Numerical modeling of macroplastic transport in rivers

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Introduction

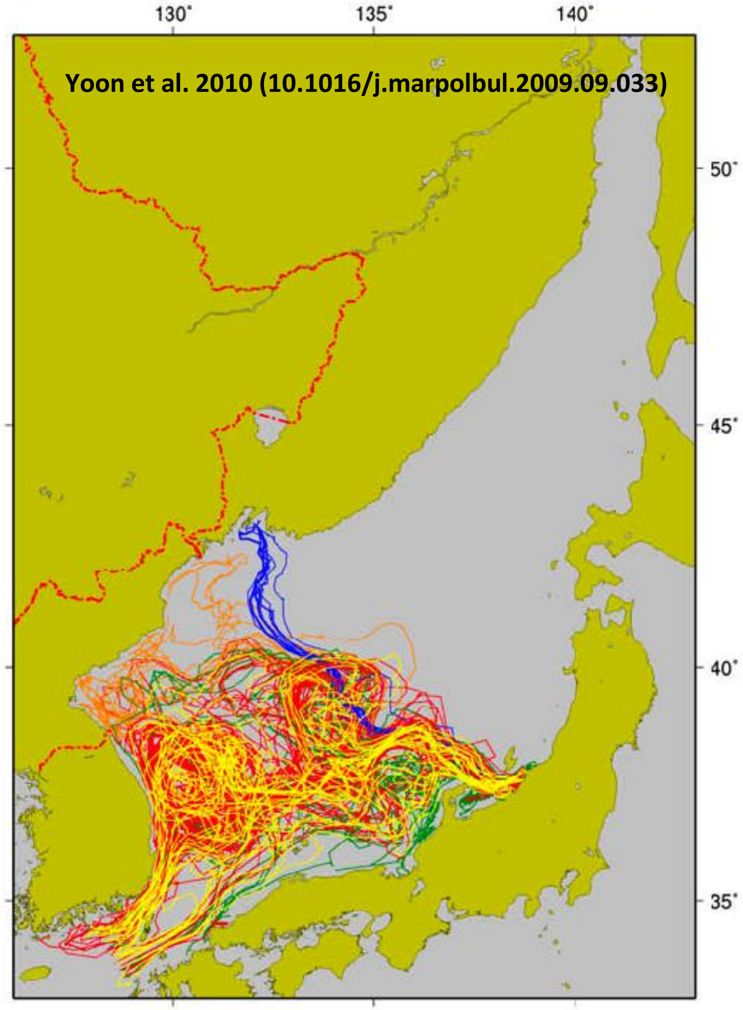
The problem of (macro)plastic pollution is well-known.

- Laboratory measurements help us understand the fine details
- Field measurements provides to the large-scale, real context
- The goal of **numerical modeling** is prediction
  - Here, only floating macroplastics
  - How are they transported in the river?
  - What processes are to be considered?
- The ultimate goal of the predictions
  - To predict potential litter hot-spots to support and optimize cleanups
  - To support the planning and implementation of interventions—best place to install litter traps?

Introduction

Numerical modeling efforts in the literature

- Most of the studies are focusing on ocean/coastal environments—that is where the problem culminates



Why can't we *simply* use the same methods?

In rivers..

- Direct influence of wind is lower
- Higher flow velocities (and more intense turbulence)
- Curvature effects—secondary currents
- Local morphology plays a key role
- Confined space—beaching, trapping
- …

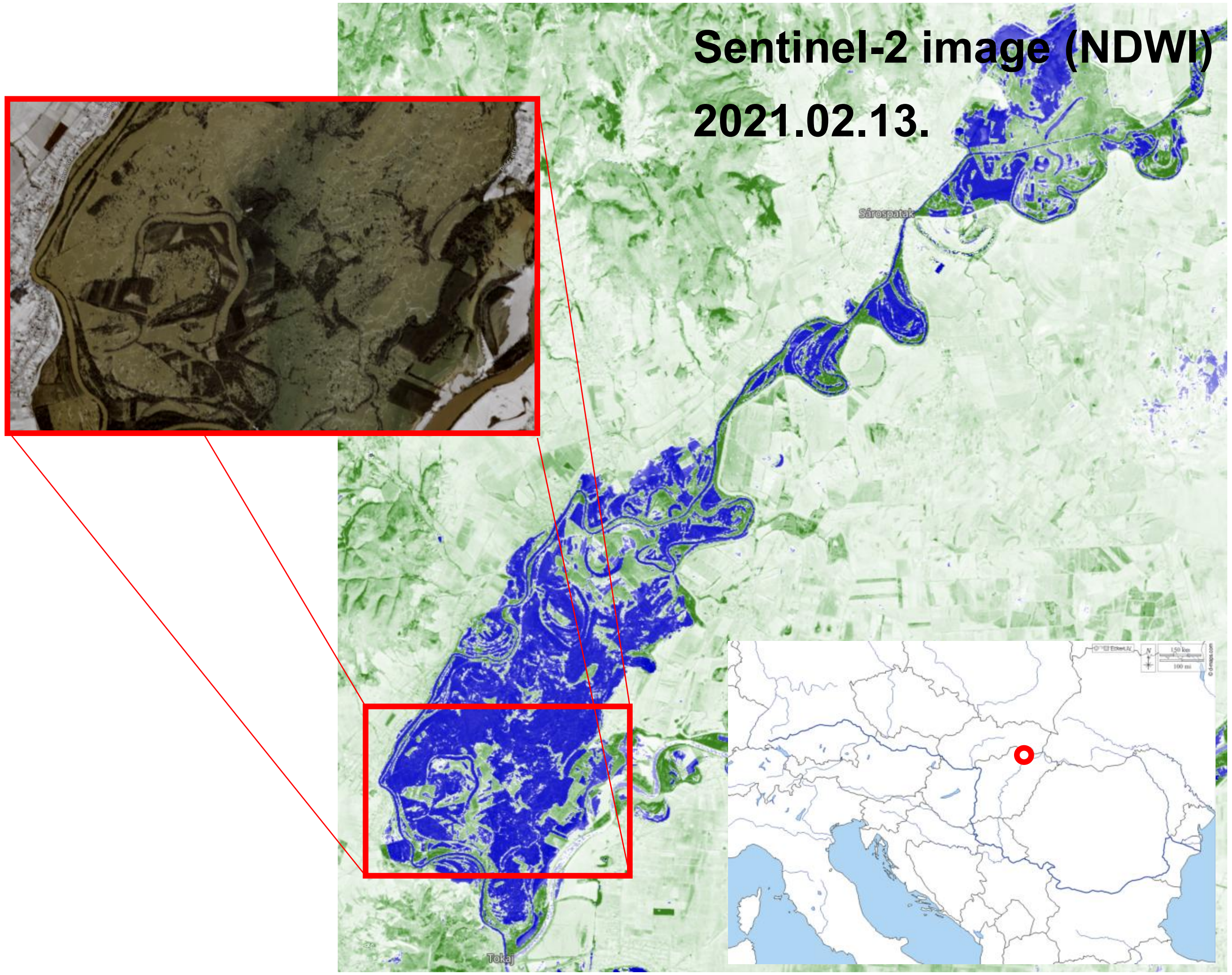
Study site

Bodrog river

- Length: 67 km (~60 km in Hungary)
- Discharge: Q_{mean}=115 m^3/s; Q_{max}=693 m^3/s
- Extensive vegetated floodplain

Key features

- Multiple floods per year (winter is typical)
- Backwater effect of the Tisza river
- The floodplain is often inundated
- Often combined with severe litter floods
- Complex floodplain
  - Forest patches
  - Submerged vegetation
  - Dead branches



Hydrodynamic modeling

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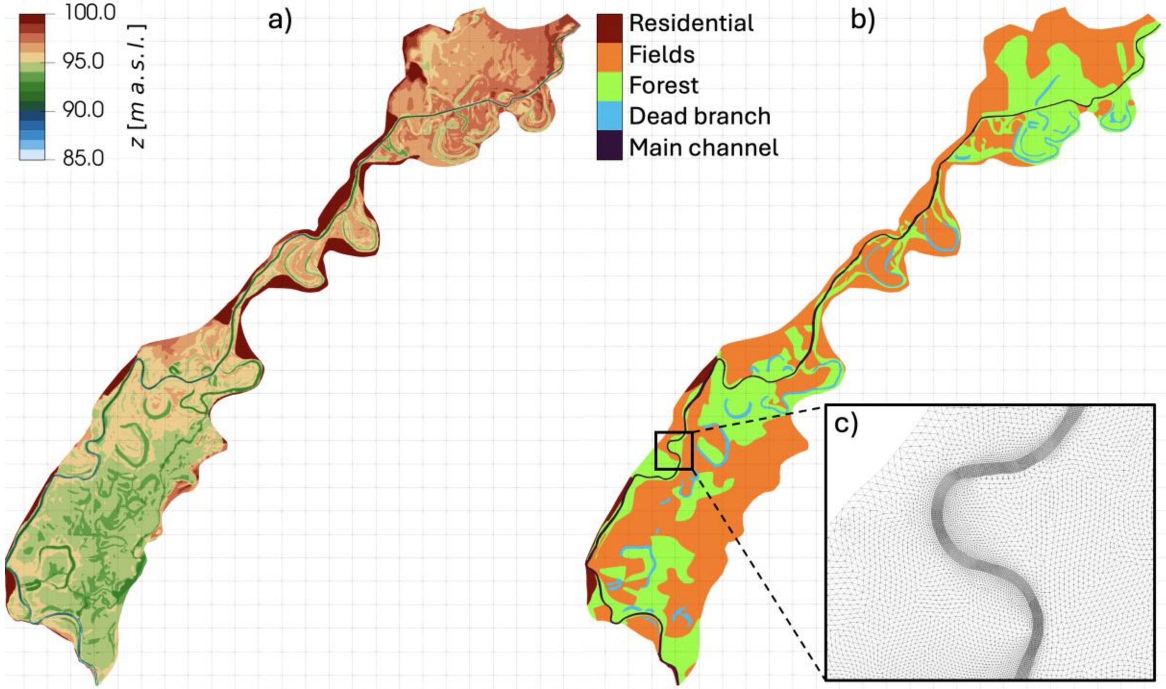
Adaptive Hydraulics (AdH)

- Developed at USACE
- Two-dimensional, depth integrated approach (SWE)
- Finite element solver (transient)
- Curvature effects are considered (vortex transport method)
- Variable roughness, sediments, etc.
- Flexible triangular mesh
- In-house experience…



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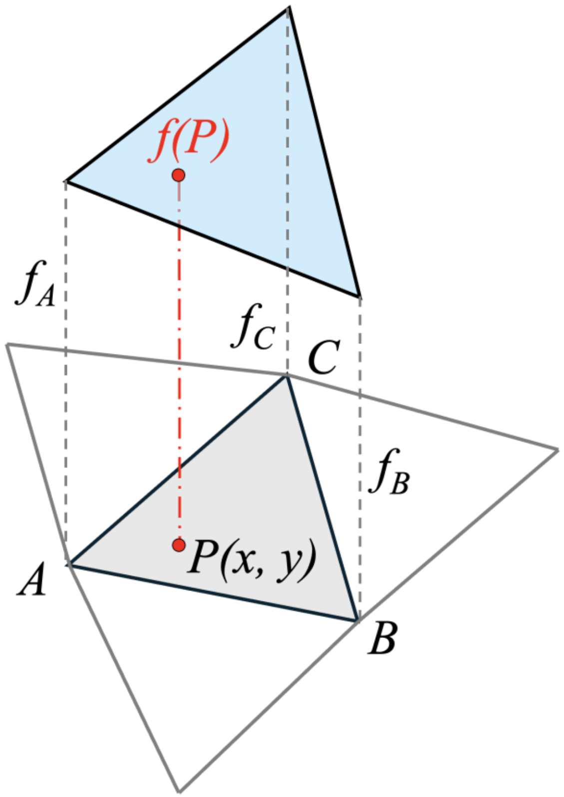
Lagrangian particle transport model

- Offline coupling with the HD model
  - In-house code (python)—particle behavior is programmable—modular design
  - Testing and sensitivity analysis (enough to run HD once)
  - Works with basically any 2D model (input: mesh + transient HD solution)
- Turbulent dispersion—random-walk approach
  - Multiple models for D_h (Elder, Smagorinsky…)
- Efficient local particle search algorithm (key in large domains)



$$x(t+\Delta t) = x(t) + \left(u(x,y,t) + \frac{\partial D_{h,x}(x,y,t)}{\partial x}\right)\Delta t + \sqrt{2D_{h,x}(x,y,t)\Delta t} \cdot R_x$$

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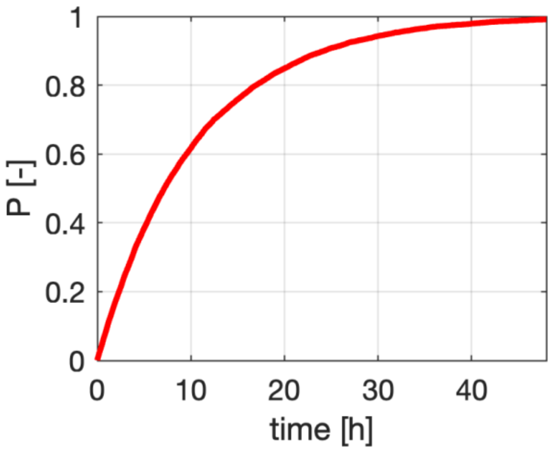
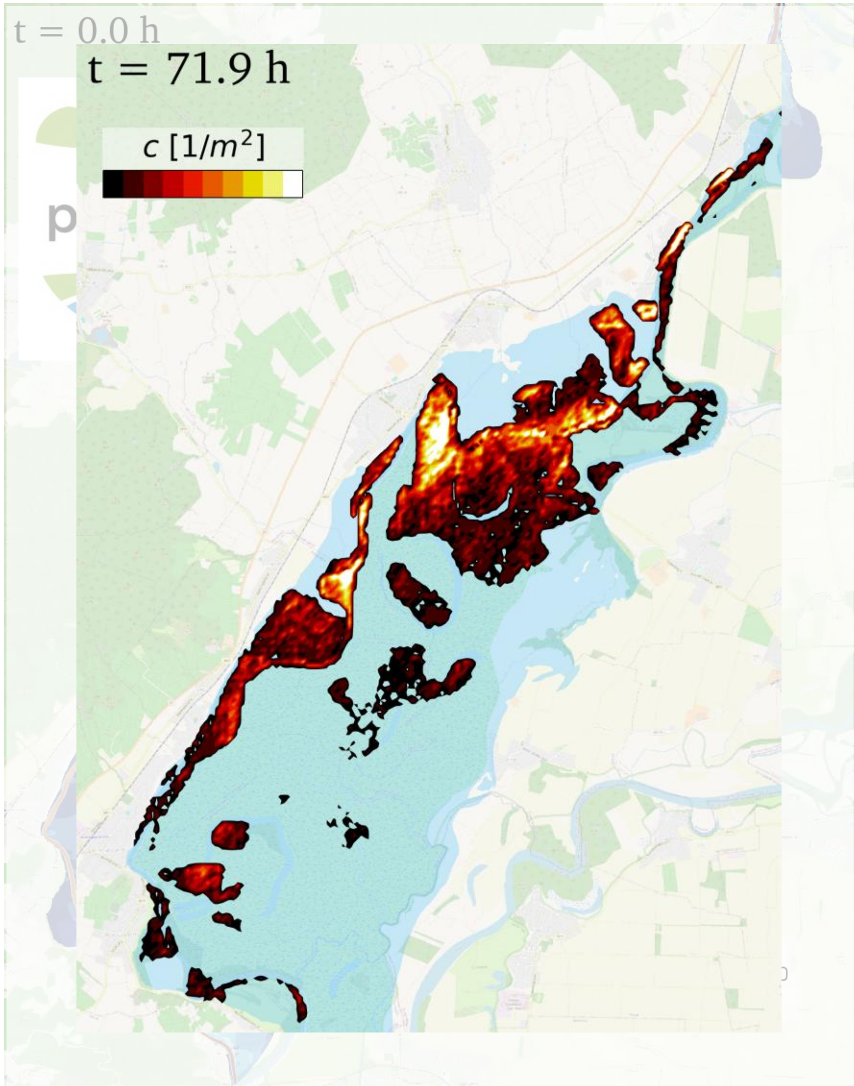
Specific mechanisms for floating macroplastic transport

- MPs are considered as virtual particles
- Velocity at the free surface ≠ depth-averaged (floating)
- Stranding—pickup (water level change)
- Trapping in vegetation (probability-based)

Output: concentration of trapped MPs—*heatmaps*





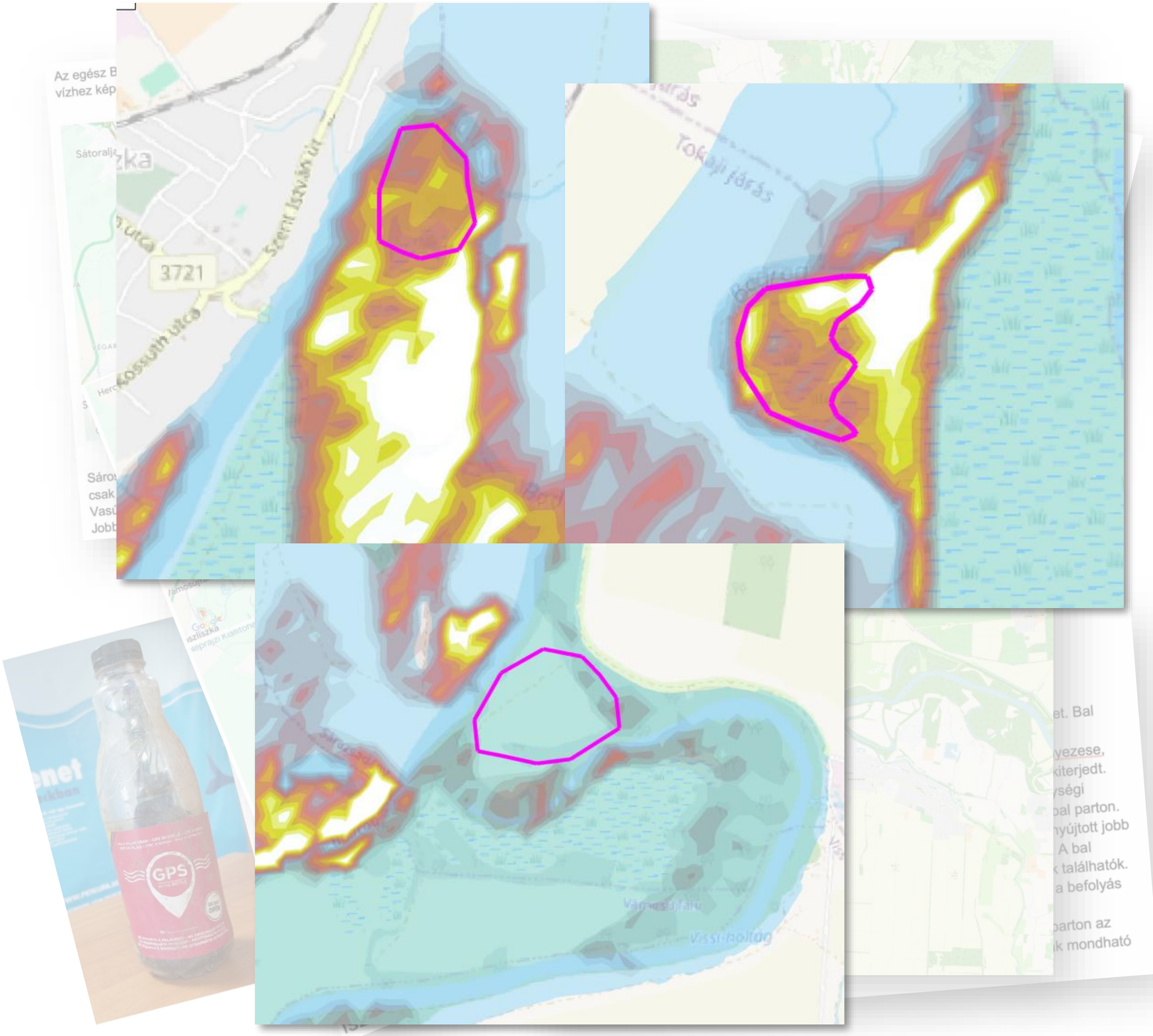
Verification

"All models are wrong, but some are useful"

/George Box/

How to make sure the particle model is *useful*?

- Verification data is key, but is far from straightforward in this case
- Field campaigns (cleanup)—qualitative data with details report → GIS
  - Comparison with *litter heatmaps*
- GPS bottles—detailed, valuable yet limited amount of information



Synergies — The role of M4

- **Modeling** efforts are crucial for predictions and **management** in particular
  - E.g.: litter traps implemented in the model ($P_{trapping}$=1) → optimalization
- For good models, we need **measurements** for verification and development
  - Experimental data—underlying physics—what/how to consider?
  - Field data—actual verification data—what are we missing?
- On the field we usually got snapshots—uncertainty for modeling
  - What were the initial conditions?
  - Transient nature?
  - Potential solution: **monitoring** data is (ML-based MP detection and counting algorithms)

Collaborative efforts across disciplines are crucial!

Thank you

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