First global overview on the

representation of water uptake by ten Global Climate Models

using a new in-situ benchmark hygroscopicity dataset

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Funded by US Department of Energy.
Project number: DE-SC0016541

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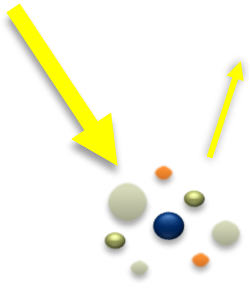
AeroCom Annual Meeting, 12 October 2020

Aerosols and Climate and Water



Aerosol Particle

Relative Humidity

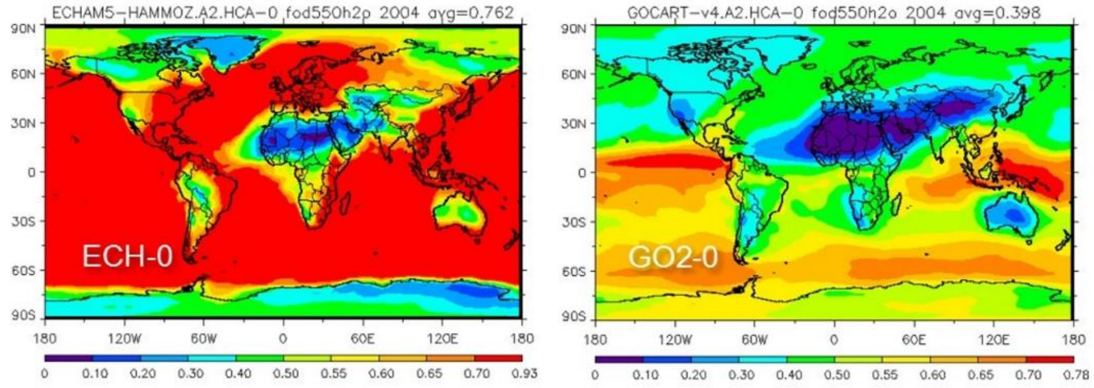
HYGROSCOPICITY:
Since aerosol particles can take up water, they can change in size and chemical composition depending on the ambient relative humidity (RH)

SCATTERING ENHANCEMENT FACTOR

$$f(RH,\lambda) = \frac{\sigma_{sp}(RH,\lambda)}{\sigma_{sp}(RHdry,\lambda)}$$

Interestingly, most models are doing well in reproducing the total aerosol optical depth (AOD), but a closer look into the individual components reveals discrepancies between them

Fraction of aerosol optical depth due to water:



Figures from Mian Chin (NASA Goddard)

How well do Earth System Models represent aerosol optical hygroscopic growth?

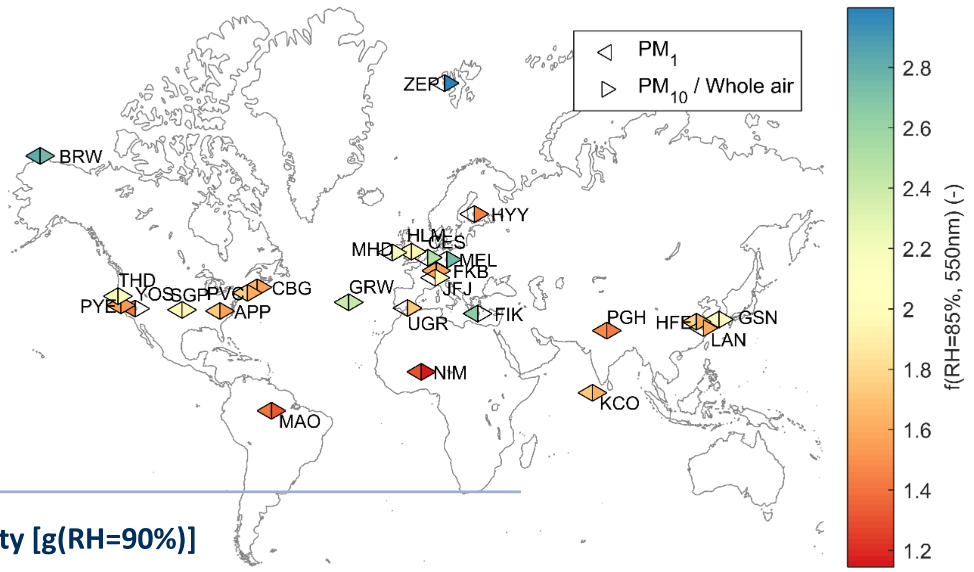
This presentation summarizes our work, published in ACP

Measurement and Model Data:

Hygroscopicity benchmark dataset

Burgos et al., 2019:

f(RH) measurements from in-situ sites around the globe used to create a benchmark dataset



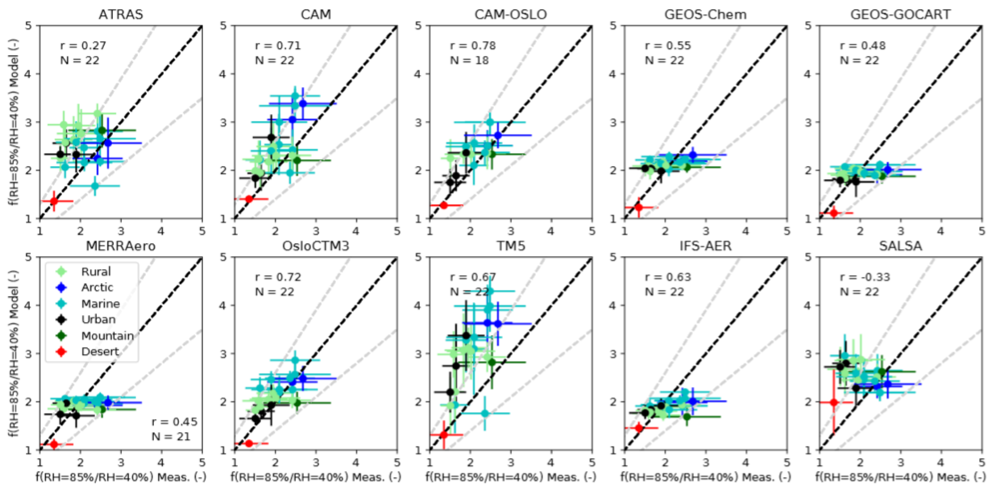
MODEL	Chemical composition	Mixing State	Hygroscopicity [g(RH=90%)]					
			parameterization	ss	so4	bc	oa	dd
ATRAS	bc,so4,oa,ss,dd + no3/nh4	I	κ-Köhler Theory	2.25	1.87	1.0	1.24	1.0
CAM	bc,so4,oa,ss,dd	I	κ-Köhler Theory	2.25	1.77	1.0	1.24	1.2
CAM-Oslo	bc,so4,oa,ss,dd	I,E	κ-Köhler Theory	2.28	1.77	1.0	1.31	1.2
GEOS-Chem	bc,so4,oa,ss,dd + no3/nh4	E	Modified GADS	2.38	1.64	1.4	1.64	1.0
GEOS-GOCART	bc,so4,oa,ss,dd	E	Modified GADS	1.9-2.1	1.8	1.4	1.6	1.0
MERRAero	bc,so4,oa,ss,dd	E	Modified GADS	1.9-2.1	1.8	1.4	1.64	1.0
OsloCMT3	bc,so4,oa,ss,dd + no3/nh4	I	Own development	2.3-2.4	1.72	1.0	1.46	1.0
TM5	bc,so4,oa,ss,dd + no3/nh4	I, E	Own development	-	-	1.0	1.0	1.0
IFS-AER	bc,so4,oa,ss,dd + no3/nh4	E	Own development	2.36	1.73	1.0	1.64	1.0
SALSA	bc,so4,oa,ss,dd	E	Own development	2.4	1.9	1.0	1.5	1.0

Model data: INSITU project - AeroCom Phase III

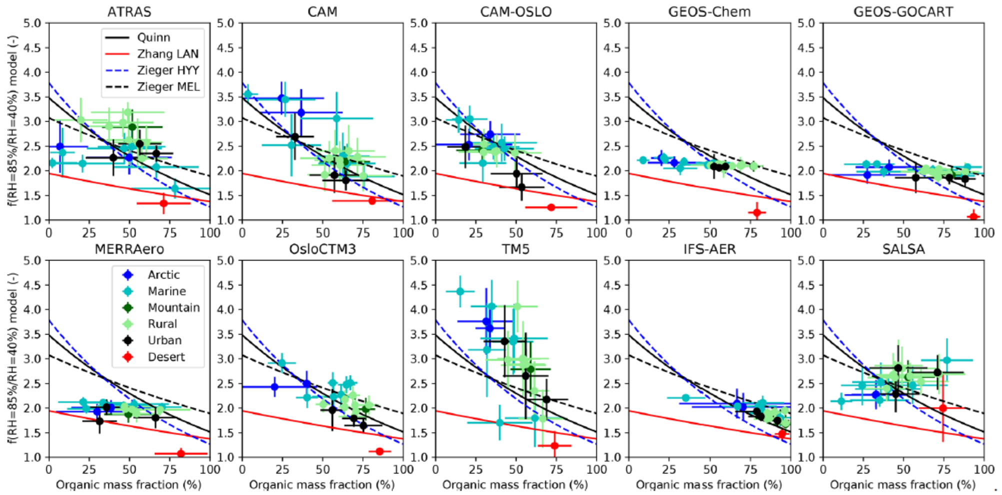
Main characteristics implemented by each model

Main Results:

(1) Modeled vs Measured *f*(RH)

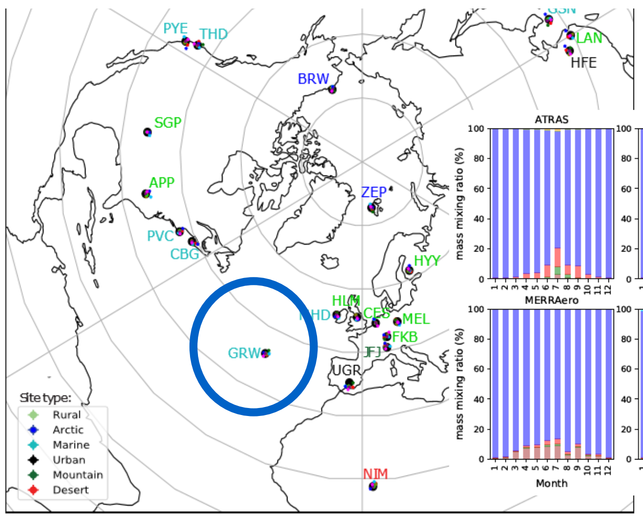


(2) *f*(RH) vs. organic mass fraction

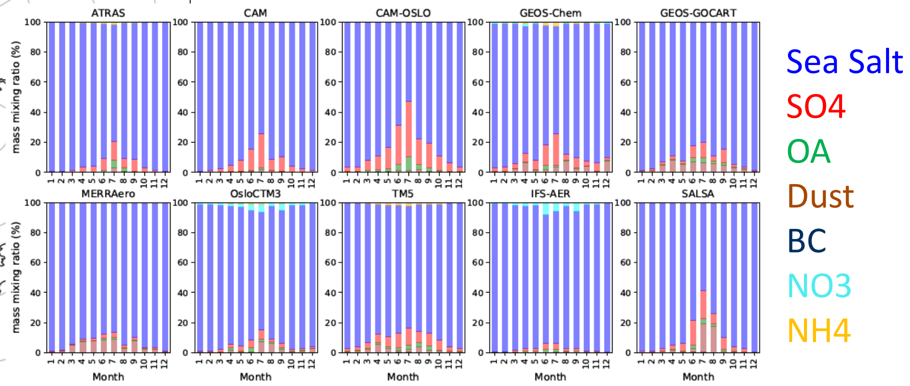


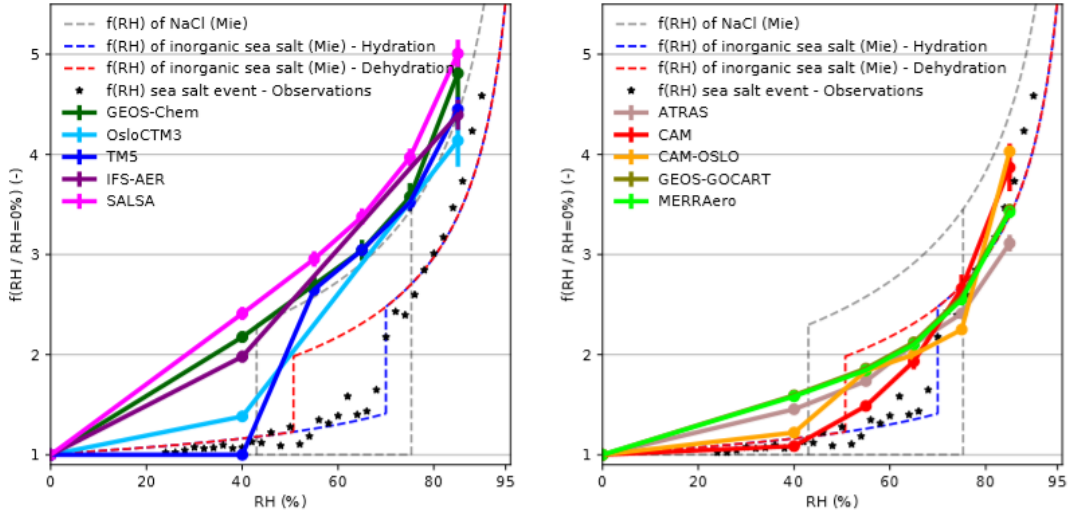
- (Some) models reproduce the range in measured *f*(RH)
- (Some) models: similar *f*(RH)-OMF relationship as parameterizations
- Diversity of behaviors: Good correlation / Inverse correlation

(3) *f*(RH) of sea salt dominated aerosol at Graciosa



Modelled chemical composition





- (Some) models treats sea salt as NaCl
- (Some) models: simulate inorganic sea salt (wrong kappa for NaCl)
- TM5: correctly models salt to be fully solid (=NaCl) as expected, while other models assume growth at RH<40%

Conclusions :

- GEOS-family models assign too much hygroscopicity to all species **->** narrow *f*(RH) range
- Models that best reproduce the observed relationship between *f*(RH) and OMF are those that assume lower hygroscopicity for organics – this allows these models to simulate a wider range of *f*(RH).
- Different assumptions about the hygroscopicity of sea salt explain some model variation at a marine location -> some models assume sea salt can be represented by NaCl, while others do not

Recommendations:

1. Update the hygroscopic parameterization of some components (e.g. sea salt) and parameterizations based on OPAC
2. Reproducing observational-based parameterizations of *f*(RH) using chemical mass fractions
3. Compare models and measurements at similar conditions:
   -> Models: calculate σ at the same variable RH conditions as the measurements
   -> Measurements: control RH_{dry} < 40% + maintaining a narrower RH_{dry} distribution

Proposed AeroCom activities:

1. Experiment with common/improved hygroscopicity scheme for all ESMs
2. *f*(RH) for individual aerosol components from models (see sea spray comparison)
3. Take into account other variables (e.g. size distribution)
4. Study the influence on aerosol (e.g. AOD, radiative forcing, lifetime) and cloud properties with improved hygroscopicity scheme
5. Is it possible to model backscattering? Is it available already? (We could calculate forcing efficiency at dry and wet conditions)