CO2 synergy product from S5+3MI

M. Herreras-Giralda[1], M. Momoi[1], O. Dubovik[1,2], D. Fuertes[1], P. Litvinov[1], T. Lapionok[2], F. Rejano[1], W. Lin[1], C. Matar[1], J.C. Antuña-Sánchez[1], A. García-Gómez[1], J. Landgraf[3], F. Lipert[3], A. Barr[3], T. Borsdorff[3], O. Hasekamp[3], B. van Diedenhoven[3], D. Gasbarra[4], B. Veihelmann[4], E. Malina[4]

[1]GRASP, [2]LOA Univ. Lille, [3]SRON, [4]ESA

Outline

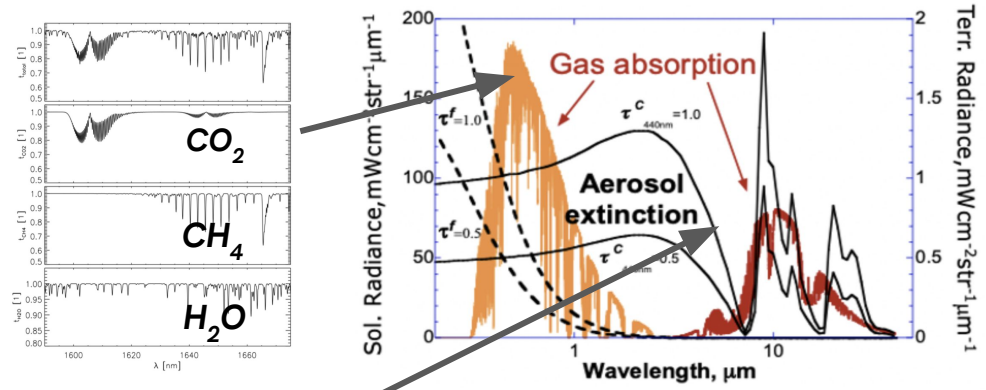
- What?
- Why?
- How?
- Synthetic results

What?: Objective

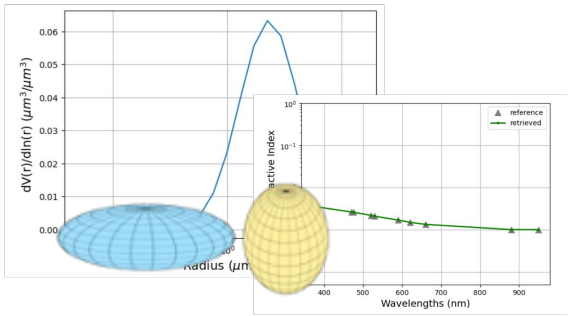
Develop a simultaneous retrieval of aerosol, surface, CO2 and CH4 properties from MAP and SWIR spectrometric measurements.

Geophysical parameters

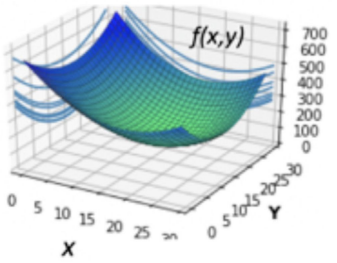
Gas



Aerosol



Surface

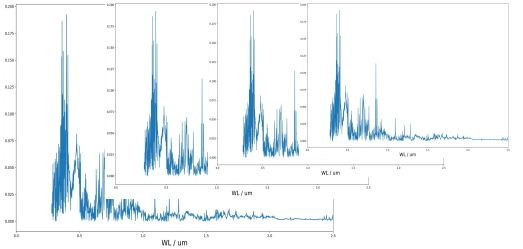


GRASP

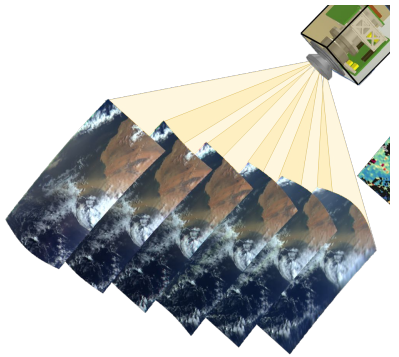
Combined retrieval scheme

Measurements

VIS-IR-SWIR spectrometric measurements



Multiangular multispectral polarimetric measurements (**MAP**)



I (λ, θ, φ)
U (λ, θ, φ)
Q (λ, θ, φ)

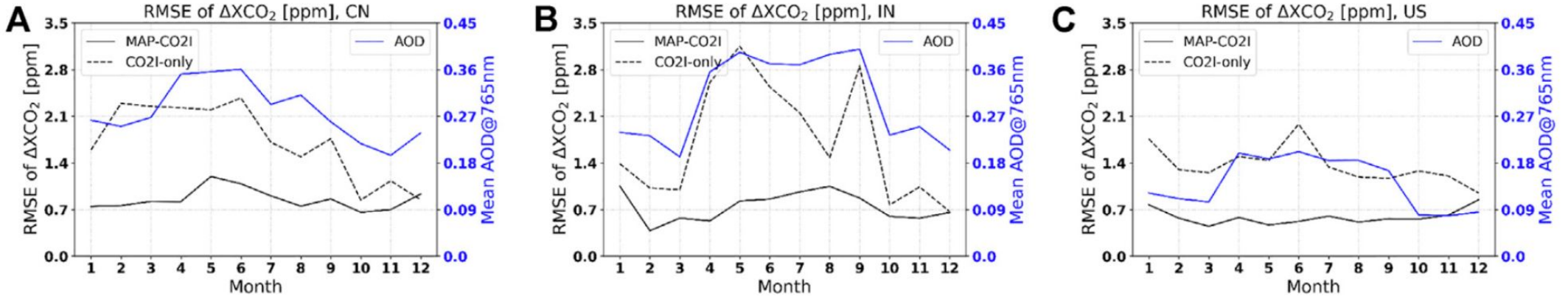
Instruments

S5/UVNS

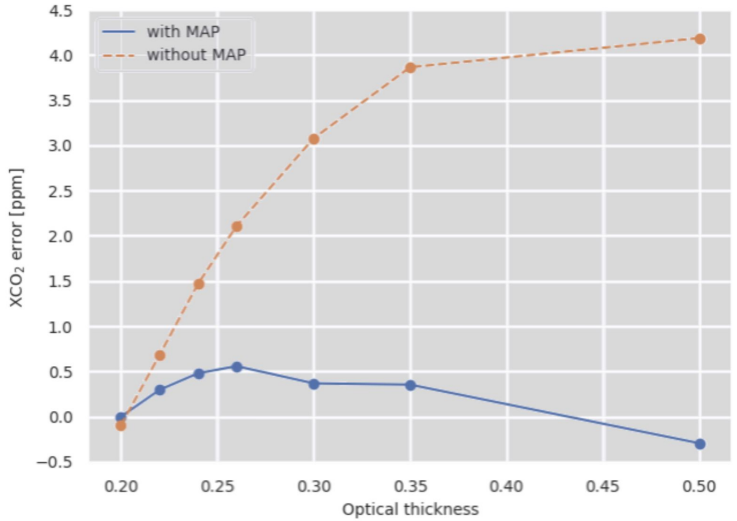
3MI

Why?: MAP vs no MAP

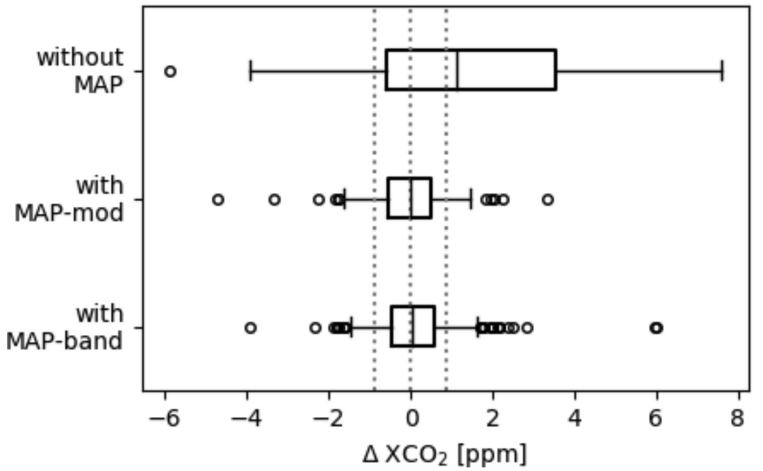
Accuracy standards for L2 XCO2 (~0.7 ppm) require precise collocated AOD characterization to infer GHG information.



(Lu et al., 2022)



(Landgraf et al., 2020)

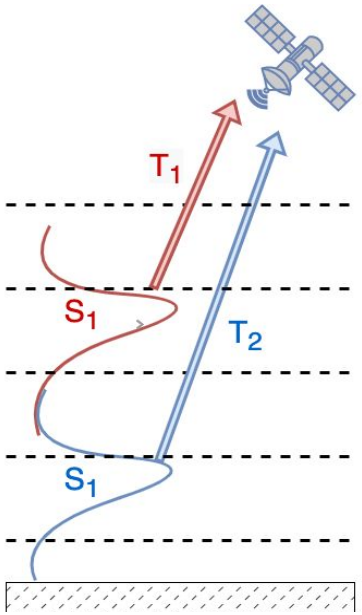


(Rusli et al., 2021)

Why?: The physics

Even if total column AOD is properly characterized the influence of the Aerosol Layer Height can significantly impact the accuracy of the GHG retrieved products.

Problem:



$S_1 = S_2$

$T_1 > T_2$

Uncertainties in ALH are propagated to gas concentrations

$$\mathbf{S}(\tau,\mu,\varphi) = \frac{\omega(\tau)}{4\pi}\mathbf{P}(\tau,\mu,\varphi,\mu_0,\varphi_0)\mathbf{E}_0 \exp\left(\frac{\tau}{\mu_0}\right) + \frac{\omega(\tau)}{4\pi}\int_0^{2\pi}\int_{-1}^{+1}\mathbf{P}(\tau,\mu,\varphi,\mu',\varphi')$$

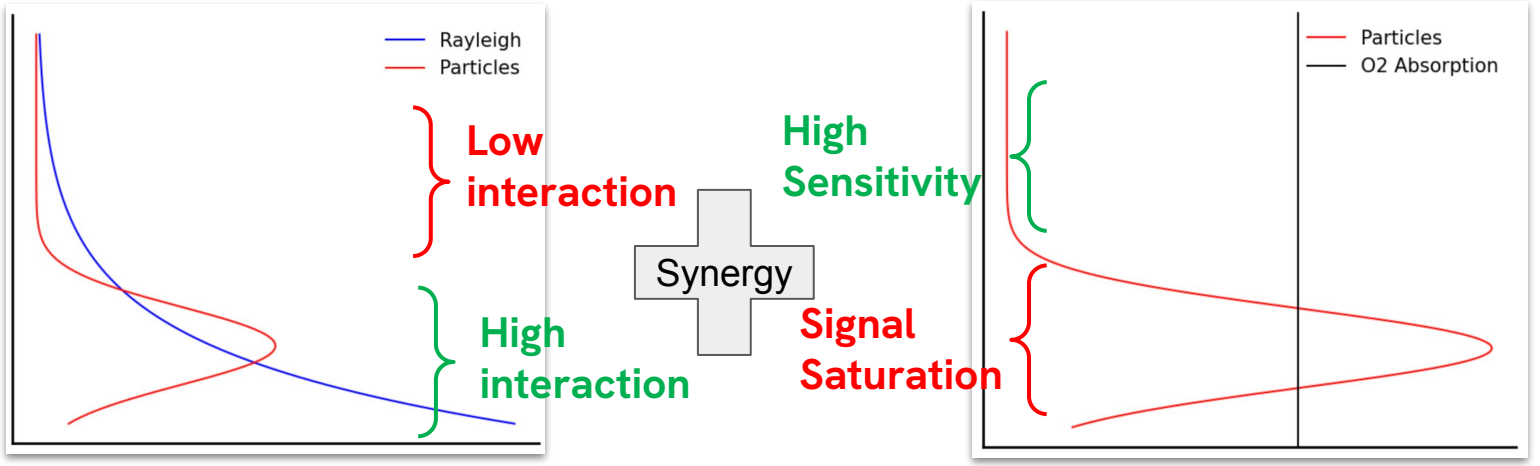
Solution: Addition of measurements with synergetic sensitivity to ALH

Multiangular Polarimeter

Sensitivity source: Polarization state vertical differences induced by the interaction of aerosols and rayleigh.

Spectrometer

Sensitivity source: Transmissivity differences induced by O2 A-band Absorption

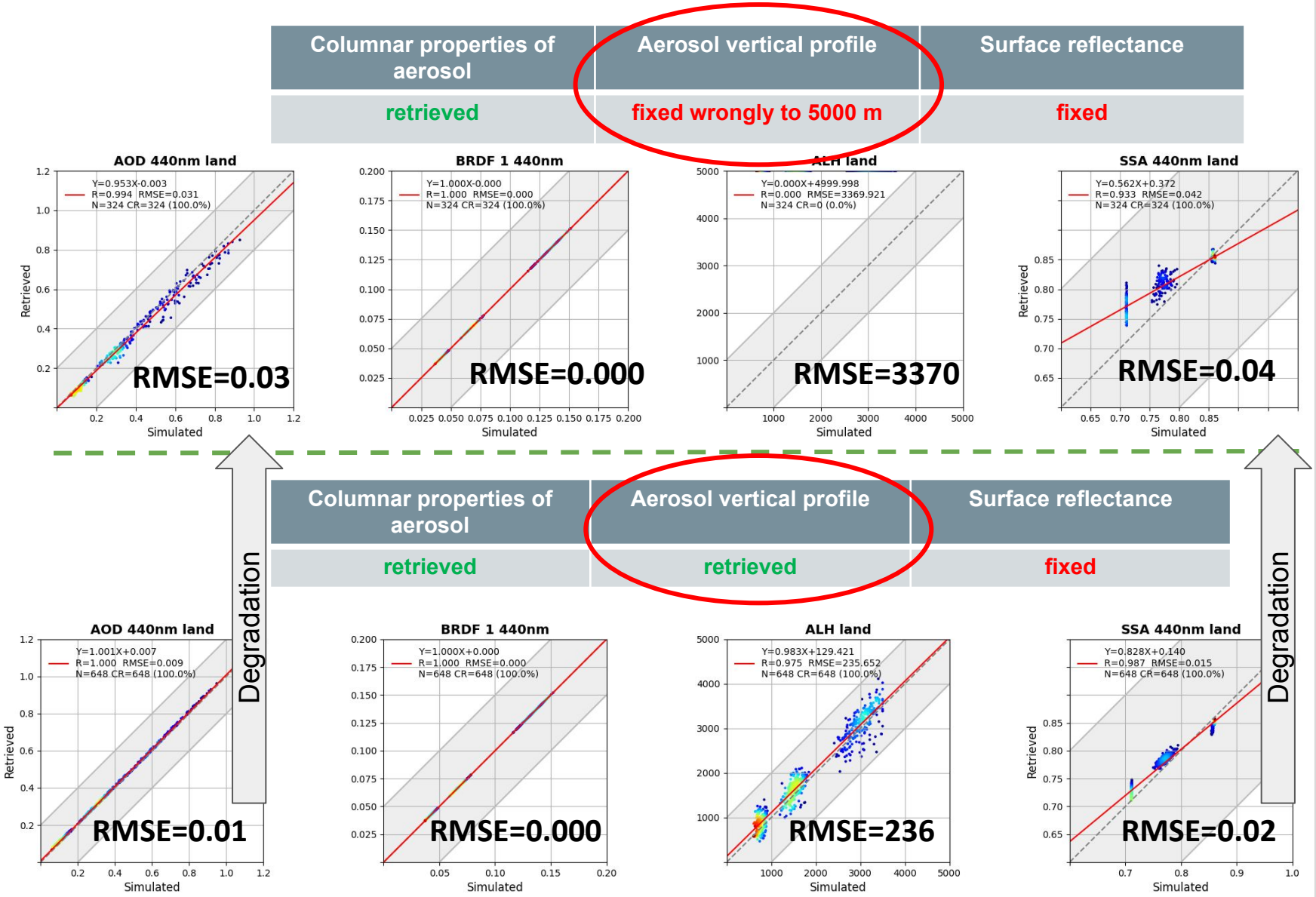


Polarimetric and O2 A band measurements show complementary sensitivity in different parts of the profile.

Why?: 3MI aerosol column products sensitivity to ALH

A wrong characterization of the ALH propagates uncertainty to aerosol columnar properties as AOD and SSA.

Synergies with spectrometric information will also enhance aerosol coumnar characterization.



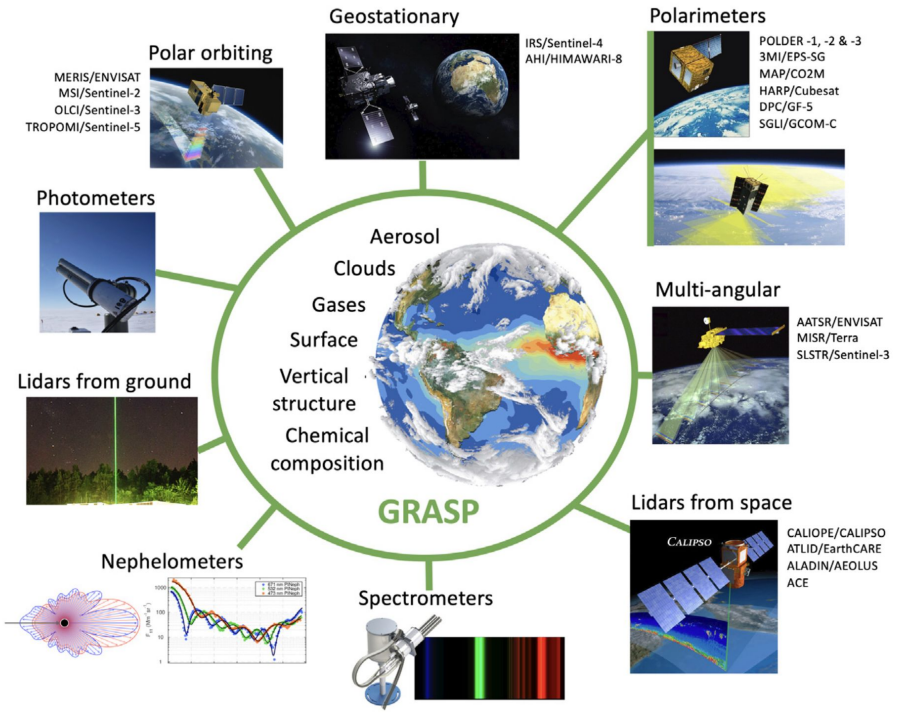
How?: Full physics retrieval

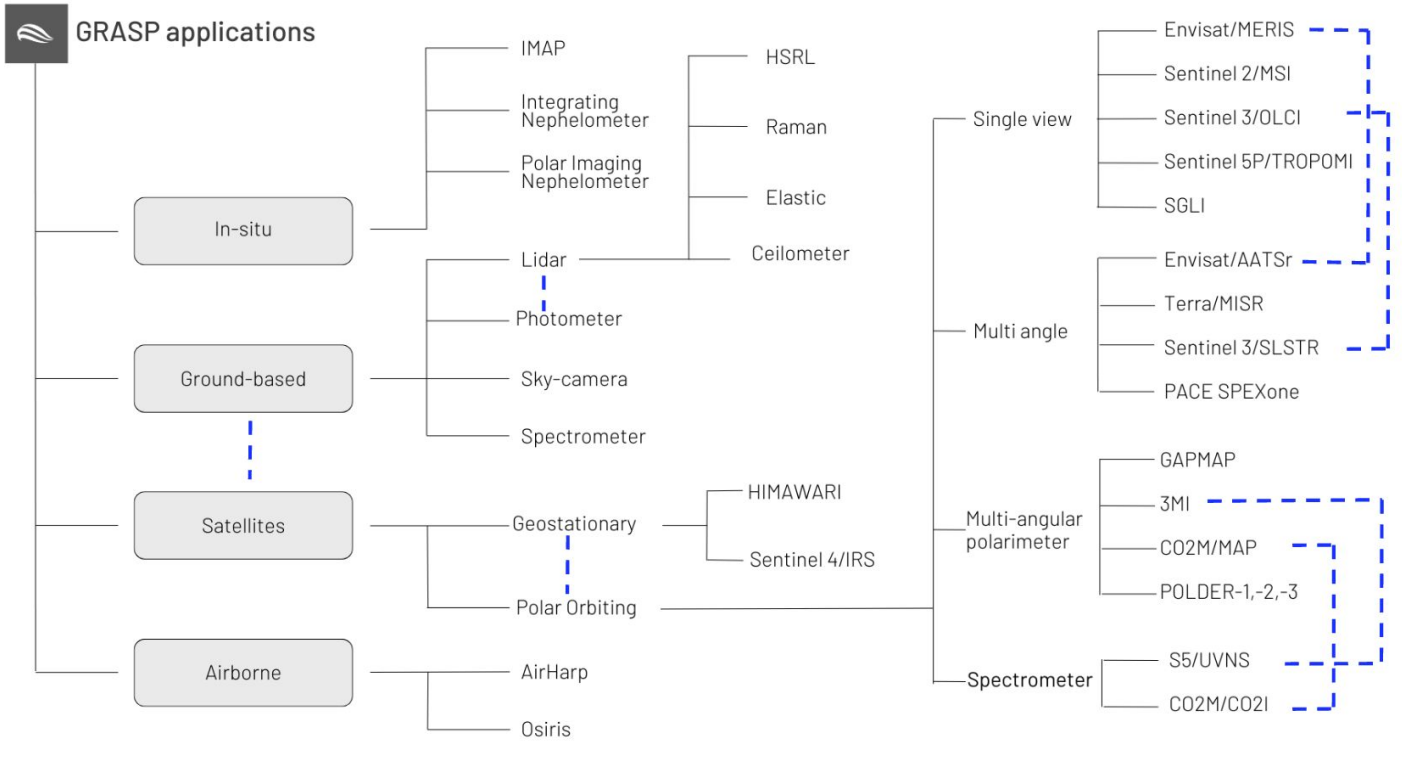
Proxy method	vs	Full physics retrieval
Atmospheric scattering elements ignored: $$I(\lambda) = F_0(\lambda)A(\lambda)\frac{\mu_{\text{in}}}{\pi}\exp^{-\tau_{abs}(\lambda)\Big/\tilde{\mu}}$$ (Lu et al., 2022)		Complete radiative transfer: $$\mathbf{S}(\tau,\mu,\varphi) = \frac{\omega(\tau)}{4\pi}\mathbf{P}(\tau,\mu,\varphi,\mu_0,\varphi_0)\mathbf{E}_0\exp(\tau/\mu_0) + \frac{\omega(\tau)}{4\pi}\int_0^{2\pi}\int_{-1}^{+1}\mathbf{P}(\tau,\mu,\varphi,\mu',\varphi')\mathbf{L}(\tau,\mu',\varphi')\,\mathrm{d}\mu'\,\mathrm{d}\varphi'.$$ (Lenoble et al., 2007)
Surface: Lambertian model		Surface: BRDF + BPDF
Only CO2 or CH4 can differ from the background		No a priori limitation
Accuracy dependency on aerosol load and aerosol layer height		No a priori limitation
Low computational cost and conceptually simple implementation.		Higher computational cost and conceptually complex.

GRASP Algorithm

GRASP: Generalized Retrieval of Atmosphere and Surface Properties

(Dubovik et al., 2021)



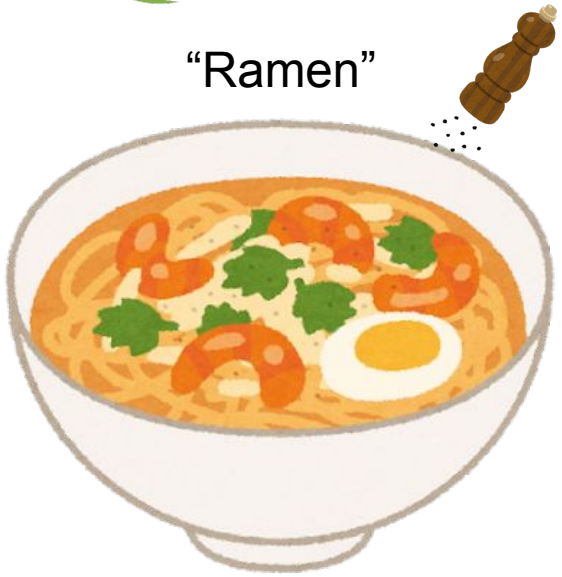


The platform: Open source community retrieval algorithm

In the framework of OPERA-S5 GRASP v2.0.0 has been developed. A totally modularized new architecture that enables a straight forward integration of any scientific code.

Version 1

"Ramen"



Version 2

"Set meal"

Current forward modules in GRASP

Module name	Description
bbflux	Broadband flux calculations
gas_absorption	Everything related to gas absorption and spectroscopic measurements
lidar	Lidar equation calculations
molecular_scattering	Models to include Rayleigh scattering
particle_scattering	All particle scattering calculations starting from optical, chemical and microphysical properties including: spheres, spheroids and more complex shapes.
radiative_transfer	Multiple scattering calculations
surface	Models to describe all reflectance properties of the surface including land and ocean.
vertical_distr	Methodologies to describe the vertical discretization of the atmosphere in terms of geometry, optics and temperature.

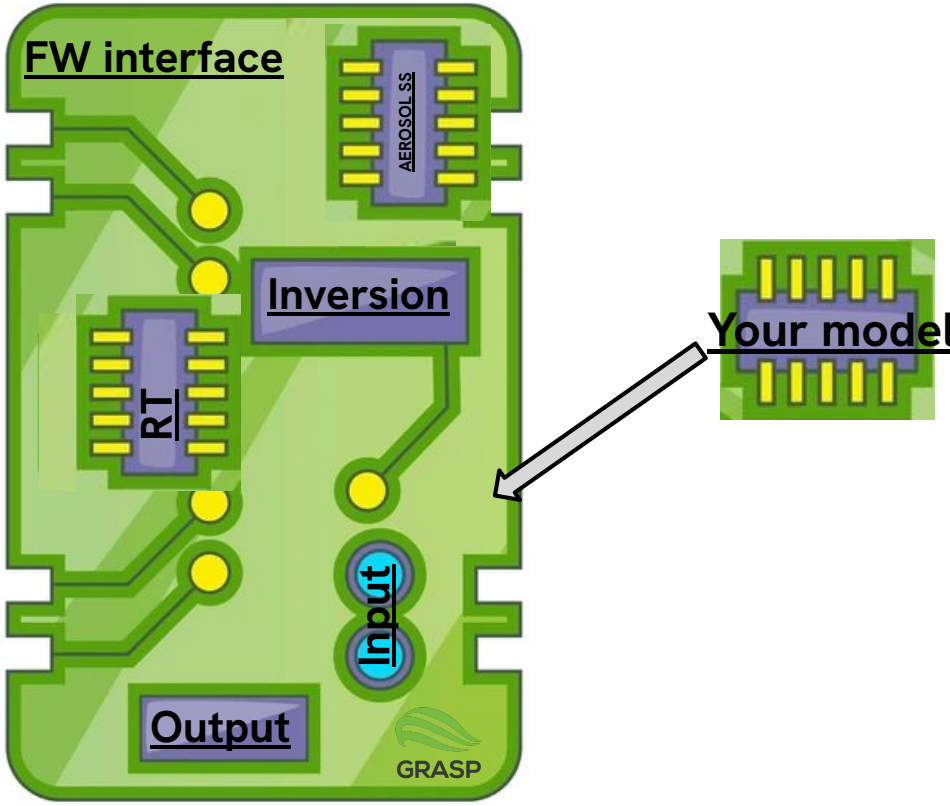
"Top-up" = module(s)

Every module is completely detachable and new code can be integrated by direct simplified interfaces to foster community collaboration and synergy development.

The platform: Open source community retrieval algorithm

GRASP retrieval code is open: https://www.grasp-open.com/ !

Version 2



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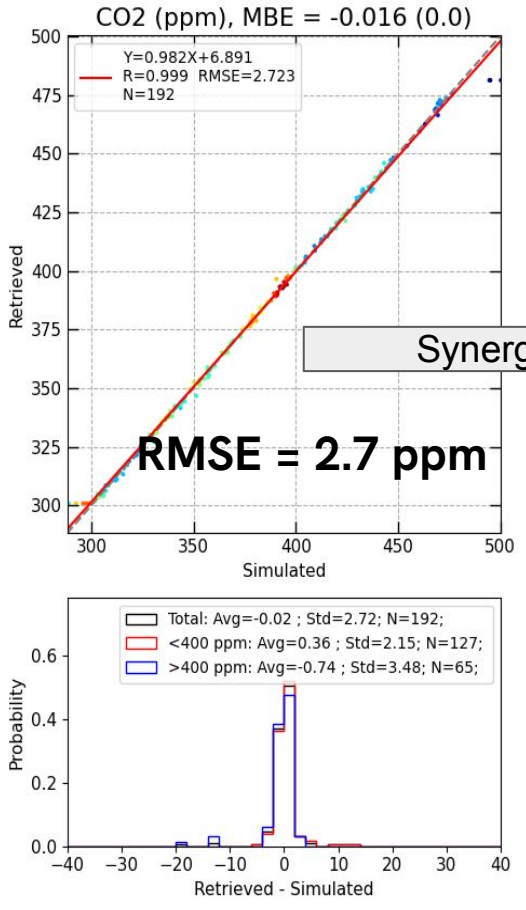
"Top-up" = module(s)

GRASP v2.0.0 is ready to be used, any collaboration for the Open Source community retrieval algorithm are welcome!

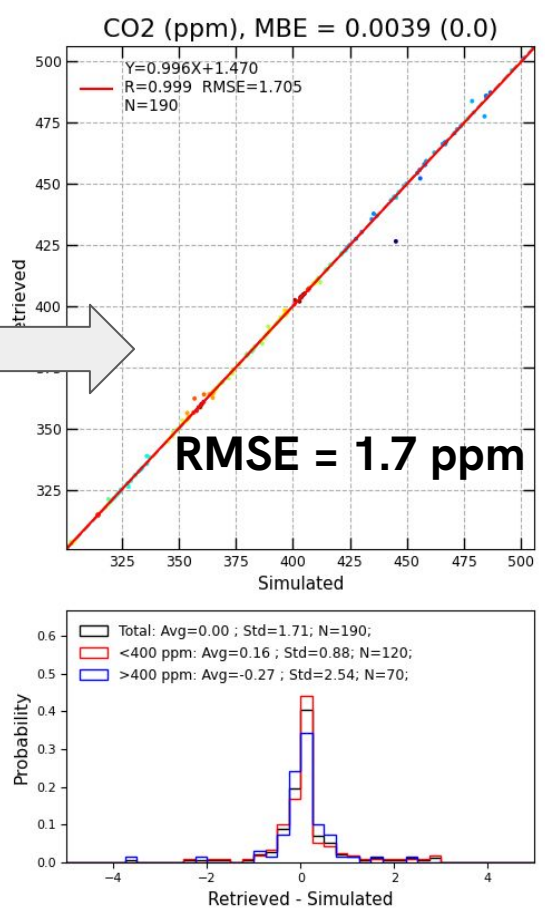
XCO2 retrievals of the GRASP Full physics Community algorithm

XCO2

GRASP/S5UVNS



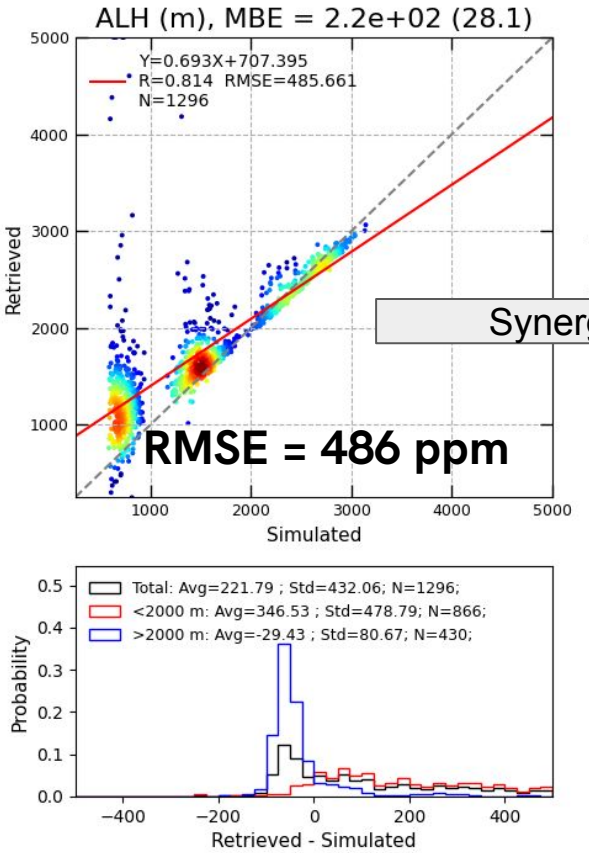
GRASP/S5UVNS+3MI



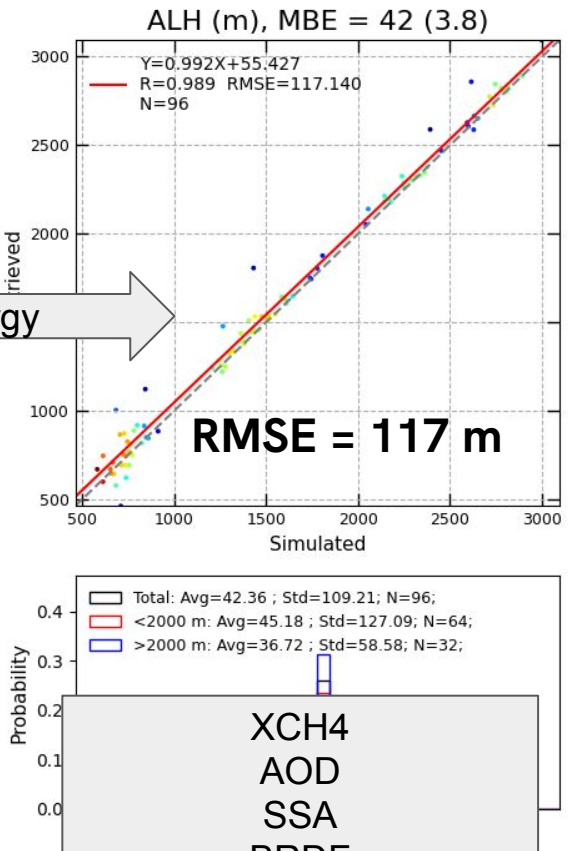
Synergy

ALH

GRASP/S5UVNS



GRASP/S5UVNS+3MI

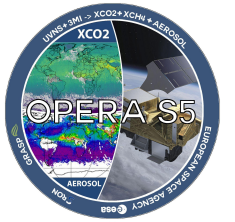


Synergy

XCH4
AOD
SSA
BRDF
Chemical components
…
Also available as retrieved products

Significant improvements in the retrieval of both XCO2 and ALH are found thanks to the synergy between S5 and 3MI satellite sensors.

Summary



- MAP and Spectrometer satellite borne synergies present enhance quality products for both GHG and aerosol retrieval
- An Open Community XCO2 and aerosol retrieval algorithm for S5 has been developed with GRASP.
  - Fully modular architecture to leverage community collaboration

- XCO2 + XCH4 + Aerosol + Surface simultaneous retrieval + …

- Application to two synergies between MAP and spectrometer:
  - S5/UVNS and S5/UVNS + 3MI
    Showing a significant improvement on the XCO2 accuracy by the combination with MAP measurements.
  - (S7 CO2M/MAP+ S7 CO2M/CO2I)