Methodology used by Oceaneye to harmonize its marine microplastics data set

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1. Introduction

Oceaneye has a data set on micro- and mesoplastic surface pollution composed of 764 net tow samples from various regions in the world. 670 samples were taken in marine environment and 94 samples in fresh waters. There are mainly two obstacles to the development of such a data set:

- The sampling:
  In order to have samples from various regions of the world, Oceaneye collaborates with volunteer sailors. More information about the sampling methodology can be found at: https://www.oceaneye.ch/wp-content/uploads/methodology_data_oceaneye_final.pdf

- The sample analysis:
  Oceaneye is a small association with limited resources and a large number of samples to analyze. In order to be able to process them all, it was decided to give up on the analysis of the "small microplastics" of dimensions lower than 1.0 mm (defined by sieving diameter). Indeed, as described by some authors (Isobe et al. 2019, Michida et al. 2019), this smallest fraction of microplastic sample represents the biggest workload of the analysis and also the largest risk of errors. In order to propose a harmonized data set comparable to the used standards, Oceaneye developed an empirical model to estimate the fraction of small microplastics (0.33 mm – 1.0 mm). This model is only applicable to the marine environment (not to fresh waters).

The table below shows the status of Oceaneye's data:

Years	Number of samples	Microplastics		Mesoplastics
2011 - 2013	103	0.33 – 5.0 mm		> 5.0 mm
2014	63	0.33 – 1.0 mm	1.0 – 5.0 mm	> 5.0 mm
2015 - 2020	504	Estimation model	1.0 – 5.0 mm	> 5.0 mm
Future	Much more	Estimation model	1.0 – 5.0 mm	> 5.0 mm

2. Reflections carried out to build an estimation model

Over time, the following reflections have emerged in our association:

1. It is more interesting to work on mass concentration than number concentration to carry out mass balances.
2. Small microplastics (< 1 mm) represent a limited fraction of the microplastic mass concentration.
3. Small particles are difficult to analyze. Their analysis is time-consuming and a main source of errors (Isobe et al. 2019, Michida et al. 2019).
4. Small (< 1.0 mm) and large (>= 1.0 mm) microplastics undergo the same transport mechanisms (Van Sebille et al. 2020) with potentially different amplitudes. There should be a correlation between the concentration of all microplastics (0.33 – 5.0 mm) and large microplastics (1.0 to 5.0 mm).
5. A lot of other parameters intervene in the evaluation of microplastic concentration, particularly wind mixing effect (Kukulka et al. 2012, Reisser et al. 2015, Enders et al. 2015) has a huge impact.
    a. According to Kukulka, the environmental factors defining the amplitude of the wind mixing effect are wind speed (u_{10}) and significant wave height (H_s). Not having the H_s value for most of the data, Kukulka proposes to obtain it from u_{10} under the assumption that fully developed sea conditions are reached. The parameter defining the level of water agitation is therefore u_{10}.
    b. The parameter defining the sensitivity of particles to this wind mixing effect is the rise speed. However, the rise speed of particles depends on various parameters, including their size (Reisser et al. 2015).

Thus, it would seem logical that, statistically, the larger u_{10} is, the smaller the ratio $C_{<1}/C_{micro}$ becomes. The model is based on this observation.

3. The model

Data from 2014 were imported into the mathematical program Scilab for the implementation of this model. Two approaches are proposed here: first, a linear least squares interpolation which will be used as a reference, and second, an empirical model taking into account the effect of wind (u_{10}). In order to evaluate their relevance, we also propose an evaluation of the average error of these models.

3.1 Model evaluation criteria

In order to evaluate a model, we use here the global error according to the following relations.

Let be a model for the evaluation of the microplastic concentration f, so that:

$$C_{micro} = f(C_{>1})$$

Where C_{micro} is the total microplastic concentration (0.33 – 5.0 mm)
And $C_{>1}$ is the concentration of large microplastics (1.0 – 5.0 mm)

The global error ε of the model f is defined by

$$\varepsilon = \frac{\sum_{i=1}^{N} |\varepsilon_i|}{N}$$

Where ε_i is the local error of the net tow I defined by the relation:

$$\varepsilon_i = \frac{C_{micro_{mes}}(i) - C_{micro_{model}}(i)}{C_{micro_{mes}}(i)}$$

Where $C_{micro\_mes}(i)$ is the microplastic concentration measured at the net tow i
$C_{micro\_model}(i)$ is the microplastic concentration calculated with the model at the net tow i

3.2 Linear interpolation using the least squares method

Model: $C_{micro} = a*C_{>1} + b$
Interpolation method: least squares

Parameters and errors obtained:

	a	b	ε [%]
Mass concentrations	1.079	2,893	24%
Number concentrations	4.082	-1,510	39%

3.3 Model with effect of wind

Model: $C_{micro} = C_{>1}{}^{a} / (b*u_{10} + c)$
Interpolation method: Iterative least squares
How to solve: Define the variable y so that:
$y = C_{>1}{}^{a} / C_{micro}$
Iterate on parameter a and solve the following relation with least squares:
$y = b*u_{10} + c$
to minimize the average error

Parameters and errors obtained:

	a	b	c	ε [%]
Mass concentrations	0.90	0.00410	0.2634	12%
Number concentrations	0.59	0.000300	0.00331	28%

4. Results

The results show that the average error is reduced by a factor 2 for the mass concentrations compared to a classical least squares interpolation. The error in the numerical concentrations of the model is also reduced but less significantly (factor 1.4).

The results depend on the quality of the data set. The figures below show the differences between the measurements and the model in the form of graphs and maps. Note the logarithmic color scale (base 2) in the maps.

5. Conclusions

Avoiding the analysis of the 0.33 to 1.00 mm fraction is a major gain of time. The proposed model could be an alternative for the evaluation of this fraction by a lab analysis and produces a limited error. This model seems particularly relevant for the evaluation of mass concentrations. Further efforts should be considered for:

- The development of a model based on analytical relationships with a physical meaning (not empiricism). This could be based on the work of Reisser et al. 2015 (paragraph 3.5. Model of vertical particle distribution), for example.
- This model could be tested on other data sets.

The Scilab code is available upon request (in French).

Related publications

Faure F., Saini C., Potter G., Galgani F., de Alencastro LF, Hagmann P. *An evaluation of surface micro- and mesoplastic pollution in pelagic ecosystems of the Western Mediterranean Sea*. Environ Sci Pollut Res Int. 2015 Aug; 22(16):12190-7. doi: 10.1007/s11356-015-4453-3. Epub 2015 Apr 19. PMID: 25893619

Michida Y. et al., 2019. *Guidelines for Harmonizing Ocean Surface Microplastic Monitoring Methods*. Ministry of the Environment Japan, 71 pp

Isobe A., Buenaventura N., Chastain S., Chavanich S., Cózar A., DeLorenzo M., Hagmann P., Hinata H., Kozlovskii N., Lusher A., Martí E., Michida Y., Mu J., Ohno M., Potter G., Ross P., Sagawa N., Shim W., Song Y., Zhang W. (2019). *An interlaboratory comparison exercise for the determination of microplastics in standard sample bottles*. Marine Pollution Bulletin, 146, 831-837. https://doi.org/10.1016/j.marpolbul.2019.07.033

Van Sebille E. et al. 2019. *The physical oceanography of the transport of floating marine debris*. Environ. Res. Lett. 15 (2020) 023003, https://doi.org/10.1088/1748-9326/ab6d7d

Kukulka T., Proskurowski G., Morét-Ferguson S. E., Meyer D. W. and Law K. L. 2012. *The effect of wind mixing on the vertical distribution of buoyant plastic debris.* Geophys. Res. Lett. 39 L07601

Reisser J., Slat B., Noble K., du Plessis K., Epp M., Proietti M., de Sonneville J., Becker T. and Pattiaratchi C. 2015. *The vertical distribution of buoyant plastics at sea: an observational study in the North Atlantic Gyre*. Biogeosciences 12 1249–5

Enders K., Lenz R., Stedmon C. A. and Nielsen T. G. 2015. *Abundance, size and polymer composition of marine microplastics 10 μm in the Atlantic Ocean and their modelled vertical distribution*. Mar. Pollut. Bull. 100 70–81

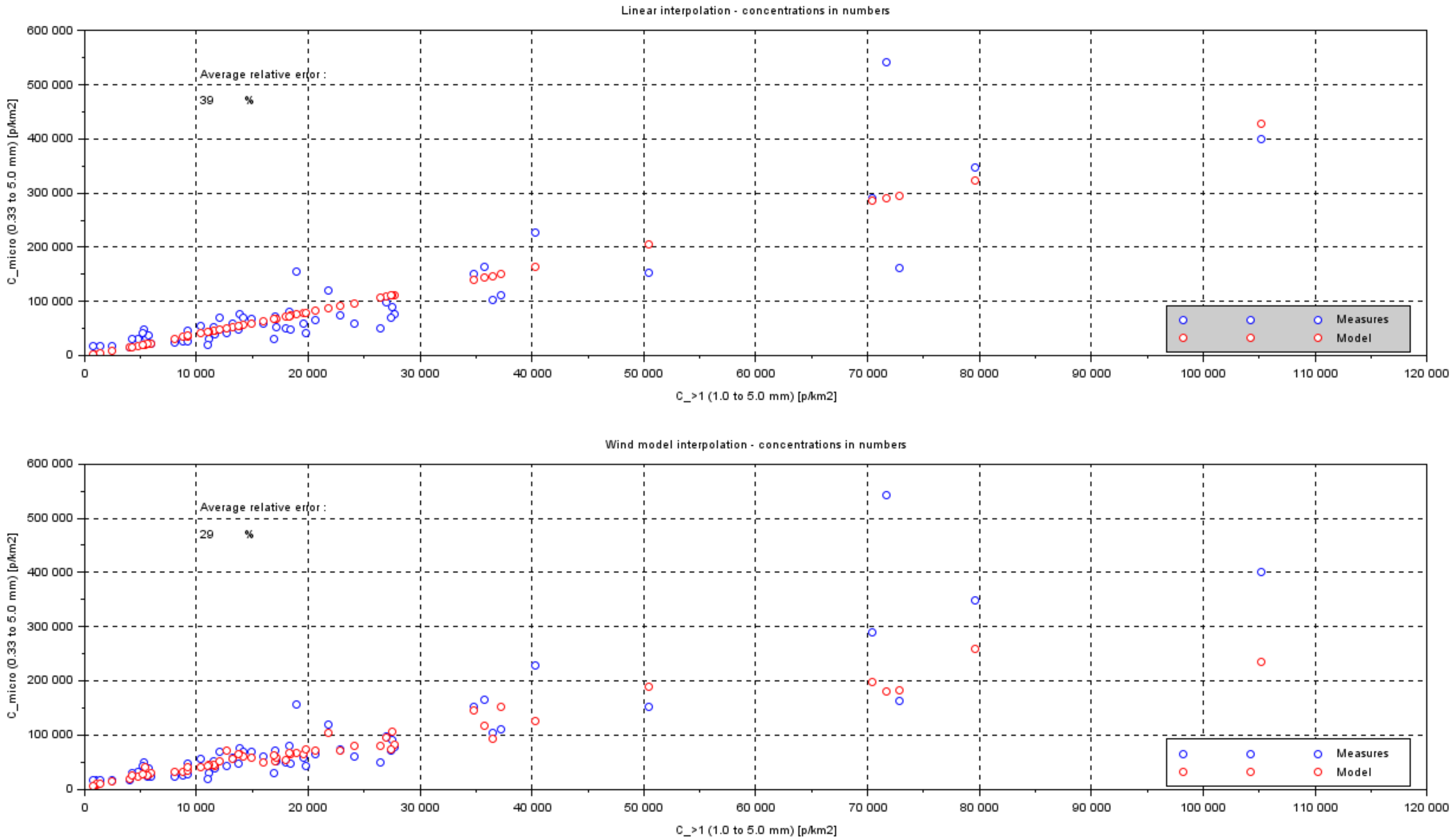


Figure 1. Results of the linear least squares interpolation model and the wind-based model for numerical concentrations (in blue the measurements and in red the model)

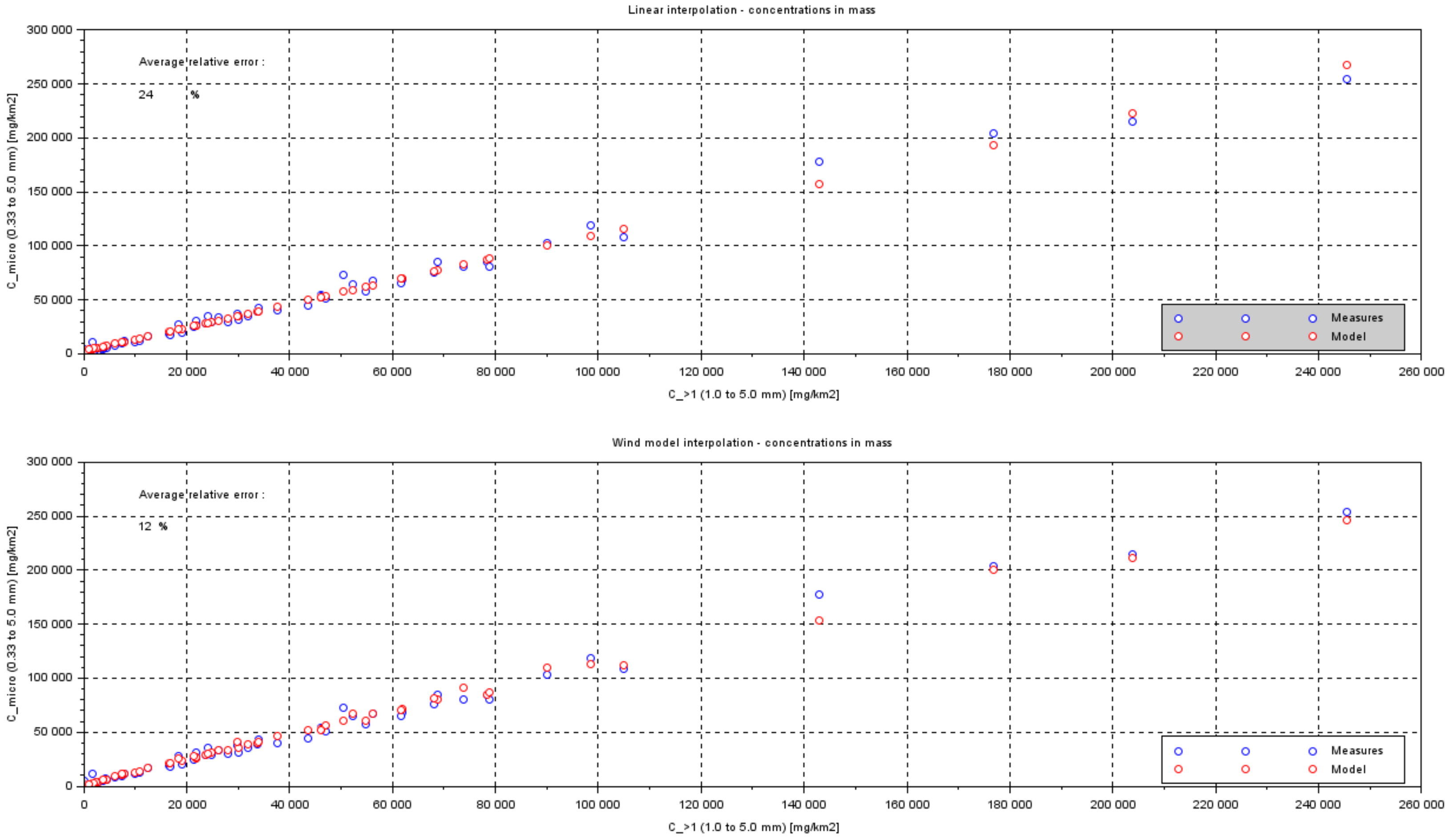
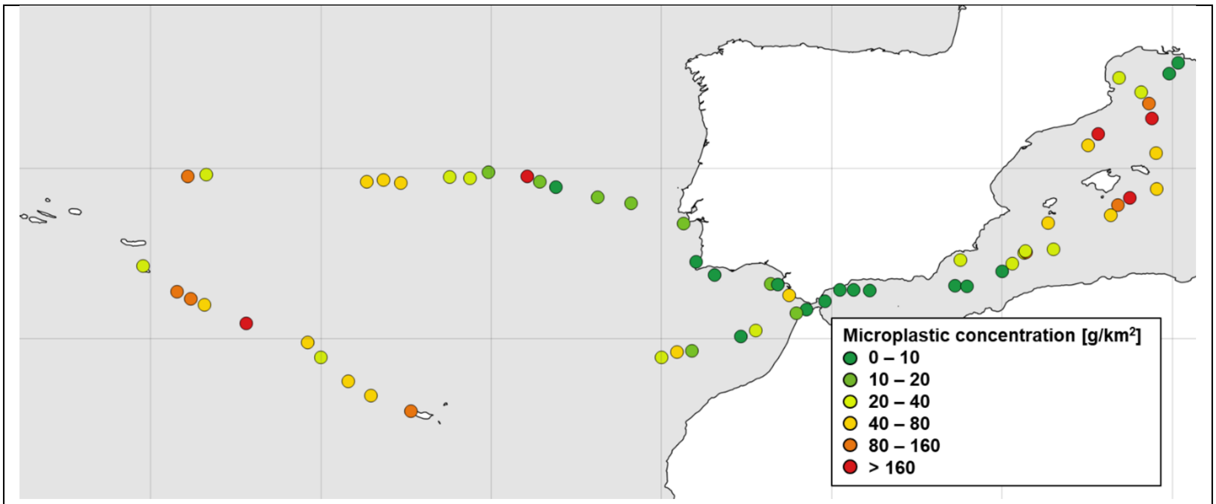
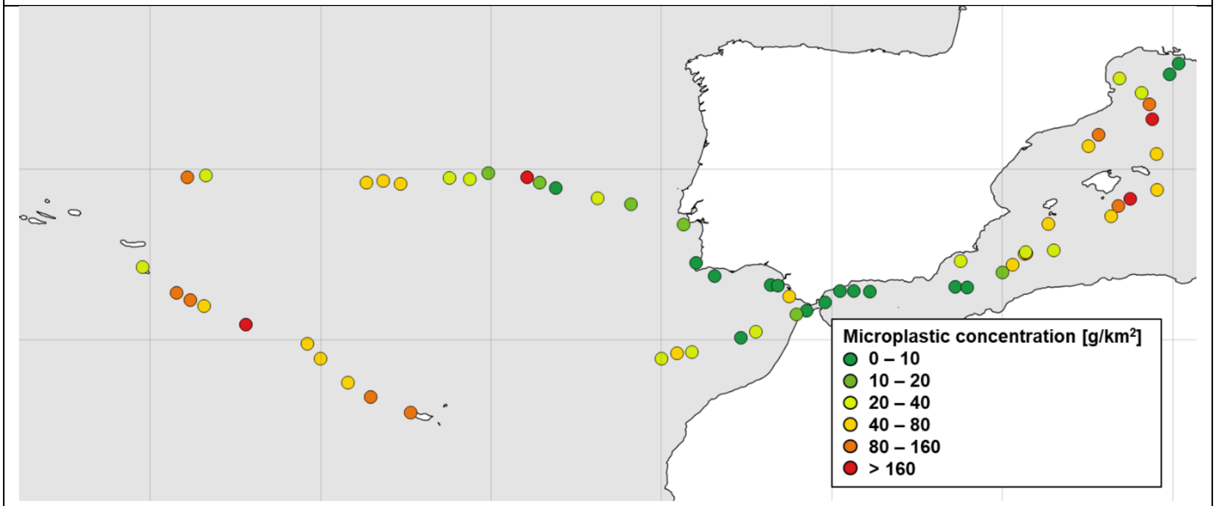


Figure 2. Results of the linear least squares interpolation model and the wind-based model for mass concentrations (in blue the measurements and in red the model)



Measurements



Model

Figure 3. Comparison of mass concentrations for the 52 samples (logarithmic color scale in base 2). Top: measurement results, bottom: model results.