Explorations of novel observations and multi-instrument synergy for studying aerosol and aerosol-cloud Interactions in frame of AIRSENSE project

O. Dubovik, Lopatin, P. Litvinov, O. Hasekamp, B. van Diedenhoven, U. Wandinger, H. Baars, V. Amiridis, A. Tsekeri, G.-J. van Zadelhoff, T. Tsikerdekis, D. Donovan, I. Stachlewska, L. Janicka, J.- C. Pere, F. Waquet, O. Sourdeval, D. Gasbarra and T. Fehr

ESA UNCLASSIFIED – For ESA Official Use Only

AIRSENSE

Aerosol and aerosol-cloud **I**nteraction from **R**emote **SENS**ing **E**nhancement

Objective: is to enhance the understanding of aerosol and aerosol-cloud interactions.

. **Part of** Atmosphere Science Cluster of ESA's EO Science for Society program an element of the ESA FutureEO programme, which aims at boosting Europe's excellence in EO science and its applications.

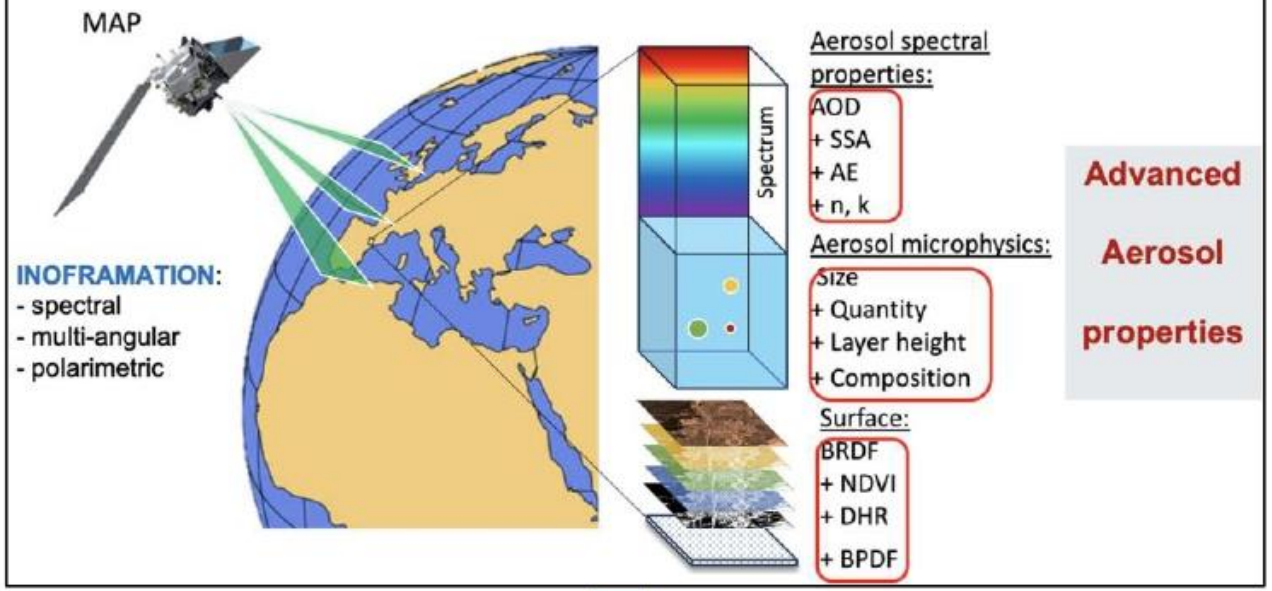
Web site: https://www.grasp-earth.com/portfolio/airsense/

ESA project officer: **Thorsten Fehr**

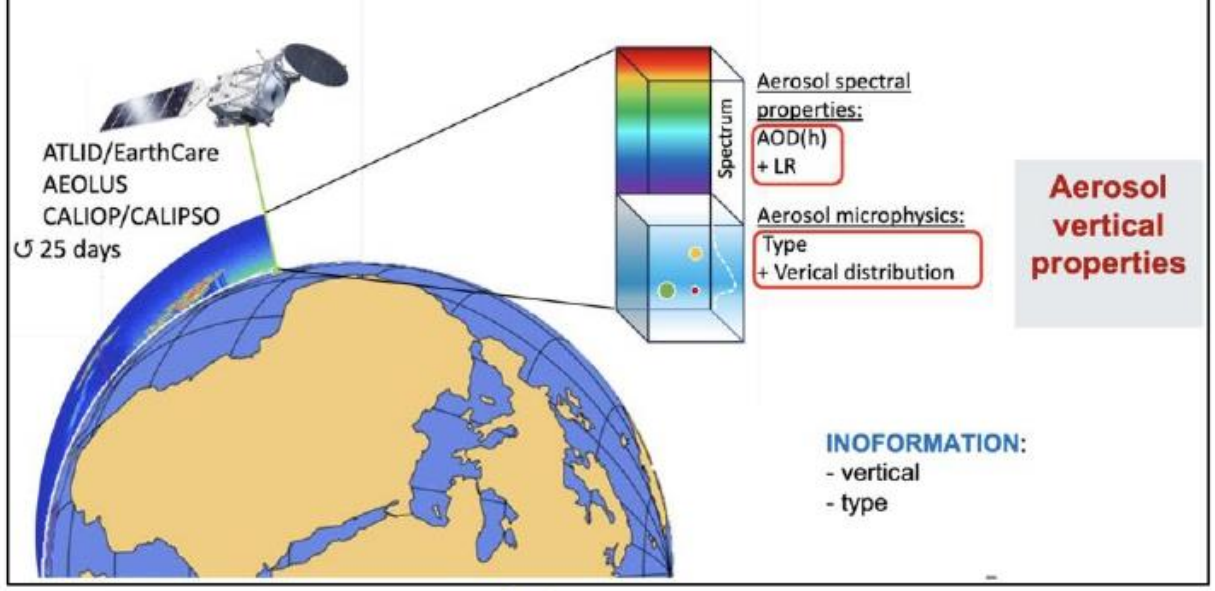
Product MATURITY of *advanced* satellite instruments

AIRSENSE

Multi-Angular Polarimetry



Space Lidar



columnar aerosol properties

more detailed and more accurate than from Single/Bi-viewing Imagers

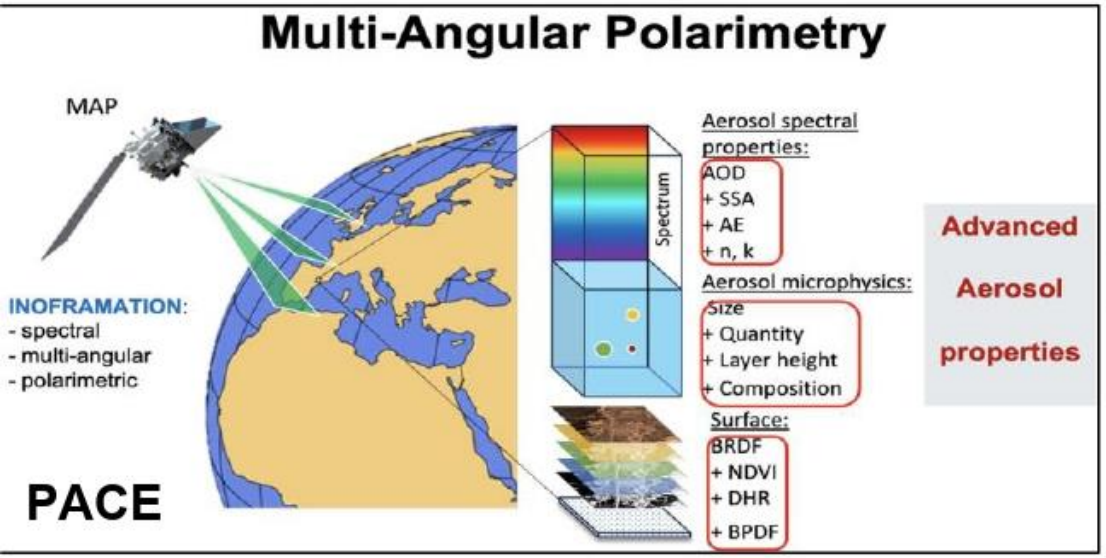
vertical aerosol properties

more detailed and more accurate than from present sensors

GRASP

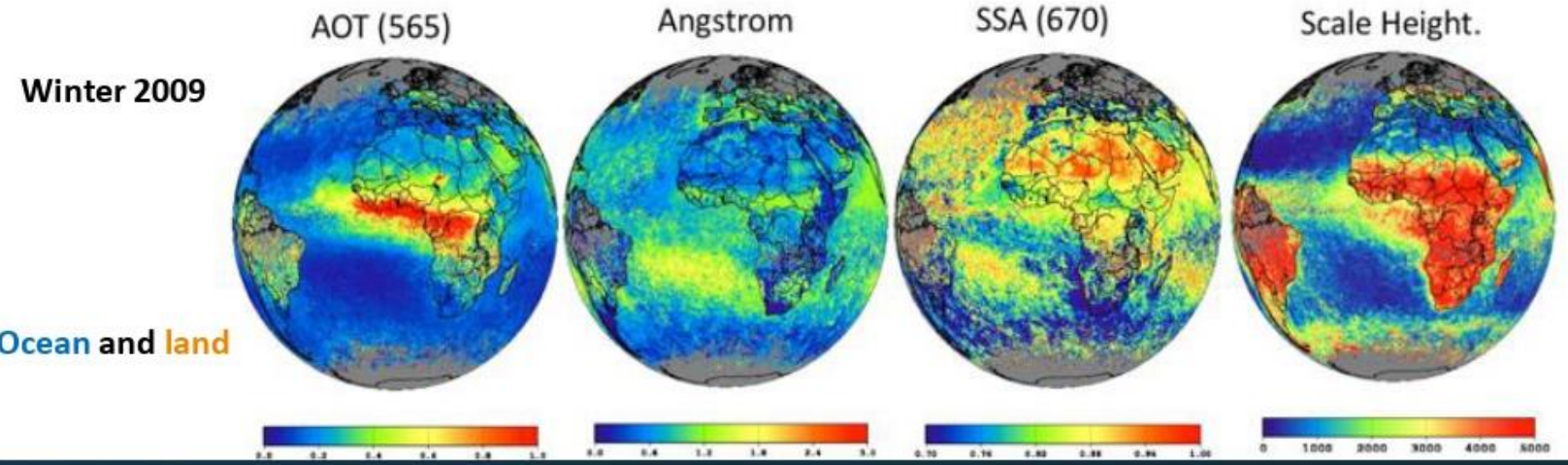
SRON Netherlands Institute for Space Research

POLDER product analysis:



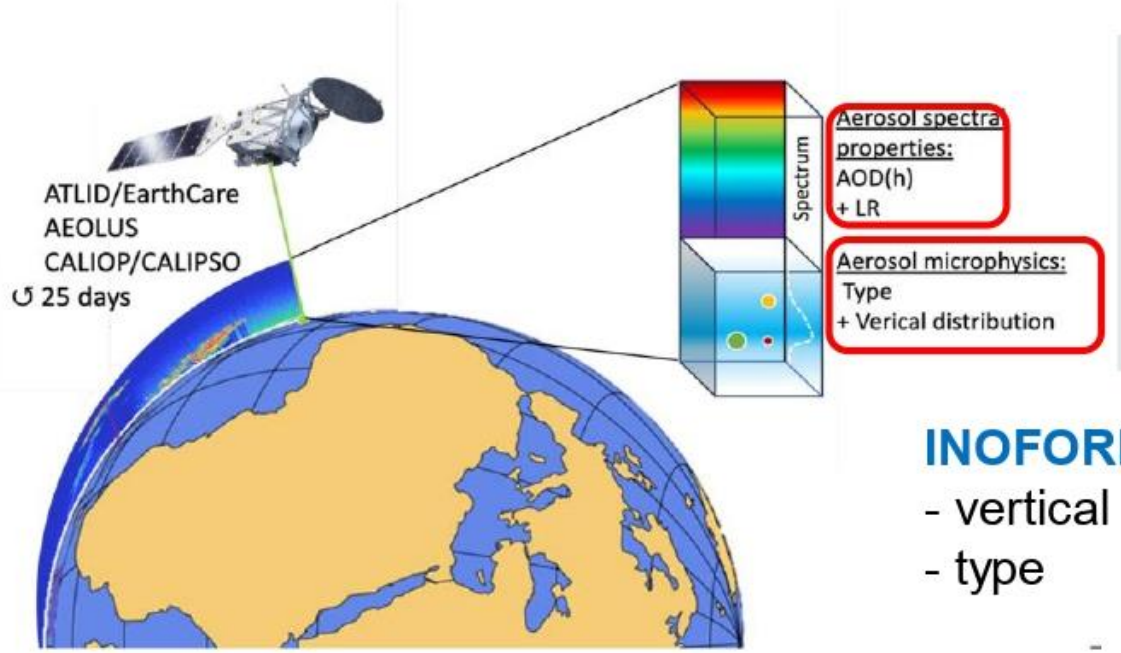
1. The baseline **AOD, AE**, **fine /coarse AOD** (ocean), **from MAP** overall have higher, accuracy than from «MODIS»;

2. Detailed properties - **AE**, **fine /coarse AOD** (land), **SSA**, **AAOD** are available **from MAP**;



AOD(land), **AE**, **fine /coarse AOD** (land), **SSA**, **AAOD** from **MAP** are of **unprecedented** accuracy

Space Lidar Product MATURITY



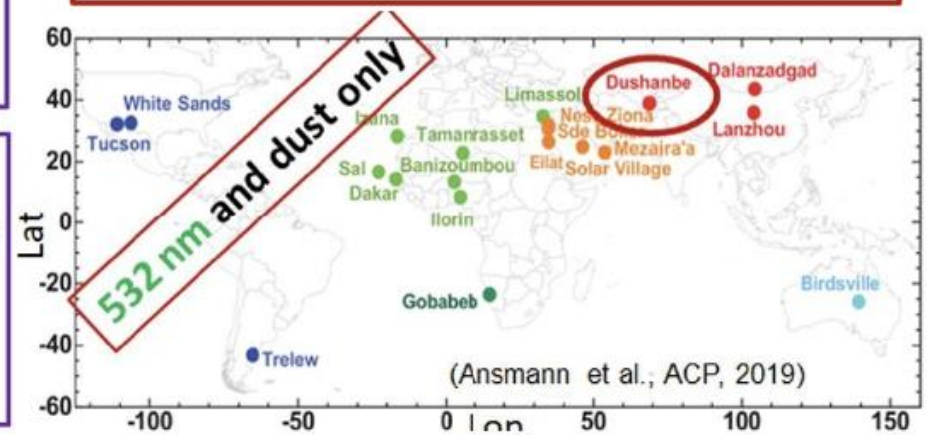
Aerosol vertical properties

INOFORMATION:
- vertical
- type

TASK 2300.1:
Retrieve novel POLIPHON conversion parameters for the application at 355 nm from global AERONET datasets.

TASK 2300.2:
Determine type-dependent depolarization and lidar ratios for profile partitioning and backscatter-to-extinction conversion at 355 nm from extensive ACTRIS/PollyNET datasets.

Testbed Tajikistan: 18-month concurrent measurements at 355 and 532 nm, highly quality controlled and cloud screened (Hofer et al., ACP, 2017; 2020a,b).



AIRSENSE

TEAMS involved:

TROPOS
Leibniz Institute for Tropospheric Research
Ulla. Wandinger, Holger Baars, etc.

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu
Gerd-Jan, van Zadelhoff, Thanos Tsikerdekis, Dave Donovan, etc.

Vassilis Amiridis, Alexandra Tsekeri, Eleni Drakaki, etc.

TASK2300.4: Extend the products in time with additional products from CALIPSO, investigate the possibility to use Aeolus products as well.

Aeolus

HSRL capability: Independent measurement of the backscatter and extinction coefficients → Direct measurement of the lidar ratio

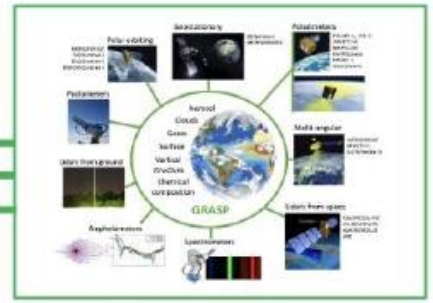
CALIPSO

Retrieval of linear particle depolarization ratio at 532 nm → Cloud discrimination, identification of non-spherical aerosols (mineral dust, volcanic ash etc.)

Retrieval developments

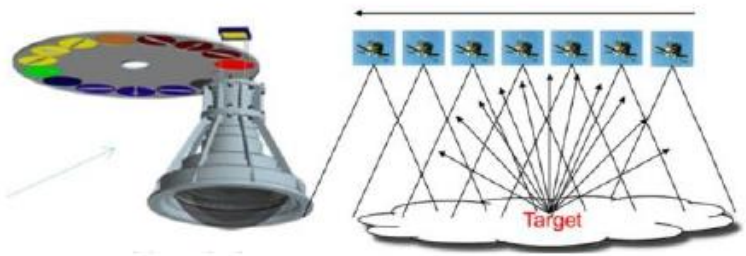
KEY ELLEMENTS:

GRASP engine



Product MATURITY of *advanced* satellite instruments:

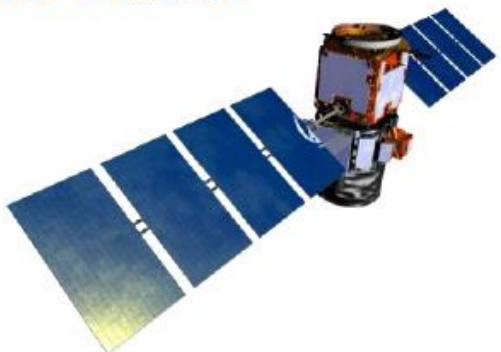
- Multi-angular polarimeters (MAP)"



PACE:
HAPR-2
SPEX

3MI
MAP/CO2M

- Space Lidars:

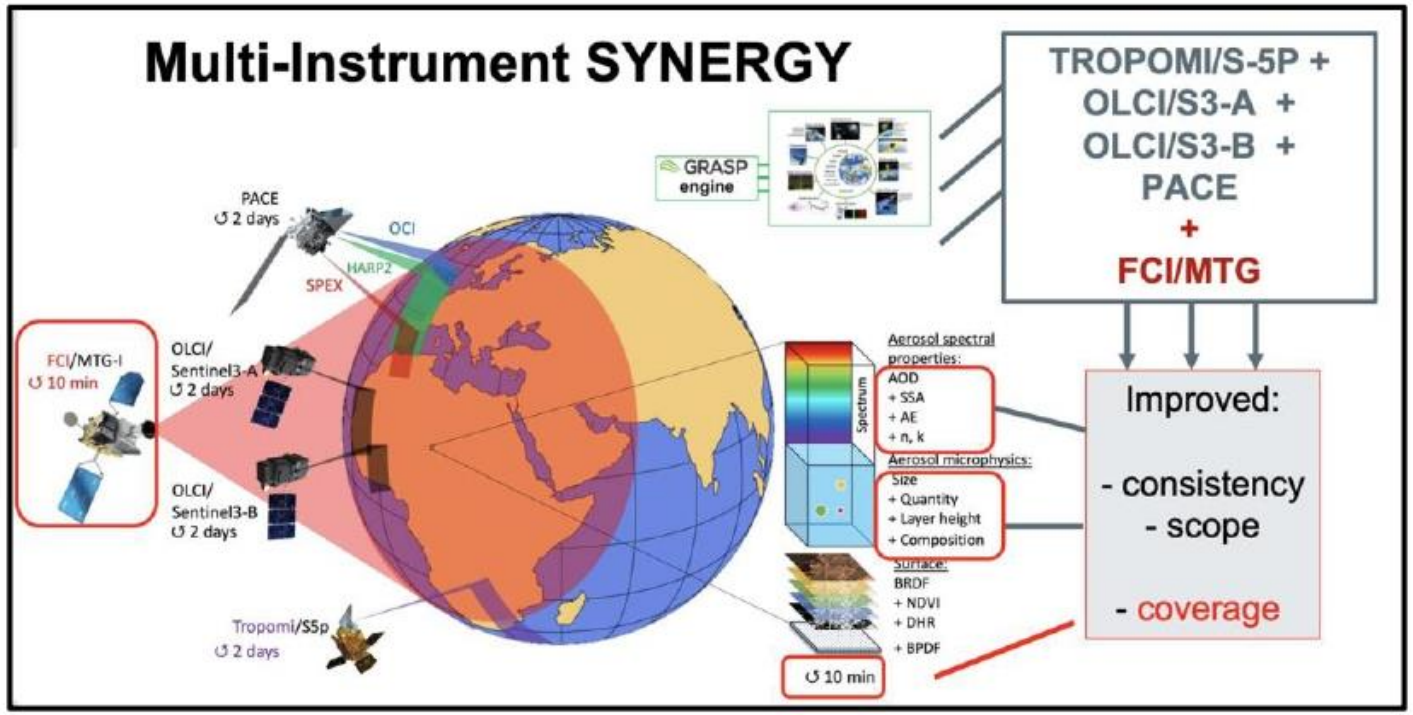


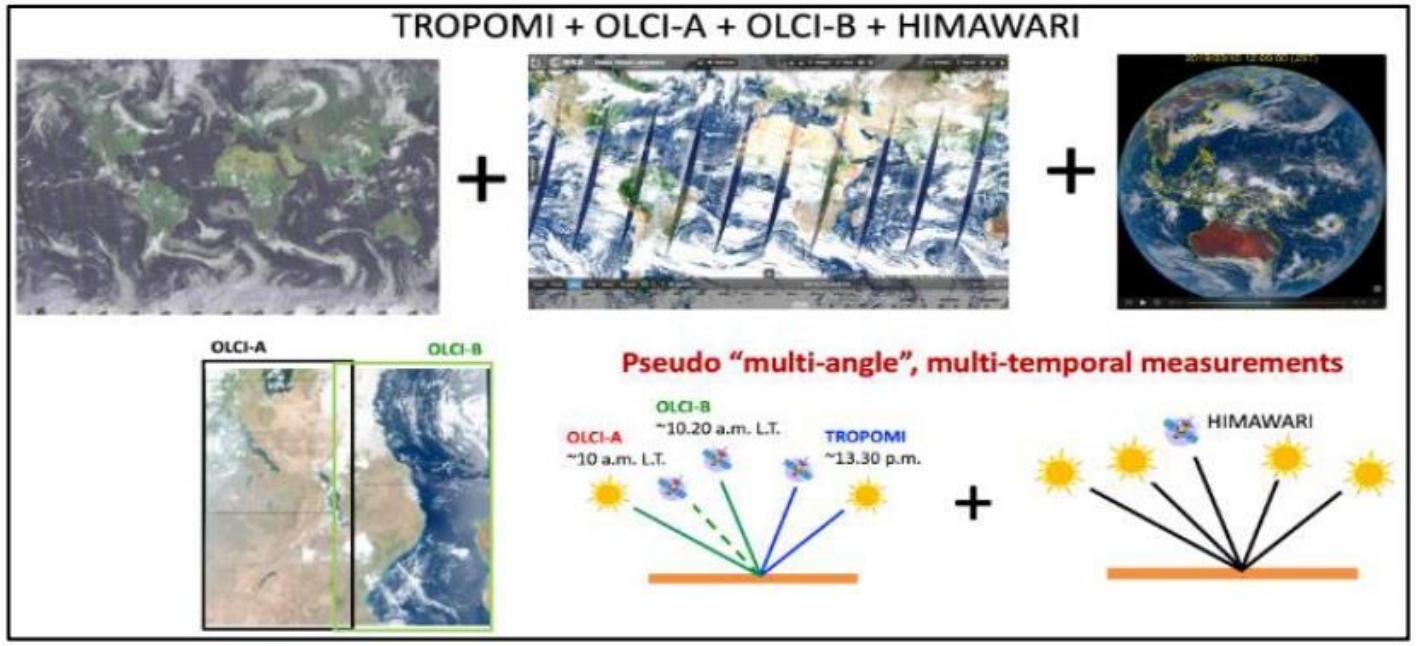
CALIPSO
AEOLUS
EarthCARE

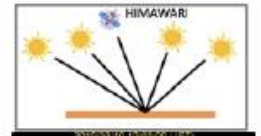
Multi-Instrument SYNERGY of *available* satellites with different complementarities:

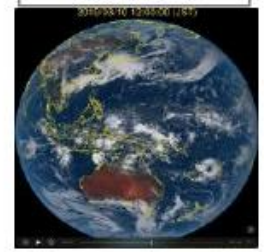
- improved global coverage;
- complementary content;
- passive GEO + LEO;
- passive conventional + advanced;
- passive + active

DETAILED
columnar and vertical properties
of aerosol and clouds

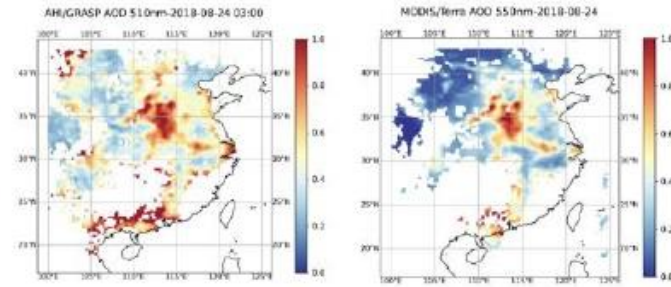




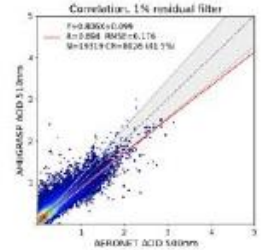




HIMAWARI/GRASP

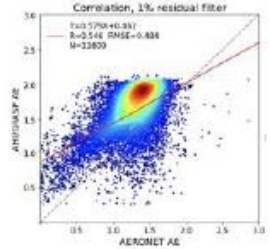


AOD



R=0.89
RMSE=0.18
Bias= 0.07
GCOS=42%

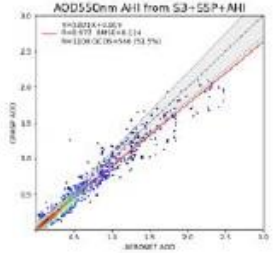
AE



RMSE=0.48

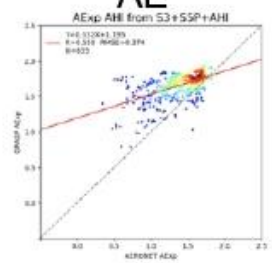
HIMAWARI- Synergy

AOD



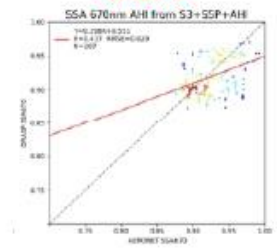
R=**0.98**
RMSE=0.12
Bias= **0.00**
GCOS=51%

AE



RMSE=0.37

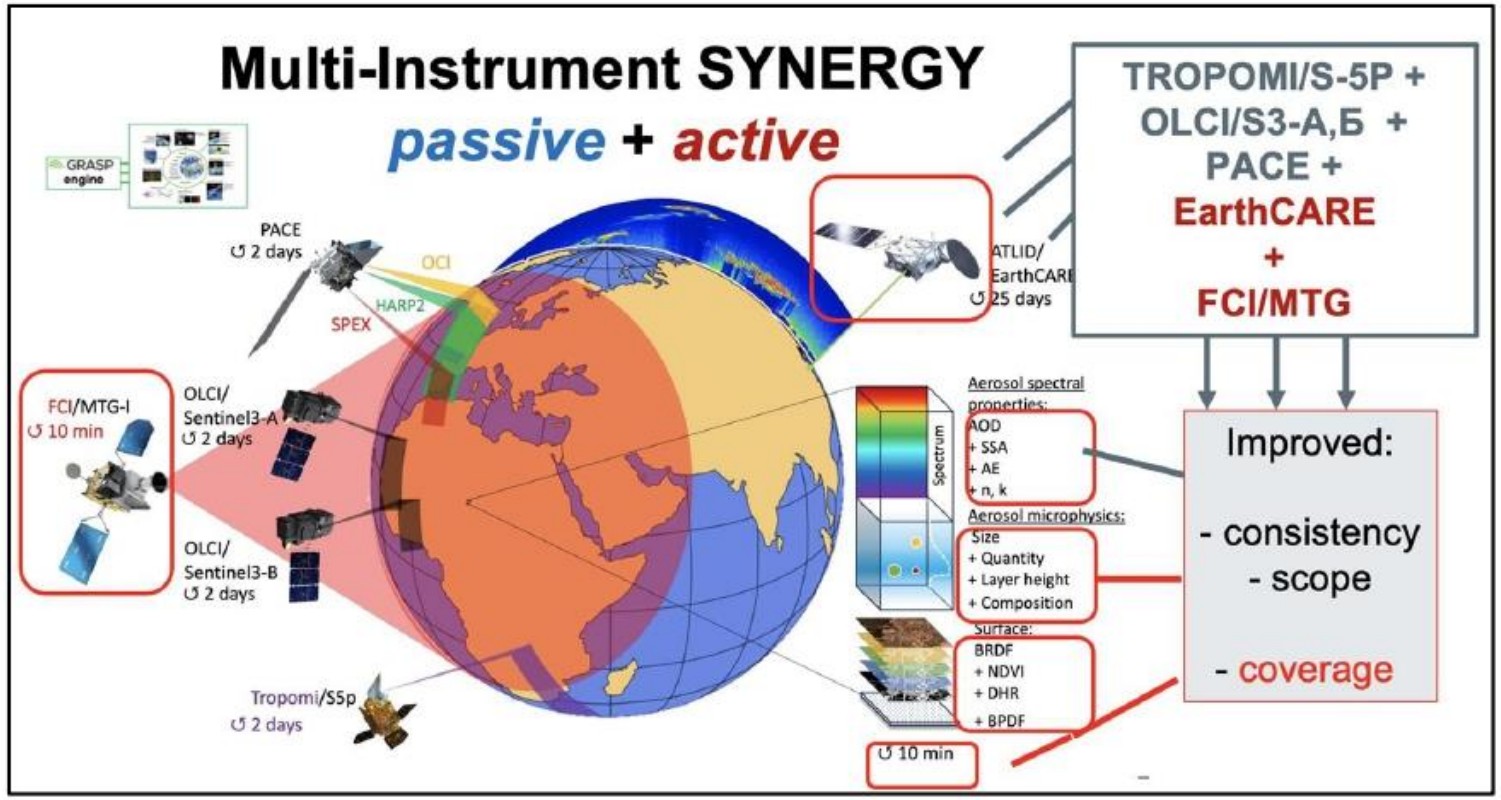
SSA



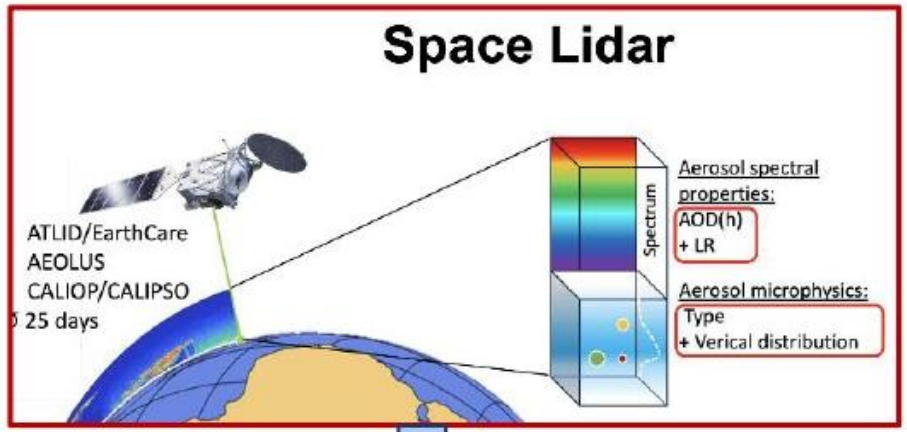
RMSE=**0.03**

Multi-Instrument SYNERGY

passive + *active*

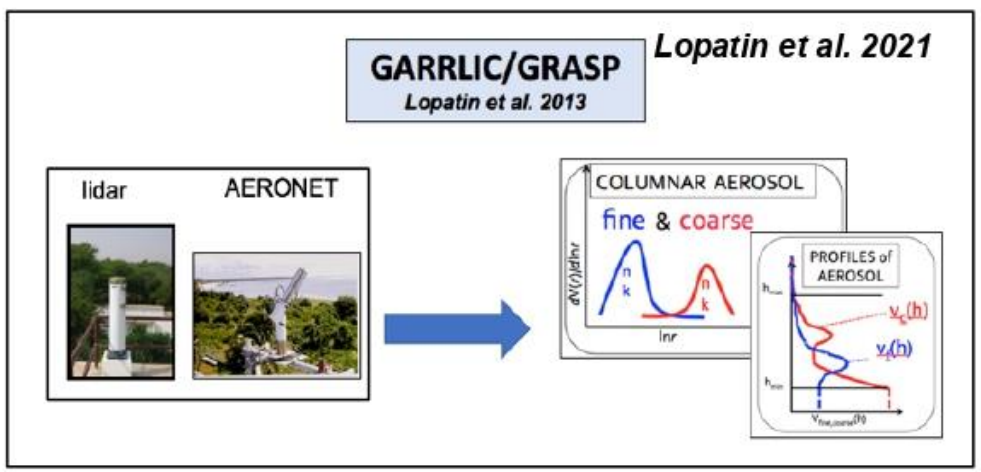


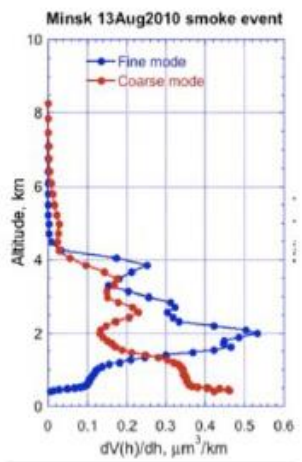
Space Lidar

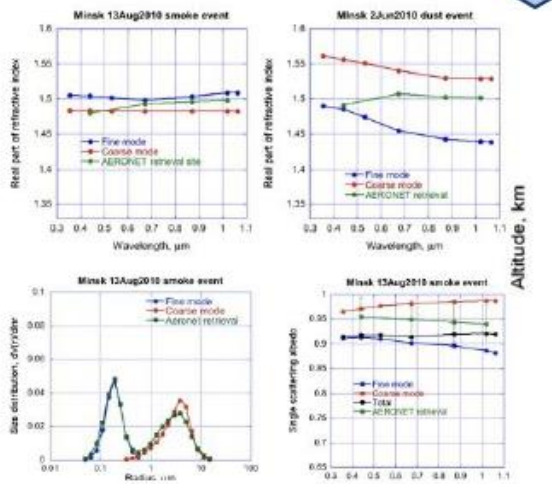


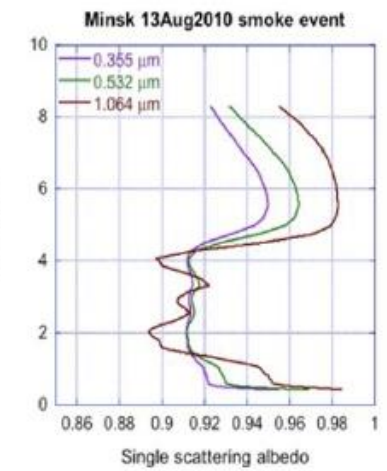
Extinction profile; lidar ratios, depolarization, aerosol type, etc.

Passive + Active Synergy:
quantitative model of vertical and columnar properties of aerosol

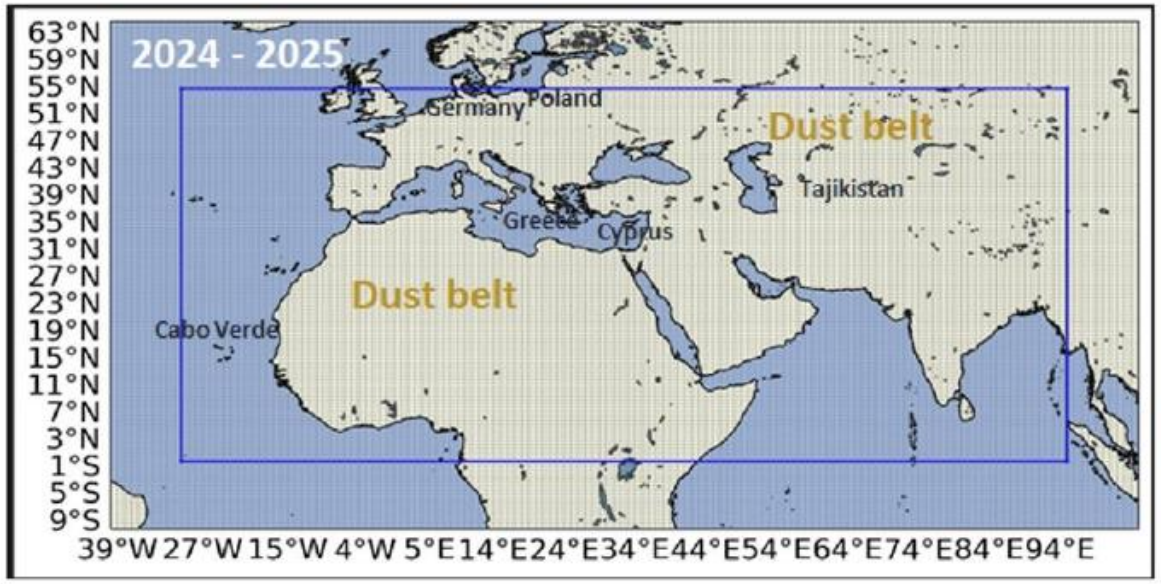








Validation of AIRSENSE products:



AIRSENSE products (WP2100, WP2200, WP2300) will be evaluated using suborbital observations from lidars, radars, radiometers and disdrometers from the **PollyNET & ACTRIS** aerosol and cloud remote sensing sites in:

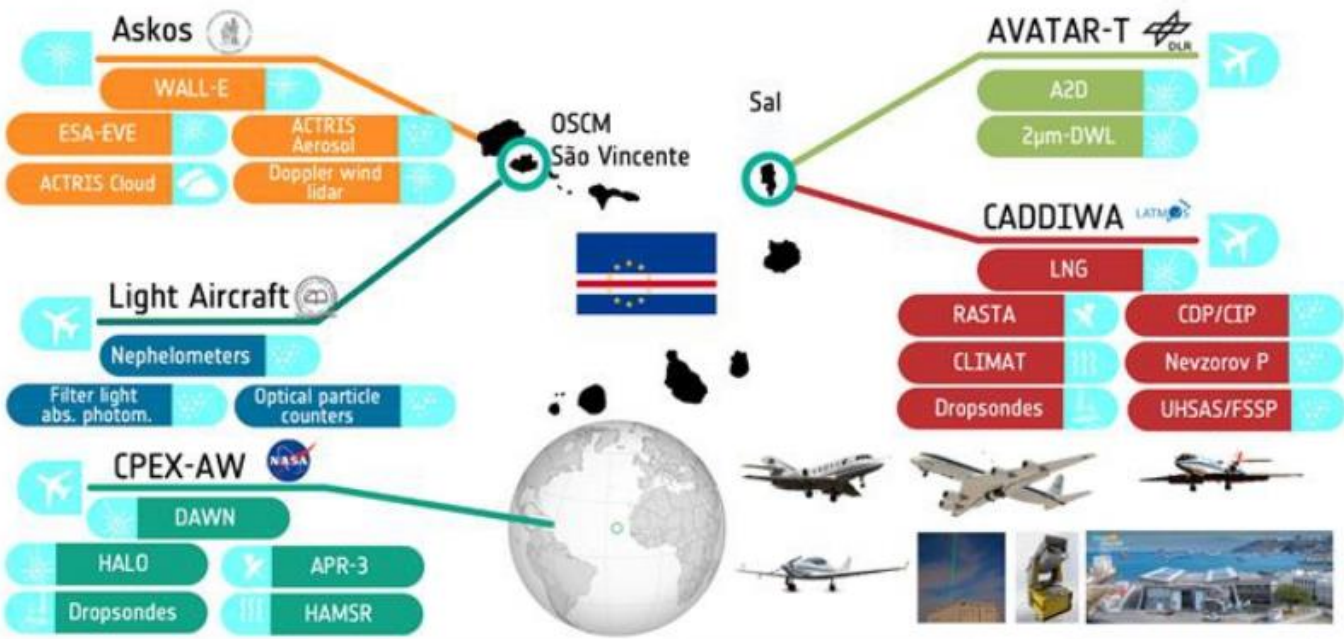
(i) Cabo Verde (atmospheric observatory operated by TROPOS),
(ii) Antikythera, Greece (PANGEA observatory operated by NOA),
(iii) Limassol, Cyprus (operated by TROPOS),
(iv) Warsaw, Poland (operated by UW),
(v) Melpitz, Germany (supersite operated by TROPOS), and
(vi) Dushanbe, Tajikistan (station operated by TROPOS).

+

- Past datasets during **Aeolus and CALIPSO overpasses** will be used along with new datasets to perform thorough validation studies for the passive and active remote sensing retrievals and long-term datasets of AIRSENSE.
- Datasets from the operation of the **eVe (CV) and EMORAL mobile lidar systems of ESA**.

Fully operated stations during EarthCARE overpasses

Aeolus Cal/Val Tropical Atlantic Campaign (JATAC) and collaborated NASA CPEX campaigns (2021–2022)



ASKOS Science Objectives:

- **Aeolus Validation using** an unprecedented amount of quality assured datasets
- **Support to future ESA missions: EarthCARE**
- Science (e.g., dust effect on cloud formation, radiation, deposition)

In situ measurements onboard UAVs

OPCs measurements (0.1 – 80 µm)
GPAC Impactor sampling (up to 100 µm)
Collected samples for chemical analysis

ACTRIS Aerosol & Cloud remote sensing facilities

eVe lidar

Radiation

+

(ii) EarthCARE Cal/Val experiments in the framework of the German Initiative for the Validation of EarthCARE (GIVE) including Tropical Atlantic in 2024

Assimilation of satellite products in numerical models

esa AIRSENSE GRASP

New satellite product development

CERTAINTY

New aerosol model for realistic particle properties

AMEO

New forward operators for
AOD, Angstrom Exponent, SSA

New forward operators for
EarthCARE (also comparison with HETEAC model):
extensive aerosol properties
b_p and e_p

ECMWF

New forward operators for
EarthCARE - DISC:
intensive aerosol properties
dp and Sp

ECMWF

Data assimilation
- IFS (ECMWF)
- WRF-CHEM 4.5 / DART

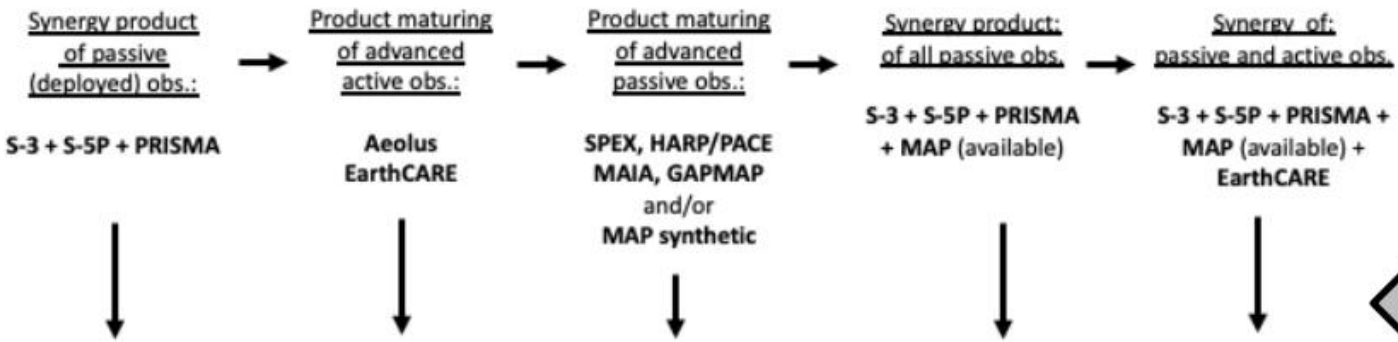
WP3

AIRSENSE

Aerosol and aerosol-cloud Interaction from Remote SENSing Enhancement

Horizon Europe
Coordinated activities

Funded by the European Union



Novel products from multi-instrument synergy:

- Improved scope: aerosol and cloud type, vertical variability, stratospheric aerosol, etc.
- Improved coverage and time x space resolution.

Science studies using observations:

- aerosol-cloud interactions, cloud formation, humidity growth, etc.

Science studies using models and data assimilation:

- atmospheric dynamics, water cycle

Ground based data (ACTRIS)
Field campaigns (ESA, NASA, Coordinated Activities

Feed back

New Products

Exchange by results and ideas

Exchange by validation data

Assimilation

CERTAINTY
CleanCloud

ACTRIS

To formulate joint scientific studies on radiative forcing?

PANORAMA

HORIZON-CL6-2024-GOVERNANCE-01-6

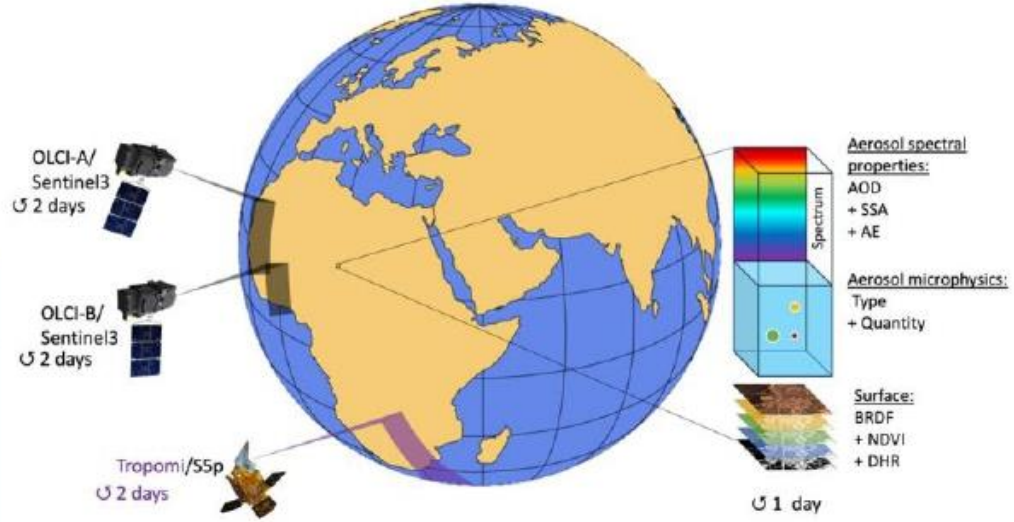
Multi - sensor synergies for improved weather - climate - environmental products and applications, to advance European services supporting green transition

Figure 1.1: The PANORAMA Concept

Thank you!

ESA-JAXA Pre-Launch
Science and Validation Workshop
13–17 November 2023
ESA–ESRIN
Frascati (Rome), Italy
esa

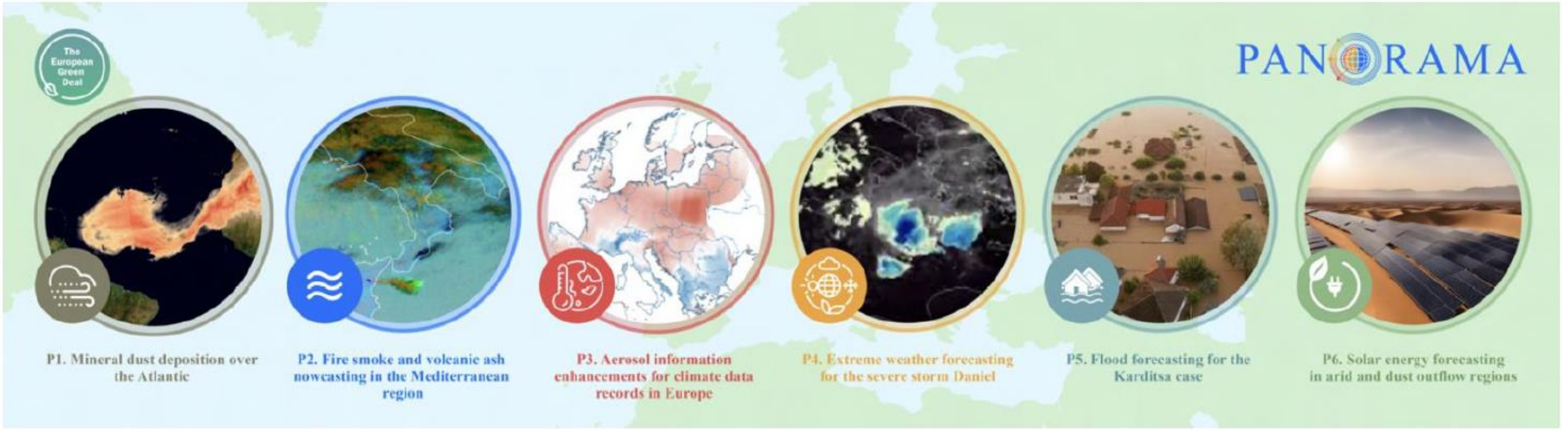
SYREMIS/GRASP synergetic retrieval in AIRSENSE project



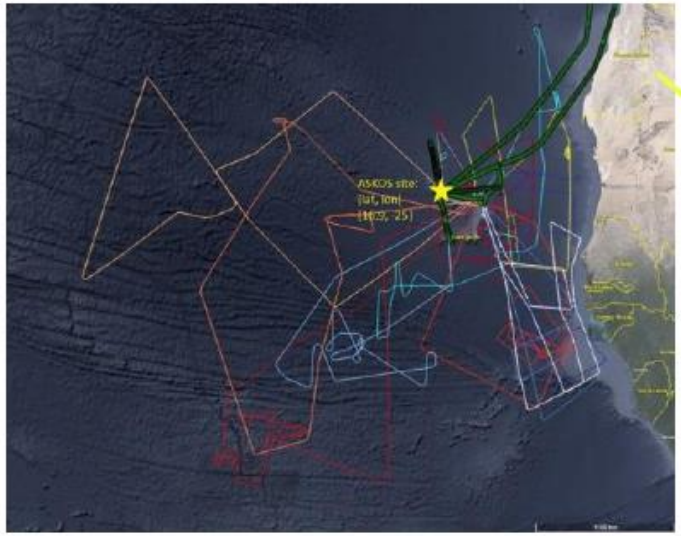
Satellites	Description
OLCI/Sentinel-3A and OLCI/Sentinel-3B	- Polar-orbiting, global coverage - One observation per pixel - Moderate spatial resolution - Radiance measurements in VIS and NIR spectral range
TROPOMI/ Sentinel-5p	- Polar-orbiting, global coverage, from 1 to a few observations per day - Hyperspectral measurements in UV, VIS, NIR, SWIR spectral range

SYREMIS Synergy	i. Multi-spectral			ii. Multi-angular	iii. Multi-Polarization	iv. Multi - Temporal
	UV	VIS - NIR	SWIR			
S3A/OLCI + S3B/OLCI + TROPOMI	+	+	+	+ Quasi multi-angular	-	+

Overview of pilots



Harmonisation of input datasets for first synergetic processing



Time frame: June –September: 2021, 2022

Preliminary Area:

Top-left corner: lat=55N, long 45W;

Bottom-right corner: lat=0, long 95E.

Collocated field campaigns:

1. ASKOS 2021,2022
2. A-LIFE dataset from the Eastern Mediterranean
3. Data from the eastern Mediterranean form the time frame of the ETNA eruptions used for Aeolus assimilation.