Using Ground Station Data for Improving Model Accuracy

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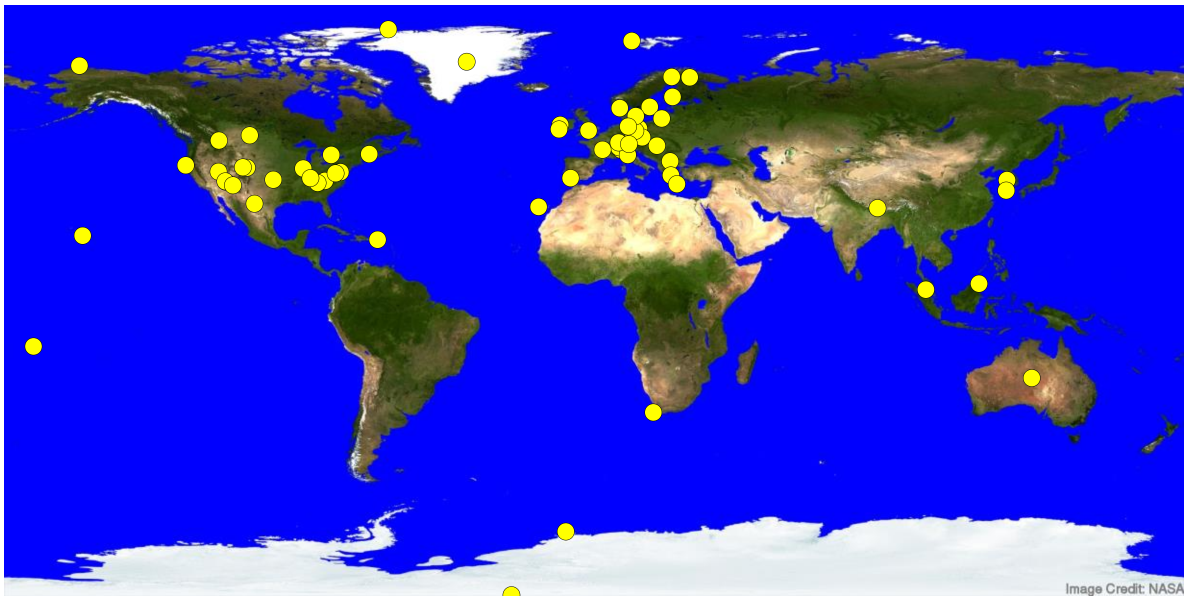
Questions to be Considered

1. **What data are available?**
   Overview over available ACTRIS / GAW datasets
2. **What needs to be considered when using them?**
   Variations in operation procedures.
3. **Why should I use them at all?**
   Comparison with alternative validation data source.
4. **Conclusions**

Active Ground Stations Represented by ACTRIS & GAW



- More sites to come, e.g. Mount Chacaltaya, Bolivia.

- 73 sites worldwide
- Includes European **ACTRIS** sites, **NOAA** network, **IMPROVE** network.
- Ground in situ observations of **particle number concentration / size distribution**, **aerosol scattering / absorption coefficient**, aerosol optical depth.
- Validation, not assimilation dataset.
- Focus on data quality, ACTRIS feeding into GAW and EMEP.
- Most sites in Europe and North America

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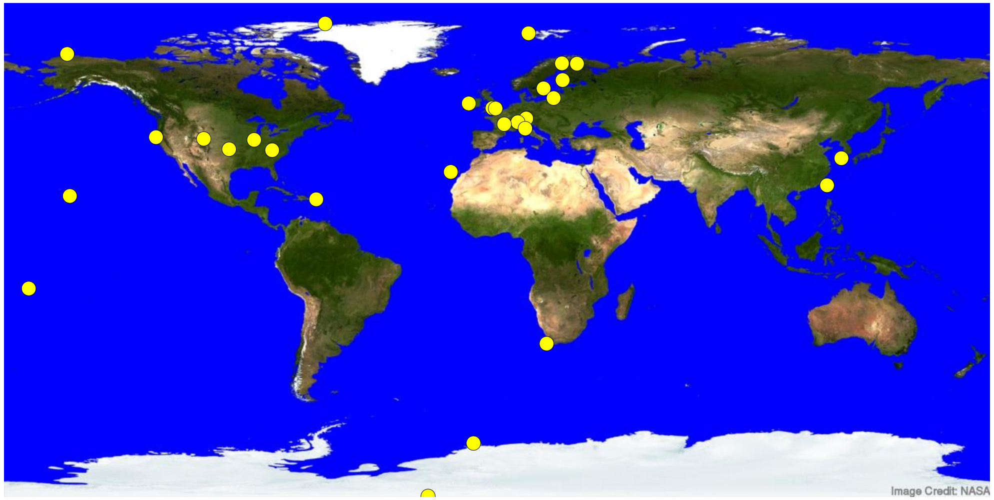
Coverage for Microphysical Parameters

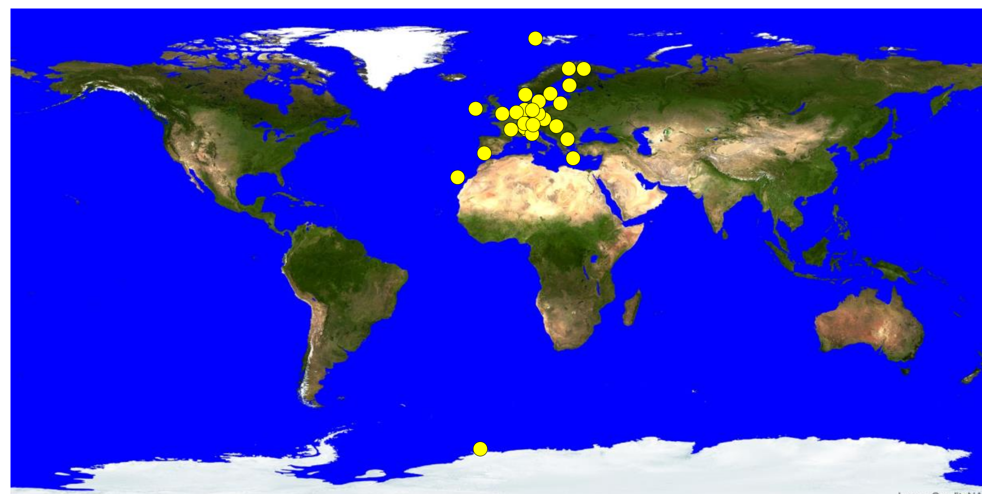


Particle number concentration:

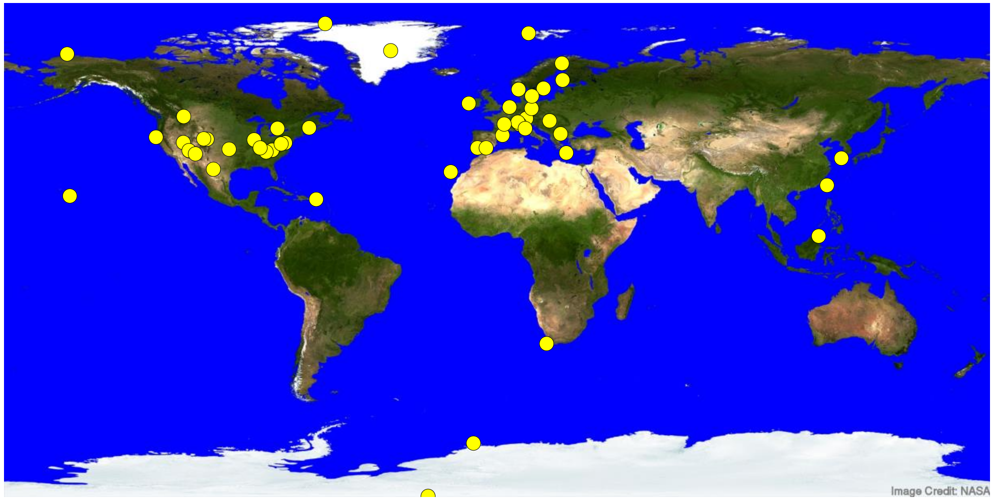
- 29 sites
- 19 sites more than 5 years
- 13 sites more than 10 years

Particle number size distribution

- 28 sites, mainly Europe
- 16 sites more than 5 years
- 5 sites more than 10 years
- **Accuracy: D_p 5%, N 10-15% (ACTRIS)**

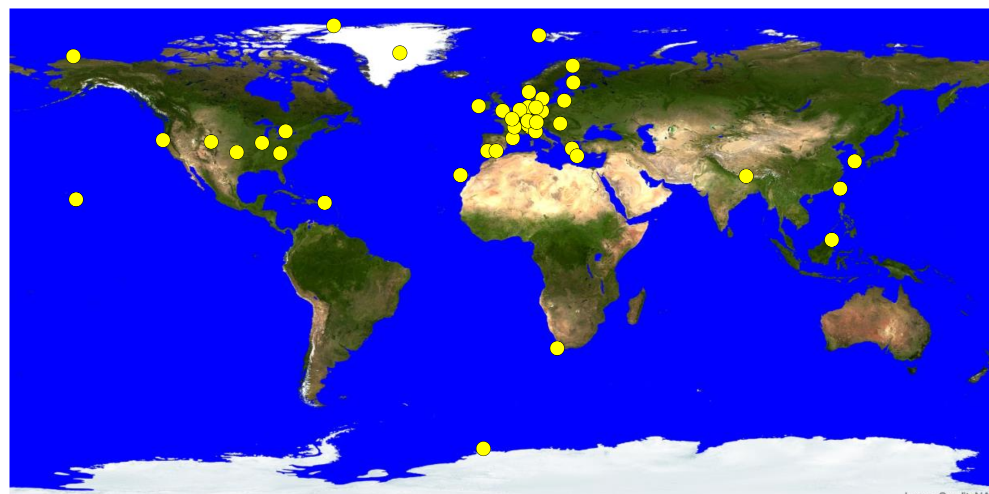


Coverage for Optical Parameters



Aerosol scattering coefficient:

- 50 sites
- 32 sites more than 5 years.
- 16 sites more than 10 years
- **ACTRIS / GAW / IMPROVE QA, accuracy 10% or better.**



Aerosol absorption coefficient

- 48 sites
- 27 sites more than 5 years.
- 9 sites more than 10 years.
- **Accuracy instrument dependent, assessed through ACTRIS**

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Differences in Measurement Protocols

ACTRIS / GAW:

- Parameters (ex. AOD) are recommended to be at “dry-state” (RH < 40%), achieved by diffusion drying or moderate heating.
- Data points with higher RH to be flagged, but reported.
- RH to be reported with data.

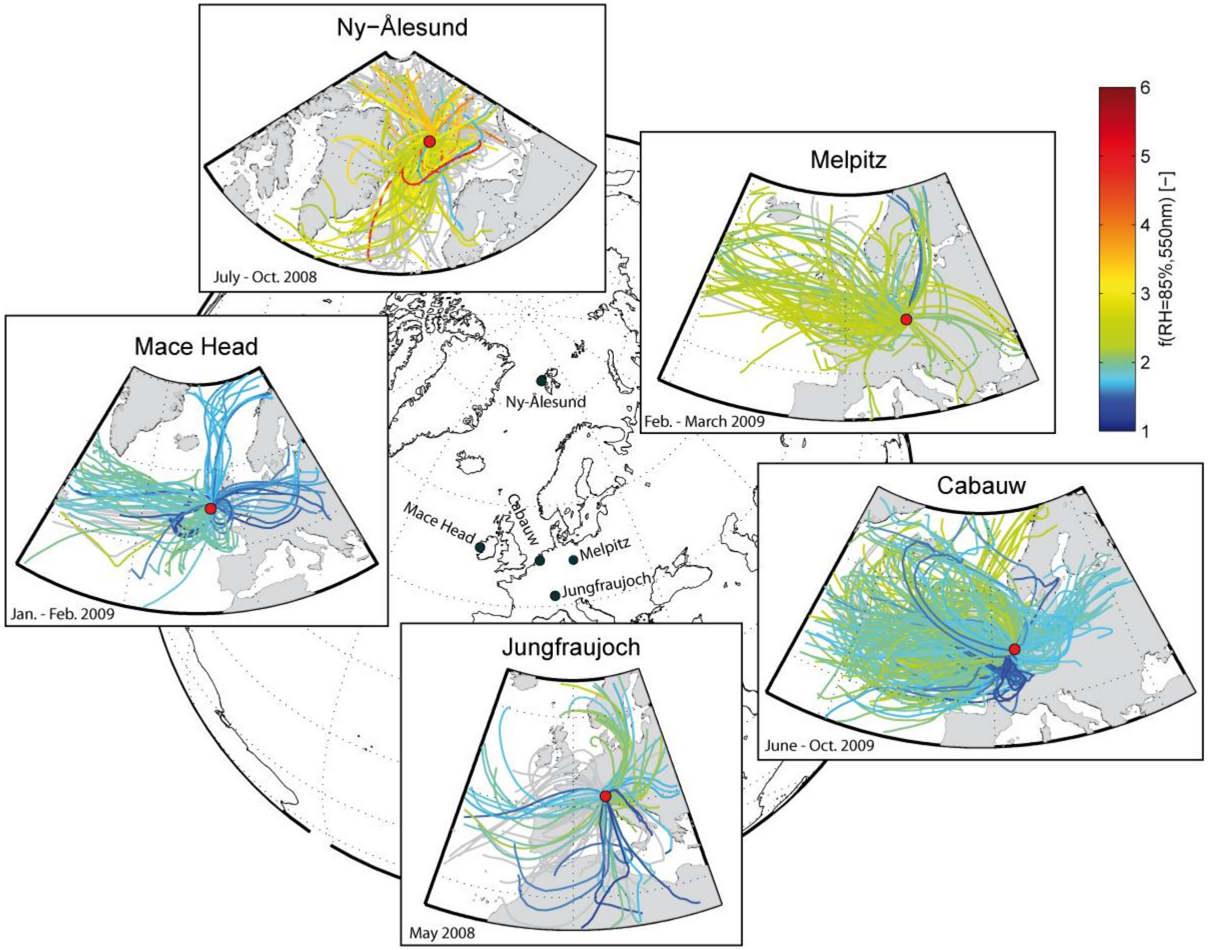
IMPROVE:

- Aerosol scattering coefficient measured at ambient RH.
- RH to be reported with data

Ways of comparing this data to model output:

1. Convert all data to dry-state for comparison under standardised conditions (requires known / assumed humidity growth functions).
2. Generate model output as function of RH, and compare under observation conditions.

No Unique Connection between Aerosol Origin and Humidity Growth



- see Zieger et al., 2013 (ACDP).
- measured aerosol humidity growth factors at 5 European sites.
- Correlated scattering humidity growth factor f(RH) and air origin.
- No correlation found.

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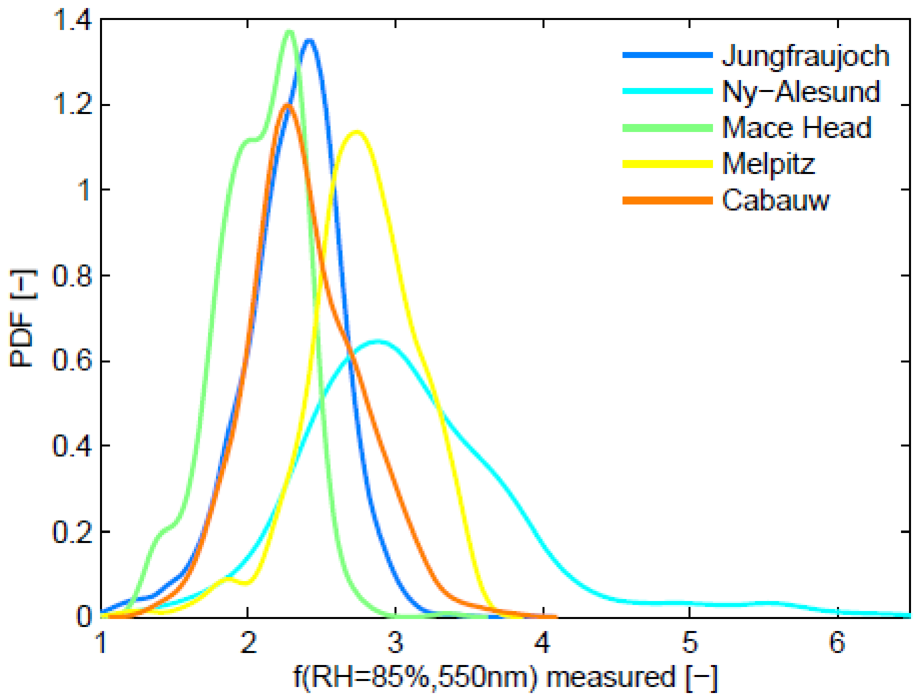
Considerable Variation of Hygroscopic Growth at Each Site



see Zieger et al., 2013 (ACDP).

- Assuming a constant humidity growth function per site implies a systematic uncertainty of ~40%.
- Correcting data measured at ground sites to homogenous dry-state will cause systematic uncertainty on the same order.
- Reliable humidity correction to dry-state requires aerosol chemical composition measured online (not routine, ACTRIS task).
- Model-data comparison must be at measured RH, model output as function of RH

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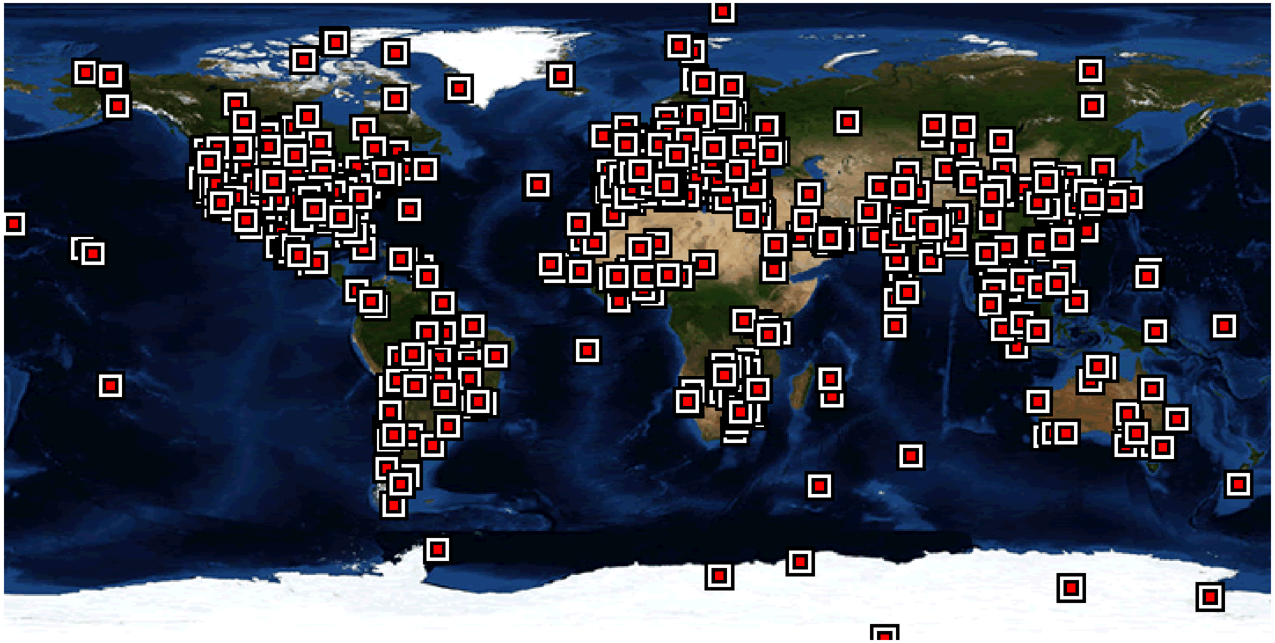
Why Should I Then be Bothered to Use Ground Station Data for Model Validation?



AERONET:

- 873 sites
- (Almost) worldwide coverage.
- Homogeneous instrumentation.
- Central, homogeneous quality assurance and data format. **ACTRIS supports European calibration centre**
- Centrally QAed spectral AOD.
- Homogeneous retrieval of part. size dist. and SSA

- **BUT**: issues concerning possible ambiguity of retrieval products.

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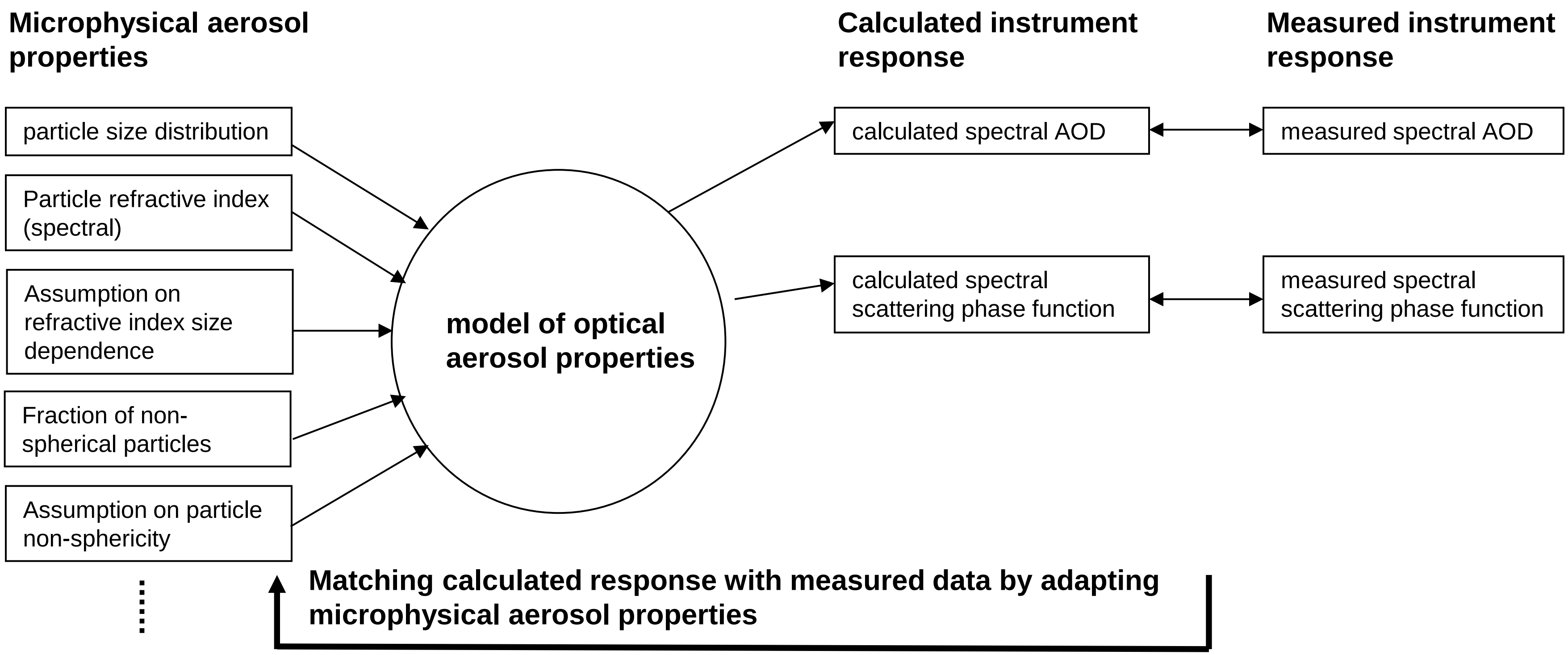
Some Essential Basic Aspects on Retrieval



- Increasing number of free parameters will always improve fit – not necessarily for the right reason.
- Measured properties need to have strong dependence on parameters to be constrained.
- In case of 2 (or more) parameters with similar dependence, assumptions are needed, test for bias required.
- Uniqueness and accuracy of result usually needs to be shown by mapping out result-space: generate synthetic data, test whether retrieval works accurately or discovers mismatch
- **Information content analysis!**

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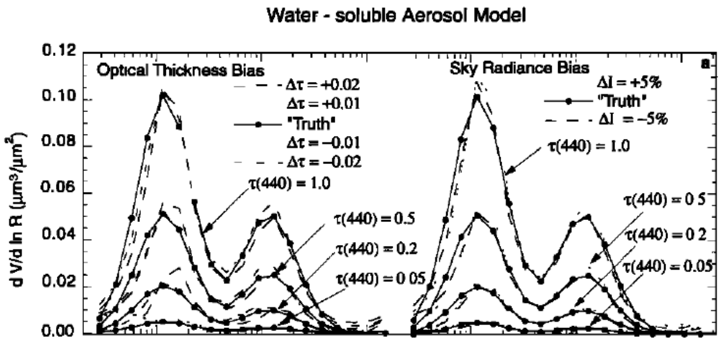
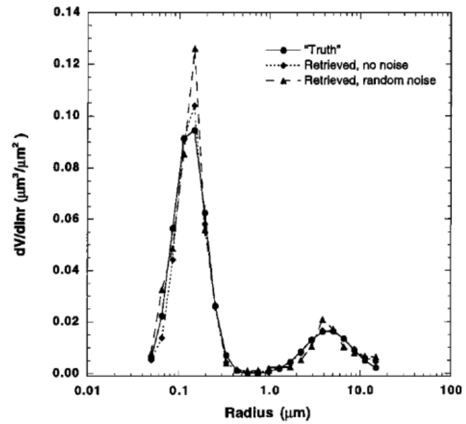
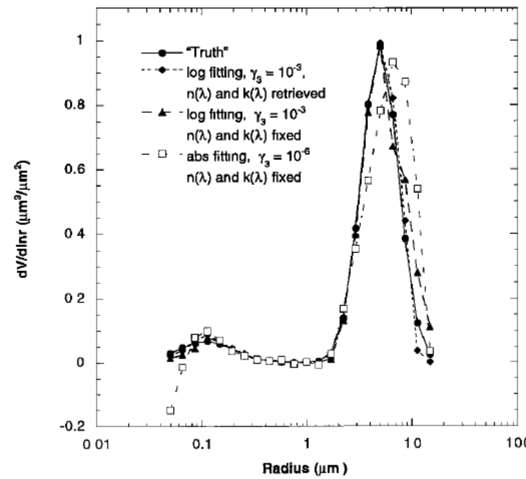
Issues About AERONET Retrieval







Dubovik & King, JGR, 2000

Dobovik et al., JGR, 2000

Number of Test Cases:
max. 6 test cases documented, “many more” mentioned, but undocumented – too few to map out result space.

Particle Outside Retrieval Range:
Reported test cases contain particles only within retrieval range (D_p 0.1-30 µm). Effect of particles outside retrieval range not assessed.

Assumption on Size Independent Refractive Index:
assumes one refractive index for all particle sizes, but BC is concentrated in fine particles. Effect of assumption on retrieved size distribution not assessed.

→ accuracy of AERONET retrieval products is somewhat unknown.

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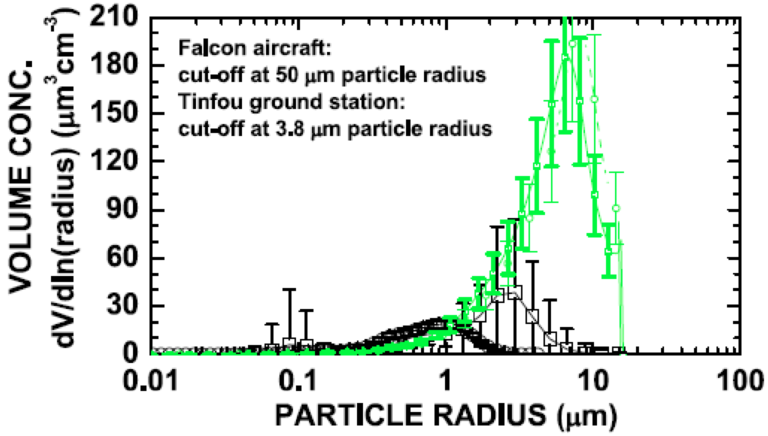
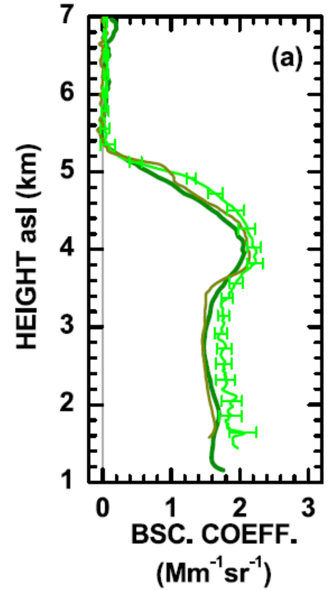
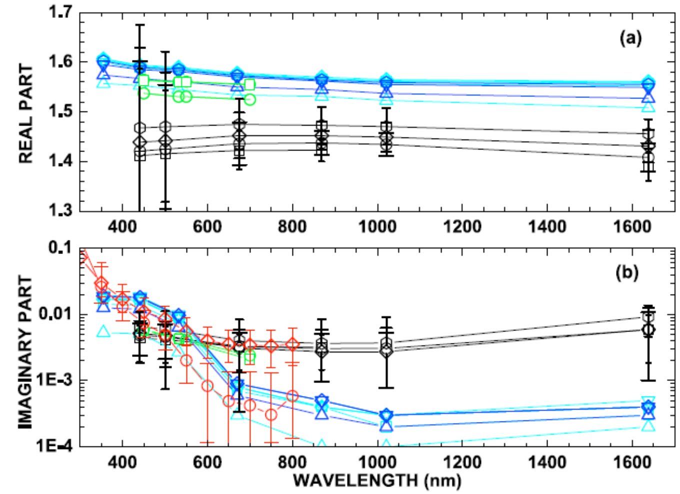
Example 1: Desert Dust During SAMUM







- Data collected on 19 May 2006 at Ouarzazate, Morocco, during Saharan Mineral Dust Experiment (SAMUM), taken from Müller et al., JGR, 2010.
- Particle size distribution measured on ground, on aircraft (3.2, 4.8 km), retrieved by AERONET.
- Airborne and ground-based lidar backscatter, profiles.
- Refractive index from AERONET retrieval and from single particle mineralogy.
- AERONET doesn't see coarse mode seen by aircraft, even though particles are within retrieval range.
- Compensated by adjustment of refractive index.

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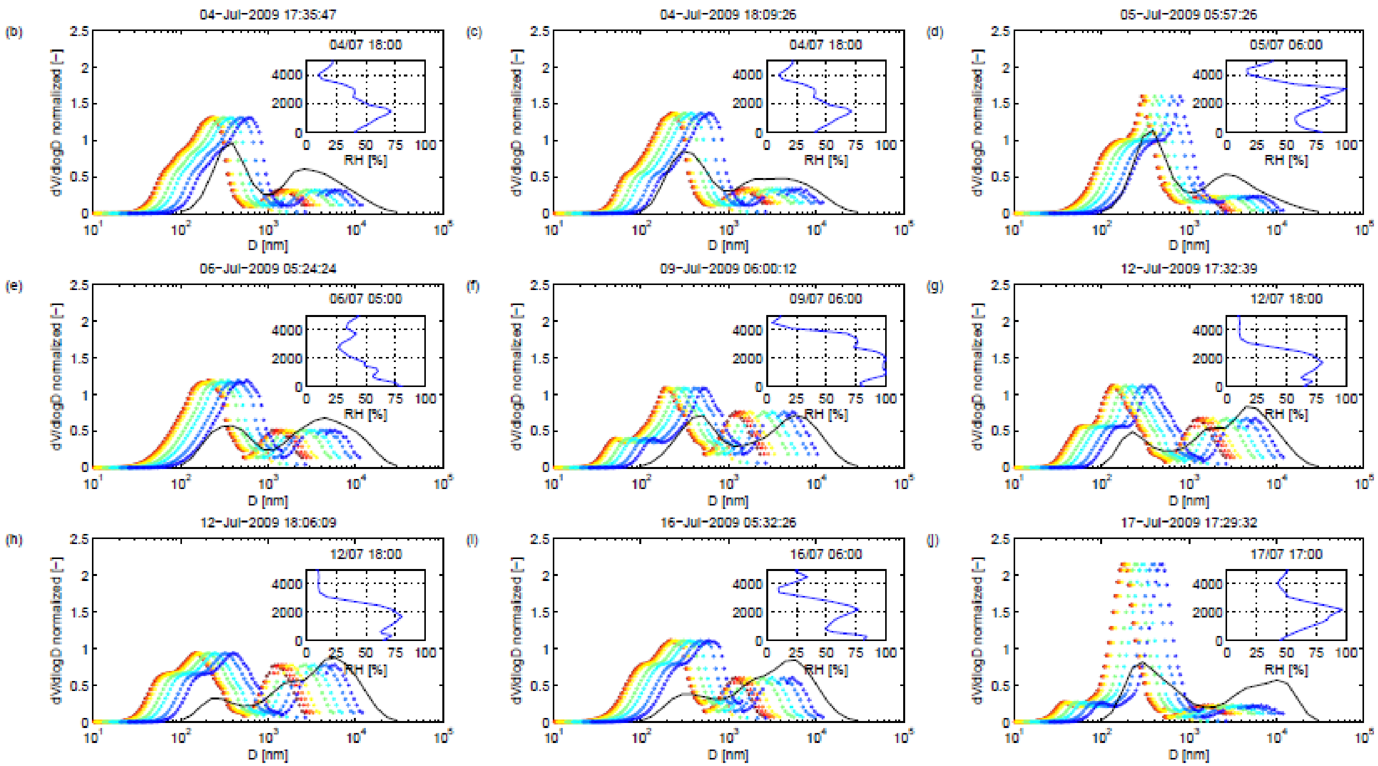
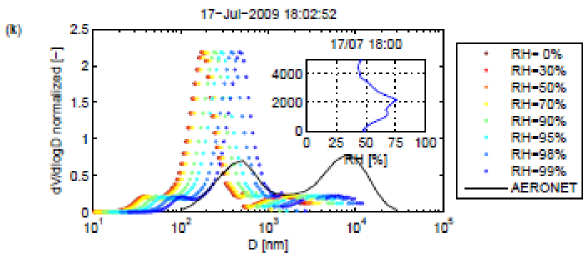
Example 2: Particle Size Distributions at Cabauw



Credits: P. Zieger



- Particle size distribution measured on ground (dry-state) and by AERONET retrieval.
- Size distribution (ground) corrected to RH between 0-99% using online chemistry and growth model.

- Even though AERONET represents whole column, it's surprising that ground and column distributions are that decoupled

Example 3: AOD and SSA over Brussels

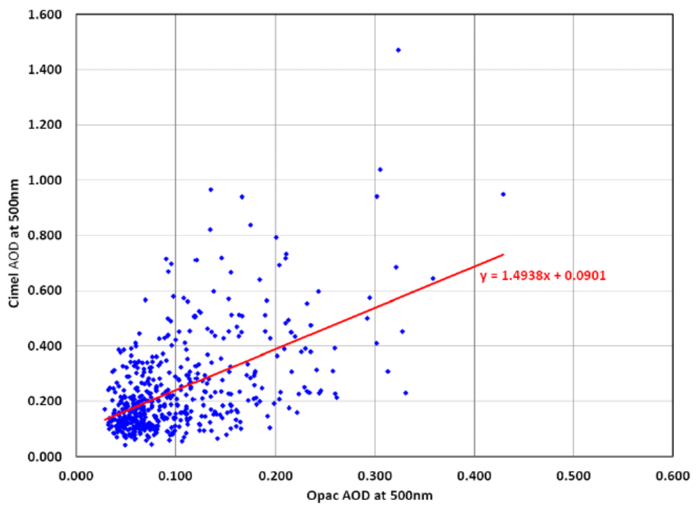


Figure 1. Comparison of Cimel AOD values and modeled OPAC AOD values, both at 500nm.

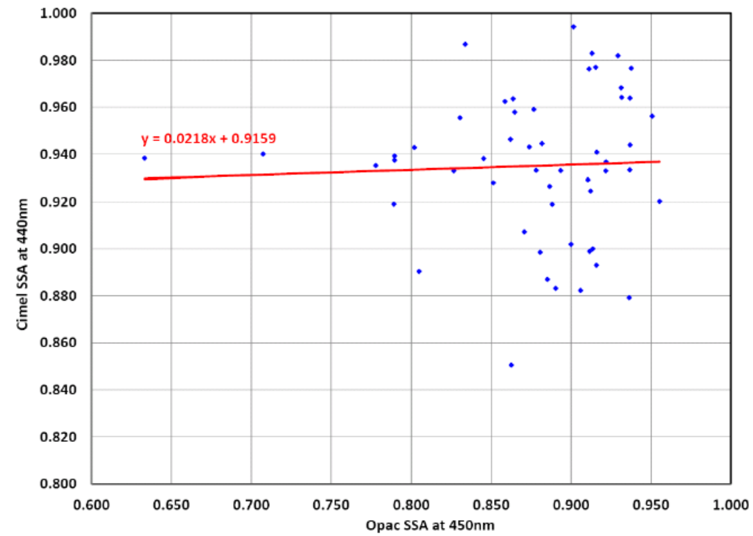


Figure 2. Comparison of Cimel SSA values at 440nm and modeled OPAC SSA values at 450nm.

Credit: **De Bock, V.,** Delcloo, A., Mangold, A., De Backer, H., Royal Meteorological Institute of Belgium

- AOD and SSA modelled with CHIMERE regional CTM, combined with OPAC optical properties, for period 1991-2010.
- Compared with AERONET measured AOD and retrieved SSA.
- Clear correlation in AOD between model and AERONET, but no correlation in SSA – surprising, even though considering uncertainties and OPAC issues.

Conclusions

1. **Use ground station in situ data for validation!**
   Sparse in space, represent surface only, but they are accurate and have long time series.
2. **There is more than chemical composition and EBC!**
   Particle size distribution is fundamental to "everything", see Graham Mann's article.
3. **Choose comparison variable to minimise assumptions / maximise accuracy, e.g.**
   1. Use absorption coefficient, not EBC as comparison variable.
   2. Compare properties at RH of measurement, avoid uncertainties of conversion to ambient RH or homogeneous dry-state.
4. **Weigh different sources of validation data according to their accuracy.**

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Outlook

- ACTRIS will soon start to collect data on CCN concentration as function of supersaturation, for some sites also as function of particle size.
- Ongoing effort to collect data on coarse mode particle size distribution, currently only fine mode covered.