GPU-ACCELERATED 2D SEDIMENT TRANSPORT MODEL FOR HYPER-TURBID EVENTS IN PARTIALLY-MIXED ESTUARIES

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Hyper-turbid events in estuaries

Estuary environments are hydrodynamical system where fresh water from the river mixed with sea water. The river dynamic (discharge) and oceanic dynamic (tide) are the main motors in estuaries

Hyper-turbid events are observed when big river floods (with high sediment concentration) are coupled with strong tidal current, lifting the sediments in the water column to very high SSC concentrations (Suspended Sediment Concentration), visible on satellite images.

Guadalquivir is a large-scale estuary, known for its periodical hyper-turbid events. So, a GPU accelerated 2D sediment transport model has been tested using a hyper-turbid event occurring on December 23rd, 2019 [2].

2D Shallow Water Equation [1]

$$\frac{\partial}{\partial t}\begin{pmatrix} h \\ q_x \\ q_y \end{pmatrix} + \frac{\partial}{\partial x}\begin{pmatrix} q_x \\ \frac{q_x^2}{h} + \frac{gh^2}{2} \\ \frac{q_x q_y}{h} \end{pmatrix} + \frac{\partial}{\partial y}\begin{pmatrix} q_y \\ \frac{q_y q_x}{h} \\ \frac{q_y^2}{h} + \frac{gh^2}{2} \end{pmatrix} = \begin{pmatrix} 0 \\ -gh\left(\frac{\partial z_b}{\partial x} + \frac{n^2 u\|\mathbf{u}\|}{h^{4/3}}\right) \\ -gh\left(\frac{\partial z_b}{\partial y} + \frac{n^2 v\|\mathbf{u}\|}{h^{4/3}}\right) \end{pmatrix}$$

Water Depth · Water Discharge · Gravitational Acceleration · Bed Level · Water Velocity: $\mathbf{u} = u\hat{x} + v\hat{y}$ · Manning Coefficient

Sediment Transport Equation [1]

Sediment Concentration

$$\frac{\partial h\phi}{\partial t} + \frac{\partial hu\phi}{\partial x} + \frac{\partial hv\phi}{\partial y} = 0$$

Numerical Solution [3]

$$(h\phi)_i^{n+1} = (h\phi)_i^n - \frac{\Delta t}{A_i}\sum_{k=1}^{Ne}(q\phi)_k^{\downarrow} l_k$$

Wall length

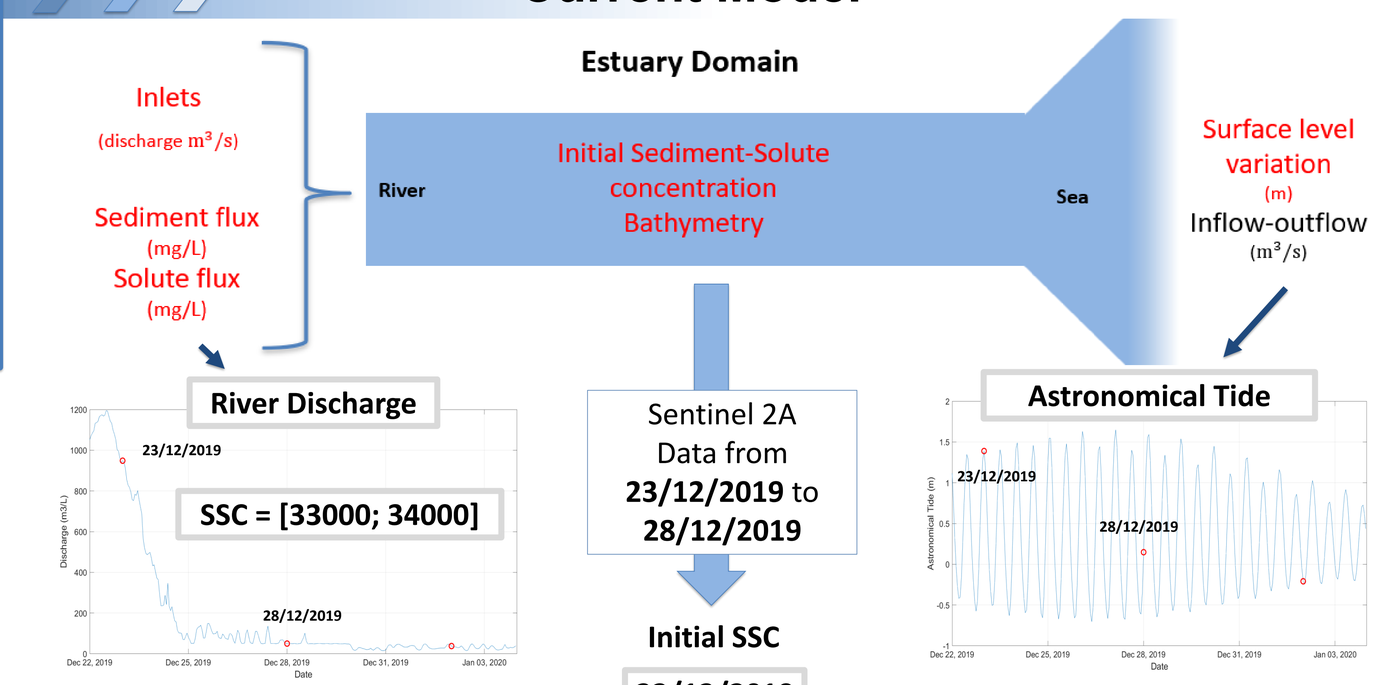
$(q)_k^{\downarrow}$ = numerical Flux and $(\phi)_k^{\downarrow} = \begin{cases} \phi i \ \ if (q)_k^{\downarrow} > 0 \\ \phi j \ \ if (q)_k^{\downarrow} < 0 \end{cases}$

i = cell and k = wall

Mesh Size

1307870 cells triangular

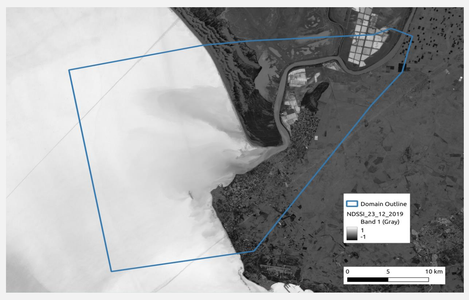
Current Model



NDSSI

$$\text{NDSSI} = \frac{\text{B2} - \text{B8}}{\text{B2} + \text{B8}}$$

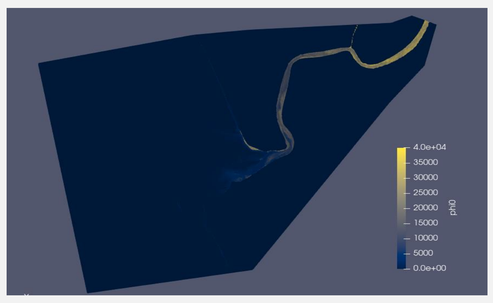
B2 = Blue band
B8 = infra-red band



$$SSC = 3193.1e^{-6.839\,NDSSI}$$

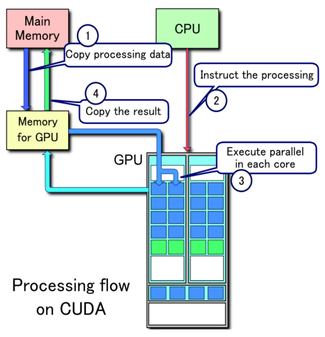
$R^2 = 0.6994$

SSC in mg/L



GPU Technology

GPU (Graphics Processing Unit) modeling: Using the GPU's parallel computing power to **accelerate numerical simulations and model training [4].**

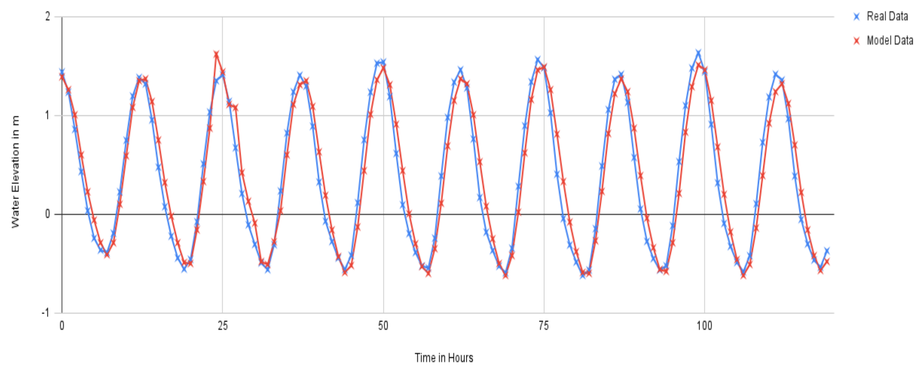


NVIDIA GeForce RTX 4070

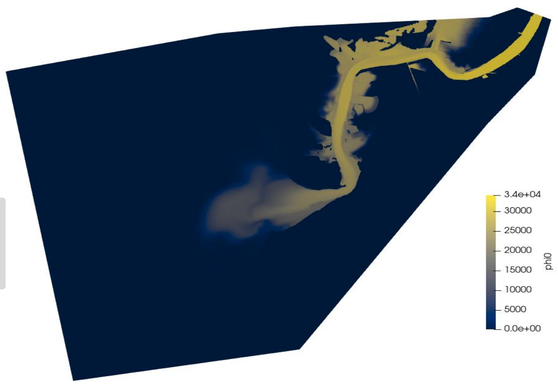
	Computation Time (min)
23/12/2019	24 min 21s
24/12/2019	25 min 56s
25/12/2019	25 min 57s
26/12/2019	26 min 12s
27/12/2019	26 min 43s
28/12/2019	26 min 40s
Total	2h 35min 51s
Mean Value	25min 58s

Comparison Real Data – Modeled Data

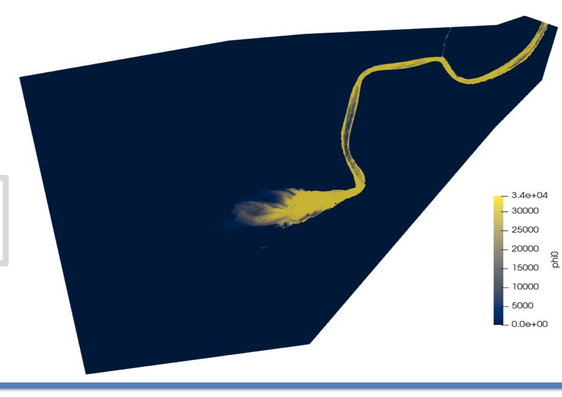
Tide Gauge VS modelled Water Level (h+z)



Model SSC (mg/L)



Real Data SSC (mg/L)



Future Work

Further studies would imply to implement a multilayer system to get the sediment concentration in the water column.

ACKNOWLEDGEMENTS

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[1] Martinez-Aranda Sergio et al. (2023). SERGHEU-SEST: A high-Performance-Computing model for soil erosion and sediment transport processes in realistic catchments. *EGU European Geosciences Union* (2023) 16, 977-1008.

[2] Megina César, Donázar-Aramedía Íñigo, Miró, Juan Miguel, García-Lafuente Jesús, García-Gómez José Carlos, The hyperturbid mesotidal Guadalquivir estuary during an extreme turbidity event: Identifying potential management strategies, Ocean & Coastal Management, Volume 246, 2023, 106903, ISSN 0964-5691.

[3] Morales-Hernández M., Murillo J., García-Navarro P. (2018). Diffusion-dispersion numerical discretization for solute transport in 2D transient shallow flows. *Environmental Fluid Mechanics (2019) 19:1217-1234.*

[4] D. J. Sooknanan and A. Joshi, "GPU computing using CUDA in the deployment of smart grids," (*2016) SAI Computing Conference (SAI)*, London, UK, 2016, pp. 1260-1266, doi: 10.1109/SAI.2016.7556141.