Impact of fog microphysical properties on its radiative properties

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Context

Numerical weather prediction models have difficulty in correctly predicting the formation and dissipation of fog.

LW cooling and SW heating drive the life cycle of radiative fog .

- Radiative cooling of the surface by LW emission initiates radiative fog then LW radiation drives the fog development.
- At sunrise, SW radiation initiates the dissipation by evaporating the dew and the fog droplets at the surface.

Radiation-fog interactions are controlled by the optical properties of fog droplet's themselves driven by fog microphysics. There are several reasons why the radiative properties of fog can be poorly simulated:

- Wrong estimation of microphysical properties (e.g. LWC or droplets concentration).
- **Wrong estimation of optical properties (the latter being parameterized in atmospheric models).**

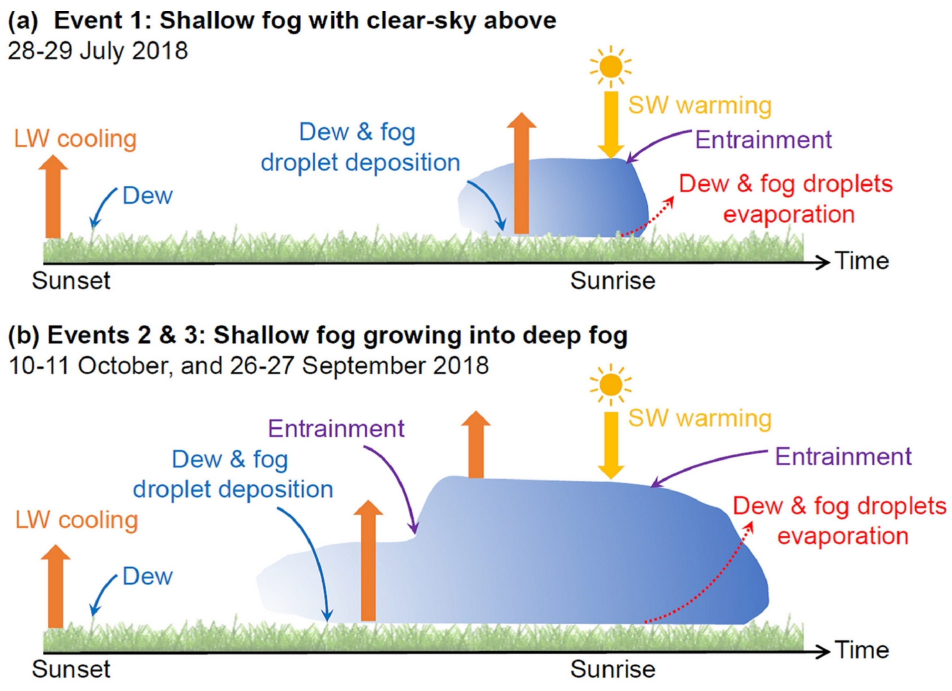


Figure 1 :Key stages of radiation fog, from, Li & al, , 2023

Objectives

What determines the radiative properties of fog ?

- Use a radiative transfer code to simulate the SW/LW radiation at the surface based on the measured microphysical properties and compare with the flux measured at the surface.
- What fog physical properties primaly drive surface radiation?

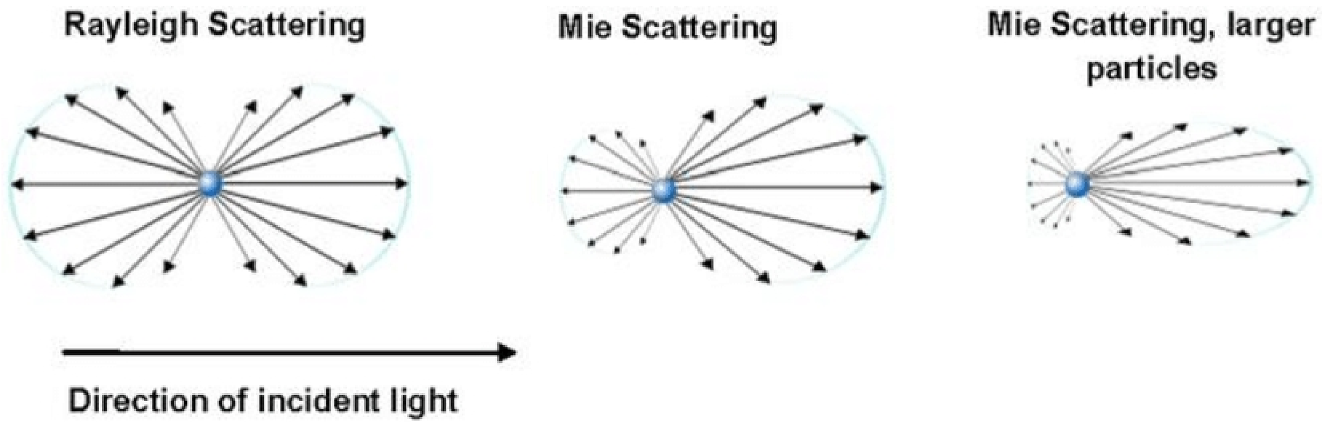
Are the radiative properties used in Meso-NH satisfying ?

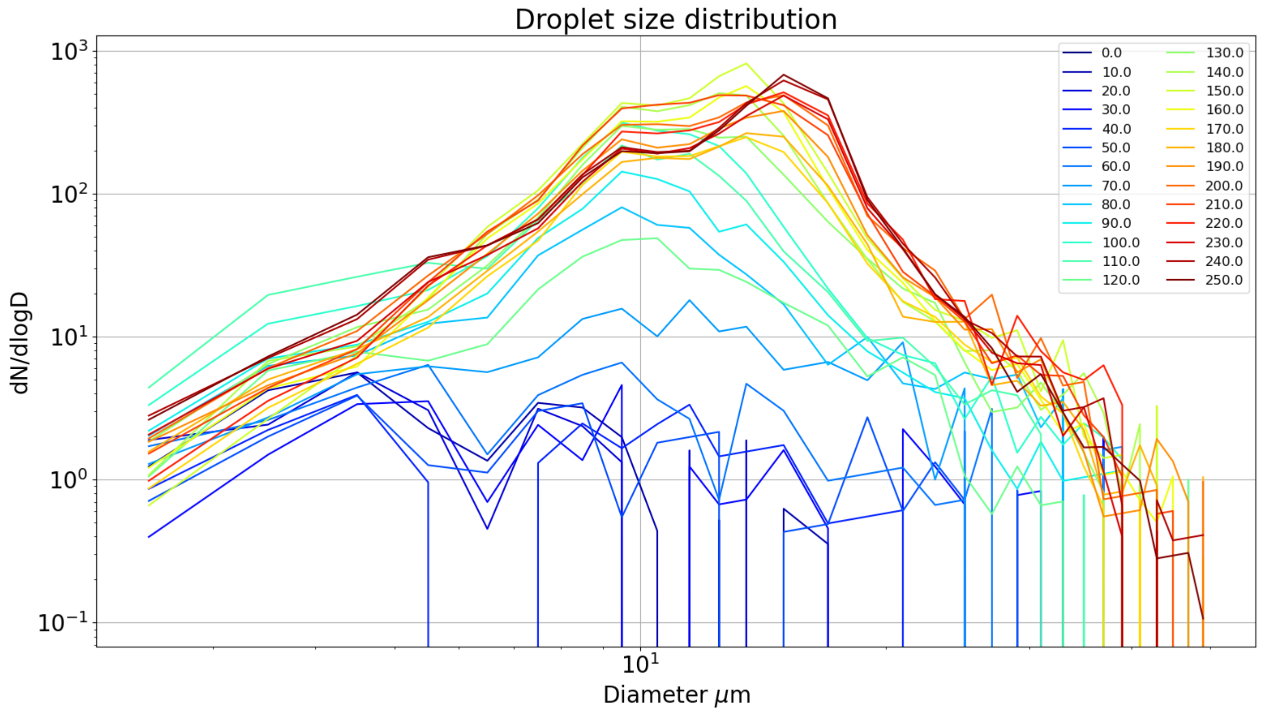
- Compare the optical properties based on measurements with the optical properties using as parameterisations in the Meso-NH atmospheric model (Lac et al., 2018).
- Develop a parameterisation based on SOFOG3D observations to evaluate if a better representation of fog radiative properties can improve the model prediction.

Optical properties

Effective diameter defined as the ratio of 3rd to 2nd moment of the distribution:

$$D_{eff} = \frac{\sum_j N_j d_j^3}{\sum_j N_j d_j^2}$$





Single Scaterring Properties **SSPs** (1,2,3) from mie theorie and microphycs properties:

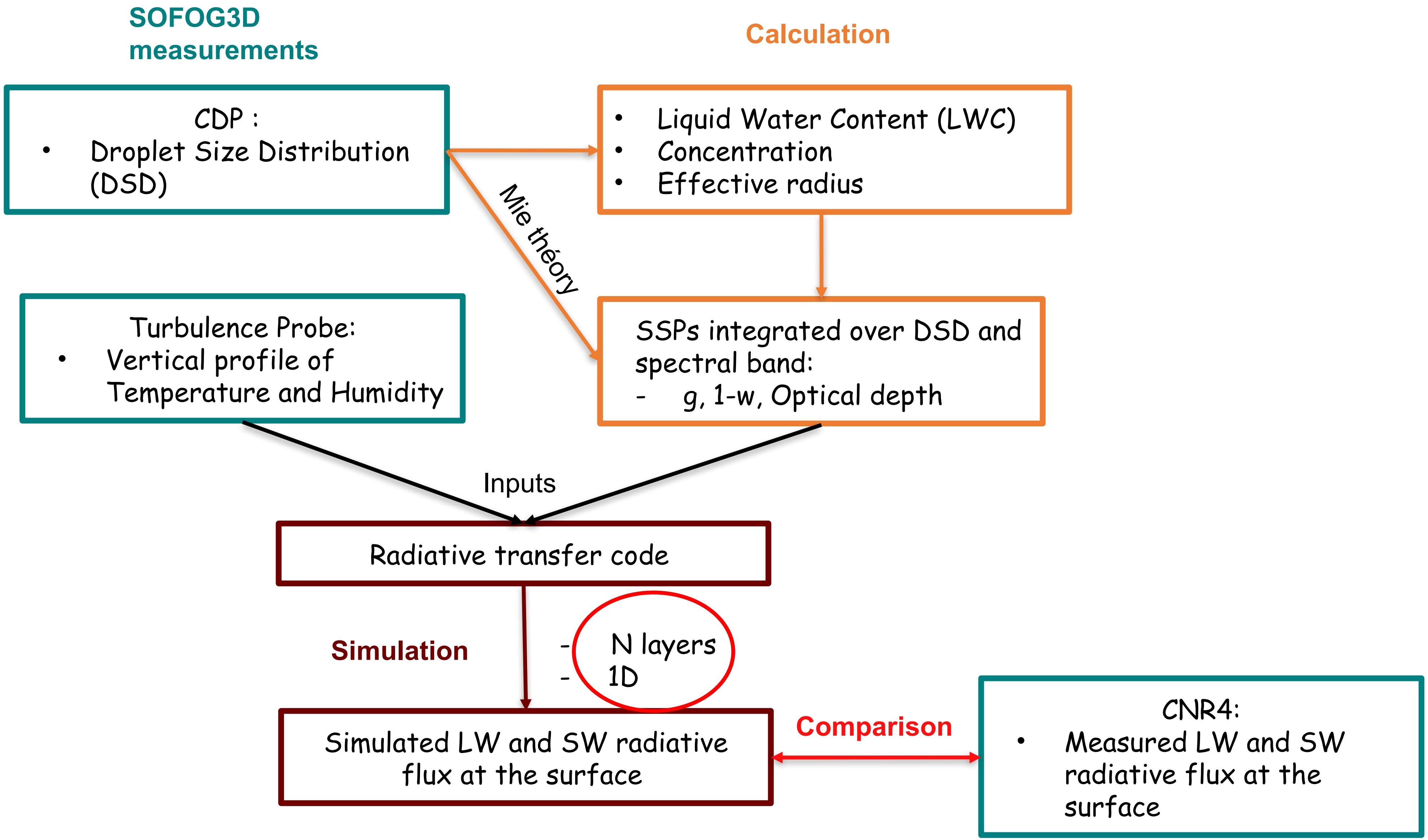
Asymétry factor (1) $-1 \leq g \geq 1$

Single scattering albedo (SSA) (2) $1 - \omega = 1 - \frac{Q_{sca}}{Q_{ext}}$

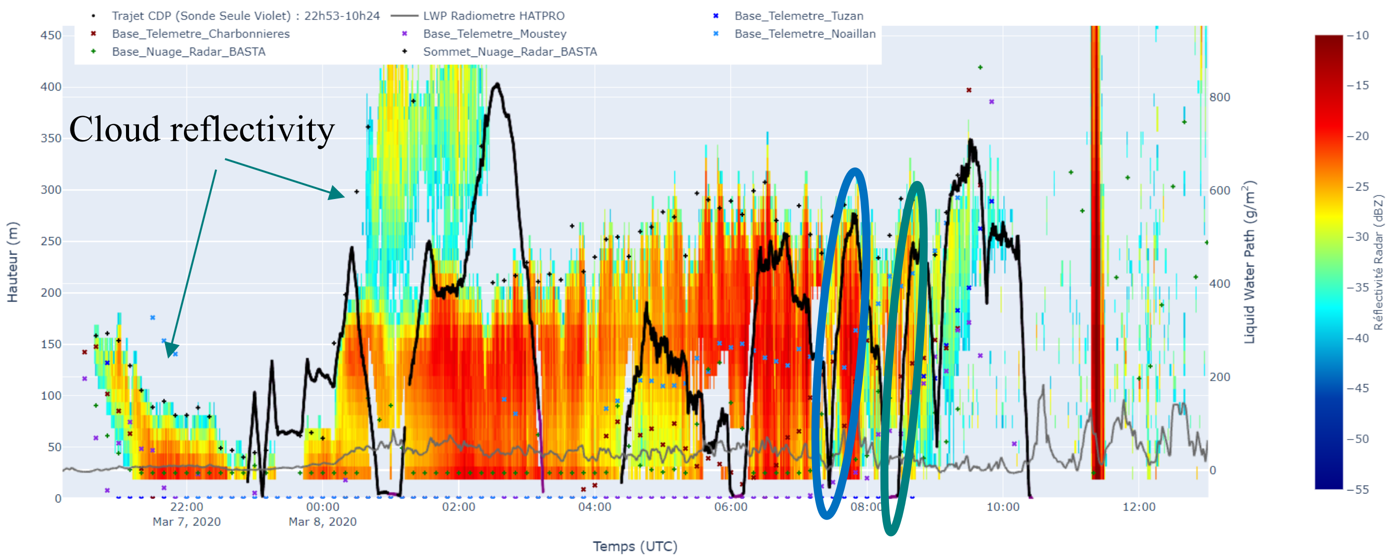
Extinction coefficient $\sigma_{ext} = \pi r^2 Q_{ext} N$

Optical depth (3) $\tau = \int_0^H \sigma_{ext} dz$

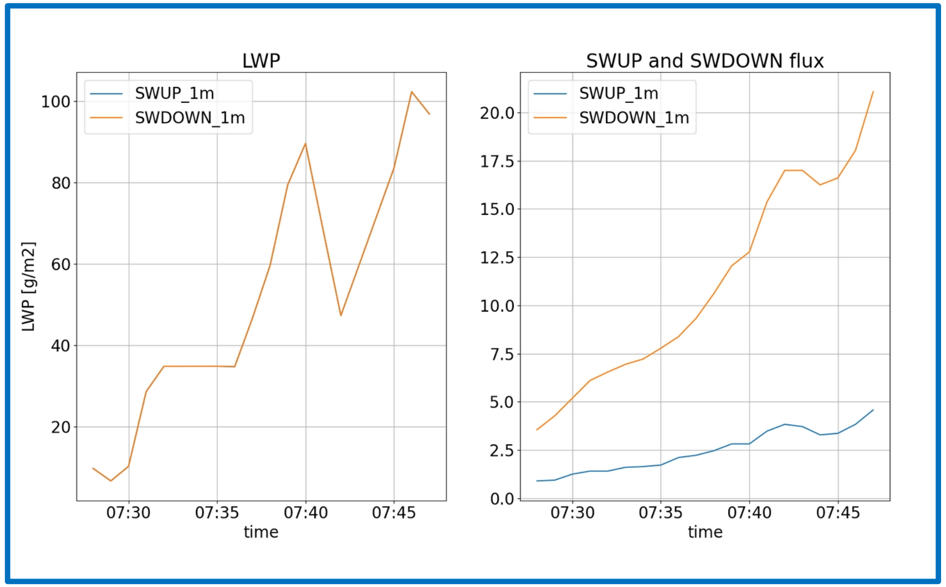
Radiative closure

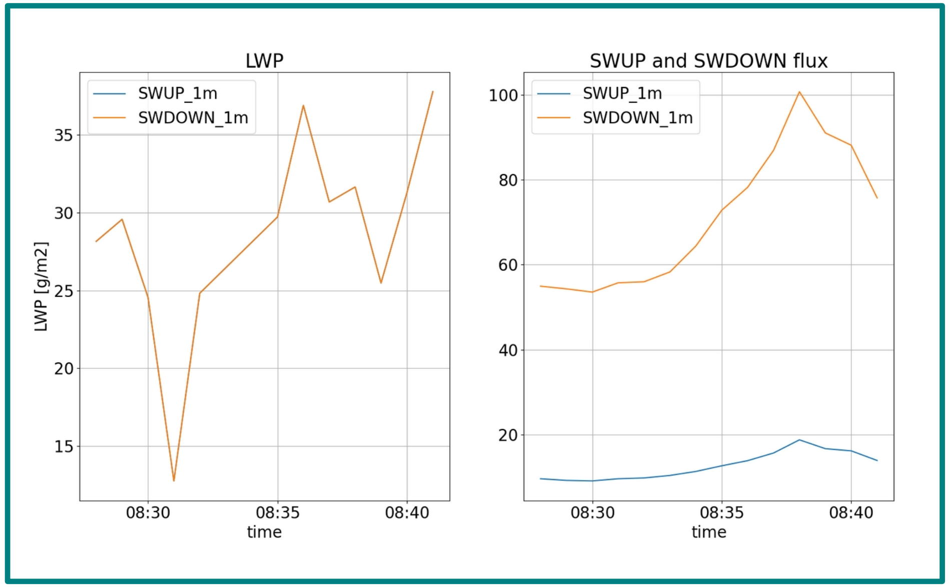


Case study



tethered balloon path : ——





Selection of a case study:

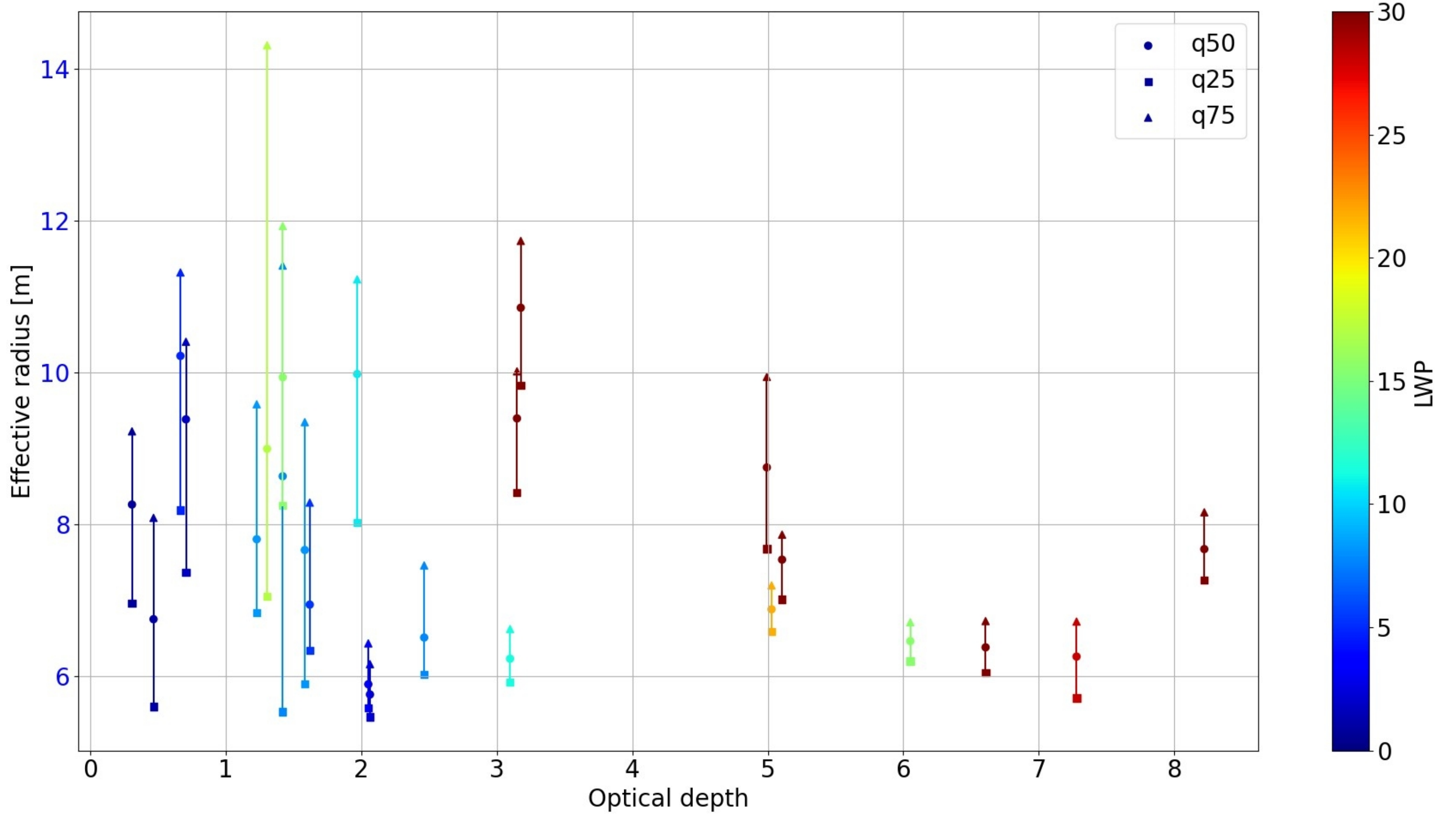
- Relative sationnary conditions
- Vertical profiles through the whole fog layer
- SW measurements with smooth evolution

What fog physical properties primaly drive surface radiation?

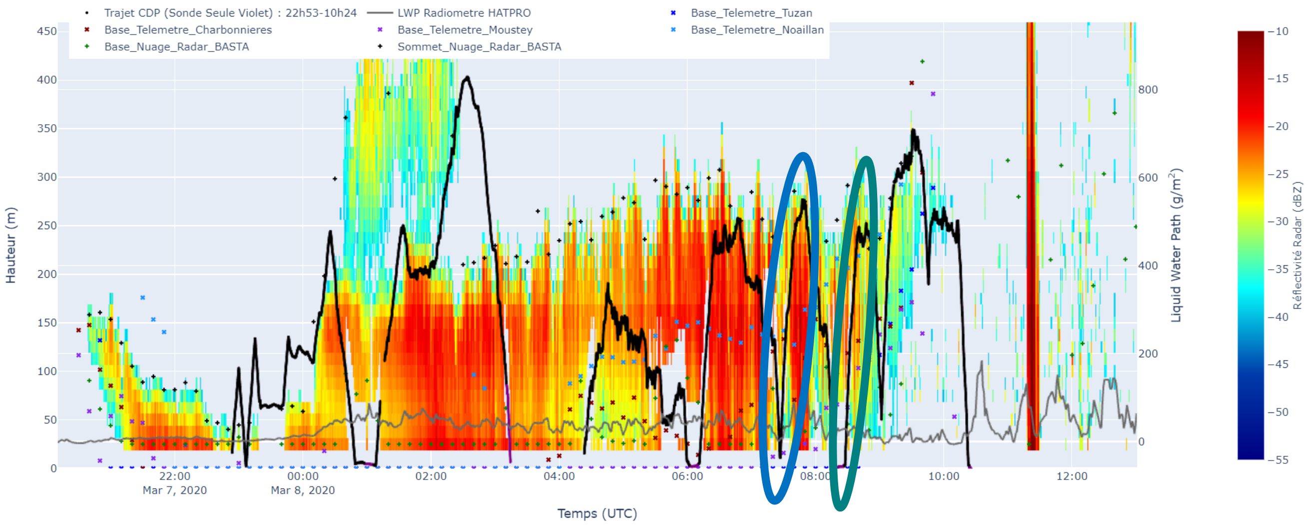
25 vertical profiles are shown in the figure from 3 POI 6,11,14.

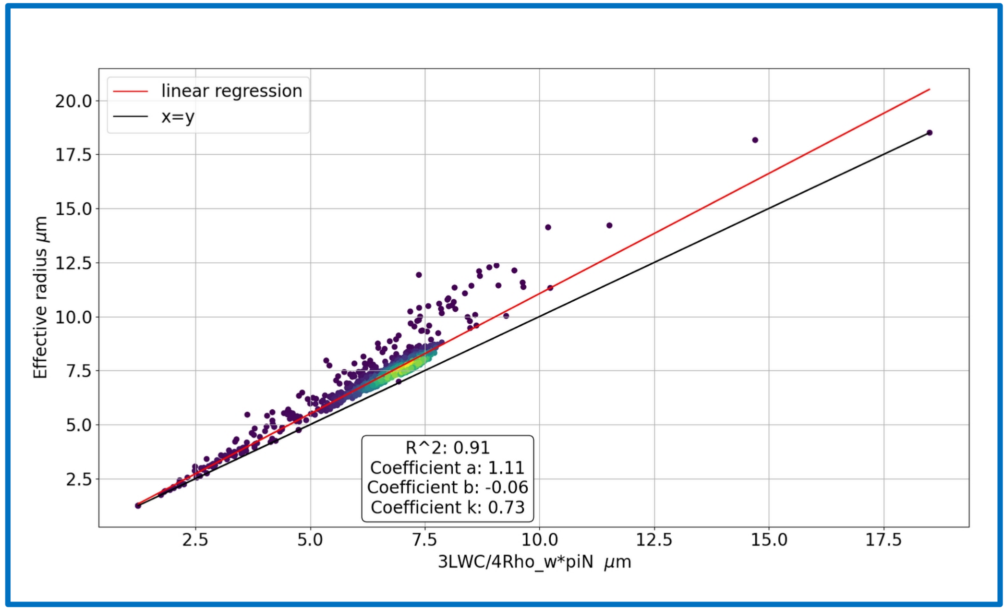
The objective was to determine if the optical thickness was controlled by the effective radius or by the LWP.

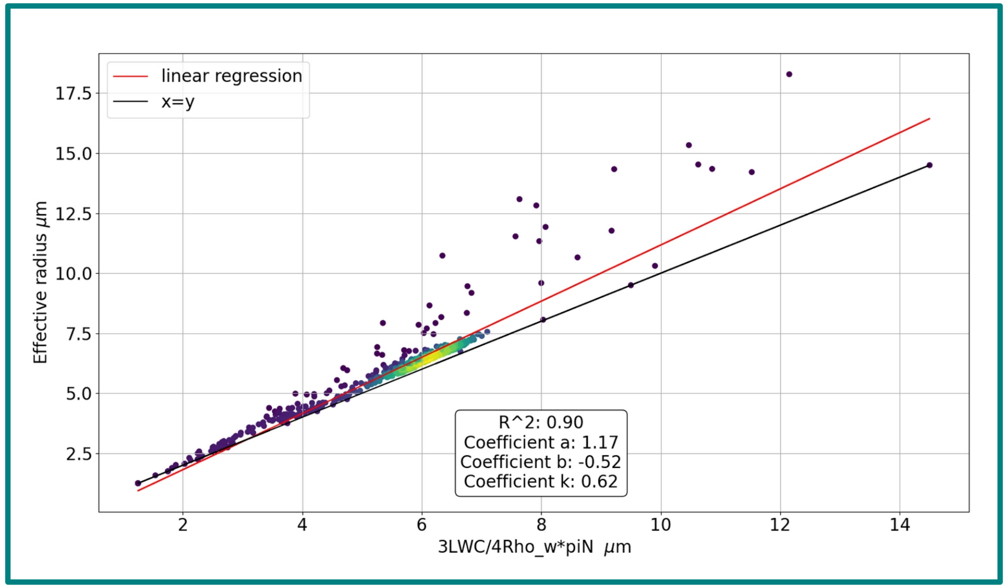
Optical depth is primarily driven by LWP



K parameter







In numerical models, the effective radius is calculated as follows:

$$r_{eff} = \left(\frac{1}{k}\right)^{1/3} \left(\frac{3LWC}{4\pi\rho_w N}\right)^{1/3}$$

k is a shape parameter of the distribution. It can be calculated from a fixed distribution or the models use fixed values introduced by Martin et al, 1994 of 0.67 over land and 0.80 over ocean.

K parameter

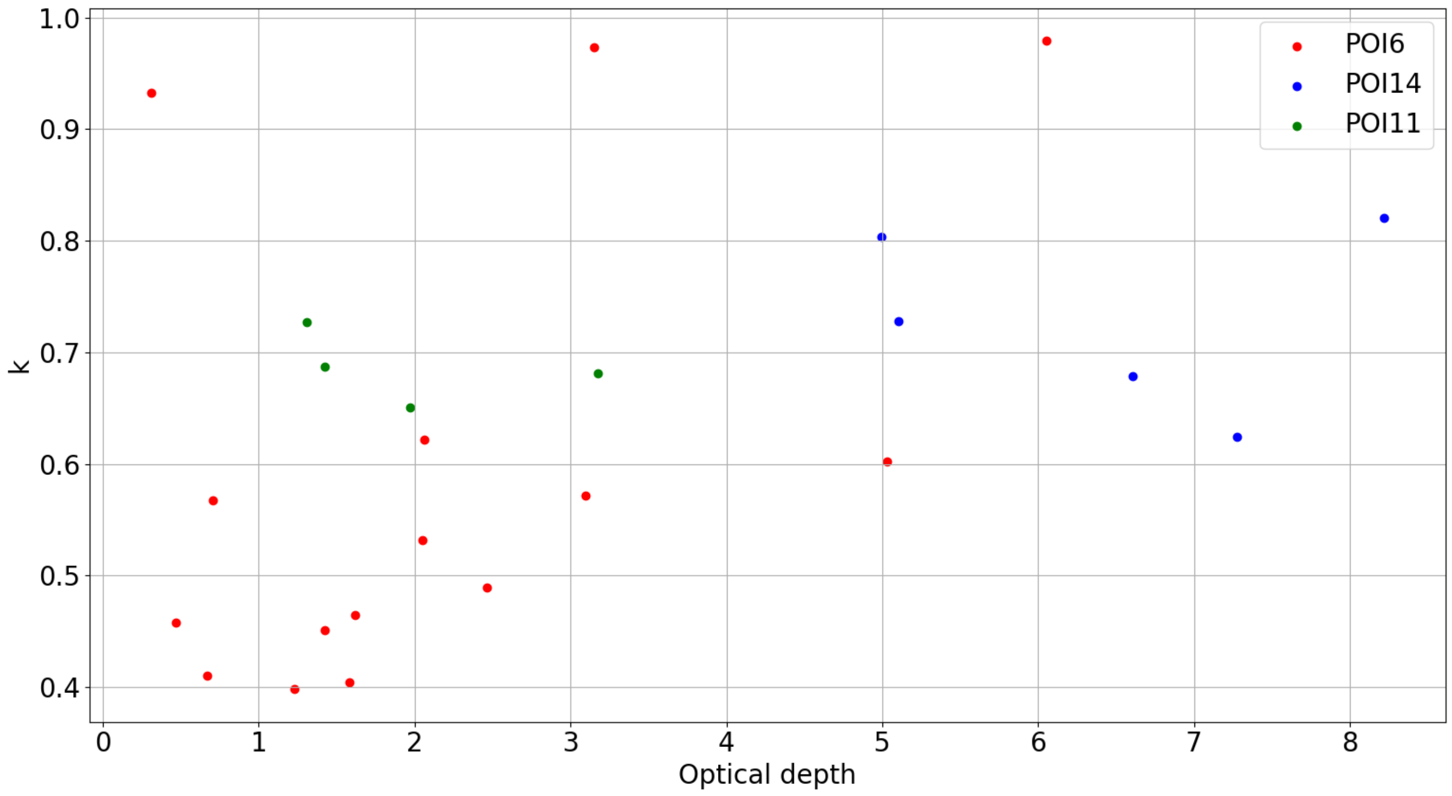
For POI 6, 11 and 14, the graph shows the value of the k-parameter as a function of the optical thickness.

Each point is calculated with a linear regression as shown before.

The variability of the k parameter is significant, with values ranging from 0.4 to 1.

This factor can therefore be a source of improvement for fog prediction models that use a fixed value.

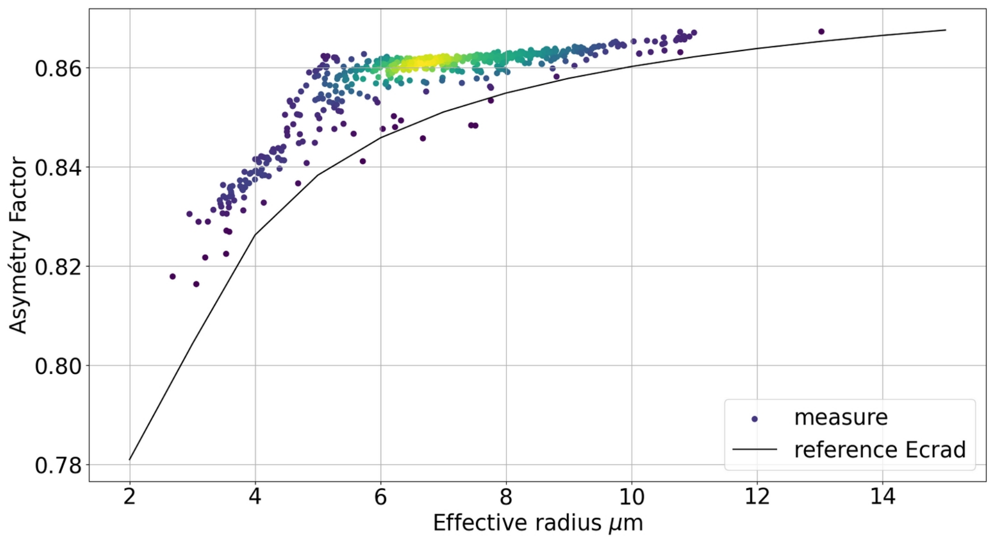
E. Jahangir et al ., Uncertainty of SW Cloud Radiative Effect in Atmospheric Models Due to the Parameterization of Liquid Cloud Optical Properties



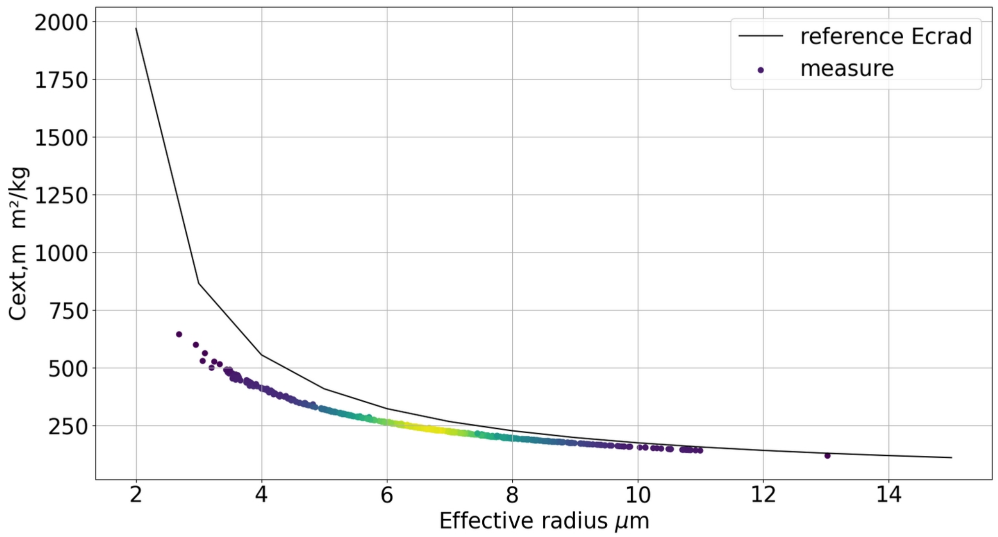
SSPs

550 nm

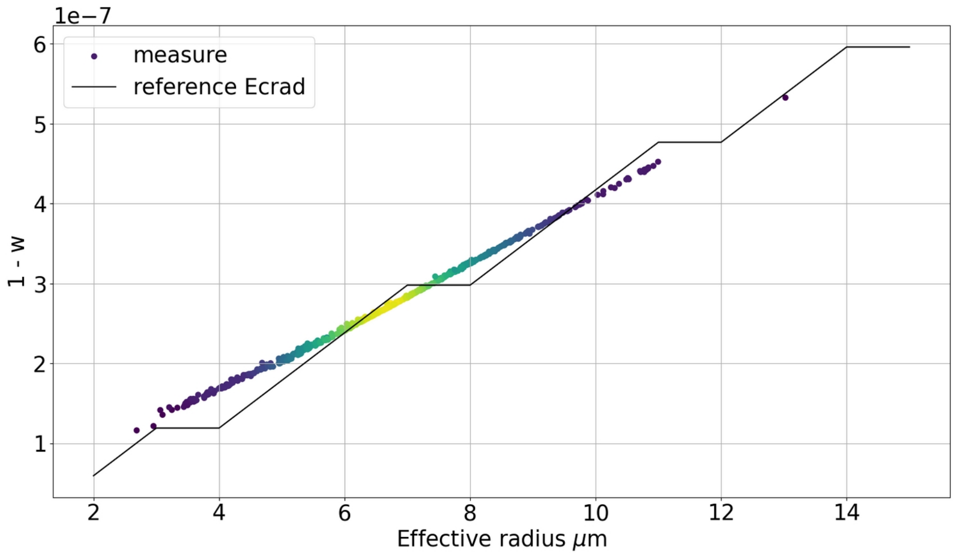
g



Mass extinction coefficient



SSA



the black curves represent the characteristic SSPs used in radiative transfer codes for spherical mie droplets with a gamma size distribution.

The other curve also represents the SSPs, but calculated using data from the SOFOG3D campaign.

conclusion and perspectives

Preliminary study of the SOFOG3D campaign shows :

- k parameter and the optical properties can be improved in the models.
- Radiation at the surface is driven by the LWP

Perspectives:

- Radiative closure.
- Implementing SOFOG3D optical properties in ecRad.
- Meso-NH simulations of fog with updated optical properties and correct “k” value.

Fin de la présentation

Thank you for your attention