

The role of sea ice for plastic pollution in the Arctic

An aerial photograph of a large research ship, likely the Alfred Wegener, navigating through a field of sea ice in the Arctic. The ship is leaving a trail of open water behind it.

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Present in all habitats



Atmospheric transport and deposition of microplastics in a remote mountain catchment

Steve Allen^{1,2,5}, Deonie Allen^{1,5*}, Vernon R. Phoenix², Gaël Le Roux¹, Pilar Duránte Jiméne¹, Anaëlle Simonneau³, Stéphane Binet^{1,3} and Didier Galop⁴



Environmental Pollution
Volume 253, October 2019, Pages 297–301



First evidence of microplastic contamination in the supraglacial debris of an alpine glacier ☆

Roberto Ambrosini^a, Roberto Sergio Azzoni^a, Francesca Pittino^b, Guglielmina Diolaiuti^a, Andrea Franzetti^b, Marco Parolini^a



Science of The Total Environment
Volume 758, 1 March 2021, 143634



Microplastics in glaciers of the Tibetan Plateau: Evidence for the long-range transport of microplastics

Yulan Zhang^{a, b}, Tanguang Gao^c, Shichang Kang^{a, b, e}, Steve Allen^d, Xi Luo^{a, e}, Deonie Allen^d

SCIENCE ADVANCES | RESEARCH ARTICLE

ATMOSPHERIC SCIENCE

White and wonderful? Microplastics prevail in snow from the Alps to the Arctic

Melanie Bergmann^{1*,†}, Sophia Mützel^{1†}, Sebastian Primpke¹, Mine B. Tekman¹, Jürg Trachsel², Gunnar Gerdt¹

AGU PUBLICATIONS

Earth's Future

RESEARCH ARTICLE

10.1002/2014EF000240

Key Points:
• Arctic Sea ice from remote locations contains tiny particles of

Global warming releases microplastic legacy frozen in Arctic Sea ice

Rachel W. Obbard¹, Saeed Sadri², Ying Qi Wong¹, Alexandra A. Khitun¹, Ian Baker¹, and Richard C. Thompson²



Degradation in the marine environment

MACRO

> 1 cm



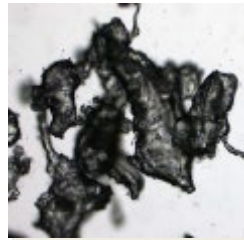
MESO

1 mm – 1 cm



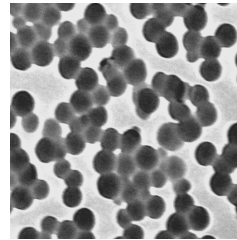
MICRO

1 – 1000 μm



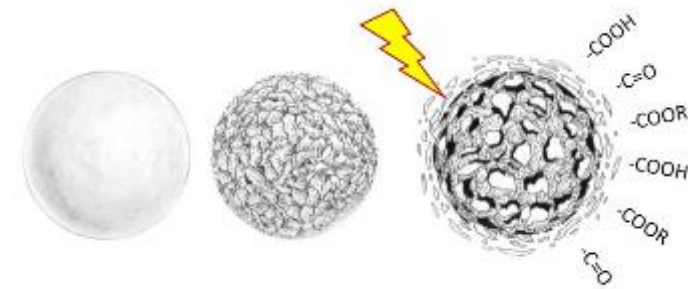
NANO

< 1 μm



SIZE

TOXICITY



Andrady, 2017 Mar. Poll. Bull.

Nanoplastic traces have been detected in the North Atlantic gyre (*Ter Halle et al. 2017 Env. Sci. & Tech.*) and in Mediterranean surface waters (*Schirinzi et al. 2019 Chemosphere*).

Fragmentation toward the nanoscale:

- Photodegradation
- Thermo-oxidation
- Hydrolysis
- Mechanical abrasion (e.g. in sea ice)
- Biological degradation

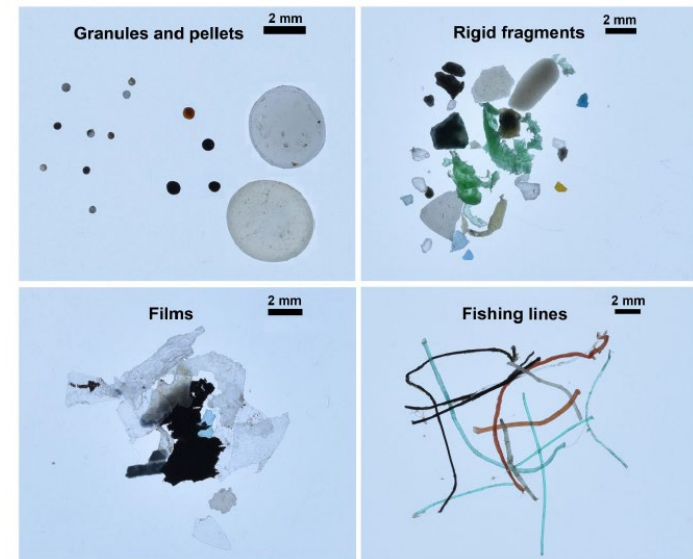
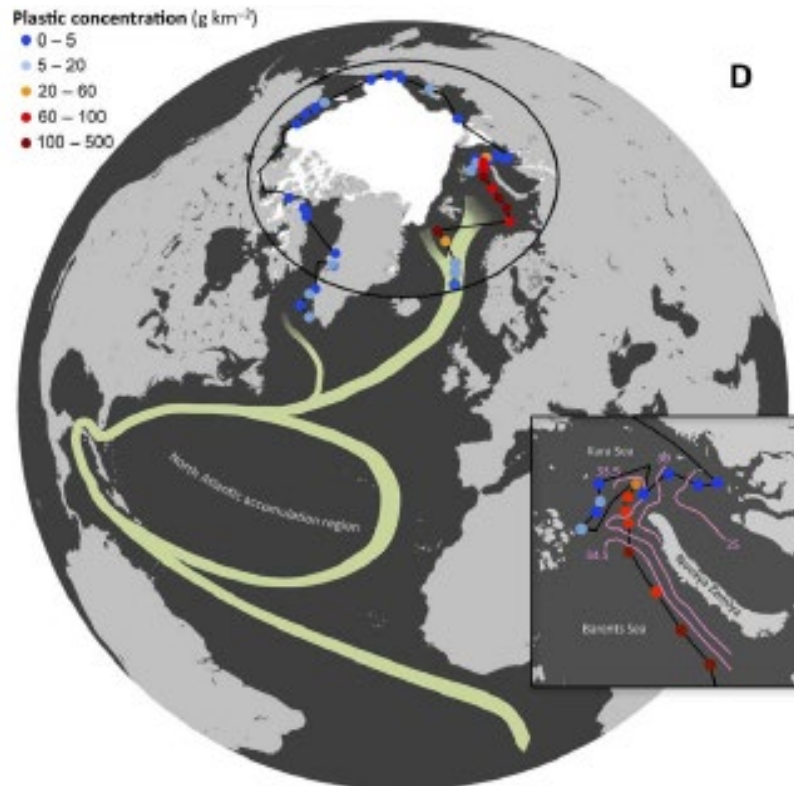
EMBARGOED UNTIL 2:00 PM US ET WEDNESDAY, 19 APRIL 2017

SCIENCE ADVANCES | RESEARCH ARTICLE

WATER POLLUTION

The Arctic Ocean as a dead end for floating plastics in the North Atlantic branch of the Thermohaline Circulation

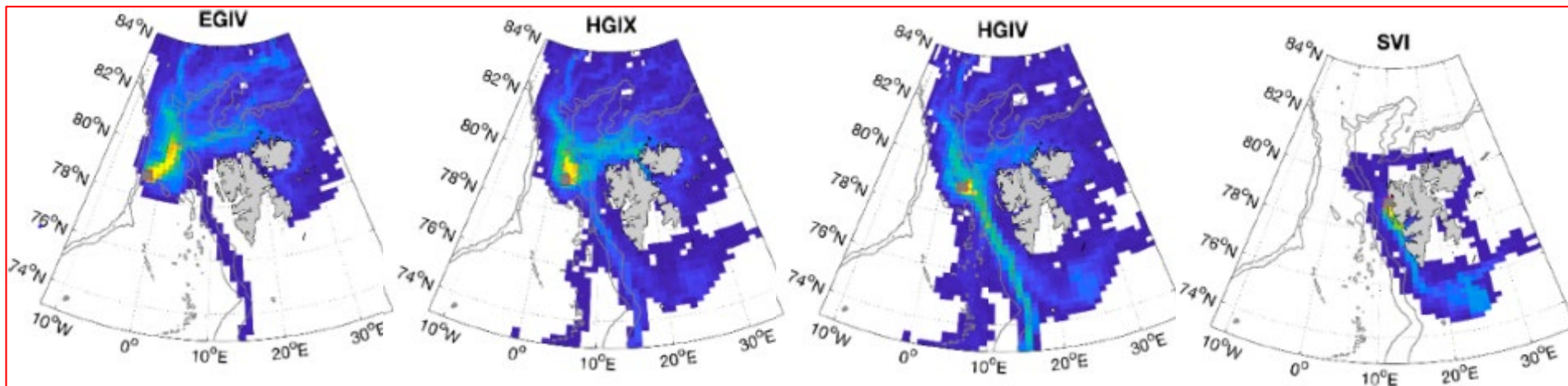
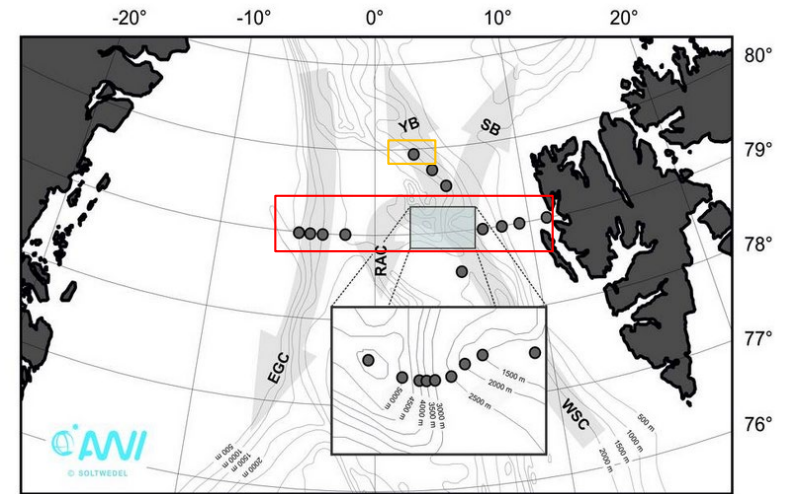
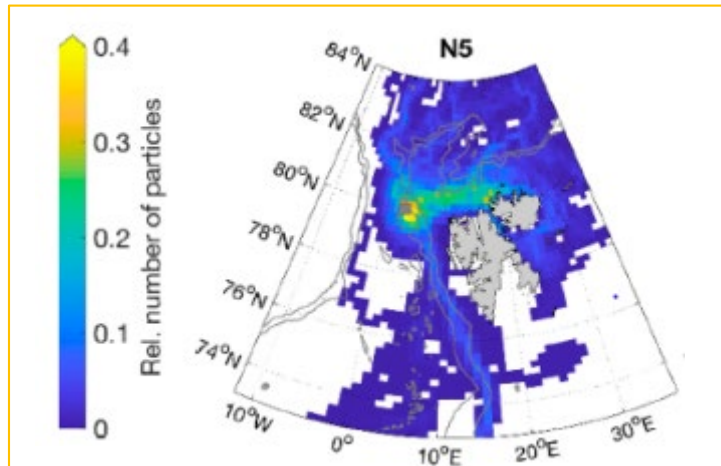
Andrés Cózar,^{1*} Elisa Martí,¹ Carlos M. Duarte,^{2,3} Juan García-de-Lomas,¹ Erik van Sebille,^{4,5} Thomas J. Ballatore,^{6,7} Victor M. Eguluz,⁸ J. Ignacio González-Gordillo,¹ Maria L. Pedrotti,⁹ Fidel Echevarría,¹ Romain Troublé,¹⁰ Xabier Irigoien^{11,12}



- High accumulation in the northern and eastern Greenland and Barents Seas
- Sea ice acts as a barrier for floating plastic

Cozar et al. 2017

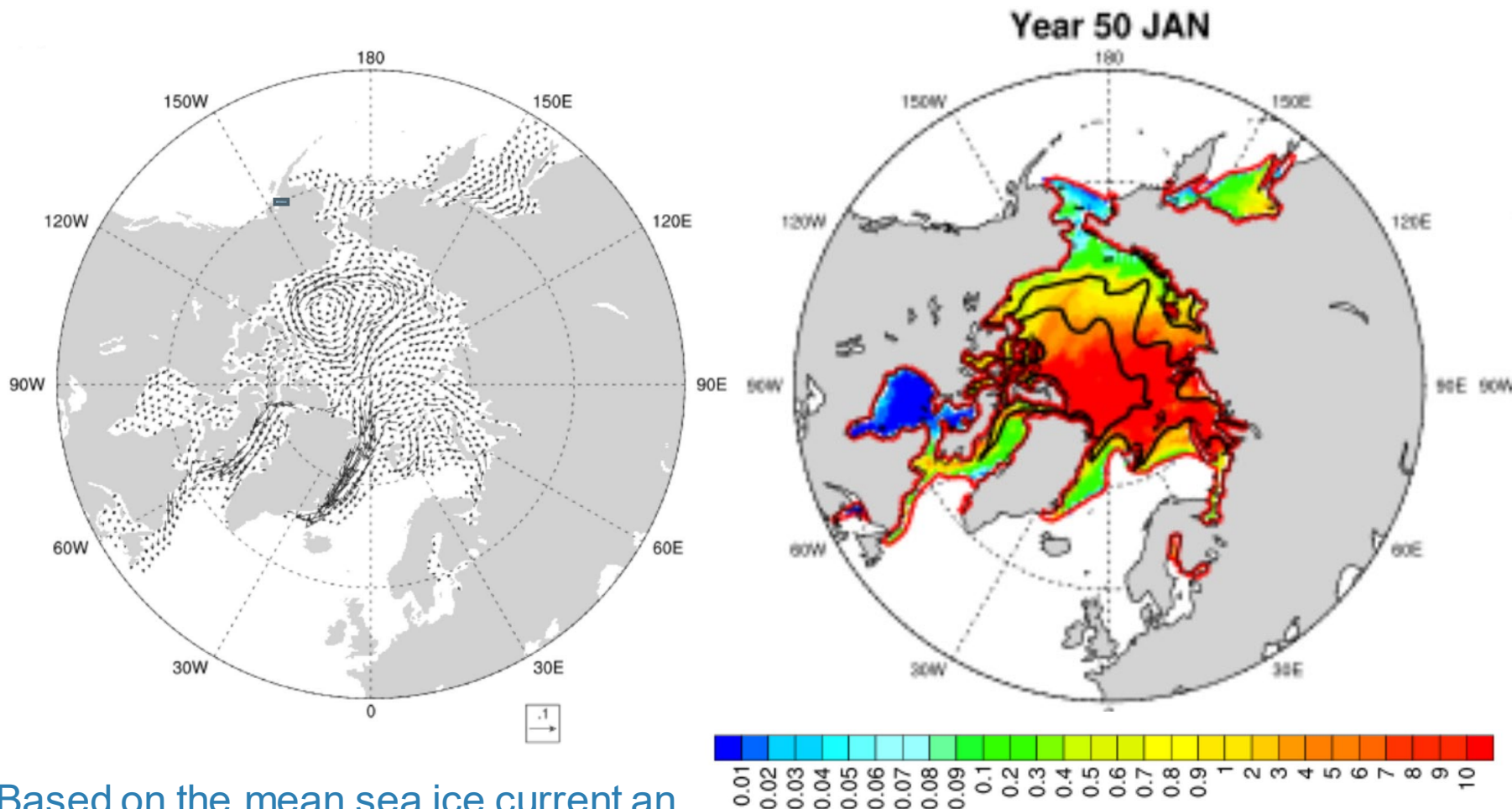
Example for origin of MP particles found in Fram Strait



Tekmann et al. 2020

Indicating horizontal sea ice transport of microplastic

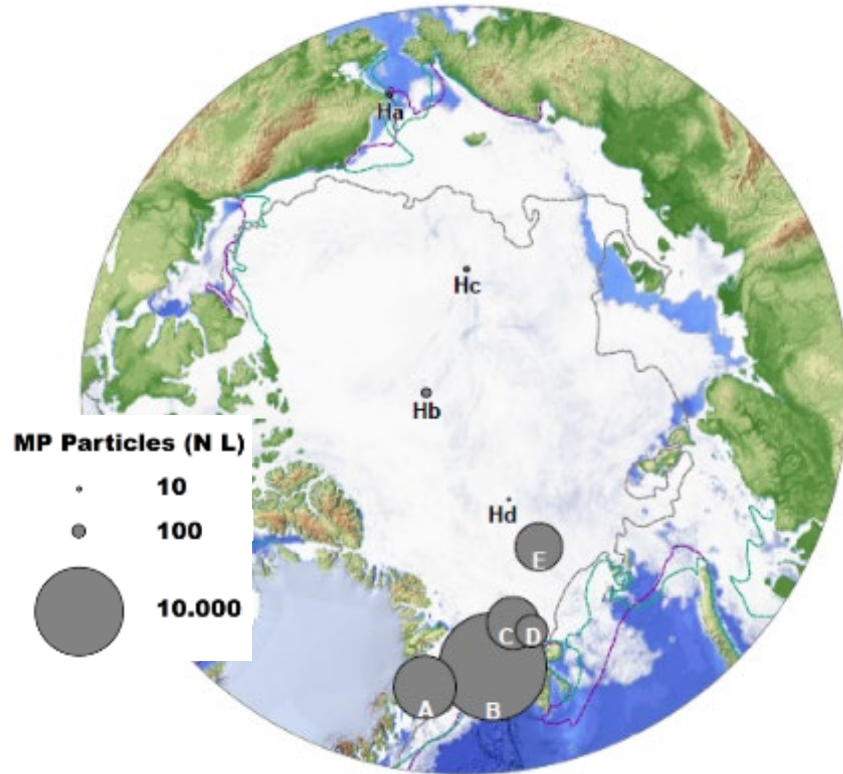
Relative abundance of microplastics in sea ice



Based on the mean sea ice current an accumulation of buoyant particles will remain in the Eurasian Arctic after 50 years

Mountford & Maqueda, 2021

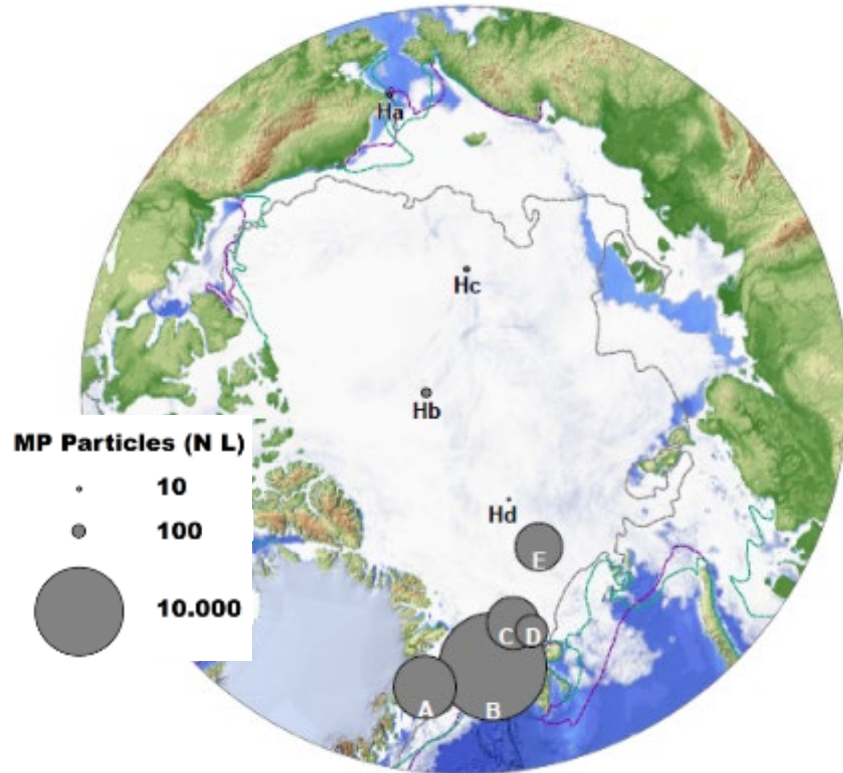
MP in sea ice



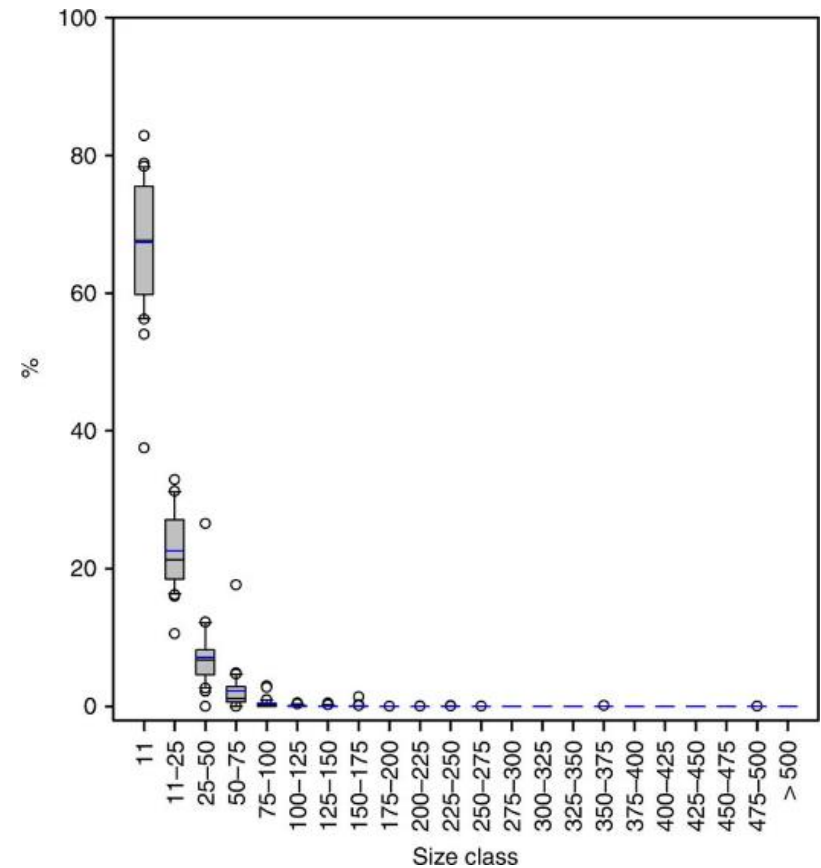
Extreme high MP
concentrations in sea ice

Peeken et al. 2018

MP in sea ice



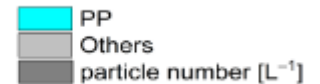
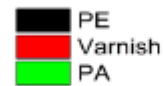
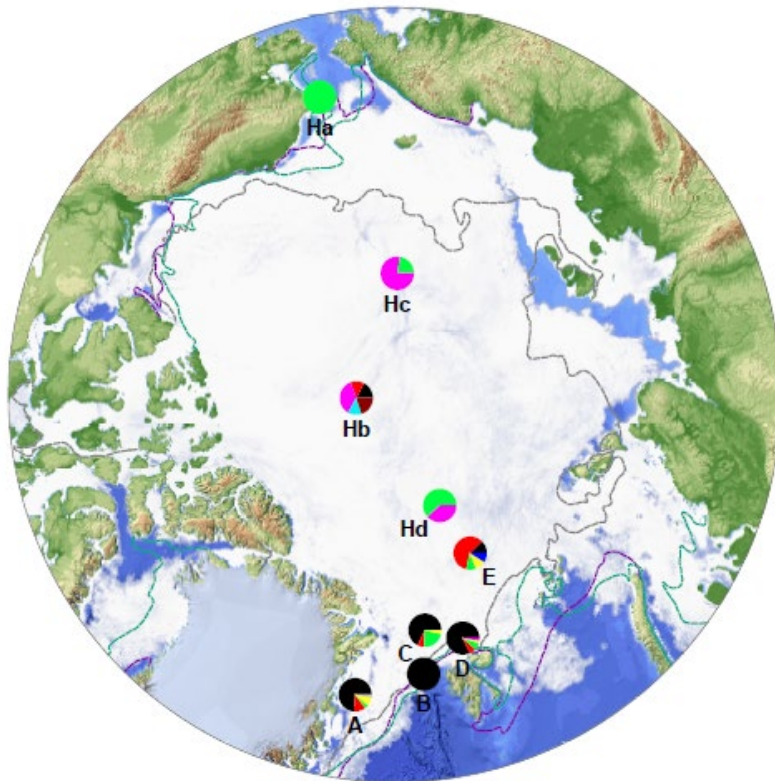
Extreme high MP
concentrations in sea ice



Most particles <50 μ m

Peeken et al. 2018

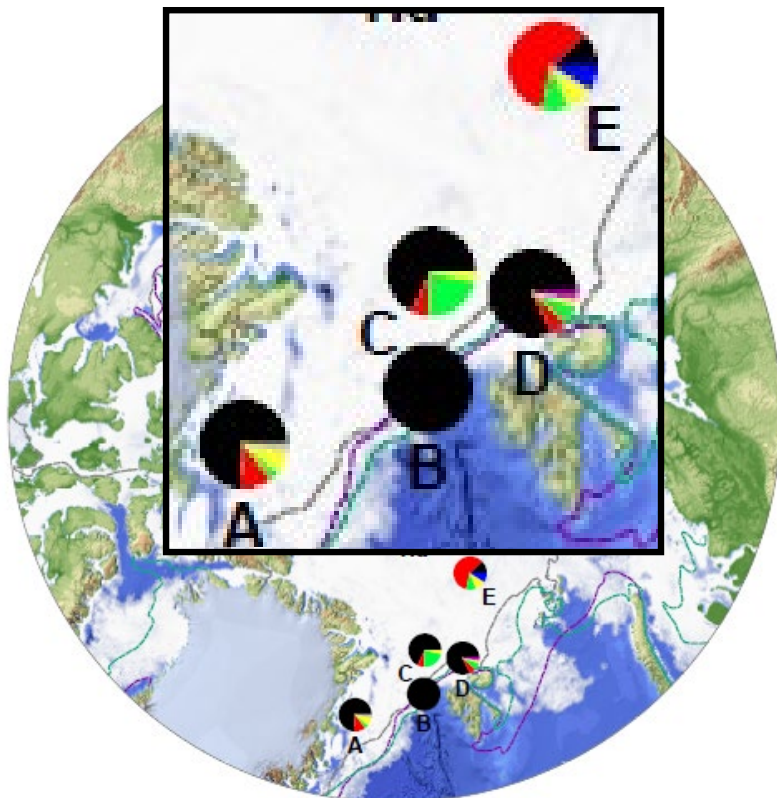
MP composition



High regional differences, even
for close by sampled cores

Peeken et al. 2018

MP composition



PE
Varnish
PA

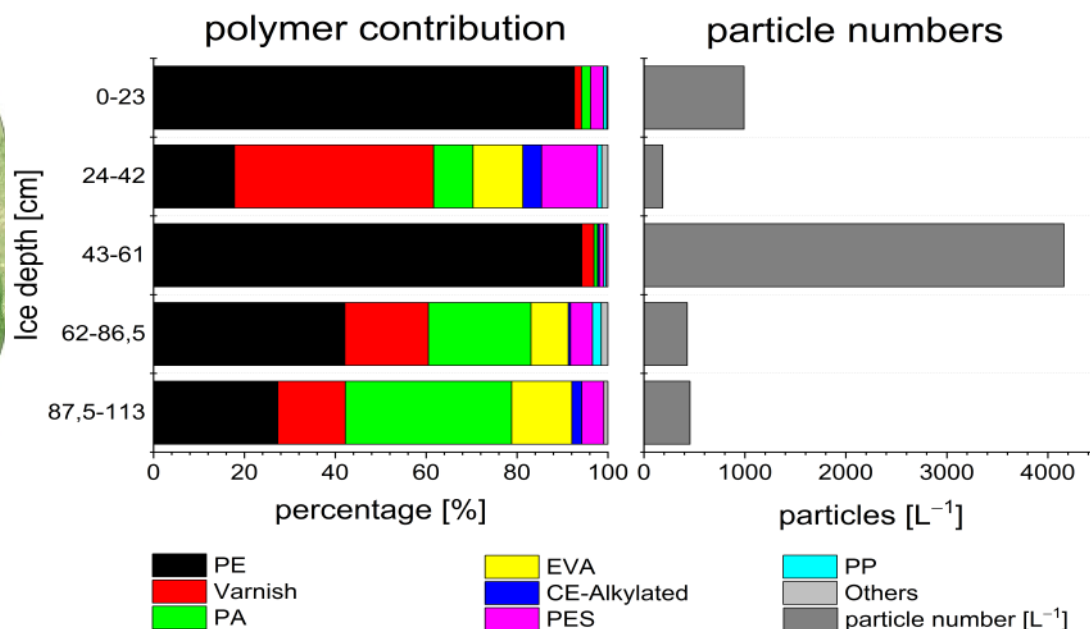
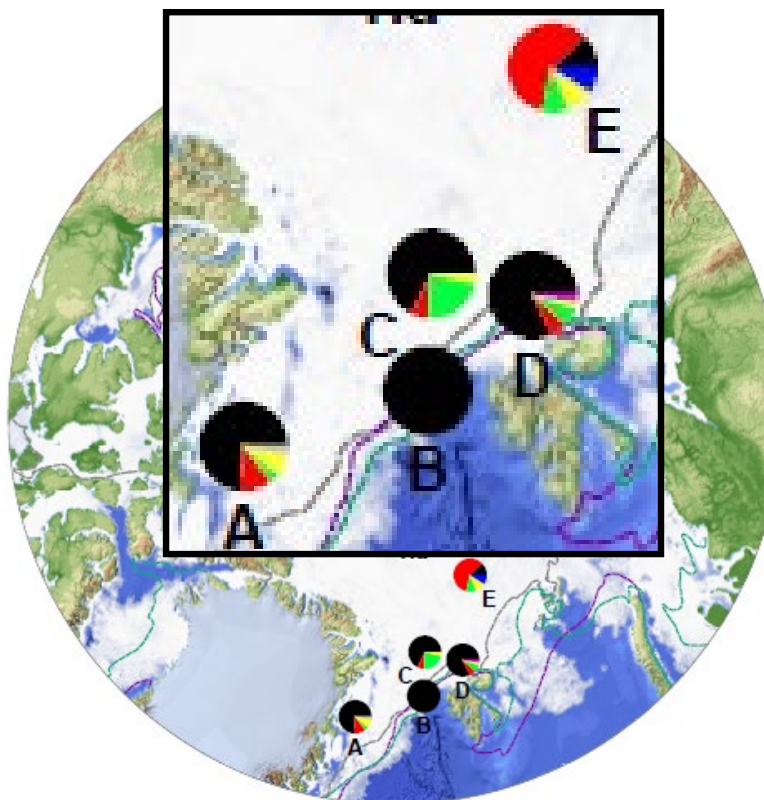
EVA
CE-Alkylated
PES

PP
Others
particle number [L⁻¹]

High regional differences, even
for close by sampled cores

Peeken et al. 2018

MP composition

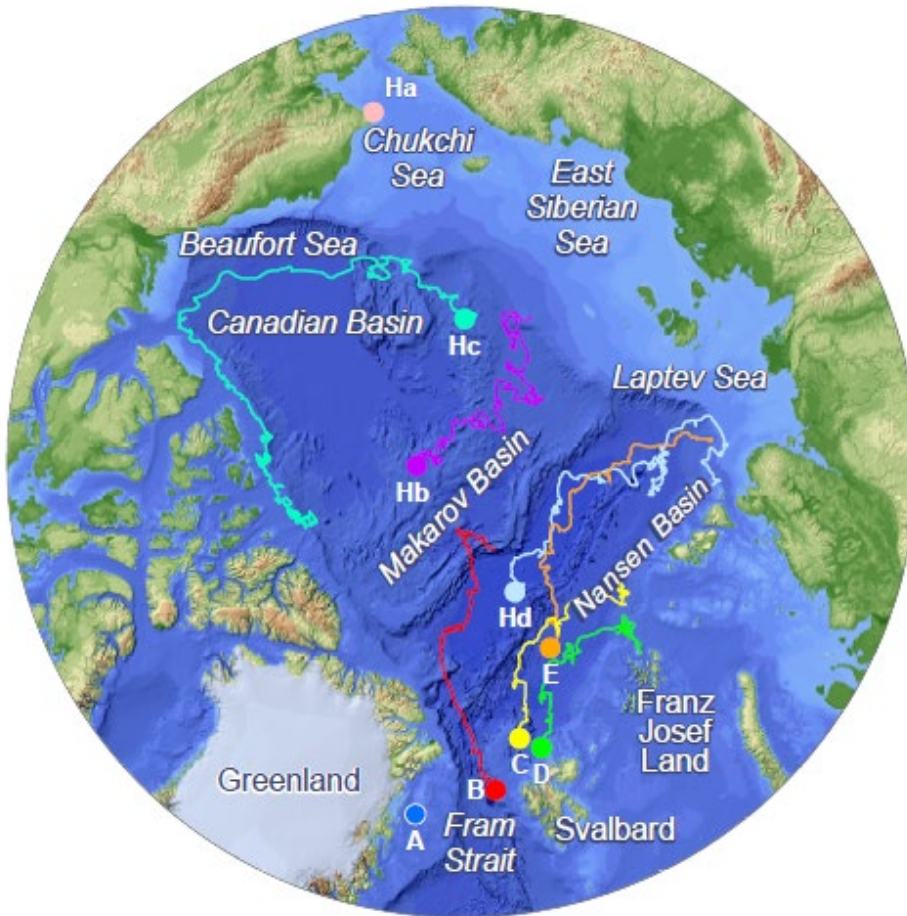


High regional differences, even
for close by sampled cores

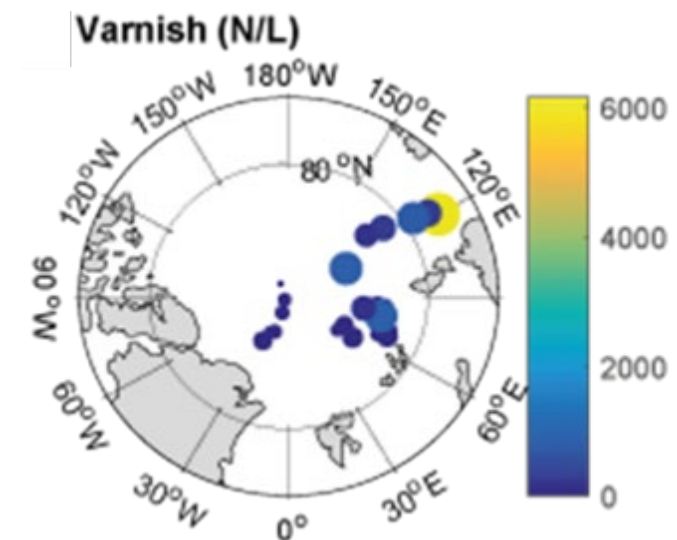
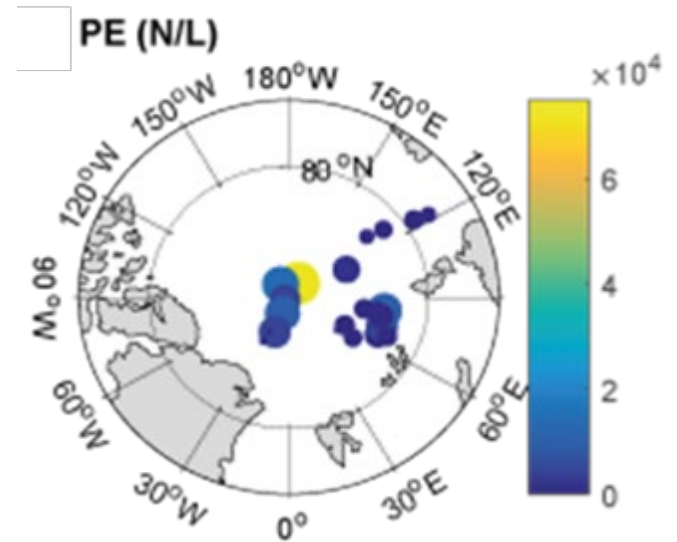
High spatial variability within sea ice

Peeken et al. 2018

Backtracking and thermodynamic modelling

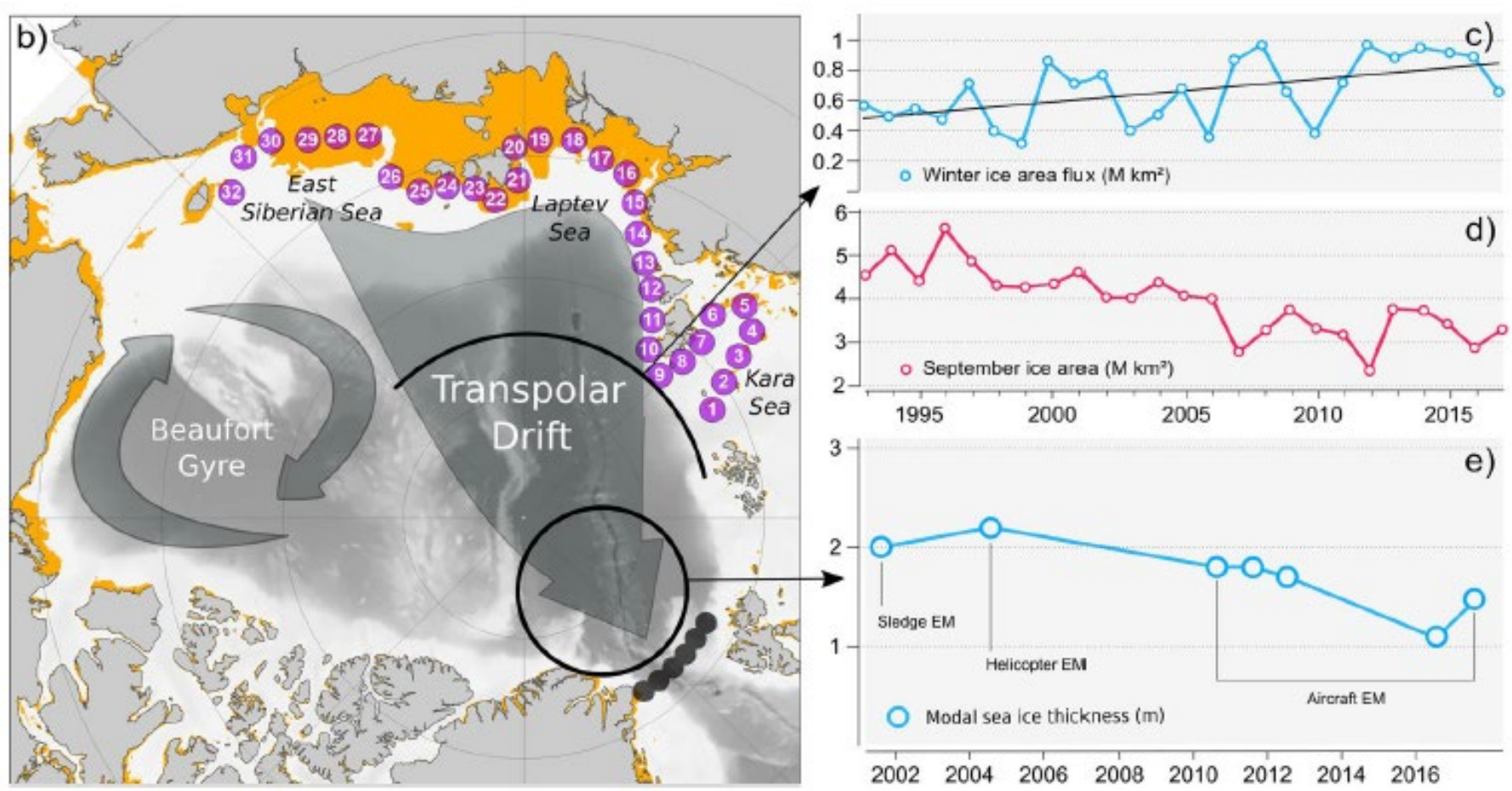


Specific footprint of MP polymer pollution



Peeken et al. 2018

Arctic warming induced change of ice rafted material release



Krumpen et al. 2019

Intensified melt in the marginal zones of the Arctic
Ocean interrupts the transarctic conveyor belt

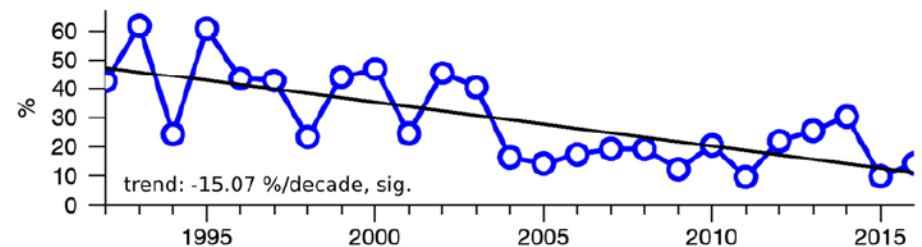
Reduced transport of sea ice from Siberian shelves



a) Survival rate of Siberian Shelf ice formed at site 1 - 32



b) Annually averaged survival rate of Siberian Shelf ice



Suggest accumulation of MP in the
Central Arctic

Krumpen et al. 2019

Reduced transport of sea ice from Siberian shelves

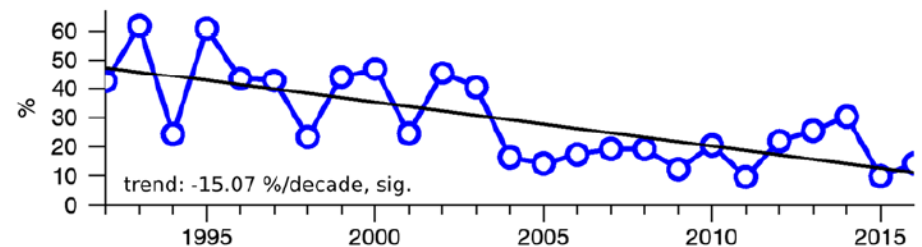


a) Survival rate of Siberian Shelf ice formed at site 1 - 32

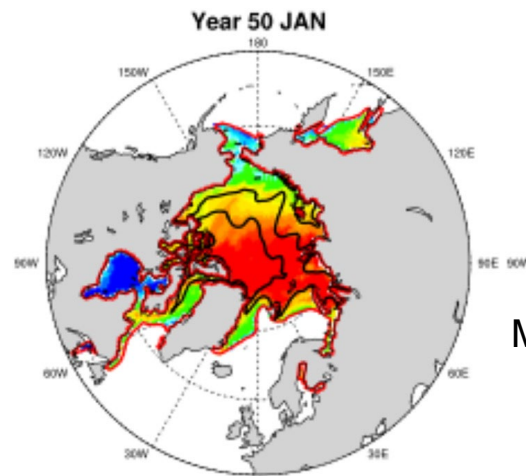


Kruppen et al. 2019

b) Annually averaged survival rate of Siberian Shelf ice



Suggest accumulation of MP in the
Central Arctic

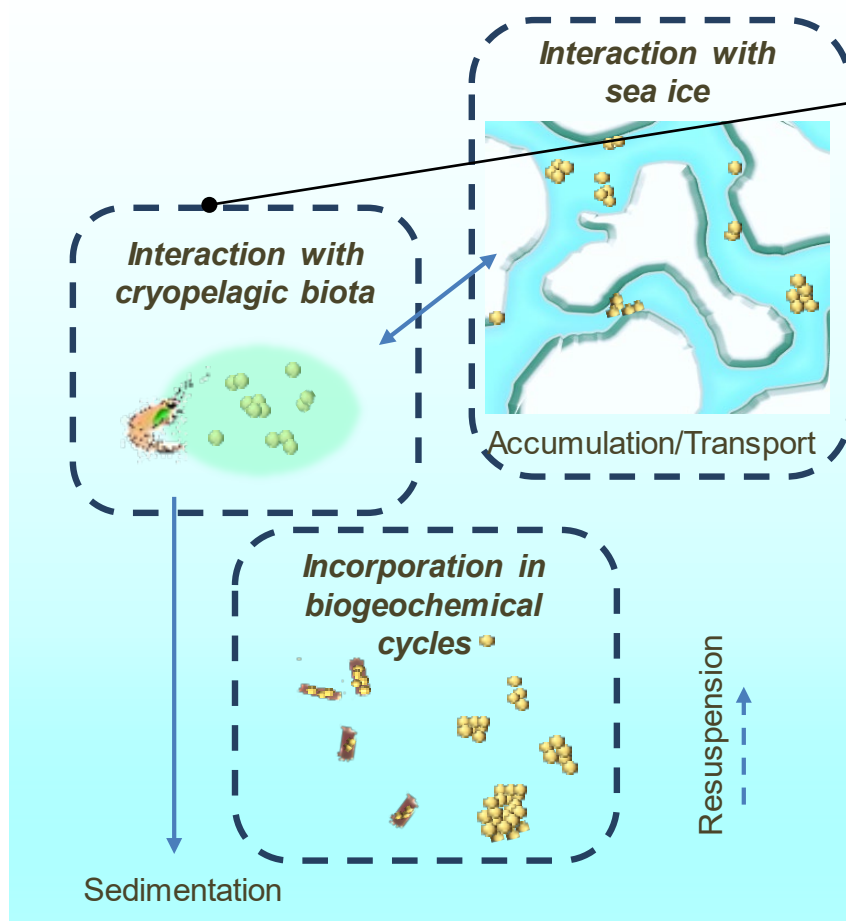


Mountford & Maqueda, 2021

Implication for future microplastic
modelling of sea ice

- Small particle size of microplastic in sea ice indicate fragmentation processes within the ice with currently unknown consequences for the Arctic ecosystem
- Sea ice is a sink for microplastic in the Arctic, however, only temporary, since large fractions of sea ice melt
- Arctic warming interrupts the Transpolar Drift and affects long range transport of sea ice, thus more microplastic will accumulate in the Central Arctic
- Sea-ice microplastic show a unique polymer footprint which seems to be affected by the growth region and drift paths of the sea ice
- Accelerated sea ice melting will allow further exploration of the Arctic and will likely increase the localised sources

Knowledge gaps: Nano-plastic in sea ice

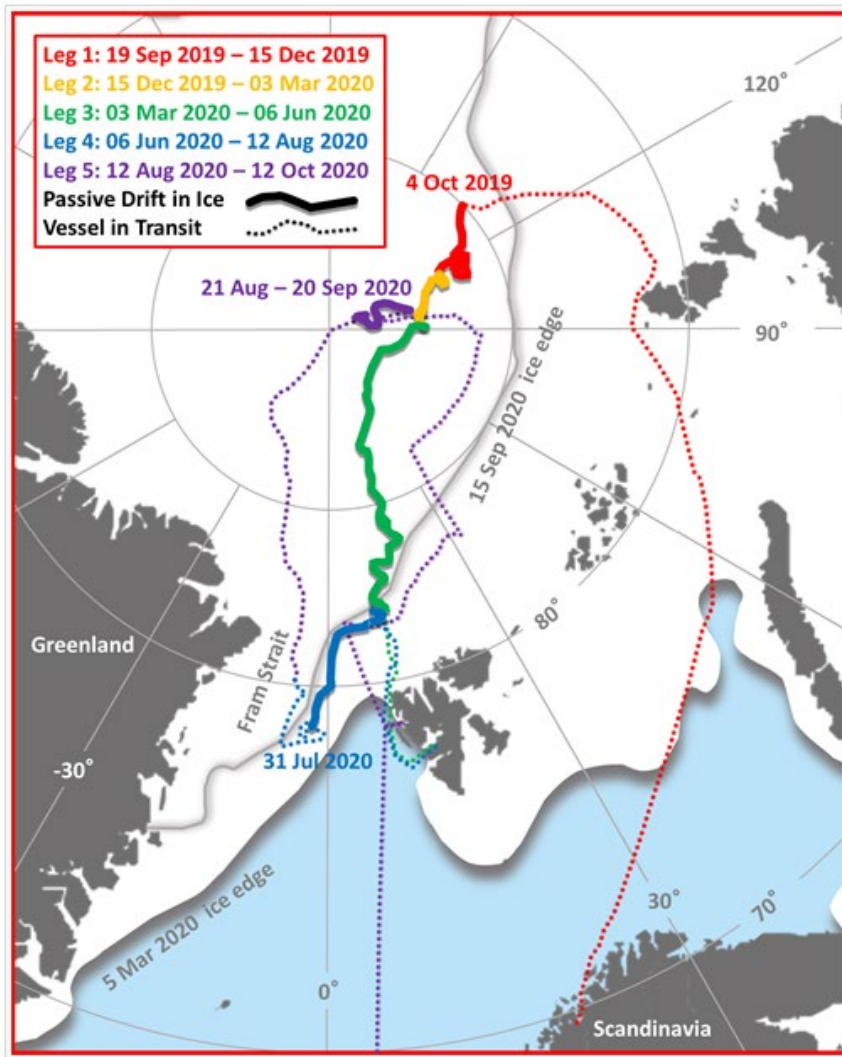


Corsi et al. In preparation



Euphausia superba

“Turning microplastics into
nanoplastics through digestive
fragmentation by Antarctic krill”
(Dawson et al. 2018)



Shupe et al. 2020

Thanks to Sea ice team: ice cores



@ Ester Horvath

Thanks to Atmosphere team: water samples



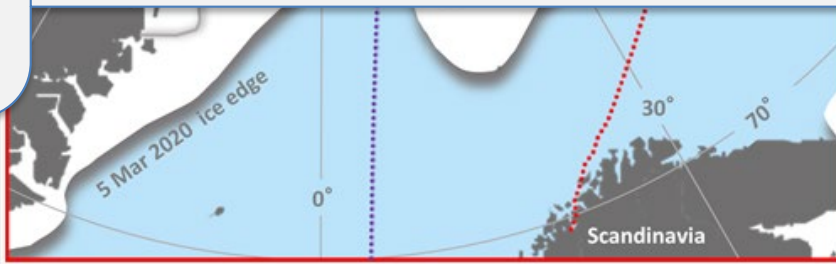
@ Ester Horvath

Thanks to Sea ice team: ice cores

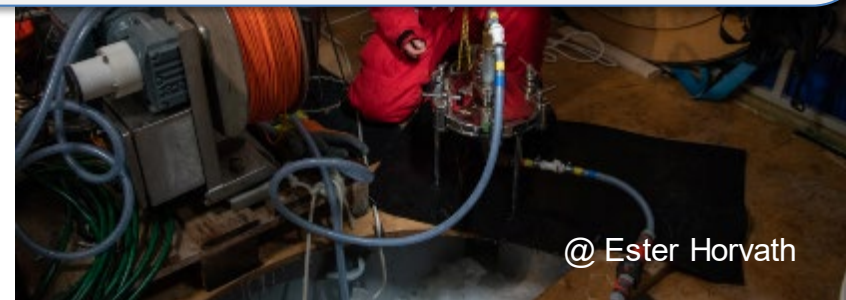
Leg 1: 19 Sep 2019 – 15 Dec 2019
Leg 2: 15 Dec 2019 – 03 Mar 2020
Leg 3: 03 Mar 2020 – 06 Jun 2020



- **Test our hypothesis that the underlying water reflects the MP composition of sea ice**
- **Allow first time NP determination in sea ice**
- **Improve current modelling of microplastic in sea ice**



Shupe et al. 2020



@ Ester Horvath