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Development of a sea salt emission parameterization for the North-western Mediterranean

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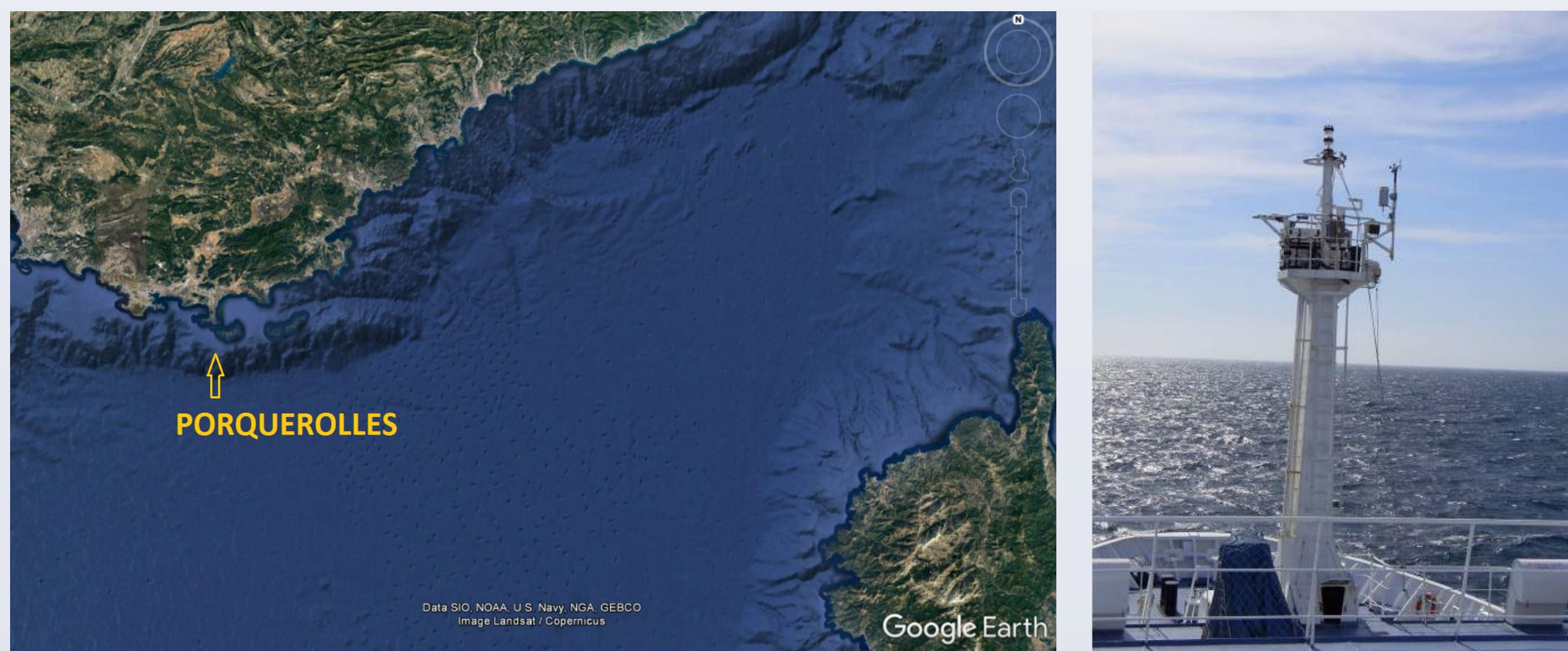
Introduction

The aim of the present work is to determinate an accurate formulation for the sea-spray source function issued from the bubble bursting processes. To this end, a simple aerosol transport Model, the Macmod Model (Tedeschi and Piazzola, 2011) was implemented in the Mediterranean area using different flux formulations for the sea spray source function (e.g., Demoisson et al., 2013; Gong et al., 2003; Monahan et al., 1986; Odvanevaite et al., 2014). The simulations were then compared to a large data set dealing with the aerosol size distributions acquired during an extensive series of measurements in the North-western Mediterranean. The results, which are part of an article that will be submitted soon, allowed determination of an accurate sea-spray source function formulation and its dependence on the wave development.

Material and Methods

Field site and instrumentation

The data set used in this present work is issued from the measurements of aerosol particle size distributions which took place on the island of Porquerolles (Fig.1) and on board of the ship Atalante during the Miramer campaign (Fig.2).



The aerosol data were acquired in the 0.1-45 μm size ranges using two particle measuring systems (PMS): one active scattering spectrometer probe (ASASP) and one classical scattering spectrometer probe (CSASP).

The MACMod model

The general governing equation for the number concentration of aerosols N at a given radius r , can be written as the budget equation:

$$\frac{\partial N}{\partial t} + (U \cdot \nabla)N = -\nabla \cdot \phi + S$$

where U is the air velocity, ϕ is the aerosol flux and S is the usual volume source-sink term accounting for condensation, evaporation, coagulation and nucleation.

According to Fairall and Davidson (1986), the vertical flux ϕ can be expressed as:

$$\phi = \overline{w'n'} - V_g X - D_m \frac{\partial N}{\partial z}$$

where w' and n' denote turbulent fluctuations, V_g is the gravitational settling velocity, D_m is the molecular diffusion coefficient and z is the height above the surface.

Sea-spray source function methods

The Mediterranean flux formulation

Using aerosol data acquired on the North-western Mediterranean, Demoisson et al. (2013) proposed a new formulation for the sea spray source function issued from the bubble bursting processes. This is based on the modification of the following Monahan et al. (1986) formulation:

$$\frac{dF}{dr_{80}} = W \tau^{-1} \frac{dE}{dr_{80}}$$

where W is the whitecap coverage fraction (e.g; Anguelova et Webster, 2006), τ is the time constant characterizing the whitecap decay.

The whitecap fraction is a modification of Lafon et al.(2007) model. The new $\frac{dE}{dr_{80}}$ established by Demoisson et al. (2013) by separating the Gaussian term of the Monahan et al. (1986) formulation into three Gaussian terms is expressed as:

$$\frac{dE}{dr_{80}} = 1,26 \times 10^6 r_{80}^{-3} \times (1 + 0,057 r_{80}^{1,05}) \times 10^{\sum_{i=1}^3 A_i \exp(-B_i r_{80}^2)}$$

With $A_1 = 4,5$; $A_2 = 0,408$; $A_3 = 0,931$

And $B_1 = \frac{-1,53 - \log(r_{80})}{0,55}$; $B_2 = \frac{-0,51 - \log(r_{80})}{0,57}$; $B_3 = \frac{-0,57 - \log(r_{80})}{0,52}$

The Odvanevaite et al. (2014) flux formulation

The S3F formulation by Odvanevaite et al. (2014) is based on the revisited dimensionless breaking wave parameter proposed by Zhao and Toba (2001) Re_{HW} . The S3F formulation is expressed as a combination of five lognormally distributed modes for different droplet sizes:

$$\frac{dF}{d \log D} = \sum_{i=1}^5 \frac{F_i(Re_{HW})}{\sqrt{2\pi} \ln \sigma_i} \exp\left(-\frac{1}{2} \left(\frac{\ln\left(\frac{D}{CMD_i}\right)}{\ln \sigma_i}\right)^2\right)$$

with $\frac{dF}{d \log D}$ is the size dependent SSA production flux, i is the mode number, $F_i(Re_{HW})$ is the flux for mode i , D is the dry particle diameter, σ is the geometrical standard deviation and CMD is the count median diameter.

Results and Discussion

The simulations presented in Fig.3 were made for a local wind speed of 9,8 m s^{-1} and for a particle radius of 5 μm using various S3F and compared to our experimental data. For each fetch, 20 experimental data at a minimum were used for our calculations:

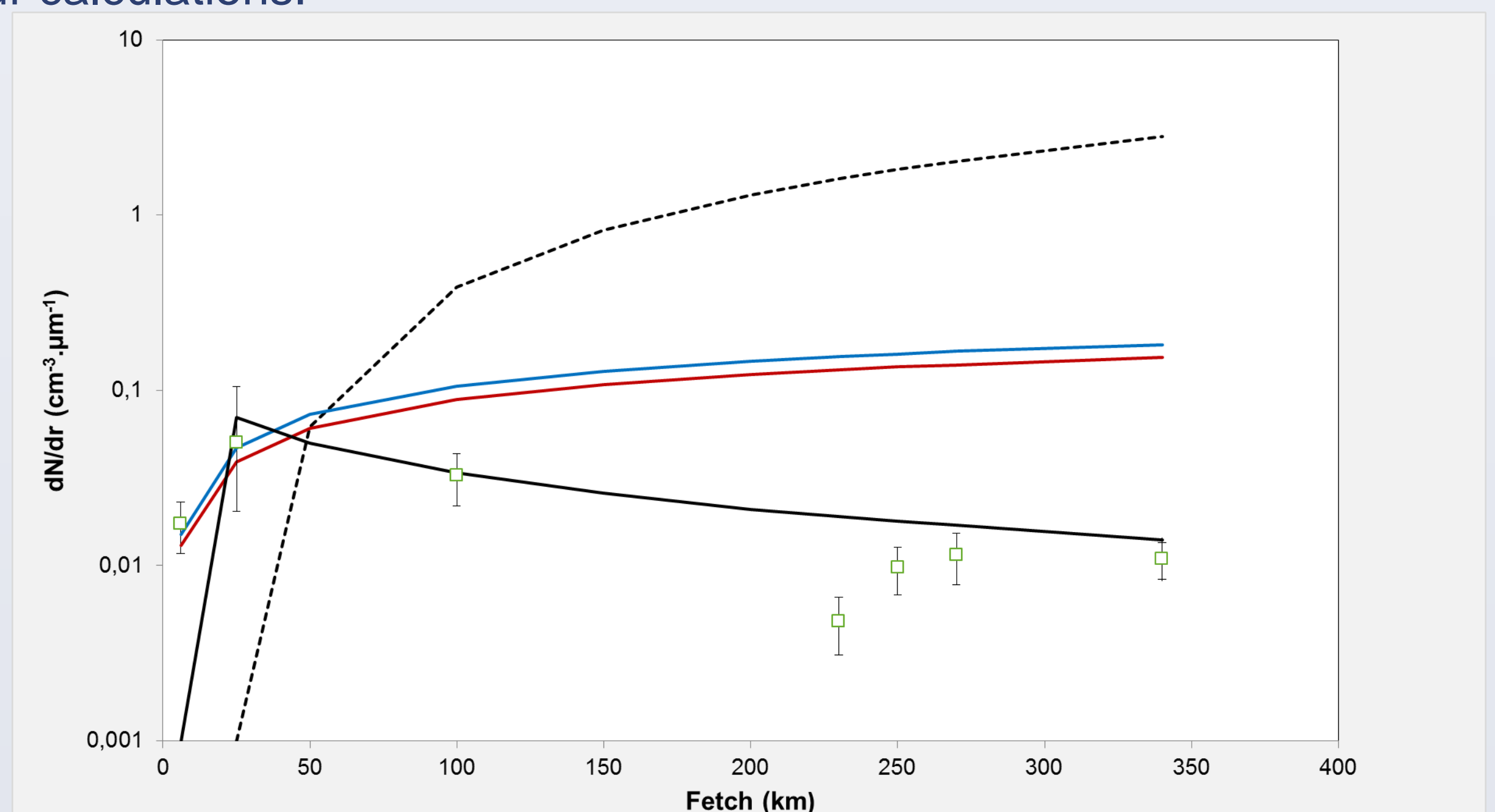


Fig. 3: Comparison between the simulations using the Monahan et al.(1986) model (the red line), the Gong et al.(2003) model (the blue line), the Odvanevaite et al.(2014) model (the dashed line), the Demoisson et al.(2016) model (black line) and the mean experimental aerosol concentration of the 5 μm particles (the squares with the standard deviation) for an averaged wind speed of 9,8 m s^{-1} and different fetches

The experimental results reported in Fig. 3 show a peak in the evolution of the sea-spray source function with respect to the fetch. At very short fetches, the sea-spray generation processes tend to increase with fetch whereas at large fetches, they slightly decrease with increasing fetch. This can be compared to the evolution of the whitecap fraction with the wave age as already noted by Lafon et al. (2004; 2007). The wave age is defined as the ratio between the wave phase velocity C_p and alternatively the wind speed U or the wind friction velocity U_* . We have therefore plotted in Fig. 4 the variation of the sea spray production versus the wave age which confirm the results previously plotted in Fig.3.

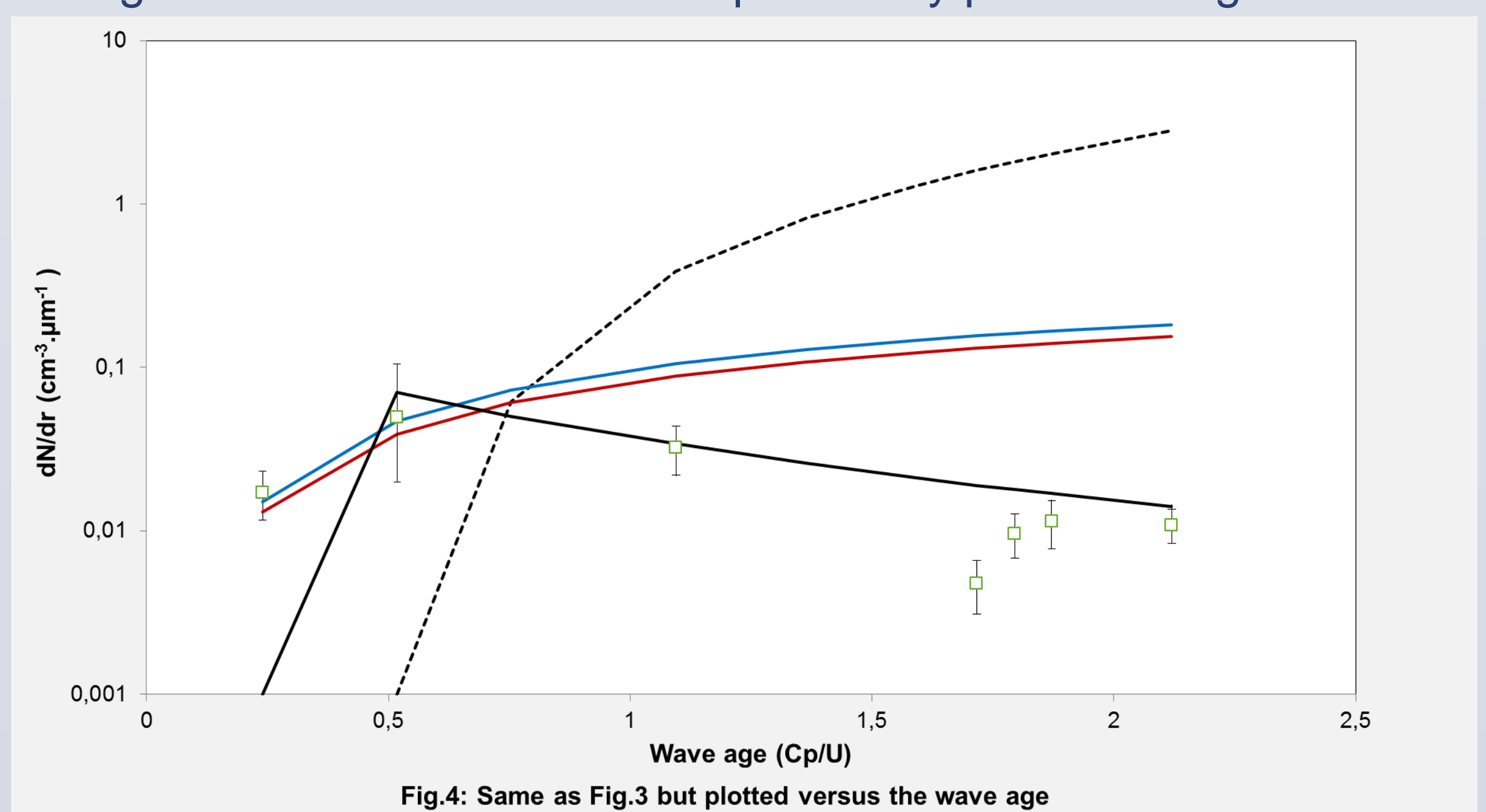


Fig.4: Same as Fig.3 but plotted versus the wave age

Conclusion

A sea-state dependent model for the sea-spray generation function has been implemented in the MACMod model and compared to experimental data acquired in the Mediterranean area. The simulations provide a relevant variation of the aerosol concentrations with the fetch evolution.

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