GRASP updates:

aerosol- surface – gases

joint retrievals

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Marcos Herreras-Giralda, Masahiro Momoi, Anton Lopatin and Fernando Rejano

- **GRASP SAS, Remote sensing developments, Lesennes, France.**

Rene Preusker and Jurgen Fischer

-SpectralEarth, Berlin, Germany

Julian Grebner, Natalia Kouremeti and Stelious Kazadzis

- PMOD, Davos, Switzerland .

LOA LABORATOIRE D'OPTIQUE ATMOSPHÉRIQUE

GRASP

Université de Lille

Freie Universität Berlin

pmod wrc

Objective: Developing methodologies for **validation** and **improving** of **aerosol**, **surface** reflectance (BRDF and BPDF) and **gases retrieval** and modeling in remote sensing

TASKS:

- ✓ **Joint retrieval aerosol** and **surface** reflectance; — **WP-2130**
- ✓ **Optimizing aerosol** and **surface** reflectance models;

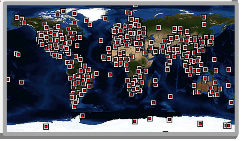
- ✓ **Inclusion of gas parameters in the GRASP retrieval** — **WPs-2131-2132**
- ✓ **Retrieval of aerosol properties from GAWPFR, and AERONET 1640 nm validation** — **WPs-2670-2675**

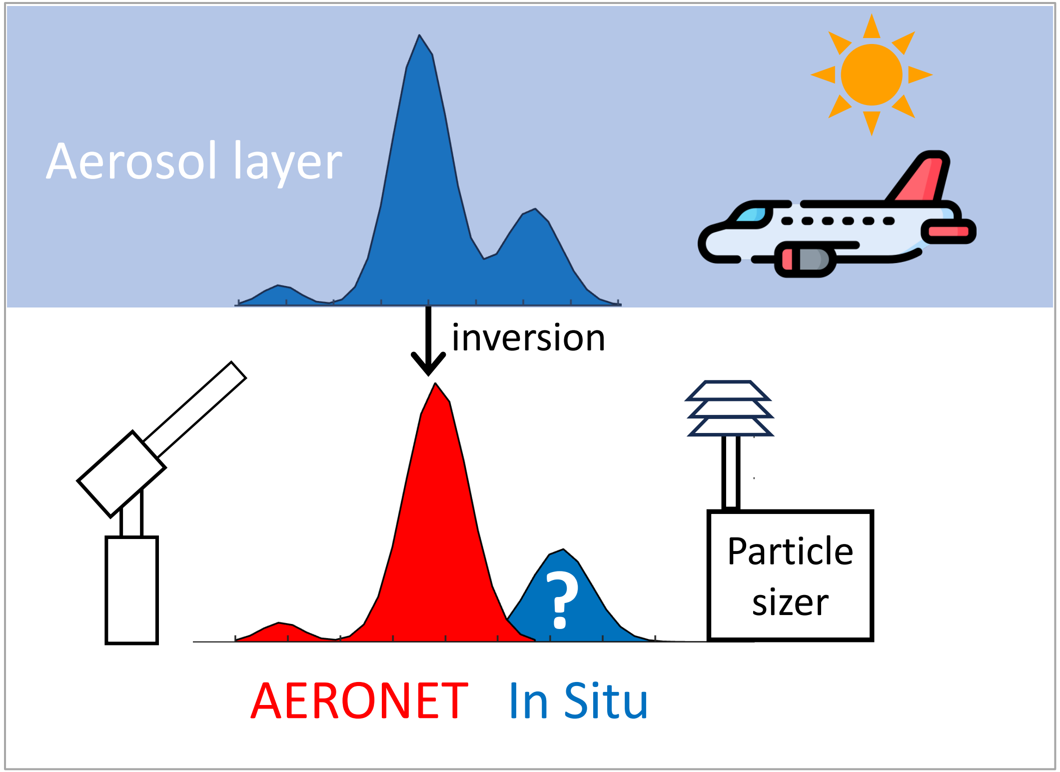
WP-2130

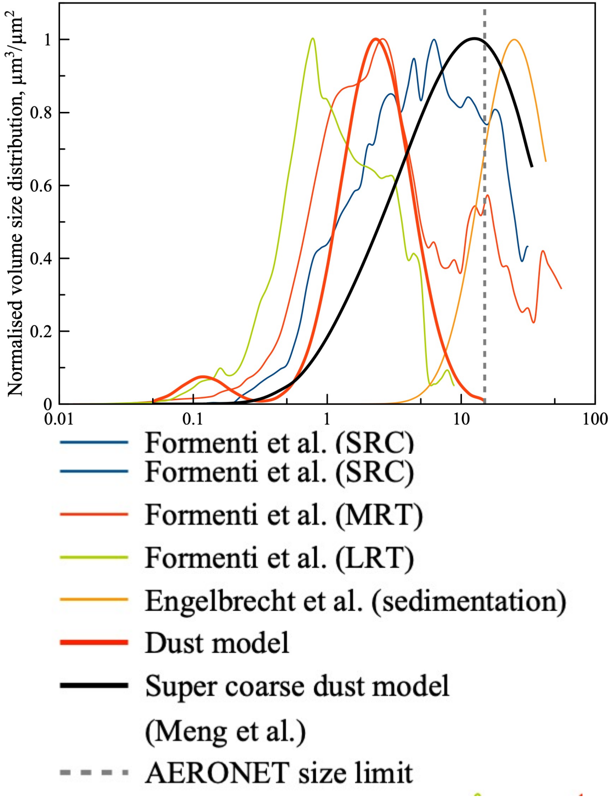
Are super coarse particles visible from remote sensing?

Collaborations with AERONET

Elena Spinei Lind,
Alexander Sinuyk, etc.

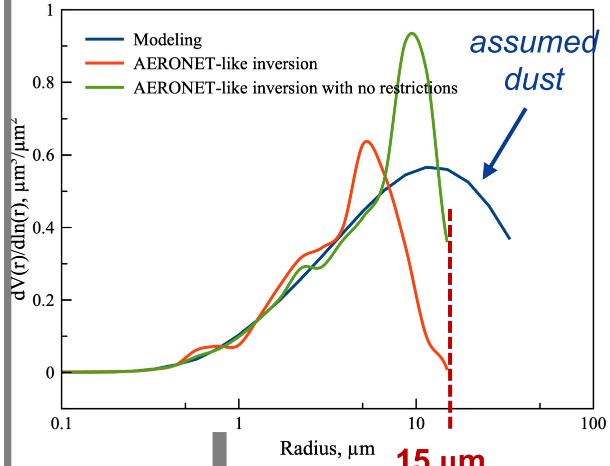


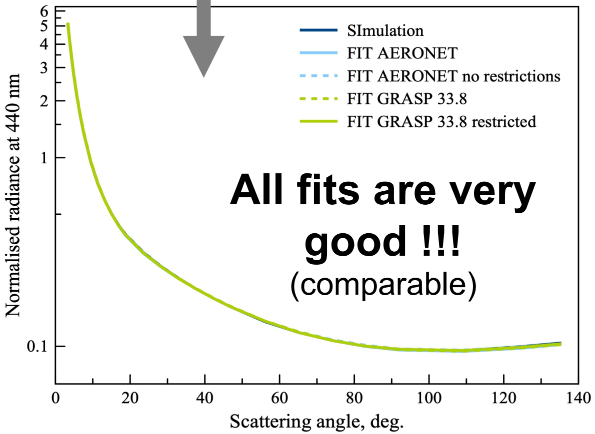




AERONET retrieval

R_{max} = 15 μm





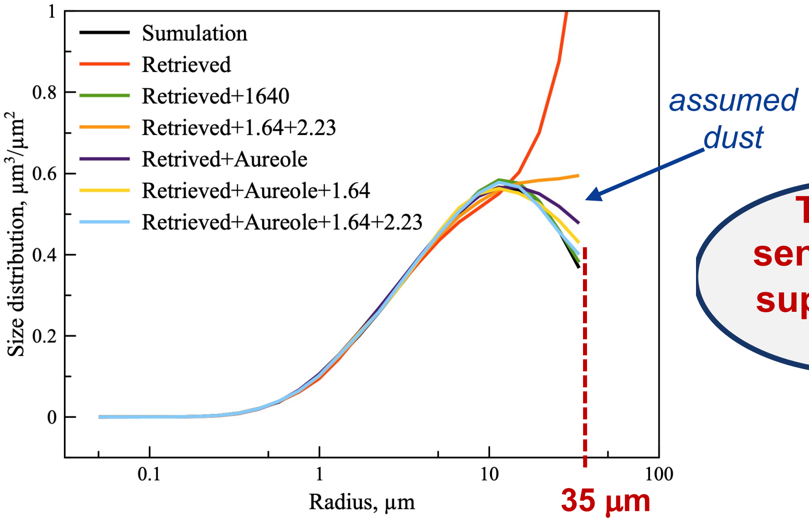
« optimized » retrieval

✓ **Optimizing retrieval algorithm:**

- R_{max} → 35 μm in the retrieval;
- relaxing a priori constraints for extreme size;

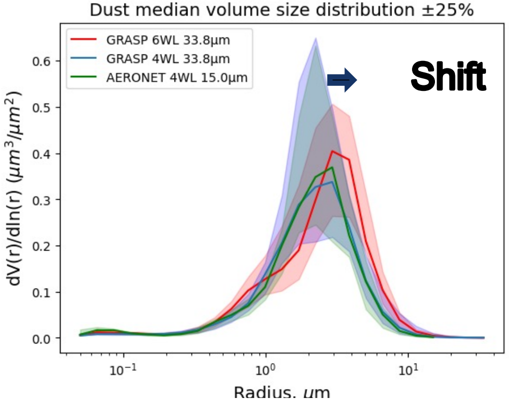
✓ **Increasing information content of observations:**

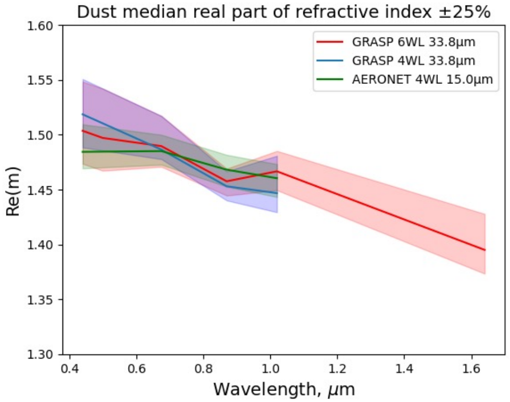
- extending spectral coverage (SWIR 1.64 and 2.2 μm);
- extending aureole measurement to the smaller scattering angles;

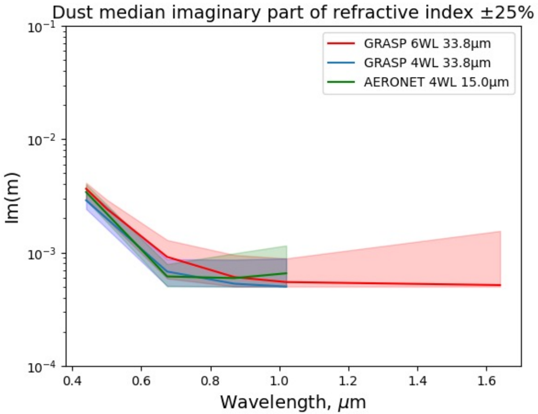


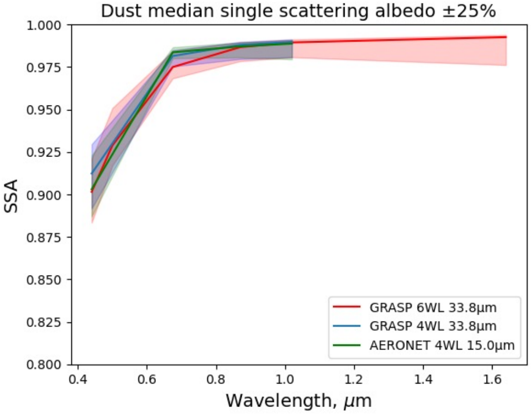
There is sensitivity to super coarse sizes!

Real observations processing: selection of **very low AE** cases with **1.64 µm**









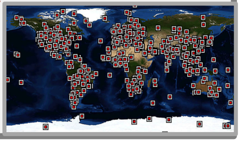
Preliminary conclusions:

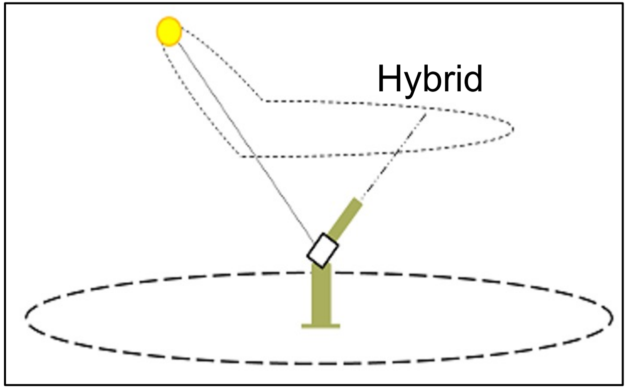
- ✓ **There is some sensitivity** for observing super coarse dust;
- ✓ **Shape of size distribution** for extreme sizes remains **somewhat uncertain**;
- ✓ **Extending max size** in retrieval **to ~ 35 µm** can be recommended for **AERONET processing** ;
- ✓ **Analysis of AERONET observations** of extreme dust events **didn't suggest** **significant** presence of super coarse particles;

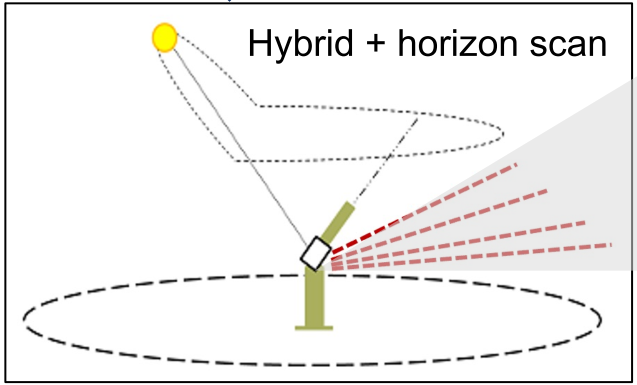
Potential of near-horizon AERONET observations for aerosol profiling

Collaborations with AERONET

Elena Spinei Lind, A. Sinuyk, T. Eck.

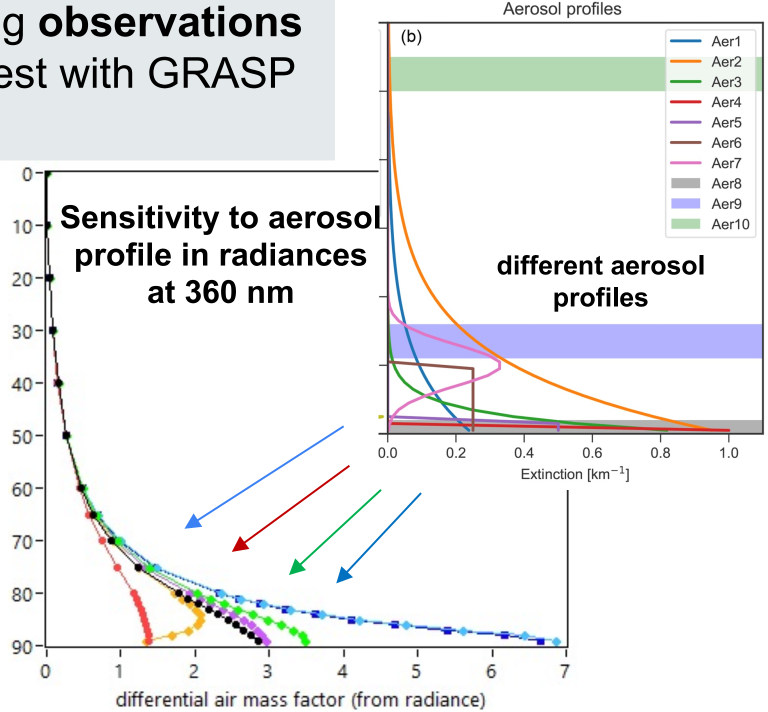






<u>TASK</u>: to simulate **near-horizon** radiometer sky scanning **observations** (e.g. **AERONET**) and test with GRASP for **aerosol profiling**

Observations at $75^0 < VZA < 89^0$ sensitivite to aerosol profile



Lind, et al., 2024 (in preparation)

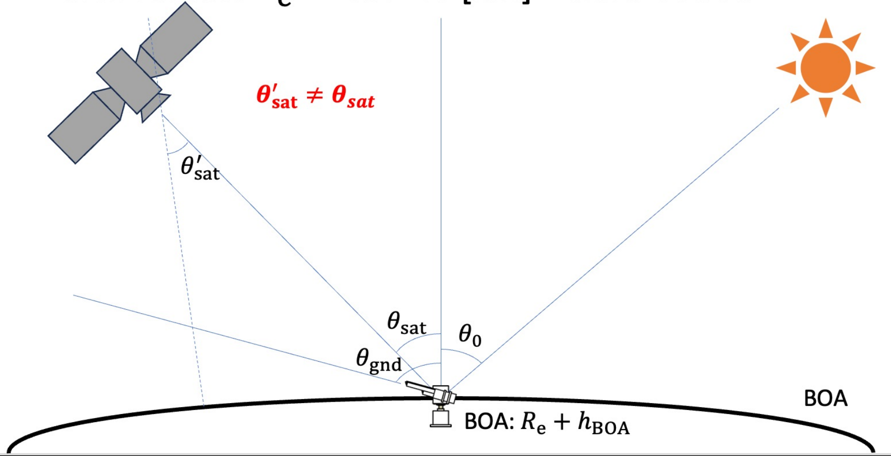
WP 2130:

Accounting for Earth sphericity in GRASP radiative transfer calculations

M. Momoi

Pseudo – Spherical Radiative Transfer

- Coordination: at BOA & target pixel ($\theta_0, \theta_{\text{sat}}, \theta_{\text{gnd}}$)
- Earth radius: R_e = 6371.0 [km] – hard-coded



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journal homepage: www.elsevier.com/locate/jqsrt

An improved pseudo spherical shell algorithm for vector radiative transfer

Peng-Wang Zhai[a,*], Yongxiang Hu[b]

[a] Department of Physics, University of Maryland Baltimore County, Maryland, USA
[b] MS 475, NASA Langley Research Center, Hampton, VA 23681-2199, USA

Plane-parallel: $L_{\text{PP}} = L_{\text{SS,PP}} + L_{\text{MS,PP}}$

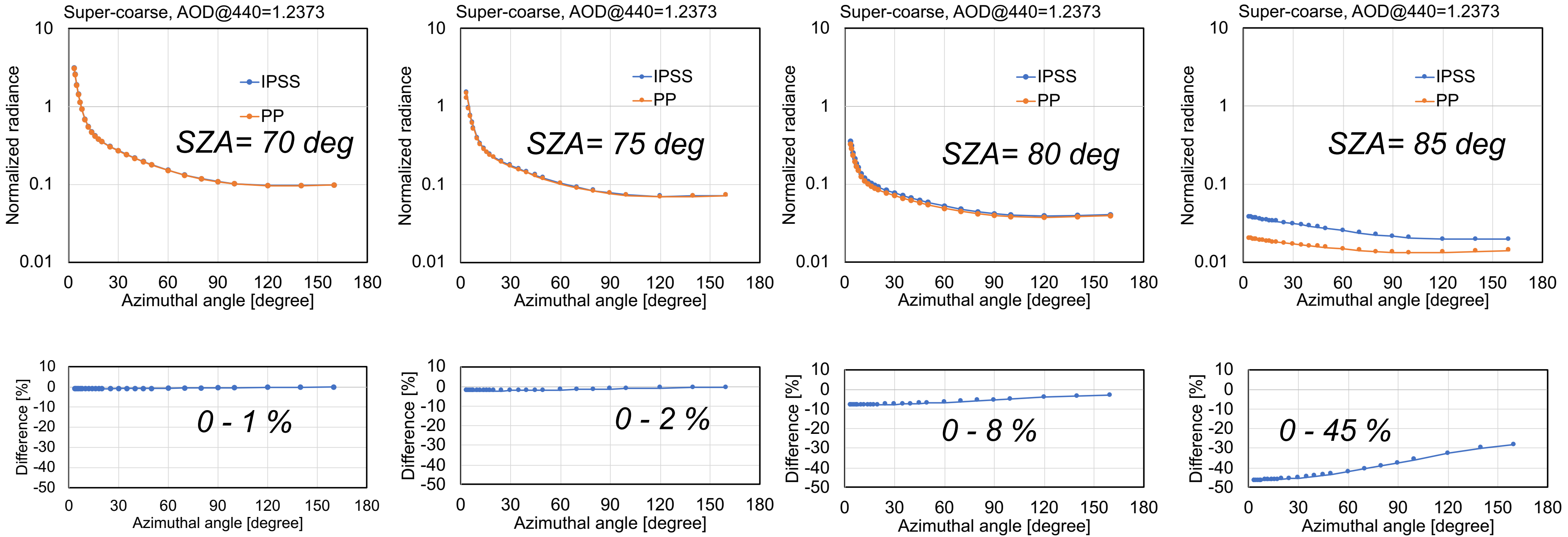
Improved pseudo spherical shell: $L_{\text{IPSS}} = L_{\text{SS,IPSS}} + \frac{L_{\text{SS,IPSS}}}{L_{\text{SS,PP}}} L_{\text{MS,PP}}$

Modifications: exacting SS (single scattering) term in spherical shell + correcting MS (multiple scattering) term from PP (plane parallel) term

WP 2130:

M. Momoi

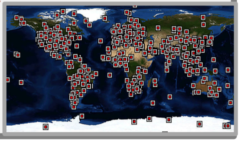
Effect of the Earth sphericity for almucantar observations



Potential of near-horizon AERONET observations for aerosol profiling

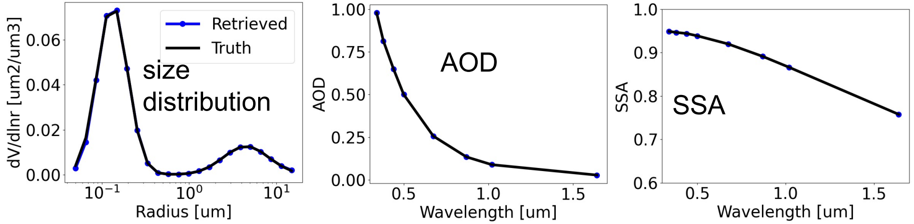
Collaborations with AERONET

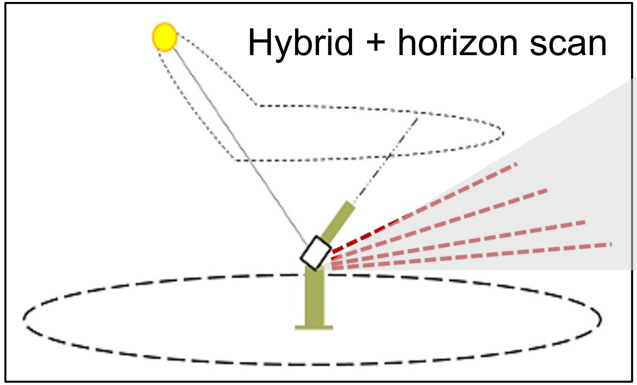
Elena Spinei Lind, A. Sinuyk, T. Eck.



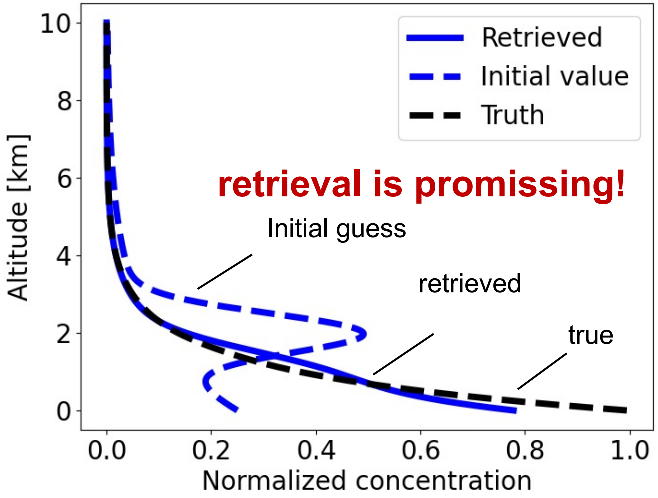
TEST: inlcude **near-horizon AERONET observation simulations** and attempt **aerosol profiling** with GRASP

Full retrieval





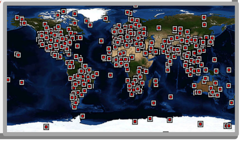
Observations at $75^0 < VZA < 89^0$ sensitivite to aerosol profile



Potential of synergy between AERONET and PGN observations for aerosol profiling

Collaborations with AERONET

Elena Spinei Lind,
A. Sinuyk, T. Eck.



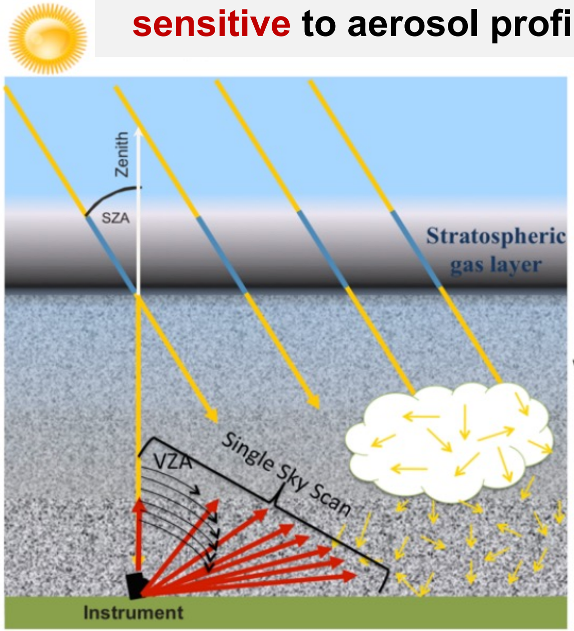
AERONET calibrated absolute radiances:

- Standard AERONET observation protocol;
- At different elevation angles (similar to multi-axis DOAS but at AERONET channels)

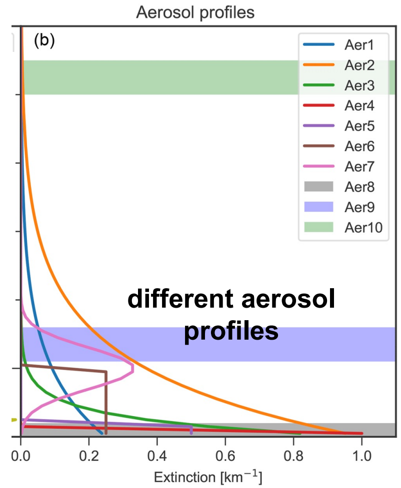
PANDONIA GLOBAL NETWORK (PGN) spectral measurements:

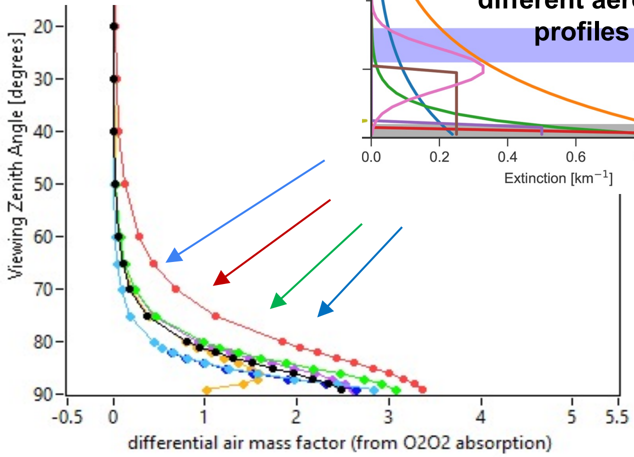
- Differential slant column densities of O_2O_2;

Pandora O_2O_2 absorption measurements are sensitive to aerosol profile



Differential air mass factor from PANDORA O_2O_2 absorption measurements



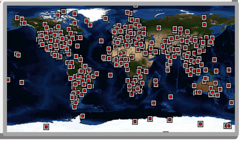


Lind, et al., 2024 (in preparation)

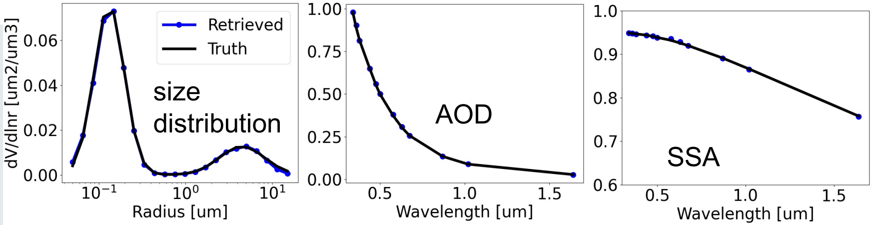
Potential of synergy between AERONET and PGN observations for aerosol profiling

Collaborations with AERONET

Elena Spinei Lind,
A. Sinuyk, T. Eck



TEST: attempt **aerosol profiling** with GRASP using **AERONET radiances + PGN ΔSCD of O_2O_2**

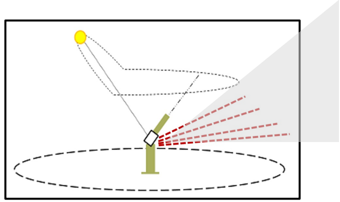


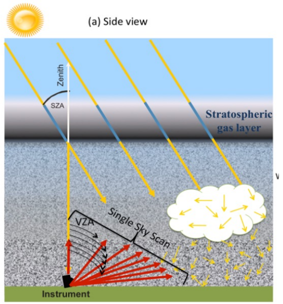
AERONET calibrated absolute radiances at:

- standard AERONET observation protocol;
- different elevation angles (similar to multi-axis DOAS but at AERONET channels)

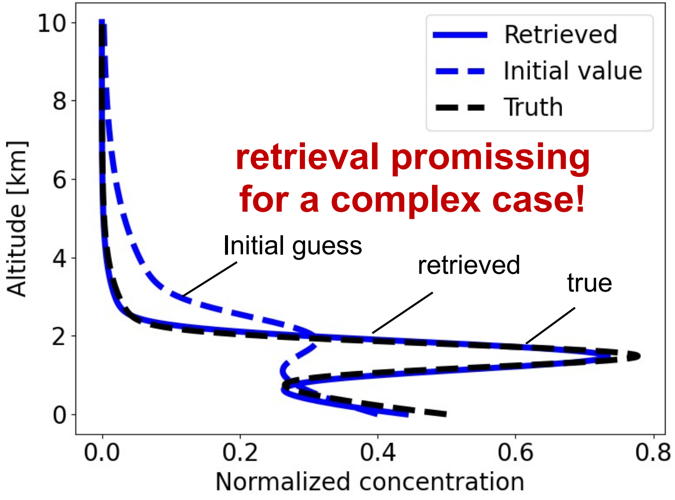
PANDONIA GLOBAL NETWORK (PGN) spectral measurements:

- Differential slant column densities (ΔSCD) of O_2O_2





Full retrieval



Lind, et al., 2024 (in preparation)

Synergy retrievals using GRASP for CINDI-3

Target properties for retrieval:

- **Total aerosol columnar**: size distributions, complex index of refraction, SSA, non-sphericity fractions, etc.;
- **Aerosol vertical profile**: concentration and extinction

Observations:

AERONET calibrated absolute radiances:
- Standard AERONET observation protocol;
- At different elevation angles (similar to multi-axis DOAS but at AERONET channels)

PANDONIA GLOBAL NETWORK (PGN) spectral measurements:
- Differential slant column densities of O_2O_2

LIDAR vertical profiles:
- Back-scattering, depolarization, extinction at multiple wavelengths

+

AERONET

+

PGN

- **Fine and coarse columnar**: size distributions, complex index of refraction, SSA, non-sphericity fractions, etc.;
- **Fine and Coarse vertical** (from low to higher layers): concentrations profiles, etc.
- **Total vertical**: SSA, extinction profiles, etc.
- **Gas profiles** (potentially) : NO_2, HCHO, H_2O, etc.

ground-based

Synergy retrievals using GRASP for CINDI-3

Observations:

AERONET calibrated absolute radiances:
- Standard AERONET observation protocol;
- At different elevation angles (similar to multi-axis DOAS but at AERONET channels)

PGN spectral measurements:
- Differential slant column densities of O_2O_2 and O_2 (e.g. A band);

LIDAR vertical profiles:
- Back-scattering, depolarization, extinction;

TROPOMI TOA radiances.

ground-based+ sattelite

\+

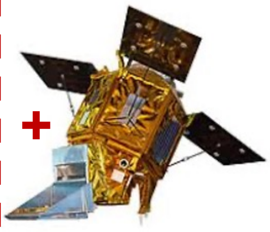
AERONET

\+

PGN

TROPOMI

\+



Retrieved properties”

- **Total aerosol columnar**: size distributions, complex index of refraction, SSA, non-sphericity fractions, etc.;
- **Aerosol vertical profile**: concentration and extinction
- **Gas profiles** (potentially) : NO_2, HCHO, H_2O, etc.
- **Surface** » albedo, BRDF

- **Fine and coarse columnar**: size distributions, complex index of refraction, SSA, non-sphericity fractions, etc.;
- **Fine and Coarse vertical** (from low to higher layers): concentrations profiles, etc.
- **Total vertical**: SSA, extinction profiles, etc.
- **Surface** » albedo, BRDF
- **Gas profiles** (potentially) : NO_2, HCHO, H_2O, etc.

Instrumental Set-up

AERONET sunphotometer (CIMEL):

- TOD: 440, 675, 870 and 1020 nm
- Sky radiance: 440, 675, 870 and 1020 nm

Pandora spectrometer (Lufblick):

- Sky radiance: 435 to 971 nm, O2-O2 region

BTS spectrometer (PMOD-WRC):

- TOD from 350 to 2150 nm

QASUME spectrometer (PMOD-WRC):

- TOD from 280 to 550 nm

Instrumental Set-up

AERONET sunphotometer (CIMEL):
- TOD: 440, 675, 870 and 1020 nm
- Sky radiance: 440, 675, 870 and 1020 nm

Pandora spectrometer (Lufblick):
- Sky radiance: 435 to 971 nm, O2-O2 region

Combined

Complex Aerosol model:

22 bin size distribution
Refractive index
ALH

Gas concentrations:

H2O
NO2
O3

BTS spectrometer (PMOD-WRC):
- TOD from 350 to 2150 nm

QASUME spectrometer (PMOD-WRC):
- TOD from 280 to 550 nm

Combined

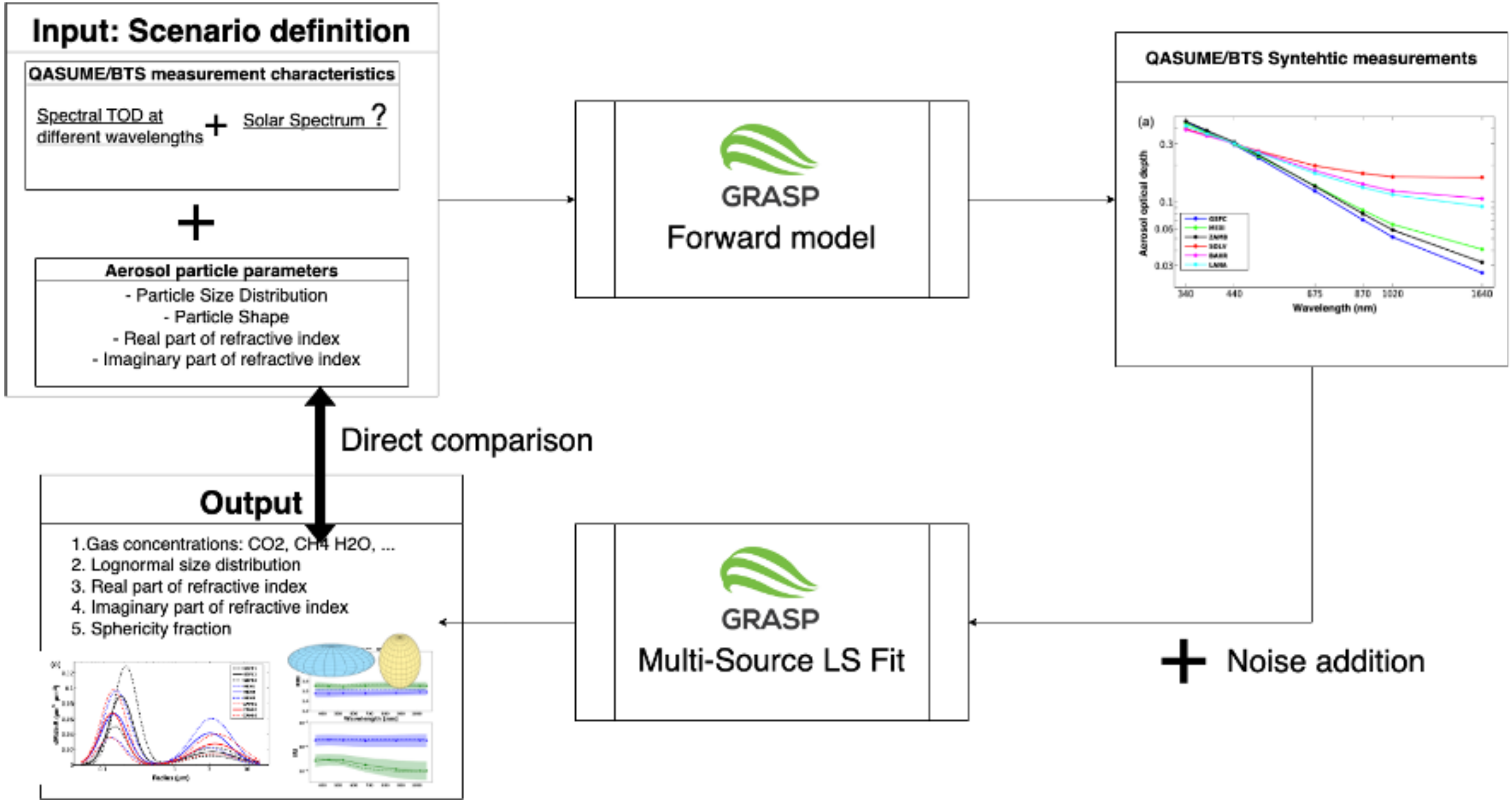
Simplified aerosol model:

Bimodal lognormal

Gas concentrations:

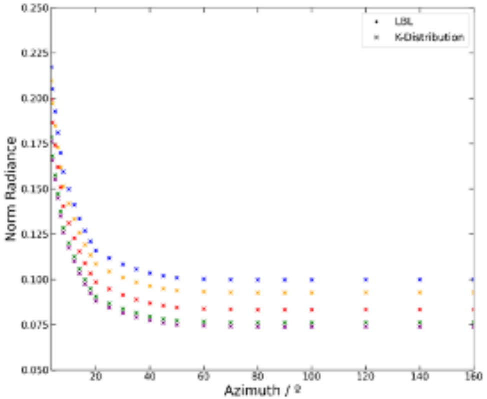
H2O CH4
NO2 O3
CO2

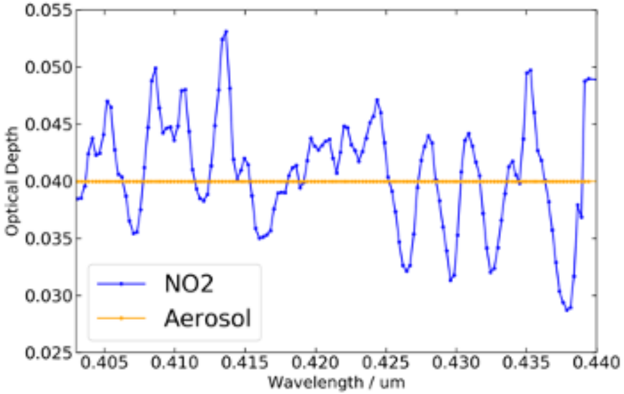
GRASP synthetic tests structure



Optimizing the use of the available data

Angular sampling vs spectral sampling



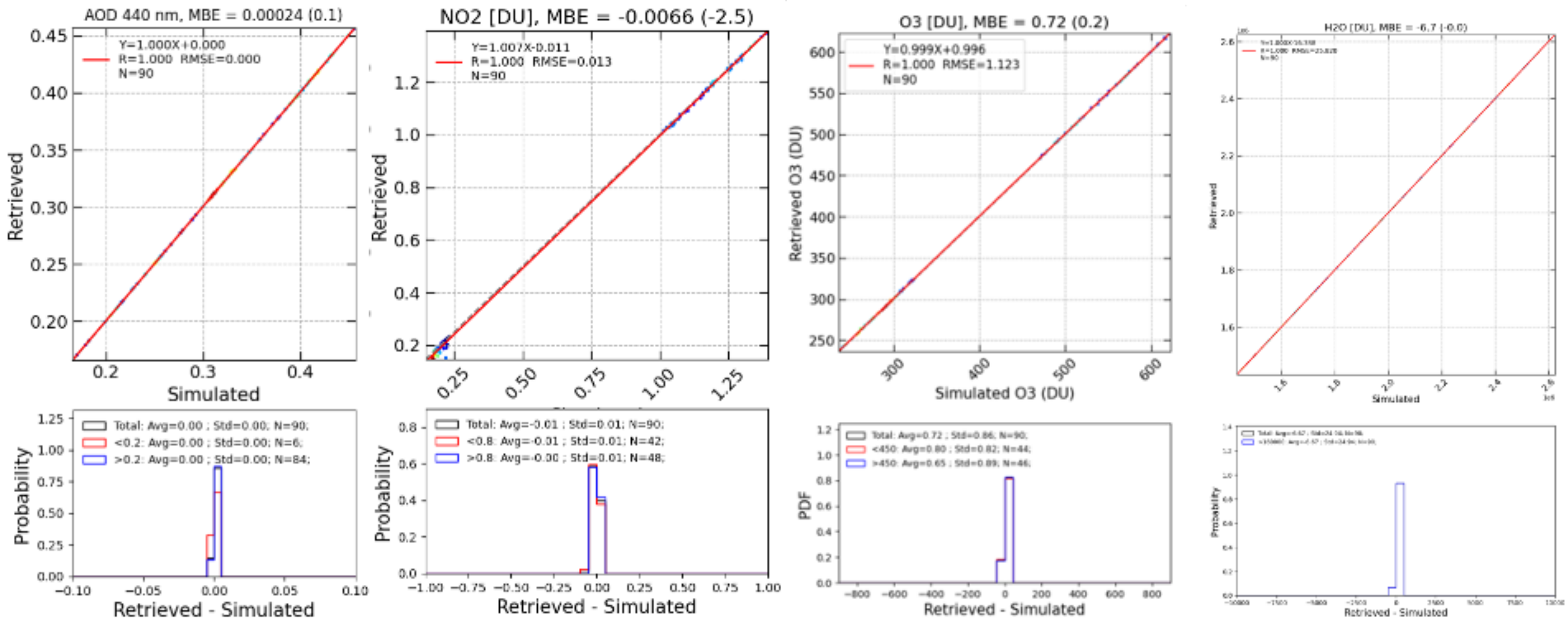


Two configurations were tested, AERONET +:

- 15 pandora channels at 26 angles
- 100 pandora channels at 5 angles

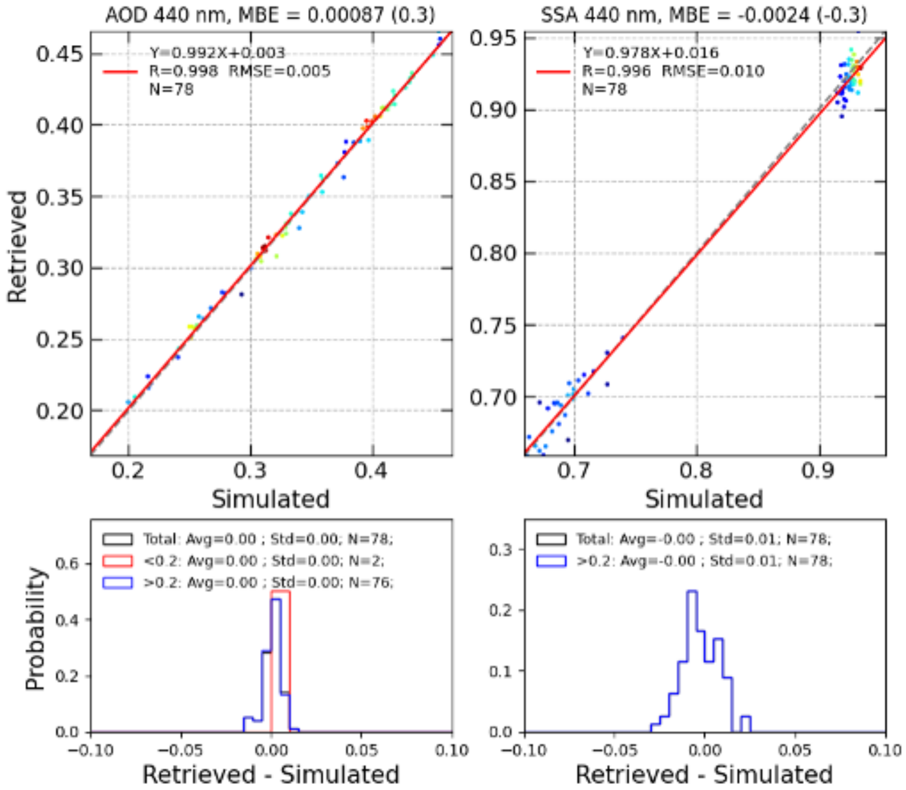
Which provides a more robust behaviour against random noise ? A better angular or spectral sampling?

AERONET+Pandora: Noise Free conditions



In the absence of measurement noise every parameter is perfectly retrieved.

AERONET+Pandora: realistic noise scenarios



Aerosol properties are always properly retrieved no matter of the selected configuration.

The random noise level assumption was:

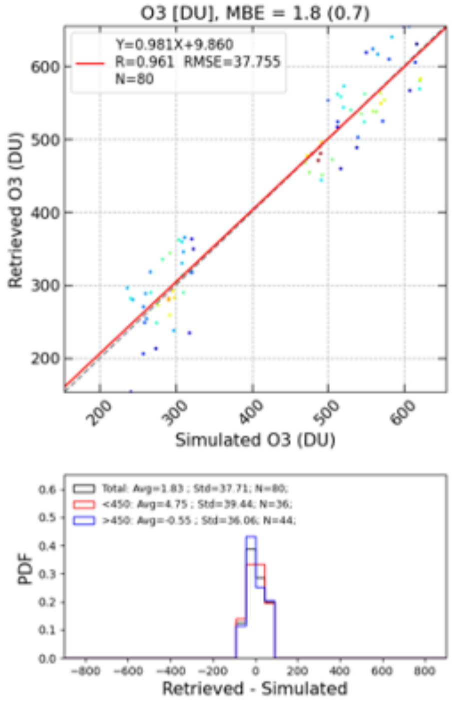
- 0.05 for all TOD
- 3% for AERONET radiance
- 3% for pandora radiance

AERONET+Pandora: Azimuth vs spectral sampling

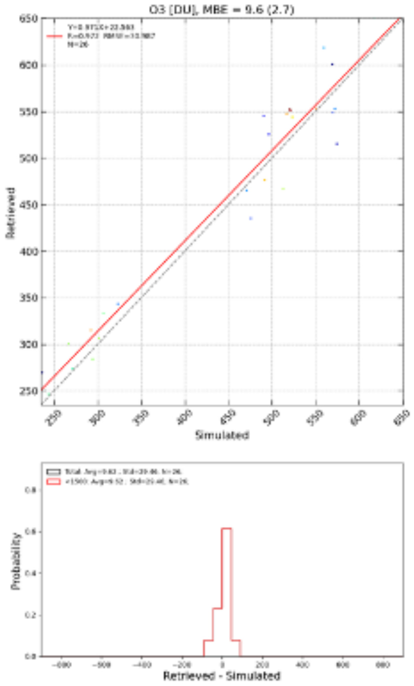
A higher spectral sampling offers a reduction of the 18% in the RMSE.

The angular sampling was done in terms of azimuth, next steps include the same comparison with additional zenith angles.

Angular Sampling



Spectral Sampling



AERONET+pandora: DSCD

Fundamental retrieval principle:

Combination of DSCD measurements in NO_2 and O_3 sensitive channels in addition to absolute radiance measurements in H_2O absorption bands.

DSCD implementation in GRASP:

$$DSCD = -\log(L(\Theta,\boldsymbol{\varphi})/L(\Theta,\boldsymbol{\varphi})_{no\_gas}/L(\Theta=0.0)_{zenith})$$

DSCD methodology corrects calibration uncertainties and maximizes gas sensitivity.

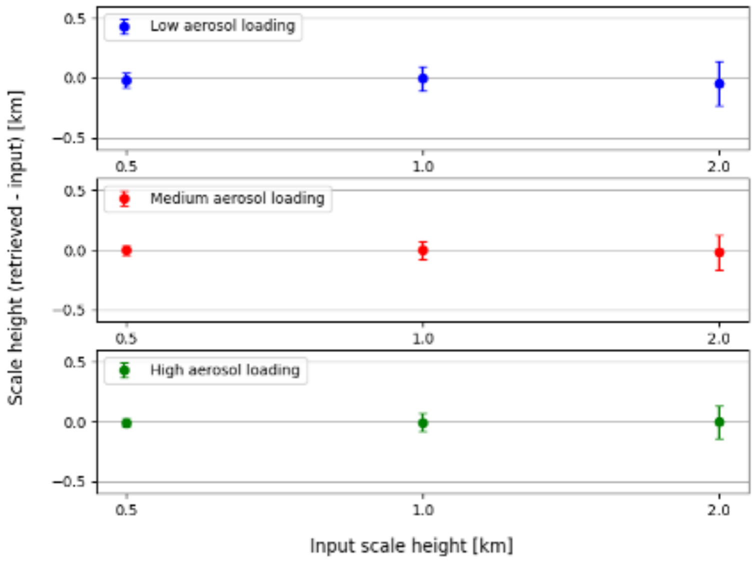
For NO_2 and O_3 retrieval the development is still under progress, because very accurate radiative transfer calculations are needed.

O_2-O_2 collision interaction have been studied to retrieve ALH from Pandora+AERONET.

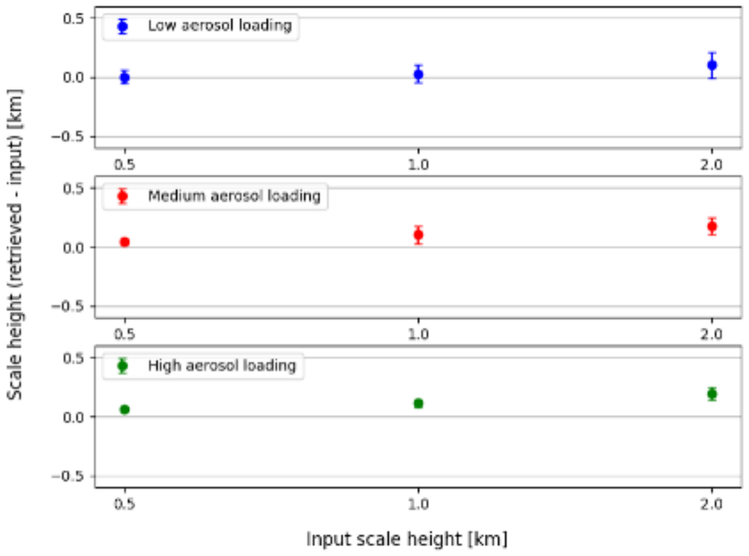
Explore new methodologies: DSCD O_2-O_2

AERONET + Center of O4 absorption: 360, 477, 577, and 630 nm

Fine mode



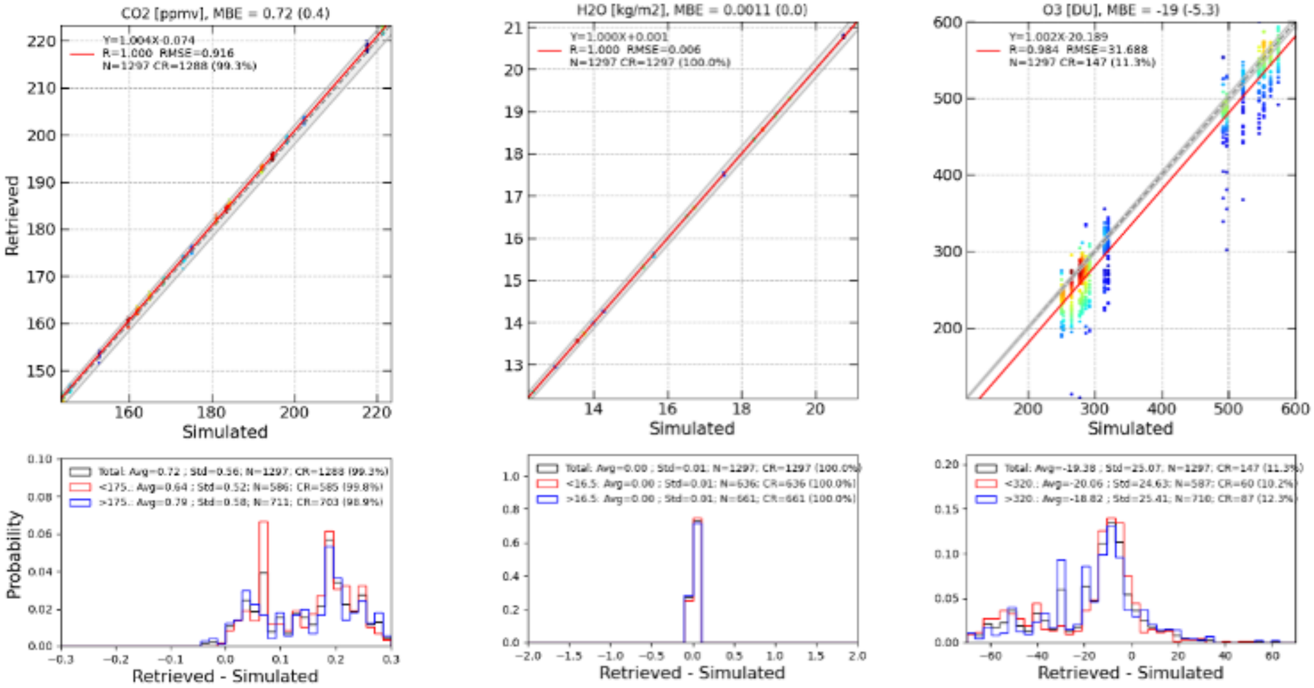
Coarse mode



With noise: 3% for radiance, 0.005 for TOD, 5% for DSCD

GRASP/BTS as stand alone: Noise Free conditions

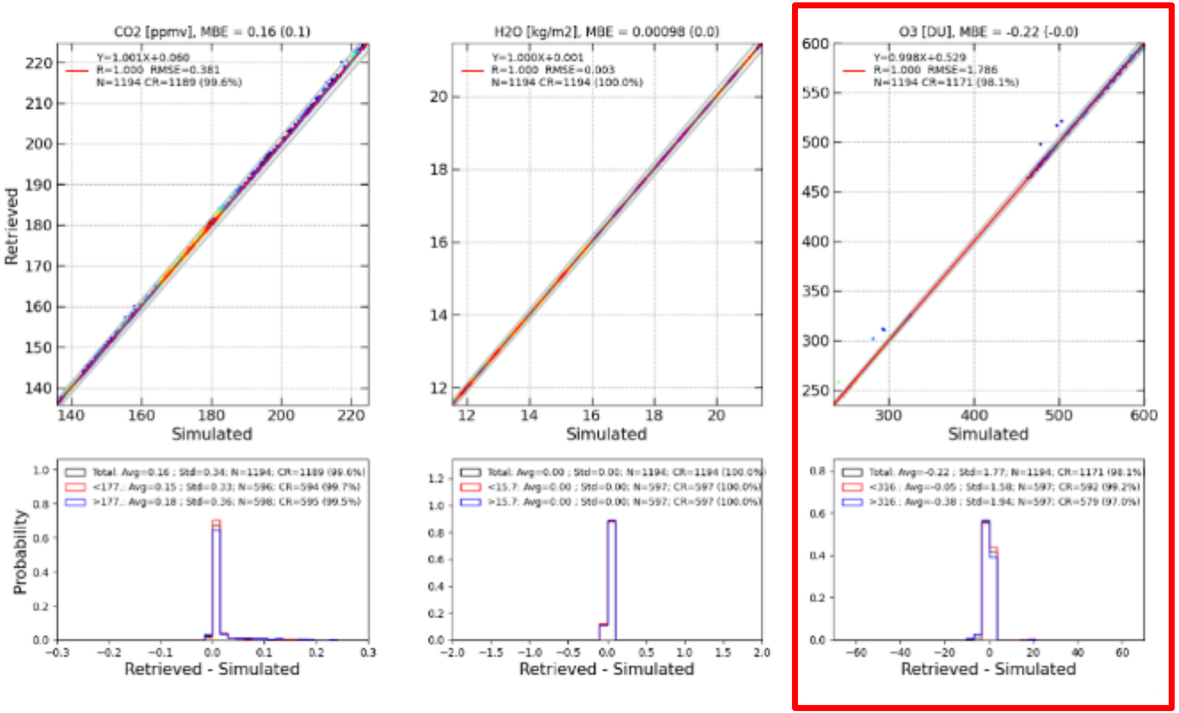
BTS spectrometer provides TOD from 350 to 2150 nm with a FWHM = ~2 - ~4 nm



BTS direct irradiance measurements show proper sensitivity to all gaseous species but: NO_2 and O_3

GRASP/BTS+**QASUME**: Noise Free conditions

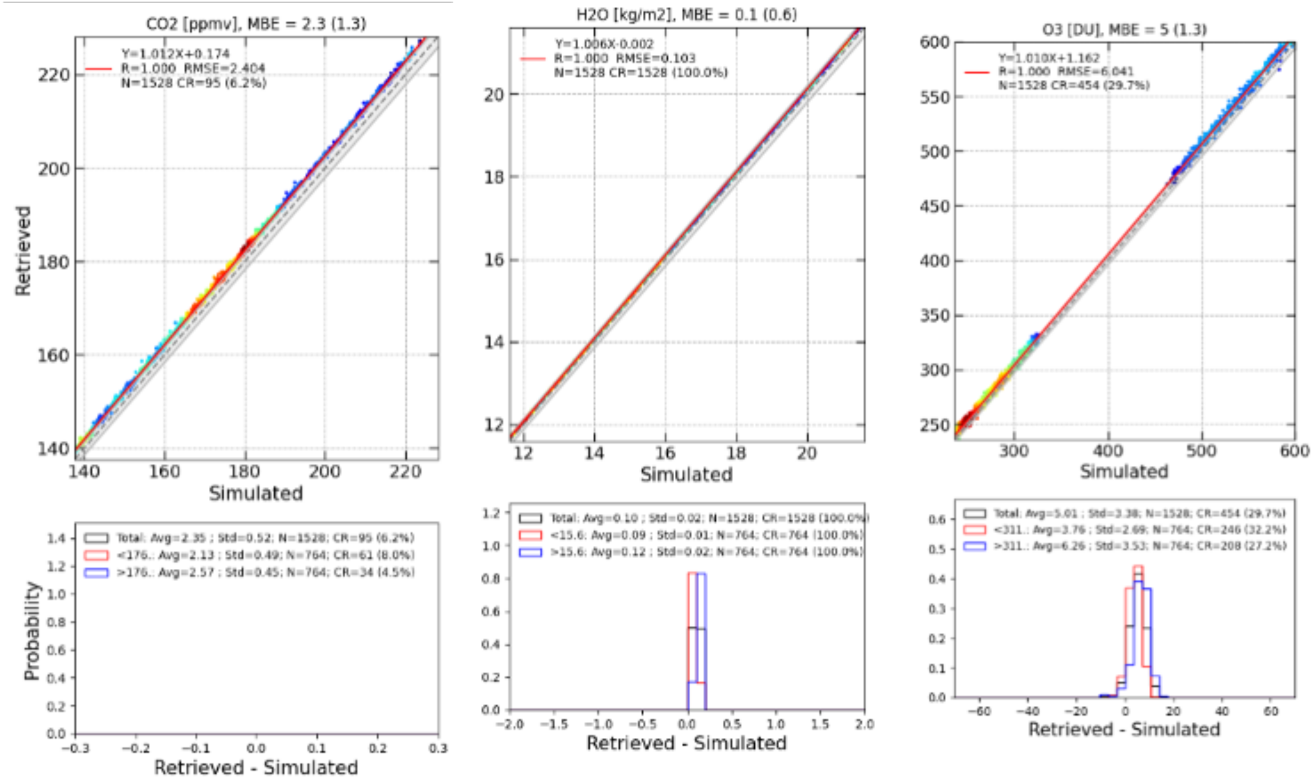
BTS spectrometer provides TOD from 350 to 2150 nm with a FWHM = ~2 - ~4 nm
QASUME spectrometer provides TOD from 280 to 550 nm with a FWHM = ~0.86 nm



QASUME measurements significantly improve the O_3 retrieval

GRASP/BTS+QASUME: **Realistic noise conditions**

TOD uncertainty 0.01 + 0.05 nm of channel center instability



RMSE < 1%

Conclusions

- Pandora DSCD measurements in combination with AERONET TOD+sky radiance seems promising to provide additional characterization of the Aerosol Layer Height.
- The application of DSCD strategy to the retrieval of NO2 and O3 in combination with AERONET measurements is still under development.
- GRASP/BTS+QASUME combined retrieval of aerosol and gas concentrations have been demonstrated within synthetic scenarios:
    - Aerosol concentrations
    - H_2O
    - CO_2
    - O_3

Future steps

- Application to real data for GRASP/AERONET+Pandora
- Application to real data for GRASP/BTS+QASUME

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BACK UP SLIDES