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Wind and Wave Dependent Sea Spray Generation Functions - From the



Laboratory to the Field



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1 MATE2019 Experiment (Luminy, Marseille)

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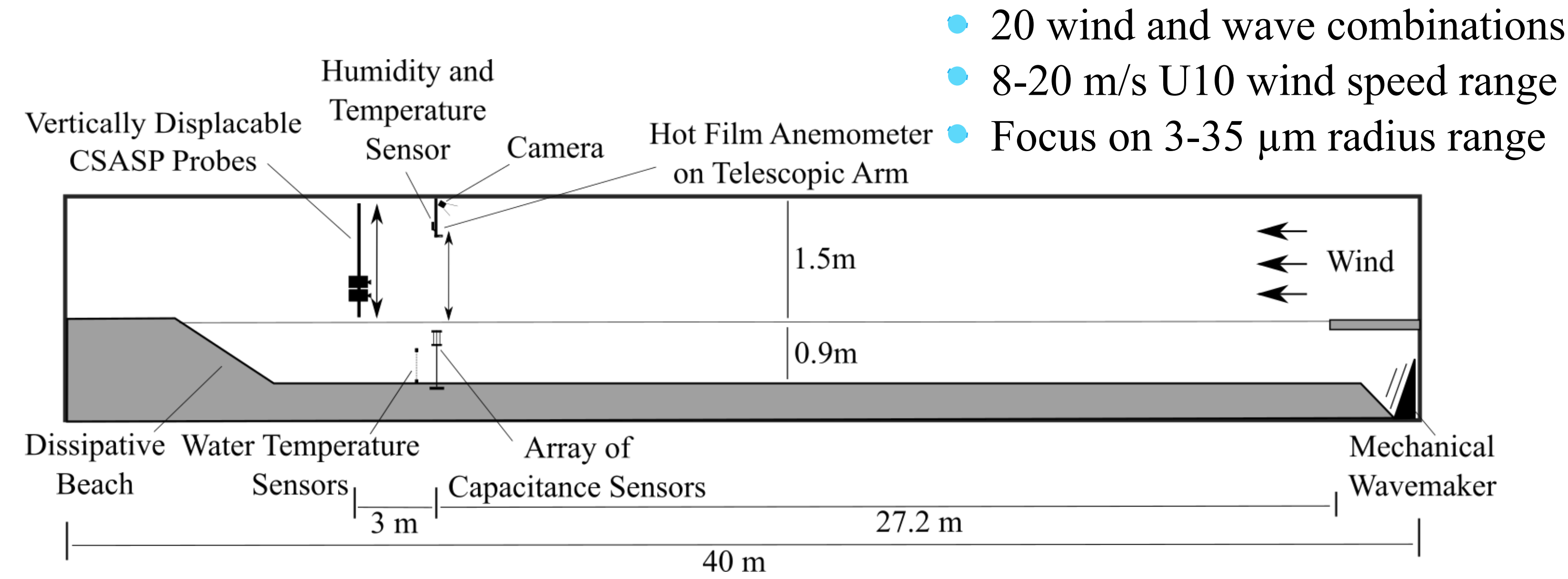


Figure : Experimental Configuration during MATE2019 at LASIF Wind-Wave (Bruch et al., 2021)

- 20 wind and wave combinations
- 8-20 m/s U10 wind speed range
- Focus on 3-35 μm radius range

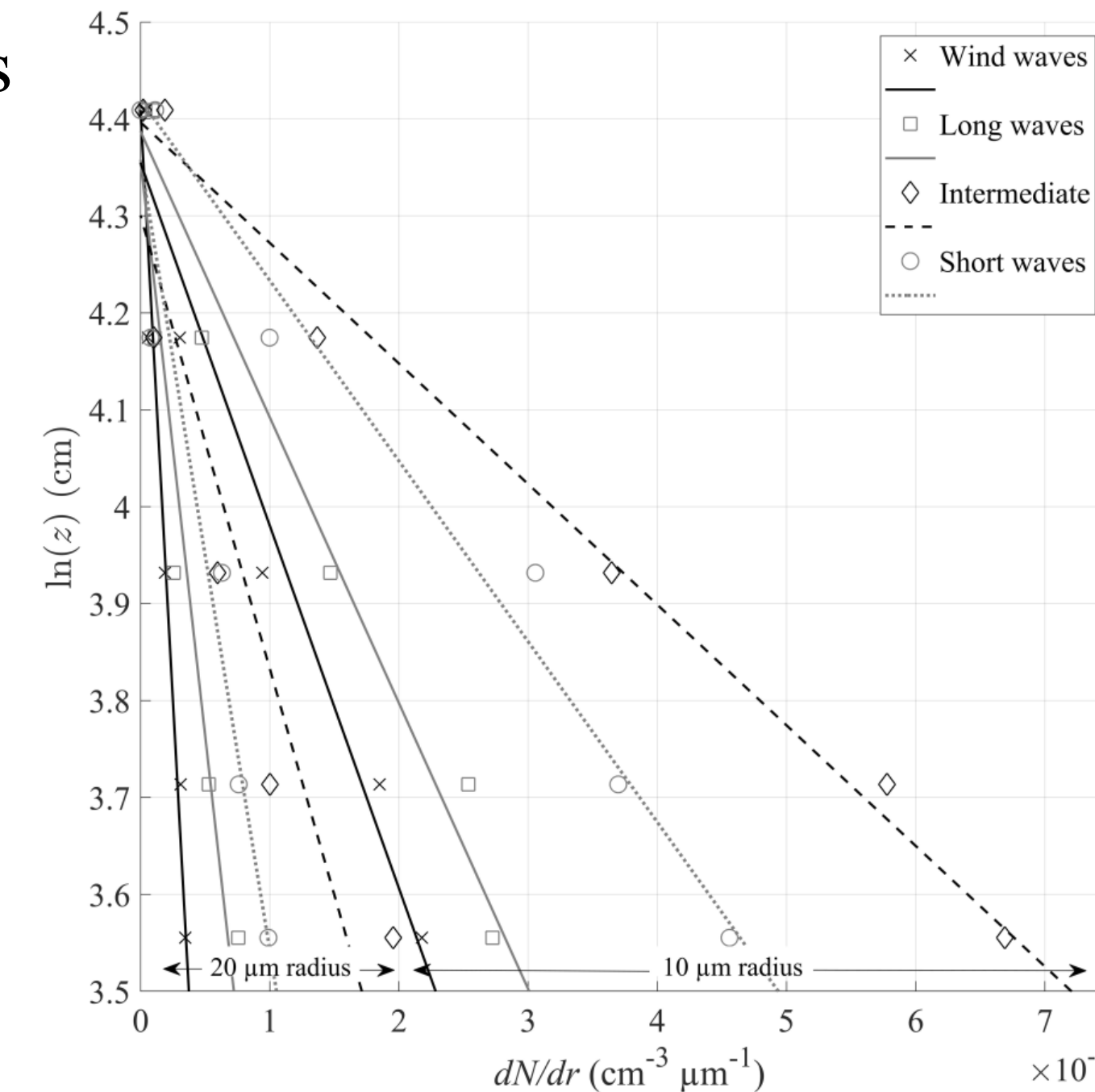


Figure : Logarithmic concentration profiles

With the selected wind speeds and the large dimensions of the tunnel, measured vertical profiles of wind speed and sea spray were found to be near-logarithmic, allowing to calculate the friction velocity u^* , and the sea spray generation flux using a flux-profile approach. Wave breaking processes are essential for the production of sea spray, and the whitecap coverage obtained in the tunnel from colour images was found to have very similar behaviour to the field.

2 Two New Source Functions

The laboratory wind & wave states were characterized using measured quantities and the calculation of known dimensionless numbers, such as the windsea Reynolds number $u_*^2/(v_a \omega_p)$ (denoted R_B), the wave age $\frac{c_p}{u_*}$ (with c_p the phase speed), whitecap coverage $W(\%)$, U10 wind speed (m/s) and wind friction velocity cubed u_*^3 . Wave measurements allowed to estimate the wave slope variance $\langle S^2 \rangle$. From the combination of $\frac{c_p}{u_*}$, $\langle S^2 \rangle$ and R_B , P_S was derived.

The sea spray generation flux was found to scale best with $\langle S^2 \rangle$ and $P_S = \frac{u_*^3}{v_a g} \langle S^2 \rangle$

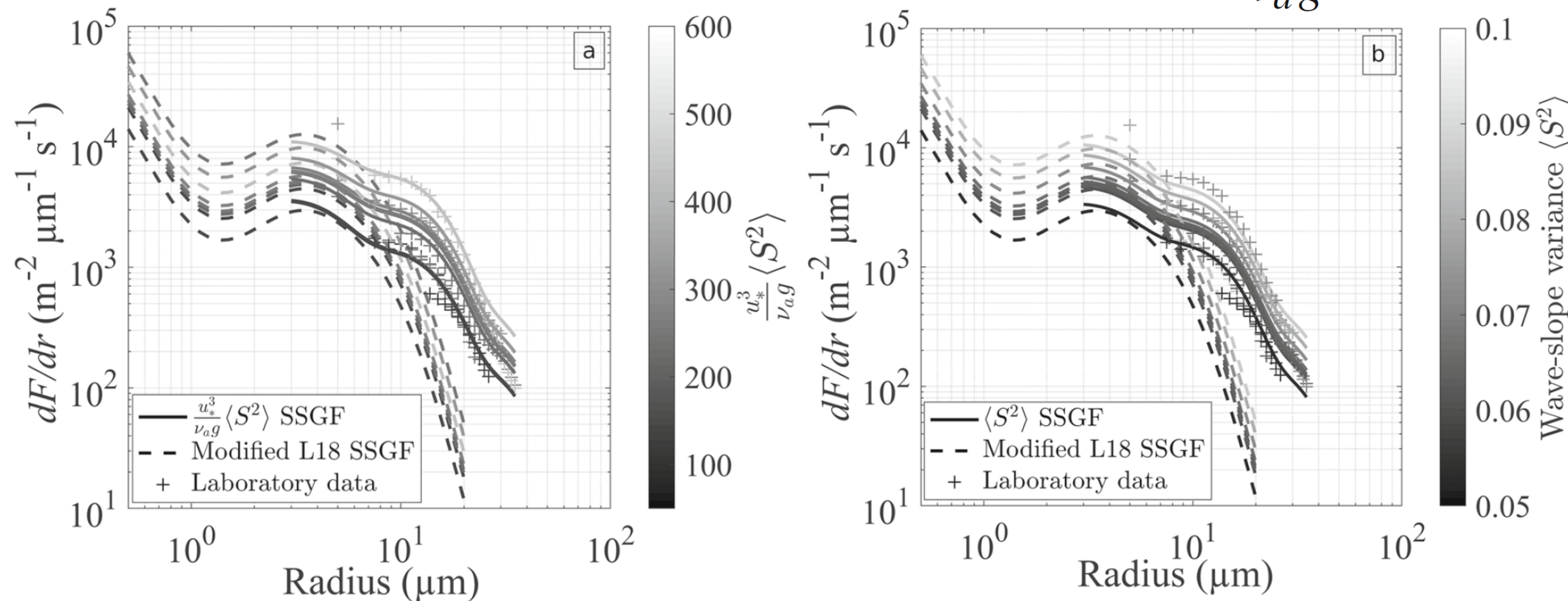


Figure : P_S and $\langle S^2 \rangle$ dependent SSGFs (Bruch et al., 2021)

The sea spray functions are computed as the sum of three gaussian distributions corresponding to three modal medians defined at 2.5, 7 and 25 μm radius,

$$\frac{dF_X}{dr_{80}} = \sum_{i=1}^n \frac{F_i(X)\tau^{-1}}{\sigma_i \sqrt{2\pi}} \exp\left(-\frac{1}{2}\left(\frac{r_{80} - \mu_i}{\sigma_i}\right)^2\right)$$

with μ the median radius, σ the standard deviation, and F the source function.

3 Mesoscale Transport Modelling

MesoNH is a non-hydrostatic atmospheric model developed by both the Laboratoire d'Aérodynamique (LA) and the Centre National de Recherches Météorologiques (CNRM). A number of sea spray generation formulations were implemented in the model, with the aim to validate existing SSGFs, as well as transport and aerosol dynamics equations (Slinn, 1980). $\langle S^2 \rangle$, necessary for both tunnel SSGFs is calculated using the Cox and Munk (1956) formulation.

Comparison between model outputs and the 2008 MIRAMER field campaign data (presented in Demoisson et al. 2013) collected in the North-West Mediterranean suggest that the OVA14 (Ovadnevaite et al. 2014) SSGF - which depends on a wave height dependent Reynolds number performs well for radii below 2 μm radius.

Promising results show that the laboratory SSGFs perform well, especially the P_S - dependent function allowing for better sensitivity to sea spray production at wind speeds below the laboratory wind speed range.

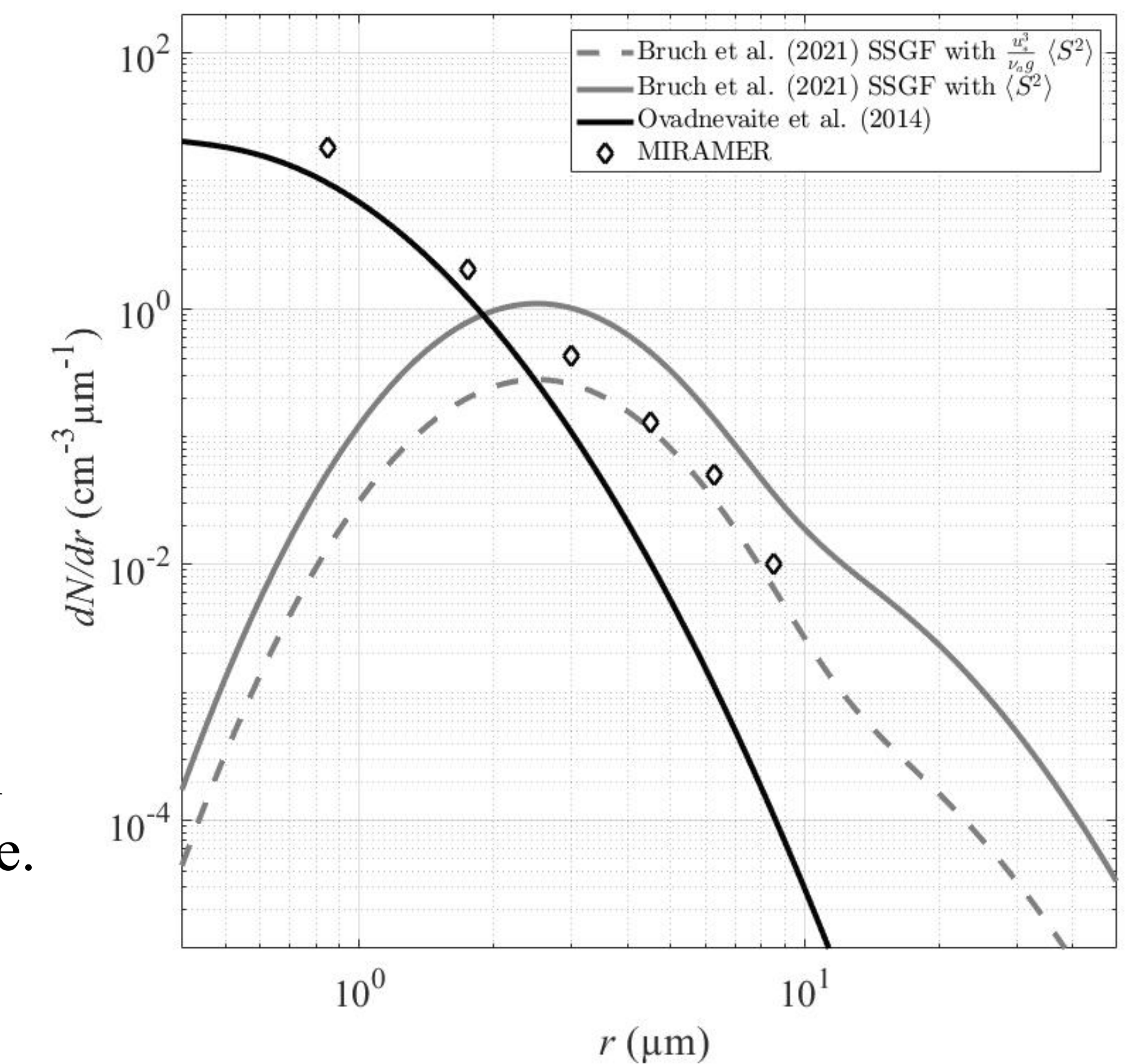


Figure : MesoNH model outputs on 21/05/2008 in 10 m/s winds

4 Take home messages

The deployment of wind, wave and sea spray instrumentation in the field is complicated by the often rough environmental conditions. Wind-wave laboratories are an interesting tool for the study of air-sea interactions, including sea spray aerosols as done in a number of recent studies (Fairall et al. 2009; Mehta et al. 2019). An important challenge is the upscaling of the results obtained in the laboratory to the field.

The presented modelling results indicate that the SSGFs obtained in the laboratory can successfully reproduce the jet and spume droplet production. The combination of the source functions proposed in Bruch et al. (2021) with that proposed in Ovadnevaite et al. (2014) allow to cover a large marine aerosol size range. Further study is required to ensure that the physical characteristics of the air-sea interface are correctly upscaled from the laboratory to the field.

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