a: GRASP b: Laboratoire d'Optique Atmosphérique

c: cloudflight d: esa

Synergetic retrieval from multi-instrument measurements for extended aerosol and surface characterisation in global scale and at high temporal resolution

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Aerosol in different applications

Atmospheric studies and applications	Extended aerosol characterization							
	AOD	1. Extended optical properties				2. Spatial resolution	3. Temporal resolution
		SSA	Size (AExp)	Vertical profile	Chemistry		
Aerosol ECVs (GCOS-245)	X	X	X	X	-	A few km or more Global	Daily or monthly
Air quality monitoring	X	X	X	X	X	The finer is better (a few meters)	Hourly or better
Aerosol dynamic, aerosol-cloud interaction etc	X	X	X	X	X	Fine and moderate	Hourly or better
Global and regional climate models	X	X	X	X	X	From a few meters to hundred km Global	Hourly, Daily
Aerosol as auxiliary product for Atmospheric and surface studies	X	X	X	X	-		From Hourly, to Monthly

Aerosol characterization from space		Extended properties			
		AOD	Extended optical properties	Spatial resolution	Temporal resolution
1. Single angle observation: - **moderate or coarse spatial resolution** - **wide swath**	**MODIS-like**	+	Rather not	Moderate	Daily
	TROPOMI-like (wide spectral range : **UV-SWIR**)	+	Absorption, size, vertical profile with moderate accuracy	Rather coarse	
2. Single angle obs. (Sentinal-2 like): - **high spatial resolution** - **narrow swath (~ 200 km or less)**		+	Rather not	High Spatial	Few days per week
3. Geostationary (Sentinel-4, FCI etc)		+	Limited	Rather coarse	High temporal
4. Multi-angular polarimeters		+	High accuracy		Daily
5. Active	Space LIDAR	+	Vertical profile	-	-
	TIR sensors	Dust AOD	Dust chemistry	Coarse	Daily

Ideal single instrument has never existed and, probably, will never exist !

Solution: Multi-instrument synergy

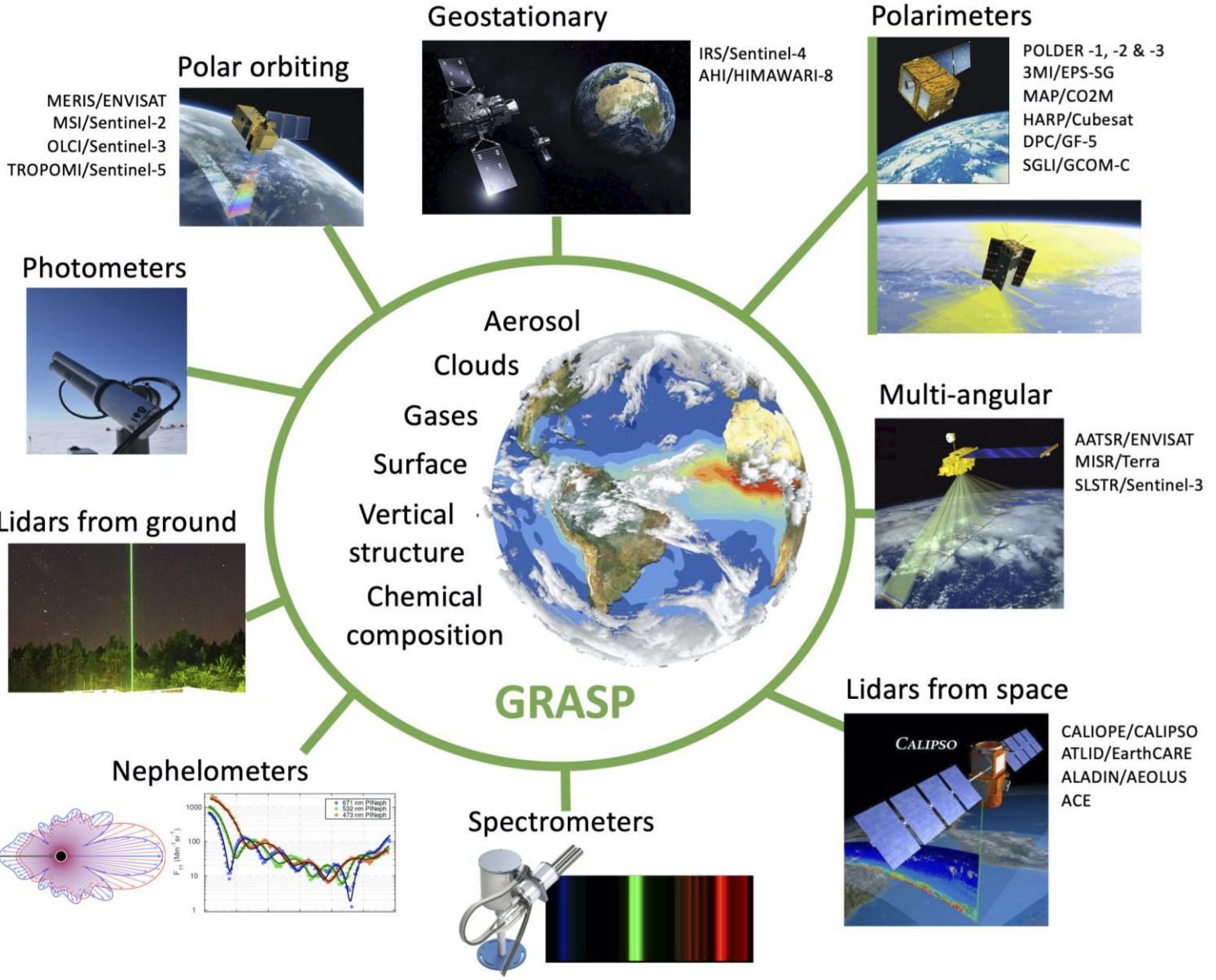
Aerosol characterization from multi-instrument synergy	Optical properties		Spatial resolution	Temporal resolution
	AOD	Extended properties		
LEO + GEO + High spatial resolution + Polarimeters + etc	+	+	+	+

Requirements on the retrieval algorithms for synergy:

1. Algorithm should be based on advanced inversion approach and adaptable flexible forward models.
2. Algorithm should be able to account diverse measurements from different instruments.
3. Algorithm should be able account for multi-temporal measurements (multi-pixel retrieval approach).

GRASP: Generalized Retrieval of Atmosphere and Surface Properties

1. Full synergetic retrieval from different space-borne instruments is impossible without accounting for **multi-temporal diverse** measurements!
2. GRASP algorithm multi-pixel (in particular, multi-temporal) approach is very suitable for synergetic purposes



Dubovik et al., Front. Remote Sens., 2021

Synergetic retrieval with GRASP algorithm

1. **Coarse and fine spatial resolution**:

PRISMA + S5P demonstration for COVID-19 studies
GRASP-SAS (FR)

Cheng Chen and Pavel Litvinov et al. JGR, 2024 (under review)

eo science for society

SENTINEL-5P+ INNOVATION – THEME 5, AEROSOL OPTICAL DEPTH (AOD) + BRDF
GRASP-SAS (FR)

Pavel Litvinov and Cheng Chen et al. RSE, 2024 (under review)

GRASP algorithm multi-pixel (in particular, multi-temporal) approach is very suitable for synergetic purposes

2. Synergetic retrieval from **satellite and ground-based measurements**:

eo science for society

Pavel Litvinov et al. FR, 2022

Synergetic Retrieval from GROund based and SATellite measurements for surface characterization and validation (GROSAT)
GRASP-SAS (FR)

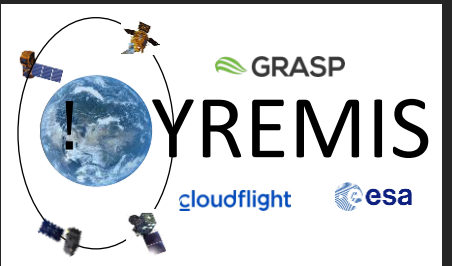
www.grasp-open.com/products/grosat-data-release/

3. Synergetic retrieval from **multi-mission space-borne instruments**:

eo science for society

Pavel Litvinov et al. FR, 2023

Synergetic retrieval from multi-mission space-borne measurements for enhancement of aerosol characterization (SYREMIS)
GRASP-SAS (FR)



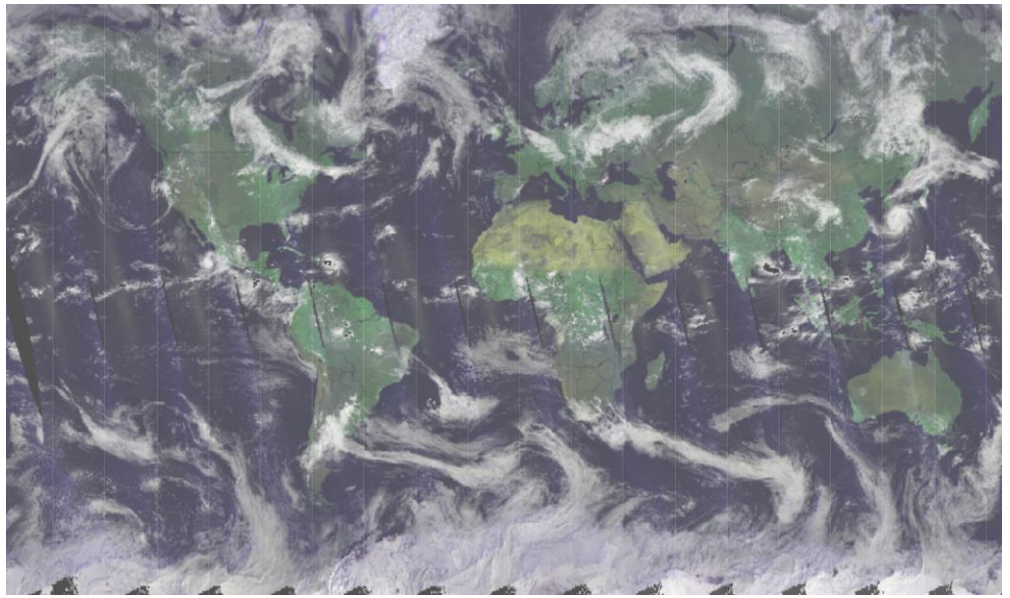
GRASP multi-instrument synergetic retrieval:

GRASP SYREMIS cloudflight esa

Satellites	Description
Sentinel-3A /OLCI and Sentinel-3B/OLCI	- Polar-orbiting, global coverage - One observation per pixel - Moderate spatial resolution - Radiance measurements in VIS and NIR spectral range
Sentinel-5p/TROPOMI	- Polar-orbiting, global coverage, from 1 to a few observations per day - Hyperspectral measurements in UV, VIS, NIR, SWIR spectral range
Himawari/AHI	- Geostationary. Coverage area: Asia - Every 15 min daily measurements - Radiance measurements in VIS, NIR and SWIR spectral range

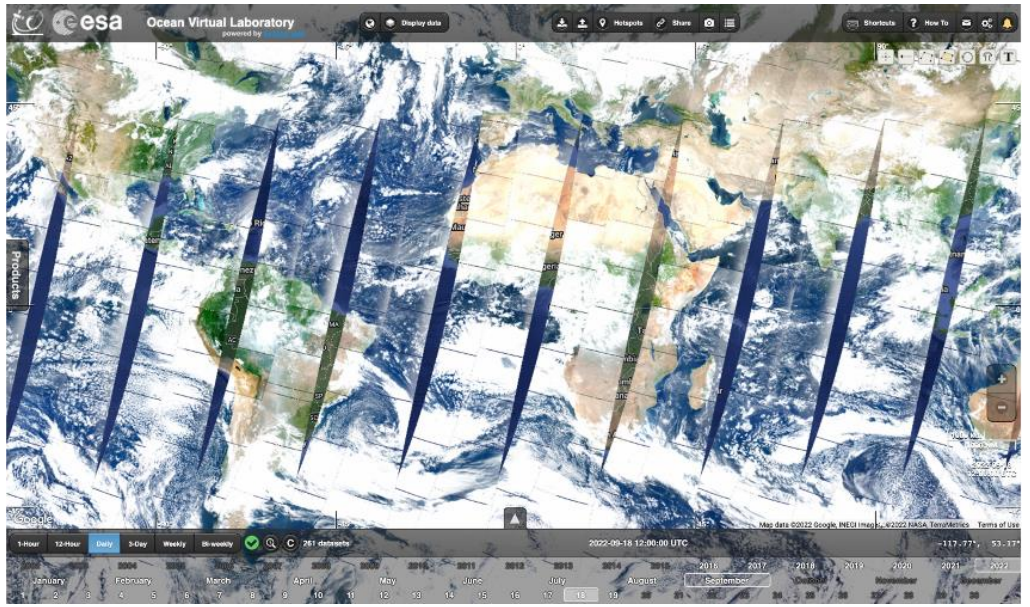
SYREMIS Synergy	i. Multi-spectral			ii. Multi-angular	iii. Multi-Polarization	iv. Multi - Temporal
	UV	VIS - NIR	SWIR			
S3A/OLCI + S3B/OLCI + TROPOMI + HIMAWARI	+	+	+	+ Quasi multi-angular	-	+

LEO synergy: Pseudo “multi-angle”

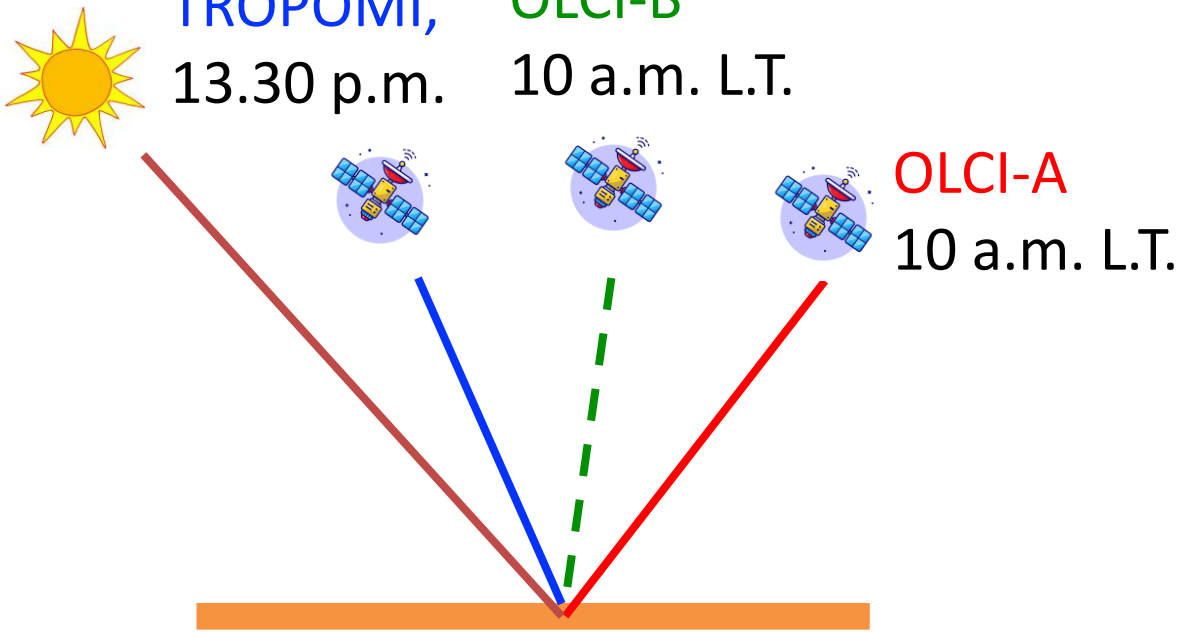


TROPOMI

+



OLCI-A + OLCI-B

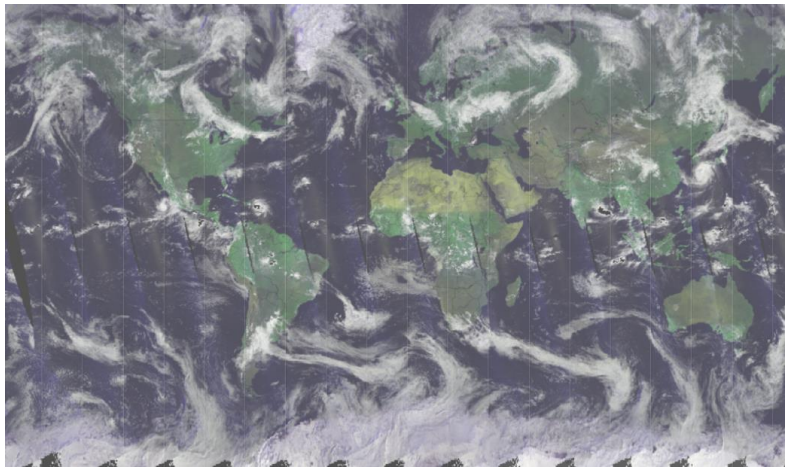


- Better surface BRDF sampling and atmosphere signal separation!
- Few measurements per day!
- Extended spectral range

Multi-temporal measurements should be accounted for !

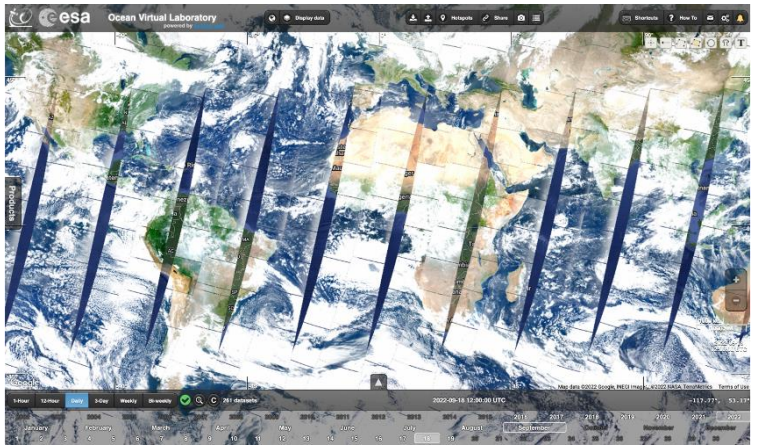
LEO+GEO synergy: Pseudo “multi-angle”, multi-temporal measurements

TROPOMI



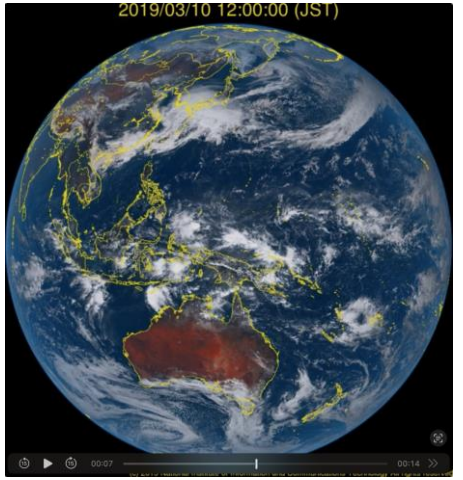
+

OLCI-A + OLCI-B



+

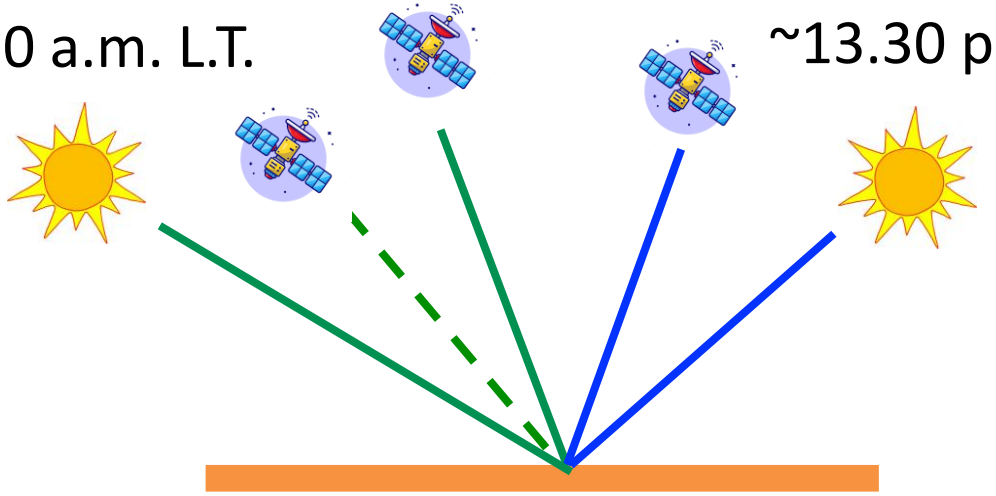
HIMAWARI



OLCI-A
~10 a.m. L.T.

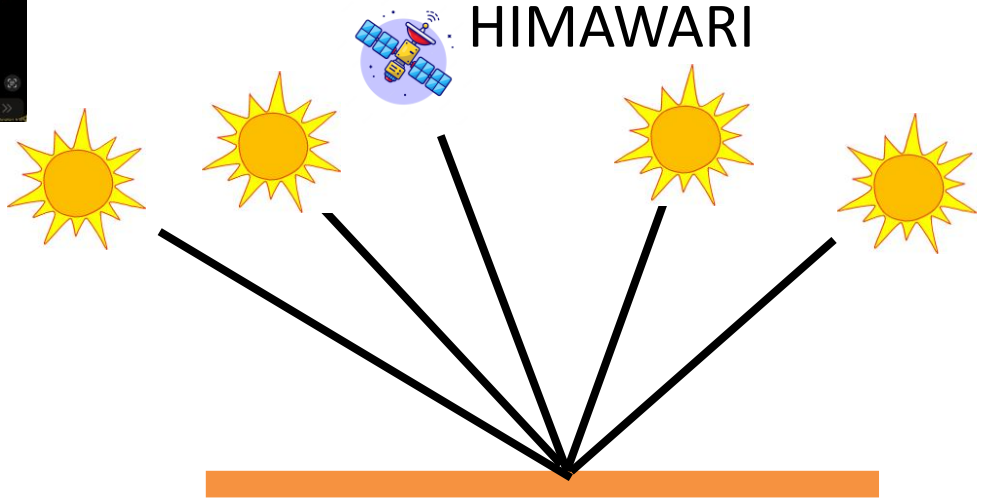
OLCI-B
~10.20 a.m. L.T.

TROPOMI
~13.30 p.m.



+

HIMAWARI



- Better surface BRDF sampling and atmosphere signal separation!
- **Hourly extended aerosol properties variability!**
- Aerosol transport!

SYREMIS synergy

vs

Single instrument

retrieval.

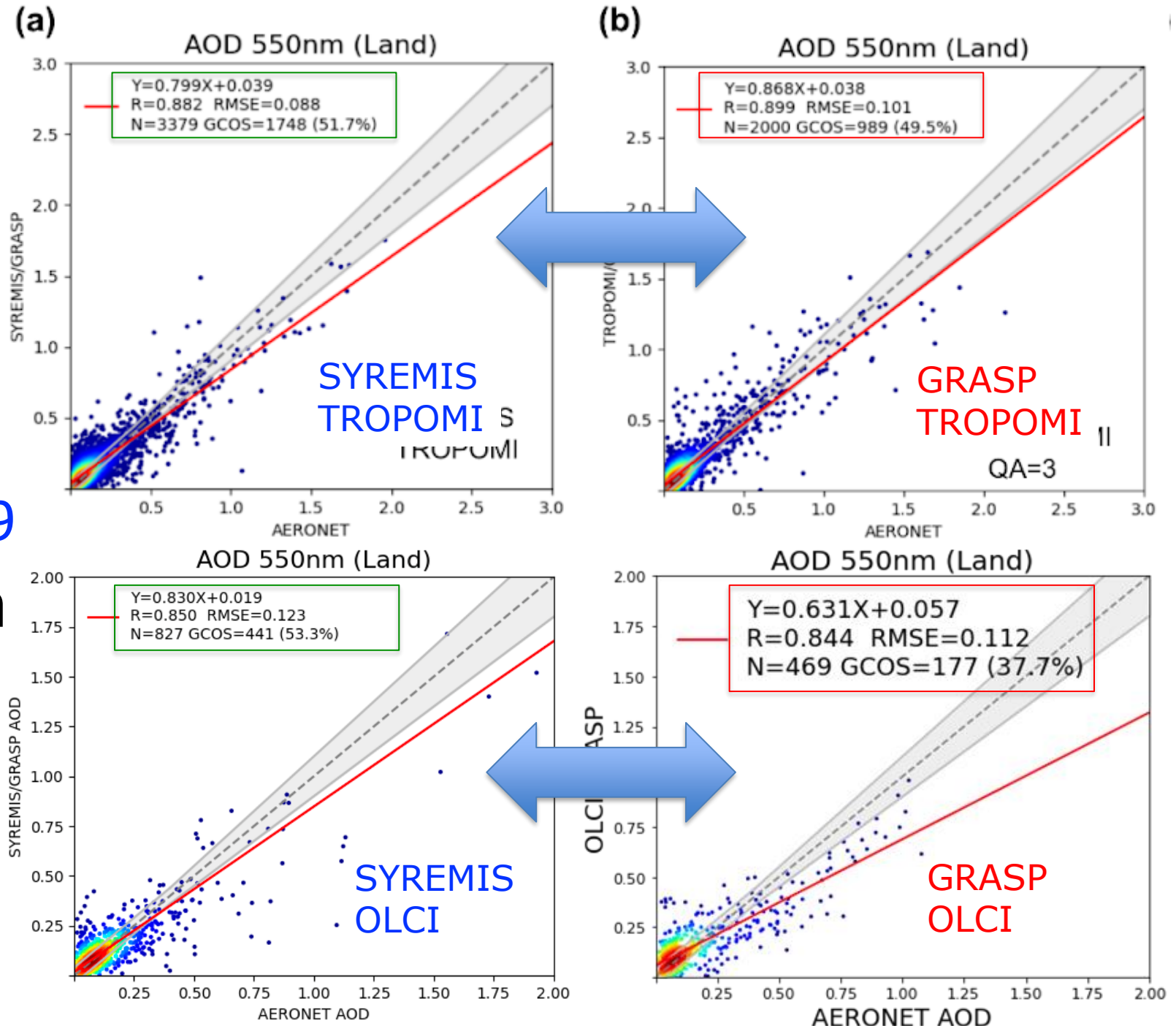
AOD.

Global. March-May, 2019

Synergy effect on AOD:

- Clear improvements in TROPOMI AOD!

- Crucial improvement in OLCI AOD!



SYREMIS synergy

vs

Single instrument

retrieval.

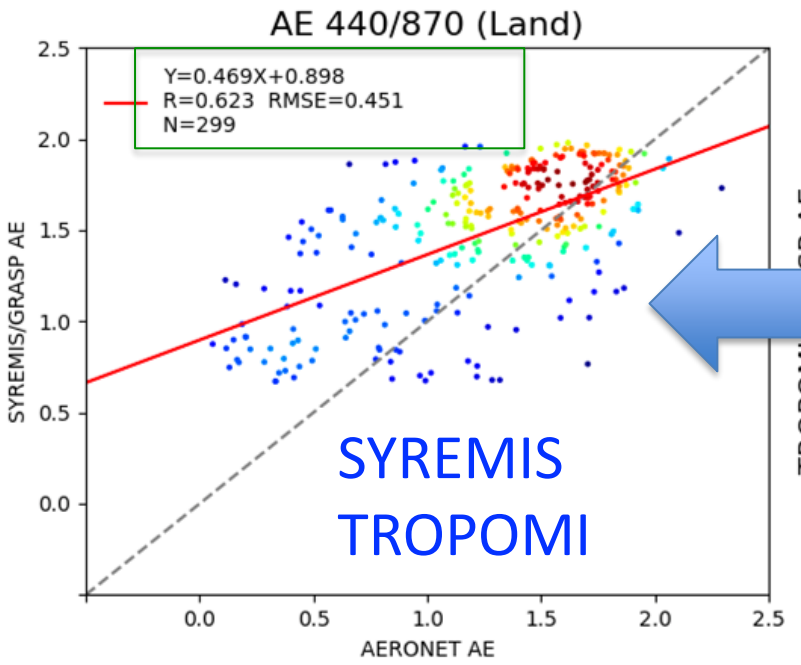
AEexp.

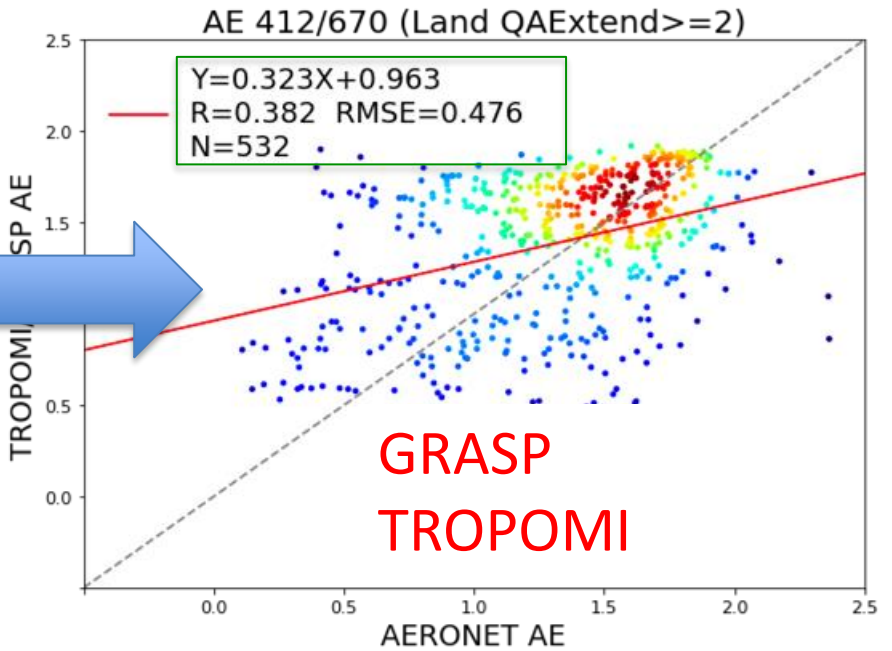
Global. March-May, 2019

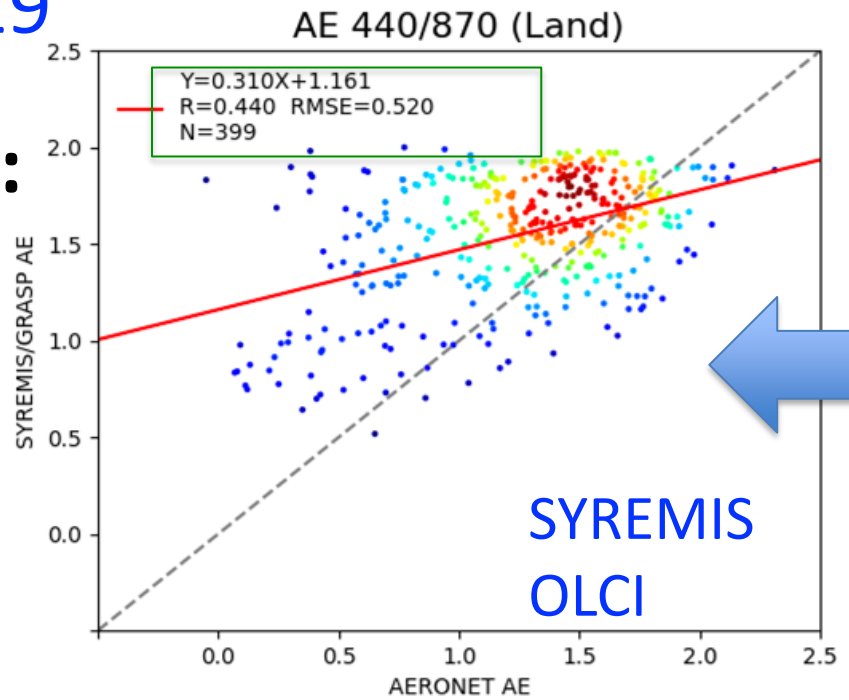
Synergy effect on AExp:

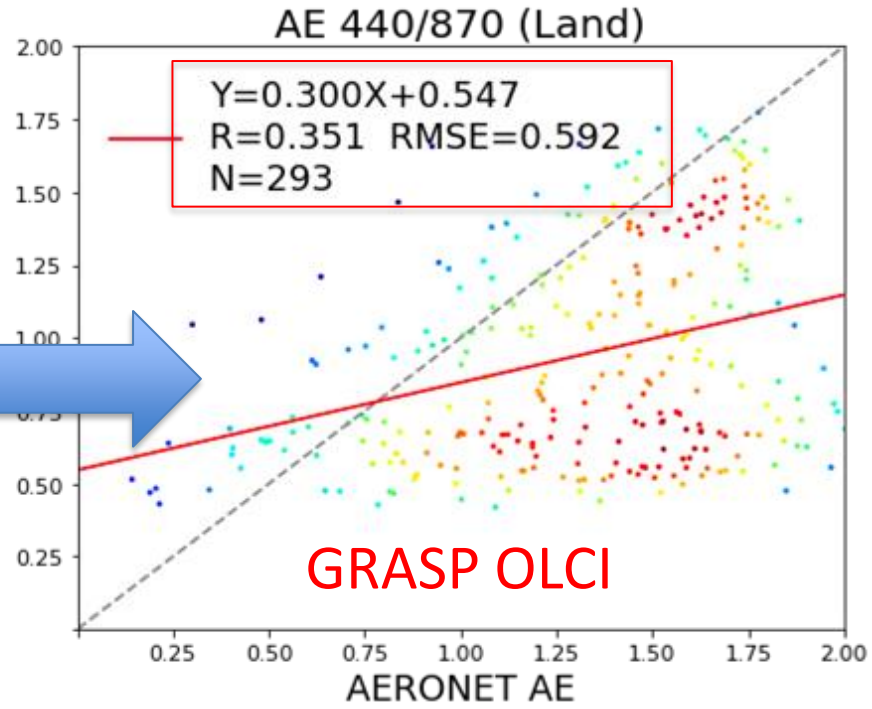
- Similar quality between SYREMIS/TROPOMI and GRASP/TROPOMI AExp!

- Crucial improvement in OLCI AExp!

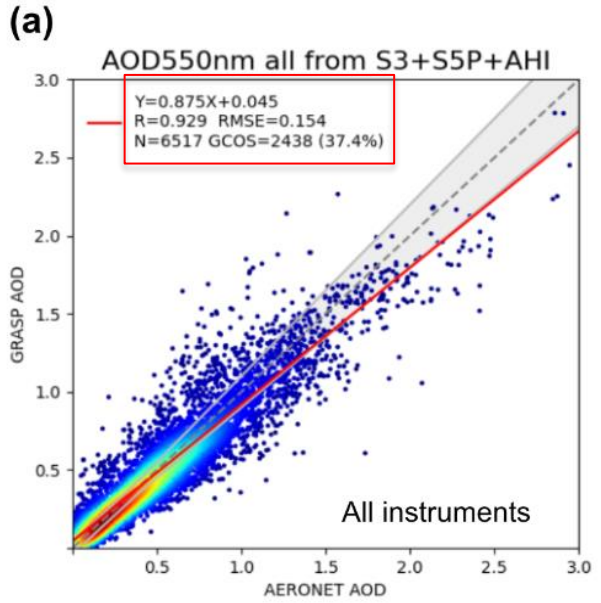


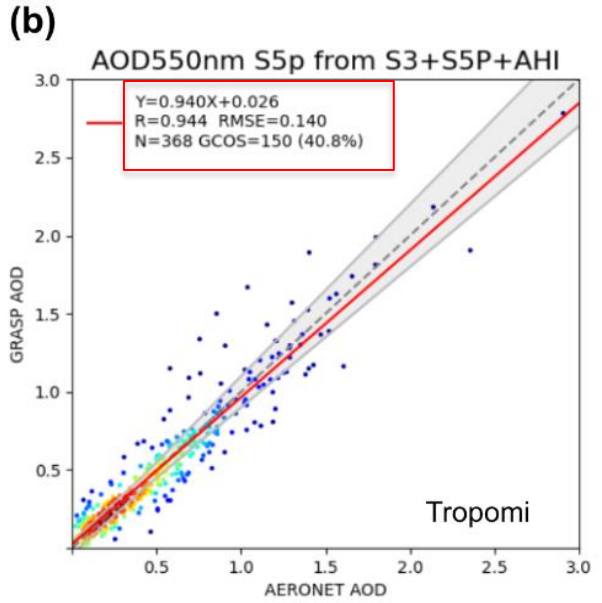


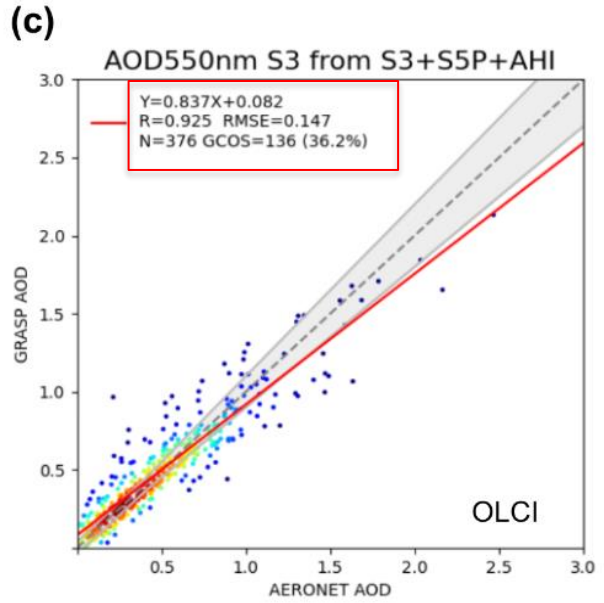


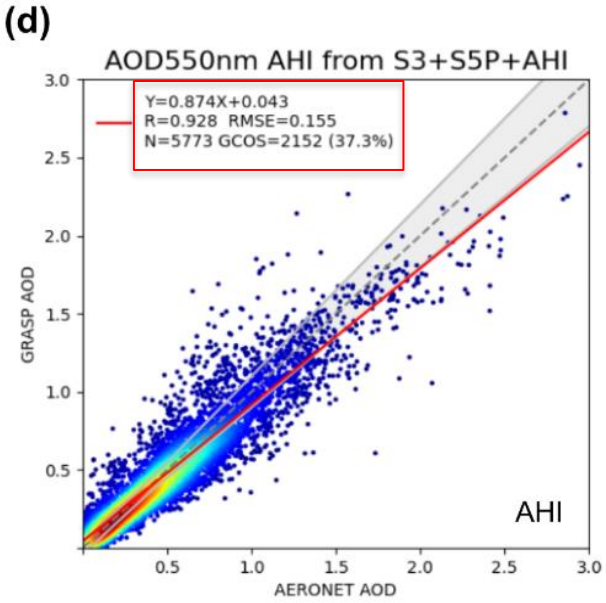


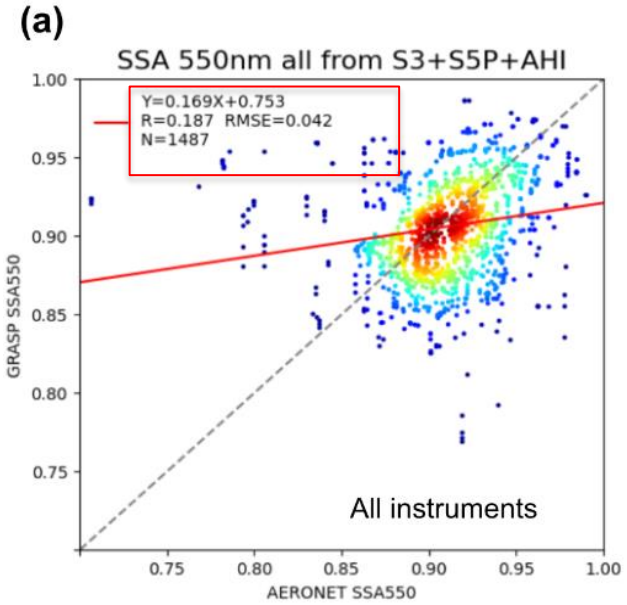
SYREMIS LEO+GEO synergy: TROPOMI + OLCI-A + OLCI-B + HIMAWARI

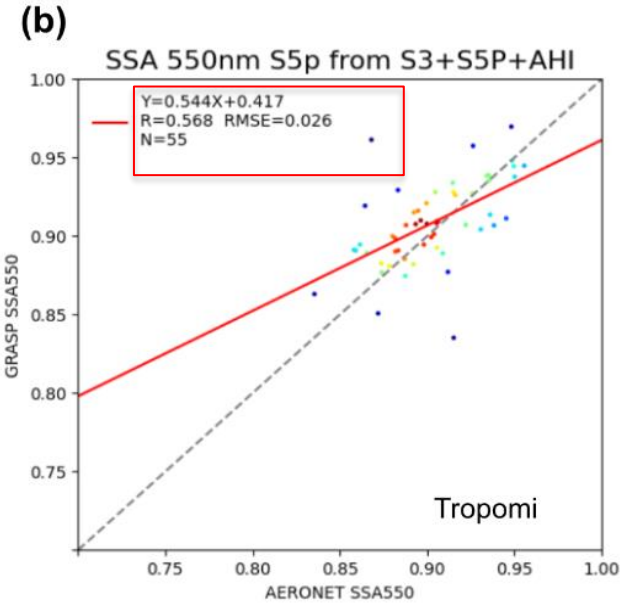


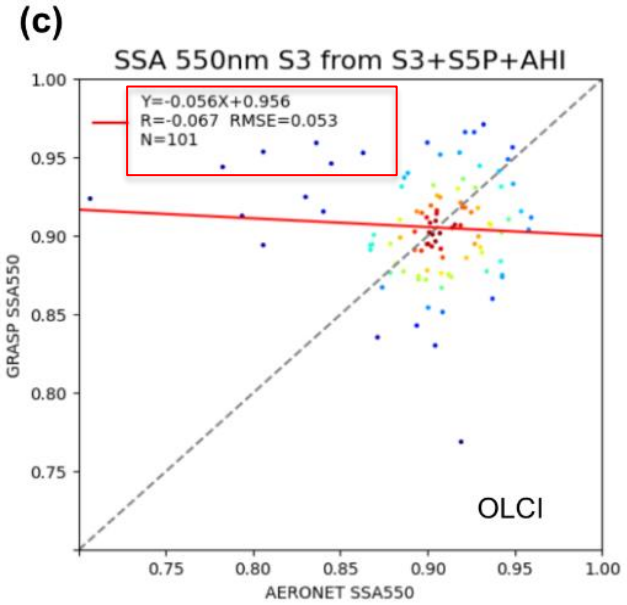


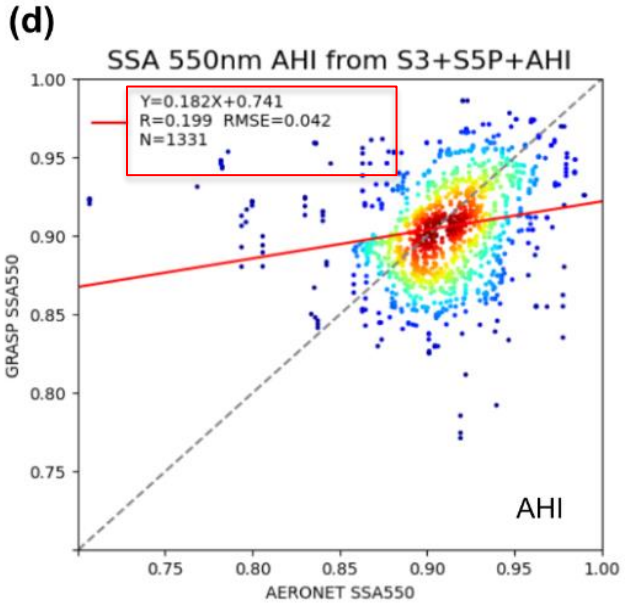












- Extended aerosol properties (including SSA!) with **high temporal resolution!**
- Consistent retrieval for all instrument in the synergy!

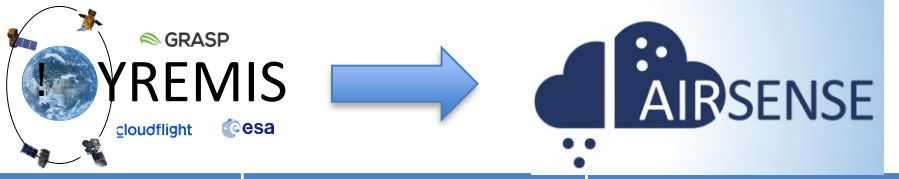
GRASP

SYREMIS /GRASP synergetic retrieval

cloudflight esa

1. Clear improvement of aerosol retrieval
2. The instrument with richest information content is a “driver” of synergetic retrieval:
   - S5p/TROPOMI in SYREMIS satellite constellation has richest information content providing information about aerosol size and absorption properties
   - The best SYREMIS/GRASP retrieval can be achieved when the “weight” of S5p/TROPOMI measurements in the synergy is requested to be higher than OLCI and HIMAWARI
   - Transition of information from the instruments with richest information (TROPOMI) to the instruments with lower one (OLCI, HIMAWARI)

From present Synergy to Future:



Future Synergy	i. Multi-spectral			ii. Multi-angular	iii. Wide Swath	iv. Multi-Polarization
	UV	VIS - NIR	SWIR			
3MI + S3A/OLCI + S3B/OLCI + Sentinel-5 + IASI-NG+…	+	+	+	+	+	+

Expected benefits of synergetic retrieval :

1. Enhanced characterization of such aerosol parameters as spectral AOD but also SSA and aerosol size characteristics etc
2. Improved global coverage and temporal resolution of the aerosol dataset.
3. Consistent retrieval from all satellites from synergetic constalation
4. New possibility for global aerosol sources identification and transport monitoring.