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Evaluation and improvement of the parameterization of aerosol hygroscopicity in global climate models using in-situ surface measurements

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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, thereby altering their optical properties and impacting their contribution to aerosol radiative forcing. In this project, the ultimate goal is to assess how well global models simulate the aerosol/water interaction using in-situ measurements of aerosol hygroscopicity. In the initial phase of the research, it is vital to compile and assess the data quality of the available tandem nephelometer humidograph measurements and to harmonize the data sets in terms of data treatment (instrument corrections, hygroscopic fitting assumptions, etc.). Here, we present preliminary analysis of the SGP humidograph record.

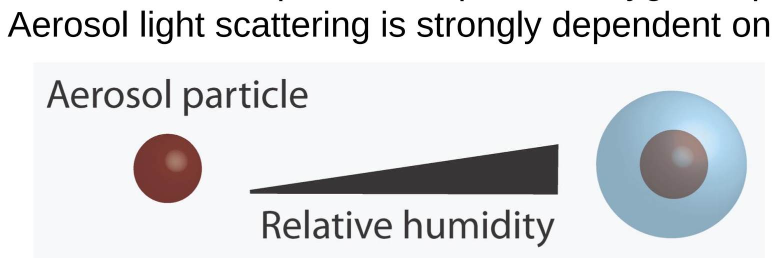
PROJECT SCIENTIFIC QUESTIONS

- Can a climatology of humidity dependent properties be developed as a function of aerosol type and/or source region?
- Can a simplified parameterization of aerosol growth be formulated for all common aerosol types using aerosol optical properties and/or other measurements as proxies for f(RH)
- How well do climate models represent aerosol hygroscopic growth and do observed biases suggest improvements to parameterization choices

First step: data evaluation and harmonization

Motivation

- Ambient aerosol particles experience hygroscopic growth at relative humidity
- Aerosol light scattering is strongly dependent on RH



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

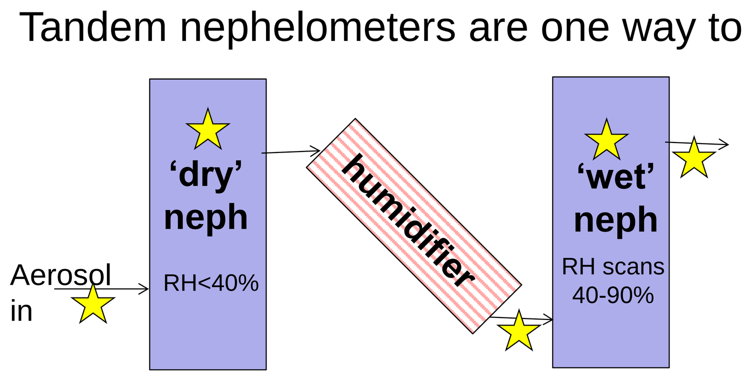
with λ: wavelength, σ_{sp}: scattering coefficient, RH: relative humidity

Knowledge of RH dependency of scattering needed for
→calculating aerosol radiative forcing
→relating dry in-situ data to ambient conditions (e.g., remote sensing measurements)
→climate model improvements

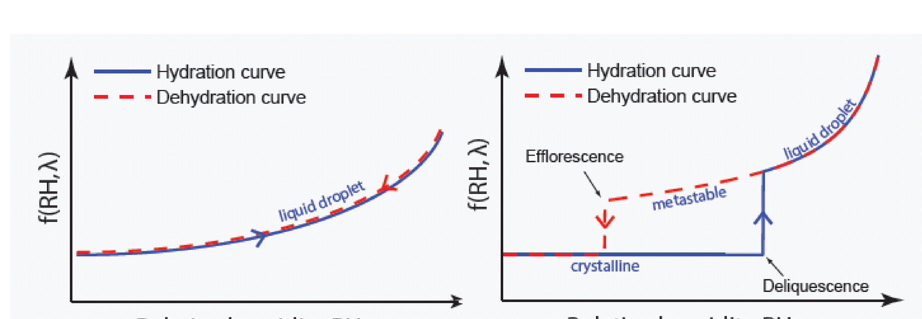
Size distribution and chemical composition matter for the scattering enhancement (f(RH))
f(RH) can be measured with tandem nephelometers and humidifier

Measurements

Tandem nephelometers are one way to measure aerosol hygroscopic growth



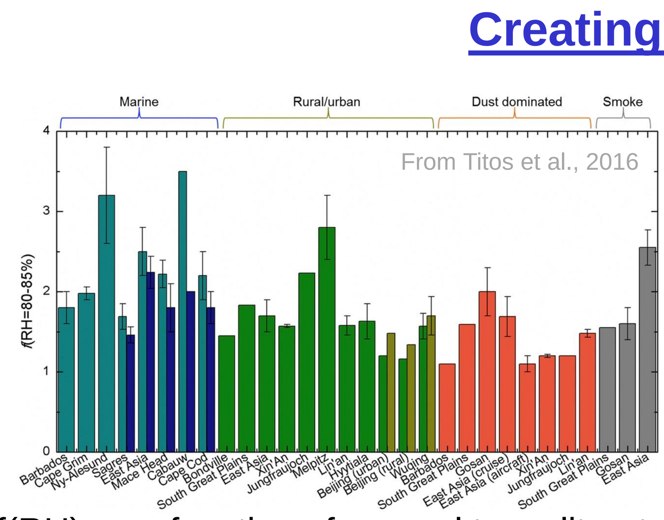
Stars indicate possible RH sensor locations



- Different configurations of tandem nephs (serial or parallel)
- Design (e.g., number and location of RH sensors) and testing (e.g., salt calibrations!) are critical (Titos et al., 2016)

- Different types of growth may be observed
- Smooth monotonic increase/decrease
- Hysteresis – at a given RH may have solid or liquid phase particle

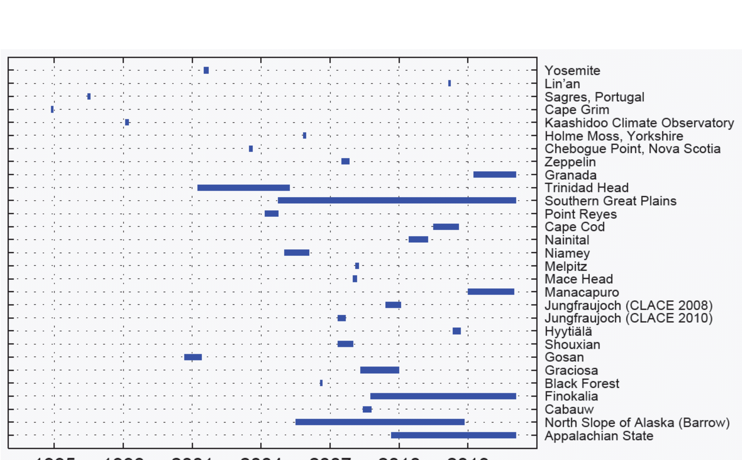
Creating a consistent data set



f(RH) as a function of aerosol type; literature studies from 1970 to present

A review of f(RH) values from the literature reveals a large variability of f(RH) values across measurement sites and aerosol types.

Comparison of f(RH) values among studies is not straightforward. Du to differences in the instrumentation, methodology, size cut and the uncertainties.



Data availability of surface in-situ humidograph measurements

Through DOE/ARM and colleagues in the wider aerosol community we have access to humidograph data from ~20 sites.

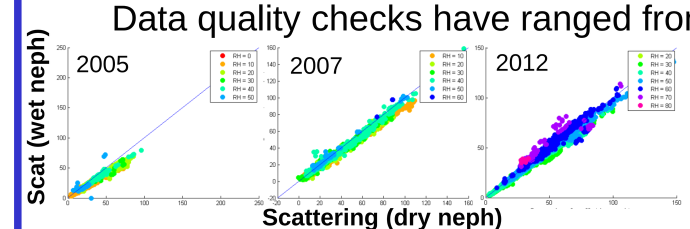
Data sets are relatively recent (last 20 years) and frequently accompanied by useful ancillary data (chemistry, size distribution, etc.)

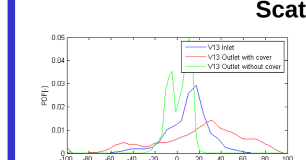
We are currently exploring and evaluating data to determine quality. This is a time-intensive and iterative process. Ancillary measurements can provide useful guidance.

Poster focus is on SGP which has the longest time series of f(RH) data. SGP should provide a framework for analyzing data from the other sites, particularly some of the older AMF1 sites and some of the earlier campaign measurement that operated a similar humidograph set-up.

SGP humidograph data – the good, the bad and the ugly

Data quality checks have ranged from the very simple to detailed closure studies





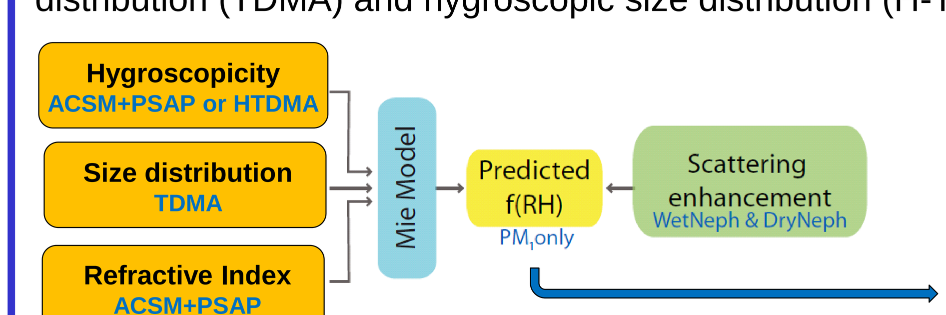
RH diff between internal and external RH sensor

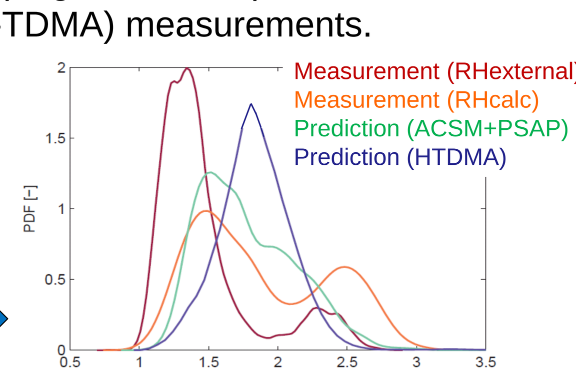
Simple checks include determining that the dry and wet nephelometer measure the same scattering at the same RH across a range of RH values and years→GOOD!

More complex checks involve comparing RH values at different points in the system.→UGLY

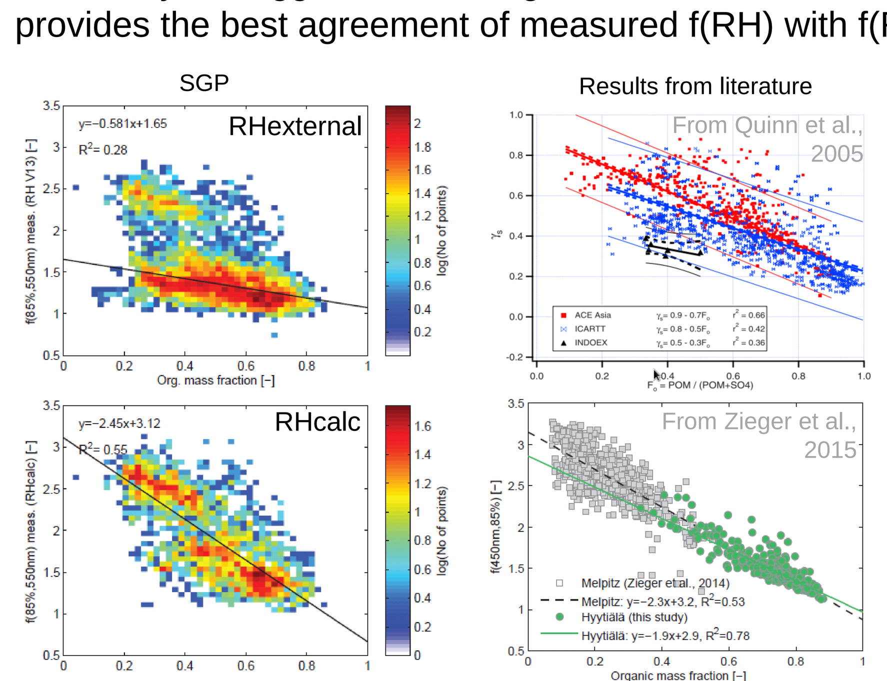
The f(RH) values will be impacted by the wet RH – but there are inconsistencies in the measurements. Can ancillary measurements be used to help decide the best system RH to use?

From 2010-2014, there was a period of time with overlapping tandem nephelometer, chemistry (ACSM), size distribution (TDMA) and hygroscopic size distribution (H-TDMA) measurements.





This analysis suggests that using an RH calculated from an internal sensor T and external sensor RH provides the best agreement of measured f(RH) with f(RH) predicted from ACSM chemistry.

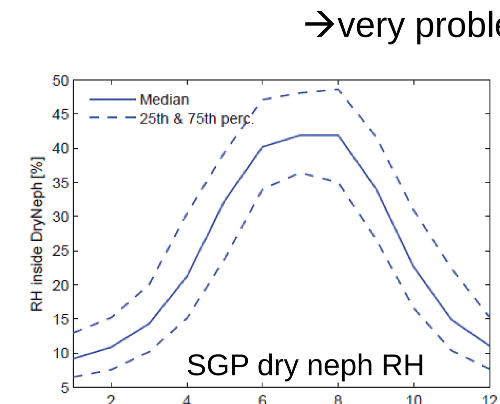


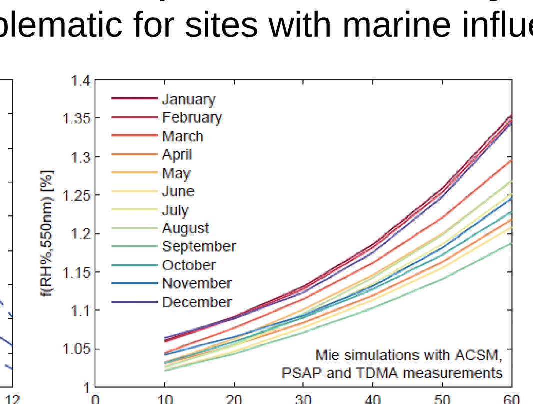
Use of the RHcalc to determine f(RH) at SGP results in a similar relationship between organic mass fraction and f(RH) as has previously been observed at other sites (e.g., Melpitz and ICARTT)…but could be coincidence!

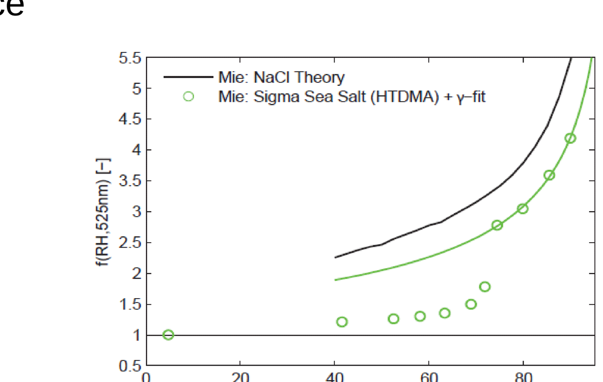
The bi-modal f(RH) values need more investigation.

What is dry??

- WMO/GAW guidance suggests RH in dry neph should be <30-40%
- There can be significant light scattering due to water at these RH levels
  →over-estimate of dry reference scattering→underestimate of f(RH)
  →very problematic for sites with marine influence







At SGP, the dry neph RH is higher in the summer. Simulations based on ACSM chemistry suggest 10-15% of **dry** scattering in summer could be due to water

At marine sites with a strong sea salt influence, 30-40% of 'dry' scattering could be due to water at RH=40%

Conclusions

Water uptake by aerosol particles has a strong influence on aerosol scattering.

Evaluating this effect with measurements requires a careful consideration of system RH

Closure studies may be a useful tool to constrain f(RH) measurements

SGP data set – is amazing, but long way to go in analysis (tools developed for this should make evaluation of other sites go more quickly)

Future Work:

→f(RH) as function of trajectory footprints
→creation of harmonized measurement data set
→bringing in the global models simulations for comparison with harmonized data sets

References:

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