



GRASP Software Overview

ATARRI

5th March, 2025



Funded by
the European Union

David Fuertes and all GRASP team



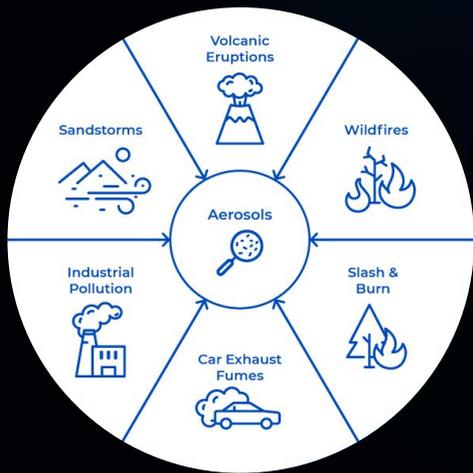
Introduction

GRASP Activities

GRASP Software Overview

Aerosols: Particles in the atmosphere

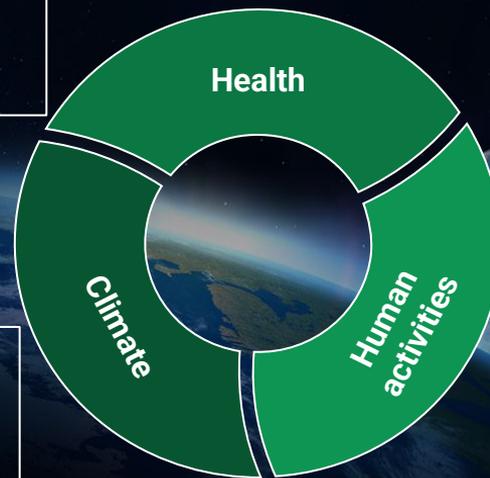
Sources:



Air quality applications:

- Regions, cities, municipalities
- Pollutant industries
- Mines

Impact:



Space agencies:

- ESA - EUMETSAT
- Copernicus
- NASA - NOAA

- Atmospheric correction
- Precision agriculture
- Solar Radiation

Volcanic ash



Dust



Forest fires



Urban smoke



Sea salt

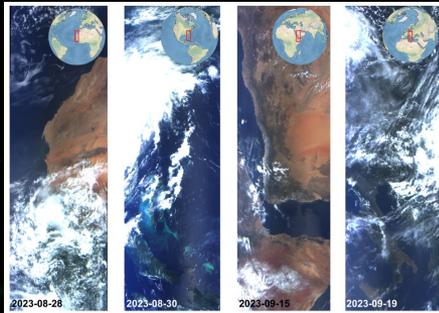


Activities :

Deep expertise in all domains of remote sensing for EO applications.

SATELLITE OPERATOR

Deployment of 10 cubesat constellation aiming to monitor Air Pollution to be integrated by polluting industries, mines and smart-cities.



HARDWARE

Conception and development of:

- our own ground-based in-situ instrumentation.
- our own space payloads.



SOFTWARE

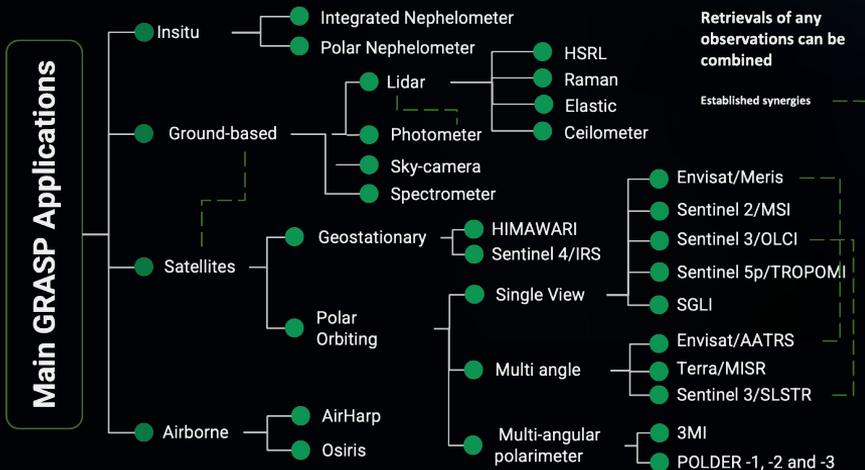
- Retrieval of atmosphere and surface properties (aerosol expertise).
- Retrieval algorithms. Operational products for several public missions:

- Sentinel-4
- 3MI
- CO2M

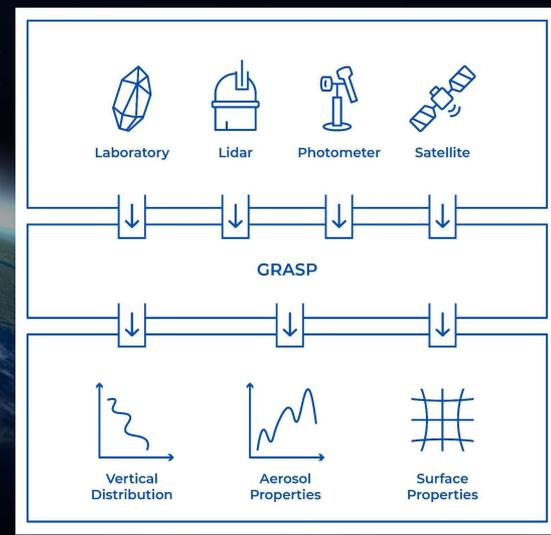


Generalized Retrieval of Atmosphere and Surface Properties

GRASP is one of the most advanced algorithms for aerosol, gas and surface properties from any remote sensing source and the combination of them. This inversion algorithm is currently used by main spatial agencies worldwide and was a subject of over 60 scientific publications in the last decade.

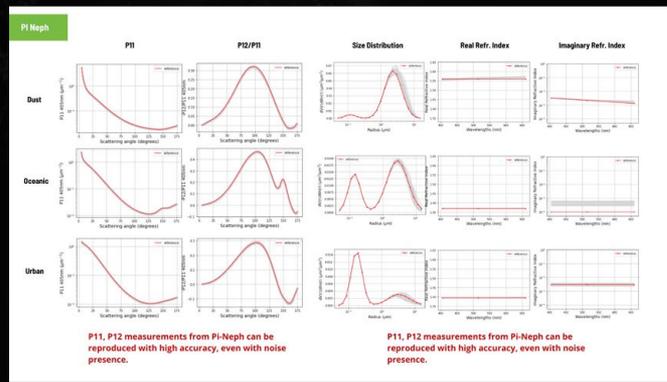
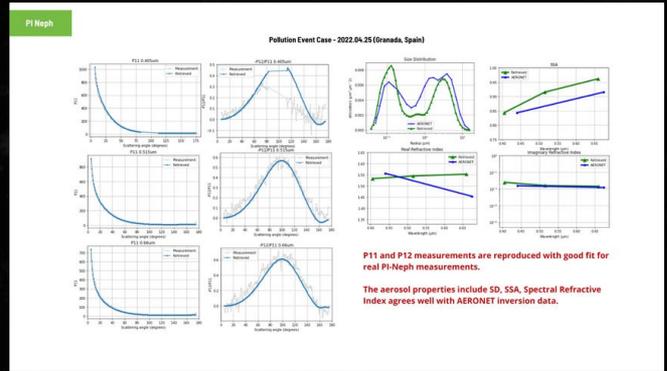


EUMETSAT



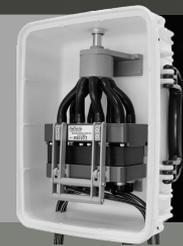


GRASP/Airphoton instruments



Integrating Nephelometers

Sampling stations



IMAP



PI Neph



GAPMAP Constellation: Payload description

GAPMAP-0 on board of ADLER-2

Launched
April 2023;
Commissioned
August 2023

3D render of GAPMAP-0 on board of Adler-2 mission launched on April 2023

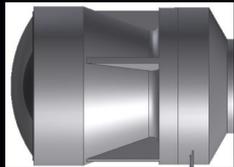


	GAPMAP Constellation
Wavelengths	440, 550, 670, 870nm
Calibration	Full onboard radiometric and polarimetric calibration; solar + moon; ground targets; satellite comparisons.
Nadir pixel resolution	0.58km
Nadir Binned resolution	2.32 km
Cross track Swath	77 deg (1070km@650km orbit)
Along track swath	105.2 deg
Hyper-Angular Sampling	Up to 60 angles
Angular sampling	Hyperangular
Satellite volume	< 1.5U

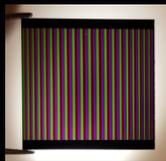
Based on HARP CubeSat
(awarded by AIAA)



Wide
FOV lens



GAPMAP
Specialized filter



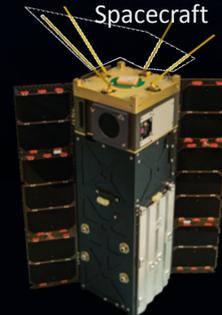
Camera
Electronics



Payload
computer



Spacecraft

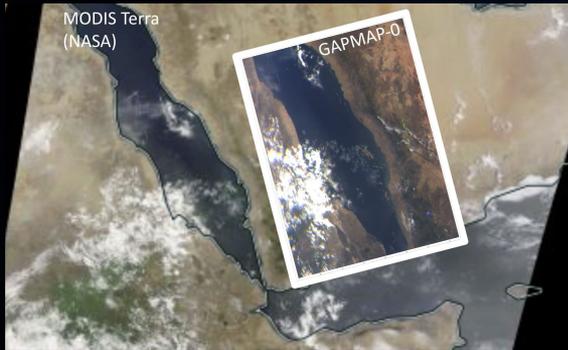


Measurements



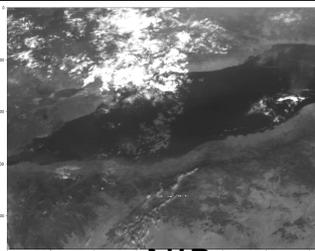
GAPMAP: First measurements from Space

RGB



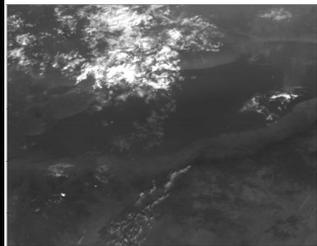
R

G



B

NIR

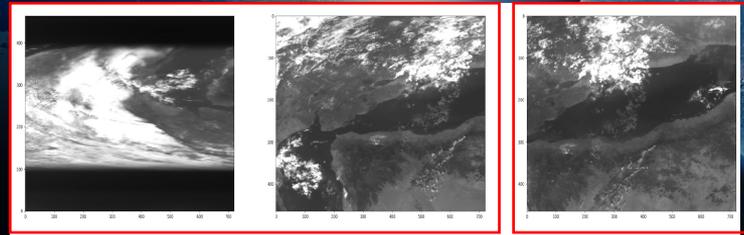


GAPMAP takes 60 measurements per pixel

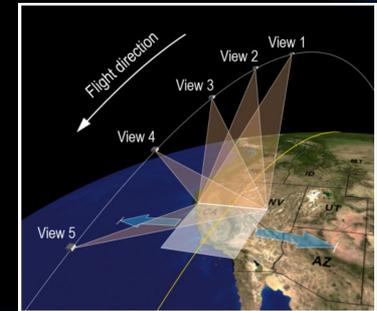
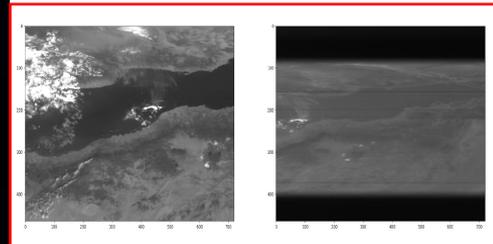
= 4 wavelengths (440, 550, 670, 870nm) x 3 polarized states [I Q U] x 5 viewing-angles

Forward view

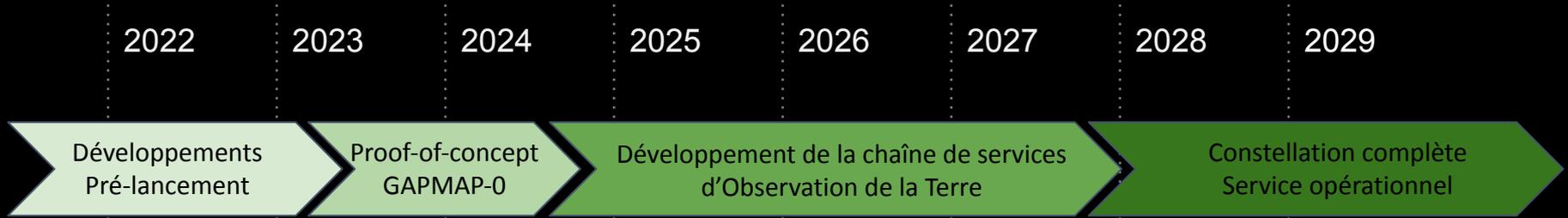
NADIR view



Backward view



Déploiement de la constellation



2022

2023

2024

2025

2026

2027

2028

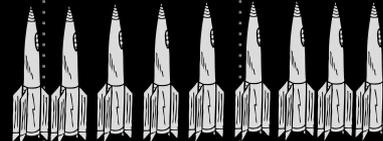
2029

Développements
Pré-lancement

Proof-of-concept
GAPMAP-0

Développement de la chaîne de services
d'Observation de la Terre

Constellation complète
Service opérationnel



GAPMAP-0

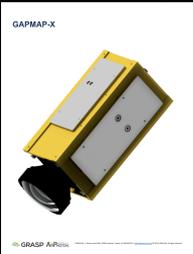
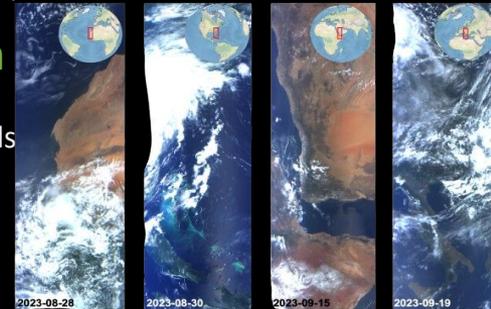
Operated by Spire
mission ADLER-2

GAPMAP-1

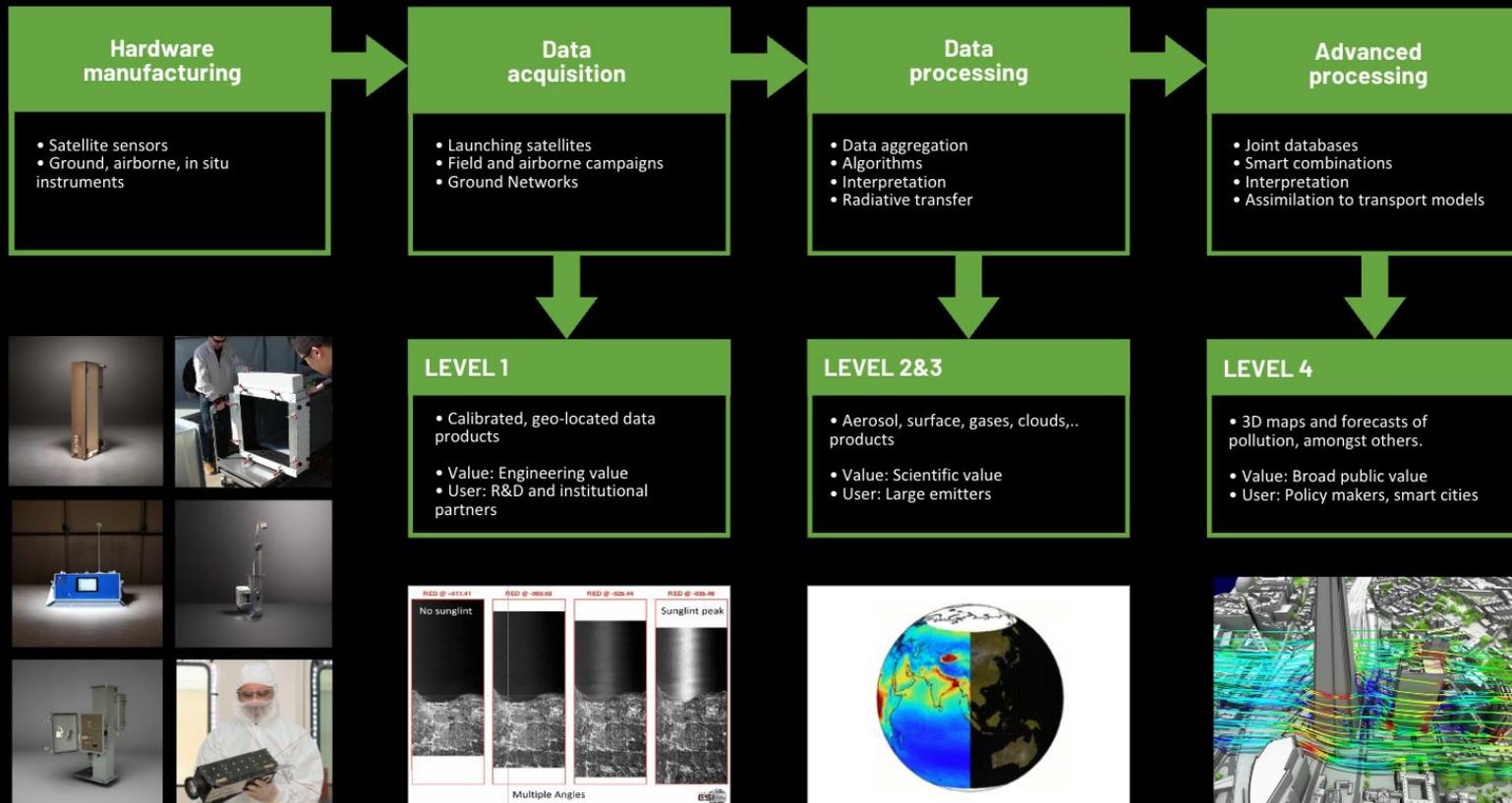
Operated by
U-Space

GAPMAP-n

Planned but funds
not secured yet



3. GRASP EARTH: PRODUCT CHAIN AND CUSTOMER SEGMENTS



GRASP Software Overview





What is GRASP?

- **Generalize**
 - Based on physical concepts
 - Multi-instrument
- **Retrieval**
 - But not only! A forward model too!
- **Atmosphere**
 - Aerosol optical and microphysical properties
- **Surface**
 - BRDF
- **Properties**



GRASP code has been developed at the University of Lille by **LOA** (Laboratoire d'Optique Atmosphérique)



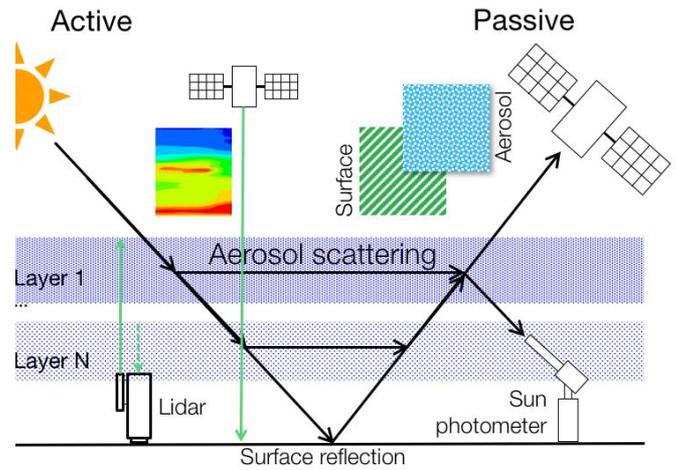
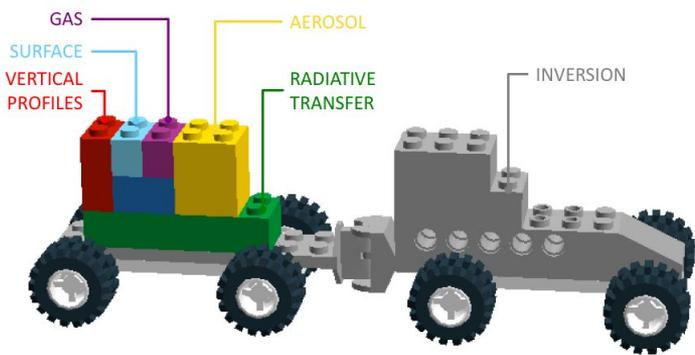
GRASP SAS:

- Promoting
- Consulting
- Maintaining
- Developing



Why GRASP ?

1. **Generalized:** Based on physics concepts instead of instrument dependent concepts
2. **Modular:** The software is highly optimized and designed as independent modules.
3. **Versatile:** Highly configurable, easily adaptable and extensible



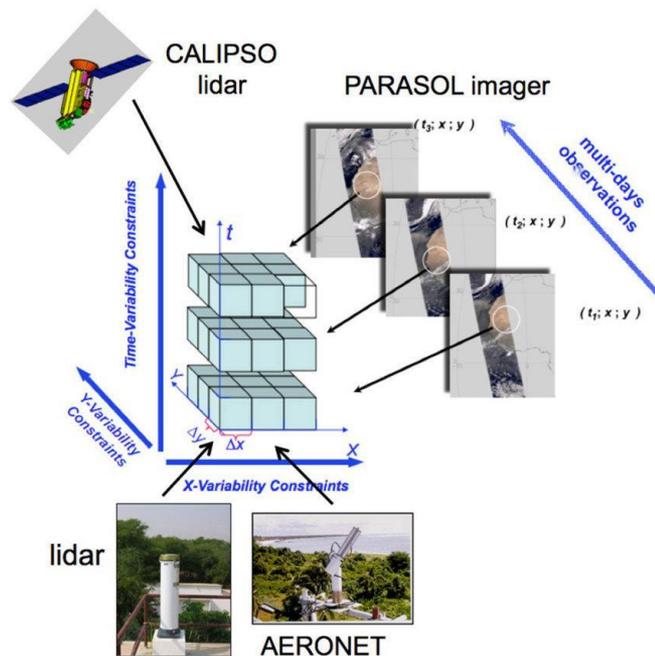


Are more reasons needed?

- Founded on solid mathematical and scientific background
- Innovative:
 - Multi-pixel constraints
 - Multi-instrument
 - Combined retrieval of atmosphere and ground

- Open Source **GRASP**
OPEN

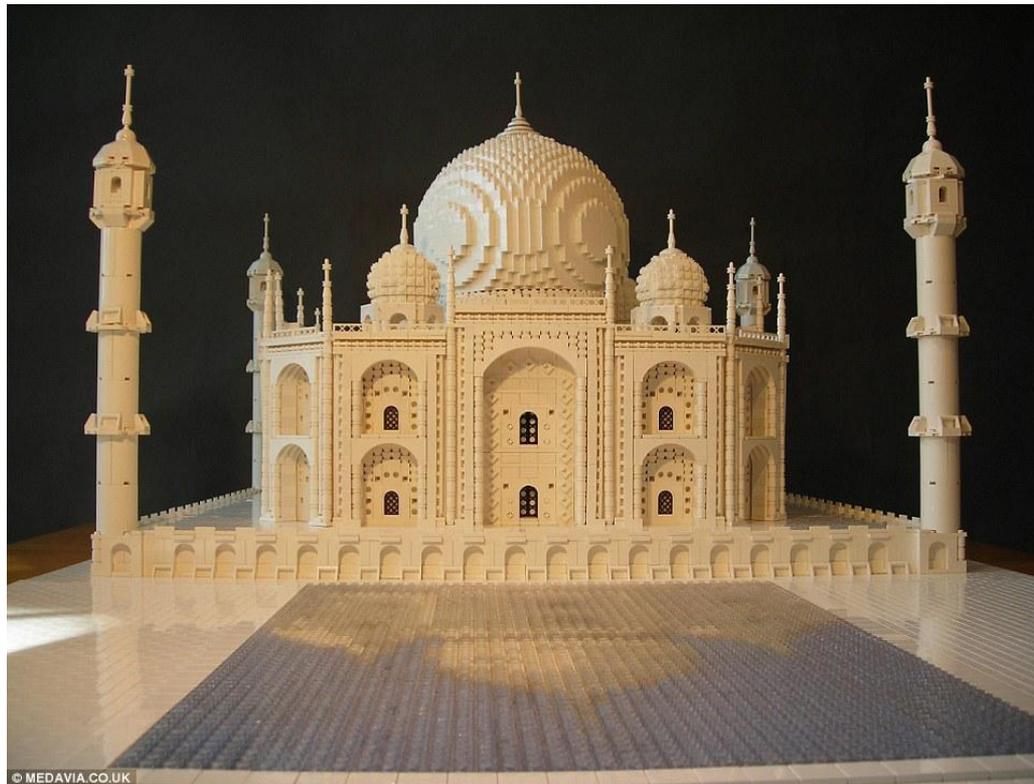
■ It's fun!



Let's start!



Our goal!





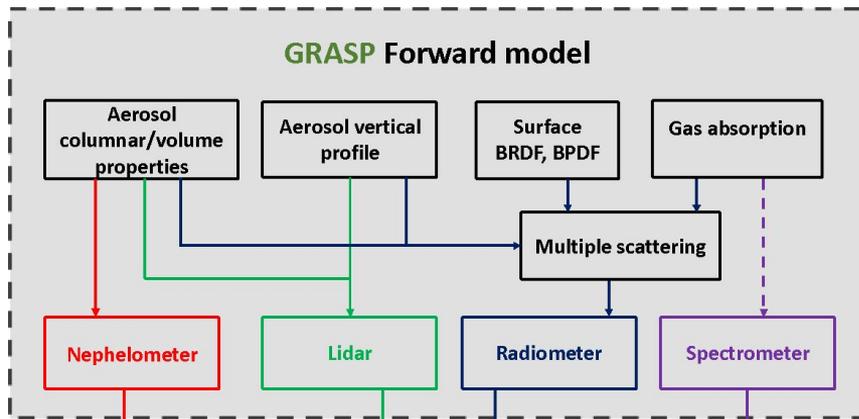
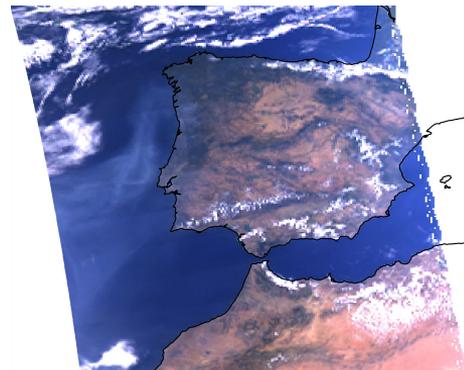
But so far... we are here:





The Forward Model

Real POLDER image
(31st Aug 2013)

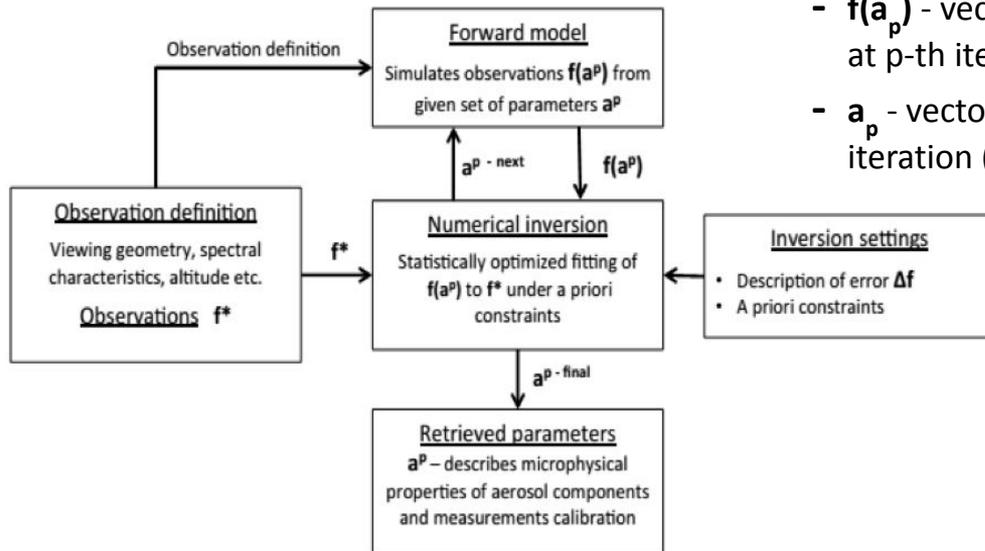


Synthetic image





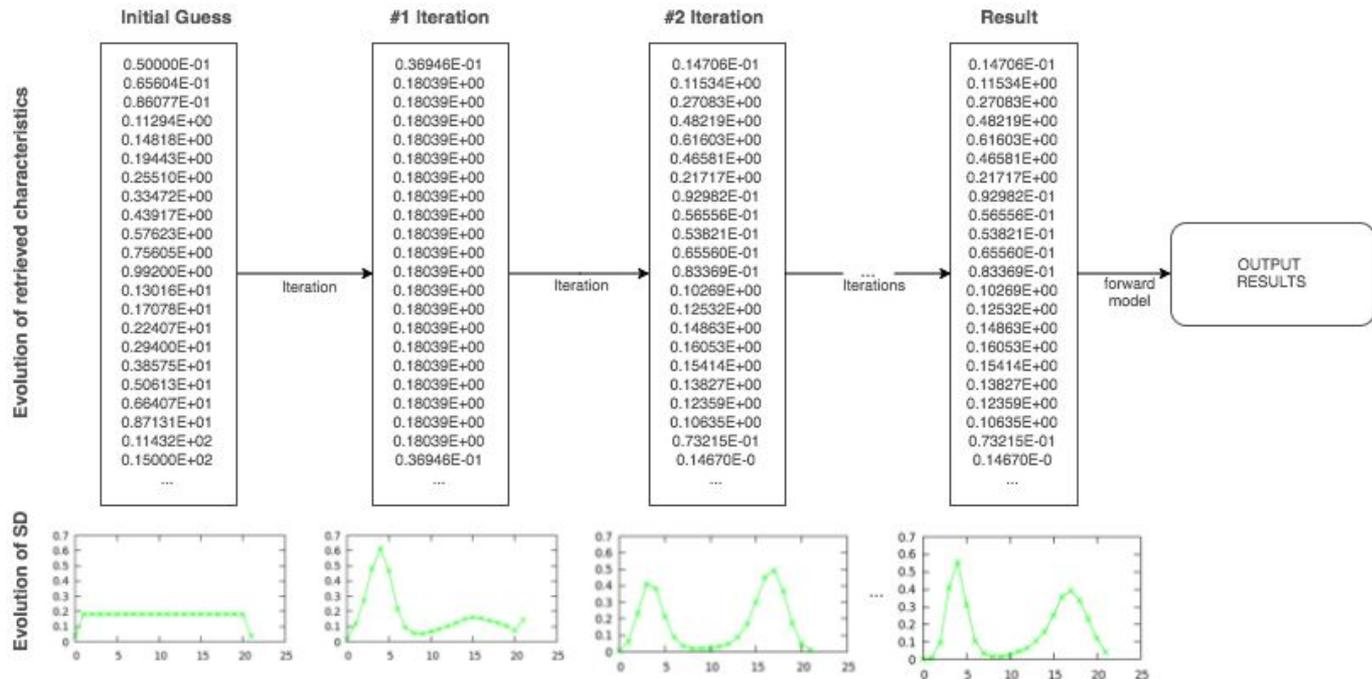
The inversion



- f^* - vector of inverted
- $f(a_p)$ - vector of measurement fit at p-th iterations
- a_p - vector of unknowns at p-th iteration (retrieved parameters).

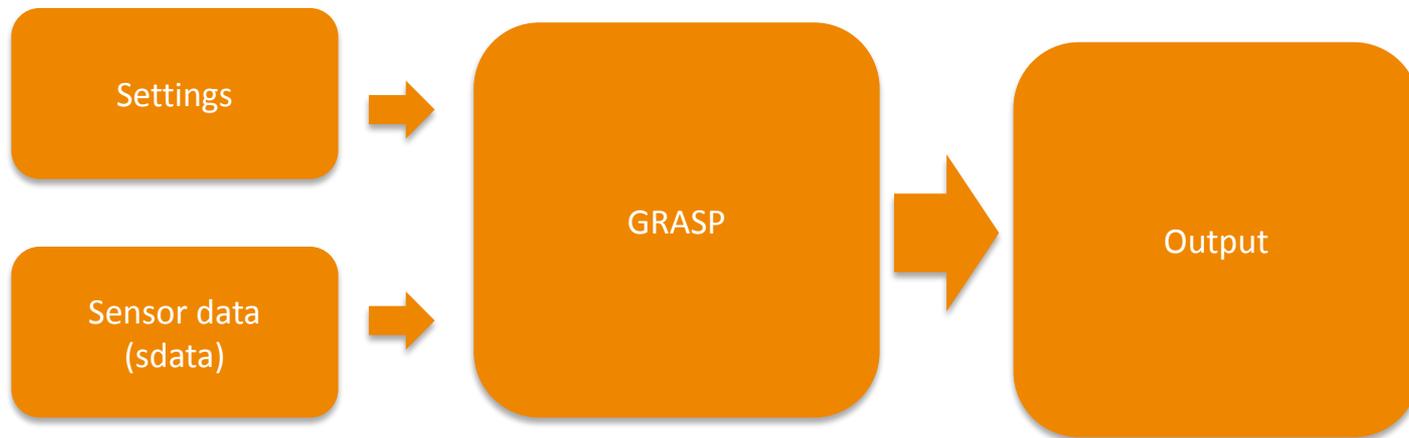


Iterative optimization



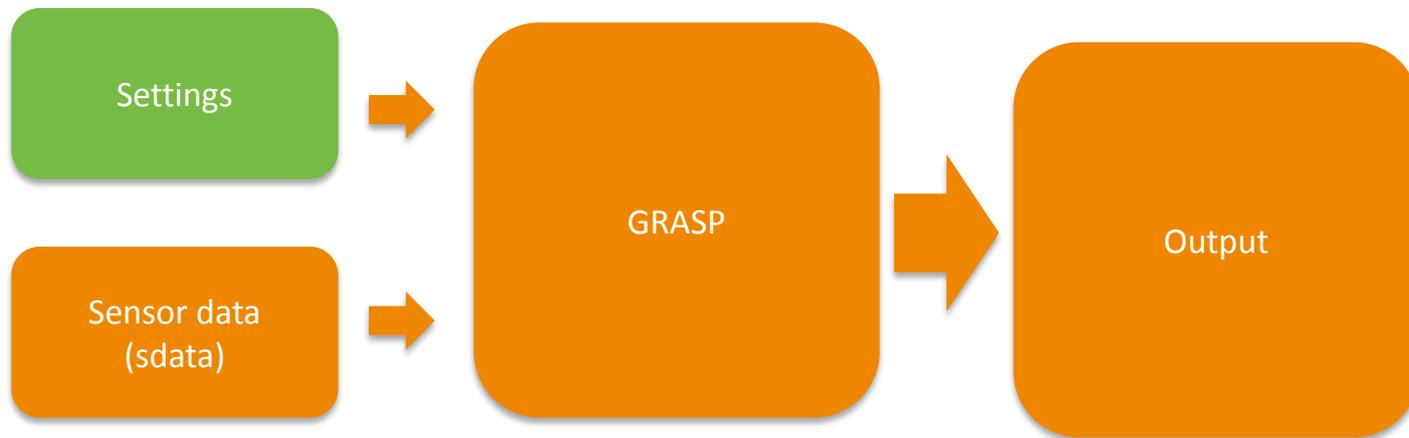


The dataflow



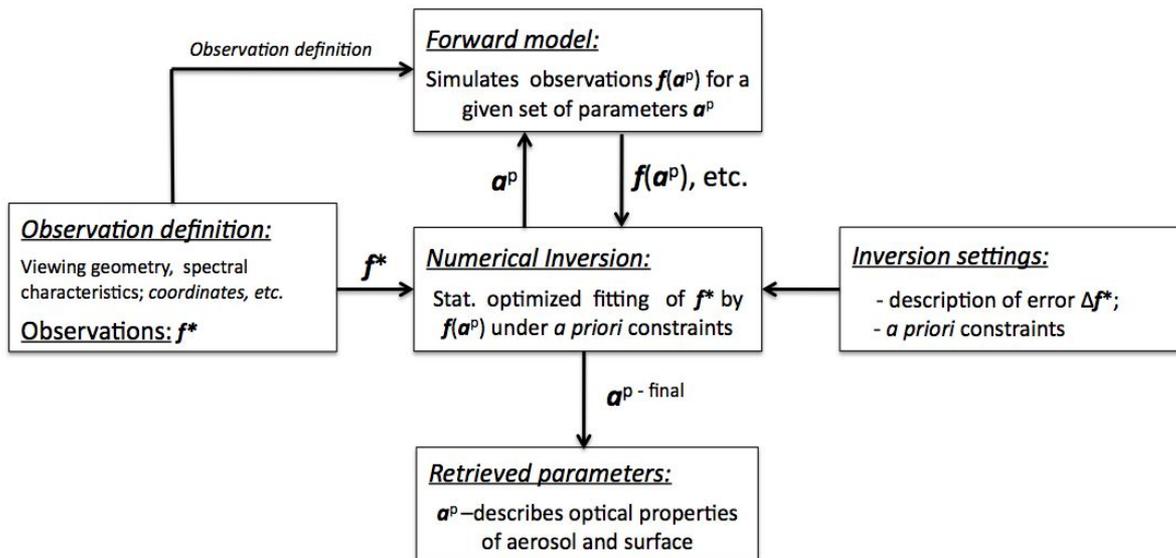


The dataflow



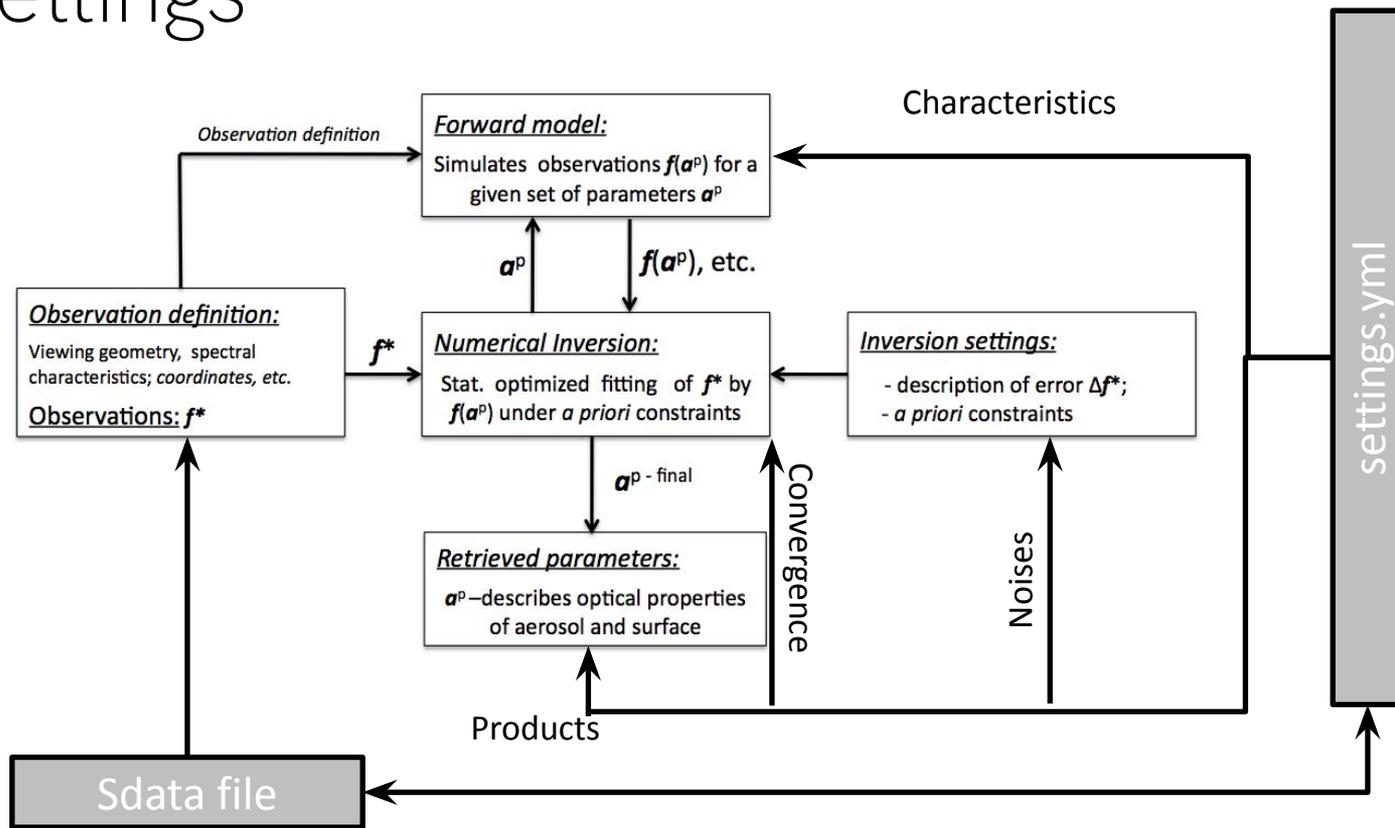


The settings





The settings





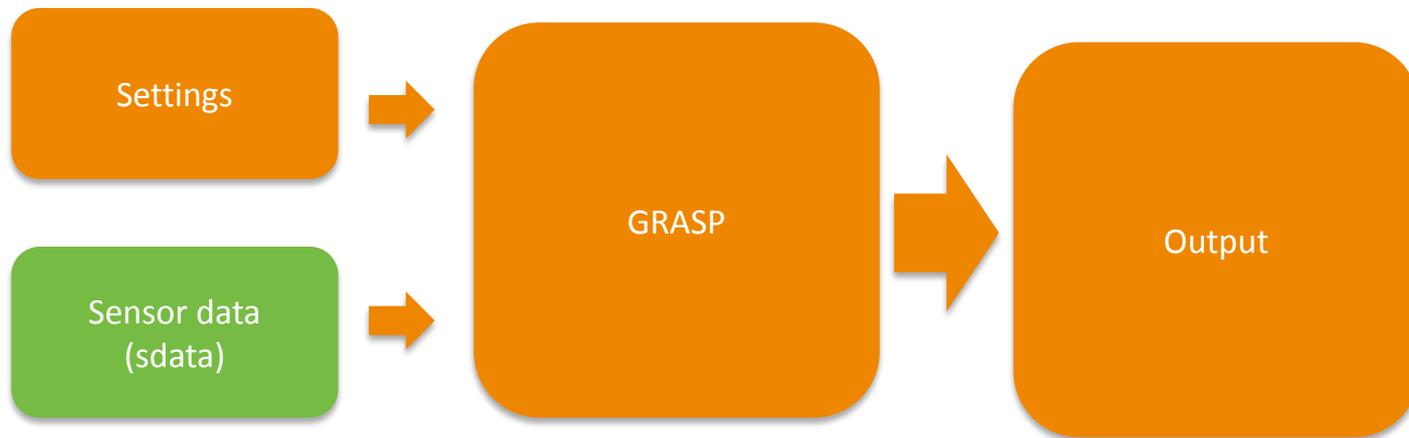
The settings

YAML file which describes the inversion strategy and its specific set up

```
1  input:<...3 lines />
4
5  output:<...4 lines /> #example_lidar_sunphotometer_inversion_test.txt
9
10 retrieval:
11   convergence:<...9 lines />
20
21   regime_of_measurement_fitting:<...2 lines />
23
24   product_configuration:<...2 lines />]
26
27   regime_of_multipixel_constraints: <...2 lines />
29
30 radiative_transfer:
31   number_of_layers: 50
32   molecular_profile_vertical_type: standard_atmosphere
33   reference_plane_for_polarization: meridian
34   simulating_observation:<...5 lines />
39   simulating_derivatives:<...5 lines />
44
45 noises:
46   noise[1]:<...7 lines />]
53   noise[2]:<...7 lines />]
60   noise[3]:<...7 lines />]
67
68
69 phase_matrix:<...11 lines />
80
81 products: <...22 lines />
103
104 debug:<...4 lines />
108
109 constraints:
110   characteristic[1]: #1
111     type: size_distribution_triangle_bins
112     retrieved: true
113     mode[1]:
114       initial_guess: <...5 lines />]
115       single_pixel:
116         smoothness_constraints:
117           difference_order: 3
118           lagrange_multiplier: 1.0e-2
119         multi_pixel:
120           smoothness_constraints:
121             derivative_order_of_X_variability: 0
122             lagrange_multiplier_of_X_variability: 0.0
123             derivative_order_of_Y_variability: 0
124             lagrange_multiplier_of_Y_variability: 0.0
125             derivative_order_of_T_variability: 0
126             lagrange_multiplier_of_T_variability: 0.0
127
128     mode[2]: <...18 lines />
129
130   characteristic[2]: #2<...39 lines />
131
132
133
134
135
136
137
138
139
```

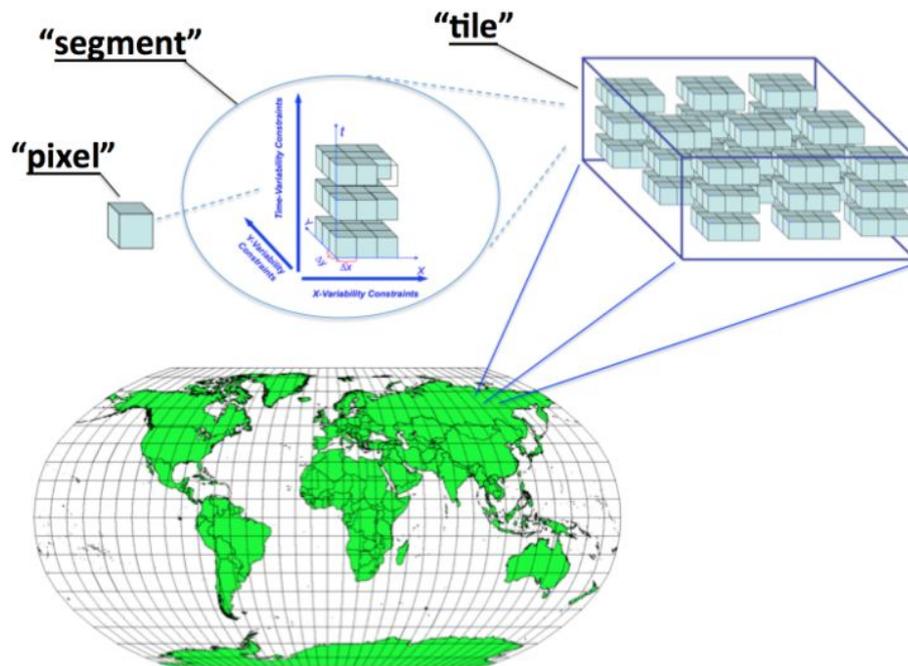


The dataflow



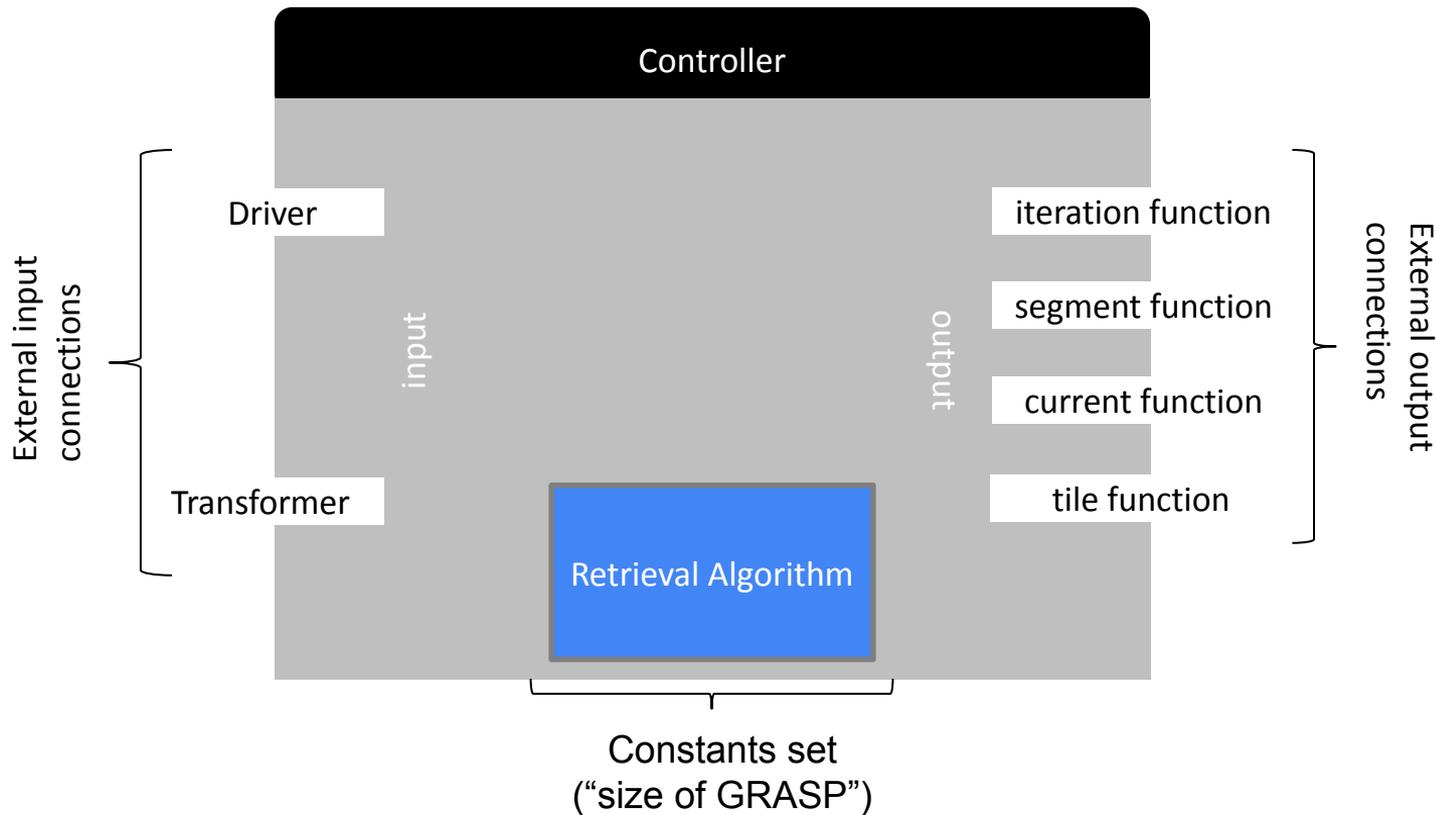


Data organization

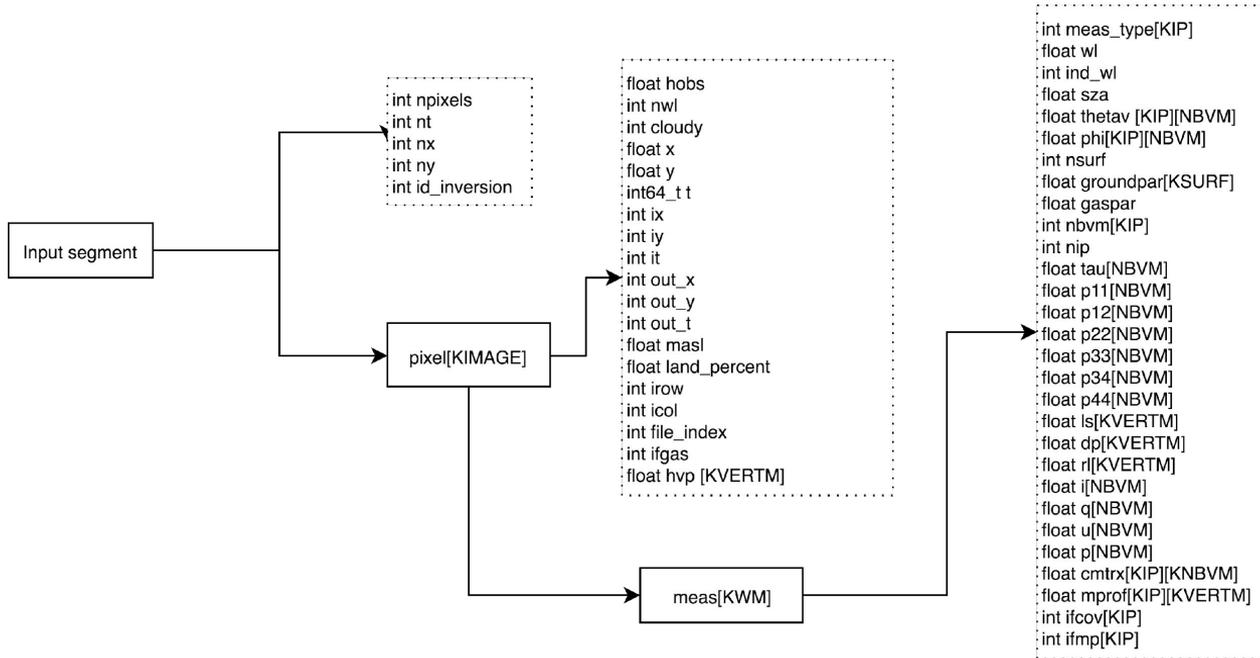




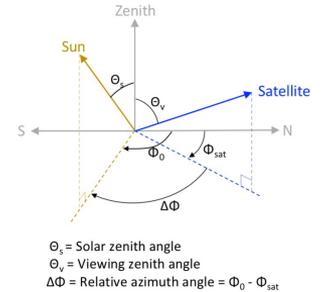
Input/output extensions



Input



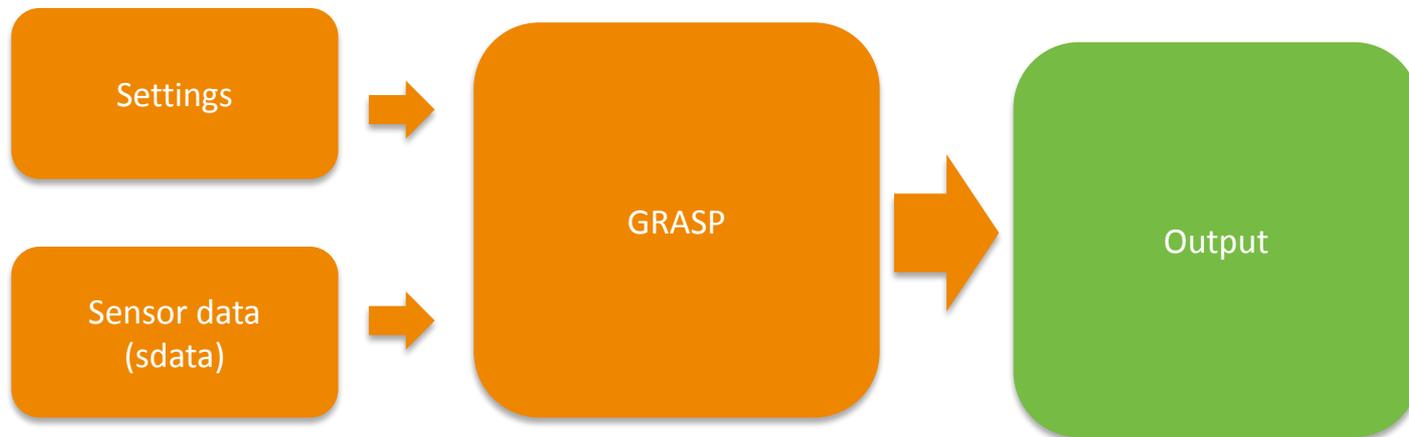
GRASP geometry definition



SDATA description in the official documentation (chapter 4.2): <https://www.grasp-open.com/doc/ch04.php>

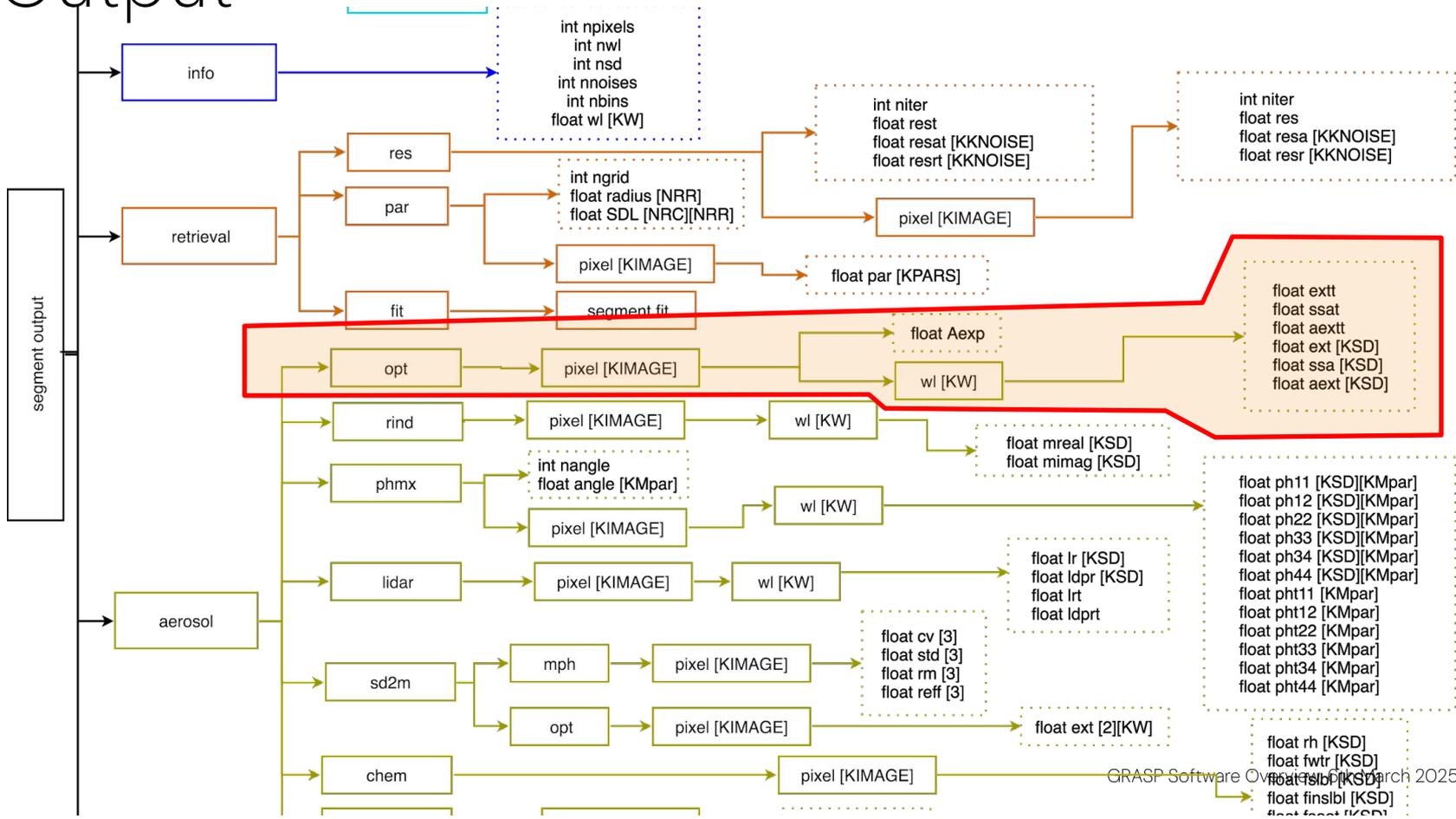


The dataflow



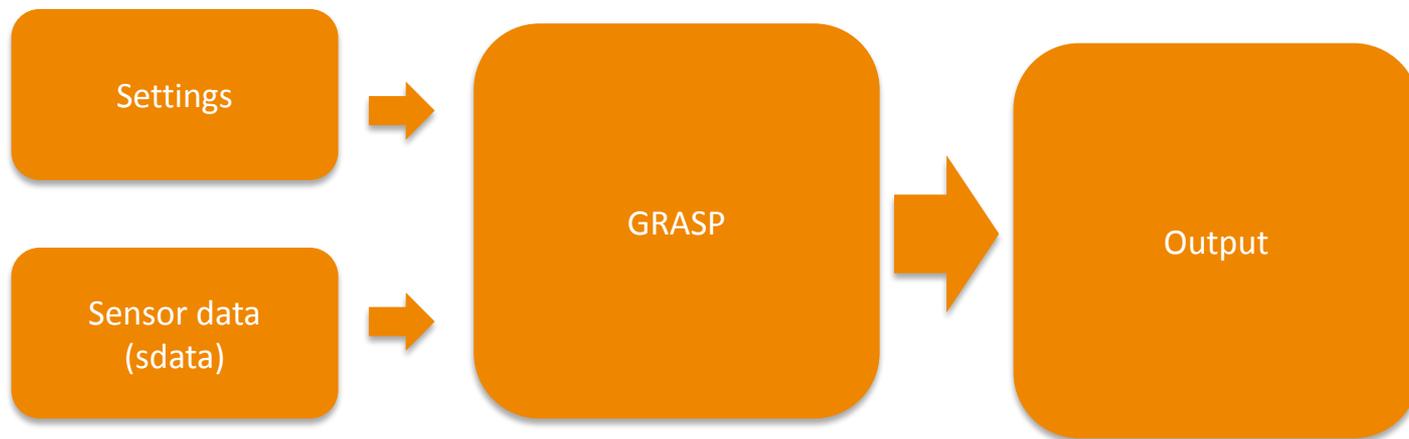


Output





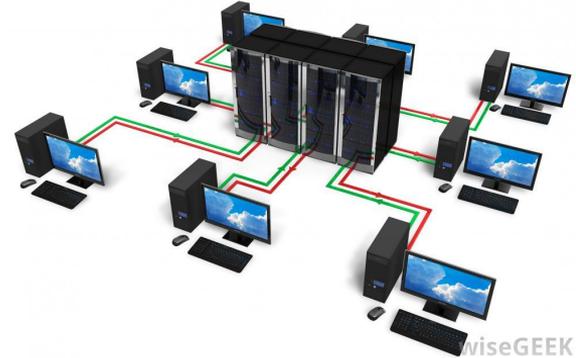
The dataflow: Let's run it!



GRASP-Cloud



GRASP
CLOUD



GRASP IS IN THE ~~AIR~~ CLOUD



GRASP-Cloud

Standalone Operation

1. Download GRASP-Open Code
2. Install Compilers and Libraries
3. Compile GRASP
4. Prepare Input Data (e.g. SDATA)
5. Prepare Configuration
6. Run GRASP Where focus should be !
7. Load and Interpret Output

```

grasp@app-dafuer-2dgrasp-2ddiva:/workspace$ grasp
GRASP core version: undefined (commit: fb3ea555 ; branch_name: dev-gases)
Compiled on 2020-10-12 09:38:27 +0000 commit of 2020-10-12 11:23:15 +0200
With C compiler: cc (Ubuntu 9.3.0-10ubuntu2) 9.3.0
With FORTRAN compiler: GNU Fortran (Ubuntu 9.3.0-10ubuntu2) 9.3.0
Using hyperspectral constant set and build type Release
Other options: models module compiled (2a98769),
Maximum segment size: nx=1 ; ny=1 ; nt=14
Input drivers loaded: sdata segmenter(f48a94fa) yaml_aod(v1.0.0.0)
Input transformers loaded: iguessmbasedonaod(v1.0.0.0) none python(v1.0.0.0) segment_imagedat
Output segment functions loaded: classic classic_plot csv none
Output tile functions loaded: csv hdf5(df34d5f) none
Output current functions loaded: none
Path to resources: /usr/share/grasp/
Sparse solver used: SuperLU
Build System: Linux-3.10.0-862.14.4.el7.x86_64
Executable path: /usr/bin/grasp_app

usage: grasp [OPTIONS] <settings_file.yml>|help

OPTIONS:
  -v      use valgrind
grasp@app-dafuer-2dgrasp-2ddiva:/workspace$

```

GRASP is installed and fully functional out-of-the-b

How to access to the platform (prototype):

1. Register at GRASP-Open website
2. Access: <https://hub.grasp-cloud.com/diva>

How to run GRASP in the terminal:

```
$> grasp settings.yml
```



GRASP-Cloud

```
[1]: import grasp.code as pygrasp
...

[2]: segment = pygrasp.Segment("example_lidar_sunphotometer.sdcat")

[7]: settings = pygrasp.Settings("settings_example_lidar_sunphotometer_inversion.yml")
...

[15]: results = pygrasp.run(settings, sdata=segment)
...

[19]: import grasp.code.plot as gplot
%matplotlib inline
gplot.size_distribution(results, total=True)

[25]: results[:, :, :].retrieval_par.sd[:, :]

[25]: <xarray.DataArray (sd_modes: 3, sd_bins: 244)>
array([[2.9160010e-04, 1.6848989e-02, 3.9935049e-02, 5.6065500e-02,
5.5439431e-02, 3.5982158e-02, 1.4690758e-02, 5.1788371e-03,
7.0376168e-03, 2.2233780e-02, 5.7262760e-02, 1.2276277e-01,
2.0673276e-01, 2.9136664e-01, 3.3773970e-01, 2.9879496e-01
```

Import the algorithm

Prepare the input

Execute the algorithm

Check the results:

- Visualization
- Access to data



GRASP-Cloud

The screenshot displays a JupyterLab environment with the following components:

- File Explorer:** Shows a directory named "Summer_School" containing files: "summer-school-exam...", "example_aod.sdat", "mapfy.py", and "settings_aod.yml".
- Code Editor:** Contains Python code for setting up the GRASP environment and running a simulation. The code includes:

```
[9]: %matplotlib inline
[1]: import grasp.code as pygrasp
Info: Used library at: /home/grasp/.venv/share/libpython_grasp.so
[2]: settings=pygrasp.Settings("settings_aod.yml")
[3]: segment=pygrasp.Segment("example_aod.sdat")
[4]: results=pygrasp.run(settings,segment=segment, print_screen=True)
Config file read successfully
The tile is divided in segments with 1 rows, 1 cols and 1 times. 1 inversions will
Retrieval #0 (1/1): 100.00%: 1 pixels will be processed
in set_RIN_retr_par_number:
  KNSING = 23 - number of parameters driving forward model for each pixel
  KNSINGF = 6 - number of retrieved parameters for each pixel
in set_RIN_RT_OSH_flags_surf:
  isurf_land(1), isurf_land(2), isurf_water:
  _ooo _ooo _ooo
```
- Code Execution:** Shows the execution of mapfy code:

```
[13]: from mapfy import *
input_path = "/input/webdav/polder-optimized/v1.1/l2/daily/GRASP_POLDER_L2_20080601.full.nc"
ds = xarray.open_dataset(input_path)
[16]: show_band(ds, ds.AOD565, **proj_sinusoidal, cmap='jet', vmin=0, vmax=1]
```
- Visualization:** A map of the Earth showing a global distribution of AOD565 values. The map uses a color scale from 0.0 (blue) to 1.0 (red), with a color bar on the right side.



Before finishing....



Resources at GRASP Open Web Page

Access to the code

The code is open for all users with scientific purposes. Let's start using GRASP algorithm by your own!

Data processed ready for:

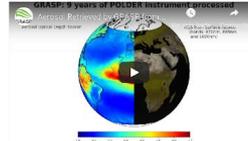
- Easy download
- Visualization

POLDER/PARASOL

GRASP algorithm has been applied to the entire archive (13 years) of the French Space Agency's PARASOL/POLDER instrument, obtaining a wide variety of aerosol and surface characteristics, including Aerosol Optical Depth of extinction (AOD) and absorption (AAOD), Single Scattering Albedo (SSA), Angstrom Exponent (AE), Surface Albedo, NDV, vegetation index, etc.

The first processing was performed at LMD (Laboratoire de Dynamique Atmosphérique) in Paris. The video on the right shows a moving overview of this parameter: AOD 550nm obtained. The latest products are available at CORE website: <http://www.core.jussieu.fr/EN/>. Additionally, the system allows the user to download the data using a web tool which gives online the results.

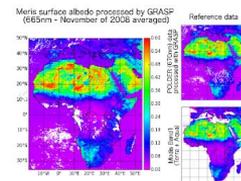
The interested users can access the preprocessed data by GRASP SAS using the following button.



Download POLDER data

DOWNLOAD

MERIS/ENVISAT



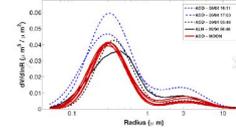
Within the framework of projects supported by ESA, GRASP algorithm has been optimized and applied to the data of MERIS instrument. Two important results have been obtained from those studies:

- The information about surface and aerosol (aerosol optical depth, single-scattering albedo, etc.) for the entire MERIS mission has been obtained. Full archives are available for free at this website. Click the button below to download the data.
- A reimplementation of GRASP forward model using SPHIG technologies has been developed successfully, allowing the code to be parallelized and over graphic cards and obtaining faster results (up to 10x). This development works as an external and optional module for GRASP. It is going to be released as an open source and can be selected at compilation time.

Download MERIS data

DOWNLOAD

GRASP-AOD



The large amount of typical depth only measurements (AERONET - near surface measurements, star photometry, air-borne sun-photometers, GAW-FR networks, etc.) has motivated the development of the so-called GRASP-AOD application. This application characterizes obtained properties of aerosols by making use of only spectral aerosol optical depth data.

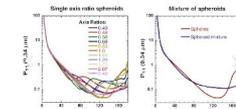
The versatility of the GRASP model allows to integrate the aerosol model to this scheme in order scattering information is not processed. Thus, the article by Torres et al. (2017) suggests to assume an known the retrieval index and the geometry parameter to retrieve the particle size distribution which is characterized by blending the typical (defined by an independent parameter volume modulus μ_{vol}), geometric standard deviation σ_{vol} and particle volume concentration C_{vol} (in $\mu\text{m}^3/\text{m}^3$) with μ_{vol} for the fine and coarse modes, respectively.

We developed a web tool that allows to play with the GRASP-AOD application in an interactive and educational way. Click the button below to try it!

Try GRASP-AOD application

DOWNLOAD

Spheroid-package



Spheroid package allows for study spheroids, and facilitates modeling of light scattering properties by polydisperse randomly oriented spheroids with different size and shape distributions. It includes a software and binary data base. The details of the spheroid package are described by the user by Dubovik et al. (2006). The software tools is also, at present, used in GRASP inversion algorithm for retrieving detailed aerosol parameters from laboratory or remote sensing radiometric measurements of light scattering.

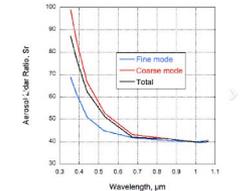
Download Spheroid-package

DOWNLOAD

Lidar + Sun/Sky Radiometer

GRASP group provides the possibility of obtaining synthetic retrievals involving simultaneously multiple instruments and lidar observations. Specifically, the following of these synthetic retrievals can be obtained:

- Inverting simultaneously surface and lidar measurements, (co)calibrated to provide the detailed retrieval of colorless, integrated properties (particle size distribution, complex refractive index, spheroid fraction, AOD) and aerosol type together with the particle radius along vertical profile of the column.
- Synergy of radiometer and lidar data allows the retrieval to distinguish between fine and coarse modes and to provide information that is not available when using only radiometer or lidar data, for example measurement of vertical distribution of aerosol absorption or single scattering albedo.
- GRASP can process observations even from rather complex lidar systems: measure non-water aerosols and optimized sampling of atmospheric layers. Using synergy of observations by both lidar and sunphotometers significantly enhances the retrieval accuracy.
- GRASP retrieval can allow user to impose a priori constraints on variability of aerosol properties that allow for reducing spurious retrieval even for the not fully co incident and/or simultaneous observations.



Documentation

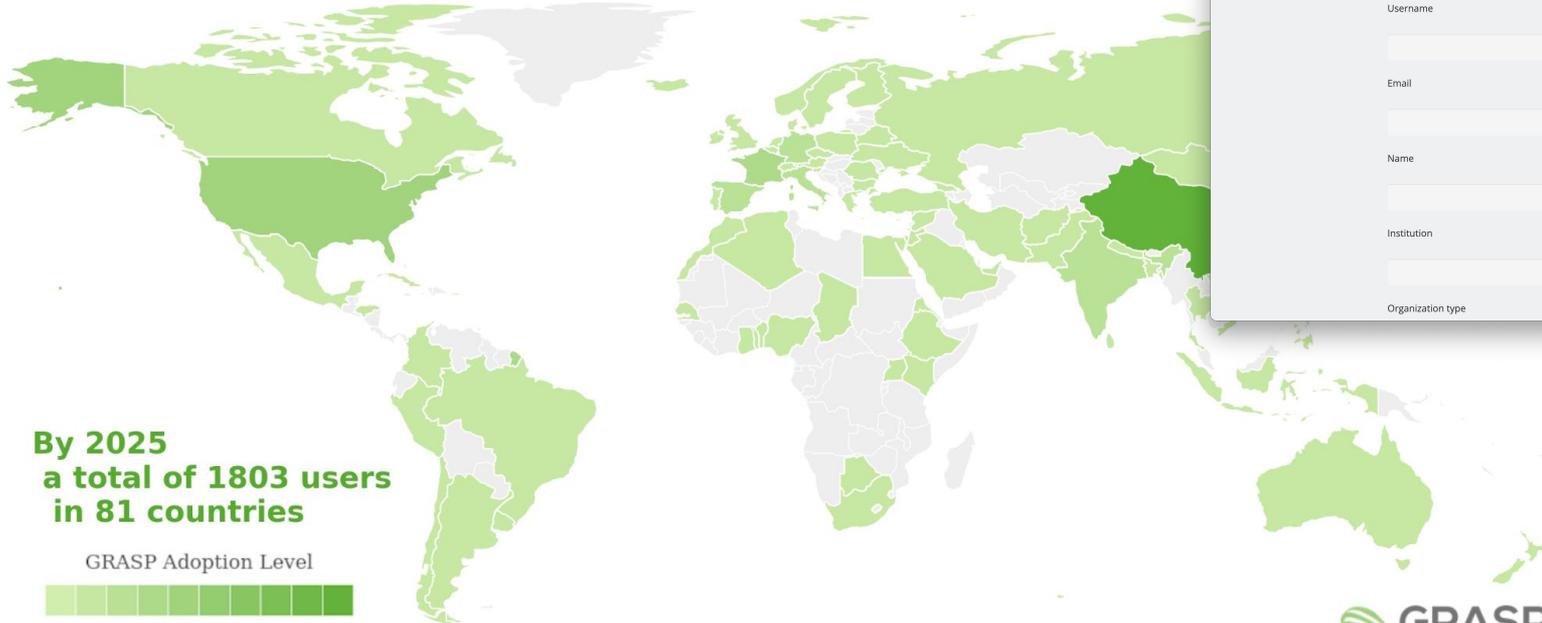
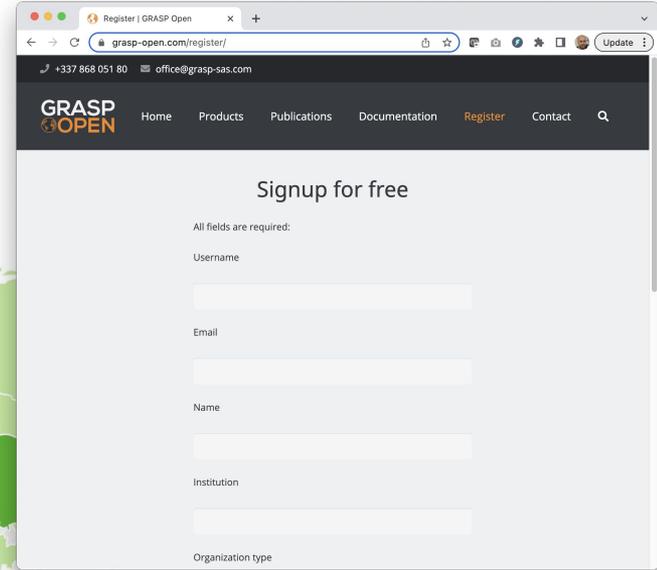
Publications

Tools



Registration

<https://www.grasp-open.com/register>



**By 2025
a total of 1803 users
in 81 countries**

GRASP Adoption Level



Fully GRASPified!

Creation date: 2025-02-26



Thank you very much...

... and good luck with the training!



ATARRI



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