Synergistic hyperspectral ground-based and sunphotometer inversion of measurements for the retrieval of gas concentration and aerosol properties using GRASP

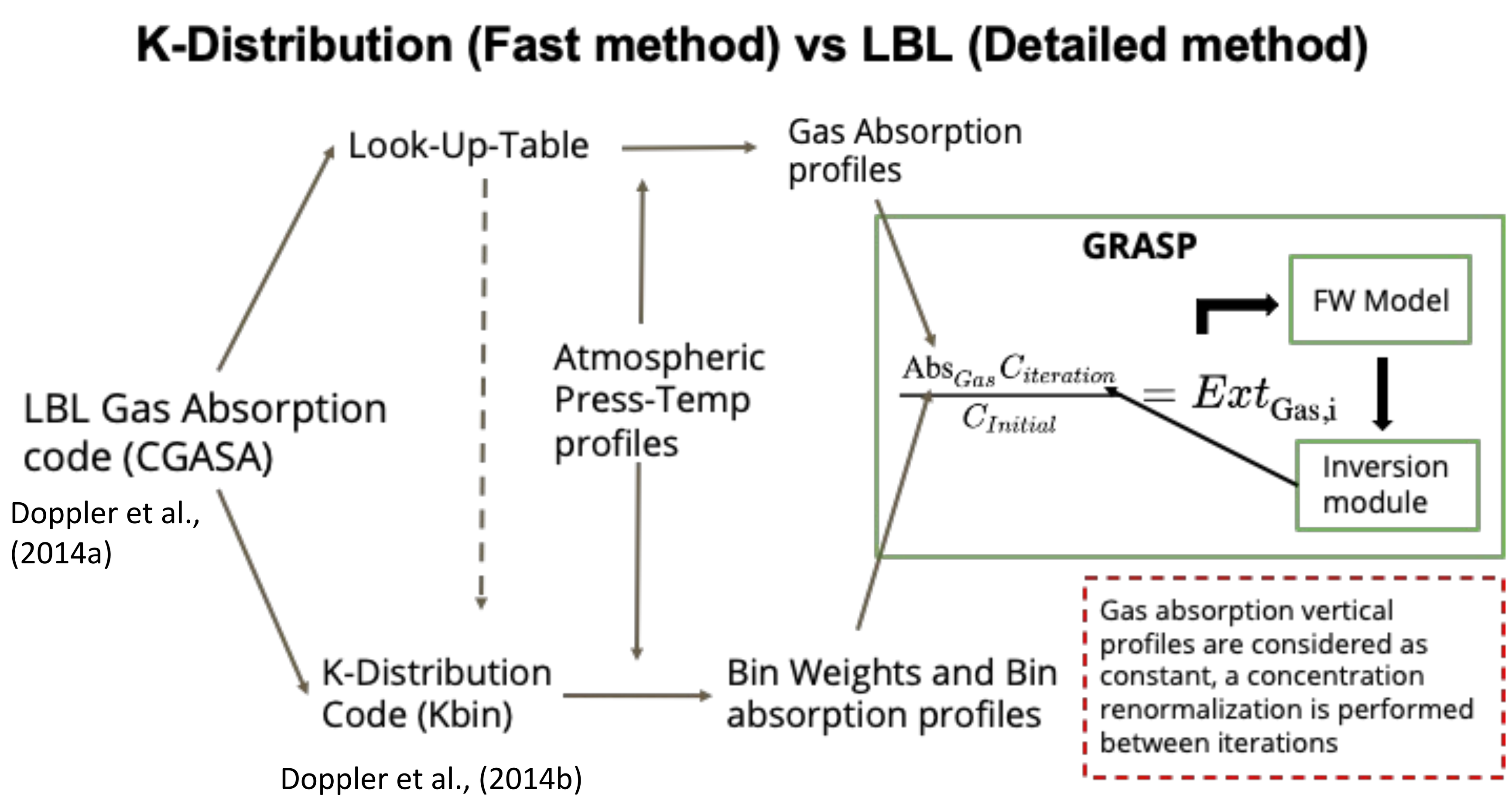
M. Herreras-Giralda[1,2], O. Dubovik[2], D. Fuertes[1], P. Lytvynov[1], T. Lapyonok[2], Y. Derimian[2], Rene Preusker[3], Jurgen Fisher[3]

[1]GRASP-SAS, Remote sensing developments, Villeneuve d'Ascq, France.
[2]Univ. Lille, CNRS, UMR815 - LOA – Laboratoire d'Optique Atmospherique, F-59000 Lille, France.
[3]*Institute for Space Sciences, Free University of Berlin, Berlin, Germany*

Motivation

Hitherto, **GRASP (Generalized Retrieval of Atmosphere and Surface Properties)** (Dubovik et al., 2021) has been fully focused on the retrieval of aerosol and surface properties, gas absorption was traditionally treated as a correction of the affected channels by the influence of gas absorption lines. The former gas absorption model of GRASP was based on simple column and channel integrated values of Gas Optical Depth (GOD) that were fixed in input data. The advantages of a **more complex and sophisticated gas absorption model in GRASP** are numerous. First of all, because the simple gas corrections made for the retrieval of **aerosol and surface in the previous schemes can be improved** with extended information of the pressure-temperature profiles and collocated measurements of gas concentrations. Thus, the higher precision in the modelling of gas absorption presents a high potential increase of the accuracy of the retrieved aerosol and surface products. However, the extended capabilities of GRASP to model more precisely gas absorption lines imply **the synergic inclusion of hyperspectral measurements and channels strongly affected by gas absorption lines** to **retrieve simultaneously aerosol and surface properties with gas concentrations**. Here are presented the preliminary results of the combined retrieval of hyperspectral measurements coming from PSR (Gröbner and Kouremeti, 2019) spectrometer and the AERONET (Holben et al., 1998) sunphotometer. The spectral characteristics of both instruments allowed a significant sensitivity increase to both: the aerosol parameters already retrieved by the AERONET-like standard product and simultaneously the total column concentration of NO_2.

Gas absorption modeling

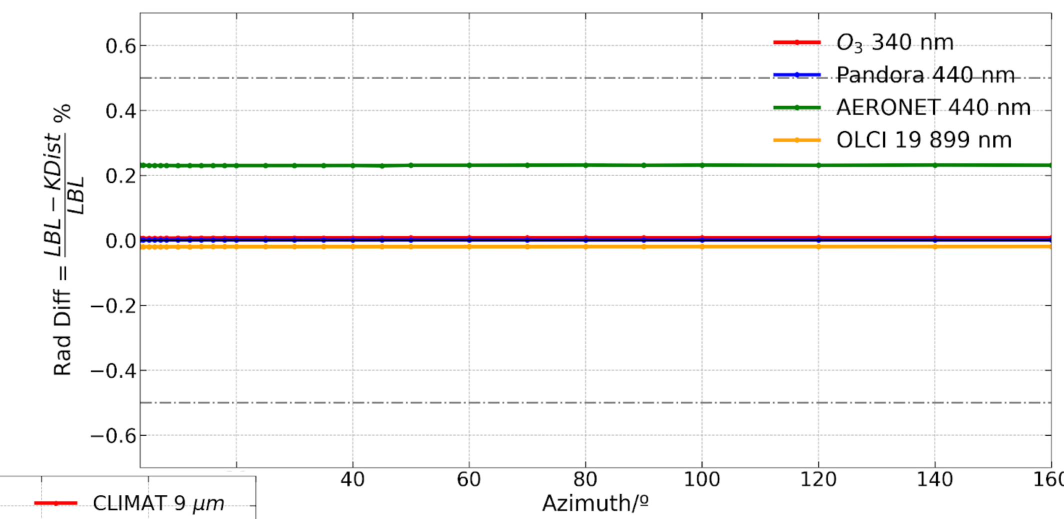


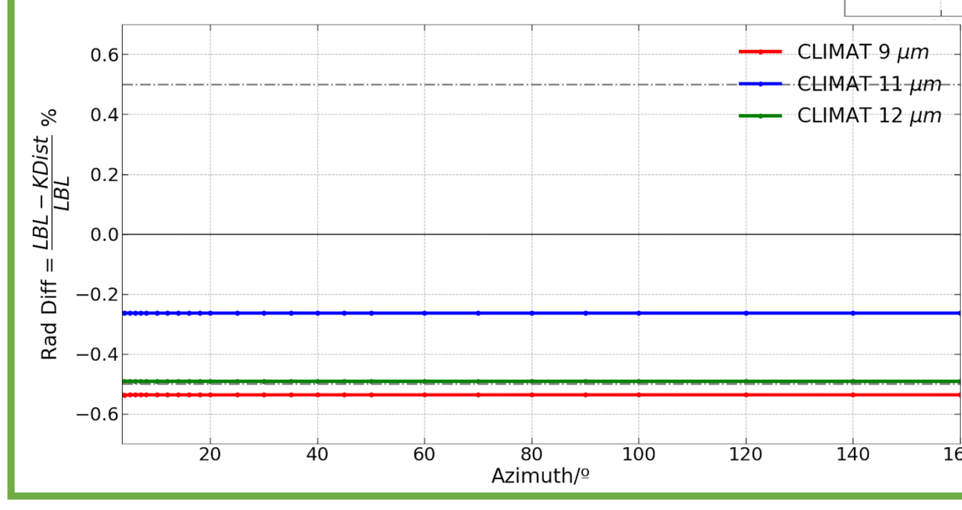
K-Distribution calculations validation

For the validation of the K-Distribution implementation in GRASP, almucantar-like geometries in different spectral bands has been simulated to compare the obtained radiance values with LBL or K-Distribution methodologies

SOLAR

In the solar part of the spectrum the channel width and the magnitude of the gas absorption lines play a fundamental role in the required number of bins for a proper simulation in comparison with the more accurate line-by-line approach.



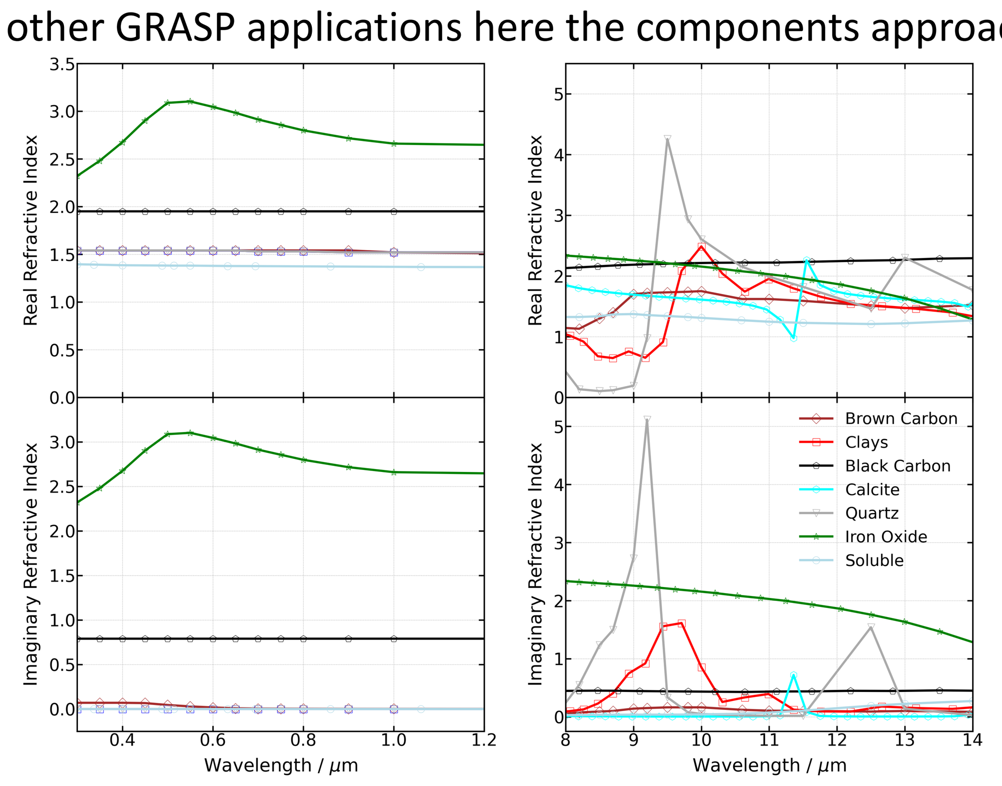


Thermal infrared

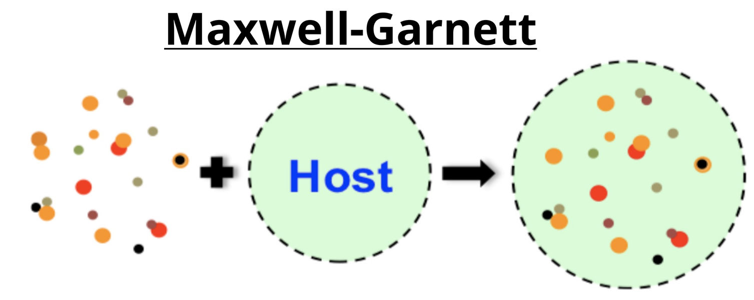
In order to perform a more complete characterization of the K-Distribution technique some TIR calculations have been done. The highest uncertainty in comparison with the solar part is the higher spectral width of the channels and the spectral Planck variations that are not accounted for in the actual implementation.

Constraining hyperspectral aerosol modeling: Components approach

Accounting for a elevated number of channels in specific spectral regions provides GRASP inversion with a high information content for the retrieval of gas absorption. However, aerosol optical properties present a much smoother behavior. As an alternative to the smoothness spectral constraints used in other GRASP applications here the components approach has been selected.



Maxwell-Garnett



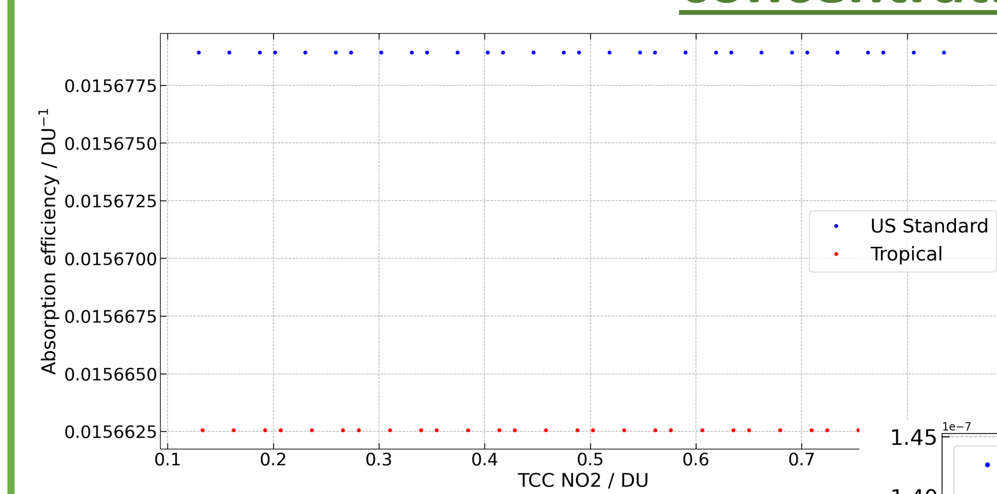
$$\varepsilon_{MG} = \varepsilon_m \left[1 + \frac{3\left(f_1\frac{\varepsilon_1-\varepsilon_m}{\varepsilon_1+2\varepsilon_m} + f_2\frac{\varepsilon_2-\varepsilon_m}{\varepsilon_2+2\varepsilon_m}\right)}{1 - f_1\frac{\varepsilon_1-\varepsilon_m}{\varepsilon_1+2\varepsilon_m} - f_2\frac{\varepsilon_2-\varepsilon_m}{\varepsilon_2+2\varepsilon_m}}\right],$$

$$m_r = \sqrt{\frac{\sqrt{\varepsilon_r^2+\varepsilon_i^2}+\varepsilon_r}{2}},$$

$$m_i = \sqrt{\frac{\sqrt{\varepsilon_r^2+\varepsilon_i^2}-\varepsilon_r}{2}},$$

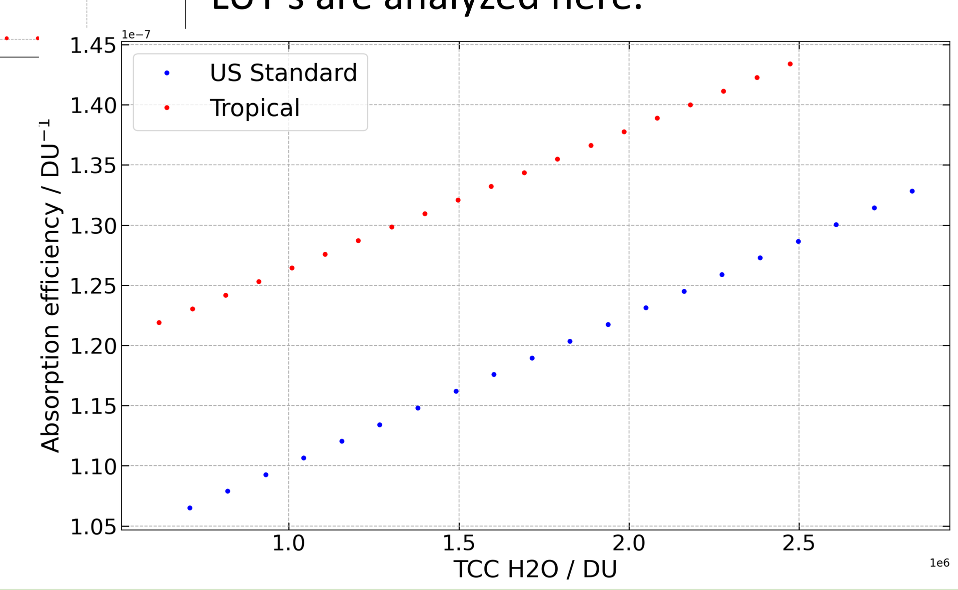
The volume fractions of the different components (f_x) are the retrieved parameters instead of the refractive index.

Non-linearity between gas absorption and concentration



For the application of this hyperspectral retrievals to large sets of measurements the use of look-up-tables is mandatory in order to perform the inversion in feasible periods of time. The influence of the assumptions for the calculation of the LUT's are analyzed here.

Meanwhile for some gaseous species the influence of the P-T atmospheric profiles is not significant in other cases is a crucial factor to account for. On the other hand, we have found that for water vapor simulations a linear concentration renormalization is not enough for a proper simulation.

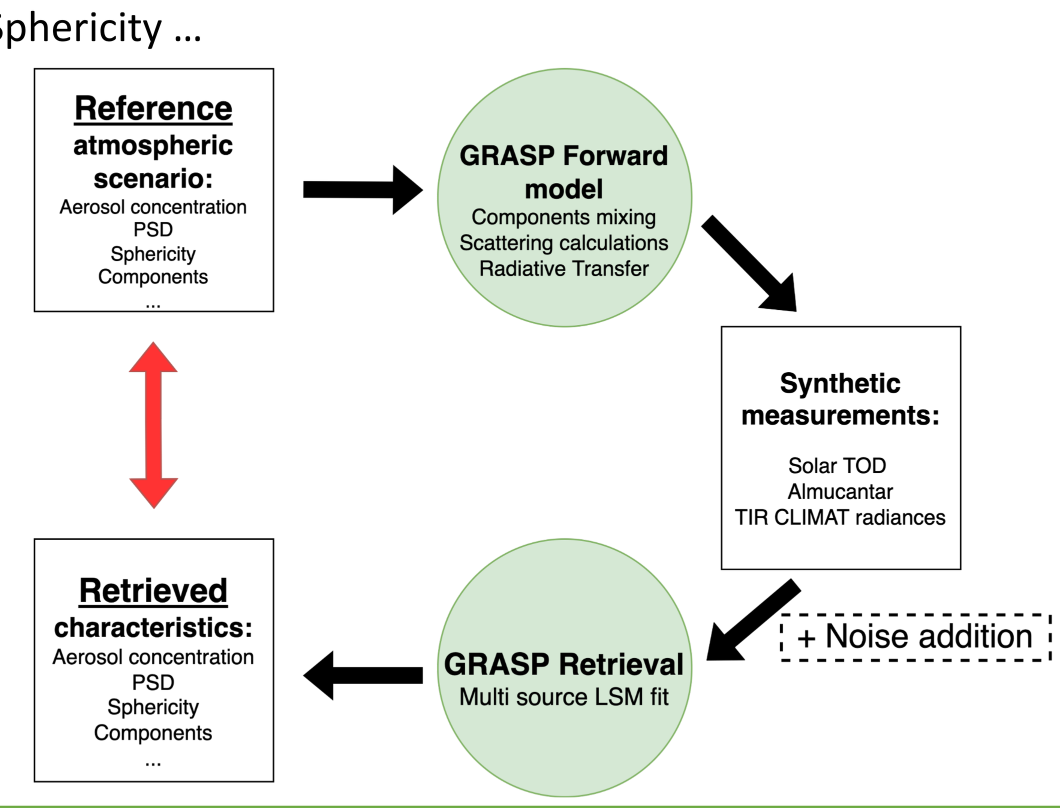


PSR spectrometer + AERONET sunphotometer Synthetic Retrieval Tests

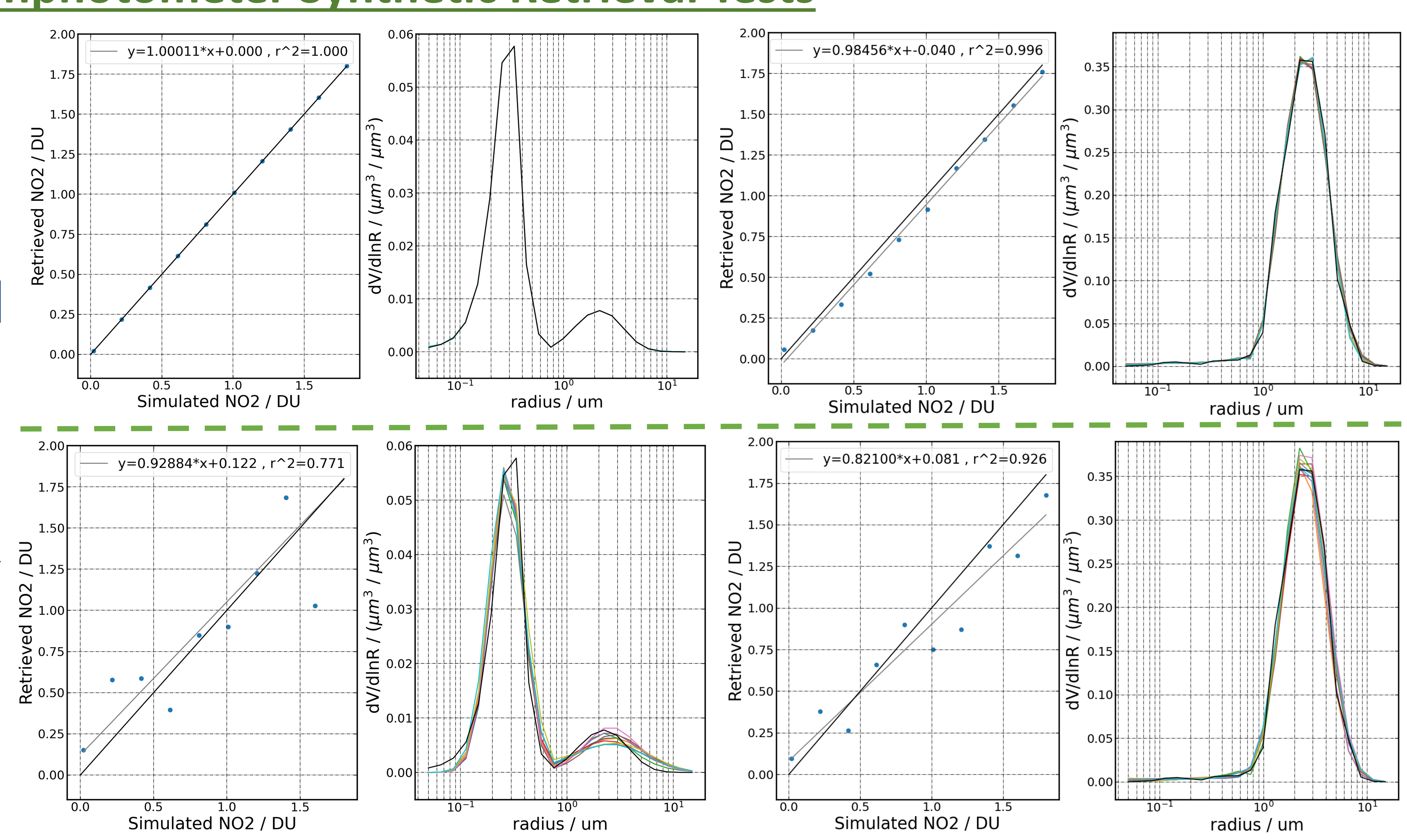
Input: 50 hyperspectral PSR measurements (400-440)
AEONET TOD + Almucantar measurements (440, 675, 870 and 1020 nm)

OUTPUT: NO2 Total Column Concentration
22 bins bimodal size distribution
Aerosol components volume fractions
Sphericity …

+ O3 absorption assumed as true



Realistic noise addition



Conclusions

The framework for the retrieval of hyperspectral measurements in GRASP code has been developed. From now on it is possible to precisely simulate gas absorption lines following line-by-line or K-Distribution methodologies. The consequences of the taken assumptions to unify the gas and aerosol spectral characteristics have been analysed in order to minimized the uncertainties introduced by them.

Different spectrometers operating in the spectral range situated between 400 and 440 nm has been used as reference for the synthetic sensitivity studies.

Future steps include the application to real ground based data, but also to satellite on-board sensors as IASI TIR sounder.

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