Modeling Microplastics Transport & Distribution within the Chesapeake Bay

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Chesapeake Bay Program Plastic Pollution Action Team Meeting

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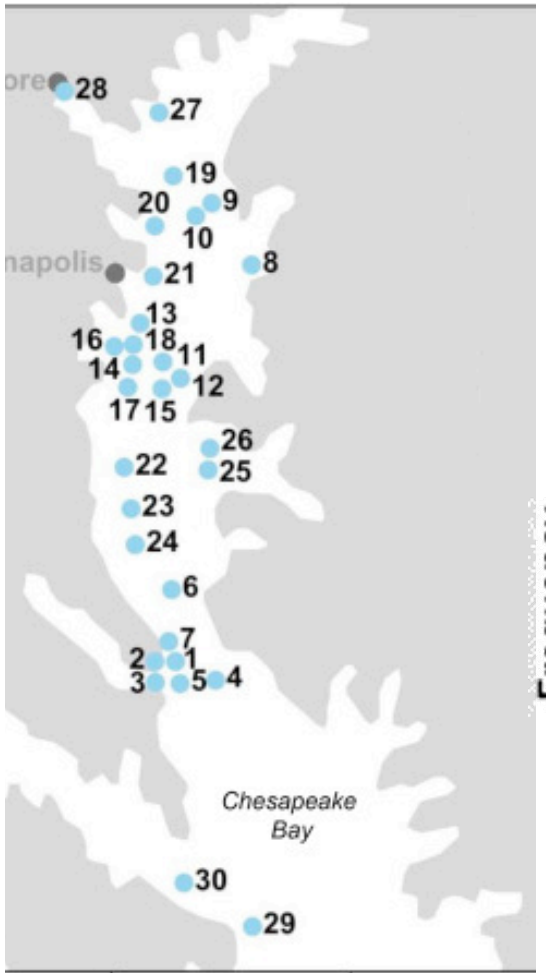
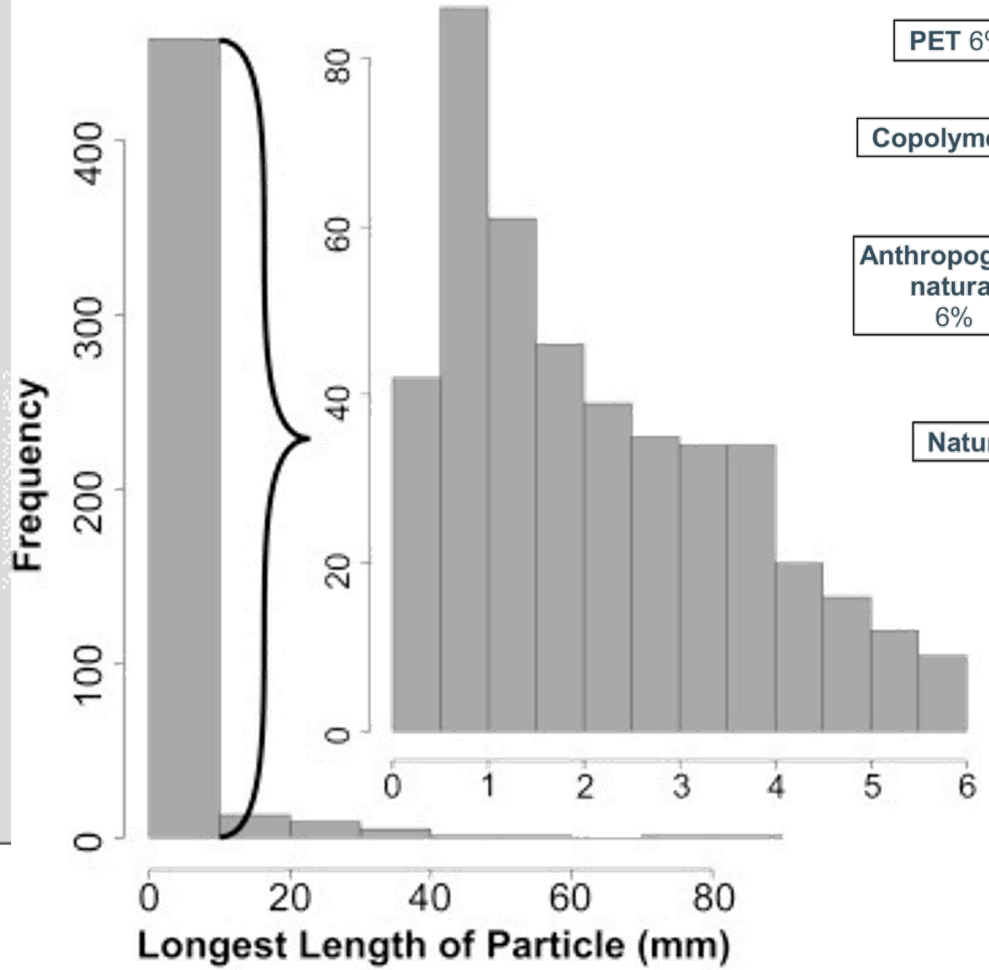
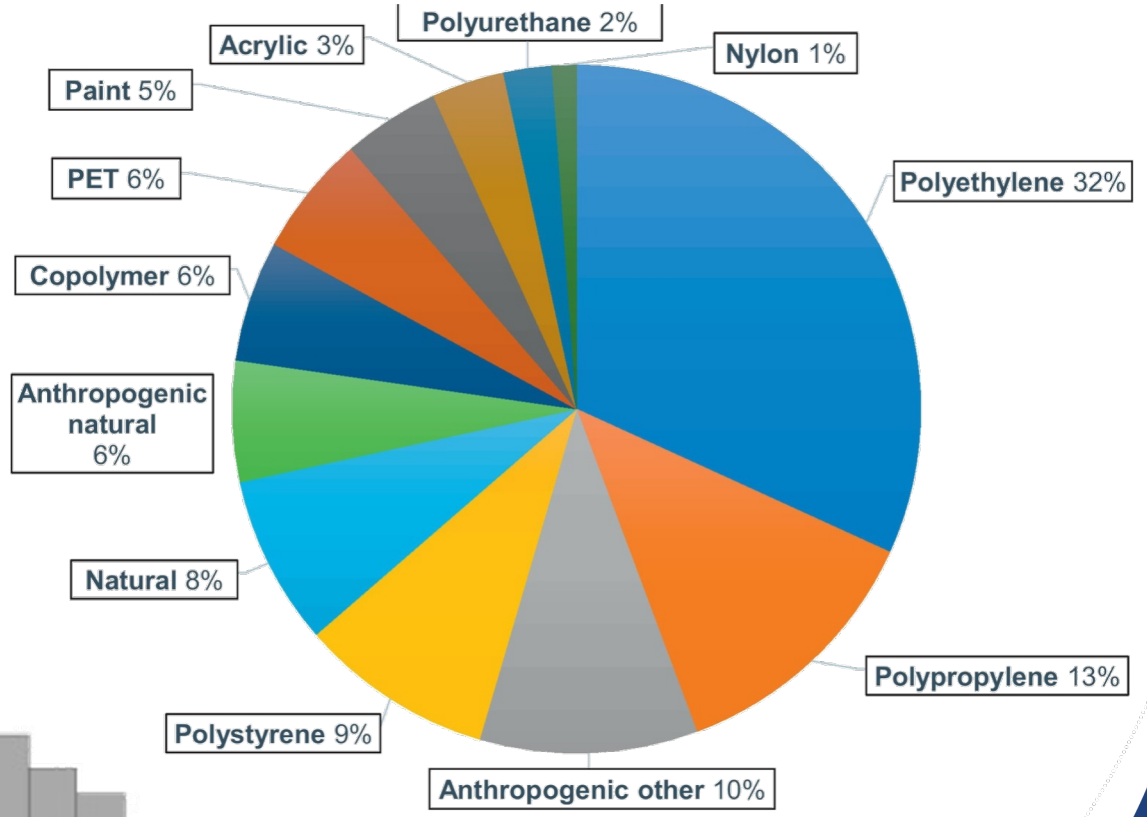
Sampling studies of microplastics within Chesapeake Bay are limited at this time







Bikker et al., 2020

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Research Questions

- Is interannual variability significant for transport & distribution of MPs?
- Does the size of a particle impact its transport & distribution?
- Does the density of a particle impact its transport & distribution?
- Does incorporating the beaching of particles significantly alter their transport & distribution? What if some of the shoreline is armored?
- Where are riverine MPs ending up?

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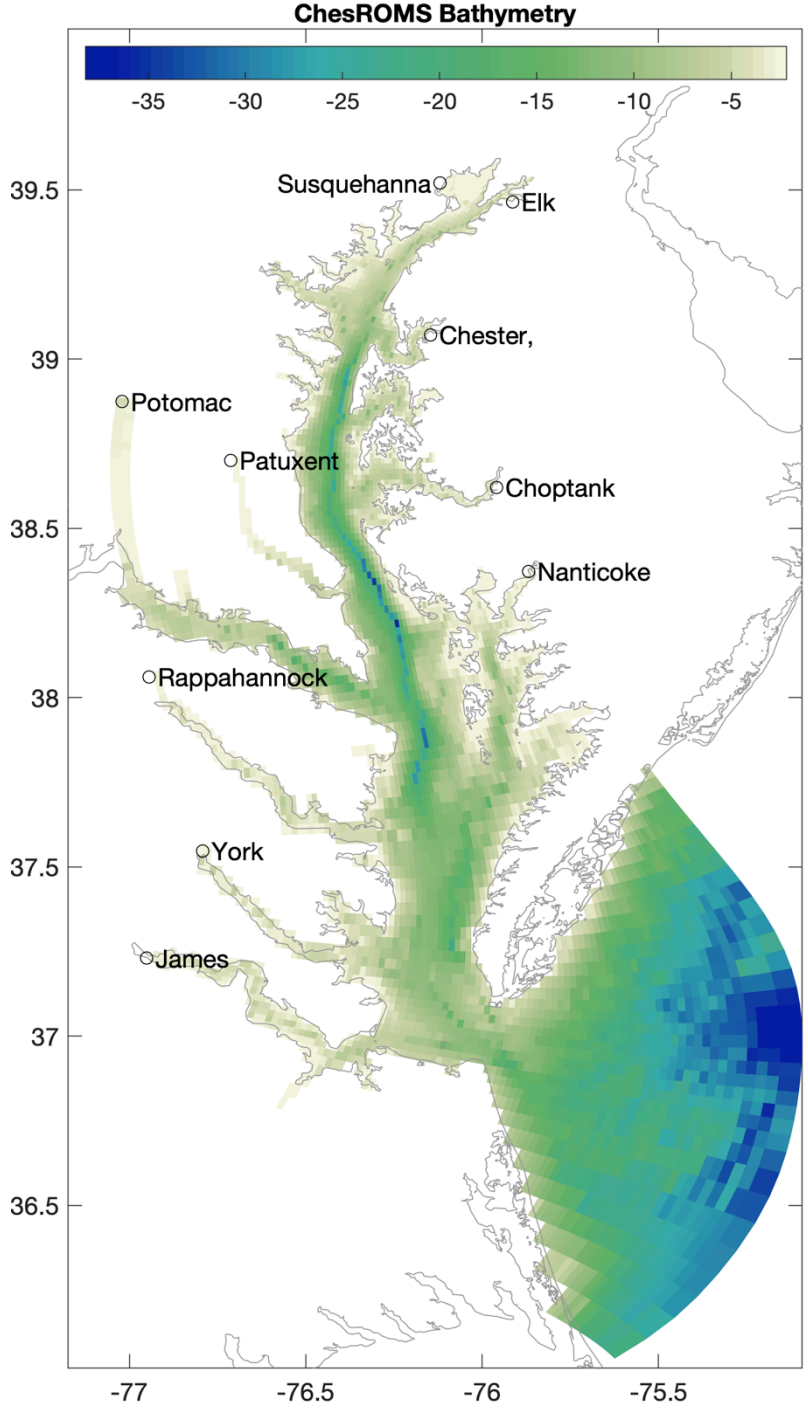
ChesROMS Configuration

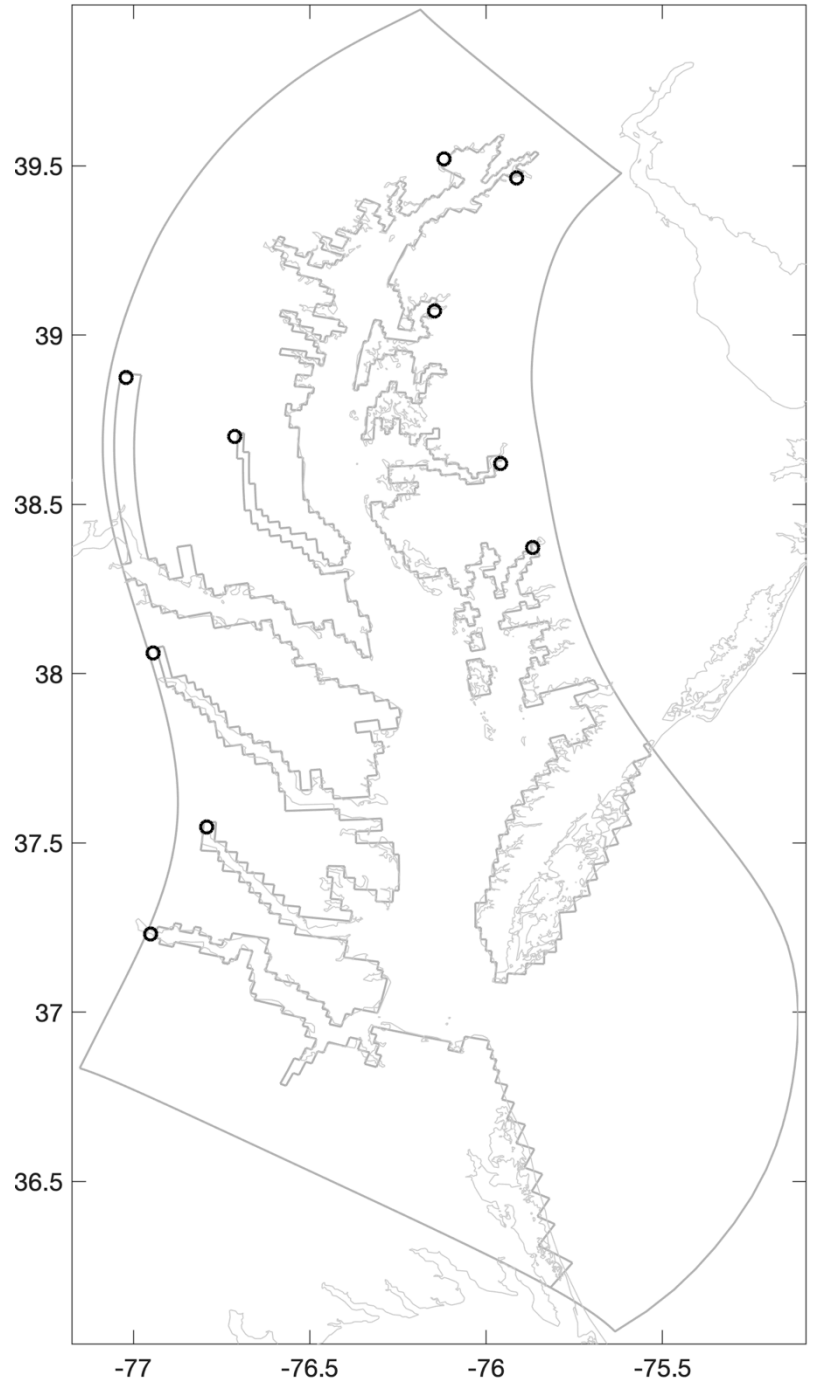
- Hydrodynamic model for the Bay that has been rigorously tested[1]
- Current configuration based upon Da et al., 2018
- 150 x 100 horizontal grid
- 1.7 km average horizontal resolution
- 20 vertical levels
- 30+ years of open boundary & forcing setup files
- 10 rivers



1 Xu et al., 2012

Ichthyop Configuration

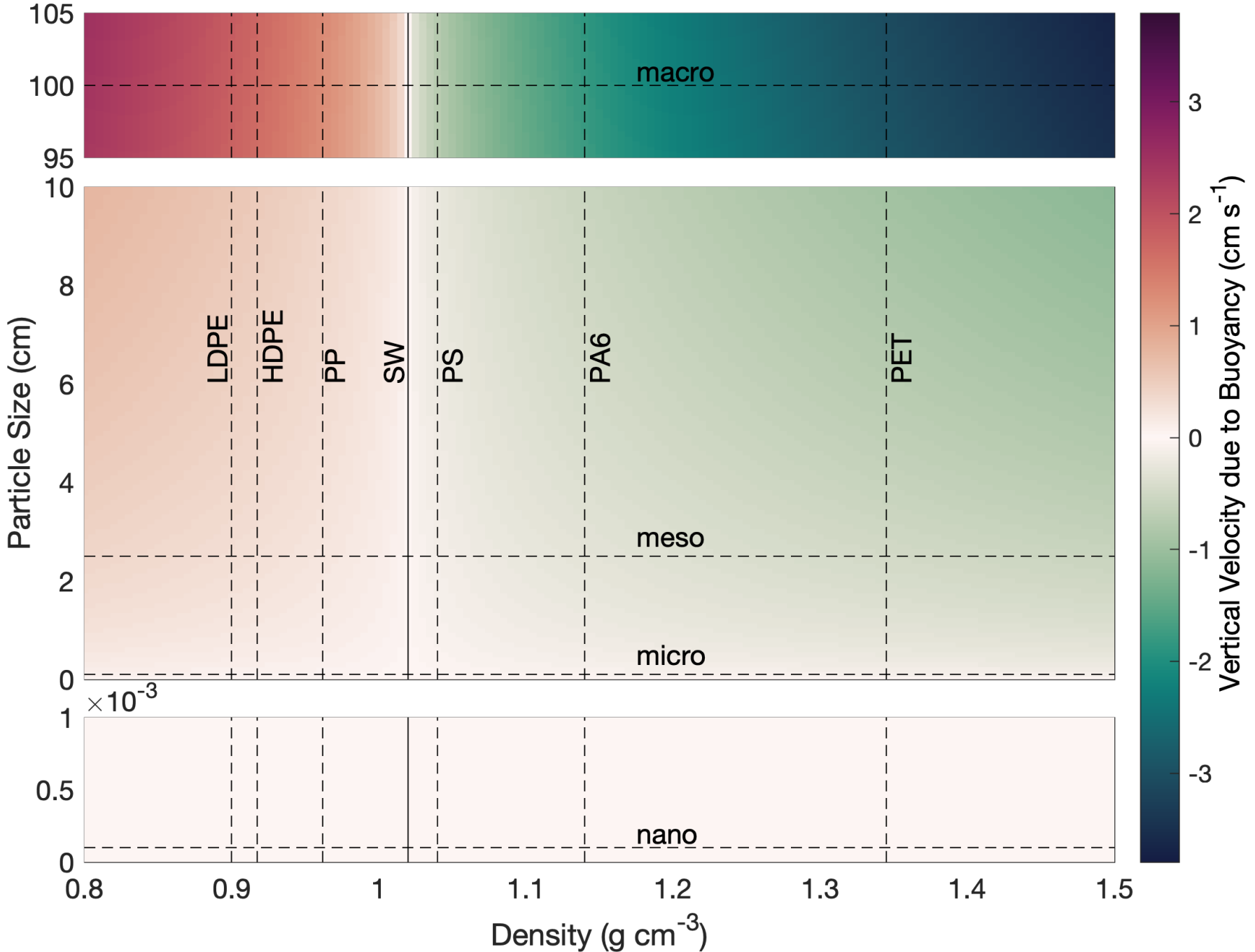
- Lagrangian particle tracking model designed for plankton[1] but has also been applied to microplastics[2]
- Reads in ROMS output
- Particles are sourced at all 10 rivers
- Default MP parameters:
  - Size: 5 mm
  - Density: 0.91 g cm^{-3}
  - Coastline Interaction: Beaching
- Sensitivity testing using one river (York R):
  - ChesROMS forcing frequency
  - Horizontal dispersion
  - Particle concentration
  - Year choice
  - Particle size
  - Density
  - Coastline interactions



1 Lett et al., 2008
2 Atwood et al., 2019

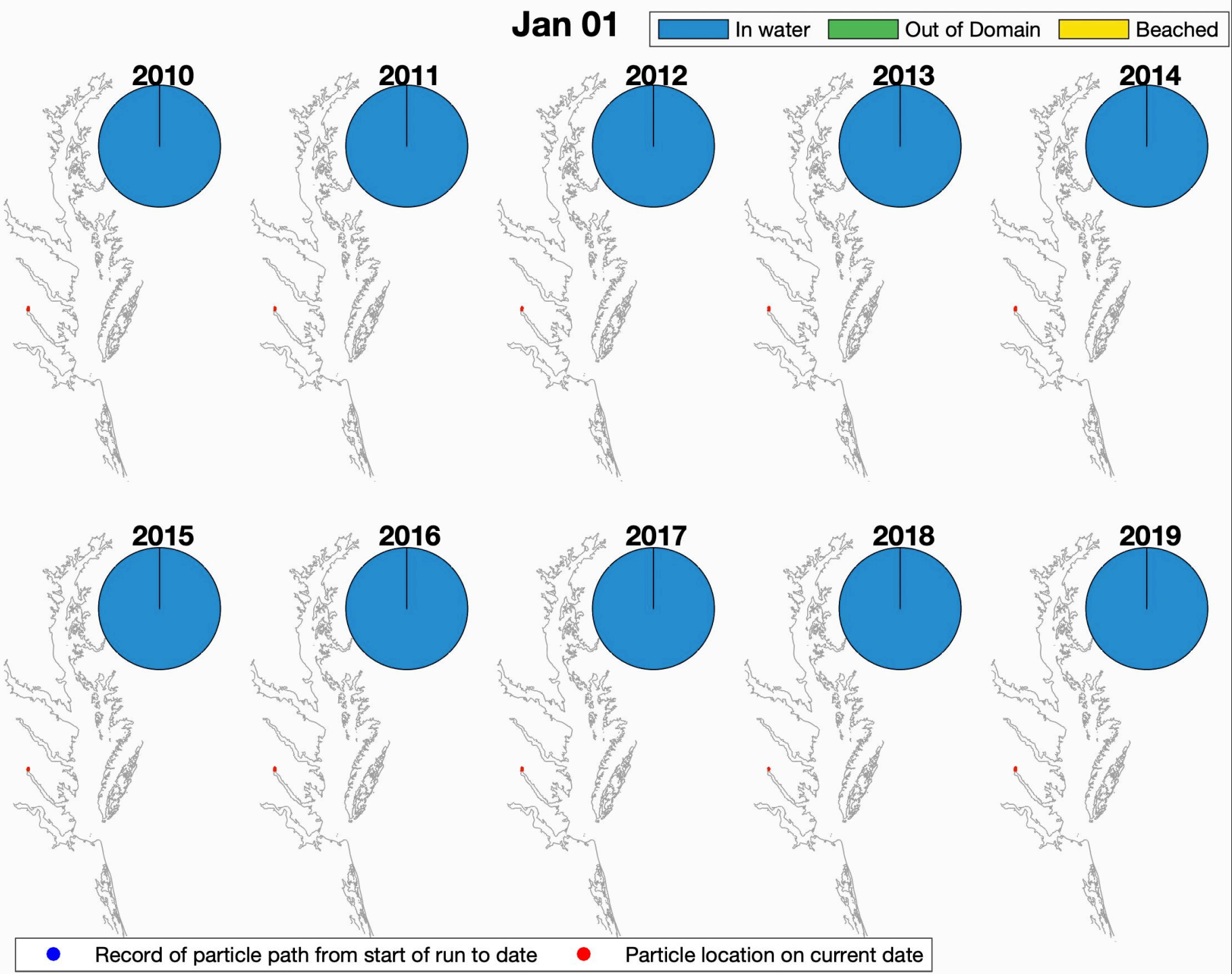
Lines of constant size and density better indicate how significant density is to vertical velocity

Values for particle size & density taken from Andrady, 2017

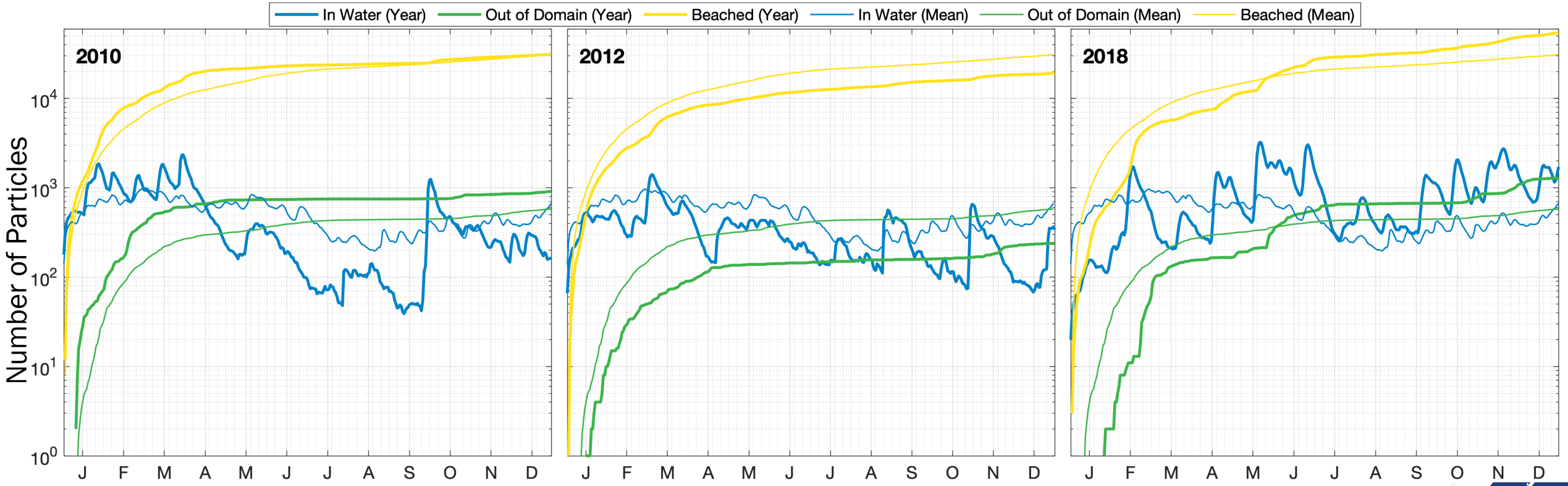


MP distribution patterns are sensitive to interannual variability

2010 is used as representative year



MP fate (beached or out of domain) is also sensitive to interannual variability



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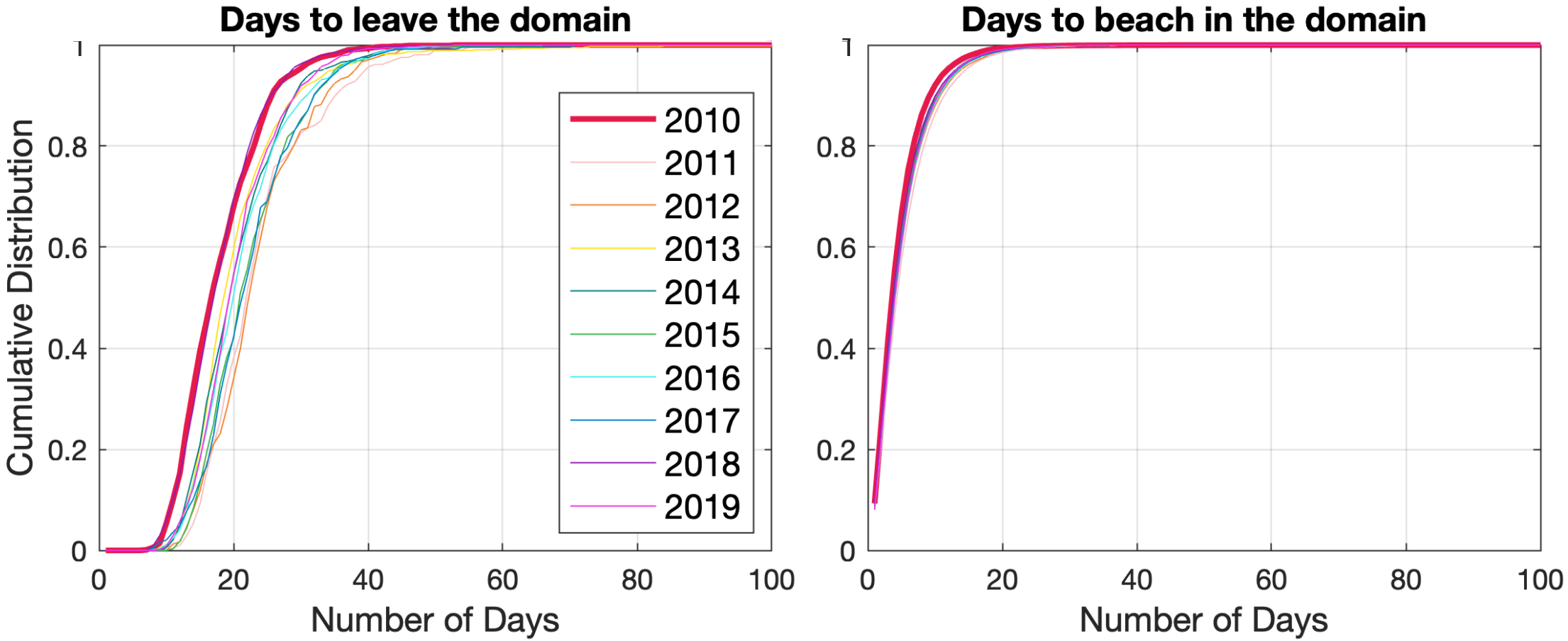
Year choice for study shows 2010 to be representative of the timing to leave domain or beach



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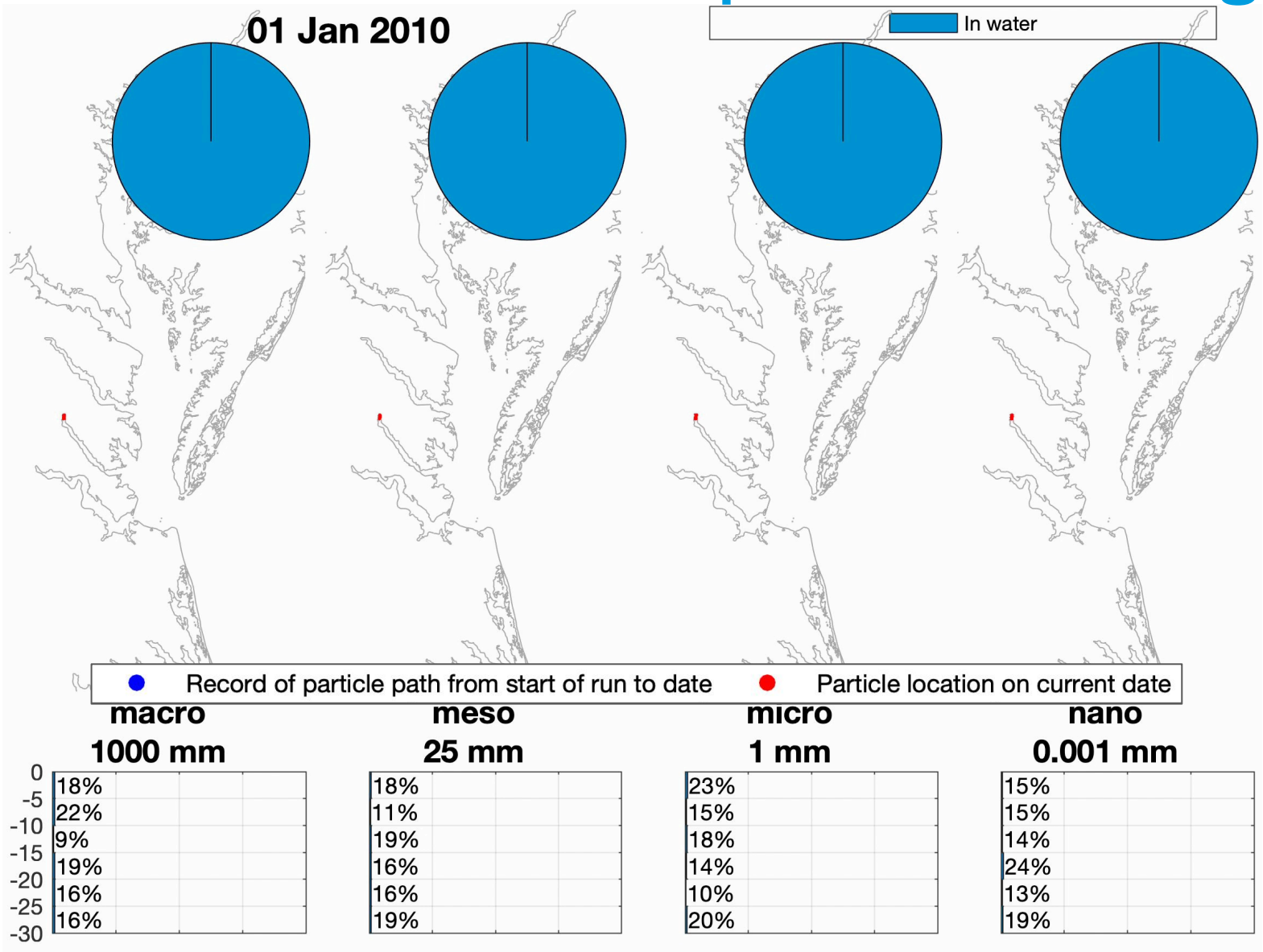
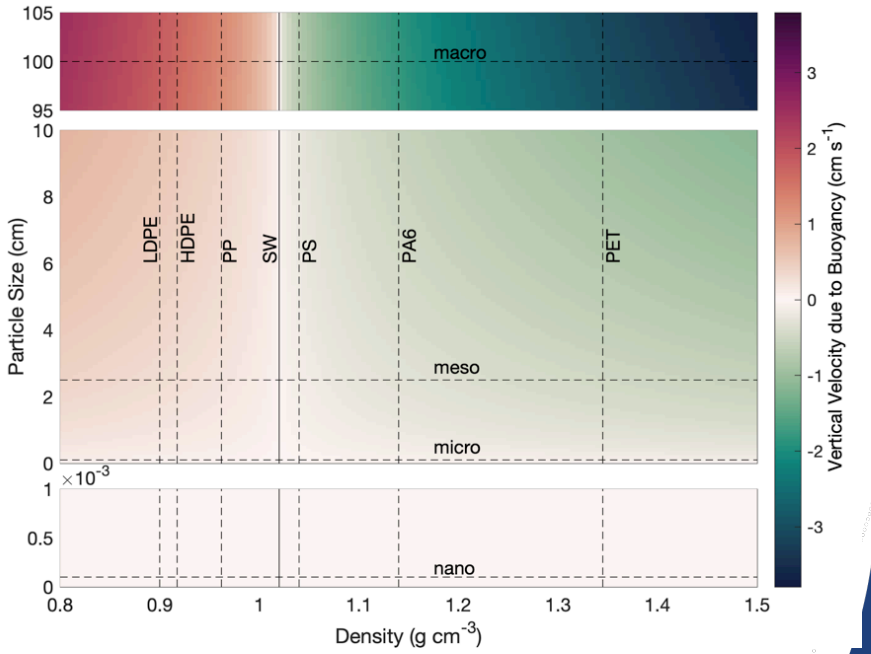
Buoyant particles with sizes from m to µm behave similarly in terms of volume export via beaching or leaving domain





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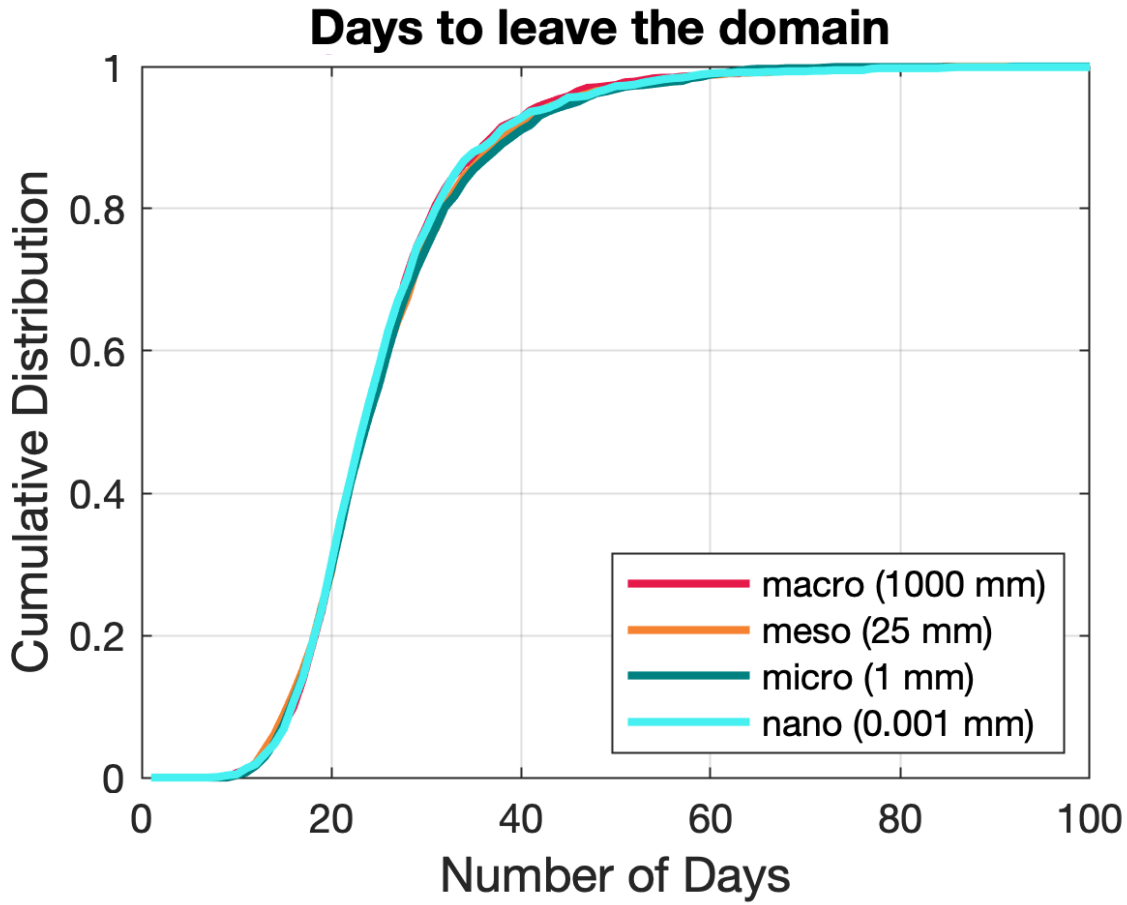
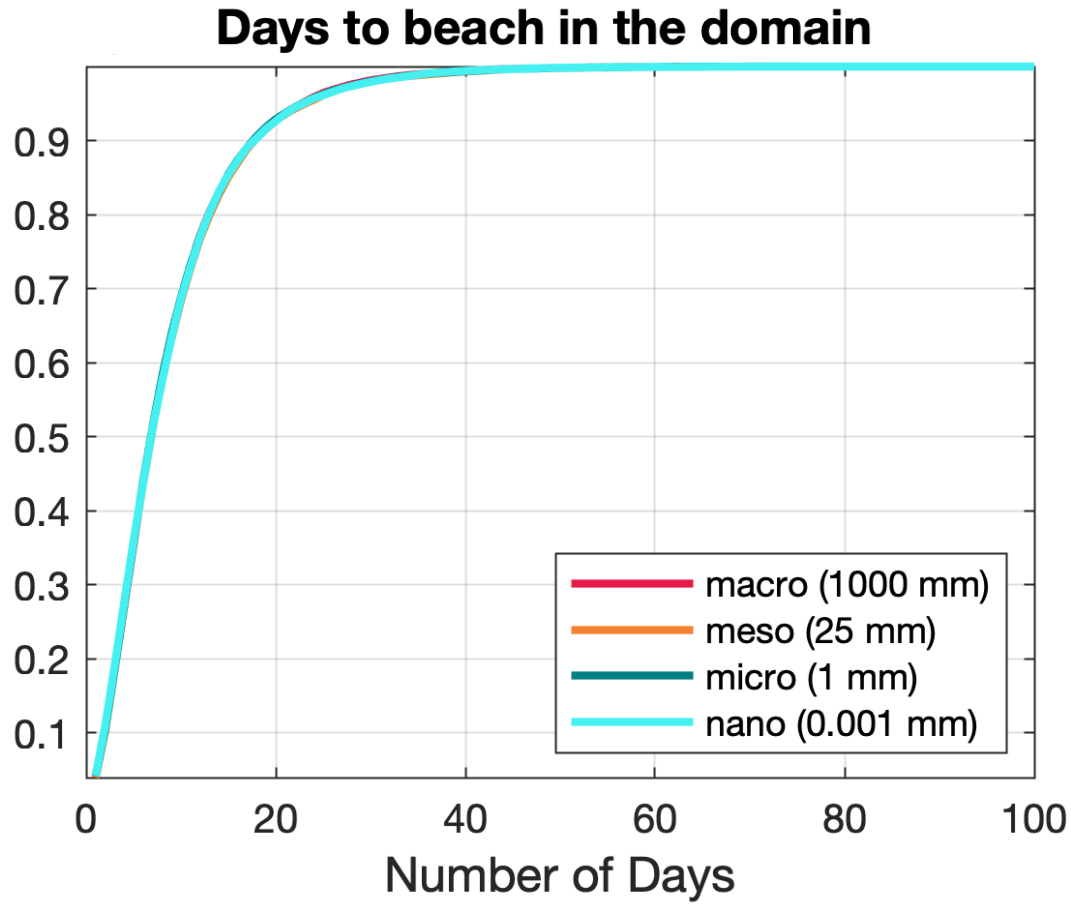
Timing of export via beaching or leaving the domain remained comparable across all sizes for buoyant particles





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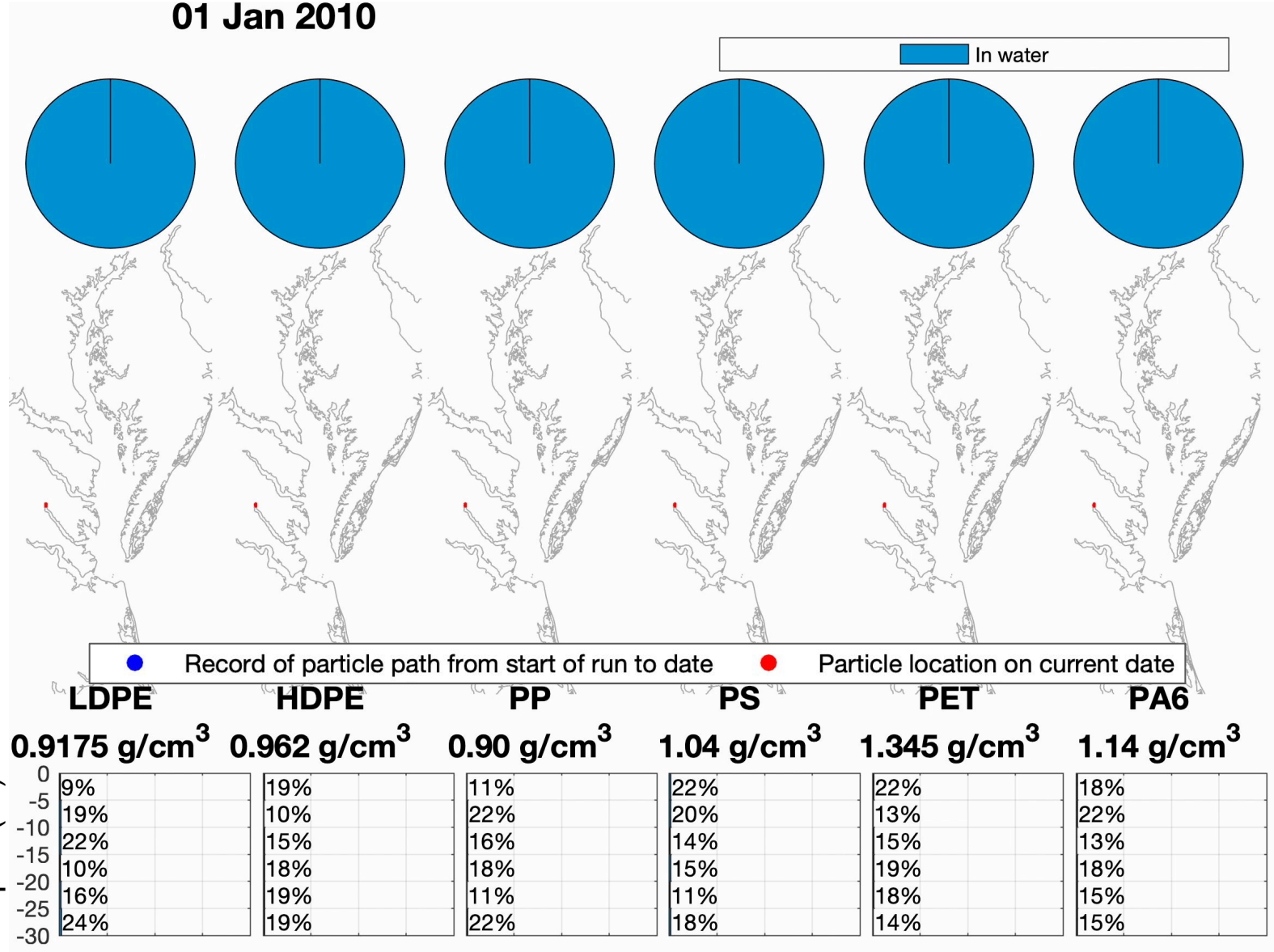
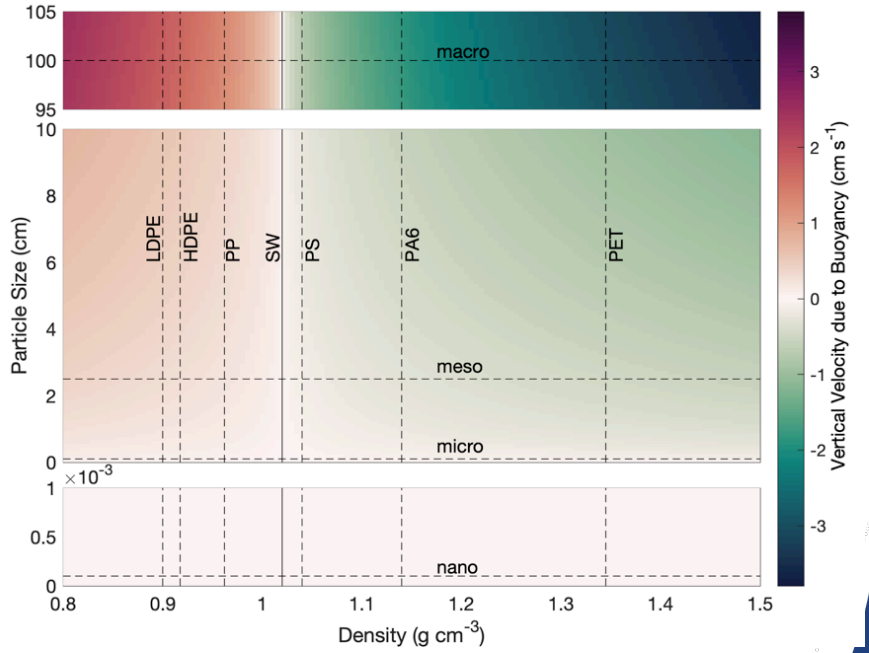
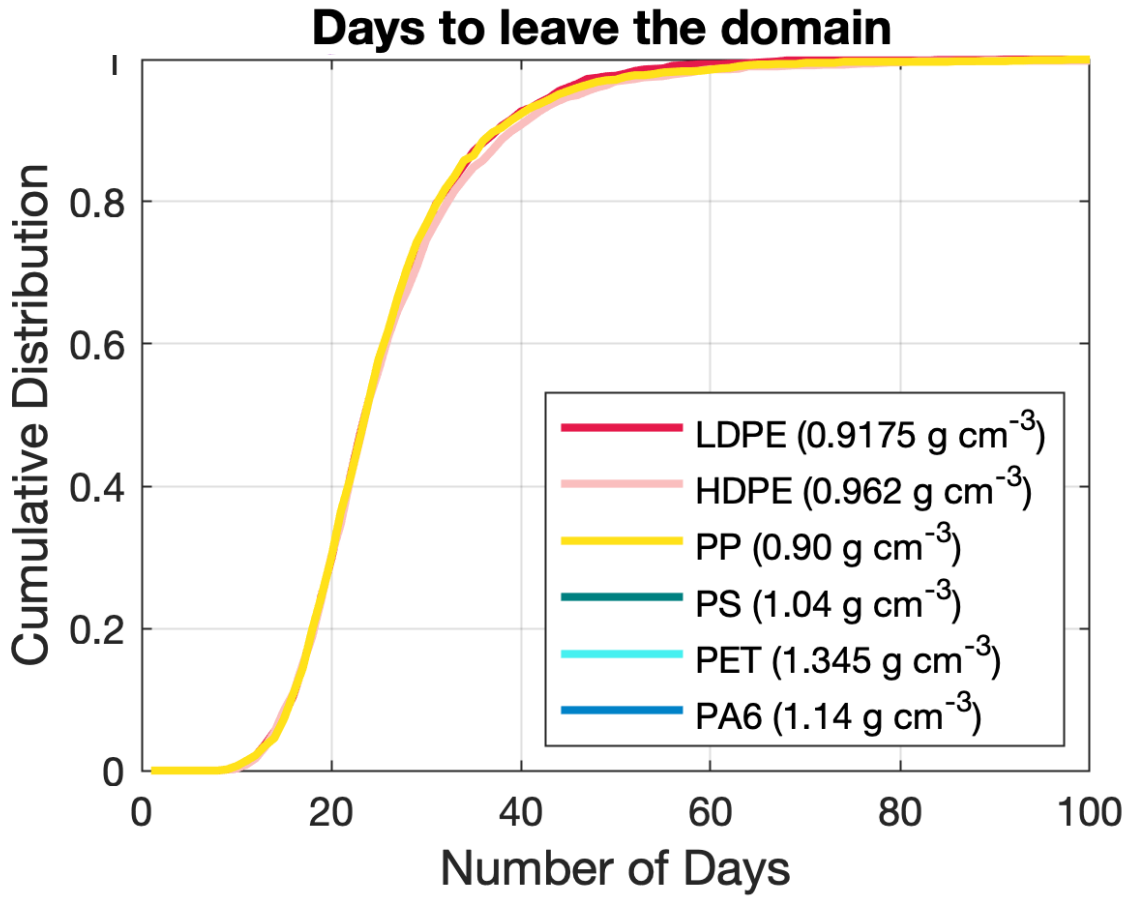
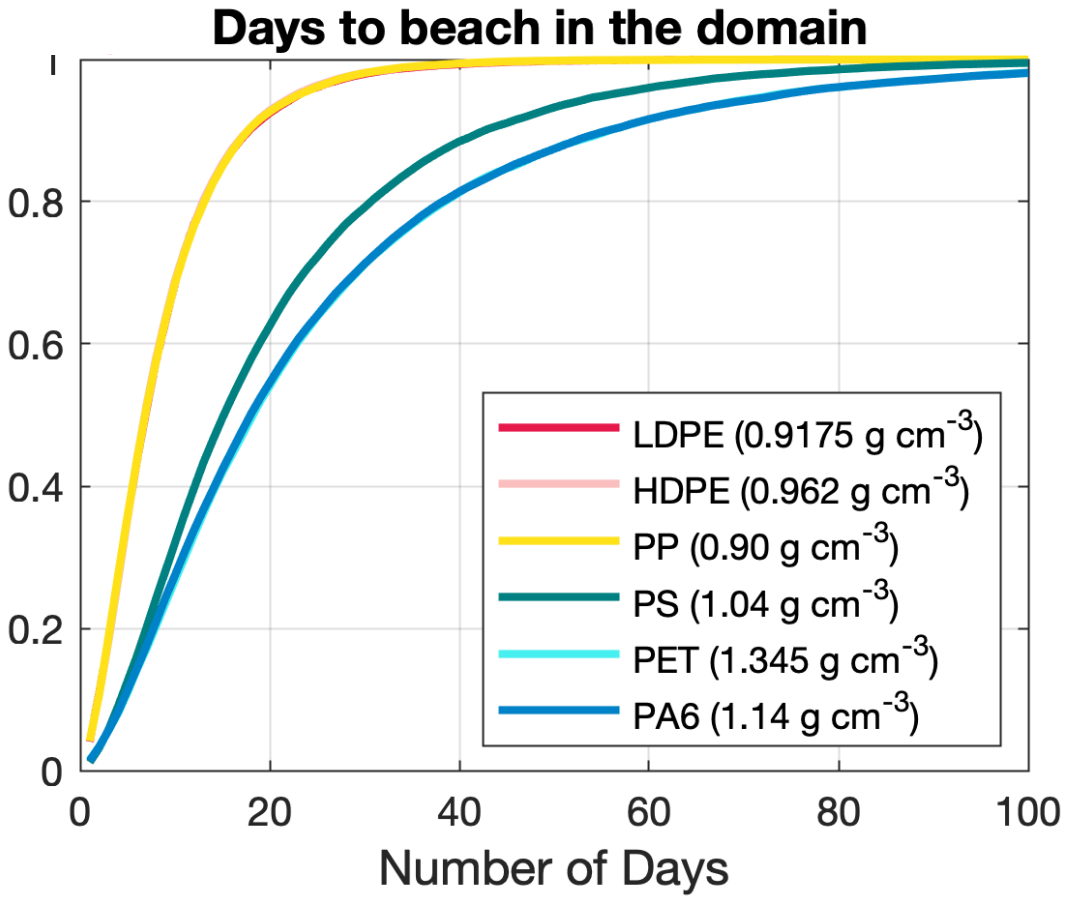
Substantial differences depending on whether the MP particles sink or float





Density differences have clear impact on transport behavior, and the duration spent in the water column





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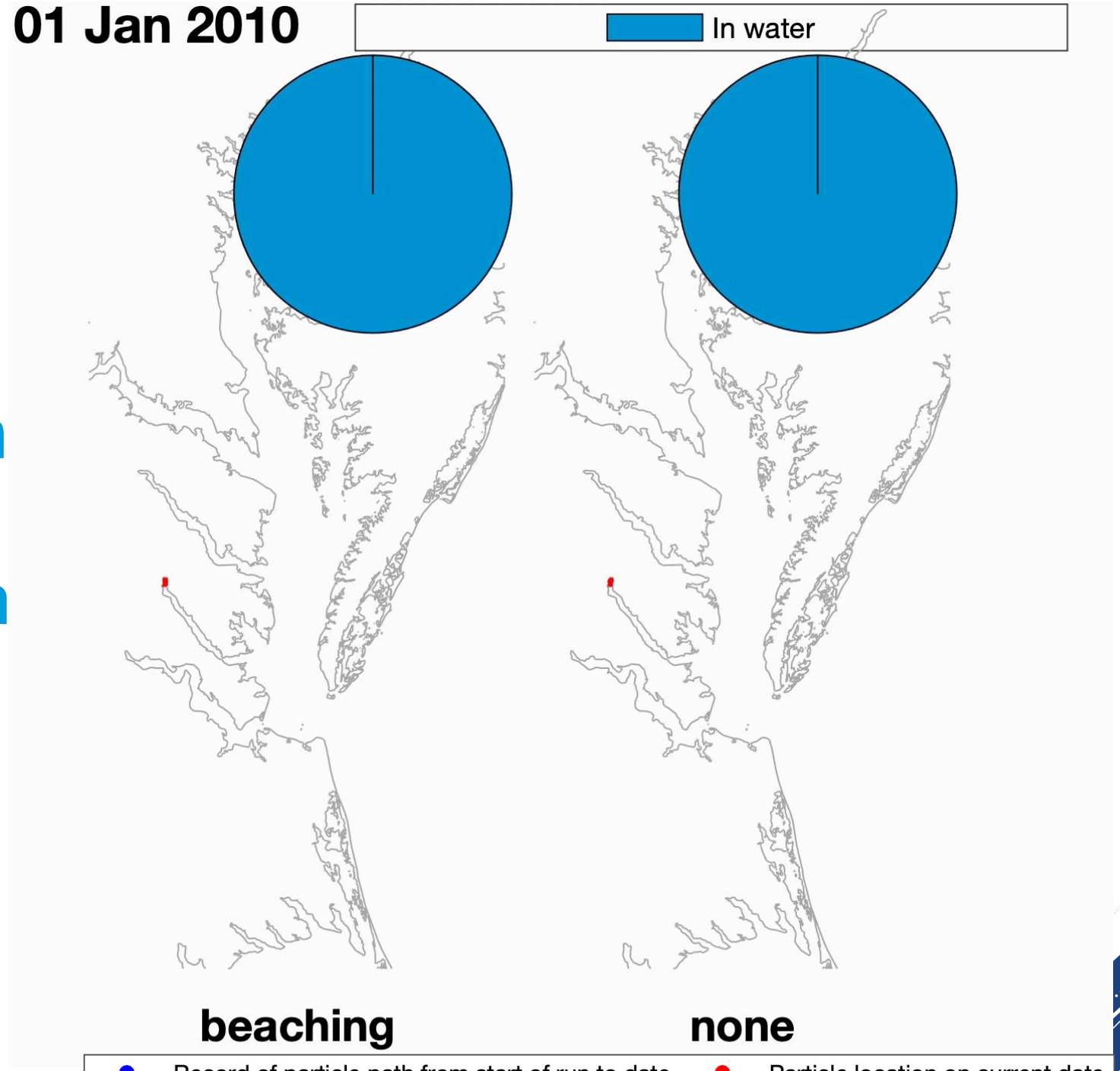
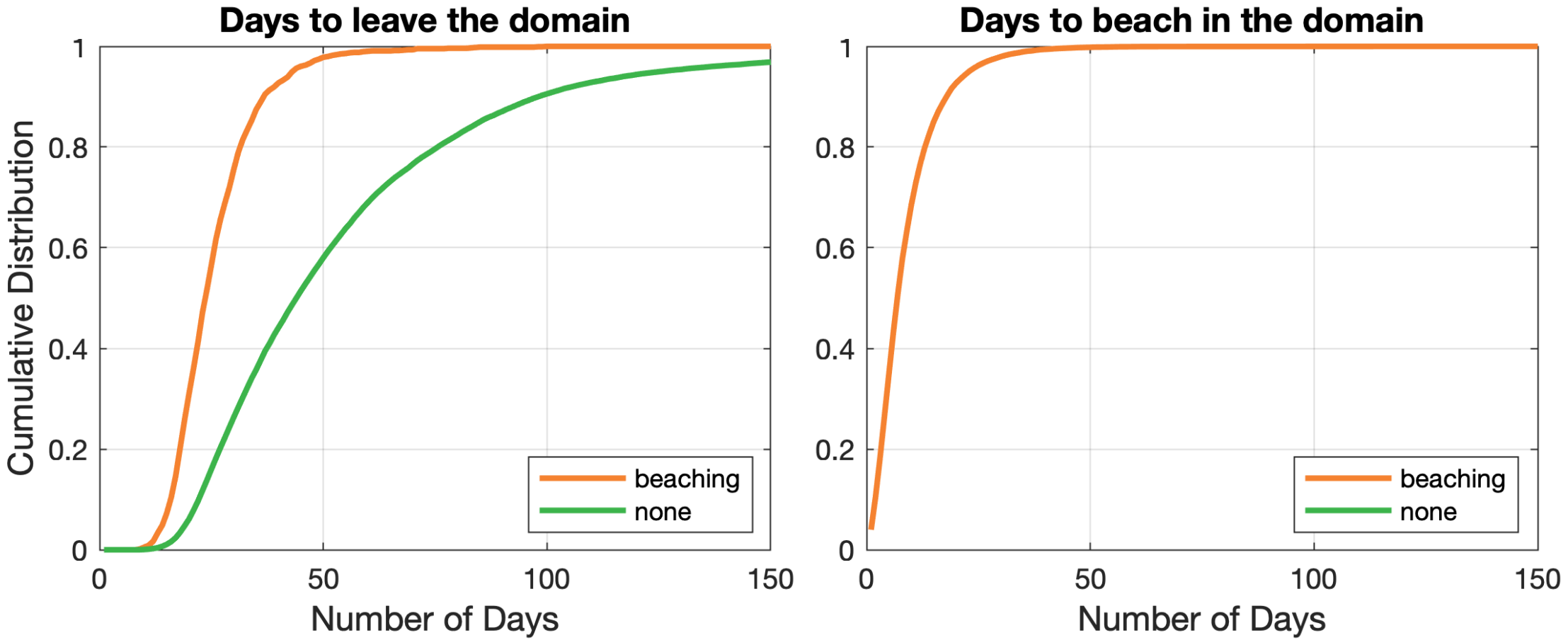
When particles are allowed to beach on the coastline, less reach the mainstem of the Bay



Particles that are able to beach are removed from the system faster than those that are not



Bilkovic et al., 2014 finds that 18% of the Chesapeake Bay's coastline is hardened. While ***beaching*** assumes 0% is hardened, ***none*** assumes the coastline is 100% hardened.

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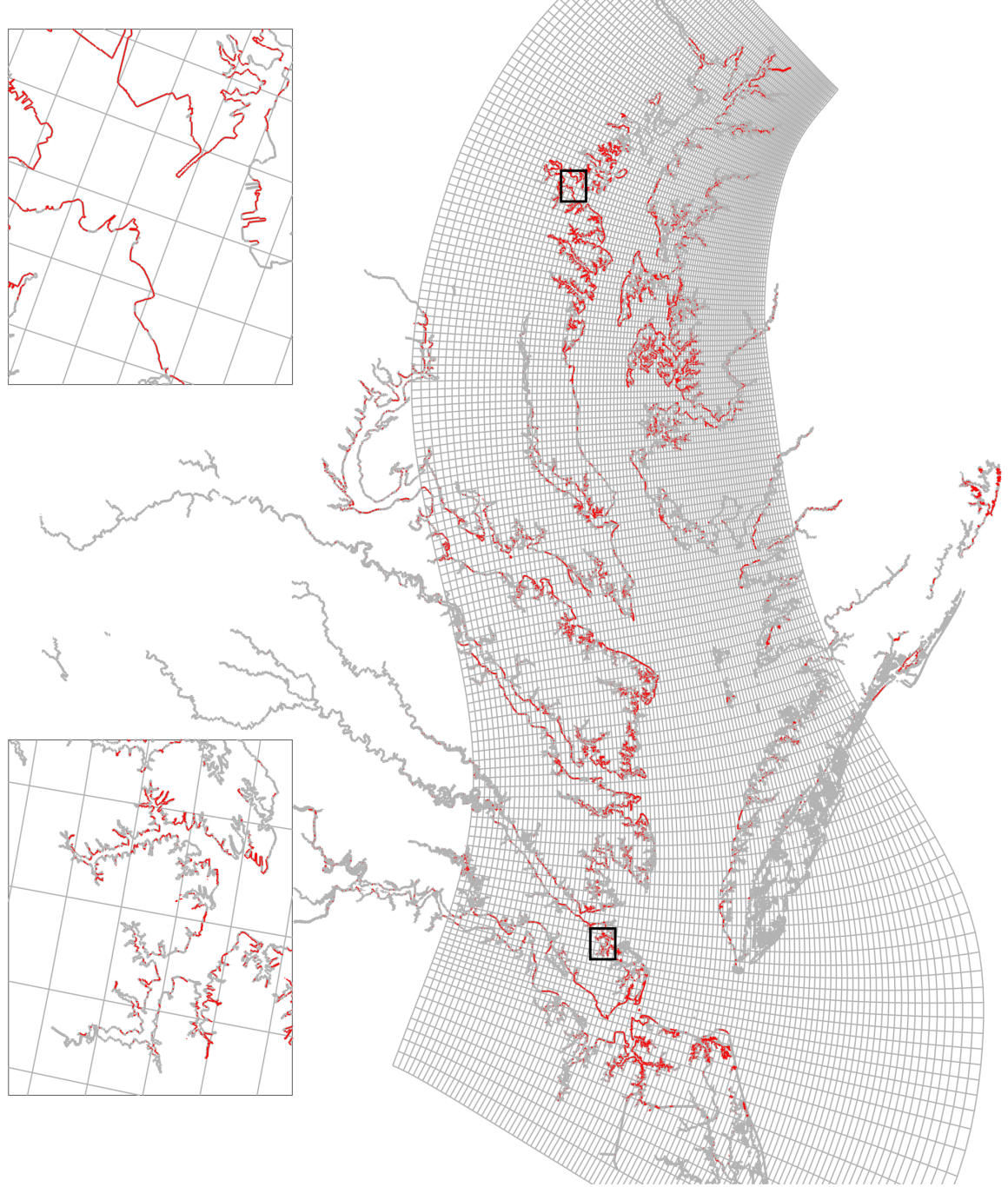
Armored coastline segments along grid



VIMS Shoreline & Tidal Marsh Inventory Data

When majority of shoreline is armored, per grid cell

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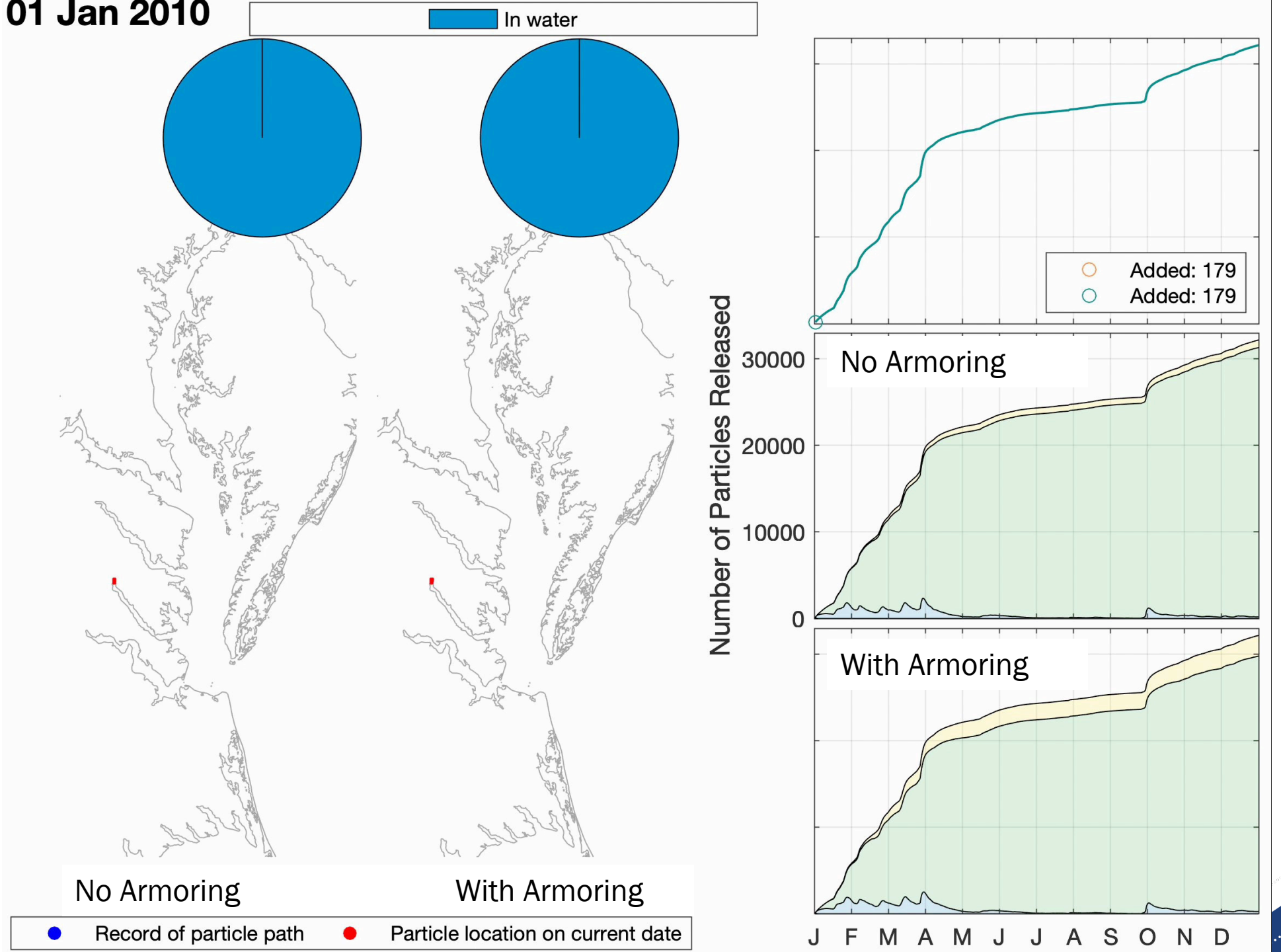
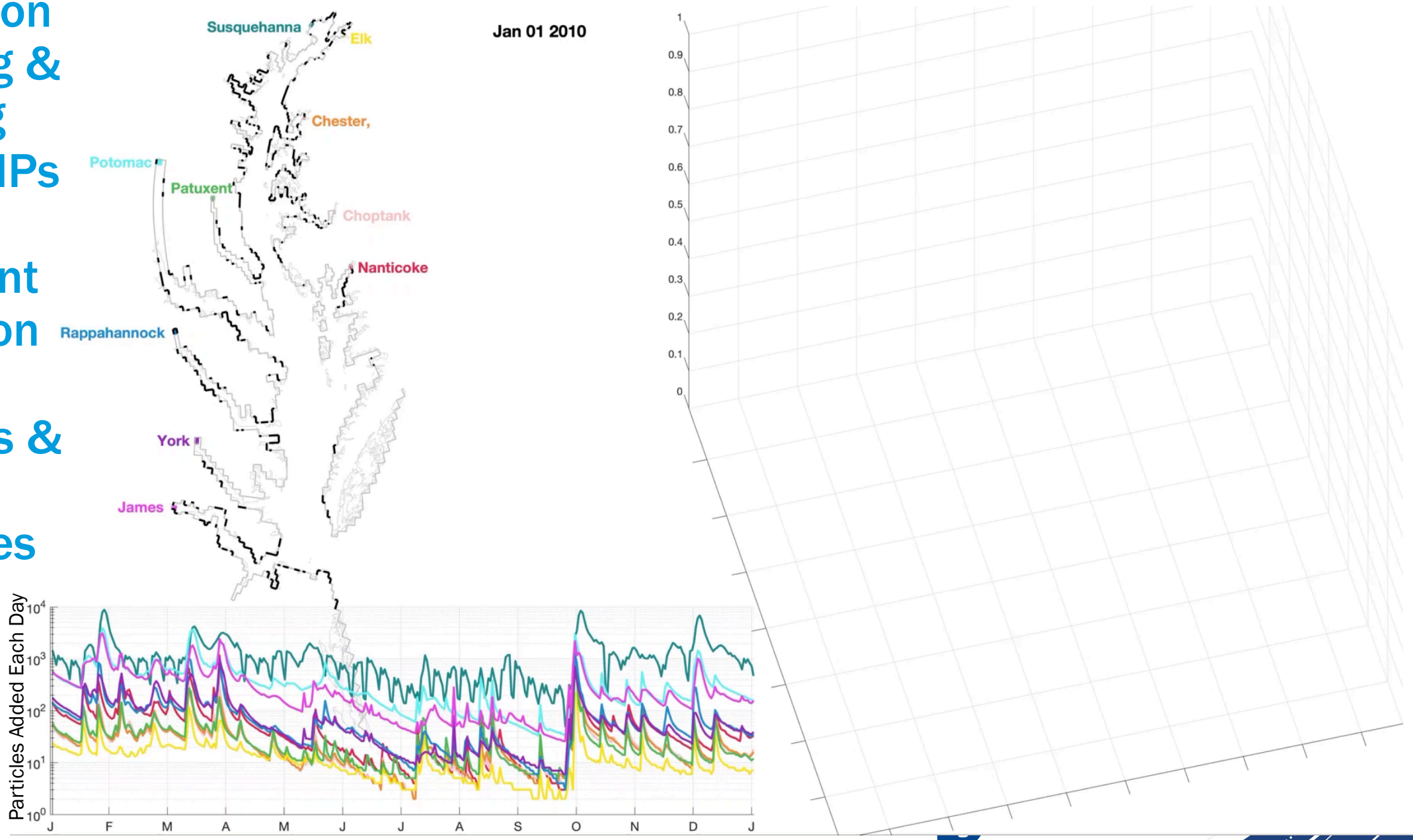
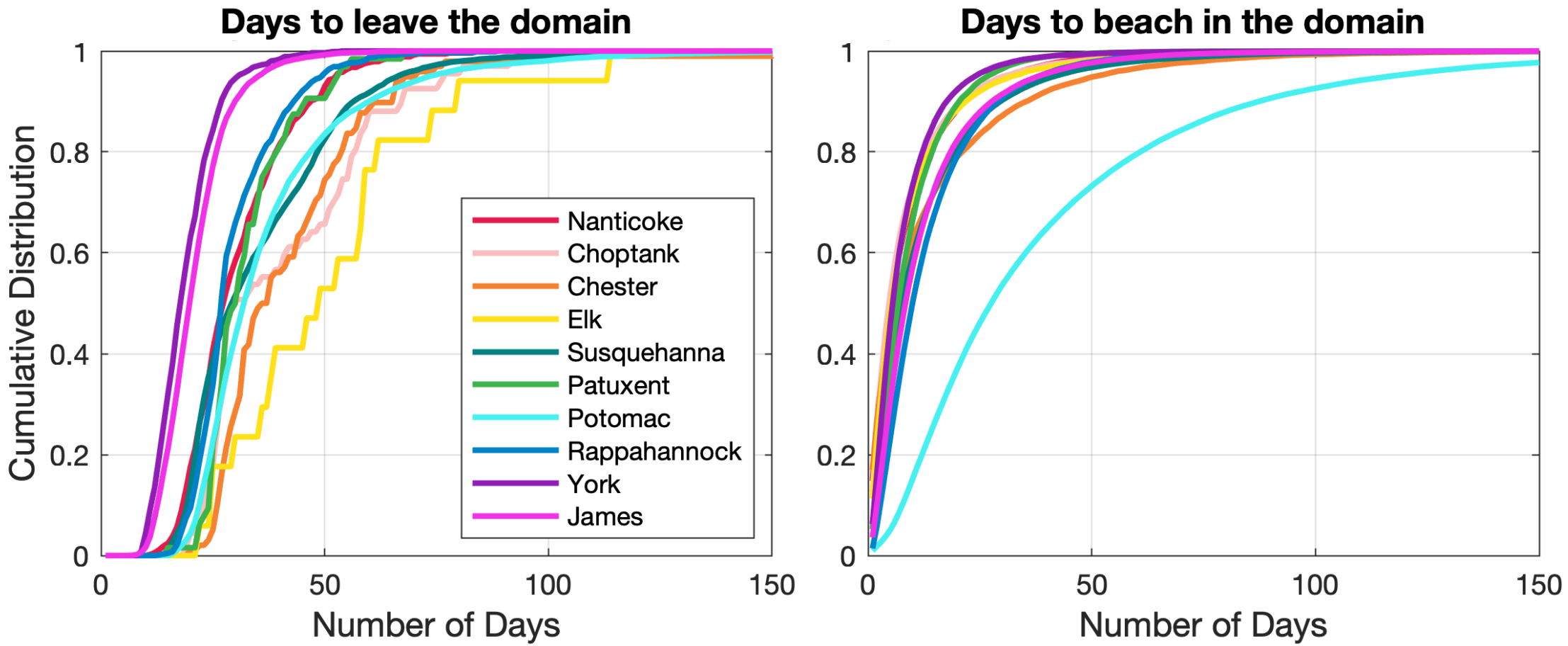

01 Jan 2010
In water
No Armoring
With Armoring
Record of particle path
Particle location on current date
Added: 179
Added: 179
Number of Particles Released
30000
20000
10000
0
No Armoring
With Armoring
J F M A M J J A S O N D

Distribution of floating & sinking riverine MPs shows significant deposition within tributaries & along coastlines



Riverine microplastics predominantly beach within a month, and most that do leave the Bay by two months



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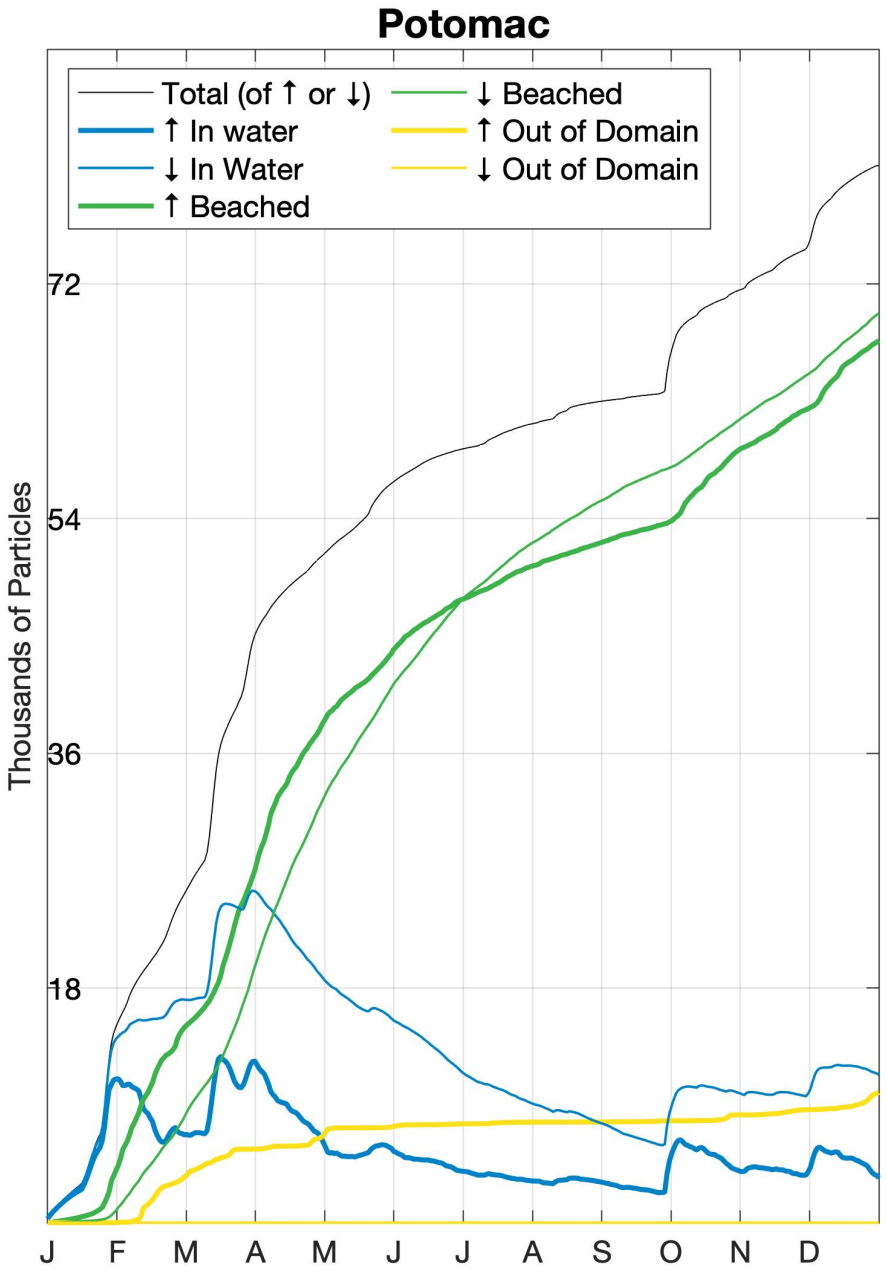
Inventory of Potomac MPs shows behavioral differences between those that leave domain and those that beach

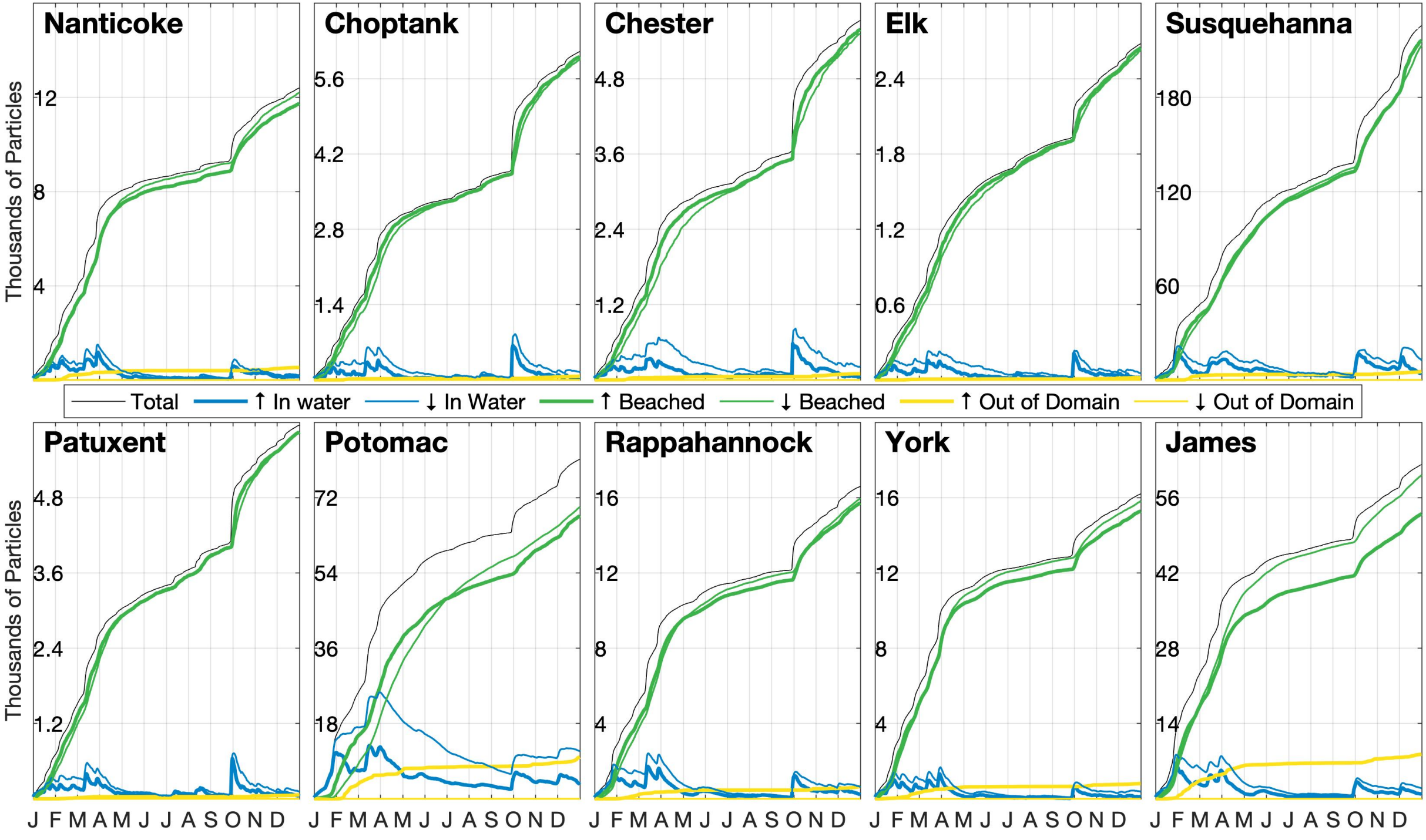
Total = Sum of floating or sinking MPs

Floating MPs = thick lines

Sinking MPs = thin lines

- No sinking MPs leave domain
- Potomac has largest amount of floating MPs leaving domain
- Potomac MPs spend a lot of time in water, especially Sinking MPs, before beaching




Nanticoke
Choptank
Chester
Elk
Susquehanna
Patuxent
Potomac
Rappahannock
York
James
Thousands of Particles
Total
↑ In water
↓ In Water
↑ Beached
↓ Beached
↑ Out of Domain
↓ Out of Domain
J F M A M J J A S O N D

Conclusions

- Microplastic distribution is sensitive to interannual variability
- Particle size impacts vertical speed but not direction, and does not impact overall distribution
- Particle density significantly impacts vertical velocity and overall distribution, as well as mean duration in the water column
- Allowing particles to beach greatly alters transport time & distribution
- Most riverine MPs remain in their tributaries of origin or beach along the eastern shore of the Chesapeake Bay

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Moving forward: how to improve the model system

- Observational data, especially for riverine inputs
- Information on particle behavior on armored coasts (seawall v riprap, etc)
- Any other suggestions / application ideas?

Thank you for listening. Any questions?

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