A global overview of the effect of water uptake on aerosol particle light scattering using in-situ surface measurements

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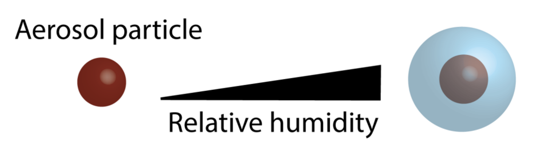
INTRODUCTION

Aerosol optical properties are strongly dependent on ambient relative humidity. Depending on their size, composition and the ambient humidity, atmospheric particles will take up varying amounts of water. This water uptake affects the aerosol optical properties and, thus, influences the direct aerosol radiative forcing. The main goal of the project "**Evaluation and improvement of the parameterization of aerosol hygroscopicity in global climate models using in-situ surface measurements**" is to evaluate how well global models simulate the aerosol/water interactions using in-situ measurements of aerosol hygroscopicity (**planned AeroCom model-measurement experiment**). The first step is to compile, harmonize and assess the data quality of the available tandem nephelometer humidograph measurements. Here, we show the data harmonization process and quality checks and the global overview of f(RH) measurements.

MOTIVATION

Ambient aerosol particles experience hygroscopic growth with increasing RH



$$f(\mathrm{RH},\lambda) = \frac{\sigma_{\mathrm{sp}}(\mathrm{RH},\lambda)}{\sigma_{\mathrm{sp}}(\mathrm{RH}_{\mathrm{dry}},\lambda)}$$

with λ: wavelength, σ_{sp}: scattering coefficient, RH: relative humidity

Aerosol light-scattering is strongly dependent on RH, which impacts aerosol radiative forcing calculations and is important for evaluation of remote sensing with in-situ measurements. Generally, the scattering enhancement factor, *f*(RH), depends on the chemical composition and aerosol size distribution.

SCIENTIFIC QUESTIONS

- Can a climatology of hygroscopic scattering enhancement, f(RH), be developed as a function of aerosol type and/or region?
- Can a simplified parameterization be formulated for f(RH) as a function of other aerosol measurements?
- How well do climate models represent aerosol hygroscopic growth and do observed biases suggests improvements to parameterization schemes?

MEASUREMENTS

The data of two different humidified nephelometer systems by NOAA and PSI (Paul Scherrer Institute, Switzerland) are being re-analyzed. Technical differences are shown below.

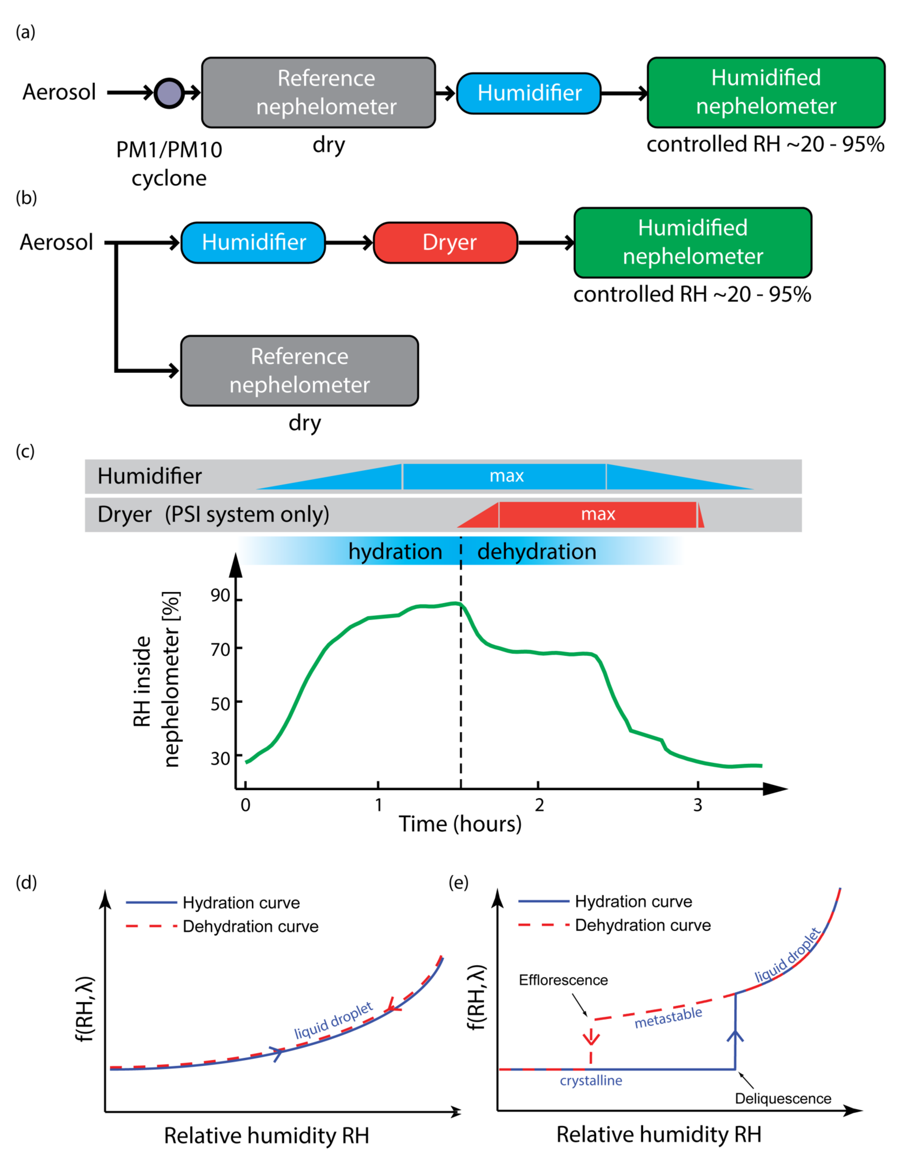


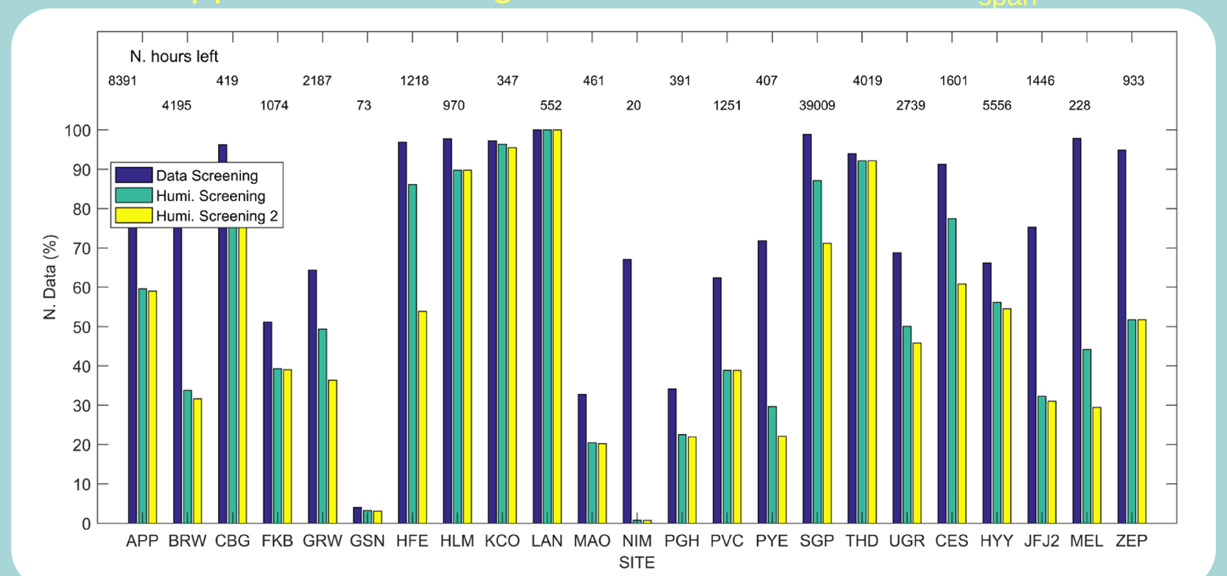
Figure: Schematic set-up of the humidied nephelometer system of the (a) NOAA system and (b) the PSI system. (c) Typical time profile of the RH inside the Humidified nephelometer system. This set-up allows to probe particles without (d) and with (e) hysteresis behavior.

Different design and procedures:

- Number and location of RH sensors
- Reference RH not as dry as desired
- Configurations of tandem nephelometers (serial or parallel)
- Availability of salt calibrations
- Scanning time
- Data treatment

DATA AVAILABILITY

- ✓ Data screening & quality checks (i.e. RH_{dry}<40%)
- ✓ Fit applied to humidograms with R^2>0.5
- ✓ Fit applied to humidograms with R^2>0.5 and RH_{span} > 30%



What is the correct reference RH?

- Particles experience hygroscopic growth already at low and intermediate RH which contributes to light scattering.
- Specially problematic for sites with marine influence where GAW guidelines (RH<30-40%) are sometimes not fulfilled.

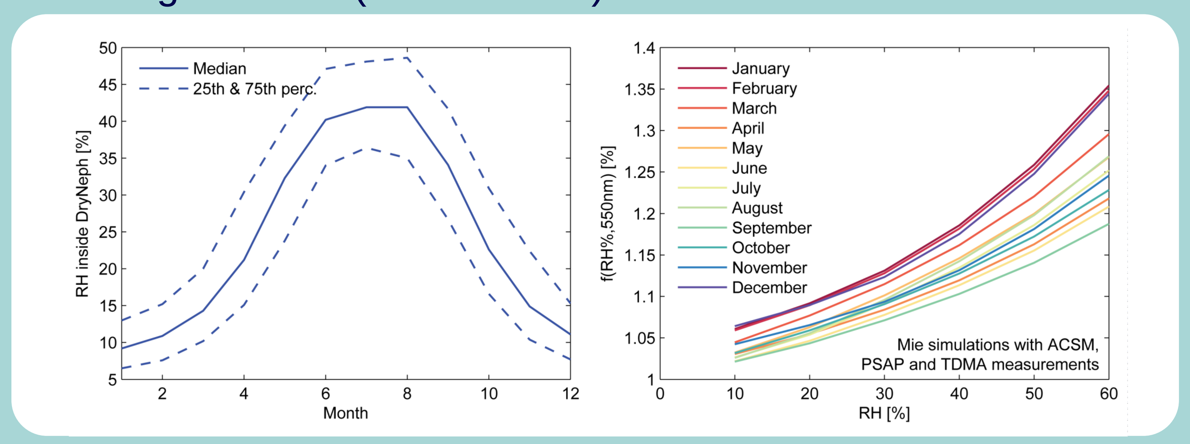


Figure: At SGP, the dry nephelometer RH is higher during summer. Simulations based on ACSM chemistry measurement suggest 10-15% of dry (RH<40%) scattering in summer could be due to remaining water.

HARMONIZED RE-ANALYSIS: A GLOBAL VIEW OF *f*(RH=85%)

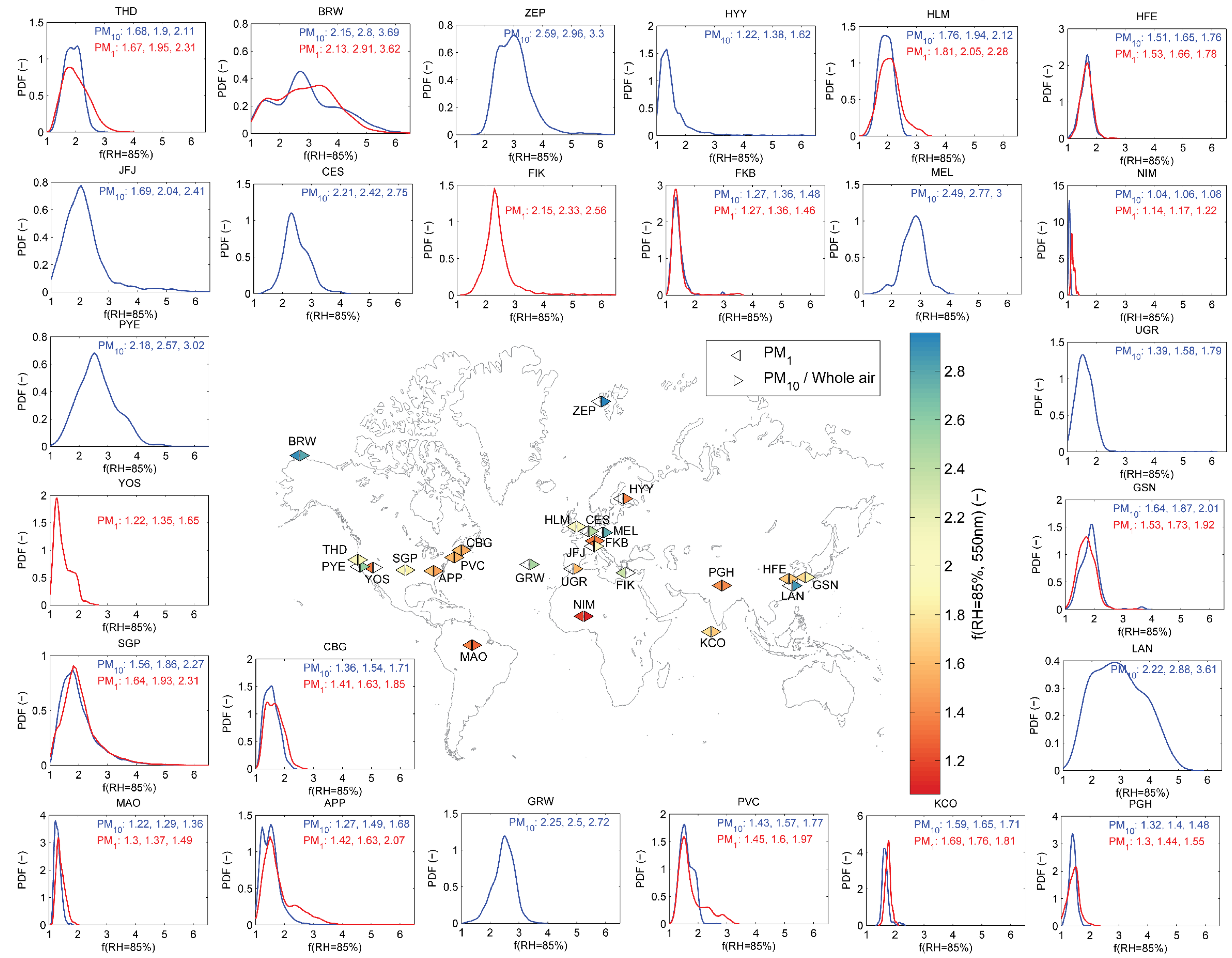


Figure: Overview of the re-analyzed data for all considered sites. Probability density function of *f*(RH=85%) calculated from the humidogram data after data screening. The inset values correspond to the 25th percentile, median and 75th percentile values of $PM_1/PM_{2.5}$ (red lines) or PM_{10}/whole air measurements (blue lines). The world map shows median values of *f*(RH=85%,550nm).

- Larger values at clean marine sites (FIK, CES, PVC, GSN, PYE, CBG, THD, GRW).
- PM_1 often shifted towards larger *f*(RH=85%) than PM_{10}, especially at marine sites (GRW, PVC, PYE).
- Lower values at dust-dominated sites (NIM) and polluted sites (HFE, PGH, UGR, KCO).
- Artic stations (ZEP and BRW) show similar median values of *f*(RH=85%).
- Our analysis are consistent with previous publications, although slight differences in mean *f*(RH=85%) were found for specific sites.
- This fact evidences that a common analysis protocol is needed for a proper comparison.

CONCLUSIONS

- A harmonized and quality assured dataset of *f*(RH) has been created using humidified nephelometer measurements of 25 sites around the world.
- Water uptake by aerosol particles has a strong influence on aerosol light-scattering and shows strong regional dependency.
- Evaluating *f*(RH) measurements requires a careful consideration of instrument configuration and site-specific characteristic.

WHAT IS NEXT?

- Adding trajectory footprint analysis for each site.
- Parametrizations for *f*(RH) as a function of other aerosol properties (i.e. single scattering albedo, organic/inorganic mass fraction, etc.).

Main goal:

- Evaluating global model simulations with our harmonized benchmark dataset of *f*(RH).

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