

# Mapping floating marine plastic debris using Earth Observation

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Photo: SEA Semester



Utrecht University



SURF SARA



European Research Council  
Established by the European Commission

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## The 'plastic soup'



Moore et al, 2001

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# What happens to our plastic waste?



WORLD ECONOMIC FORUM, ELLEN MACARTHUR FOUNDATION, MCKINSEY & COMPANY, A NEW PLASTICS ECONOMY: RETHINKING THE FUTURE OF PLASTICS (2016) ELLENMACARTHURFOUNDATION.ORG/PUBLICATIONS

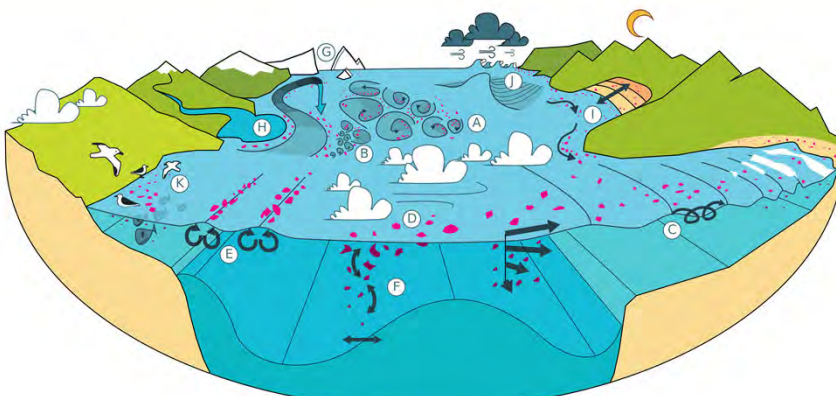
1 Closed-loop recycling: Recycling of plastics into the same or similar-quality application  
2 Cascaded recycling: Recycling of plastics into other, lower-value applications

Source: Project Mainstream analysis – for details please refer to the extended version of the report available on the website of the Ellen MacArthur Foundation: www.ellenmacarthurfoundation.org

Source:  
Ellen MacArthur Foundation

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# Simulating the pathways of plastic



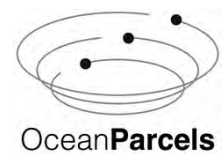
### PHYSICAL PROCESSES

- A Large-scale open ocean processes
- B Submesoscale open ocean processes
- C Open ocean Stokes drift
- D Direct wind transport (windage)
- E Langmuir circulation
- F Vertical mixing
- G Ice formation, melting and drift
- H River plumes and coastal fronts
- I Coastal currents, surface waves and beaching
- J Extreme events
- K Transport by organisms

Van Sebille, Aliani, Law, Maximenko, Alsina, Bagaev, Bergmann, Chapron, Chubarenko, Cózar, Delandmeter, Egger, Fox-Kemper, Garaba, Goddijn-Murphy, Hardesty, Hoffman, Isobe, Jongedijk, Kaandorp, Khatmullina, Koelmans, Kukulka, Laufkötter, Lebreton, Lobelle, Maes, Martínez-Vicente, Morales Maqueda, Poulain-Zarcos, Rodríguez, Ryan, Shim, Suaria, Thiel, van den Bremer and Wichmann, submitted to Environmental Research Reviews



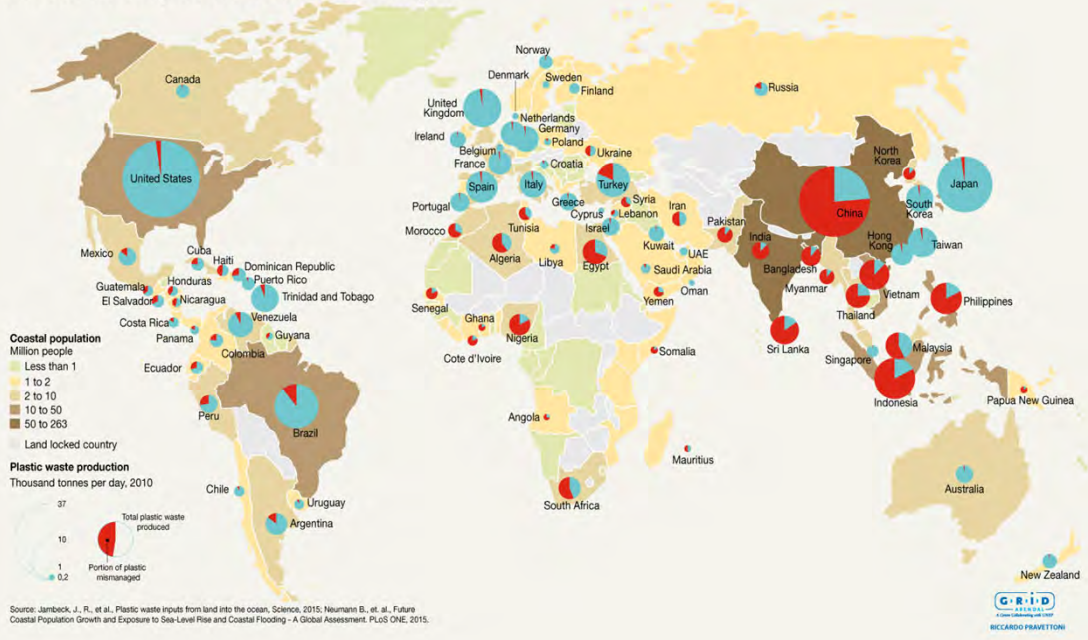
ERC Starting Grant: Tracking Of Plastic In Our Seas (TOPIOS)



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## Plastic waste per country

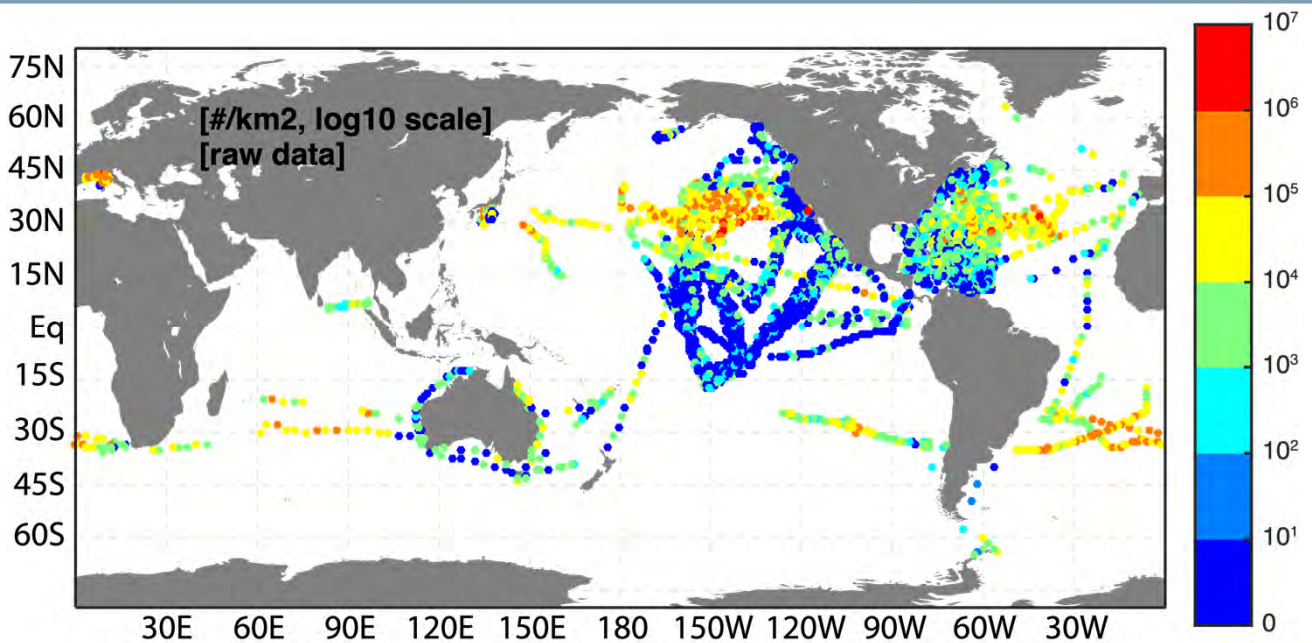
### Plastic waste produced and mismanaged



Source:  
Jambeck et al  
*Science*, 2015

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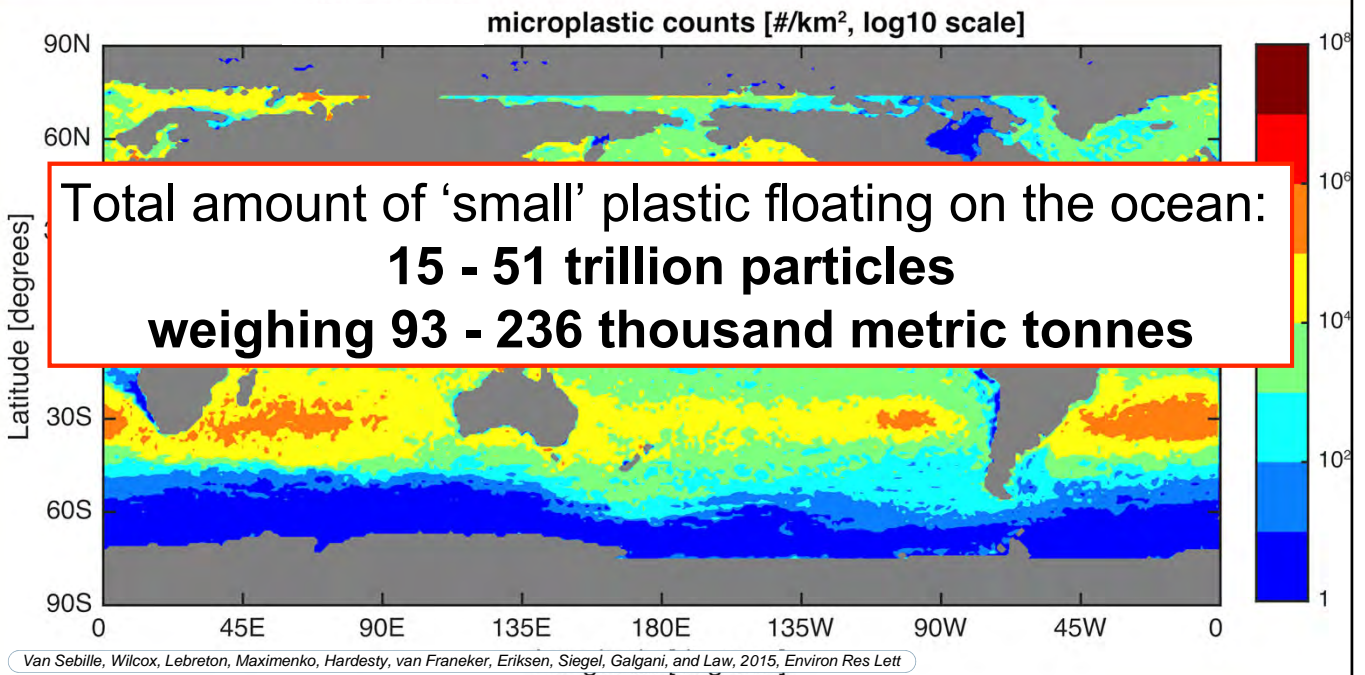
## Combining 11,000 trawl data points



Van Sebille, Wilcox, Lebreton, Maximenko, Hardesty, van Franeker, Eriksen, Siegel, Galgani, and Law, 2015, *Environ Res Lett*

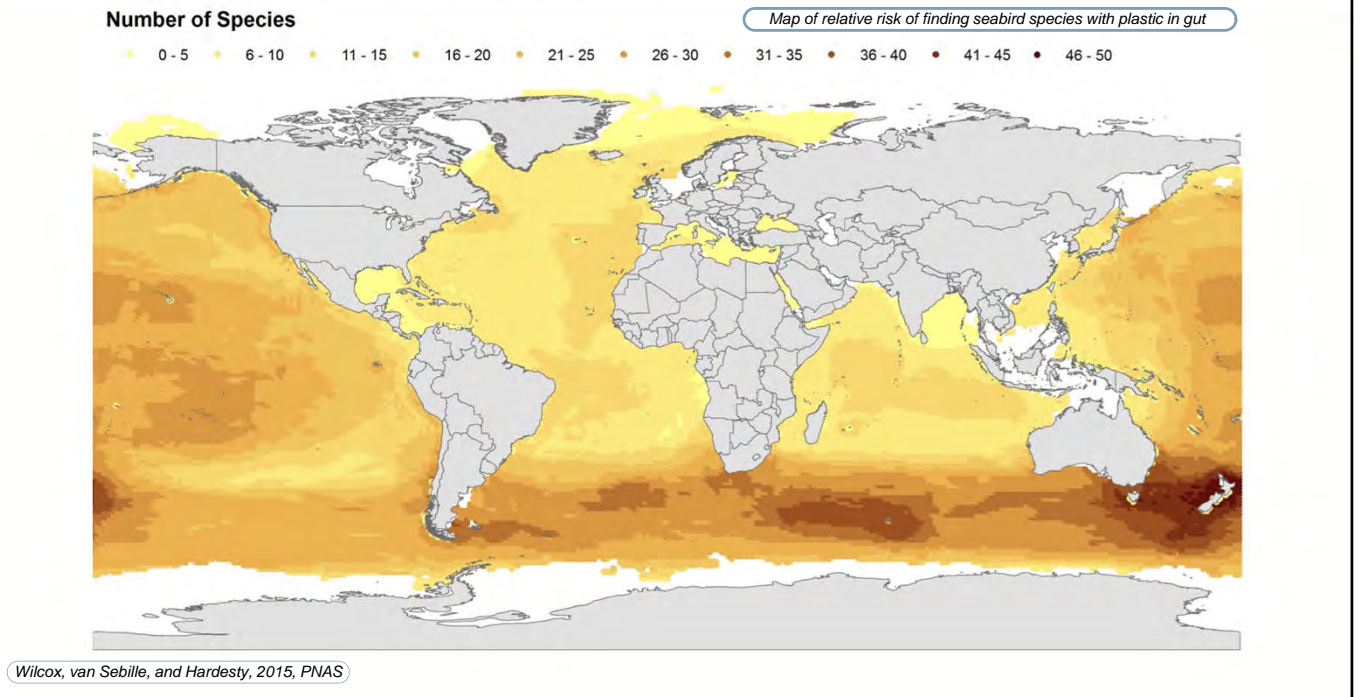
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### Estimating the amount of small floating plastic



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### Impacts of plastics on seabirds



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## Mapping of plastic with Earth Observation?

Marine process	Spatial	
	Spatial Extent(max)	Required Spatial Resolution of observations
River discharge	100 Km	30 m (G) 500 m (T)
Spill	100 Km	1 m (G) 50 m (T)
Shoreline accumulation	1000 km	1 m (G) 5 m (T)
Submesoscale convergence filaments	10 km	30 m (G) 100 m (T)

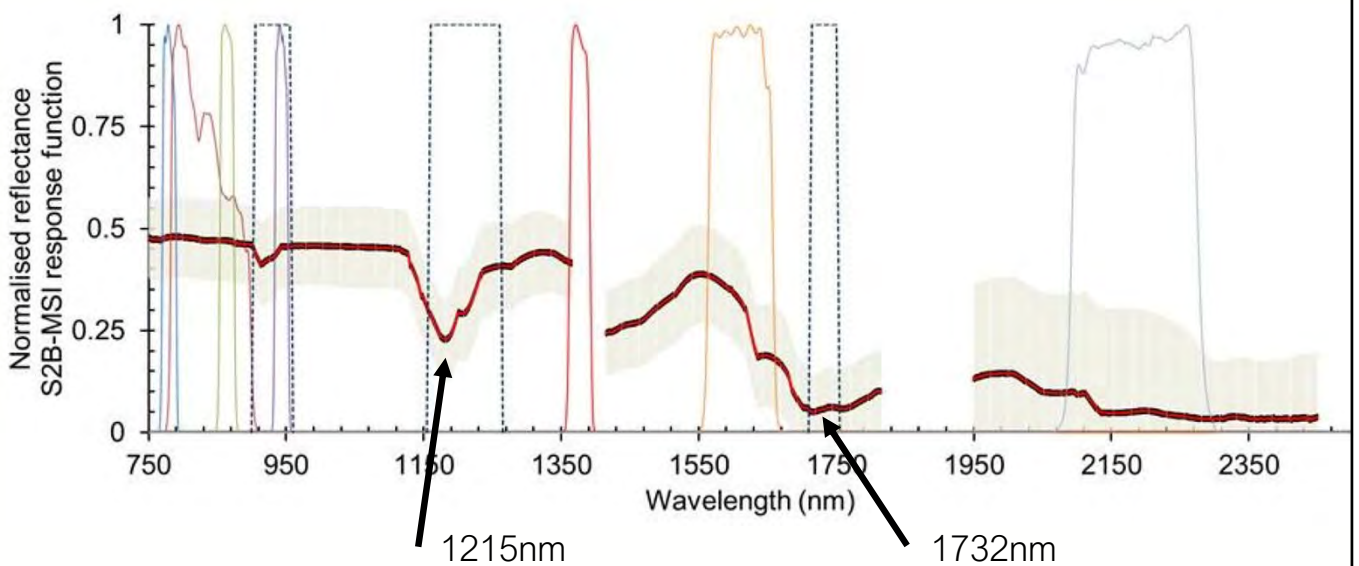
Marine process	Temporal	
	Lifetime of process (max)	Required frequency of observations
River discharge	1 month	3 h (T)
Spill	1 month	2 h (T)
Shoreline accumulation	10 year	12 h (G) 5 d (T)
Submesoscale convergence filaments	1 month	1 d (T)



*Martinez-Vicente, Clark, Corradi, Aliani, Arias, Bochow, Bonnery, Cole, Cozar, Donnelly, Echevarria, Galgani, Garaba, Goddijn-Murphy, Lebreton, Leslie, Lindeque, Maximenko, Martin-Lauzer, Moller, Murphy, Palombi, Raimondi, Reisser, Romero, Simis, Sterckx, Thompson, Topouzelis, Van Sebille, Veiga, Vethaak, in review at Remote Sensing*

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## Using radiometry and imaging spectrometry

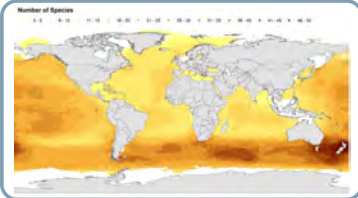
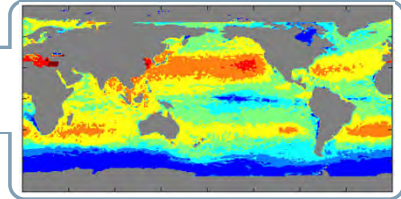


*Martinez-Vicente, Clark, Corradi, Aliani, Arias, Bochow, Bonnery, Cole, Cozar, Donnelly, Echevarria, Galgani, Garaba, Goddijn-Murphy, Lebreton, Leslie, Lindeque, Maximenko, Martin-Lauzer, Moller, Murphy, Palombi, Raimondi, Reisser, Romero, Simis, Sterckx, Thompson, Topouzelis, Van Sebille, Veiga, Vethaak, in review at Remote Sensing*

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## Conclusions

▶ Floating plastic litter accumulates in garbage patches & hotspots



▶ To quantify harm requires mapping interaction with marine life

▶ Mapping of plastic using Earth Observation will be challenging



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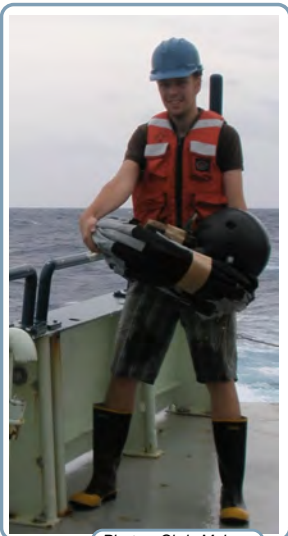


@ErikvanSebille



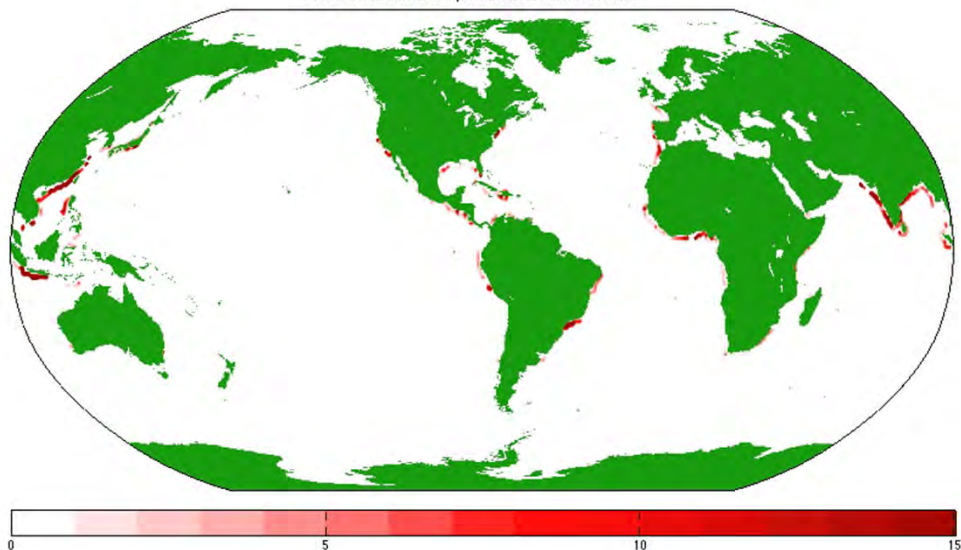
## Simulate how ocean currents transport plastic

Releasing tracer scaled to coastal population



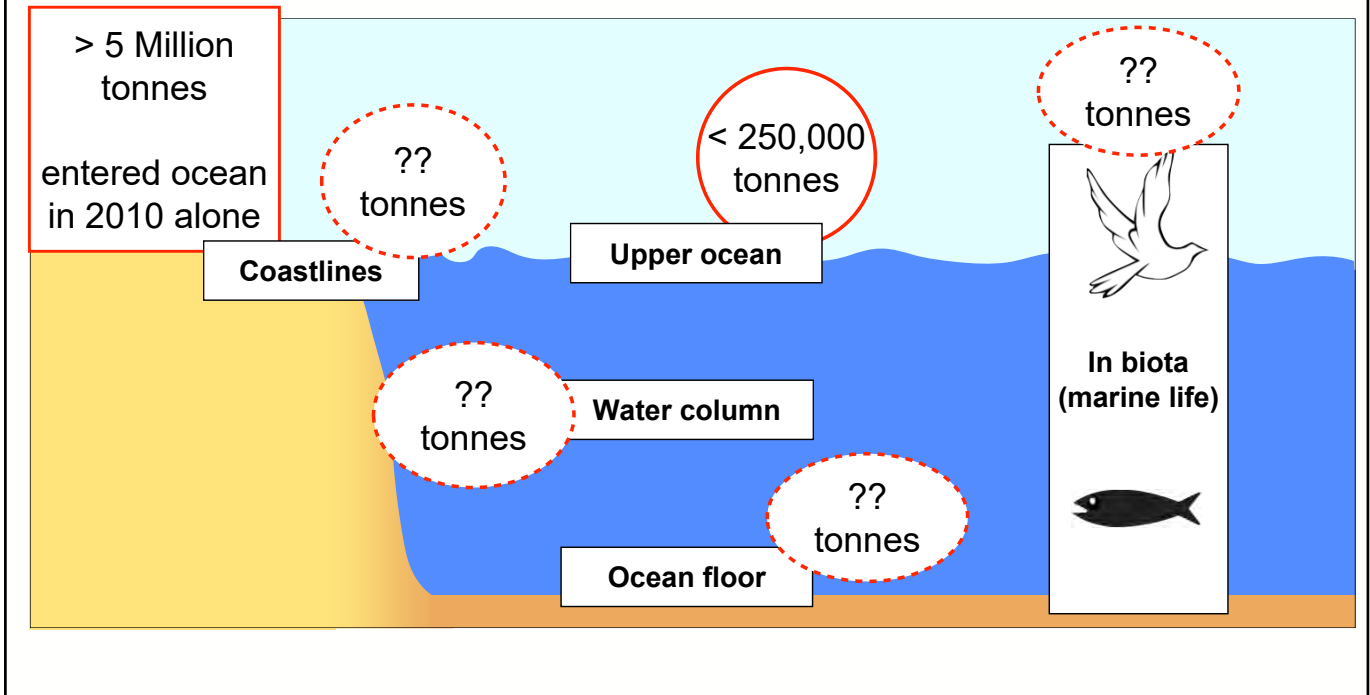
Photos: Chris Meinen

Tracer accumulation factor 0 years and 00 months after release



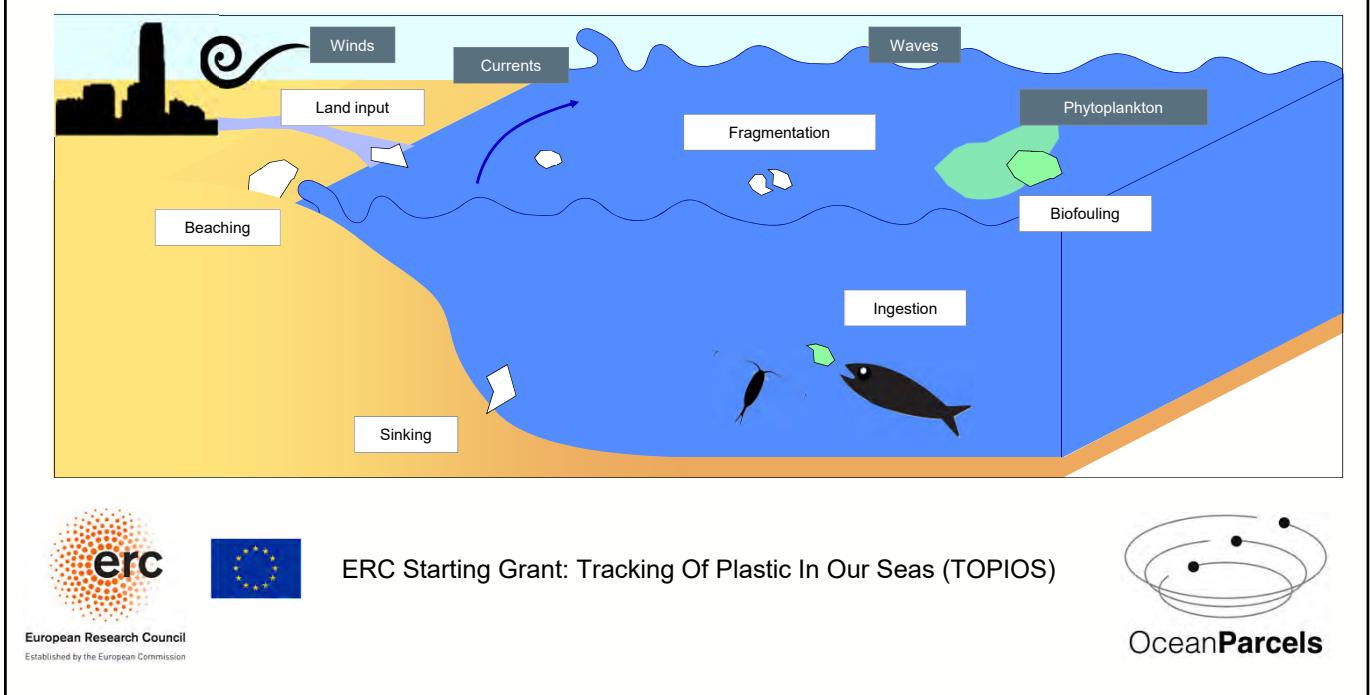
van Sebille, England, and Froyland, 2012, Environ Res Lett

### The case of our 99% missing plastic

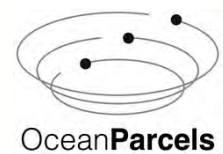


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### Simulating the pathways of plastic



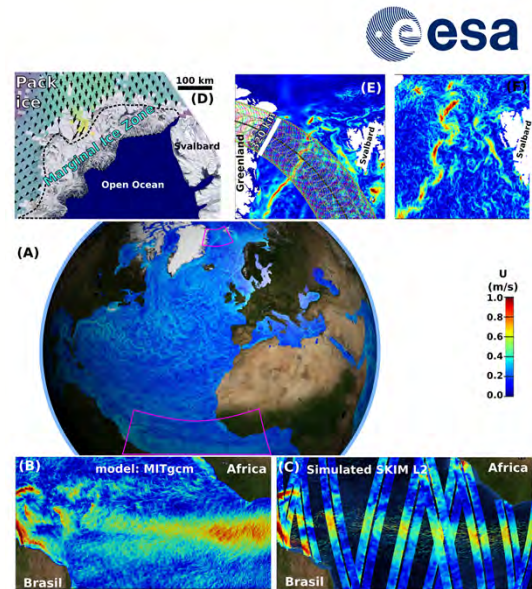
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## The SKIM mission to measure waves, winds and currents

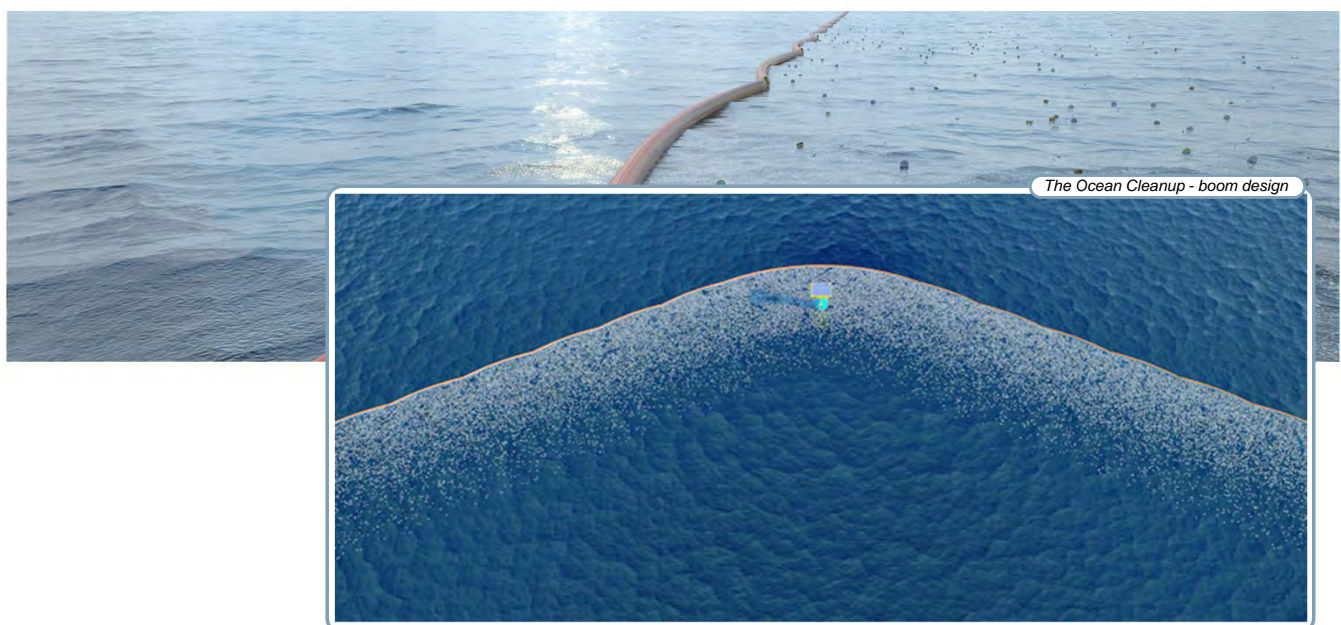
- ▶ We can't observe the surface currents that transport floating plastic... yet!
- ▶ Enter the **S**ea Surface **K**inematics **M**ultiscale monitoring (**SKIM**) mission
  - ▶ One of two ESA Earth Explorer concept missions
- ▶ Uses rotating radar to directly measure waves and currents from Doppler shift
- ▶ Expected to be useful for
  - ▶ Tracking 'stuff' in global ocean
  - ▶ Surface flow at the Equator
  - ▶ Ocean-atmosphere interactions
  - ▶ Sea ice in polar regions (daily coverage!)



*Arduin et al, 2019, Frontiers in Marine Science*

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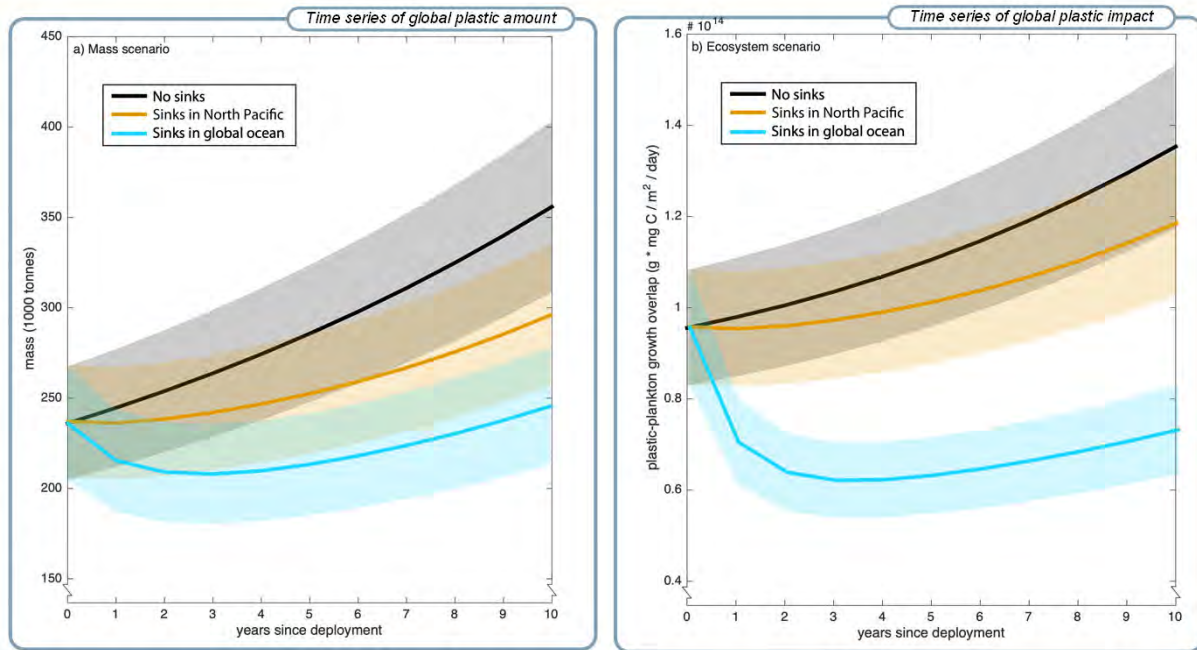
## Cleaning up the plastics?



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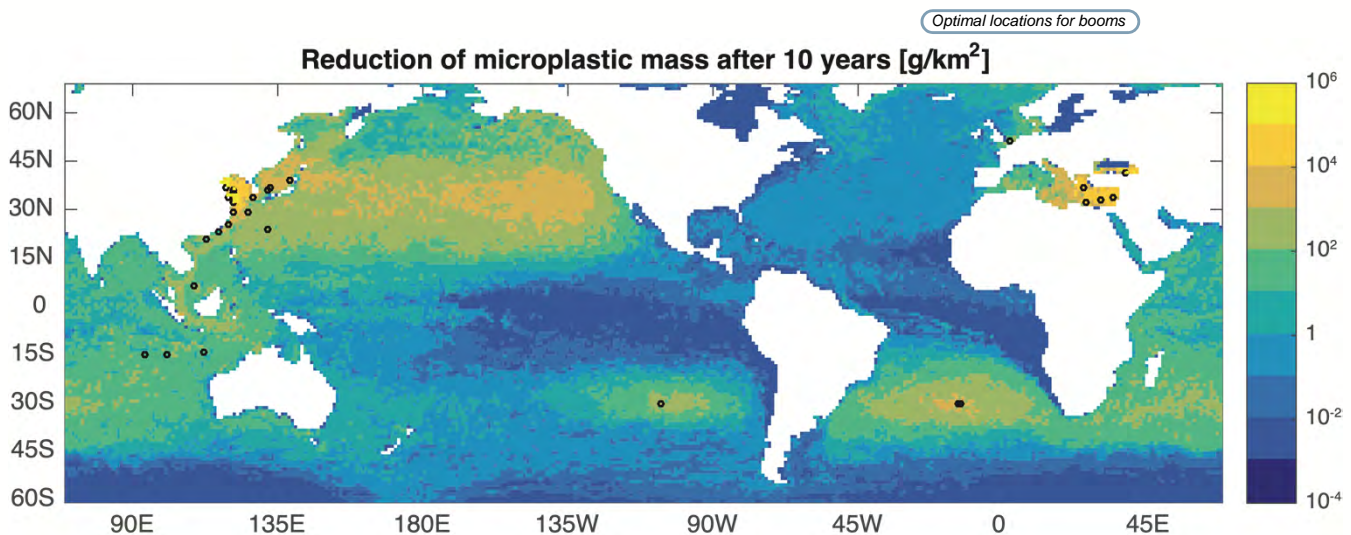
### Where to clean up the plastics?



Sherman and van Sebille, 2016, Environ Res Lett

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### Where to clean up the plastics?



Sherman and van Sebille, 2016, Environ Res Lett

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# So what are the solutions?

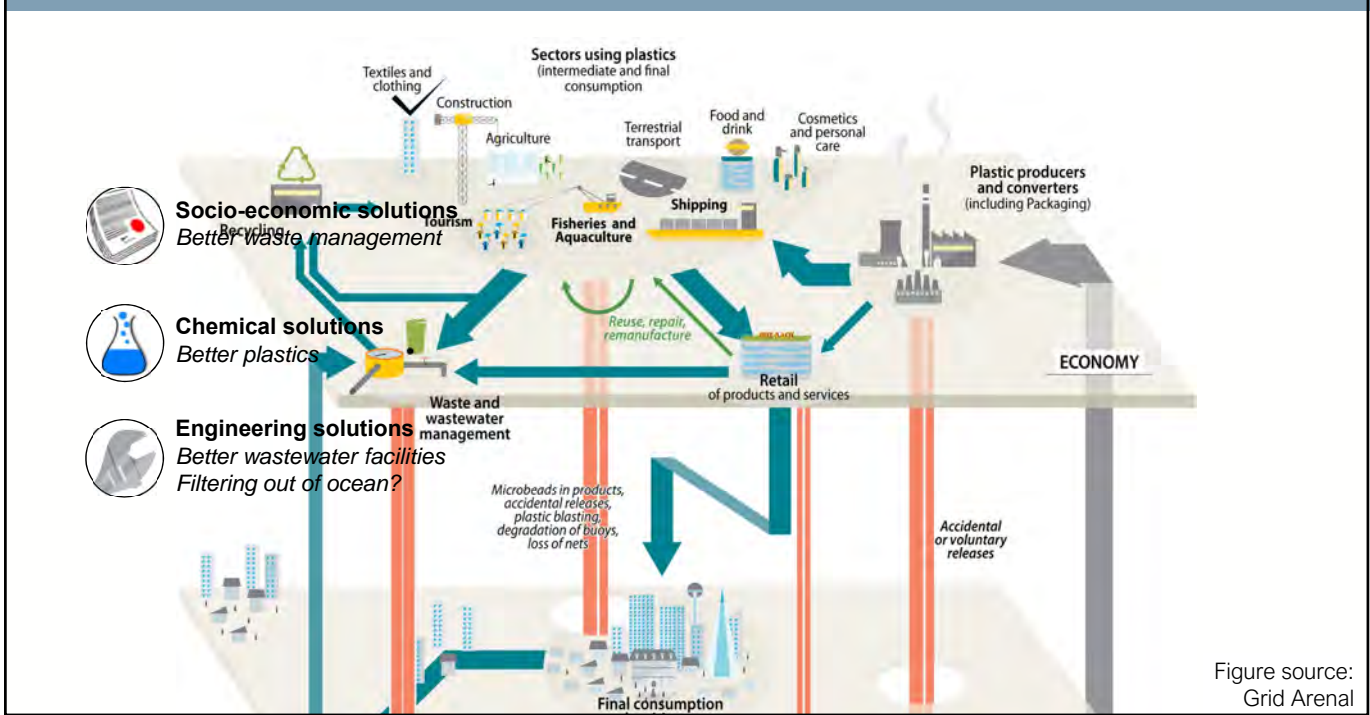


Figure source: Grid Arenal