Simulating Microplastics in the Arctic using CESM2

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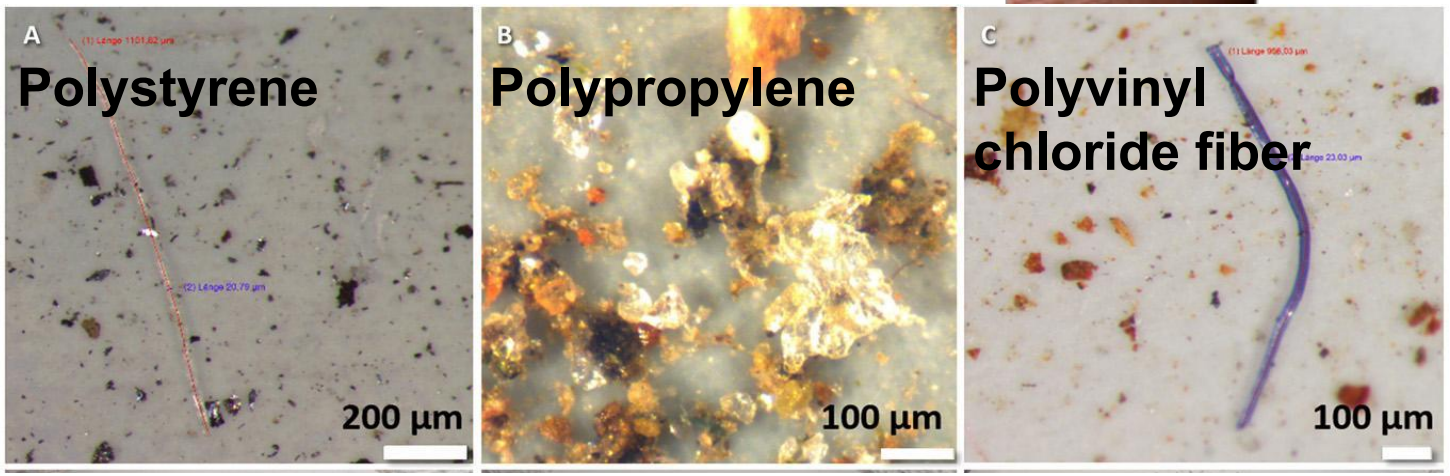
Microplastics (MPs) in the Arctic

- Microplastics (MPs) generally refer to plastic pieces **< 5 mm in mean diameter**.
- Due to the rapid increase in plastic use over the past decades and the mismanagement of waste, MPs are now prevalent in the global environments.
- Poses questions about their effects on planetary climate and consumers' health across the food web.

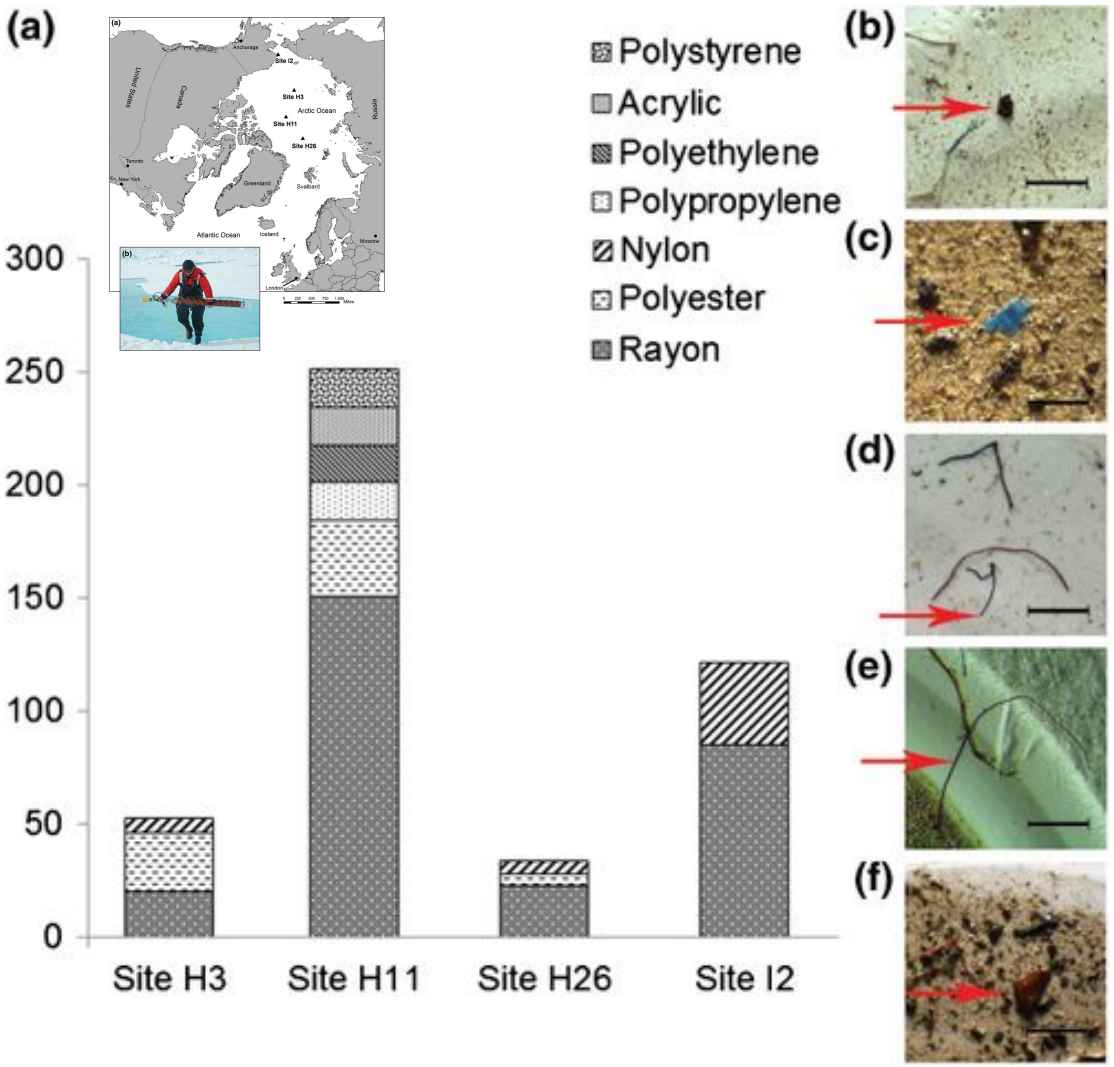
Are there MPs in the Arctic?

- Arctic Ocean is no longer a pristine refuge from the world's pollution, and MPs are found in all components: rivers, oceans, glaciers, ice….



Photographs of MPs detected in snow. Bergmann et al. 2019

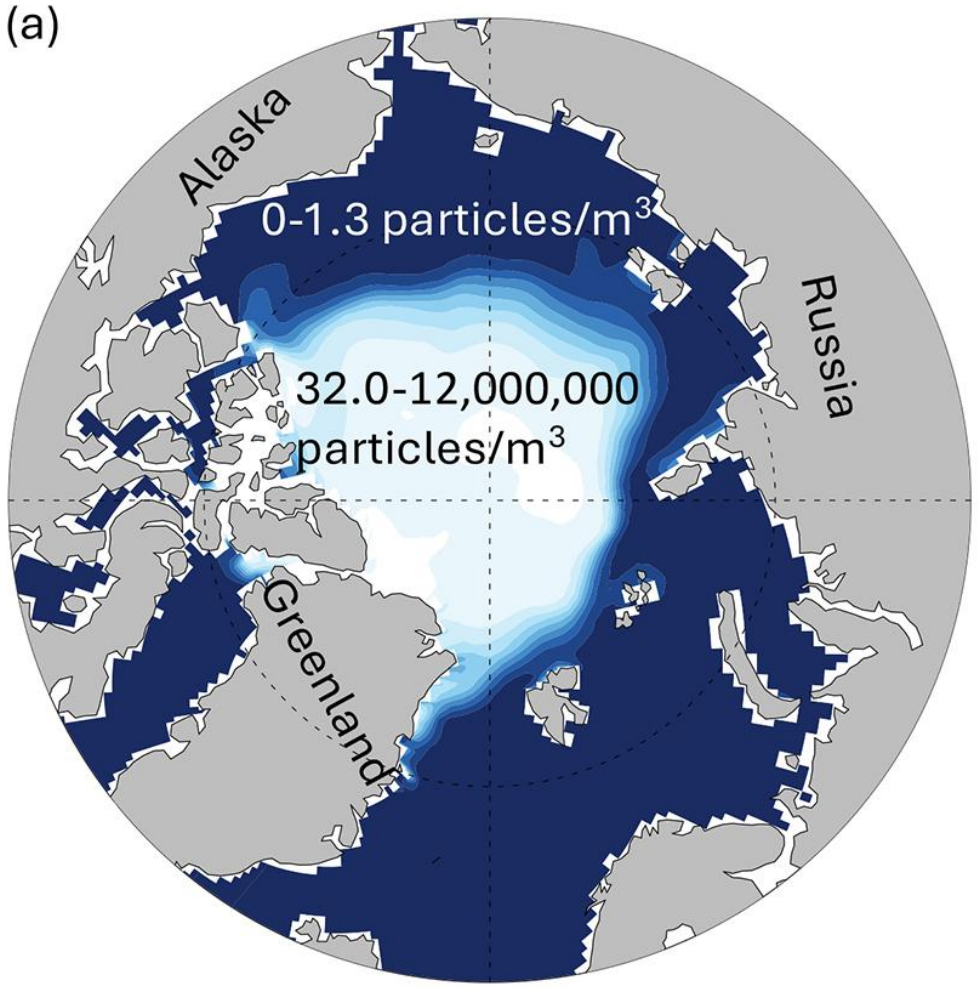
Microplastics in Arctic sea ice



Total number of microplastic pieces presented as values per liter of seawater, by polymer type, according to the location sea ice cores. Obbard et al., 2014

- MPs were first discovered in subsection of 4 ice cores retrieved from various locations in the Arctic Ocean.
- **MPs are in higher concentrations in the Arctic sea ice than the underlying ocean.**
- This high concentration in sea ice has since been confirmed using more samples collected at different locations and in different years.

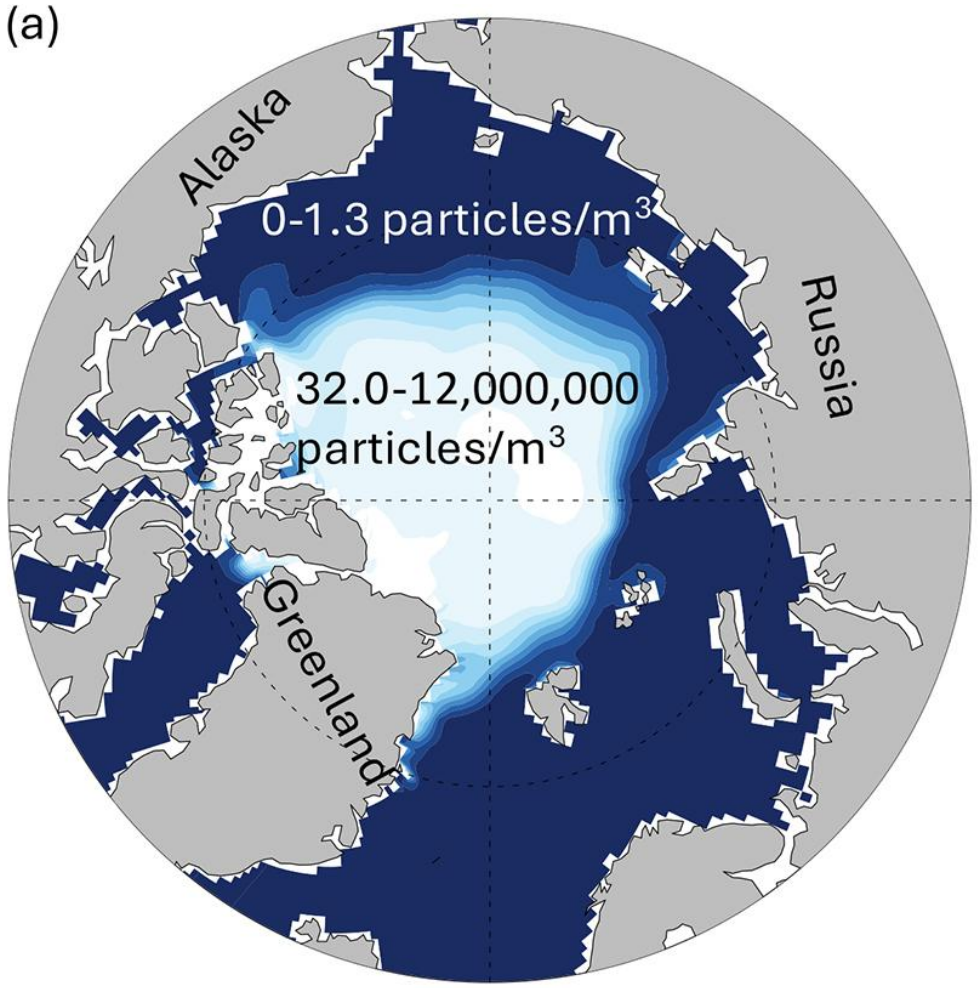
Microplastics in Arctic sea ice



The numbers refer to the abundance of microplastics in Arctic sea ice and underlying ocean (Bergmann et al.,

- **Concentrations of MPs are ~1-6 order of magnitude higher in sea ice than in underlying Arctic ocean.**
- MPs have accumulated far from population centers and Arctic sea ice is an important sink and means of transport for MPs.

Unknowns about microplastics in Arctic sea ice



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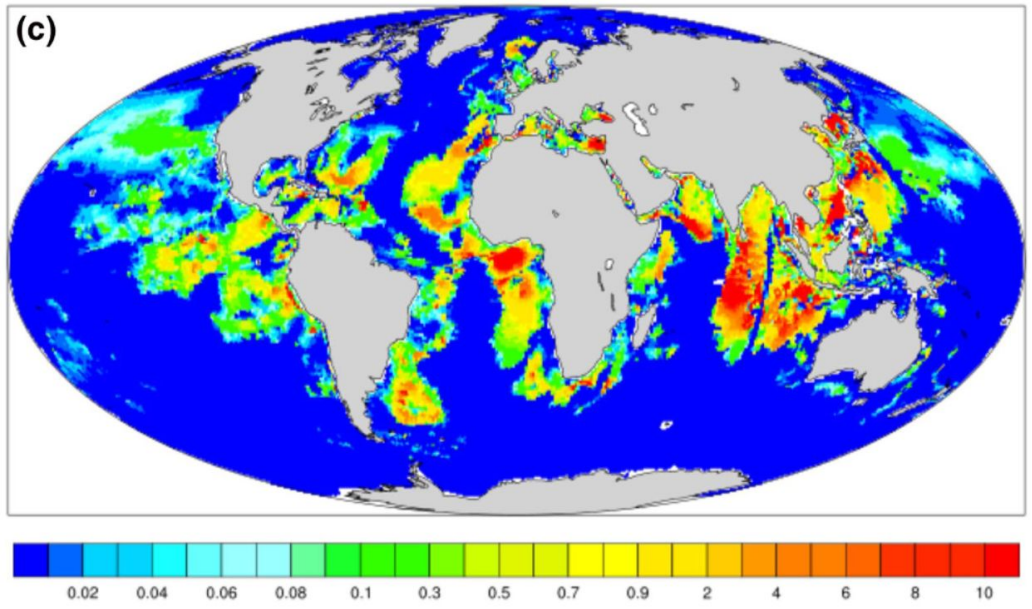
- The reasons for its high concentrations in the Arctic sea ice are still a mystery.
- The distributions of MPs in the sea ice and ocean remain underreported.
- Few modeling studies have focused on the Arctic MP problem and explored how big the impact of arctic MPs in sea ice on global oceans
  - How the ice growth and melt processes affect the MPs in the ice and ocean are largely unknown.

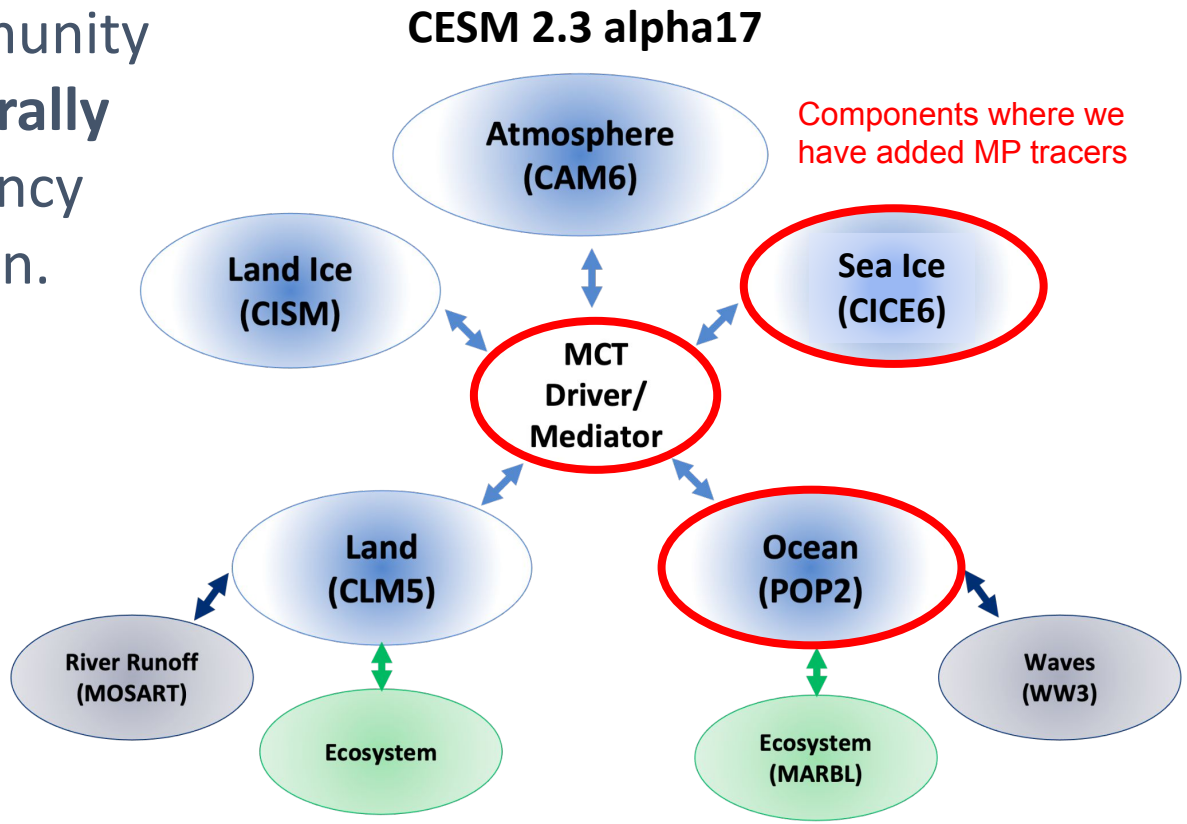
Modeling microplastics using CESM2

Model development:

- Two MP tracers were developed in the Community Earth System Model version 2 (CESM2): **neutrally buoyant and positively buoyant MPs**. Buoyancy only affects the tracer movement in the ocean.
- Does not have negative buoyant MPs.



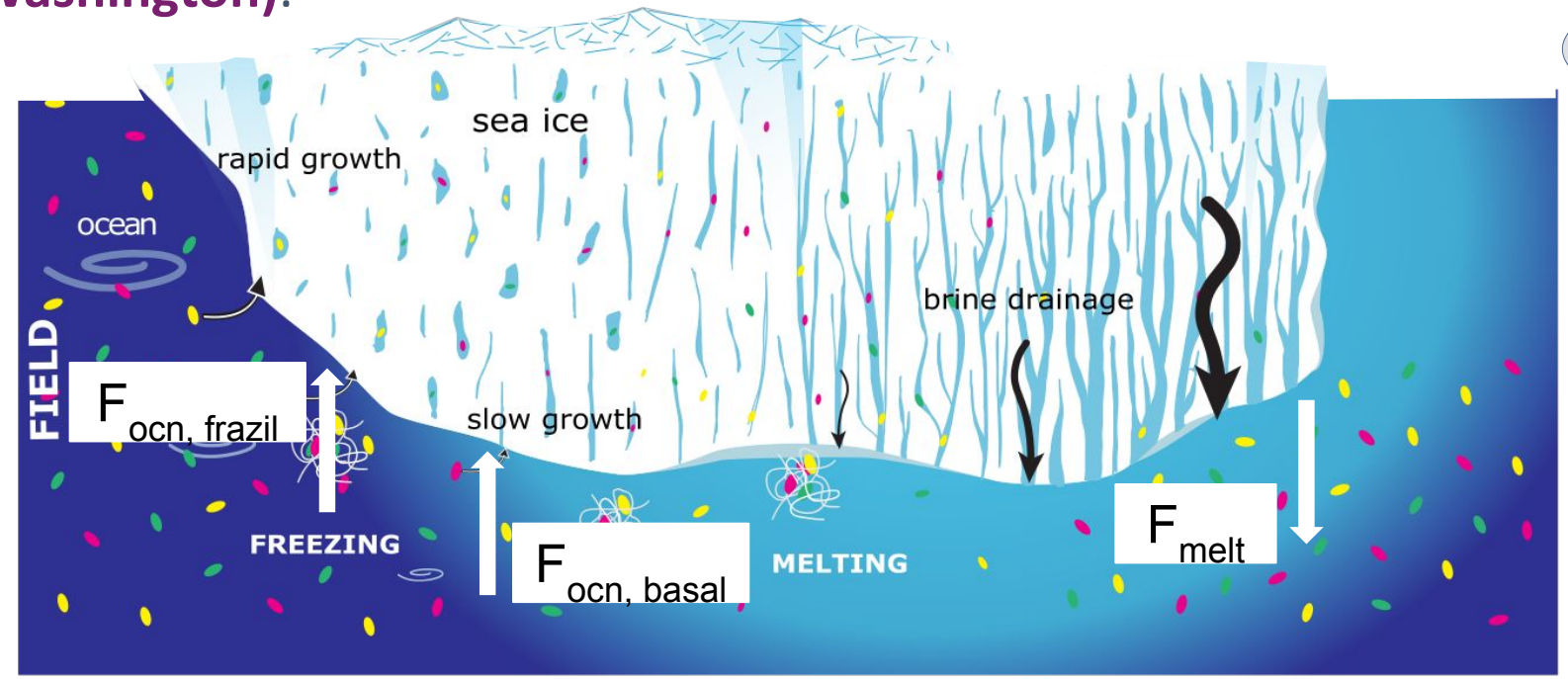
Relative abundance of negative microplastics to global average MP concentrations (Mountford & Morales Maqueda 2021)

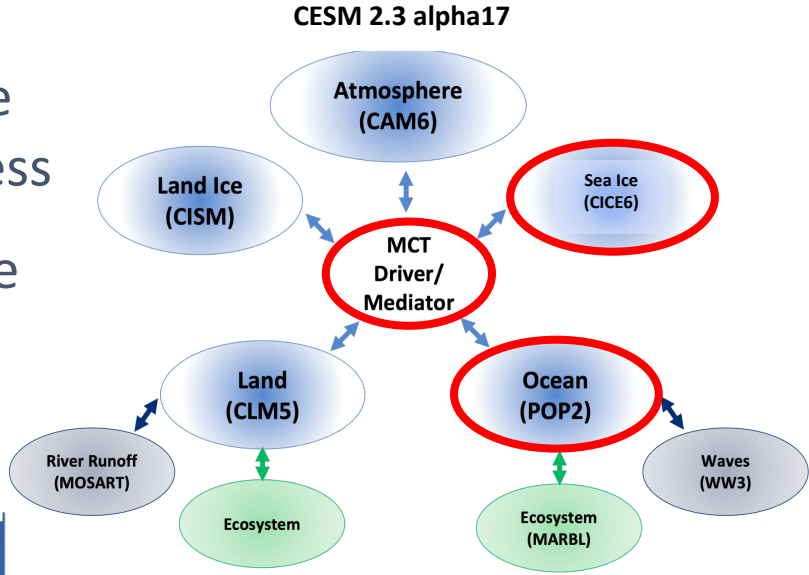


Modeling microplastics using CESM2

Model development:

- Three factors to play around: uptake factors for MPs during frazil ice and congelation ice growth and release factor during ice melt process
- Final MP uptake and release factors will be determined in the future based on the sensitivity tests and lab results **(Lab team at Univ. of Washington)**.



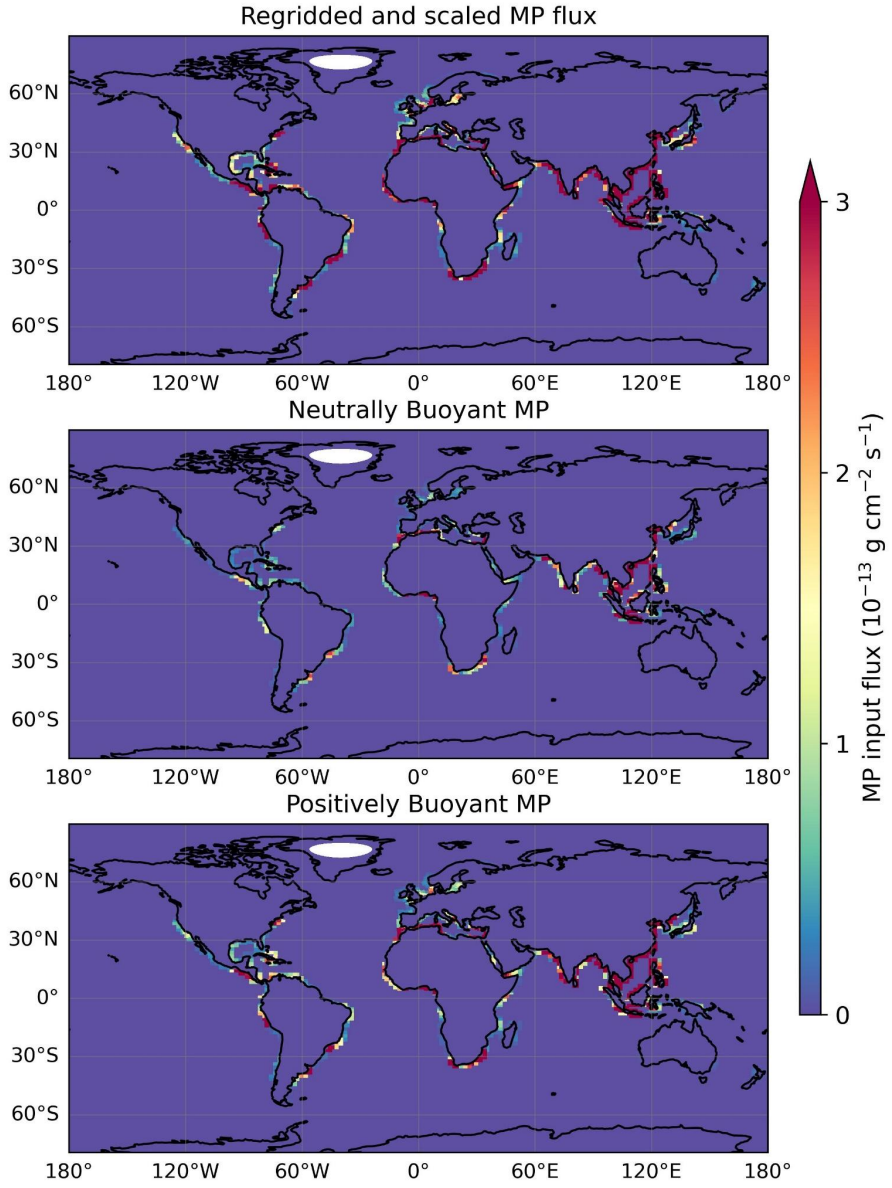


Modeling microplastics using CESM2

- Three 1-deg JRA-55 forced ocean-sea ice coupled simulations with the MP tracers were conducted.

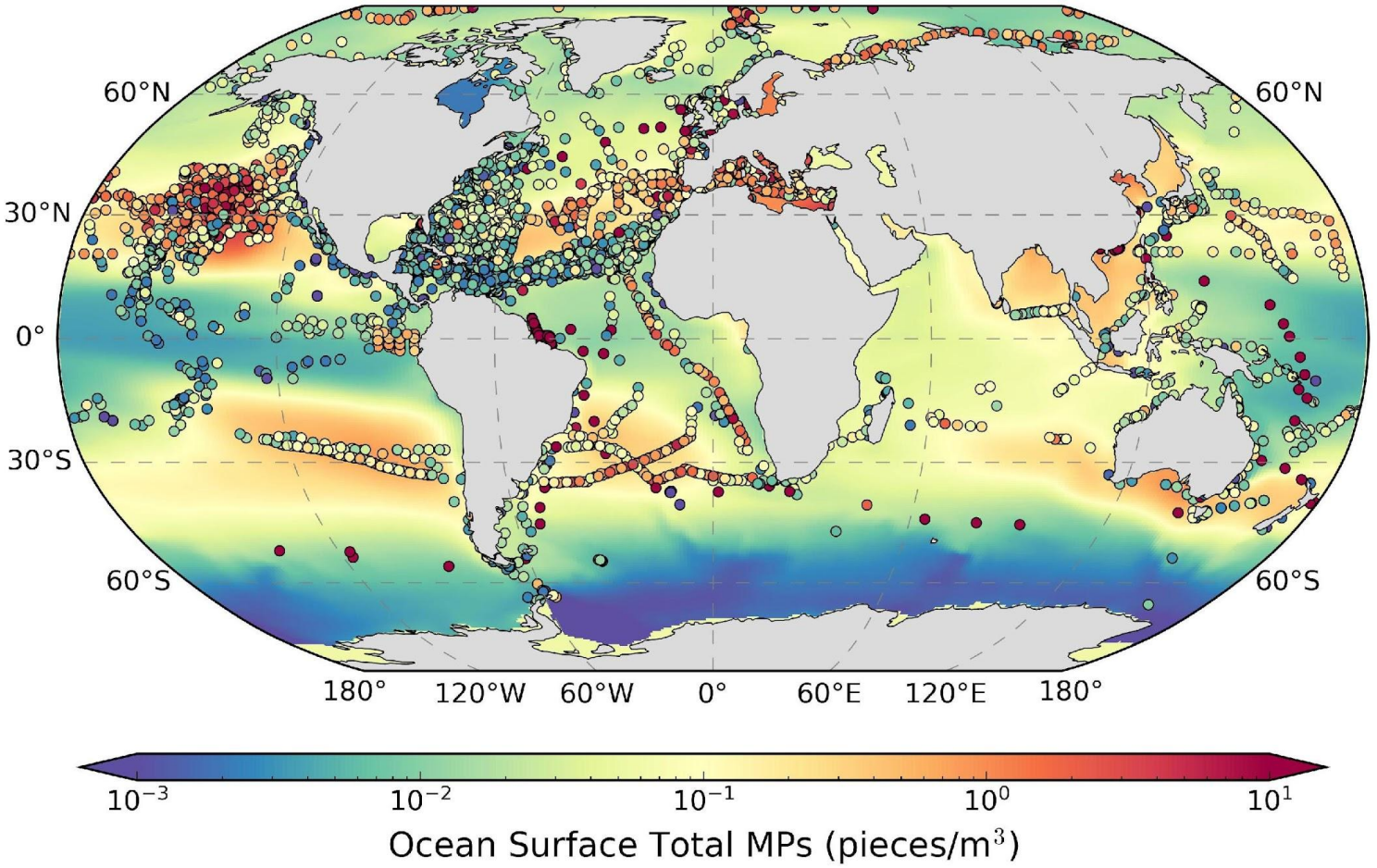
Case Name	Descriptions
S1_Uptakes	MPs get trapped into sea ice during ice growth
S2_NoUptakes	No MPs get trapped into sea ice
S3_Uptakes+Release	MP get trapped into sea ice during ice growth and released into ocean during melt

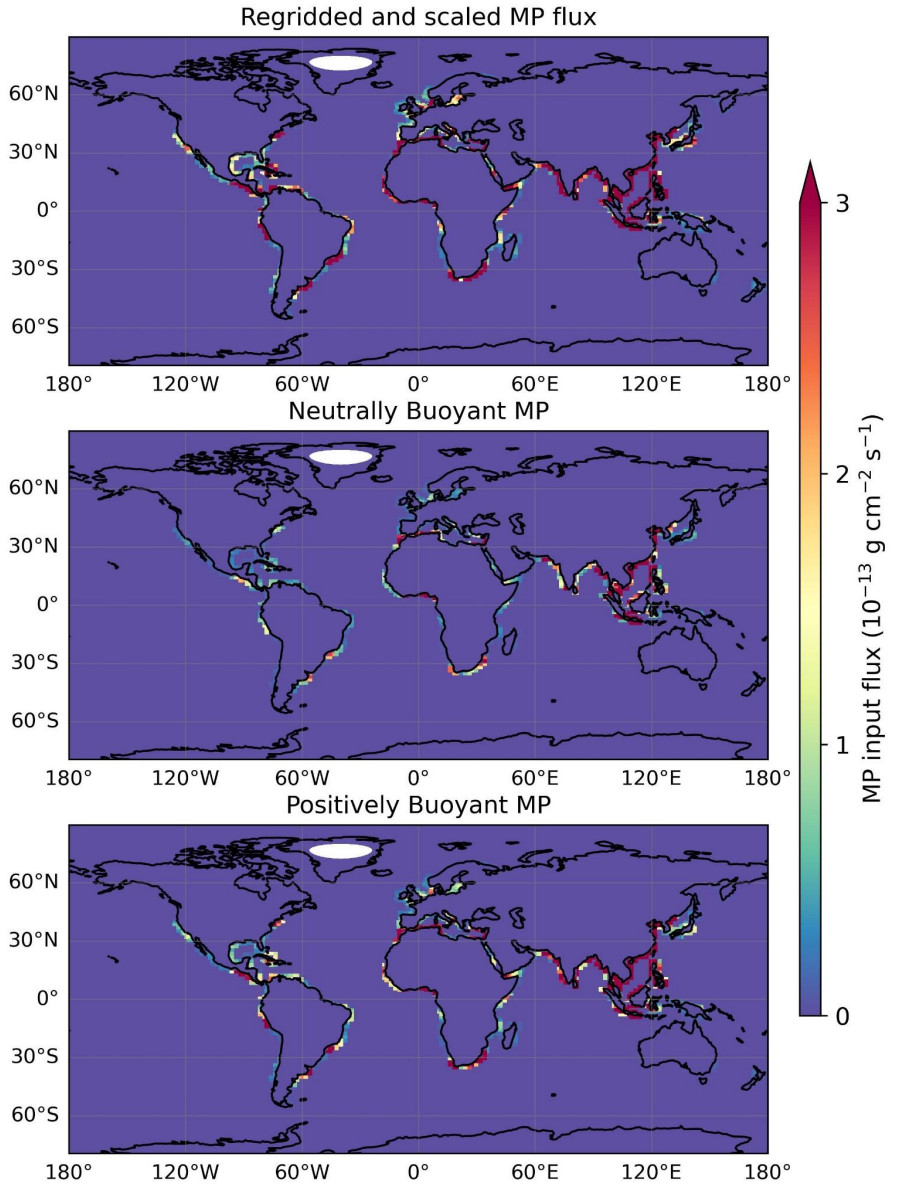
- Using a global MP forcing field (Mountford & Morales Maqueda 2021), which prescribes the mismanaged plastic waste input along the coastlines in proportion to the total population along the coastline.
- Scale down the plastic input for neutrally buoyant (NB) and positively buoyant (PB) MPs:
  NB MP fraction = 0.19 and PB MP fraction = 0.49



Modeling microplastics using CESM2

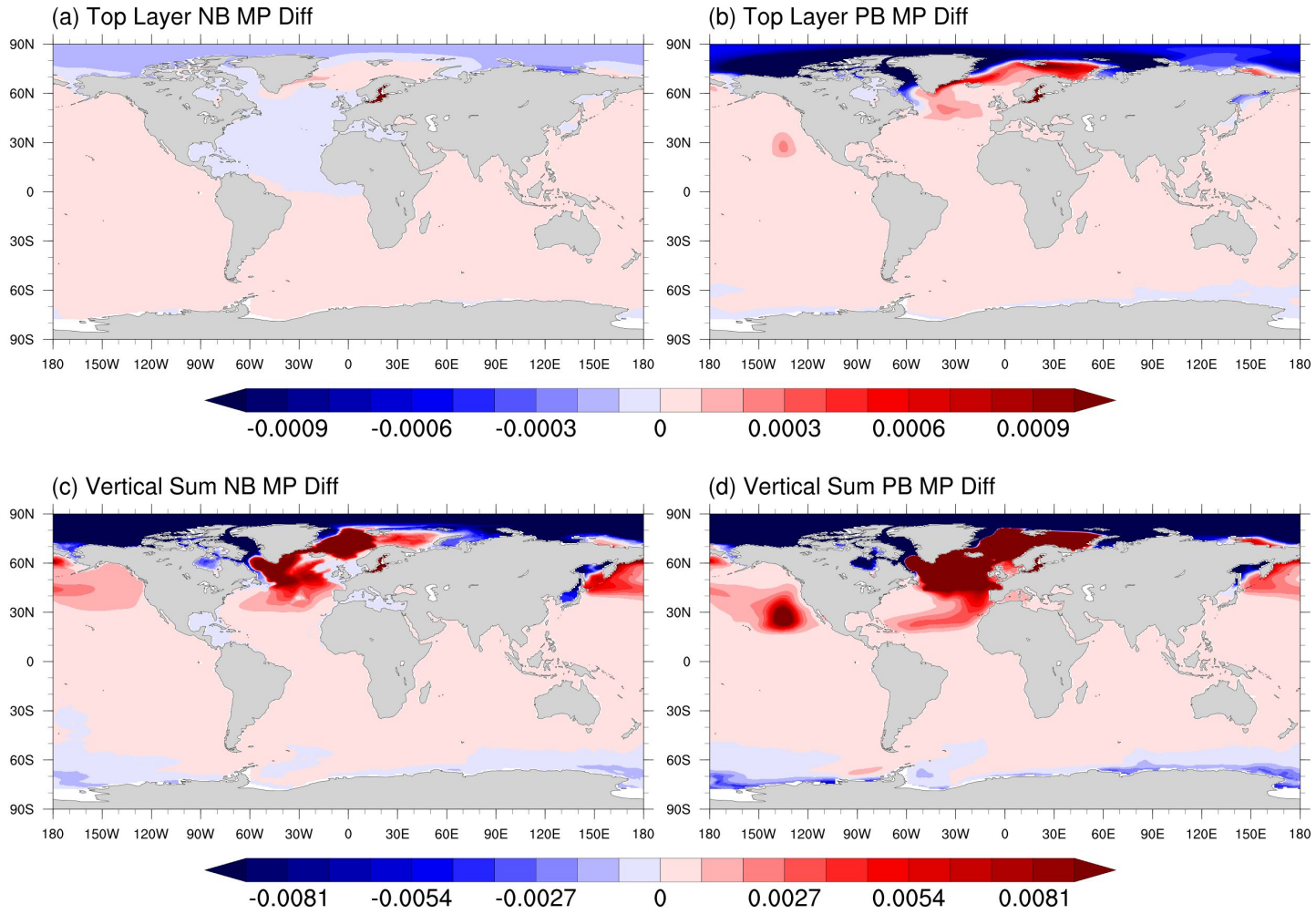
- Comparing S1_Uptakes ocean surface total (NB+PB) MPs in year 60 to ocean observations shows good agreement.





Modeling sea ice – ocean exchange of microplastics

Uptakes – NoUptakes (yr-60 particles/m^3)



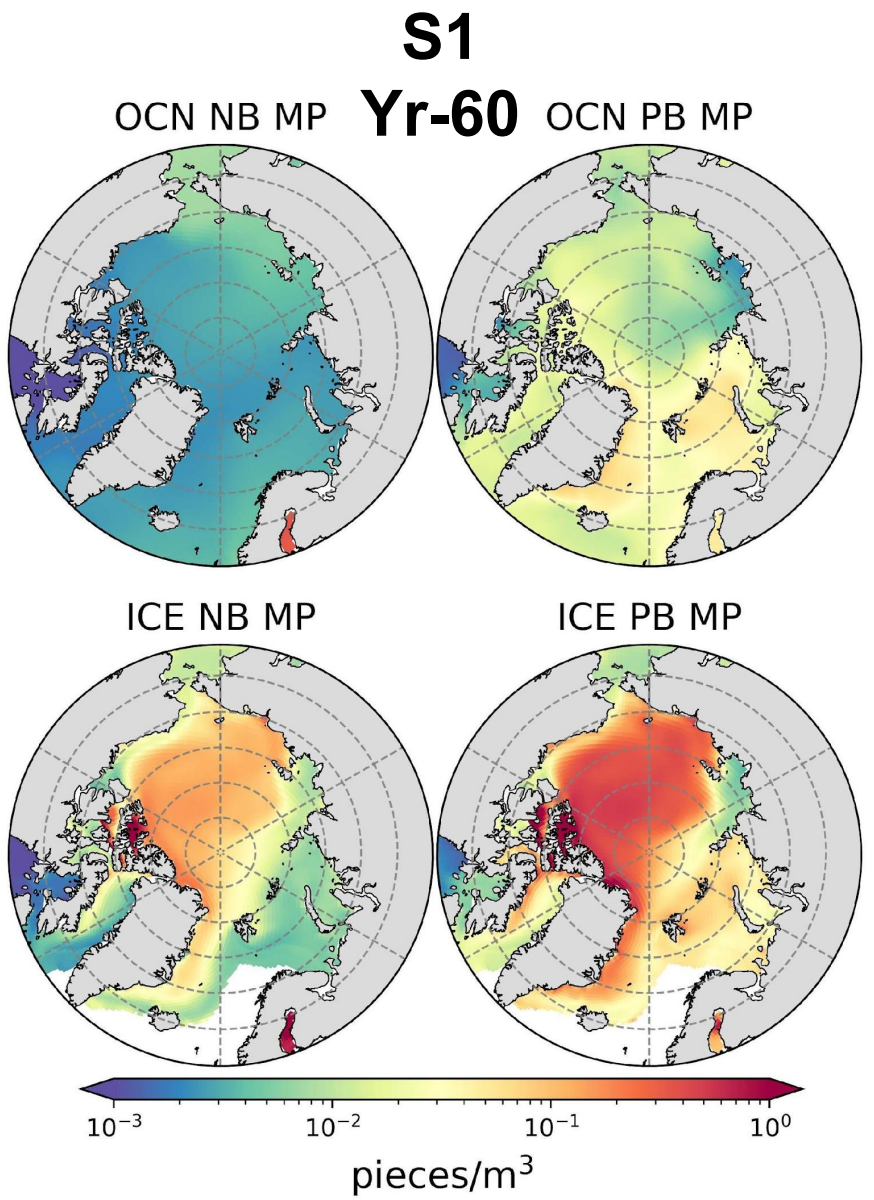
How does ocean MPs change globally by having MPs in the sea ice?

- Reduces MPs in the Arctic ocean.
- Increases MPs in the North Atlantic and North Pacific regions

Modeling sea ice – ocean exchange of microplastics

- Different spatial patterns for NB and PB MPs in the Arctic ocean.
- **The model can reproduce higher MPs concentrations in sea ice than in the ocean, consistent with observations.**

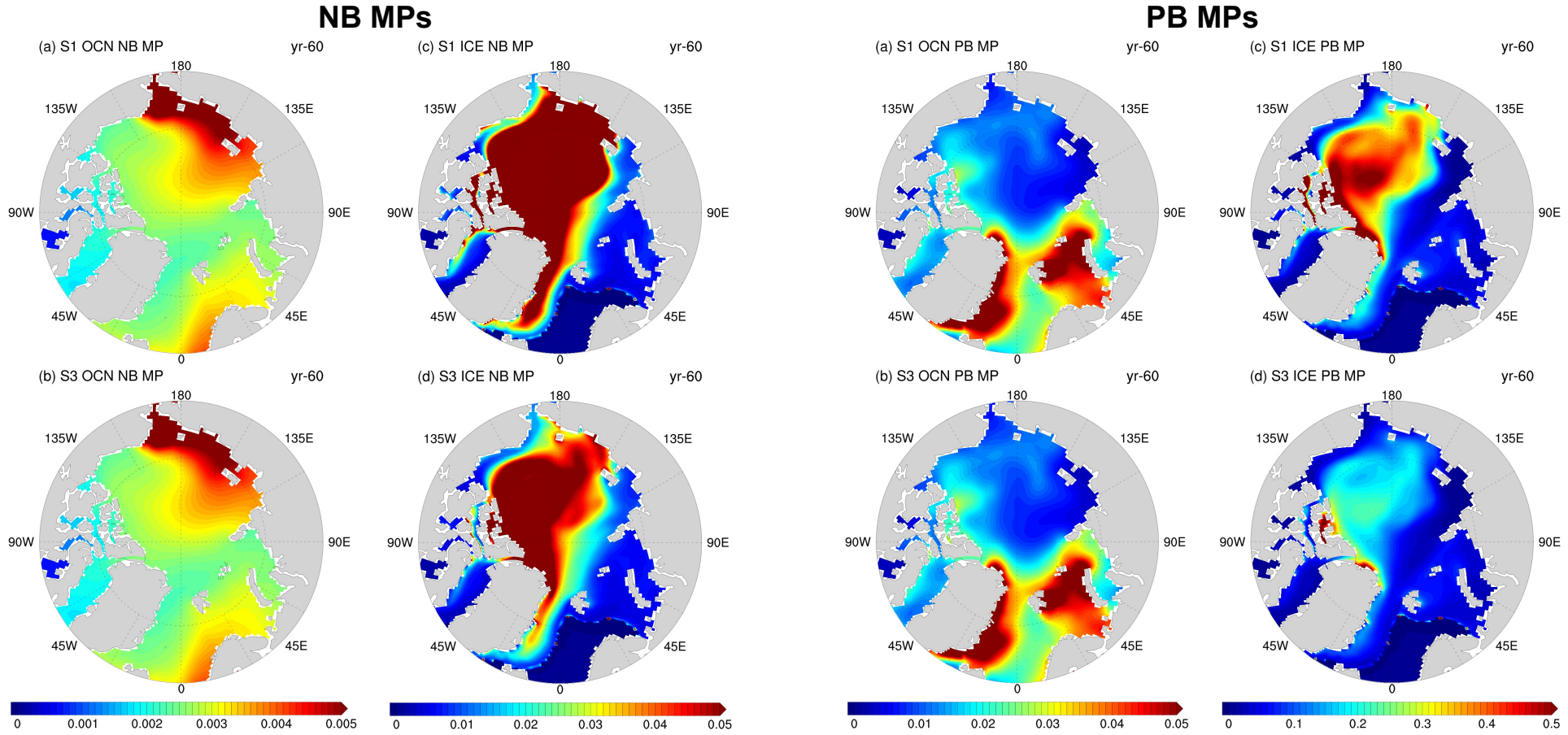
- S1 only includes uptakes factors trapping MPs into sea ice during ice growth.
- Compare to S3 which includes uptakes and release factors where MPs will be taken into sea ice during ice growth and released from sea ice during ice melt.



Modeling sea ice – ocean exchange of microplastics

How does MPs change in the Arctic ocean by releasing MPs during top ice melt?

- Higher concentrations of MPs in sea ice than in the ocean, with small differences in the Arctic ocean



Modeling sea ice – ocean exchange of microplastics

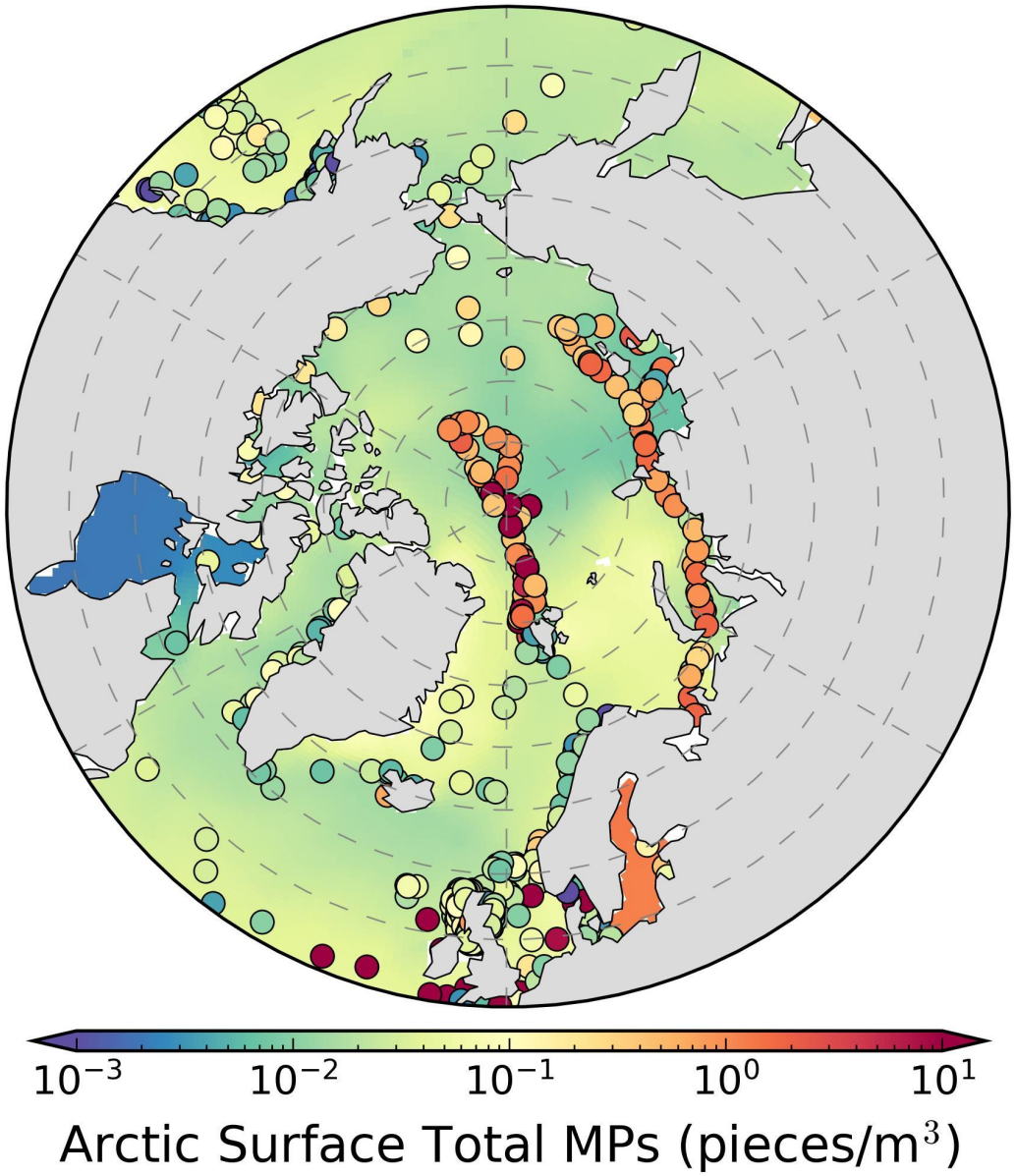
Summary:

- The model can reproduce higher MPs concentrations in sea ice than in the ocean, consistent with observations.
- The model shows differences in spatial patterns for neutrally buoyant and positive buoyant MPs.
- The uptakes of MPs into the sea ice does affect Arctic and north Atlantic MP concentrations.

Next Steps:

- ❑ Further explore how MPs are exchanged between sea ice and ocean.
- ❑ Assess the role that sea ice plays for changing the Arctic MPs distributions.
- ❑ Investigate how future climate will change impact the MPs distributions in the Arctic.

Modeling sea ice – ocean exchange of microplastics



Modeling sea ice – ocean exchange of microplastics