Exploring microplastic particle behavior: combining models and measurements

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As part of Erik van Sebille's research group,
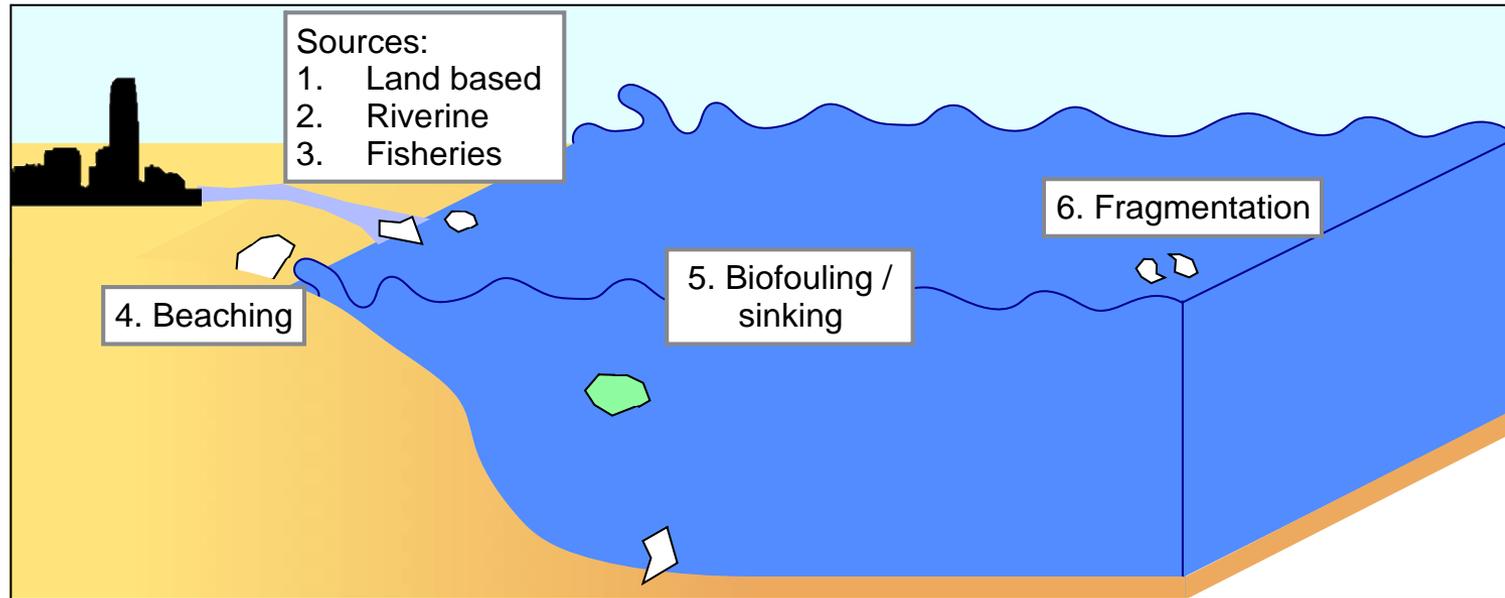@ Utrecht University, the Netherlands

Who am I?

- PhD at Utrecht University

- Part of TOPIOS

- Combining modelling and data

- Previously: MSc at Delft University of Technology, machine learning & turbulence modelling

Pathways of plastic

Sources:
1. Land based
2. Riverine
3. Fisheries

4. Beaching

5. Biofouling / sinking

6. Fragmentation

Adapted from: TOPIOS.org

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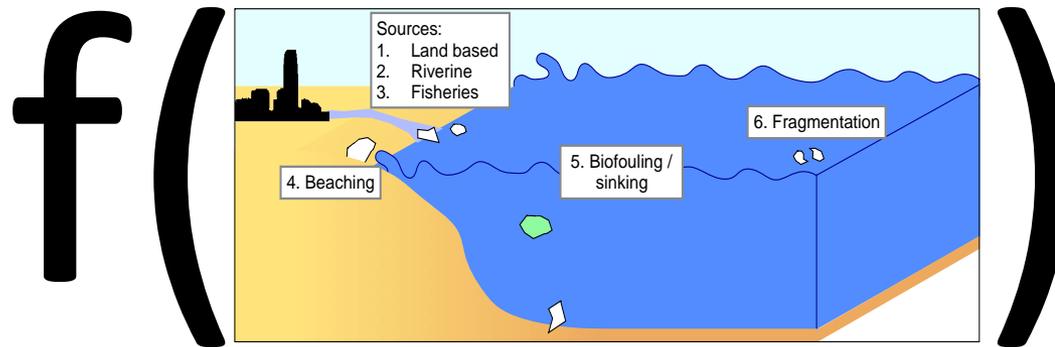
Lagrangian model

- Virtual particles: placeholder for larger collection of microplastics
    - Abundance (N), mass (g)
    - Relative weight: depends on source/sinks
    - Mediterranean
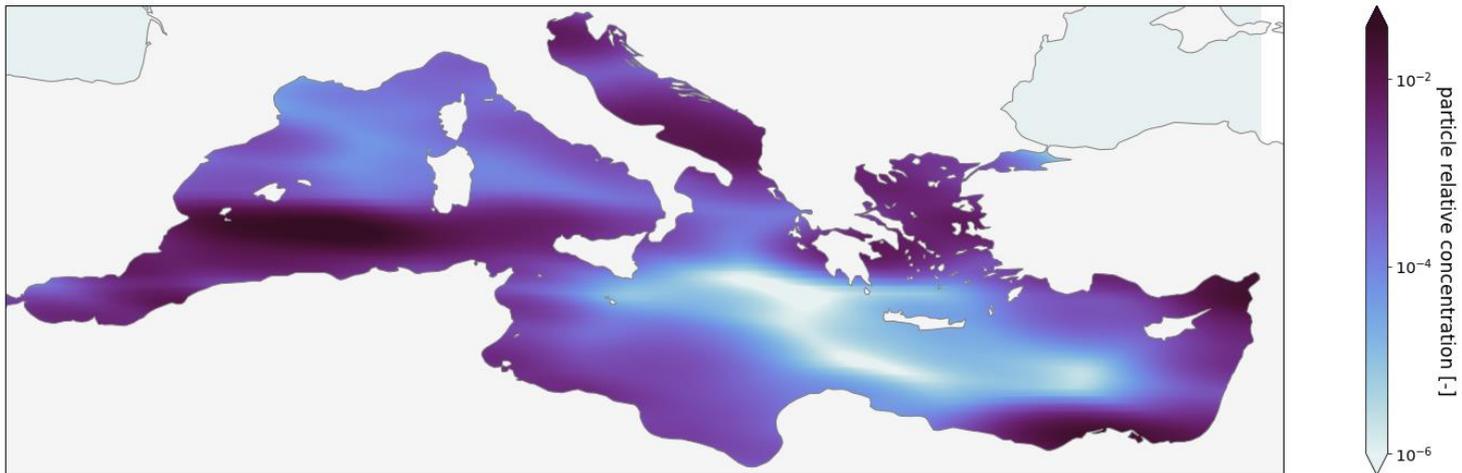
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How to parametrize the sinks and sources?

How to parametrize the sinks and sources?

- Sources (1, 2, 3): simulate different release scenarios
- Sinks: time scales τ

Parameter:	Model:	(Proxy) Data:
τ_{beach} (4)	Constant near coast	Drifter buoys
τ_{sink} (5)	Fazey and Ryan, (2016)	Experiments (Fazey and Ryan, 2016)
$\tau_{fragm.}$ (6)	Fractal model	??
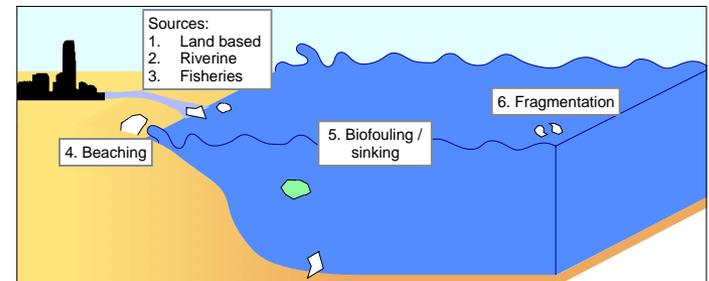
- Research Goal:
  - Constrain parameters using data (measurements)
  - Bayesian framework

$$P(param. \,|\, data) = \frac{P(data \,|\, param.) \, P(param.)}{P(data)}$$

Fragmentation

Measurements Cozar et al., (2015)
Power law fit

Loss of particles

Cascade from larger to smaller particles

Slope: fragmentation dimension
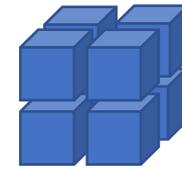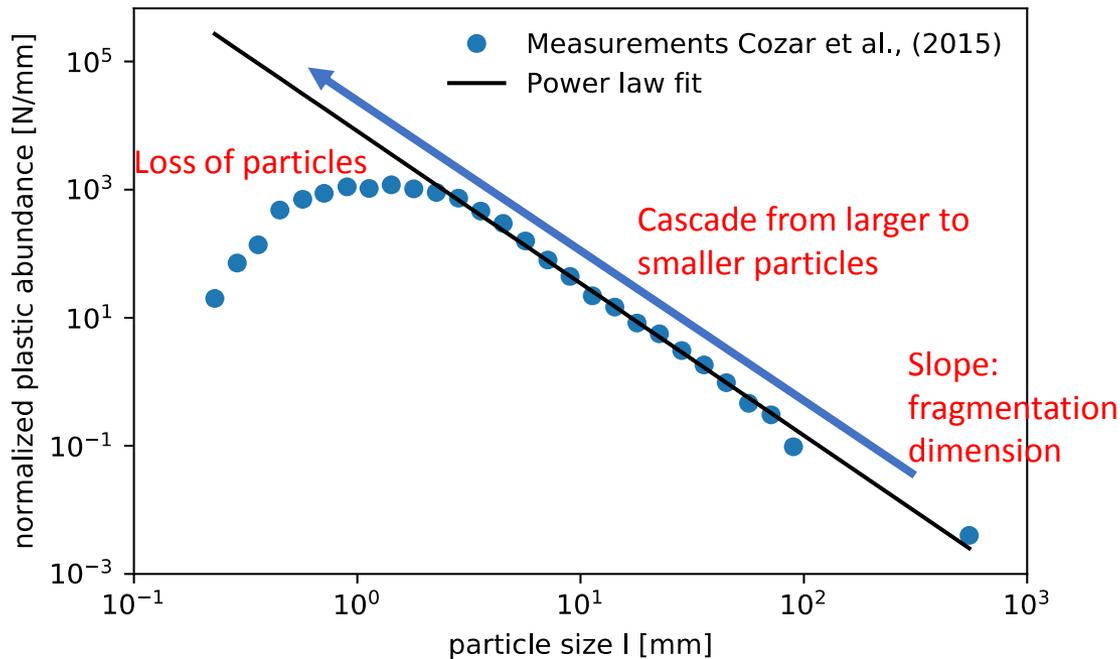
$$\frac{\log(8)}{\log(2)} = 3$$
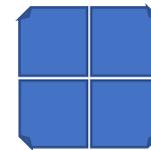
$$\frac{\log(4)}{\log(2)} = 2$$

Slope: $\pm 2.38 \left(\frac{\log(5.2)}{\log(2)} \right)$

- Plastic input size
- Model: age of removed particles
- $\rightarrow$ Time scale ($\tau_{fragm.}$)

Intermezzo

- Expert opinion: $\tau_{fragm.}$

- Slope: $\pm 2.38 \left(\frac{\log(5.2)}{\log(2)} \right)$

- Domain: water + coast (beach)

- Mediterranean

L   L/2

$\tau_{fragm.}$
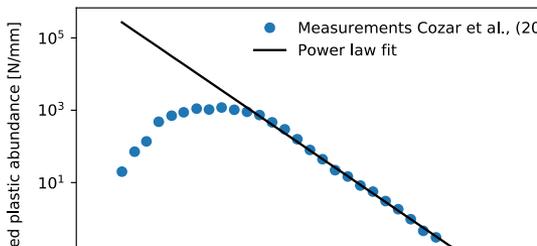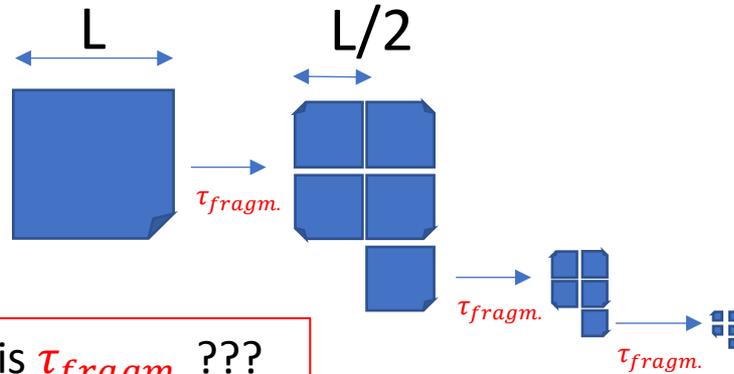
$\tau_{fragm.}$

$\tau_{fragm.}$

$\tau_{fragm.}$

What is $\tau_{fragm.}$???
A. O(1 day)
B. O(1 week)
C. O(1 month)
D. O(1 year)
E. O(1 decade)
F. O(1 century)

normalized plastic abundance [N/mm]

10^5

10^3

10^1

- Measurements Cozar et al., (20...
— Power law fit

+

versity |

Sources

Riverine plastic output [tonnes/year]

10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2}

Fishing intensity, 2012-2016 [hours]

0   2500   5000   7500   10000   12500   15000

MPW density, 2010 [kg/day/km^2]

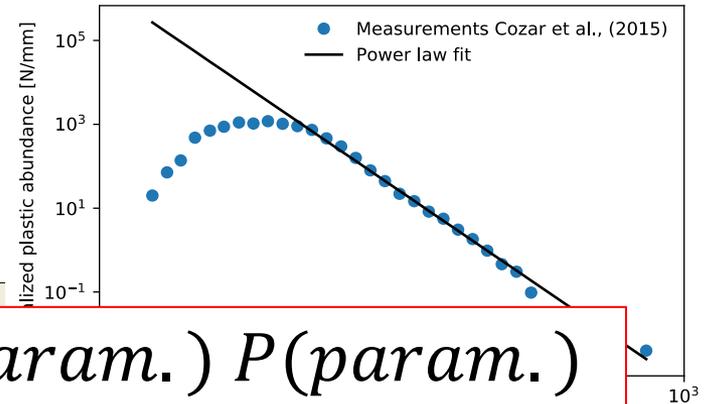10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3}
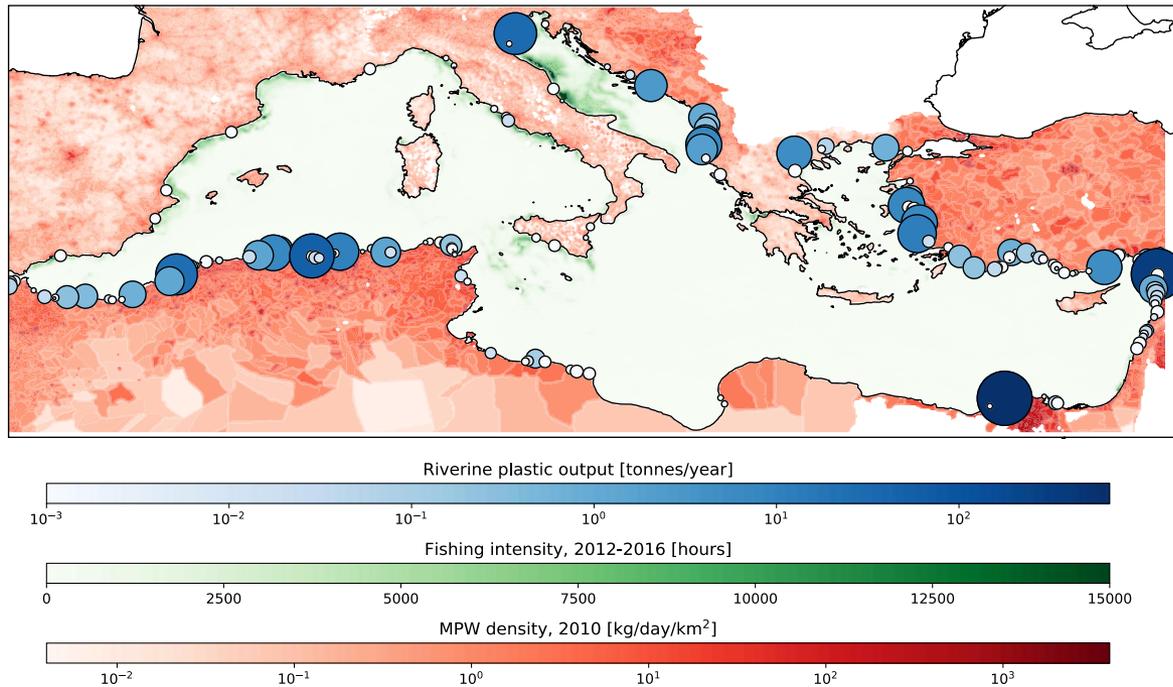
References:
Lebreton et al., (2017)

Global Fishing Watch, (2018)

Jambeck et al., (2015)

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Measurements

$$\#/km^2, g/km^2$$

$$P(param.\,|\,data) = \frac{P(data\,|\,param.)\;P(param.)}{P(data)}$$

Legend:
- Baini et al., 2018
- Collignon et al., 2012
- Fossi et al., 2012
- Galgani et al. 2011
- Galgani et al., 2012
- van der Hal et al., 2017
- Panti et al., 2015
- Güven et al.,, 2017
- Gajšt et al., 2016
- Suaria et al., 2016
- Cozar et al., 2015
- Collignon et al., 2014
- Ruiz-Orejón et al., 2016
- Ruiz-Orejón et al., 2018
- Gündoğdu et al., 2017
- Gündoğdu et al., 2018
- Gündoğdu & Çevik, 2017
- Zeri et al., 2018
- Pedrotti et al., 2016
- de Haan et al., 2019
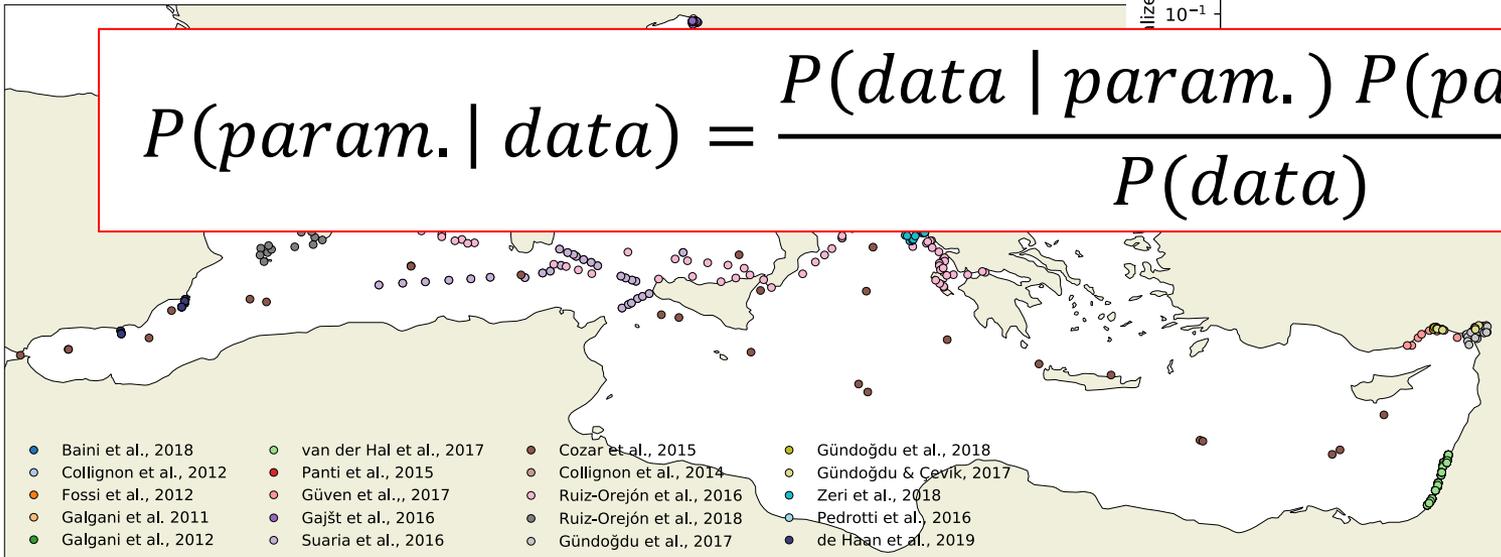
Bayesian inference results
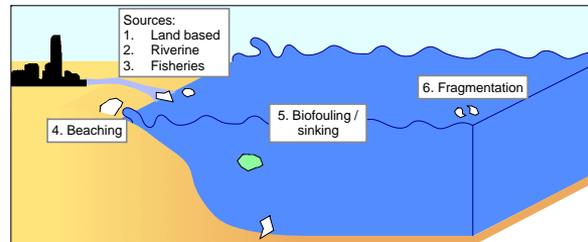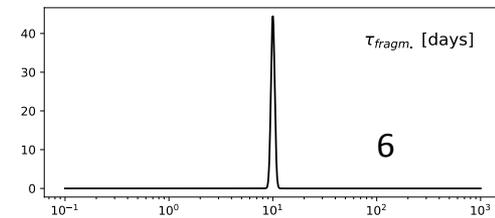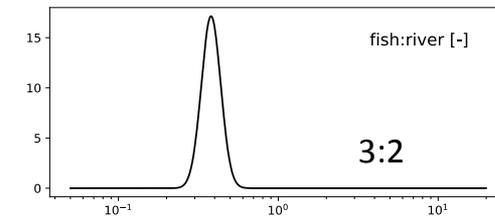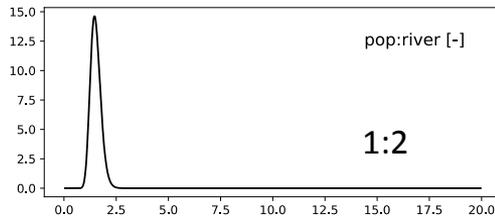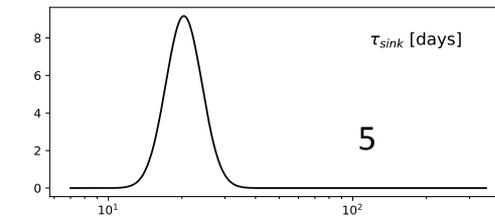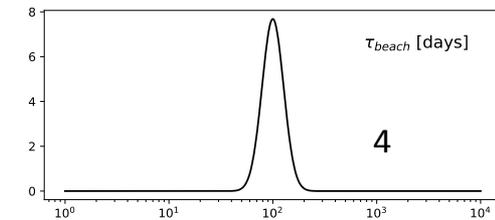
X-axes: the different parameters values
Y-axes: pdf of the parameters

Preliminary:
- Long τ_{beach}
- τ_{beach}: $\pm 2 - 3$ weeks
- Much waste from coastal population
- Less waste from fisheries
- Short $\tau_{fragm.}$

Where is all the plastic?

Preliminary!
- Floating: $\pm$250 tonnes (5%)
- Sunk: $\pm$1900 tonnes (40%)
- Beached: $\pm$700 tonnes (15%)
- Fragmented (<0.3mm): $\pm$1800 tonnes (39%)

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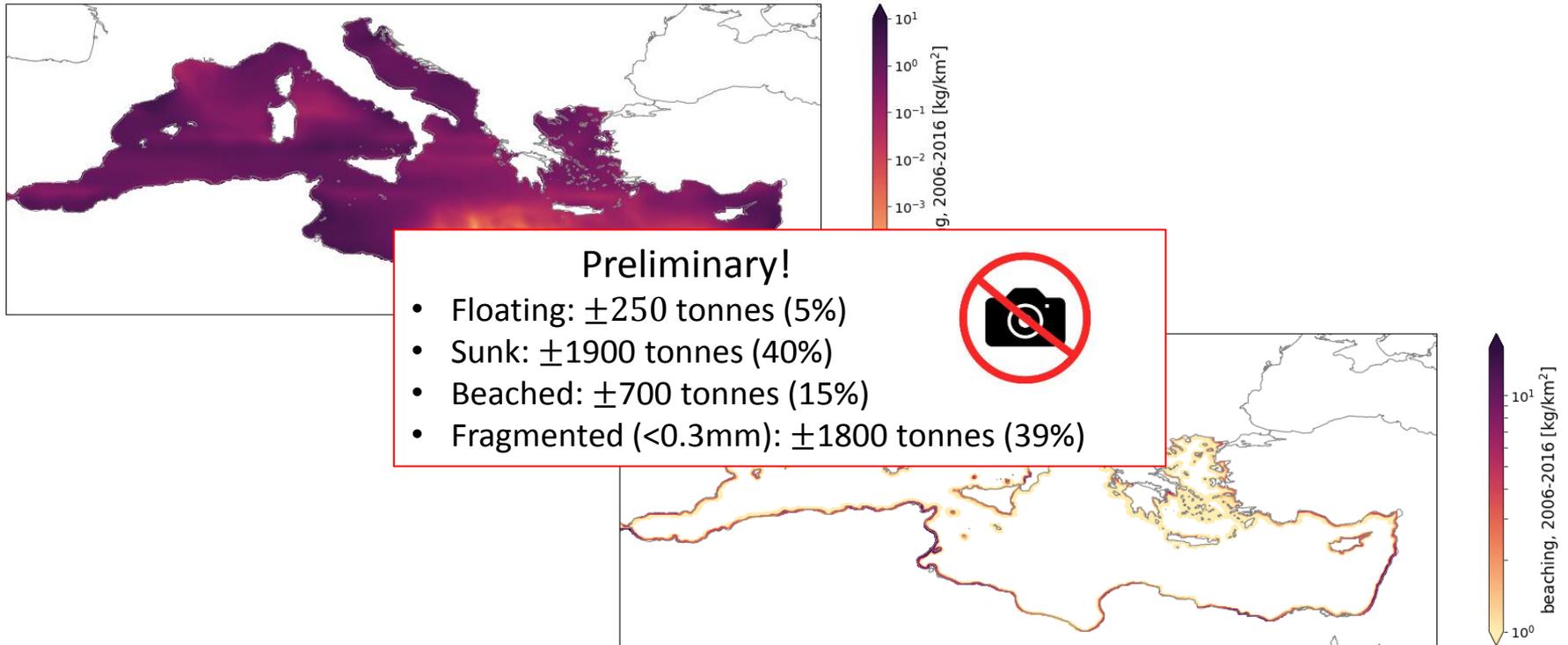
Take-home message

- Parametrize sources and sinks
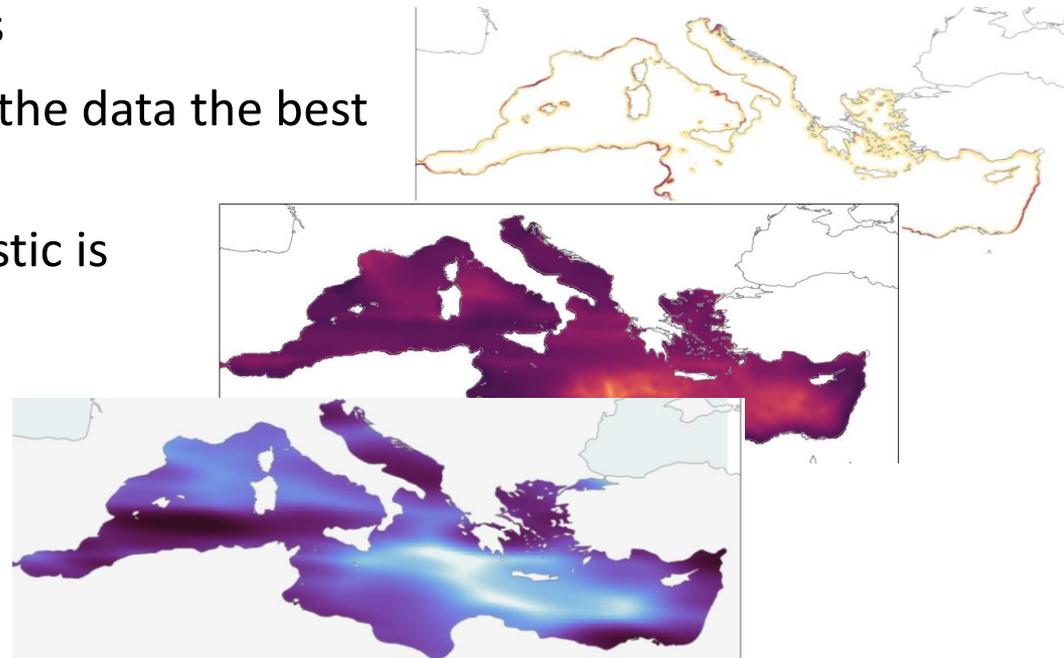
- See which parameters match the data the best (Bayesian inference)

- Reconstruct where all the plastic is

- Future work: include

beaching / sediment data

(globally?)

- TOPIOS.org

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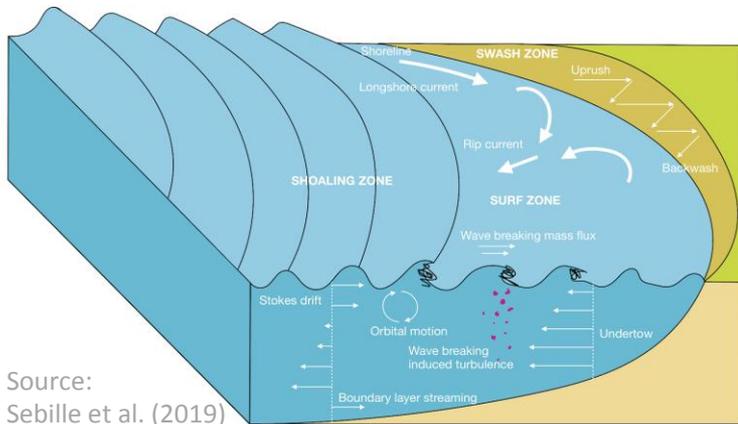
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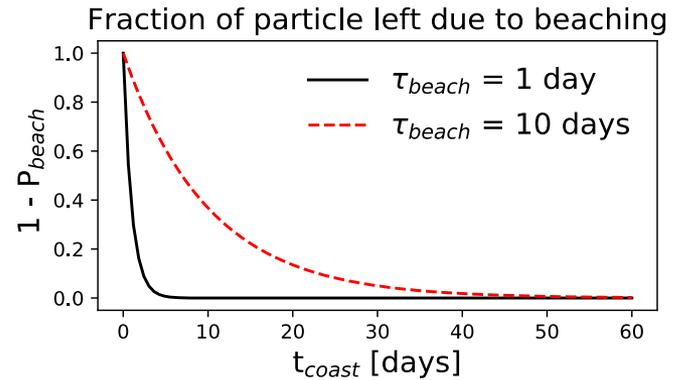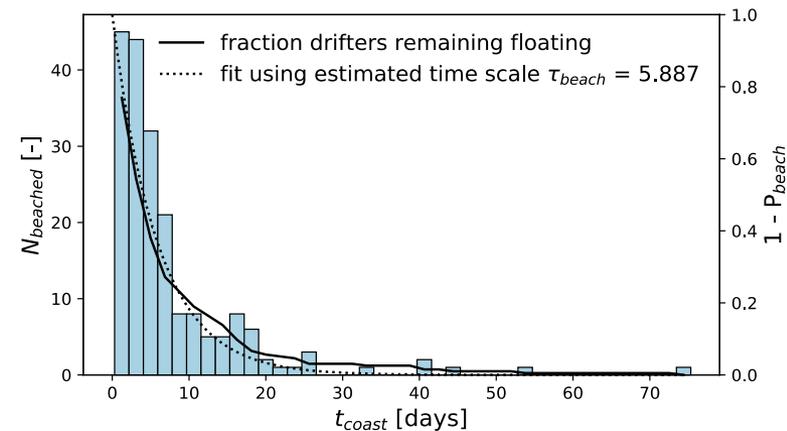
Full parameter set
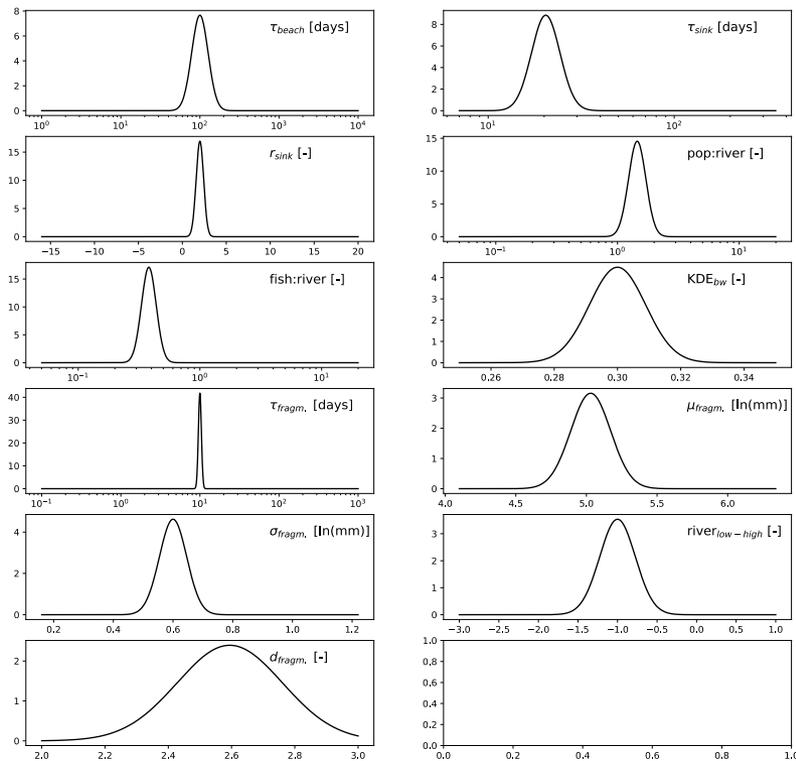
Beaching of plastics

- Numerical grid:
  $1/16°$ ($\pm 7\ km$)

- Coastal cells?

  - simplistic assumption of a constant beaching probability

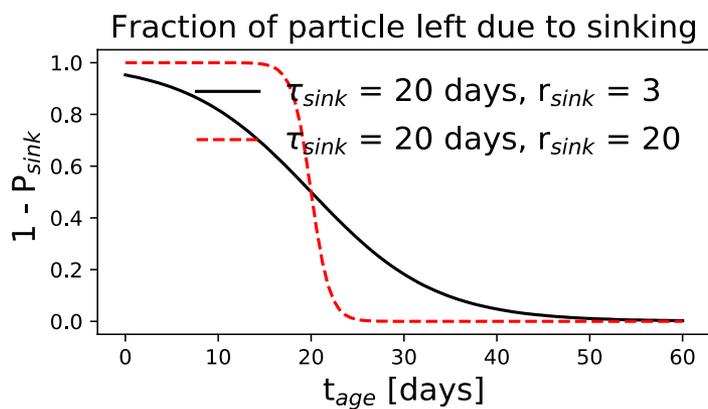Fraction of particle left due to beaching

$$1 - P_{beach} = e^{-t_{coast}/\tau_{beach}}$$

195 drifter buoys, OGS Mediterranean Drifter Dataset

Source:
Sebille et al. (2019)

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Biofouling/sinking

- Fazey and Ryan (2016)

Fraction of particle left due to sinking

$\tau_{sink} = 20$ days, $r_{sink} = 3$

$\tau_{sink} = 20$ days, $r_{sink} = 20$

$$1 - P_{sink} = \frac{1}{1 + e^{r_{sink}/\tau_{sink}*(t_{age}-\tau_{sink})}}$$

2-12 weeks
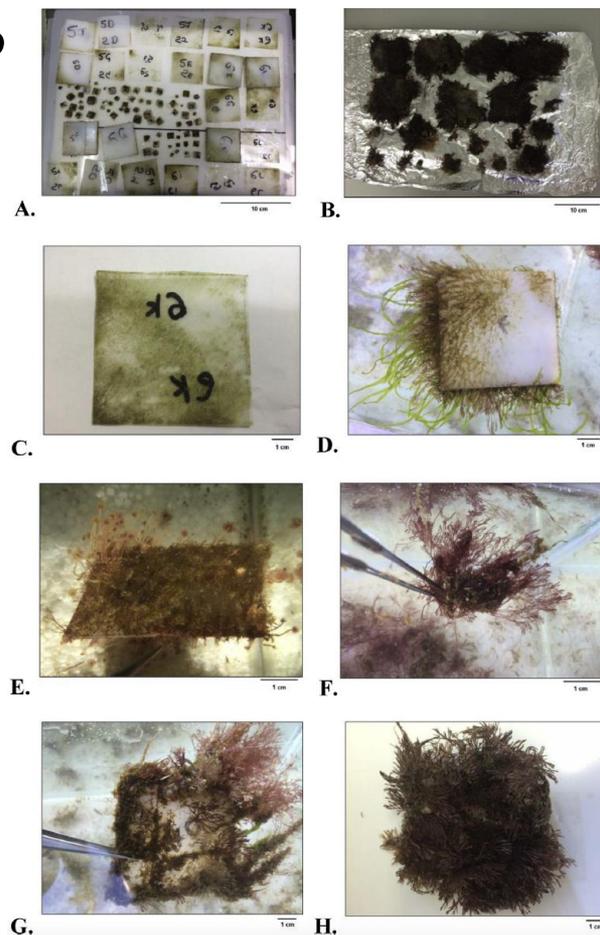
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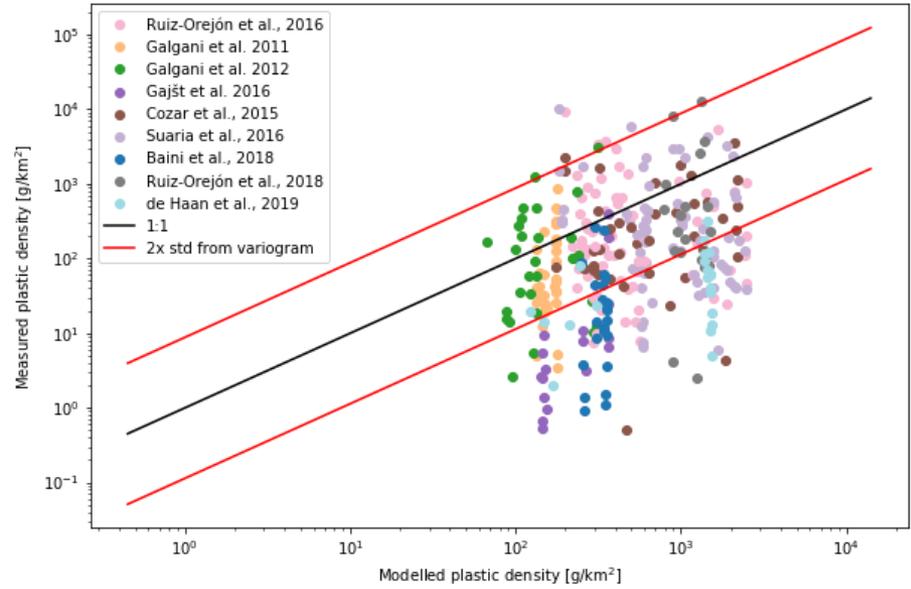
Measured vs. modelled plastic densities, R: 0.269917
percentage within 2σ: 74.9
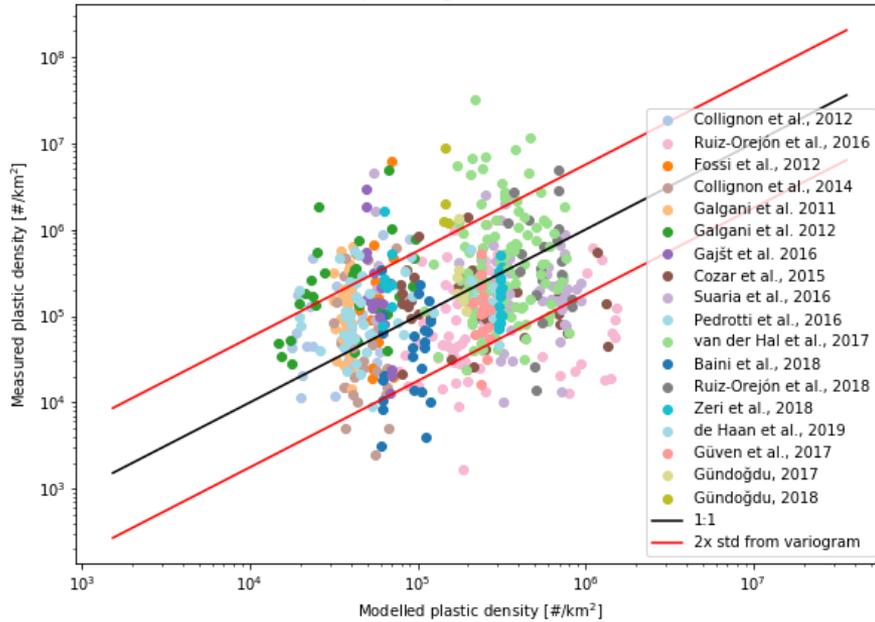
Measured vs. modelled plastic densities, R: 0.239787
percentage within 2σ: 61.6

Modelled vs. measured size abundances, RMSE: 0.311642