Observations requirements for marine litter concentration characterization in the Mediterranean Sea.

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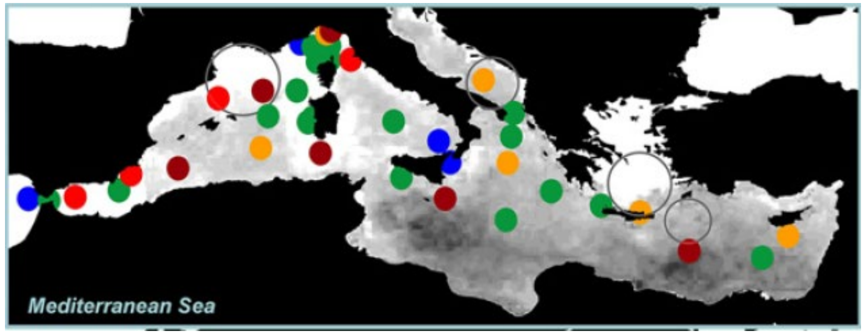
How we characterize the spatial distribution and variability of the marine litter concentration at basin scale

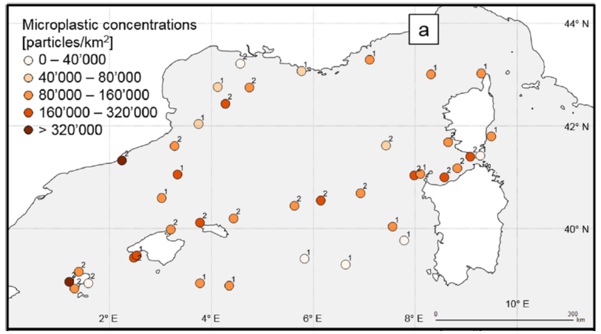
Observations

- Expensive. Need many resources.
- Spatial coverage very limited.
- Observations concentrated near the coast, mainly in enriched countries.
- Usually carried out in spring – summer periods

Marine litter observations



Cozar et al. *PLOS ONE* (2015)
Sampling period: May 2013, July 9th – August 6th 2010, July 2012 and 2013.



Faure et al. *Environ Sci Poll Res* (2015)
Sampling period: August – September 2011.

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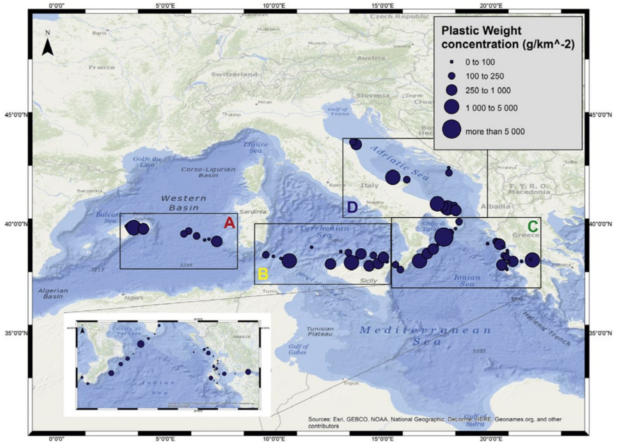
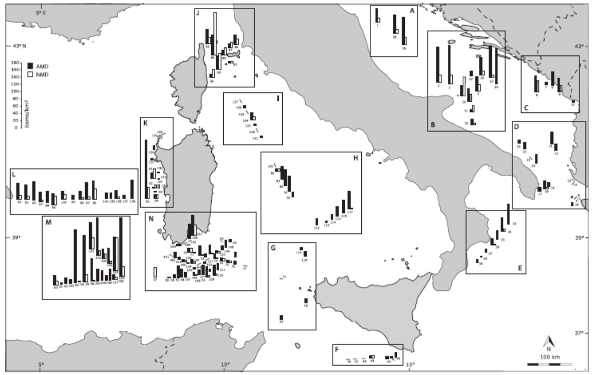
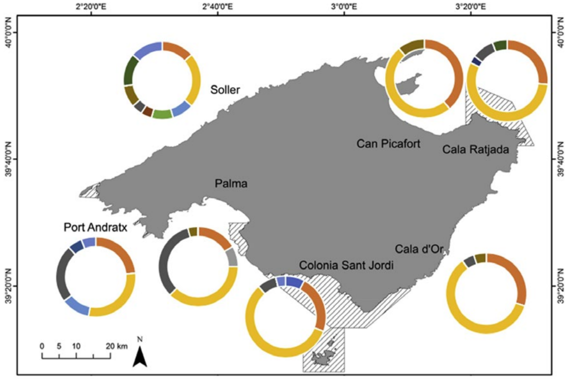


Ruiz-Orejón et al. *Mar Environ Res* (2016)
Sampling period: May – July 2012, April – June 2013



Suaria and Aliani *Mar Poll Bull* (2014)
Sampling period: May – October 2013



Compa et al. *Mar Environ Res* (2020)
Sampling period: July - September 2017

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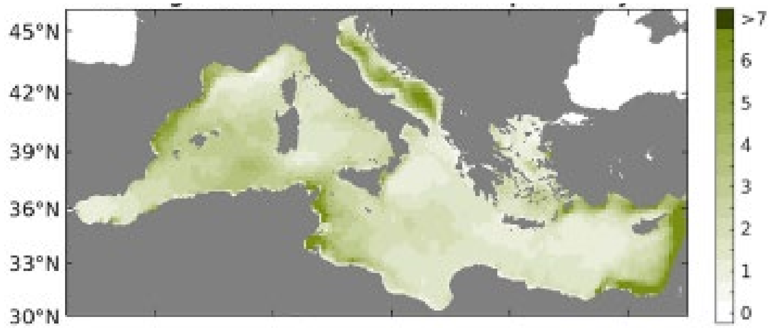
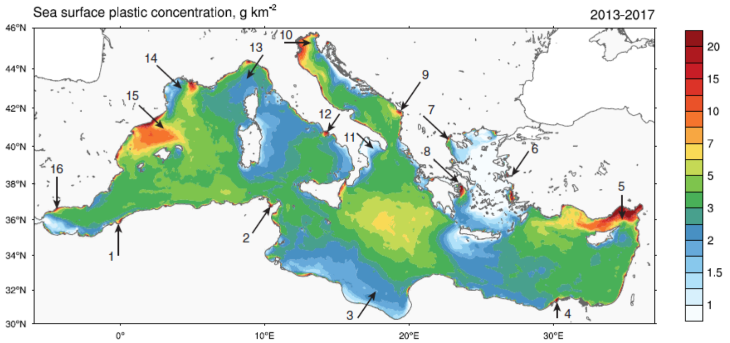
Numerical modelling

- Low accuracy of the models.
- Strong discrepancies depending on the model set-up.
- Large uncertainties in the initial conditions (ML sources).
- Unable to resolve all the processes involved in the ML transport.
- Cannot be validated with the available observations at basin scale.

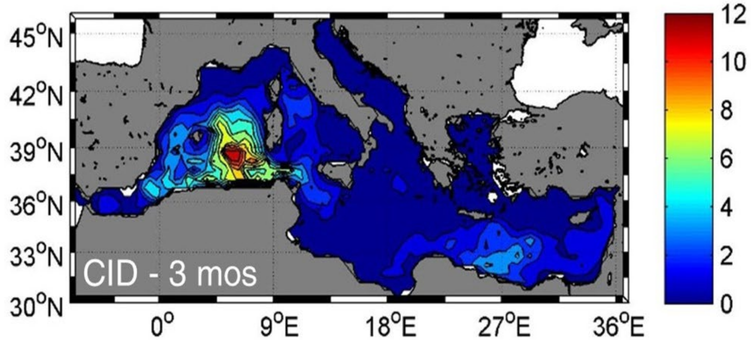
Marine litter modelling



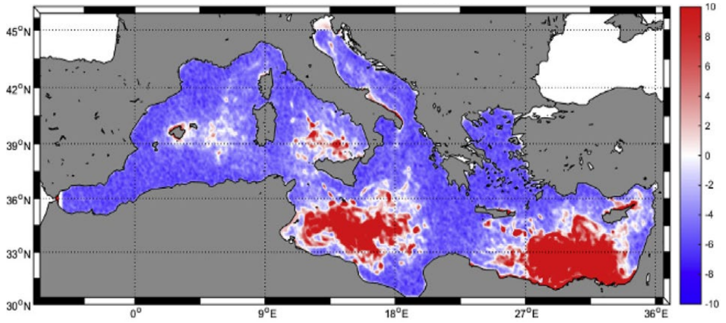
Soto-Navarro et al. *Mar Pol Bull* (2020)



Liubartseva et al. *Mar Poll Bull* (2018)



Zambianchi et al. *Frontiers Env Sci* (2017)



Macias et al. *Mar Poll Bull* (2019)

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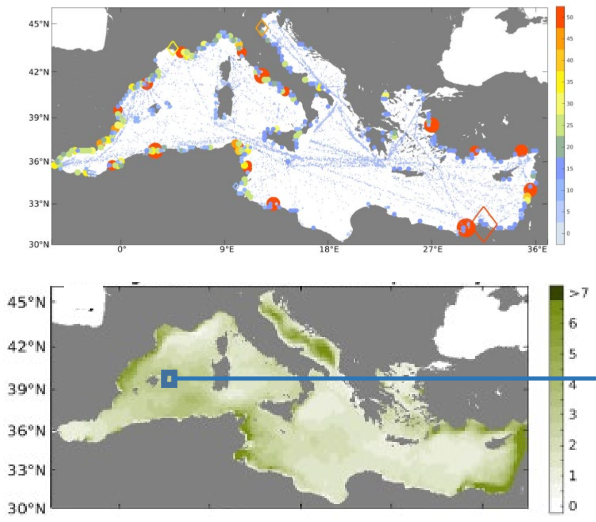
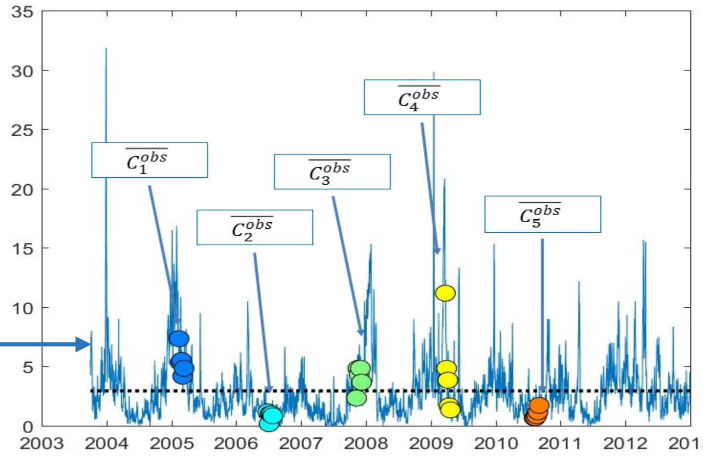
Given the complexity and limited resources, how could we optimize the ML sampling to capture the average ML concentration, its spatial patterns and to be able to validate numerical simulations?

Synthetic reality based on numerical simulations

Monte Carlo simulations of ML temporal sampling



Soto-Navarro et al. *Mar Pol Bull* (2020)



Ex.: Daily samples over 7 days periods

- 10 years of ML concentration at 25x25 km
- At each grid point, we extract the time series *c(t)*
- We randomly select values at a certain sampling interval *Δt*, during a given observational period *T*
- $C_{obs}(t_1, \dots t_n) \rightarrow \overline{C_{obs}} = \frac{1}{N}\sum_{k=1}^{N} C_{obs}(t_k)$

$$\overline{C_{true}} = \frac{1}{N}\sum C(t)$$

- The process is repeated N_{MC} times (500)
- The spread of the ensemble is considered the error of estimated the mean concentration for *Δt* and *T*
- $Eps\{\Delta t, T\} = \frac{1}{N}\sum N_{MC}\left(\overline{C_{obs}} - \overline{C_{true}}\right)^2$

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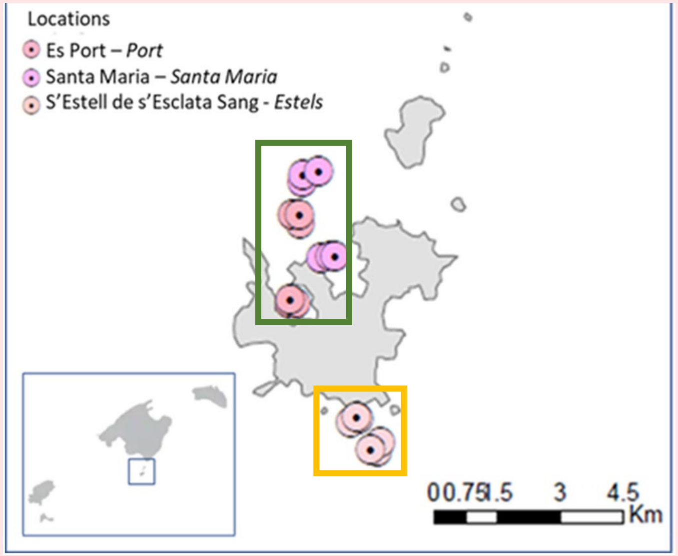
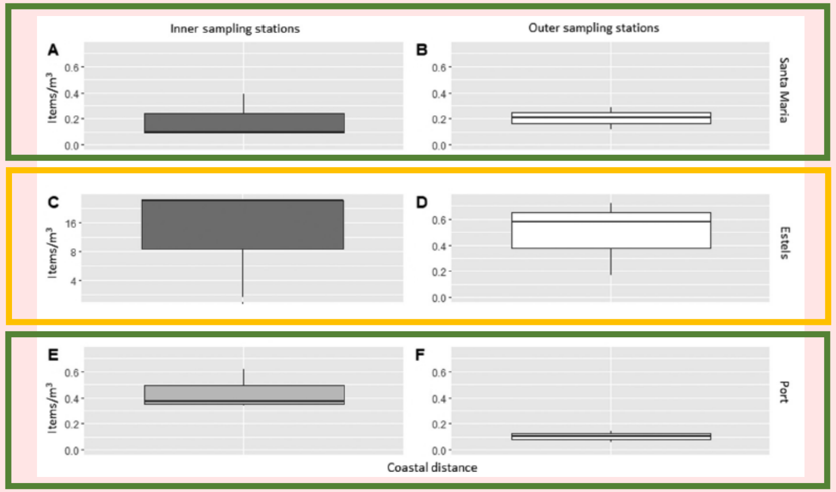
Given the complexity and limited resources, how could we optimize the ML sampling to capture th… …lidate

Limitations of the methodology

- The concentration in the simulations is estimated in pixels of 25 x 25 km.
- We assume homogeneity over the pixels.
- Studies show that the ML concentration can present a very strong spatial variability.

Concentrations in **yellow area 10 times higher than in green area**, separated 3 km.





Fagiano et al. *Sci. Tot. Envirn.* 2022

Synthetic rea…
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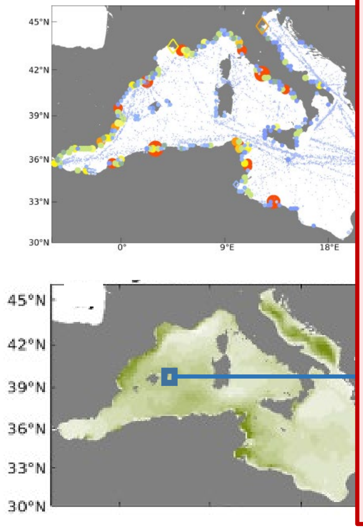

Soto-Navarro et al. *Mar Pol Bull* (2020)

…tion at 25x25 km

…t the time series *c(t)*

…t a certain sampling

…servational period *T*

$\sum_{k=1}^{N} C_{obs}(t_k)$

$\sum C(t)$

…times (500)

…is considered the

…concentration for

$- C_{true})^2$

Ex.: Daily samples over 7 days periods

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Errors in the temporal sampling

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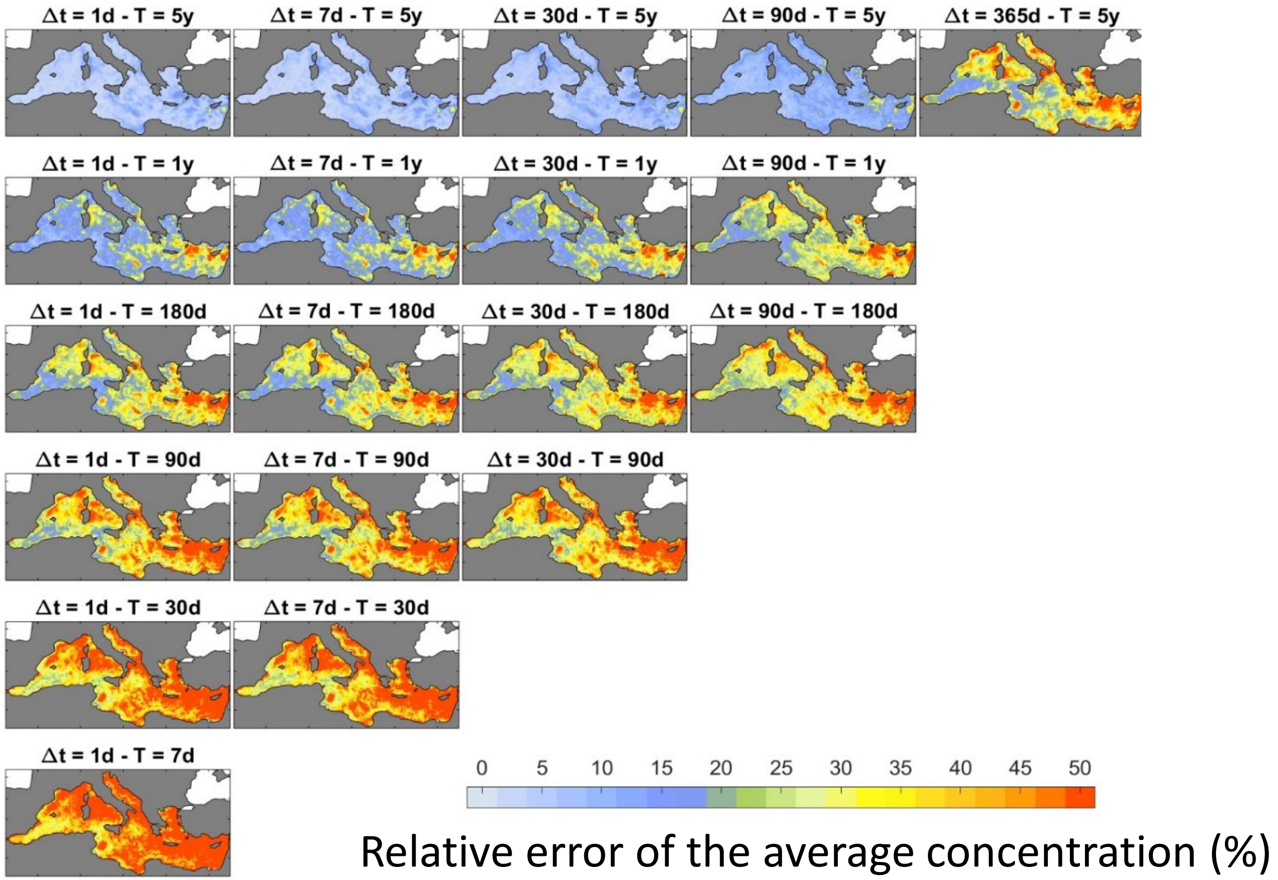
Period T (days)	Frequency Δt (days)	Number of Observations	Mean Relative Error (%)	Spatial STD of the Mean Relative Error (%)
1825 (5 years)	1	1825	5,5	4,8
	7	261	6,2	11,7
	30	61	8,9	29,0
	90	20	14,0	55,7
	365	5	39,1	103,8
365	1	365	20,4	14,3
	7	52	21,4	24,4
	30	12	25,6	42,8
	90	4	33,1	104,8
180	1	180	31,3	20,1
	7	26	32,6	38,7
	30	6	36,1	102,2
	90	2	43,4	187,4
90	1	90	41,1	25,7
	7	13	42,6	42,8
	30	3	46,9	133,8
	3	30	51,5	37,3
30	7	4	52,2	34,1
7	1	7	60,4	41,2



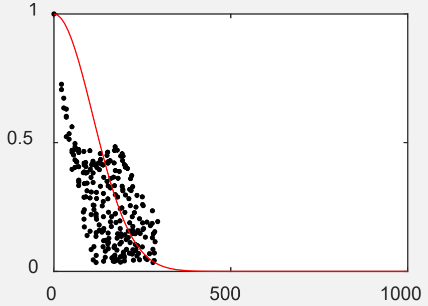
- Relative errors using the ‘typical’ sampling periods and frequencies (daily or weekly sampling over 7 - 90 days periods) are very high.
- For an error lower than 20%, at least one year sampling weekly, or 5 years sampling every 90 days.
- For a similar number of observations, it is always better to extend then observational period rather than to shorten the sampling interval.
- General larger errors in Adriatic, Levantine basin and North WMed. Lower at the Algerian basin and central WMed.

Errors in the spatial sampling

Estimation of the correlation length to estimate the spatial sampling errors

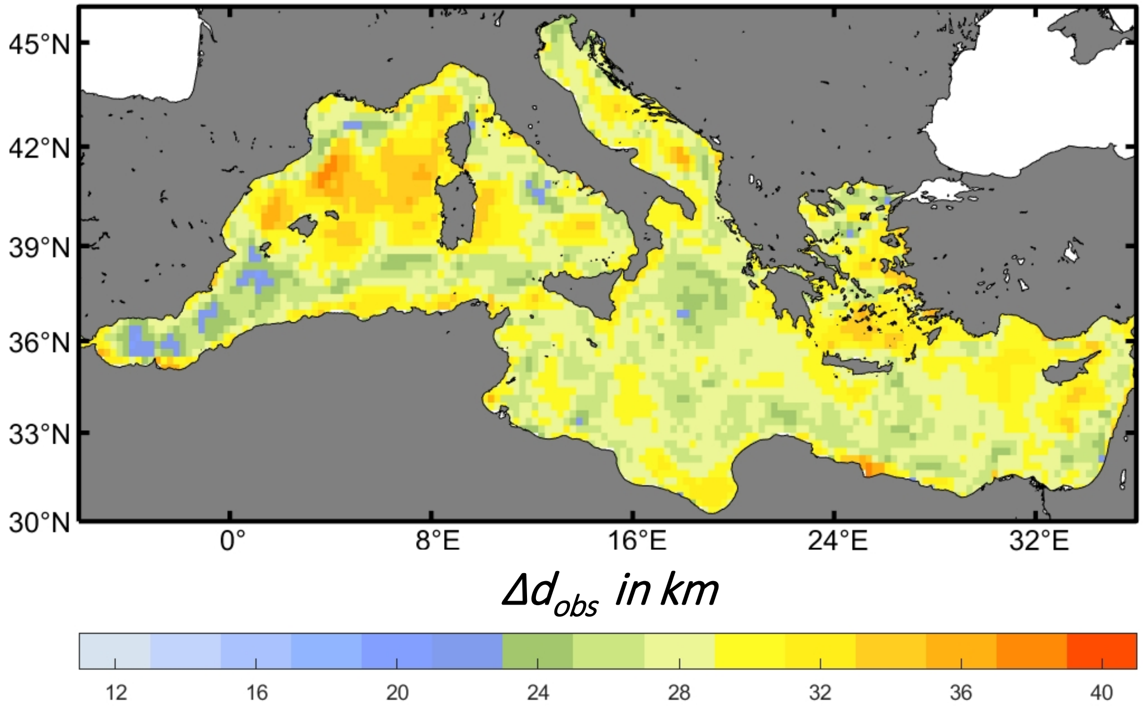
- $L_{corr}(x_k) \rightarrow$ computing the temporal correlation of the concentration at point k with all the other points of the domain (ρ_{kj}).
- Fitting of a Gaussian function defined as:

$$\rho = e^{\left(-L^2/2L_{corr}\right)}$$



- The spatial resolution required for the observational grid is computed as:

$$\Delta d_{obs} = L_{corr}/4$$



- Locations where the sampling should be denser are the Alboran Sea and parts of the WMed $\rightarrow$ Δd_{obs} below **25 km**.
- In the NW Med, N of Crete and in isolated spots in the Adriatic Sea and the Egyptian coasts, Δd_{obs} increases up to **40 km.**
- These patterns are probably linked to **hydrodynamic provinces**. ML concentrations are expected to be coherent within each province

Summary and Conclusions

The available ML observations are insufficient for a good characterization at basin scale

We provide an initial assessment of the required sampling frequency to obtain accurate estimates of the mean ML concentration

We use a synthetic reality based on realistic high resolution numerical simulations of ML dispersion in the Mediterranean Sea

- Monte Carlo simulation of temporal sampling at different frequencies and periods
- Length of correlation to compute the spatial resolution needed for the observations.

For the same number of observations
↓
Same observational effort

Better to maintain long observational records rather than to intensify the sampling

The required spatial density of the sampling depends on the characteristic correlation length scale.

Regions where the ML concentration structures are larger would require less dense observational samplings.