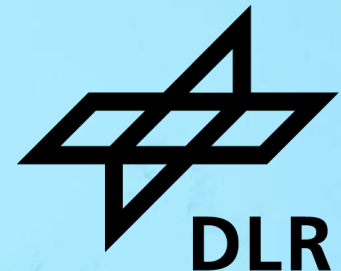# PEGASOS PROJECT OVERVIEW

Ronny Lutz and the PEGASOS team

CEOS Atmospheric Composition Virtual Constellation

24-27 October 2023, Brussels, Belgium and virtual

DLR

Product Evaluation of GEMS L2 via Assessment with S5P and Other Sensors

PEGASOS OVERVIEW

Product Evaluation of GEMS L2 via Assessment with S5P and Other Sensors

PEGASOS consortium

- **DLR**
  - German Aerospace Center
  - Remote Sensing Technology Institute

- **AUTH**
  - Aristotle University of Thessaloniki
  - Laboratory of Atmospheric Physics

- **BIRA-IASB**
  - Royal Belgian Institute for Space Aeronomy

- **IUP-UB**
  - University of Bremen
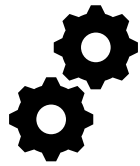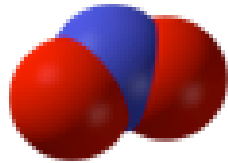 - Institute for Environmental Physics

ESA - ESRIN

Main objectives

- Evaluation of **GEMS** L2 data products using
  - a) TROPOMI and other space-borne instruments
  - b) ground-based instruments

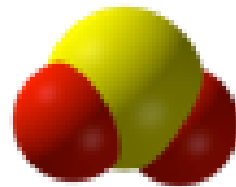| a)	b)
TROPOMI / S5P	Brewer
OMI / Aura	Dobson
GOME-2 / MetOp	Ozonesondes
IASI / MetOp	FTIR
VIIRS / S-NPP	MAX-DOAS
CALIOP / CALIPSO	PGN
AMI / GK-2A	NDACC

Work packages

DLR

Management
WP000

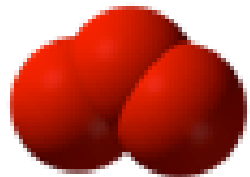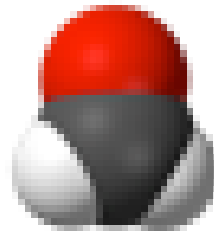**Nitrogen dioxide**
WP400

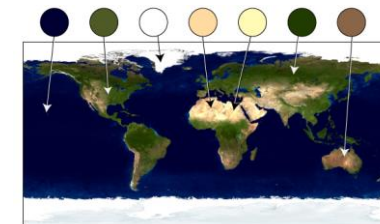**Clouds**
WP700

Sulfur dioxide
WP500

Aerosols
WP800

Ozone
WP100 (total)
WP200 (tropospheric)
WP300 (profile)

Formaldehyde
WP600

Surface properties
WP900

▪ Work packages and GEMS L2 products to be evaluated

HIGHLIGHTS

WP100 – GEMS Total Ozone Column

Evaluation Team:

K. Garane, AUTH (Team Lead)
**T. Verhoelst,** BIRA-IASB
K.-P. Heue, DLR
S. Compernolle, BIRA-IASB

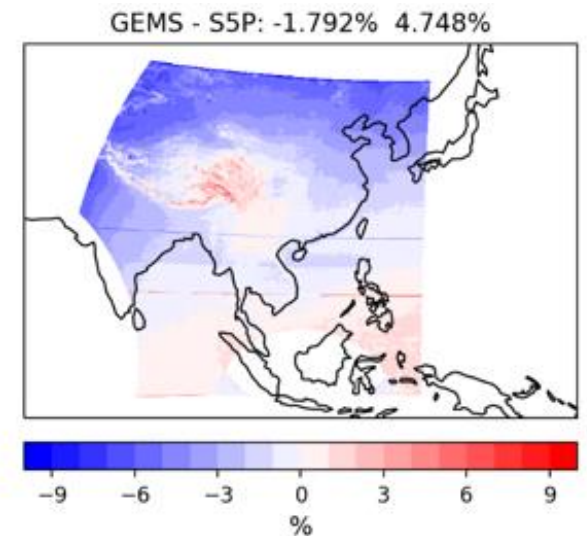**Main results so far:**

20 months of GEMS O3T v2.0 data showed:

- Mean relative bias w.r.t. gr-based stations and other satellite missions: -2 %

- **North – South gradient** with an annual cycle:

  – Very good agreement during spring, summer and autumn months (0 to -1%).

  – During winter months and for higher latitudes GEMS underestimates total ozone by up to 4-6%.
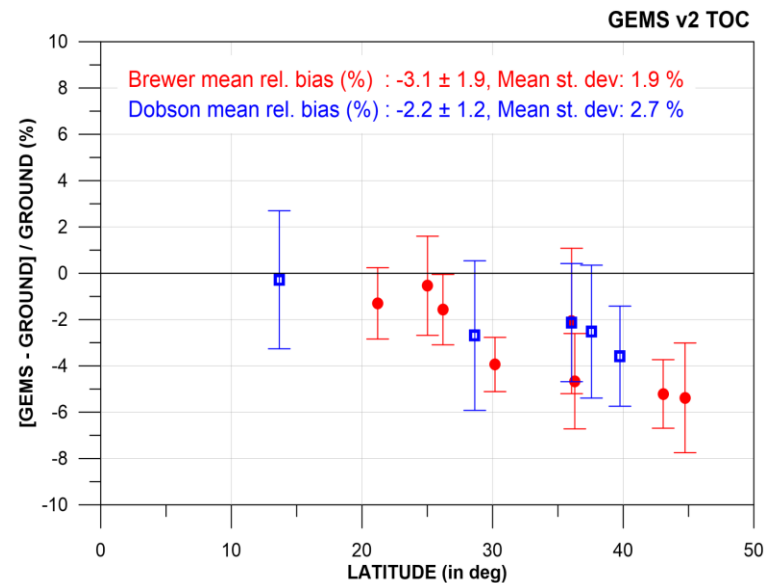
August 2022 to April 2023

Left: Mean relative bias (%) of the GEMS O3T observations w.r.t. ground-based reference measurements from Brewer and Dobson stations within the GEMS FOV.

Right: The mean percentage difference between the O3T observations from GEMS and S5P over the GEMS FOV.
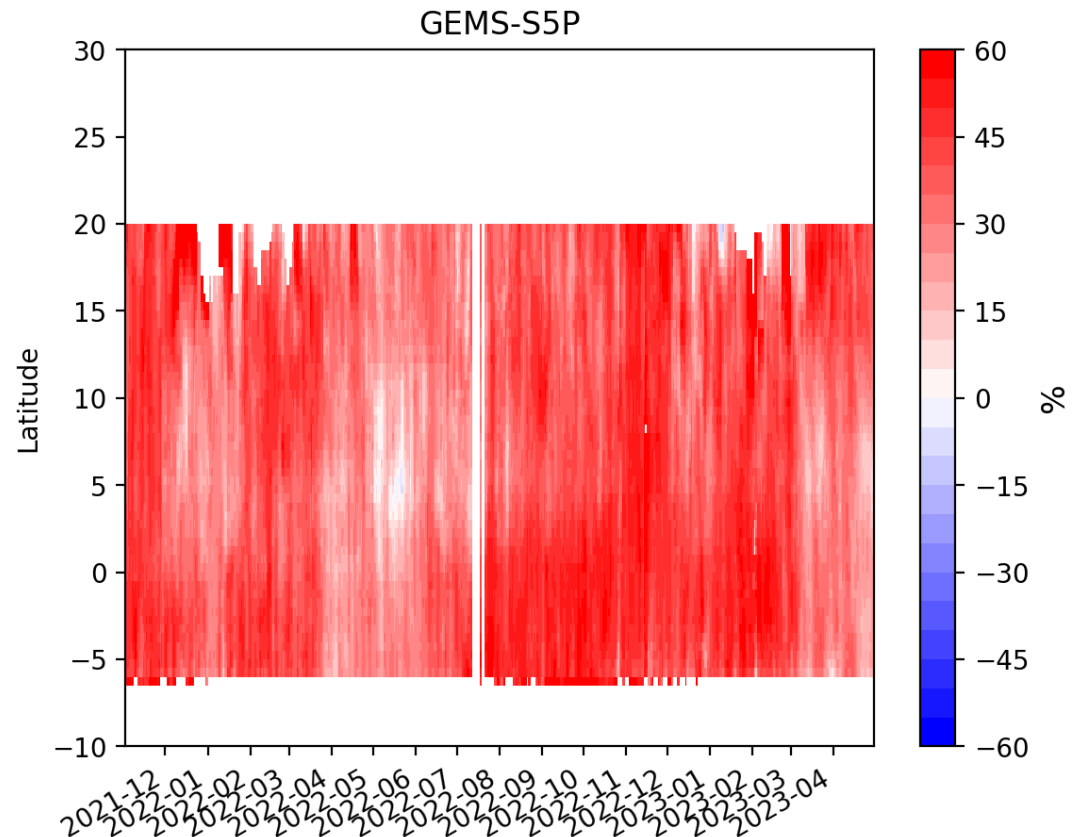
WP200 – GEMS Tropopspheric Ozone

Evaluation Team:
Klaus-Peter Heue, DLR / TUM
Daan Hubert, BIRA-IASB

Main results so far:

- Positive bias (~40%) in the tropics relative to S5P and GOME-2
- Positive bias (~20 DU) relative to sondes in Kuala Lumpur and Hong Kong
- Good agreement to sondes in Pohang and Pengyiachu

Mean deviation of tropospheric ozone relative to S5P for the period Dec 2021 -April 2023. The S5P CCD data is not available outside the tropical band.

WP300 – GEMS Ozone Profile (O3P)

Evaluation Team:
Keppens, Arno (BIRA-IASB)
Hubert, Daan (BIRA-IASB)
Lambert, Jean-Christopher (BIRA-IASB)

Main results so far:
- Order of 10 % negative bias and 10-20 % dispersion in strato
- Strong positive UTLS / tropo bias
- ~5 % integrated negative bias
- Clear effect of optical path
- Mostly off-diagonal sensitivity
- DFS ~1.5 from lower stratosphere
- 5-10 km effective vertical resolution (FWHM)
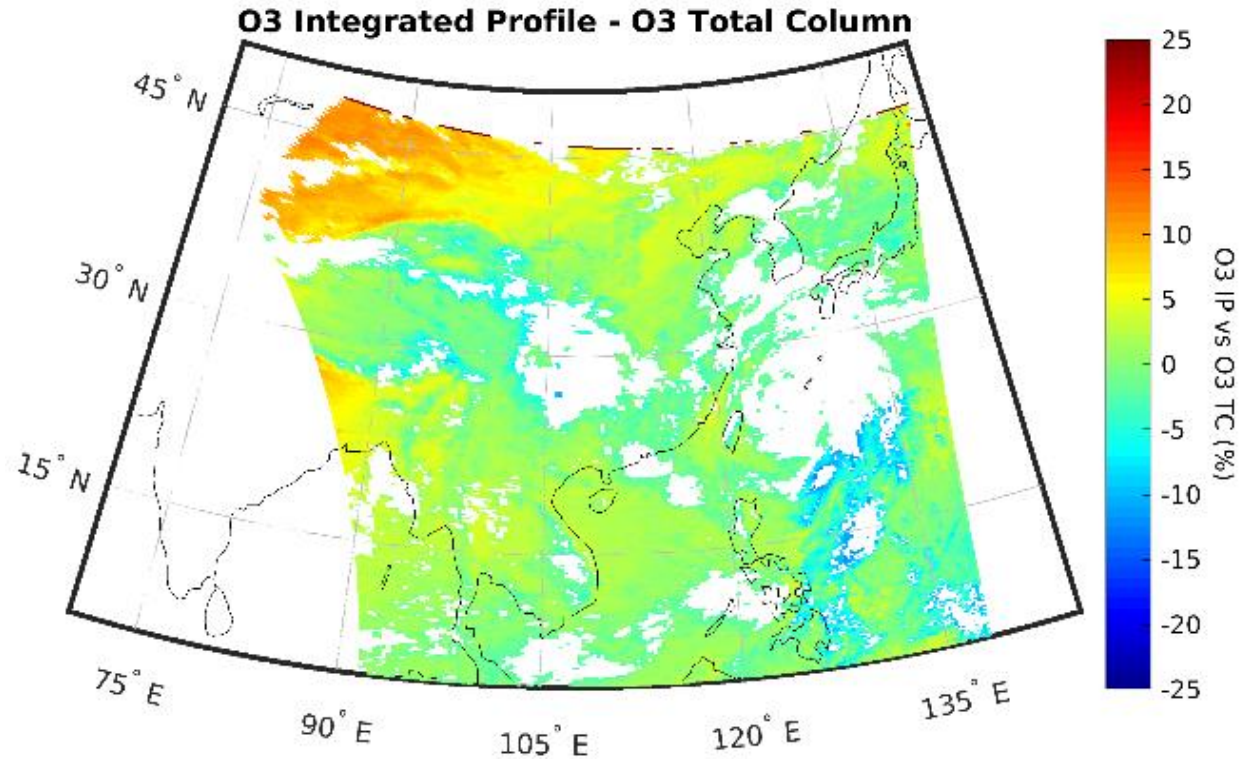
Diff. between O3P and O3T is positive for high SZA, seasonal for low SZA, overall ±1 % with 2 % dispersion (1:45 UTC FC scan for June 1, 2022)

WP400 – GEMS NO2

Evaluation Team:
Kai-Uwe Eichmann (IUP-UB), Gaia Pinardi, Steven Compernolle, Tijl Verhoelst (BIRA)

Main results so far:

- GEMS V2 total NO2: good agreement in cleaner areas towards the North
- GEMS low bias (~ -1 PMC) in the South.
- In polluted cases mainly in winter GEMS shows a high bias (> 10 PMC).
- Tropospheric/stratospheric NO2 currently not usable (->V2.1).
- Comparison with ground-based PGN measurements show a positive total NO2 bias at all 5 sites, ranging from almost zero (Kobe) to over 10 PMC (90%) at Beijing.

*PMC: Pmolec/cm^2

GEMS-S5P no2su: 20211001-20211030 (DF=-0.0, RDF=-9.6 %, CCP=0.95)

October 2021

[PMC]
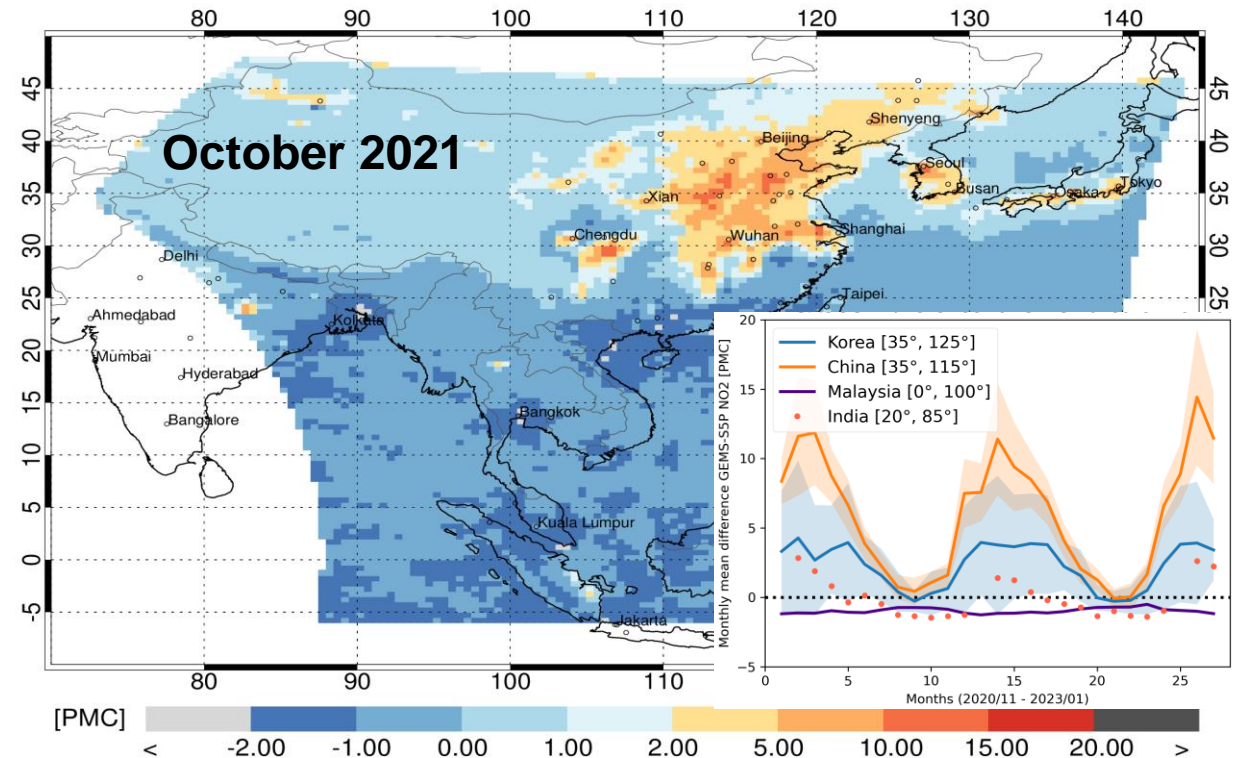
Monthly mean of time collocated GEMS – TROPOMI total NO2 column differences [PMC]. Monthly mean differences for 4 regions [PMC] and standard deviation (China/Korea).

WP500 – GEMS Sulphur dioxide columns

Evaluation Team:
M. E. Koukouli | AUTH (Team Lead)
N. Theys | BIRA

Main results so far:

- Performed daily, monthly & seasonal comparisons of GEMS v2.0 with OMI/Aura, OMPS/NPP & S5P/TROPOMI SO_2
- For regions with low viewing angles (mostly volcanoes), similar patterns are observed. GEMS v2.0 VCDs agree with other sensors within 50% (even better for SCDs).
- For large viewing angles (India and North China), comparison is less conclusive as several artefacts are present in the GEMS data.

Power plants
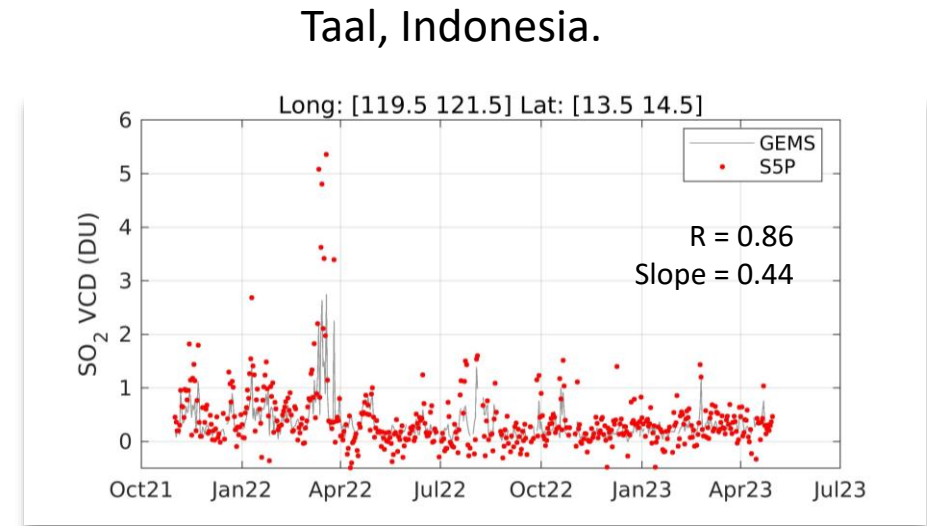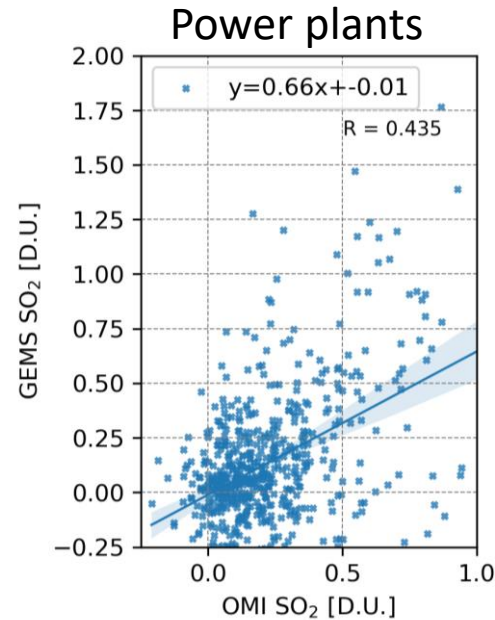
Taal, Indonesia.

Scatter plot (left) of the L3 spatiotemporal collocated GEMS v2.0 and OMI/Aura SO_2 VCD over Power Plant locations in the GEMS FOV.
Timeseries [right] over the continuously outgassing Taal volcano in Indonesia for GEMS v2.0 and S5P.

WP600 – GEMS HCHO

Evaluation Team:
Isabelle de Smedt, Gaia Pinardi, Corinne Vigouroux, Steven Compernolle (BIRA), Kai-Uwe Eichmann (IUP-UB)

Main results so far:

- Good agreement with TROPOMI over Eastern China and Korea, but strong underestimation over India.
- MAX-DOAS and FTIR comparisons give results equivalent to TROPOMI, with the exception of Mohali in India.
- However, it has been shown that the GEMS HCHO column is dominated by the model correction over Eastern China and Korea.
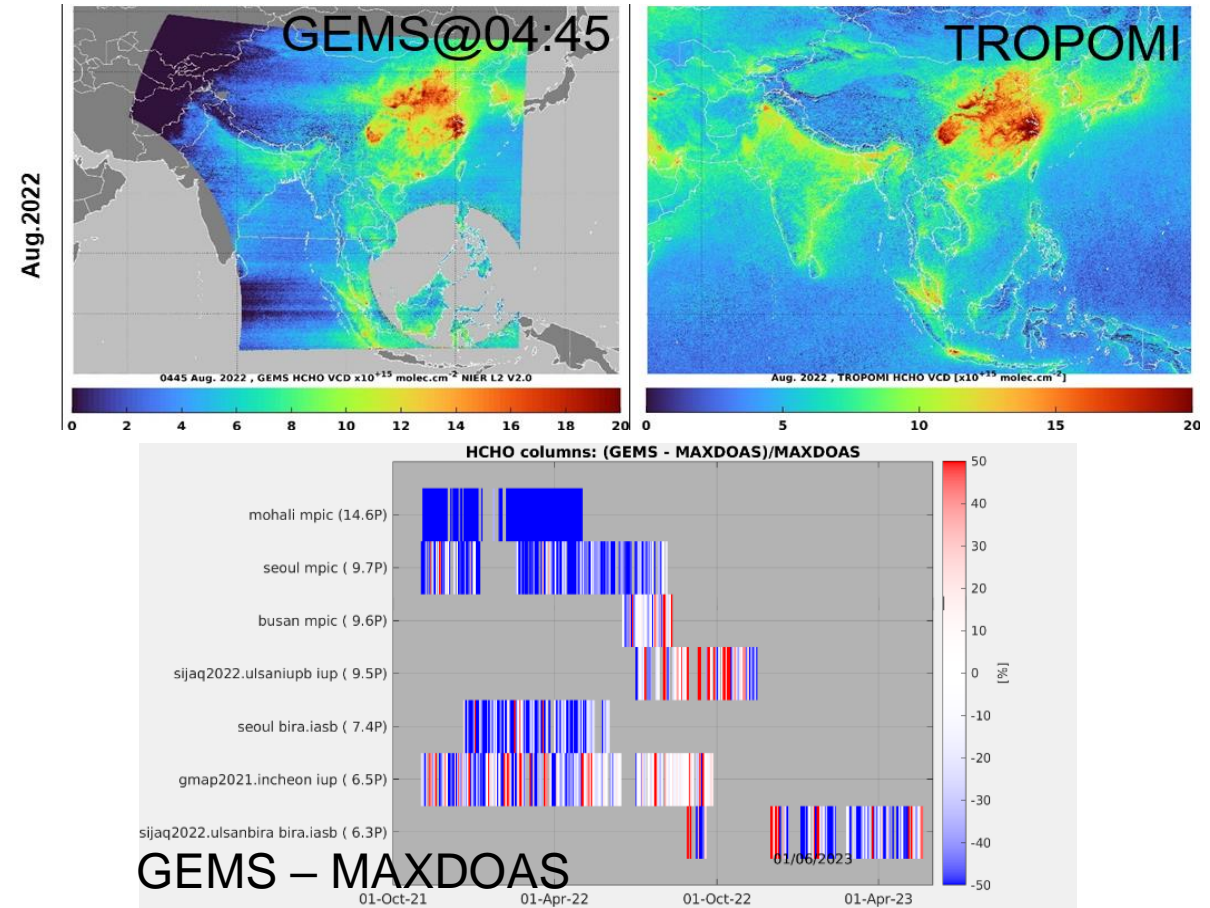
(Top) GEMS@04:45 - TROPOMI monthly mean HCHO columns from August 2022.
(Bottom) GEMS – MAXDOAS relative differences for 7 Asian stations.

WP700 – GEMS Clouds

Evaluation Team:
Ronny Lutz, DLR

Main results so far:

- Very good agreement for cloud fraction:
  - correlation 0.87
  - mean difference 0.04

- Good agreement for cloud pressure:
  - correlation 0.65
  - mean difference -50 hPa

- Deviations appear over bright surfaces and extreme viewing zenith angles
  - to be addressed in v3 of the CLD data
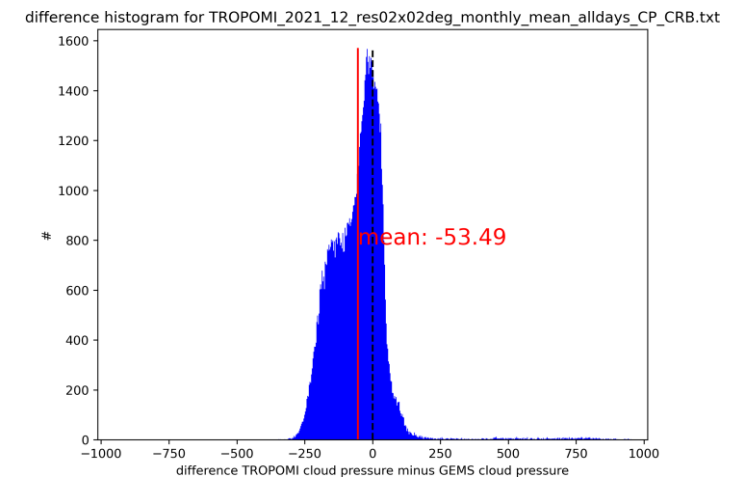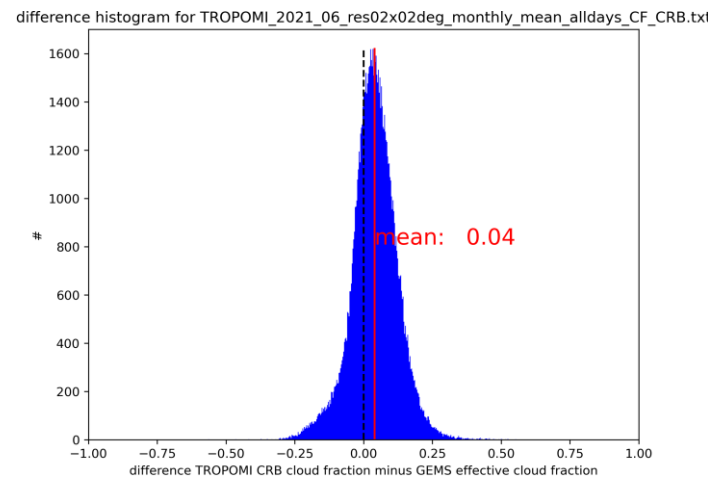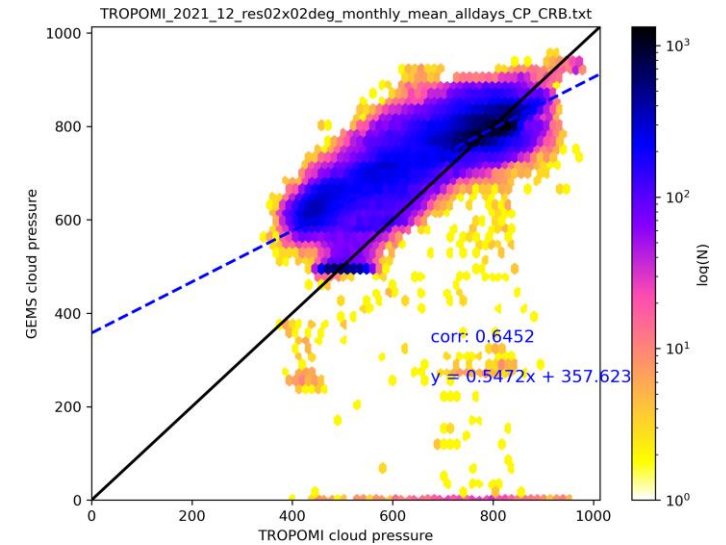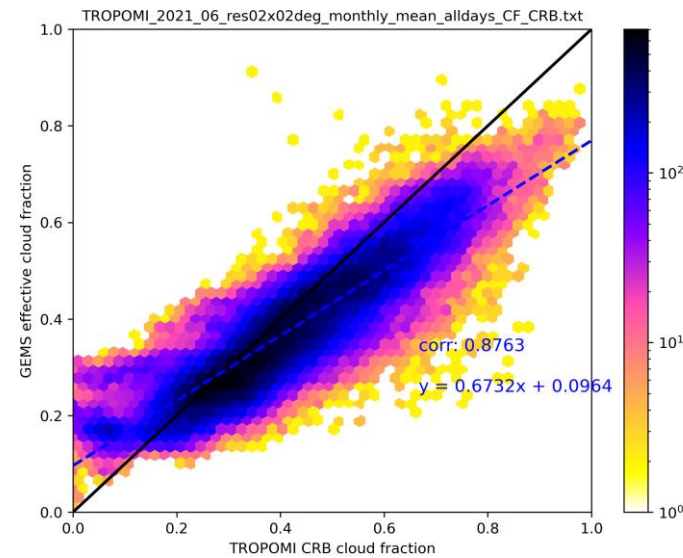
Comparison with TROPOMI/S5P cloud fraction (left) and cloud pressure (right) for June and December 2021.
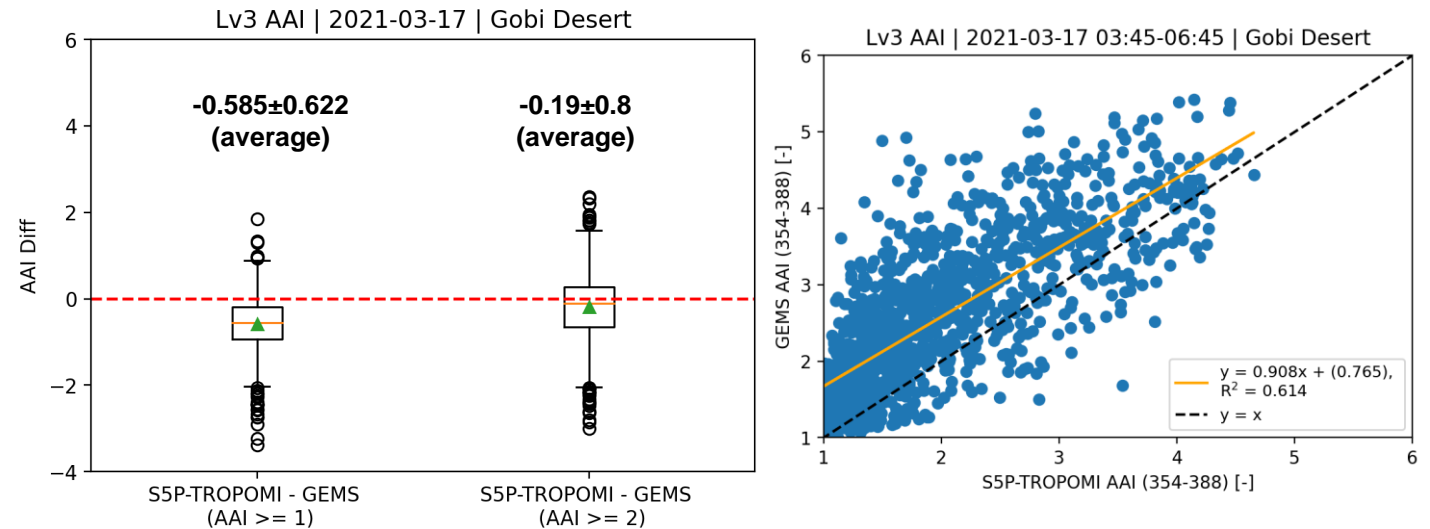
WP800 – GEMS Aerosols (UVAI)

Evaluation Team:

M. E. Koukouli | AUTH (Team Lead)
P. Fountoukidis | AUTH
D. Balis | AUTH

Main results so far:

- Overall, the GEMS AAI over-estimates the levels reported by S5P & GOME2/Metop.
- Comparisons were found to have strong dependency on the specific event and/or the sensors pixel size.
- For strong dust events, a satisfactory agreement between S5P and GEMS is reported.

Box plot (left) and scatter plot (right) of the L3 spatiotemporal collocated AAI between S5P and GEMS, for the case study on 17 March 2021. Filtering for the high dust events, for AAI > 2, brings the two sensors is great agreement.

WP800 – GEMS Aerosols (ALH)

Evaluation Team:

M. E. Koukouli | AUTH (Team Lead)
K. Michailidis | AUTH
D. Balis | AUTH

Main results so far:

- GEMS ALH v2.0 is reported well within range with the S5P ALH & CALIOP/Calipso backscatter signal for the identified dust events.

- Figure comparisons will focus on the CALIOP/Calipso spatio-temporal collocations, cleanly separating dust and smoke events.
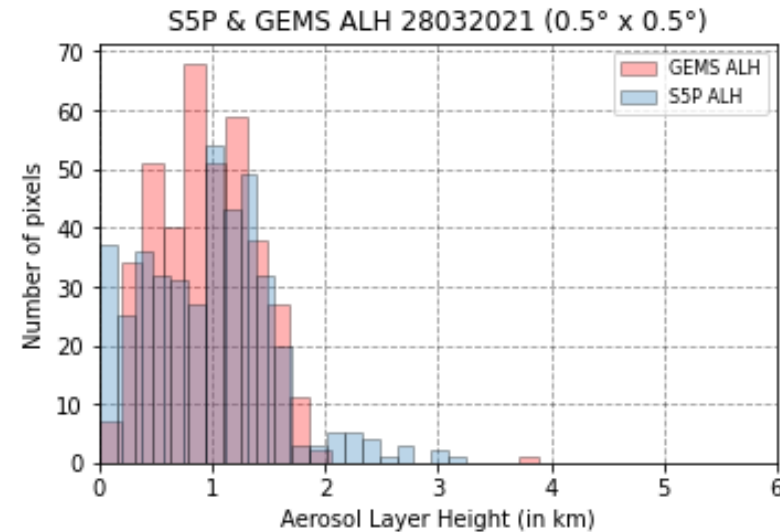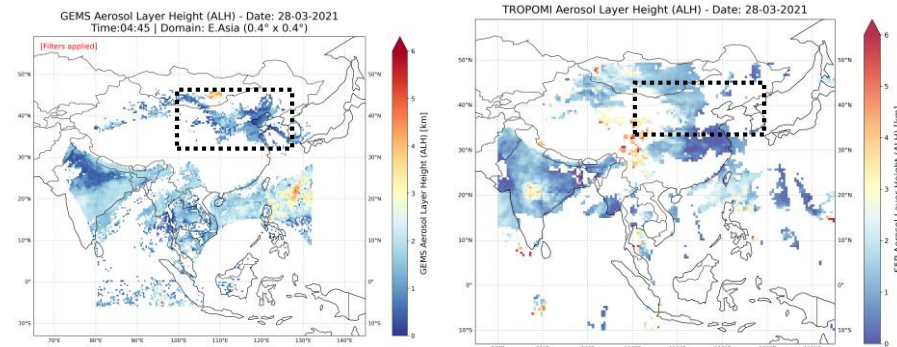

Upper: GEMS [left] & S5P [right] ALH on 28/03/2021.
Lower: Histogram comparison of heights within the black box at the top plots.

WP900 – GEMS Surface Product

Evaluation Team:
Pascal Hedelt, DLR

Main results so far:
- Definition of quality flag needs to be reconsidered, mostly bad quality over land pixels
- Strong difference between daily BSR and S5P/GOME2 DLER database
- 380nm BSR shows significantly high bias
- Strong latitudinal dependency of BSR as a function of season is visible in all wavelengths
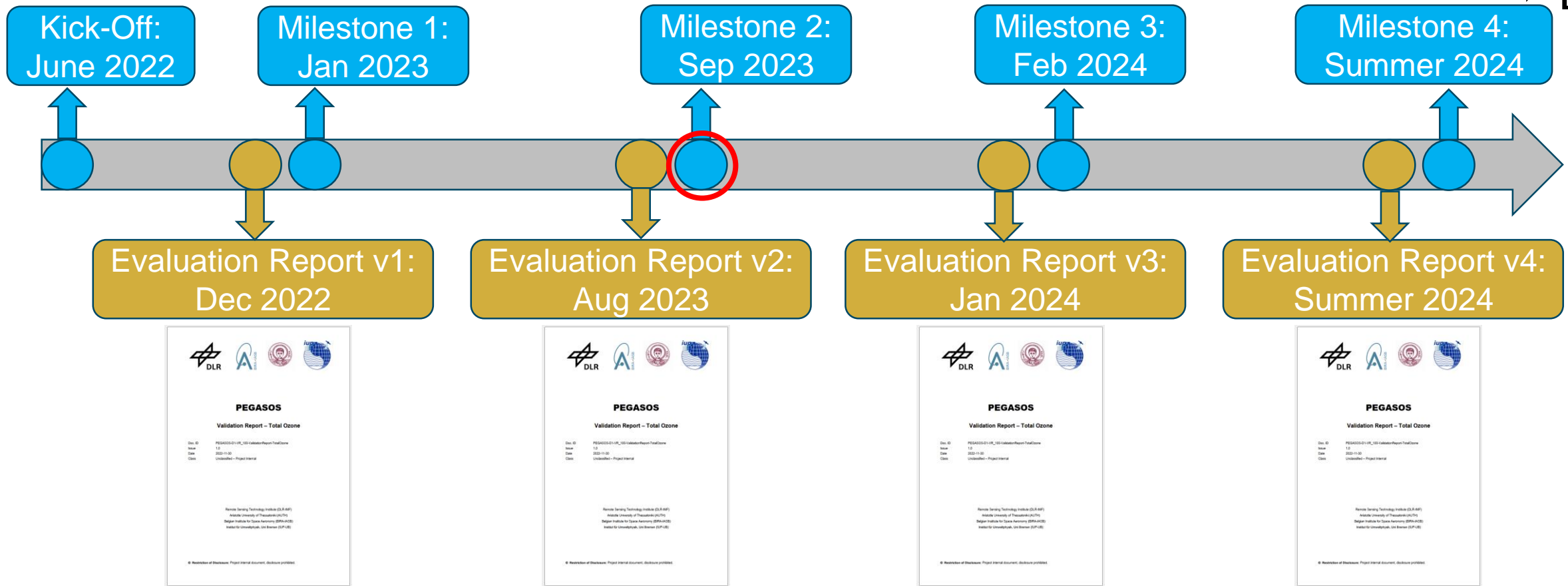 → Straylight issues might be the cause
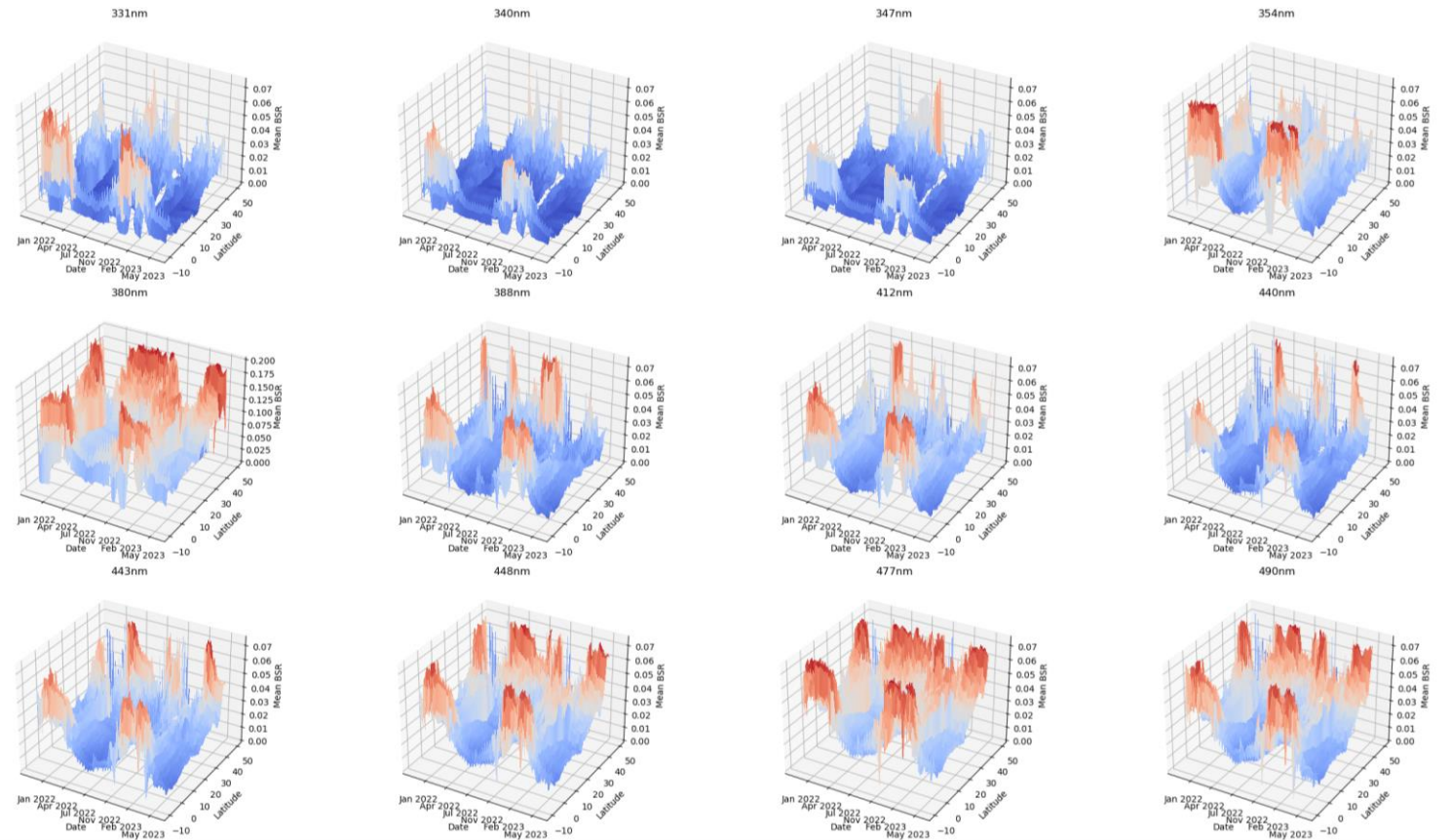
Zonal mean BSR as a function of time for each wavelength:
A strong latitudinal dependency as a function of season is visible.
380nm BSR shows exceptionally high values in comparison to other wavelengths.

PROJECT STATUS

Project Timeline

Kick-Off: June 2022

Milestone 1: Jan 2023

Milestone 2: Sep 2023

Milestone 3: Feb 2024

Milestone 4: Summer 2024

Evaluation Report v1: Dec 2022

Evaluation Report v2: Aug 2023

Evaluation Report v3: Jan 2024

Evaluation Report v4: Summer 2024

- Intermediate Evaluation reports (v1-v3) are not public and only shared with the GEMS team.
- Feedback from the GEMS colleagues on the reports is well appreciated
- Final Evaluation reports (v4) will be published on the ESA website.
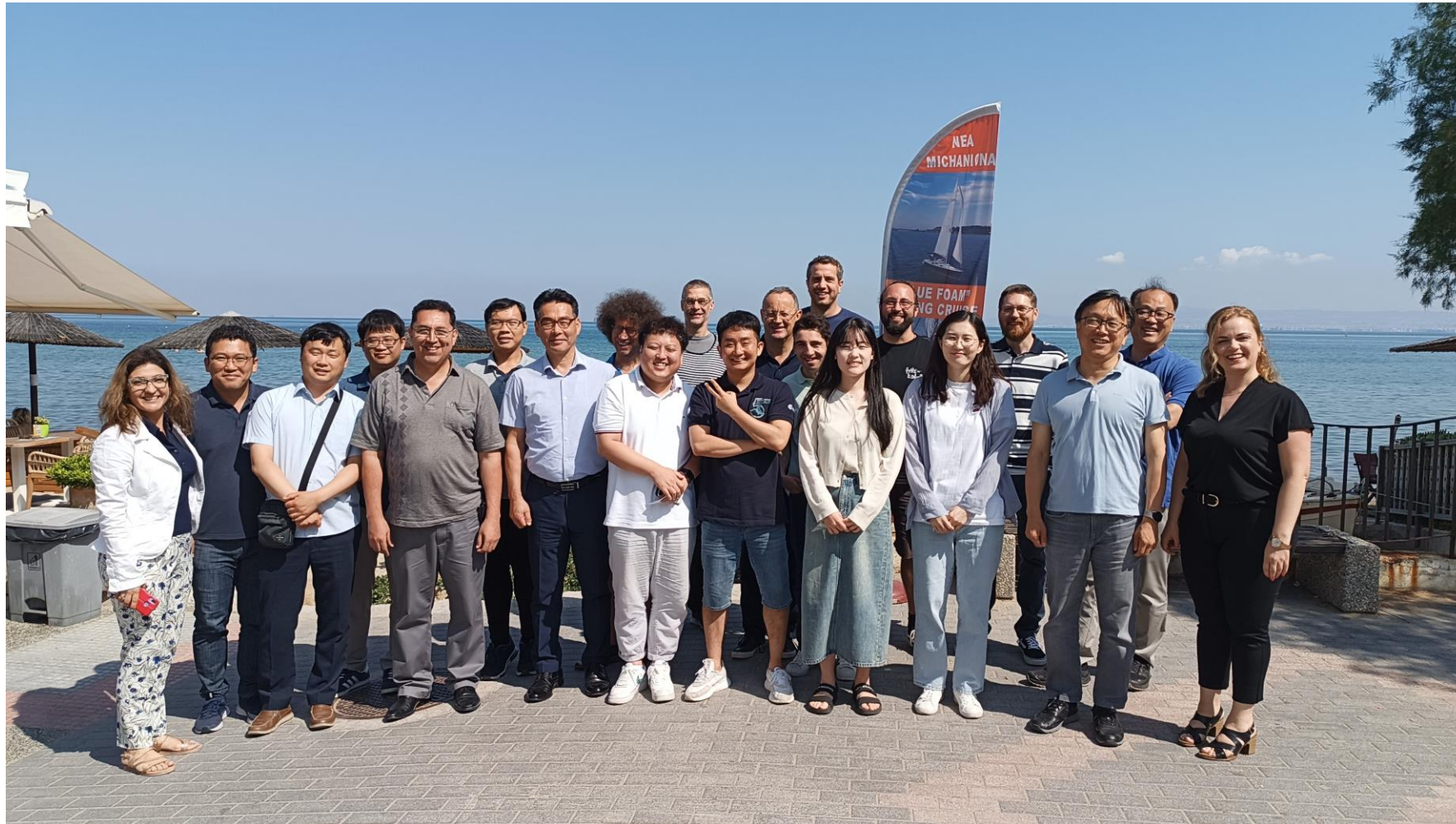
OUTLOOK

Outlook

- **The PEGASOS project ends in summer 2024, but a potential PEGASOS follow-up to include TEMPO would certainly be beneficial to strengthen the Virtual Constellation network**

Thank you for your attention

And a special THANKS for the very good collaboration with our GEMS colleagues!

Picture taken at the 2nd PEGASOS project meeting in June 2023, Greece