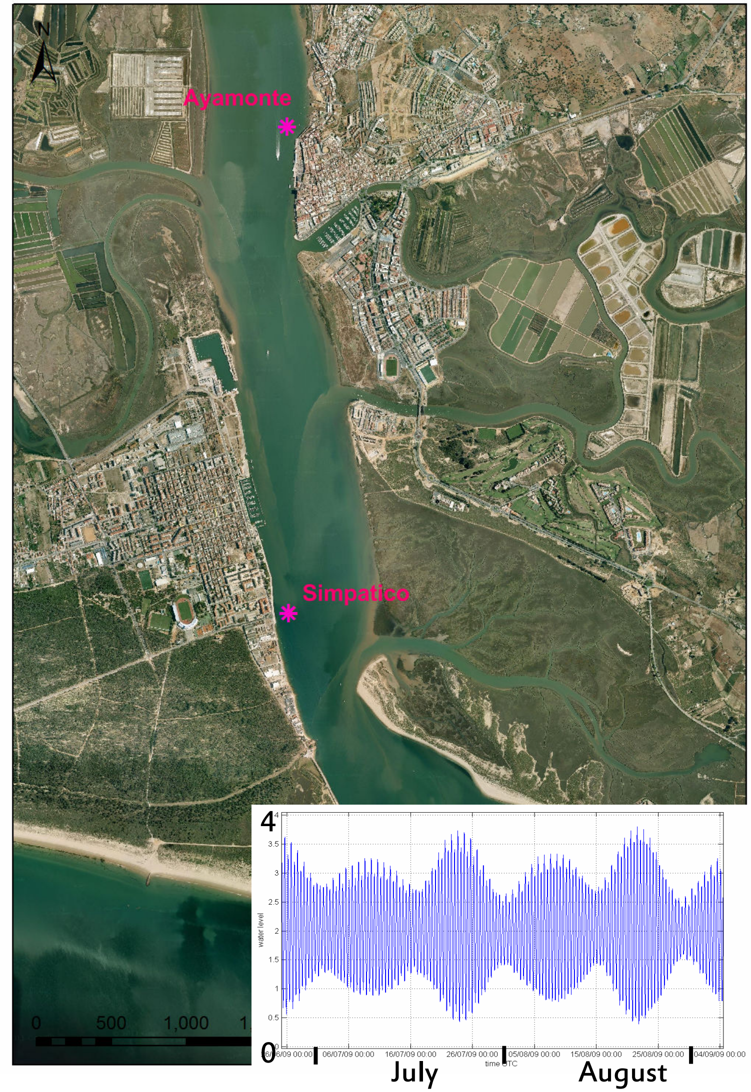


Model setup

- 2D model (one vertical layer)
- Tide and river flow at the boundaries
- Spring-neap tidal cycle
- High and low river flow conditions
- Initial bathymetry interpolated by triangulation

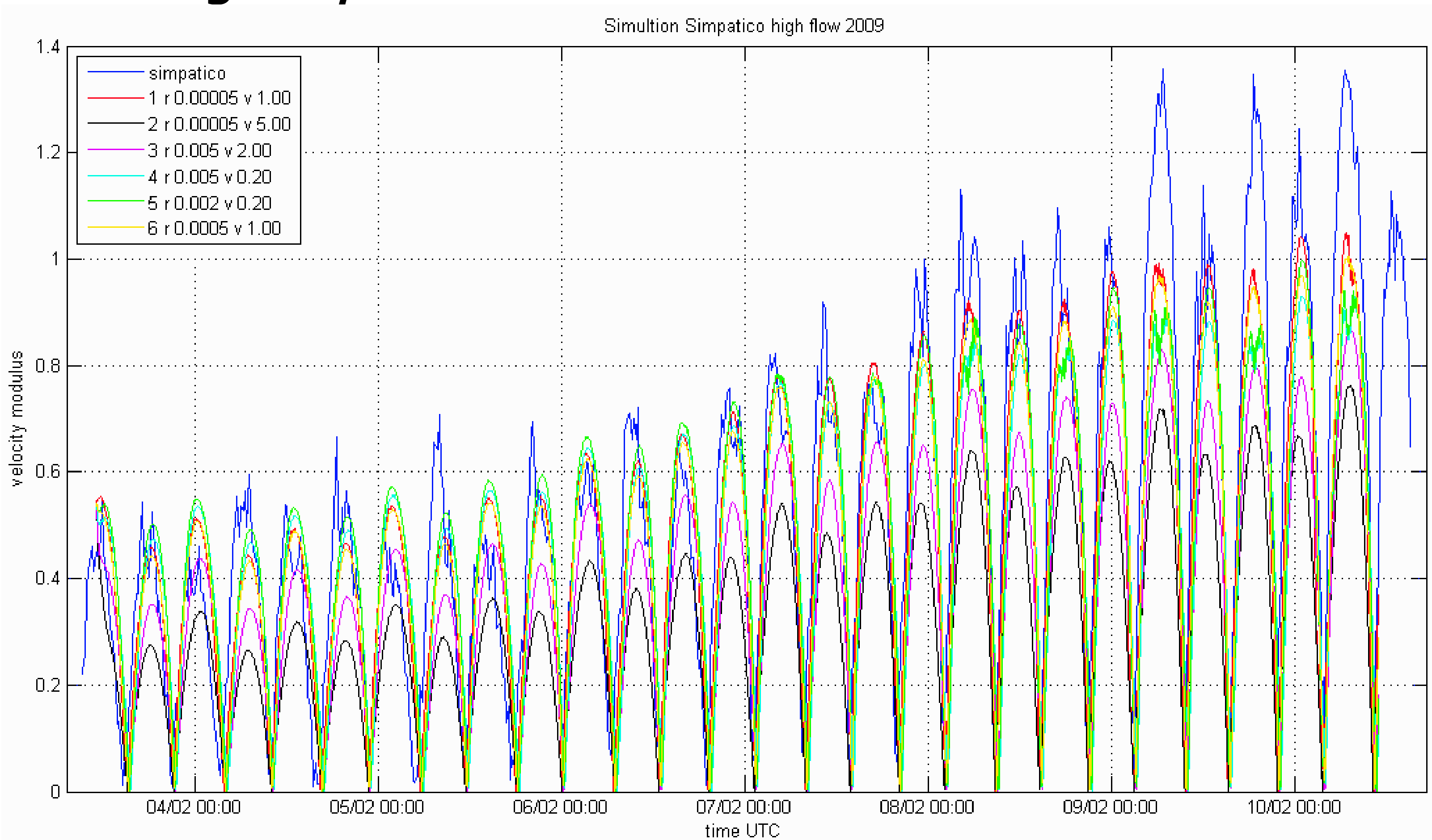
Calibration data stations





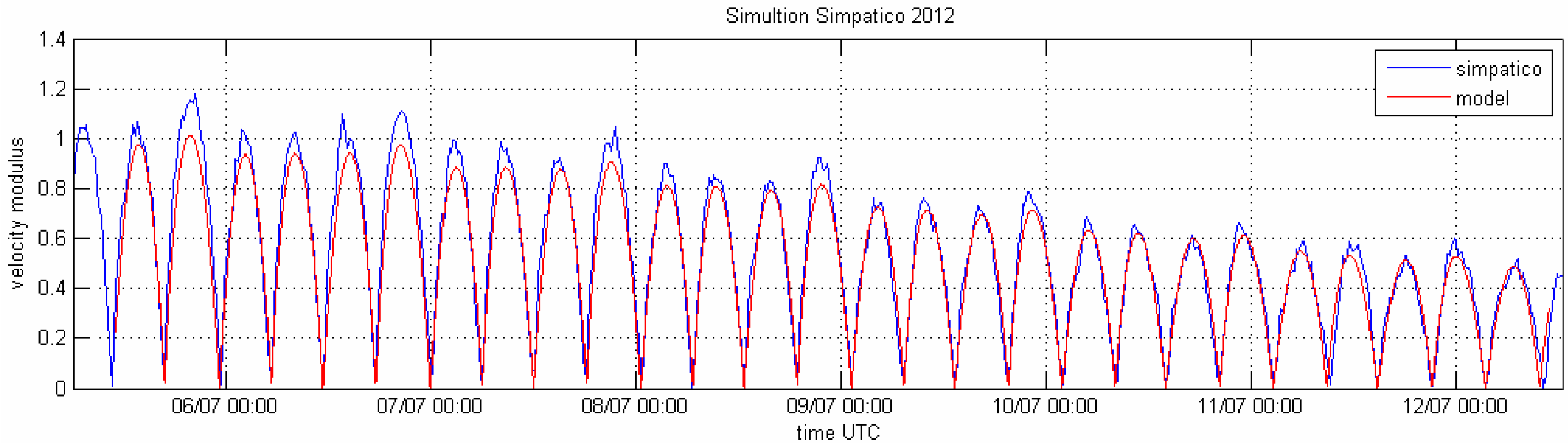
Calibration

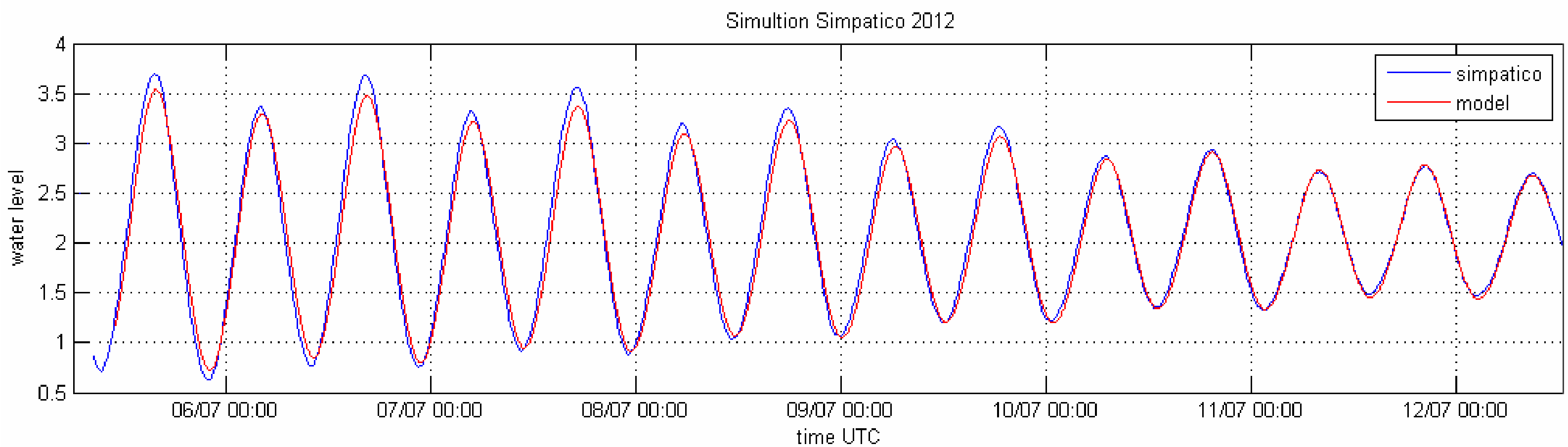
- Horizontal viscosity: 1.00
- Rugosity: 0.0001



Validation, Simpatico

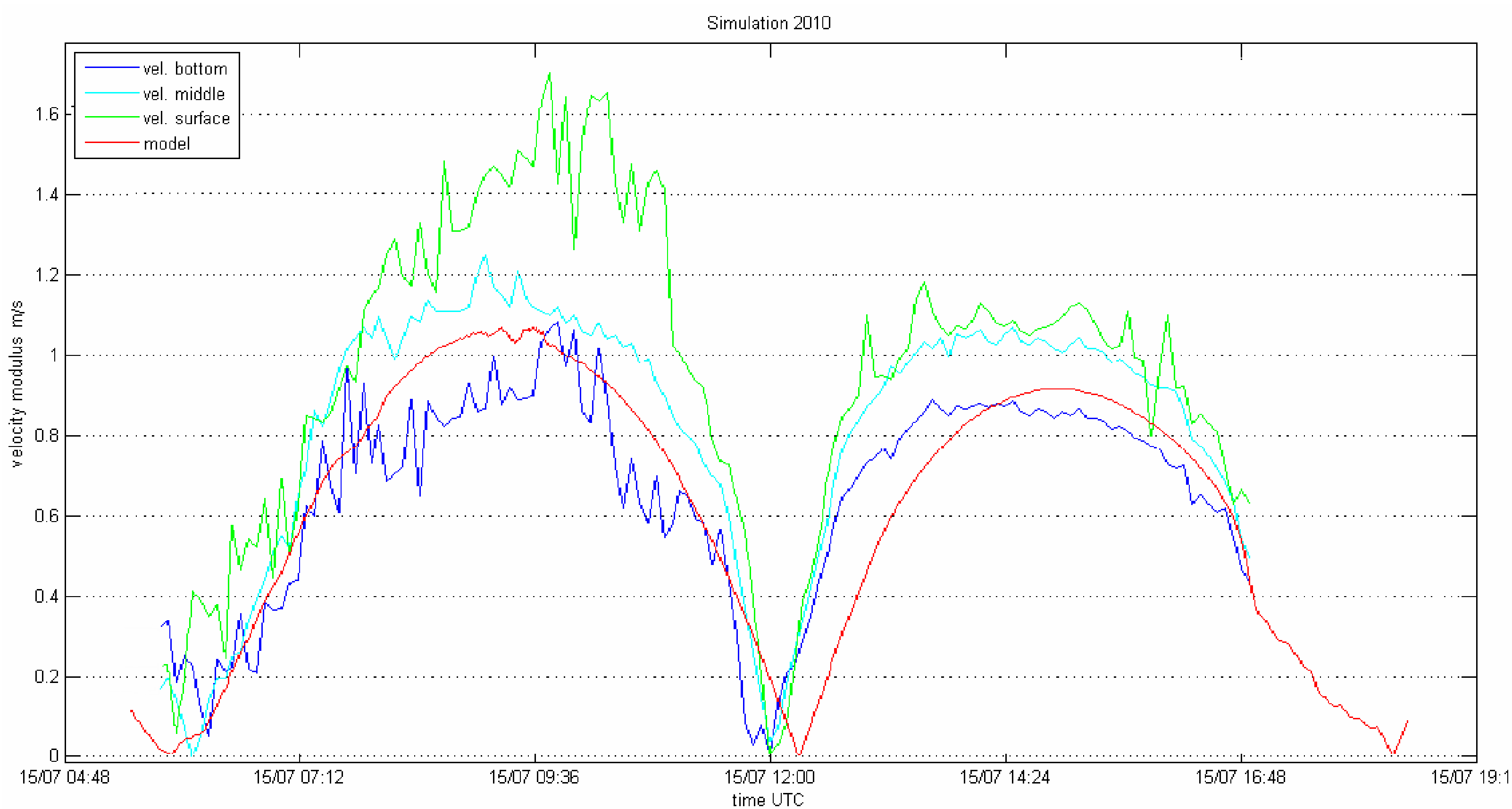
- Low river flow summer 2012 (mixed estuary)





Validation, Ayamonte

- Domain until Mertola



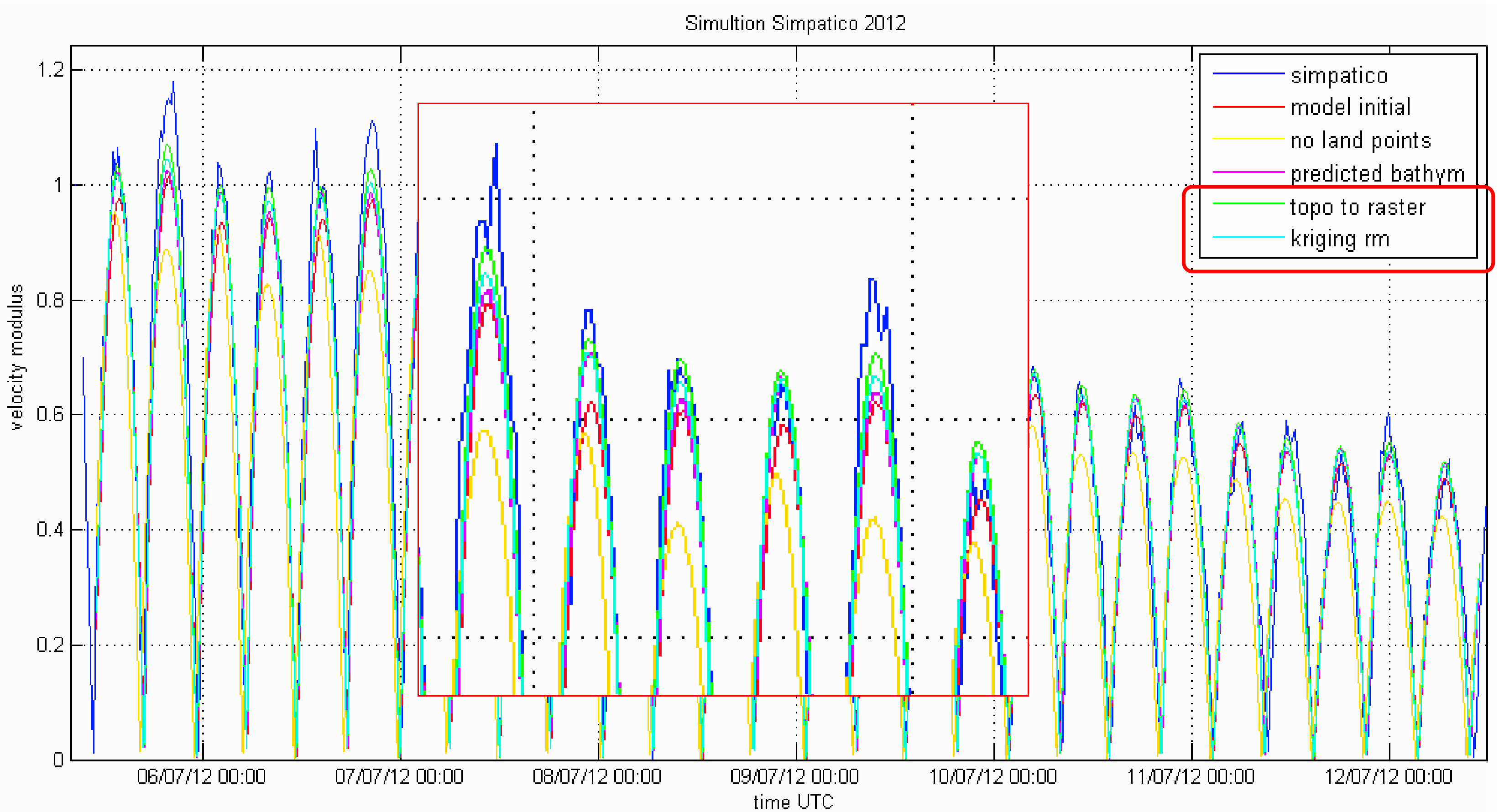
Comparing bathymetry inputs

- Several model input bathymetries were created and their results were compared to the measurements

	Interpolation
Test 1	Triangulation (MOHID)
Test 2	Topo to Raster (ArcGIS)
Test 3	Along-channel kriging

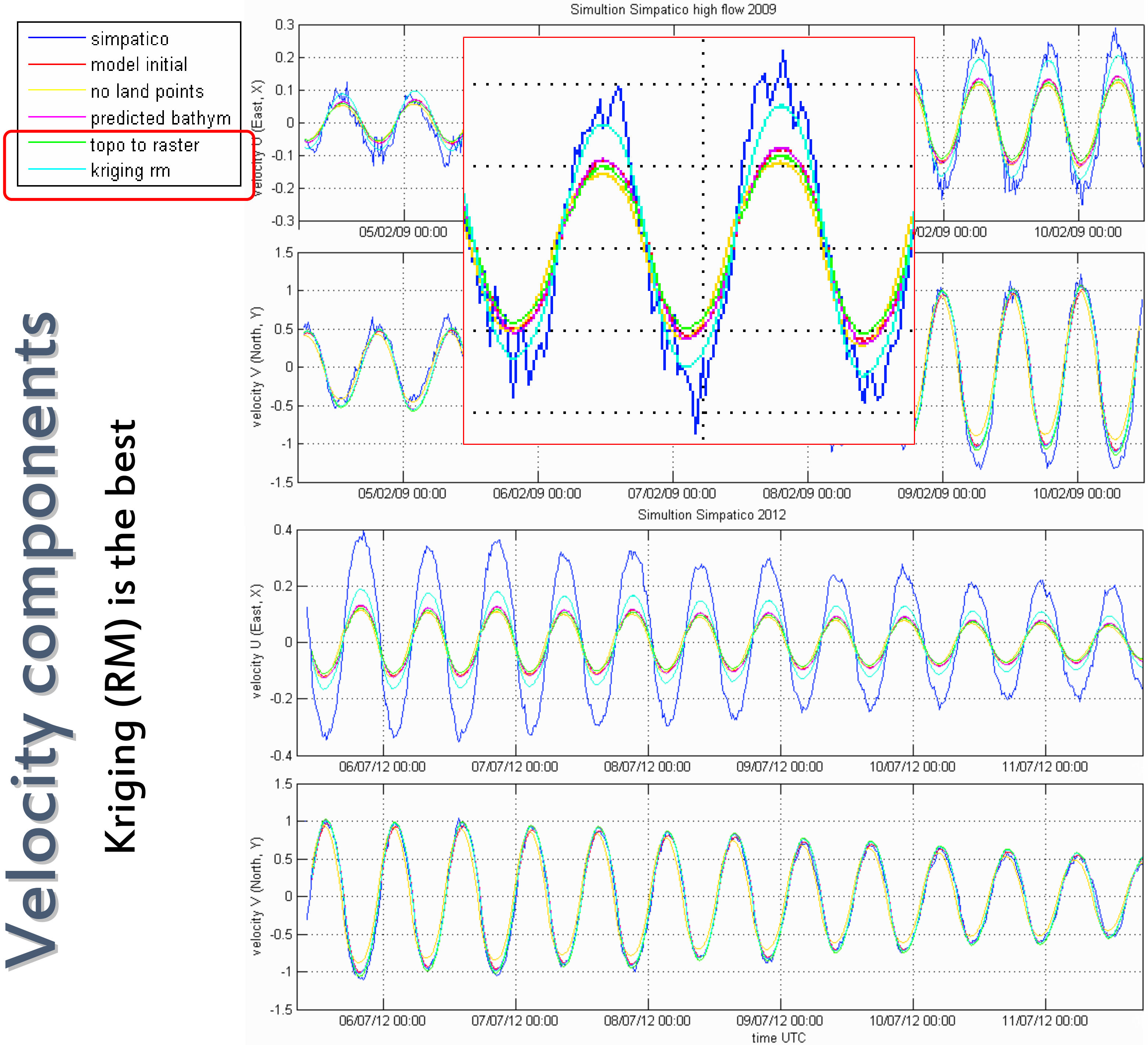
Velocity modulus

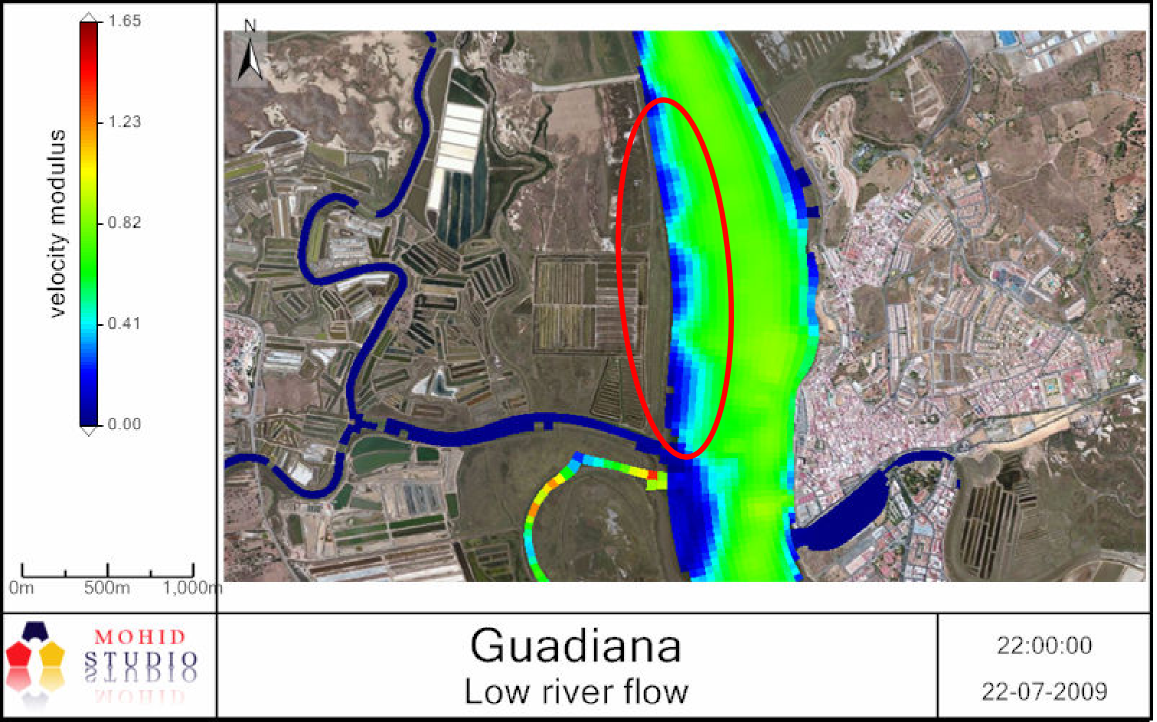
- Topo to Raster and Kriging (RM) improved the model accuracy



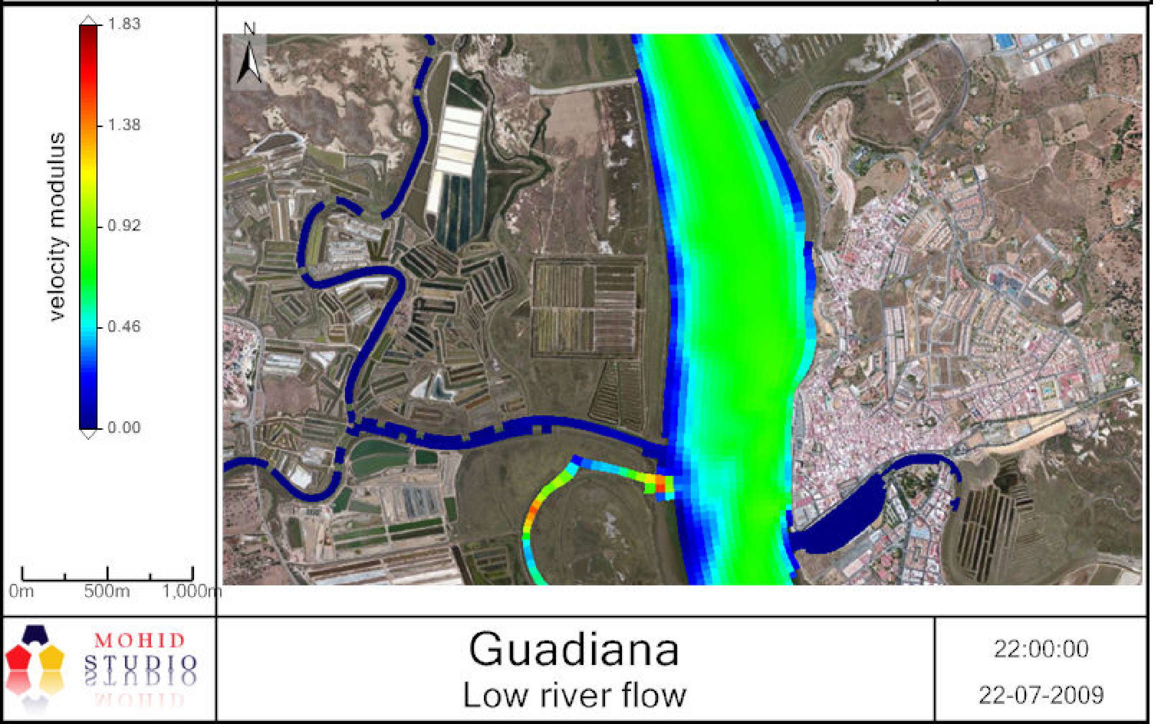
Velocity components

Kriging (RM) is the best





- Isotropic interpolation

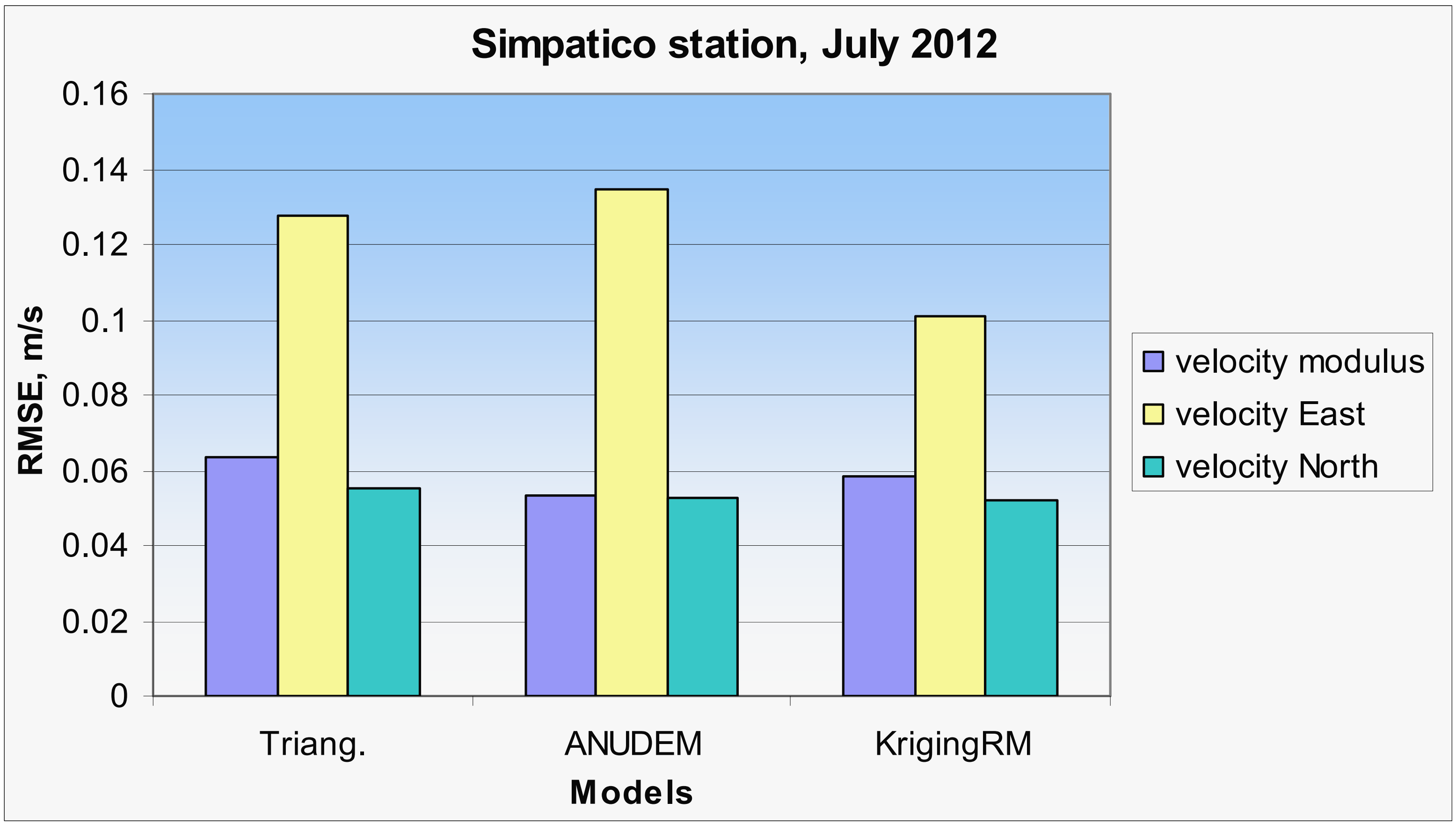


- Channel-oriented kriging

Garbage in, garbage out...

Error analysis

- Along-channel kriging improves the East component and gives in general the best result



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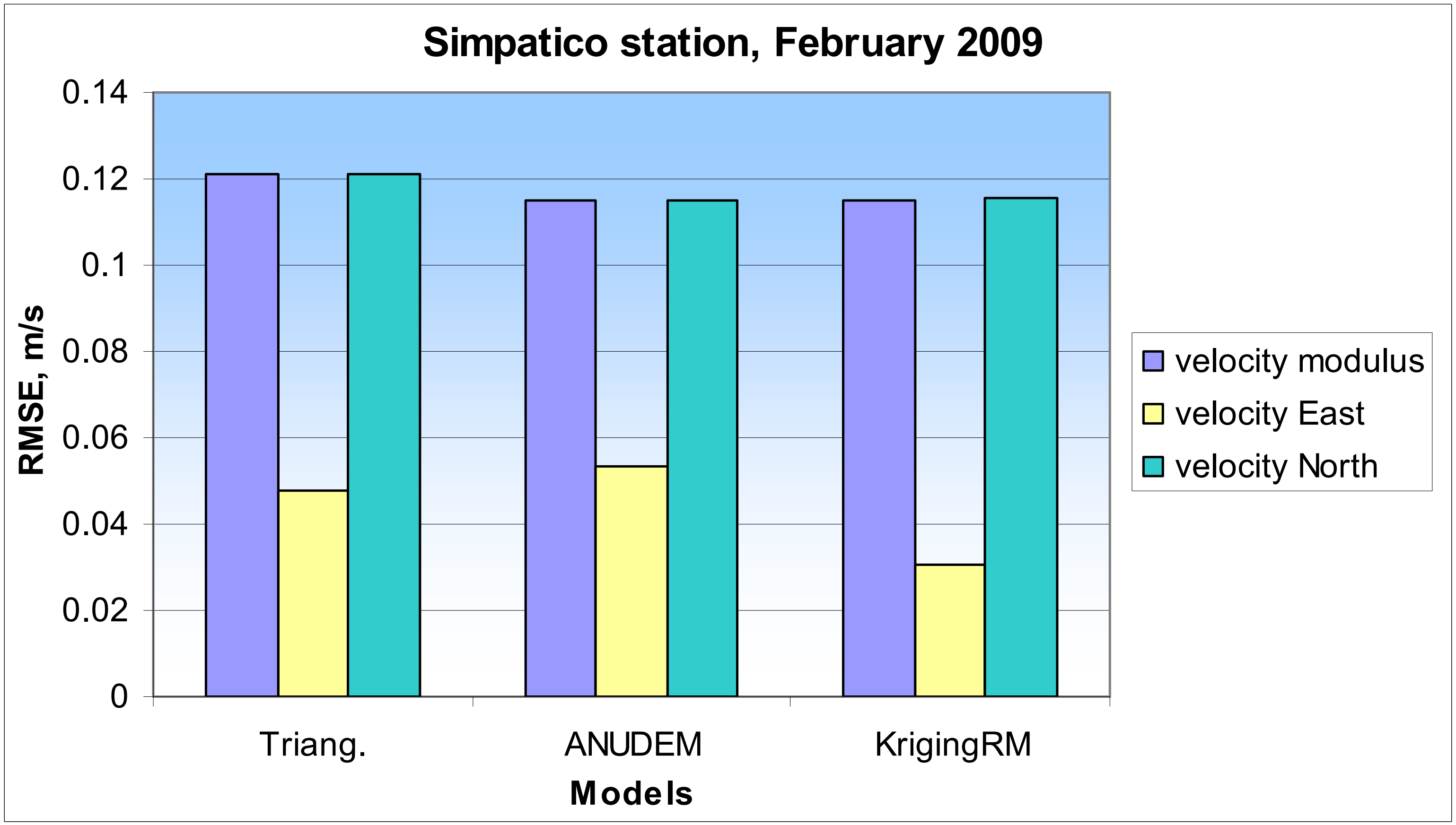


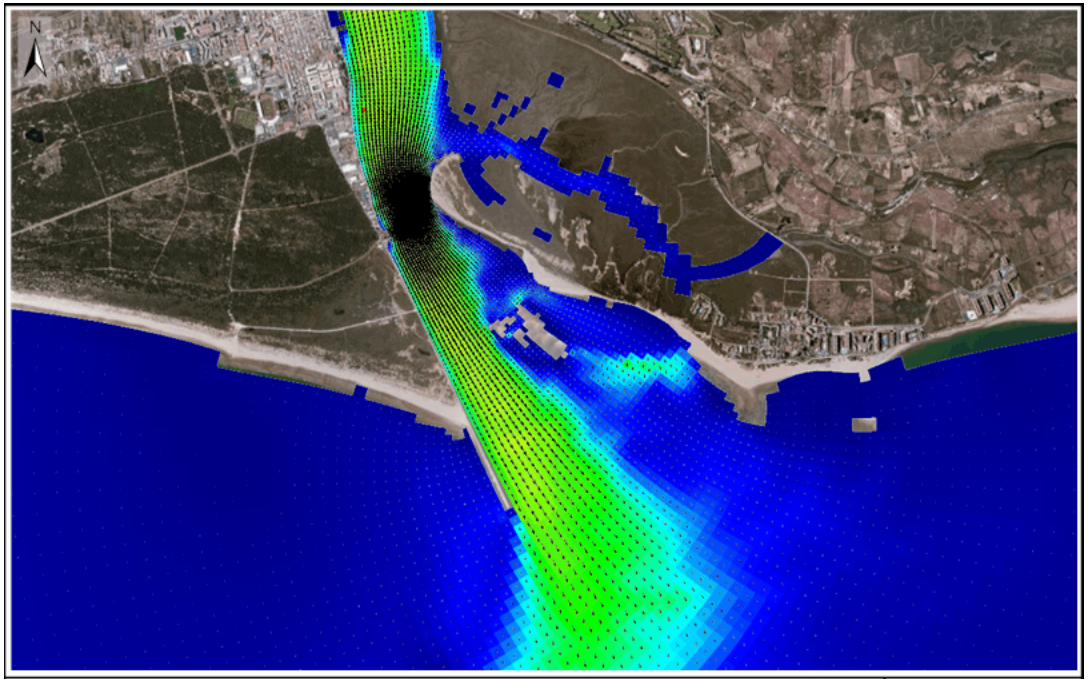
Discussion

- The use of bathymetry, interpolated in the channel-oriented coordinates, significantly improved the direction of the water current and slightly improved the velocity modulus values
- Under the stratified conditions the results of the 2D model were not very good
- There was only one point with dense recent data for calibration

Conclusions

- The use of advanced interpolation improved the model results
- Good quality of the spatial input data (especially, bathymetry) is critical for model accuracy
  - It is impossible to obtain good results with spatially incorrect inputs, despite all numerical calibration efforts – "Garbage in, garbage out"
- Curved rivers and estuaries should be interpolated in channel-oriented coordinates respecting their anisotropy
  - For other cases Topo to Raster method is very good

Thank you for attention!



GIS as a tool to aid pre- and post-processing of hydrodynamic models (MSc thesis, 2013, UALG)