Process-based sensitivity analysis of a Lagrangian particle tracking model for microplastics

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Introduction

- A Lagrangian particle tracking model was employed to investigate the impact of various processes on microplastic (MP) transport and accumulation in marine environments
- The particle model incorporates **processes related to MP behavior**:
  1) Mixing;
  2) Beaching;
  3) Resuspension;
  4) Biofouling
- **The main objective** of the study is to perform a **sensitivity analysis** of the four processes to investigate the importance of each process on the distribution of MPs in the **Gulf of Finland**
- Additionally, the model's **performance was validated** to confirm the stability of the advection and diffusion scheme

Sensitivity scenarios and simulation setup

- Experiments to assess the sensitivity of processes on MP distribution in simulation
- Initial reference run focused solely on advection
- Individual testing of each process by modifying specific parameter, disabling other processes
- Simulation period: February 5, 2018, to December 31, 2018
- Daily particle release primarily from rivers along the Estonian coast
- Particle release proportional to river discharge, total of 145,146 particles
- Initial particle properties: radius: 0.1 mm, densities: 920 kg/m^3 and 1380 kg/m^3

Particle model description

- Uses output from hydrodynamic model (e.g. **GETM**) to simulate the transport of particles
- Able to work with **decomposed domain**
- Advection of particles using Heun's method
- Horizontal diffusion coefficient calculated according to the Smagorinsky sub-grid scale parametrization
- Beaching determined by time spent in beach area
- Biogeochemical data from **ERGOM** used to determine biofilm growth
- Bottom friction velocity used as threshold for resuspension

Table 1: Parameters used in sensitivity analysis

Process (parameter)	**Low**	**Moderate**	**Strong**	**Very strong**
Beaching (beaching time [d])	30	10	1	0.5
Mixing (Smagorinsky coef. C_s)	0.01	0.3	1.0	2.0
Resuspension (threshold [m/s])	0.191	0.148	0.075	0.0375
Biofouling (T_s [d])	20	10	1	0.5
Biofouling (h_{max} [% radius])	5	10	20	30

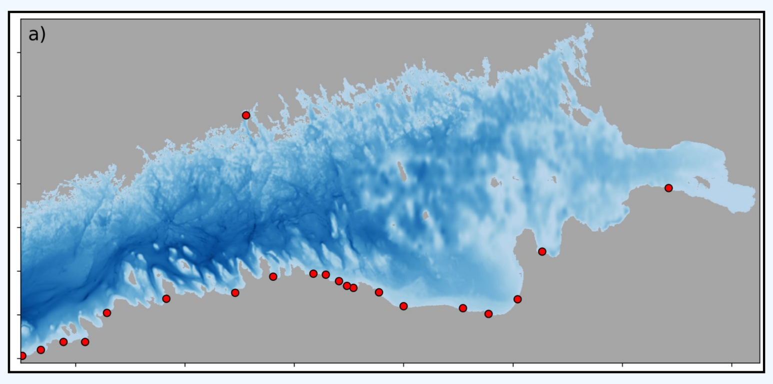

Figure 1: Simulation domain and release locations.

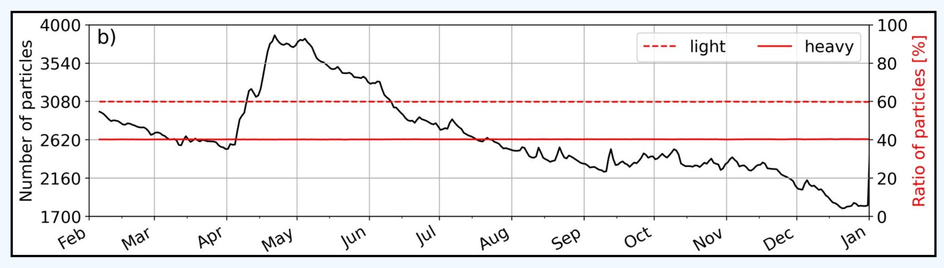

Figure 2: Timeseries of total released particles (black line) and ratio of light (red dashed line) and heavy (red solid line) particles.

Results

- **Diffusion**
  - Diffusion reduces the particle count in the water column and enables more intense settling
  - ~1.8% of the total released particles remained in the water column under very strong diffusion conditions (reduction of ~96.8% compared to the reference run)
- **Beaching**
  - Longer beaching times (low beaching) increased particle transport to the GoF off-shore areas
  - Particle count in the water column significantly decreased: ~80% with low beaching, ~90% with moderate beaching, and over 95% with strong/very strong beaching, compared to the reference run
- **Biofouling**
  - Maximum biofilm thickness (h_{max}) parameter had greater influence than saturation time scale (T_s) parameter: modifying h_{max} had immediate impact on water column particles
  - Particles remaining in water column: 38.4% to 40.4% (varying T_s), 3.6% to 7.1% (h_{max})
- **Resuspension**
  - Increased resuspension intensity raised particles in water column, reducing presence in bottom sediments.
  - Water column particles increased by 3.8% with low resuspension and approximately doubled with moderate, strong, and very strong resuspension to 6.4%, 12.8%, and 22.7%
- **Combination**
  - Particle budget shows significant decrease in water column particles compared to reference run
  - ~2.3% (low) and 1.6% (very strong) of particles remain in water column (95.8% and 97.1% decrease from reference run)

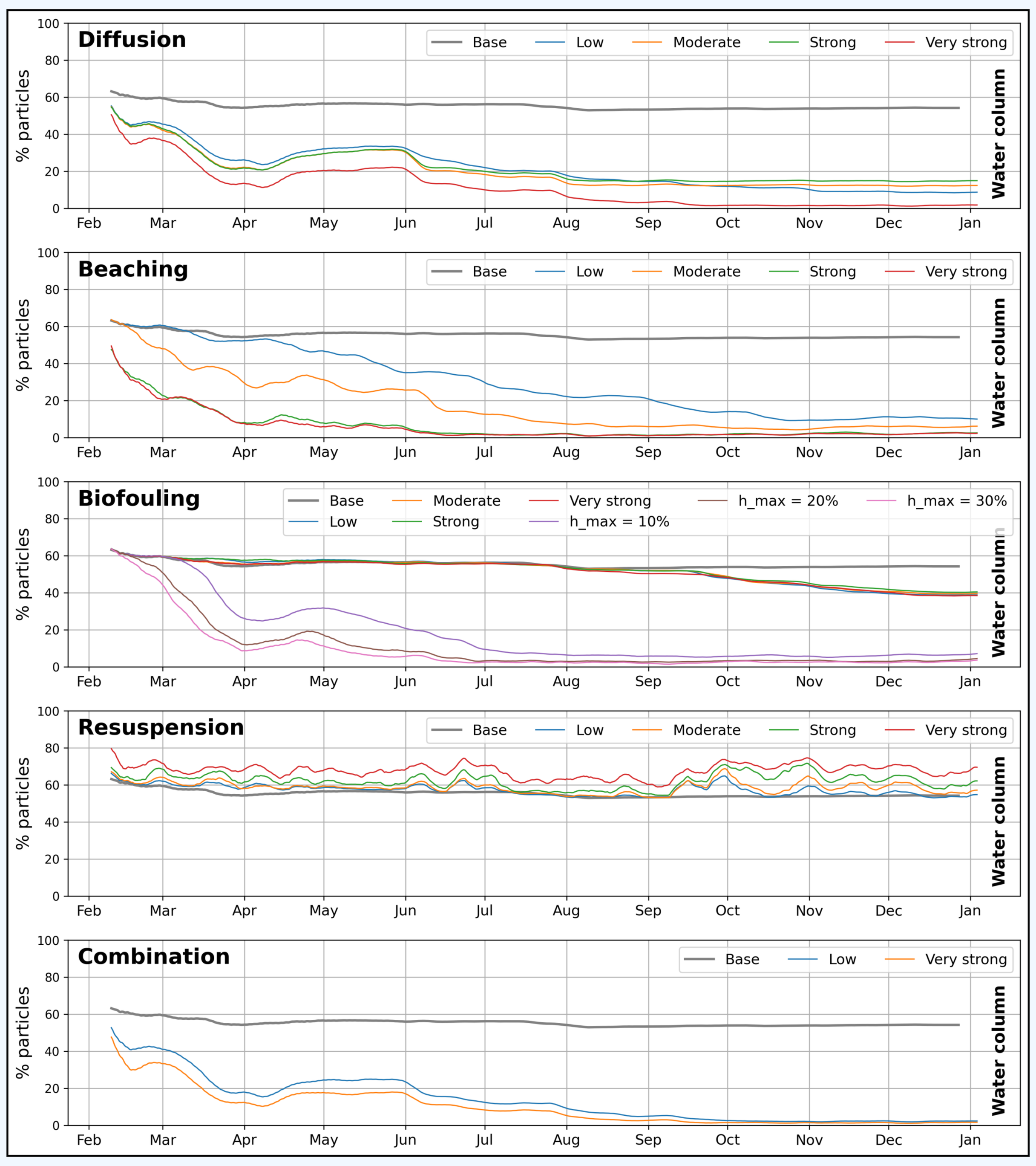

Figure 3: Timeseries of particle budget presented as the percentage of particles in the water column with respect to the cumulative number of particles across the entire domain.

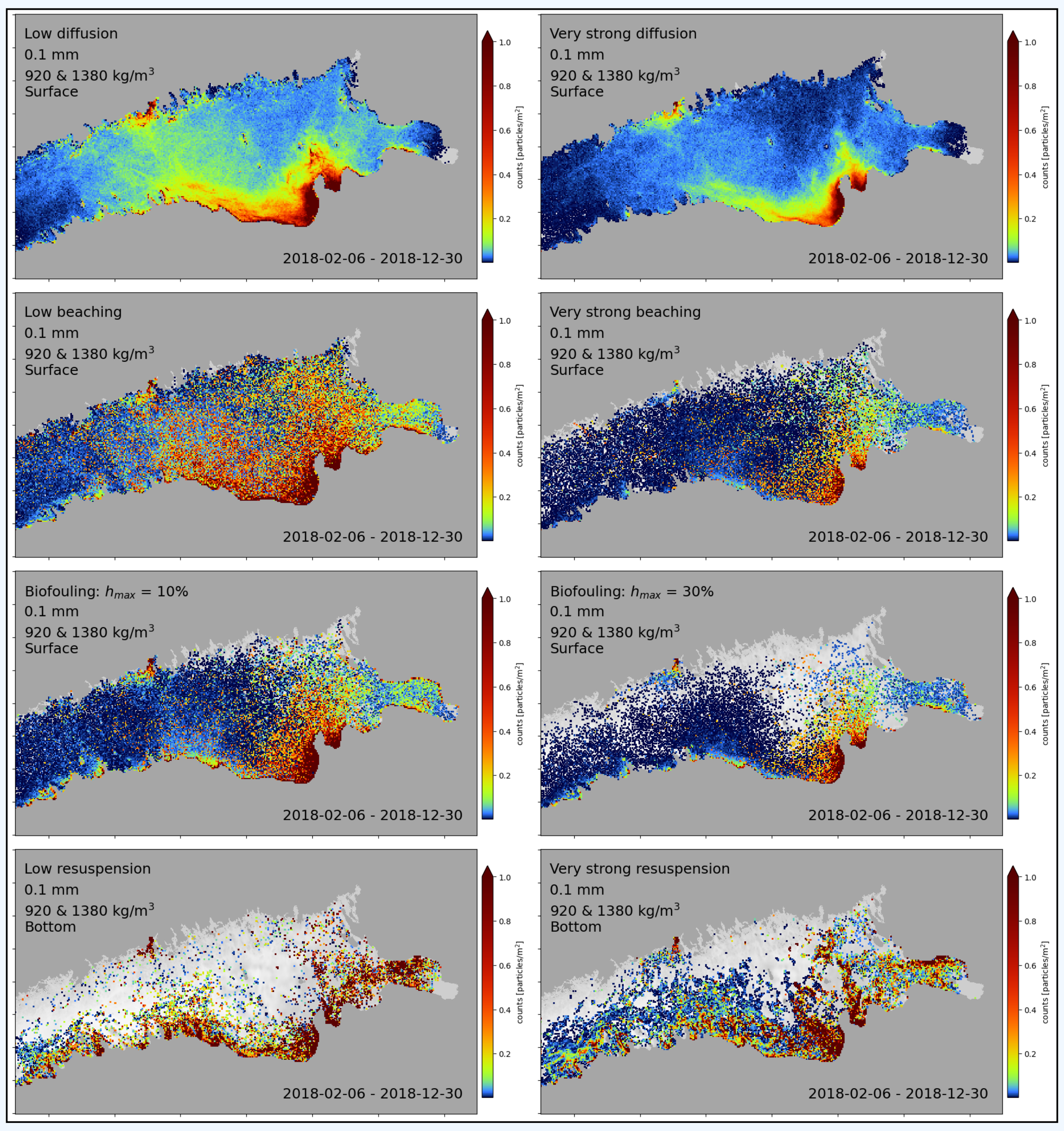

Figure 4: Average particle counts in case of low and very strong processes. Particle counts are shown at the bottom for the resuspension experiments and at the surface for all other processes.

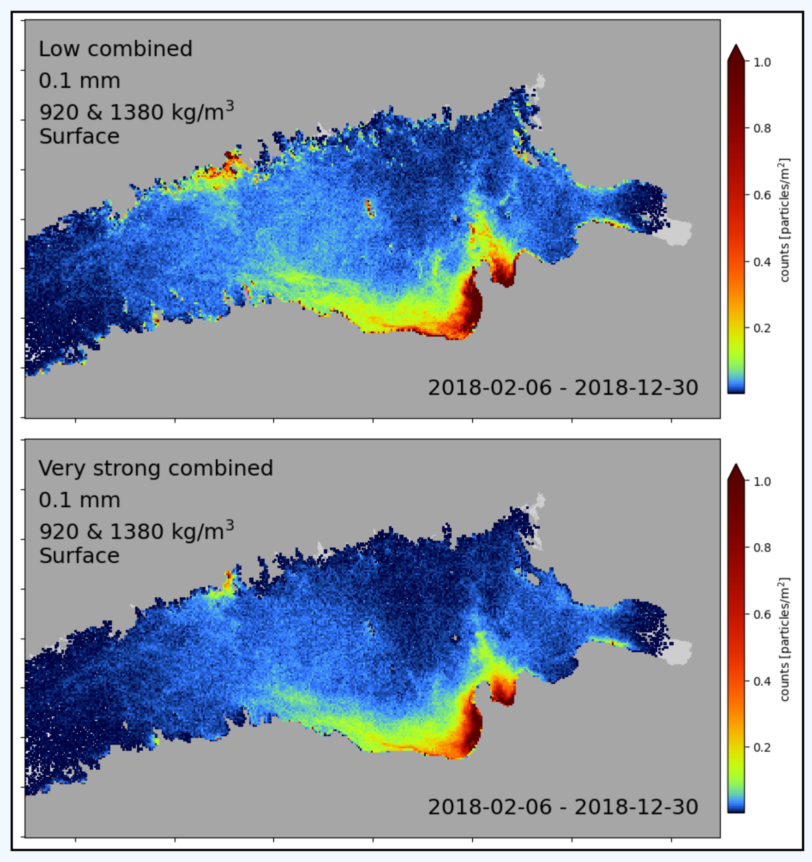

Figure 5: Average particle counts in case of low and very strong combined processes.

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Link to particle model:

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