Modeling Plastic Transport in Aquatic Environments: the Ebro River case

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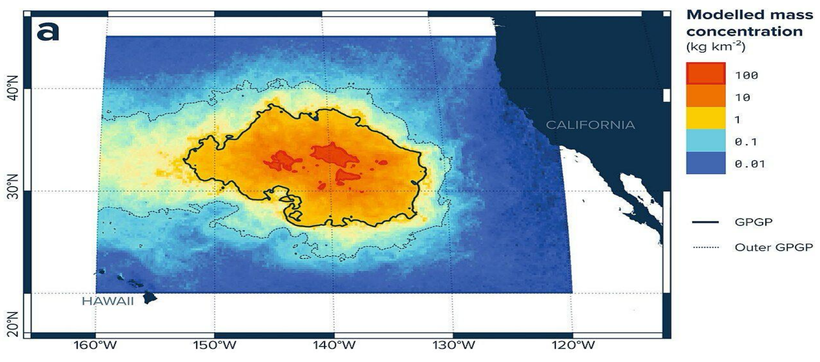
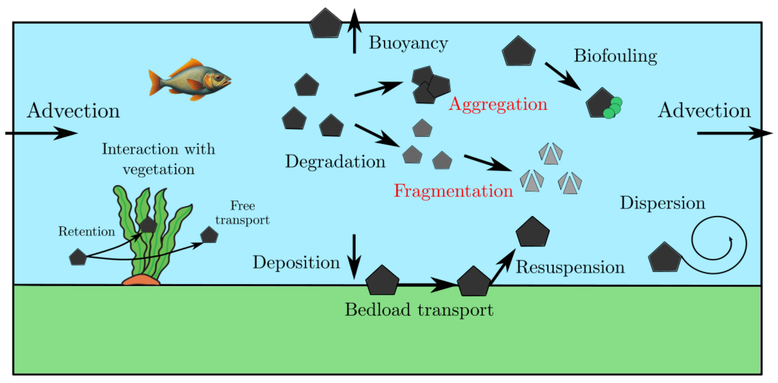
ABSTRACT. Plastics are one of the most important environmental challenges due to their presence in most natural scenarios such as rivers. Computational forecasting tools are therefore essential to understand their transport behavior. This work presents a computational model for plastic transport in shallow flows, including preliminary results for the Ebro River.

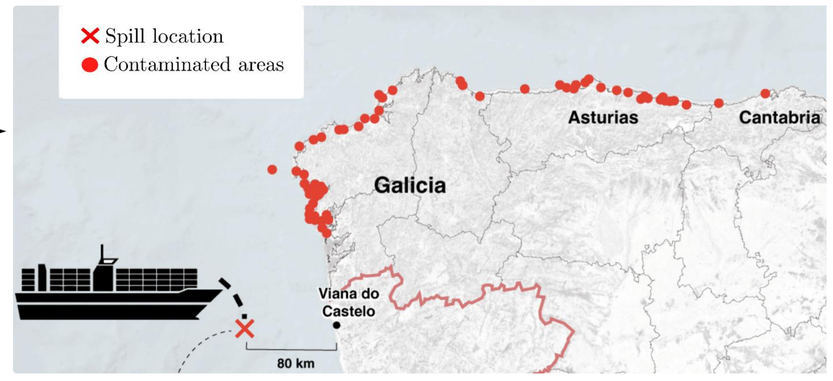
MOTIVATION. **Plastic pollution** in **rivers** and **seas** is an **escalating environmental concern** [1]. Recent incidents, such as the contamination along the Spanish coast of the Galicia region, highlight the urgent need to understand the spread of these pollutants. Therefore, developing a **transport model** capable of predicting how plastics are **transported by water** flow and suffer specific processes such as **buoyancy/deposition**, **biofouling** or **degradation**, is essential to addressing this growing issue.



Great Pacific Garbage Patch extension. [Source: Wikipedia]



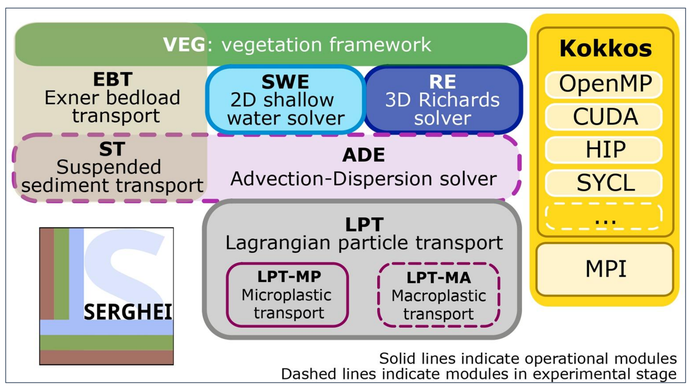
Representation of the main processes affecting plastic transport in aquatic environments. Processes in red are not implemented.



Contaminated areas from plastic spill ocurred near the Galicia coast (Spain), December 2023.

SERGHEI FRAMEWORK.

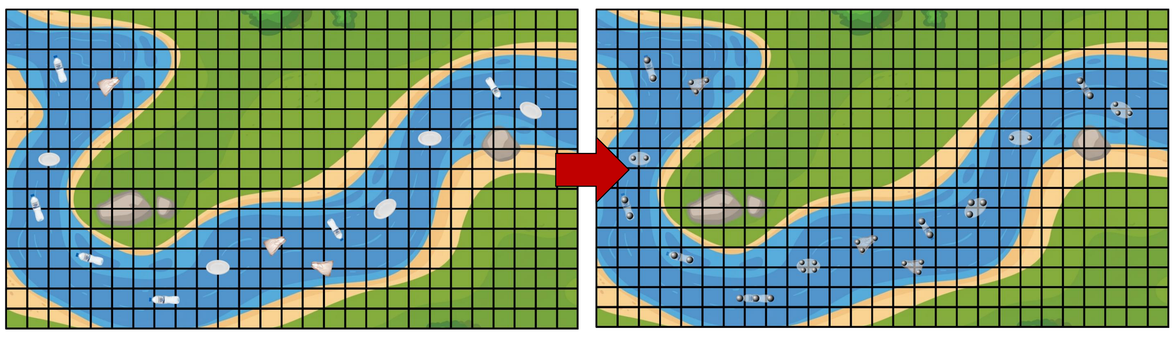
SERGHEI is an **open-source** project, implemented using **MPI** and **Kokkos**, being an **accurate** and **performance-portable** tool for environmental hydrodynamics [2].



Modules in SERGHEI. LPT available since v2.1 [3], Plastics-LPT module in dev-branch.

CURRENT MODEL. For **microplastics**, transport is governed by advection, turbulent dispersion and specific processes (**settling velocity, degradation and biofouling**):

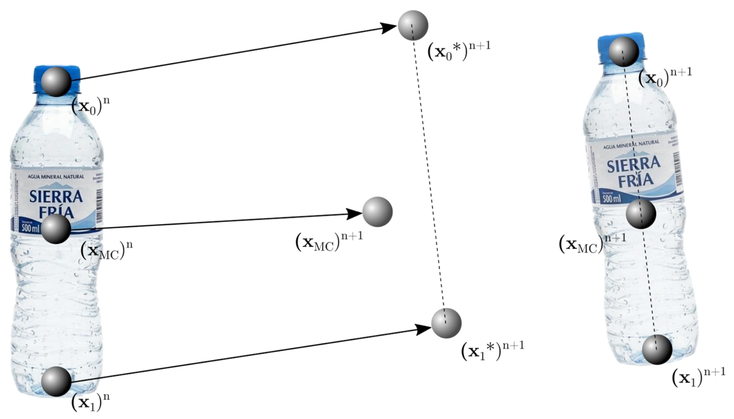
$$\mathbf{v}_p = \frac{d\mathbf{x}_p}{dt} = \mathbf{v}_{\text{advection}} + \mathbf{v}_{\text{dispersion}} + \mathbf{v}_{\text{mp}}$$



Representation of plastic objects using multiple Lagrangian particles.

For **macroplastics**, the temporal evolution of particle velocity is described by a simplified form of the **Maxey-Riley equation**:

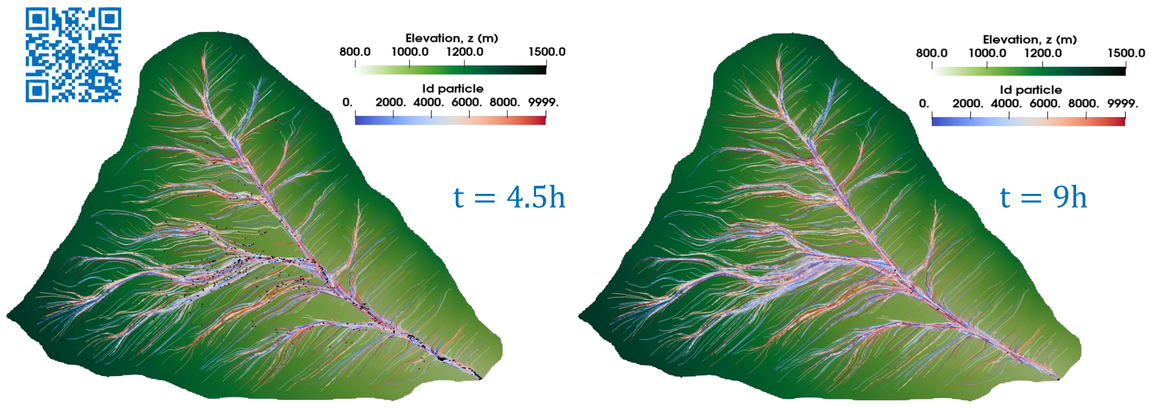
$$m_p \frac{d\mathbf{v}_p}{dt} = \frac{1}{2}\rho_w C_d |\mathbf{v} - \mathbf{v}_p|(\mathbf{v} - \mathbf{v}_p) A_{\text{proj,D}} + (\rho_p - \rho_w)\mathbf{g}V_p$$



Position and orientation update of a plastic object represented by multiple particles.

RESULTS. The current model has been validated by simulating **experimental test cases** and **real events**.

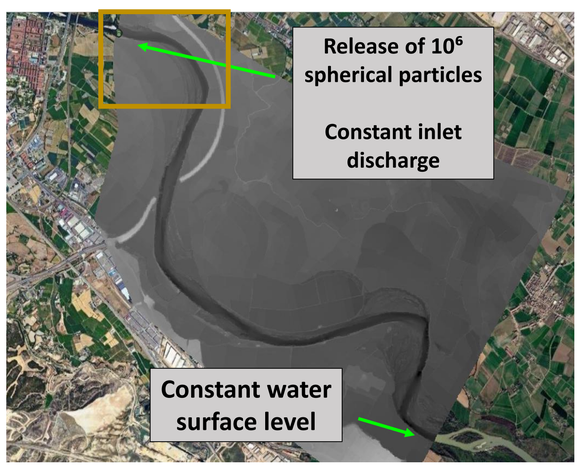
ARNÁS CATCHMENT [3]



Trajectories of 10,000 particles in the Arnás catchment at t=4.5 h and t=9 h.

EBRO RIVER CASE [5]

Simulated reach: Zaragoza–Burgo de Ebro (multiple plastic sources)



Initial and boundary conditions.

Final state of the simulation, with all particles deposited.

CONCLUSIONS AND FUTURE WORK. The results provide valuable information about how plastics are transported by the flow, concluding that the model implemented can be a powerful tool for environmental risk prediction. However, additional experimental and field data are required to further validate the model. Preliminary results obtained for the Ebro River case indicate that particle deposition may be overestimated, suggesting that the parameterization of specific transport processes should be revisited and calibrated. Future work will therefore focus on improving and validating these processes, as well as incorporating additional mechanisms such as particle collisions.

References

[1] Gao, S., Orlowski, N., Bopf, F. K., & Breuer, L. (2024). A review on microplastics in major European rivers. *WIREs Water*, 11(3), e1713. DOI: 10.1002/wat2.1713.
[2] Caviedes-Voullième, D., Morales-Hernández, M., Norman, M.R., & Özgen-Xian, I. (2023). SERGHEI (SERGHEI-SWE) v1.0: a performance-portable high-performance parallel-computing shallow-water solver for hydrology and environmental hydraulics. *Geosci.Model Dev.*, 16(3), 977-1008. DOI: 10.5194/gmd-16-977-2023.
[3] Vallés, P., Morales-Hernández, M., Roeber, V., García-Navarro, P., & Caviedes-Voullième, D. (2025). SERGHEI v2.1: a Lagrangian Model for Passive Particle Transport using a 2D Shallow Water Model (SERGHEI-LPT). *EGUsphere [preprint]*. DOI: 10.5194/egusphere-2025-722.