Modelling CCN and cloud droplet number concentration (CDNC) in the boreal forest using long-term measurement data

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1. Introduction

- Radiative properties of a cloud depend on the size and number concentration of droplets (Fig. 1).

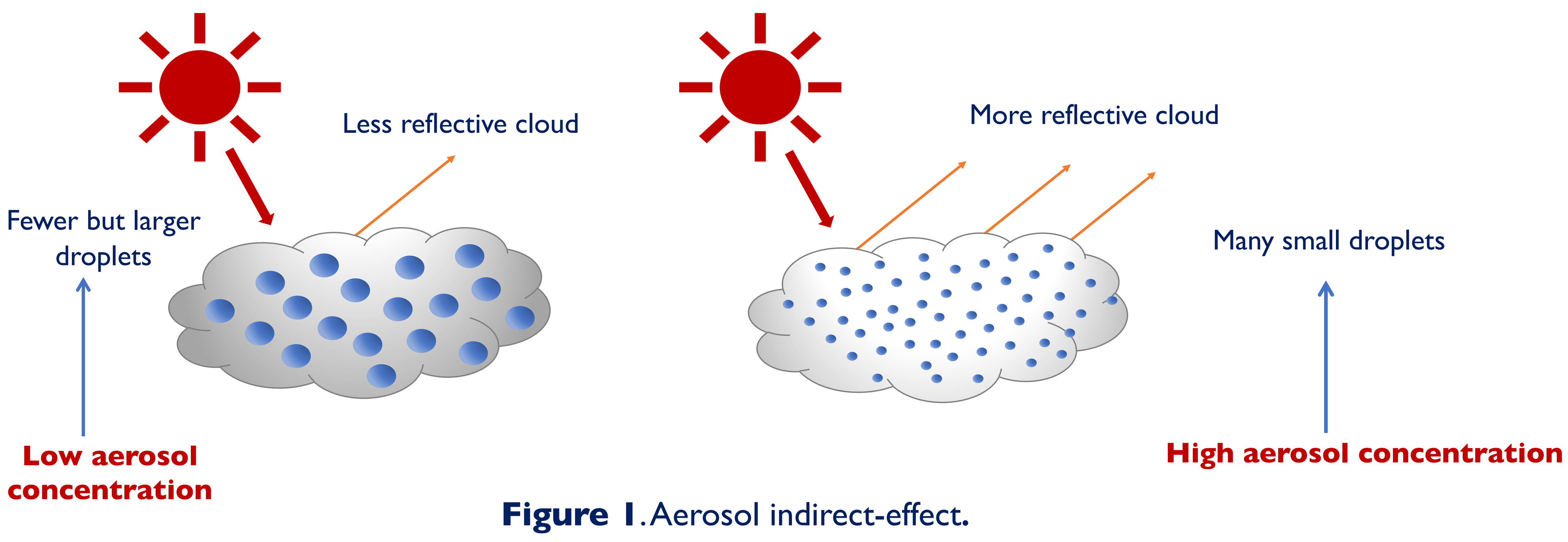


Figure 1. Aerosol indirect-effect.

- To become a cloud droplet, aerosol particles have to absorb water vapor and activate i.e. grow beyond a critical diameter, D_c (Fig. 2). However, growth of a droplet is not a straightforward process.
- Multiple parameters related to aerosol properties and meteorological variables make its growth a complicated process (Fig 2).

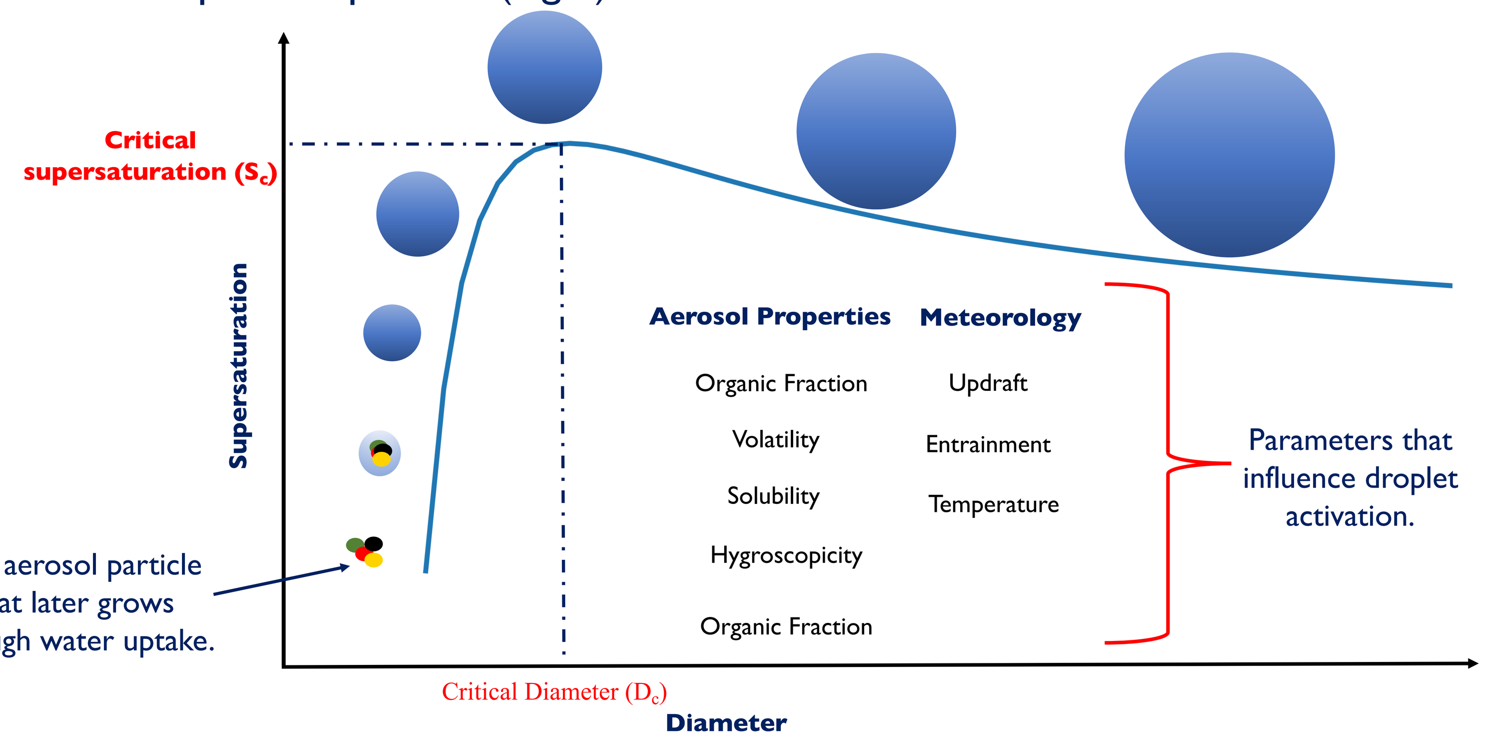


Figure 2. Activation and growth of a droplet.

2. Motivation and Aims

- While cloud condensation nuclei (CCN) concentrations under fixed supersaturations (SS) can often be predicted using κ-Köhler theory (Petters and Kreidenweis, 2007), accurate predictions of CDNC remain a challenge and introduce large uncertainties in predicting cloud properties.
- **In this work we aim to improve the understanding of links between CCN and CDNC over the boreal forest.**
- **We utilize long-term measurement data (2012 to 2020) of aerosol properties at SMEAR II station, Hyytiälä (Petäjä et al. 2021) in Finland to perform a CCN-hygroscopicity closure study.**

3. Data and Methods

- Aerosol number size distribution with 52 size bins ranging from 2.82 nm to 1000 nm.
- CCN data for SS levels at 0.1%, 0.2%, 0.3%, 0.5%, and 1.0% .
- Chemical composition data (Heikkinen et al. 2020): Mass concentration of ammonia, nitrate, sulphate and organics measured using Aerosol Chemical Speciation Monitor (ACSM).
- D_c at given SS and corresponding CCN numbers were predicted using the κ-Köhler theory, where, hygroscopicity parameter (κ) was used to describe the aerosol chemical composition.

4. Aerosol Composition in Boreal Forest

Organics make the major proportion of aerosol population at Hyytiala

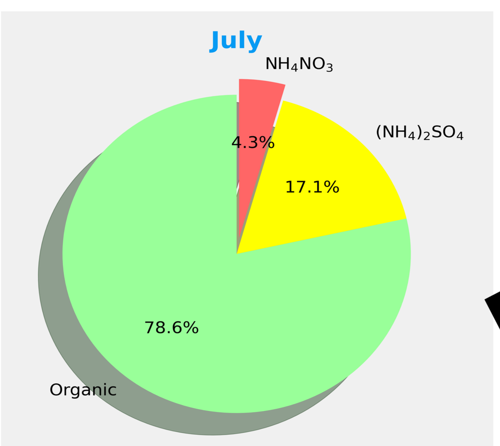
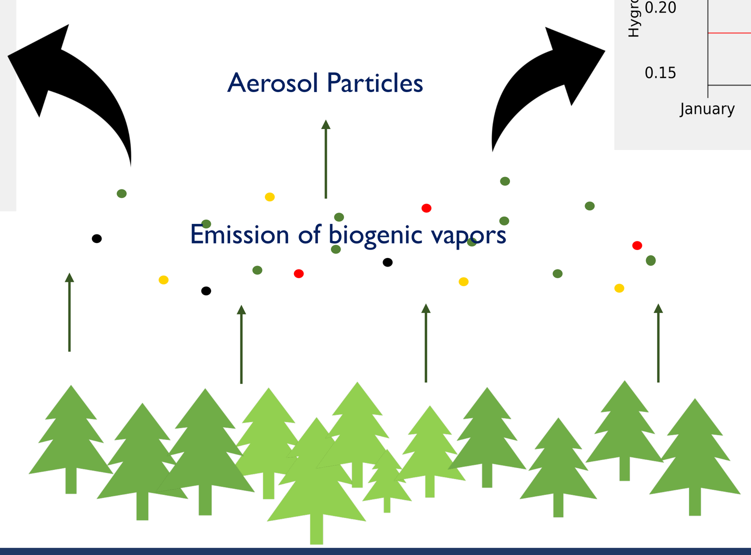


Figure 3. Mass fractions of major chemicals in the aerosol population.



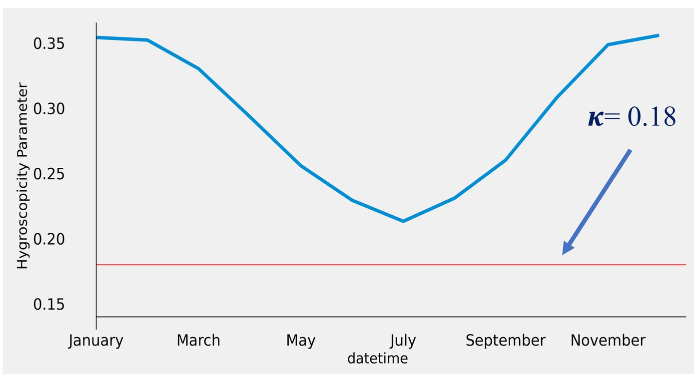


Figure 4. Predicted Hygroscopicity parameter (κ) from the chemical composition (blue curve) and mean κ (red line) for boreal forest (Sihto et al. 2011).

5. Preliminary Results

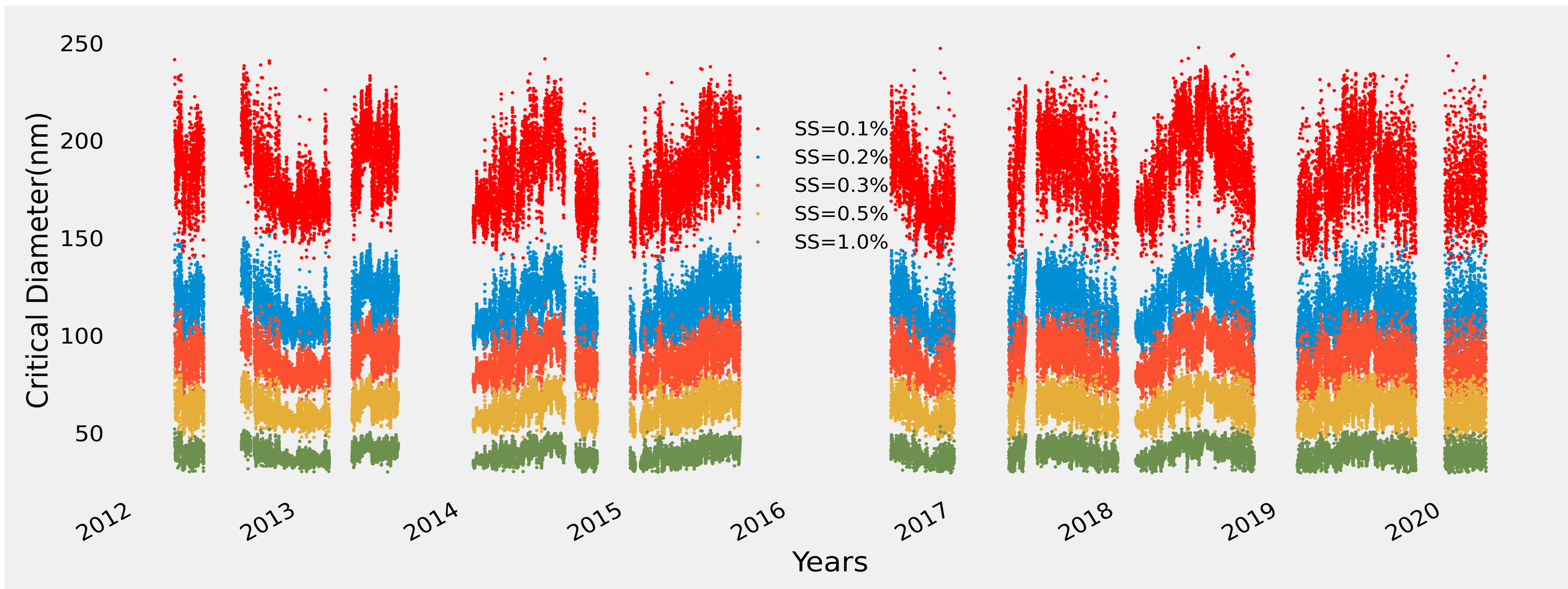


Figure 5. Model predicted critical diameter for different SS levels different years. Due to high amount of organics (Low hygroscopicity) during summer, D_c is high, while in winters due to low organic fraction, hygroscopicity increases and D_c decreases.

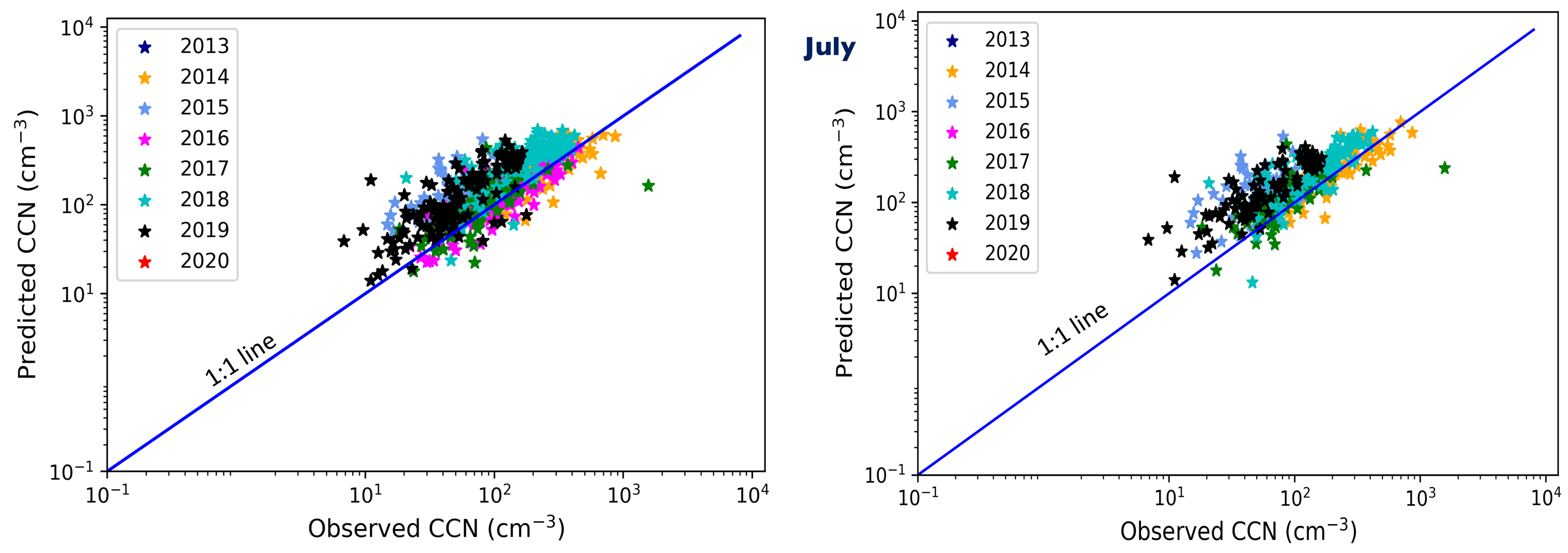


Figure 6. Predicted vs observed CCN (SS= 0.1%) for κ = 0.18 (left) and composition based κ (right).

To see how much the prediction and observation disagree, the Normalized Root Mean Square Error (NRMSE) is plotted (Fig. 7)

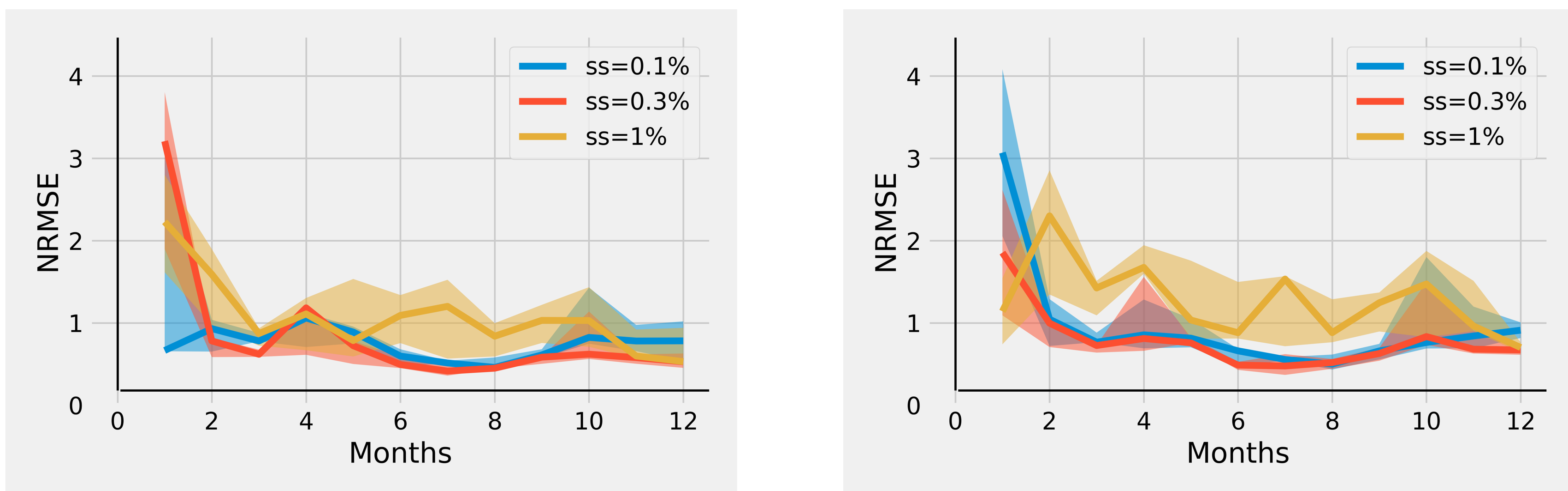


Figure 7. NRMSE for κ = 0.18 (left) and composition based κ (right).

6. Conclusion and Future Work

i. Critical diameter has a seasonal variability (Fig. 5).
ii. Predicted and observed CCN are very well correlated but there is slight overprediction (Fig. 6).
iii. As NRMSE are similar, we get good closure with both, constant κ for all seasons as well as for κ derived from composition data (ACSM).
iv. ***Next step:***

v. Repeat similar study for other environments like Melpitz (rural background) and Mace Head (marine background).
vi. Application of inverse modelling framework to identify the optimal model input parameters to match observations as well as a sample set of the underlying (posterior) uncertainty which can be used to produce confidence intervals on the model predictions.

Acknowledgement

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