Preliminary validation results of the GEMS AEH product under the PEGASOS project

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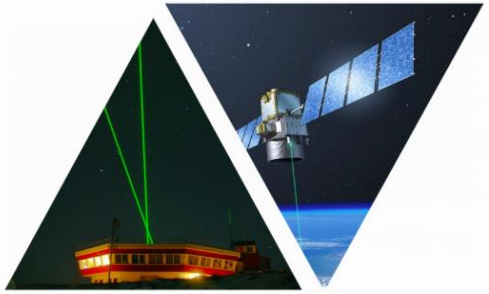
Motivation - Background

Why is the height of the aerosol layer so important?

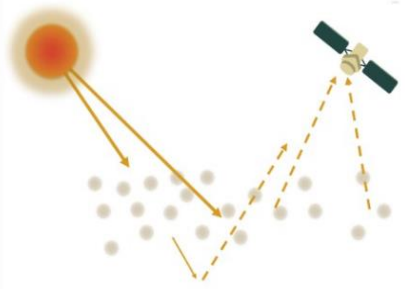
- Knowledge of the ALH, is essential for understanding the impact of aerosols on the climate system.
- Important in the framework of aviation safety, transported dust and ash aerosols over large distances the source.
- Critical for global aerosol transport and dispersion of smoke, dust, biomass burning aerosols, volcanic ash.
- Can provide accurate values to the modelling communities - improving air quality forecasting.

How the Aerosol height can be detecting?

- Lidar instruments can provide aerosol profile information with high vertical resolution of a few meters.
- Offer high accuracy and calibration results **BUT** their geographical coverage is spatial limited.
- More recently, a number of passive satellite sensors have been designed to provide ALH (e.g. GOME2, TROPOMI, MISR, DSCOVR)

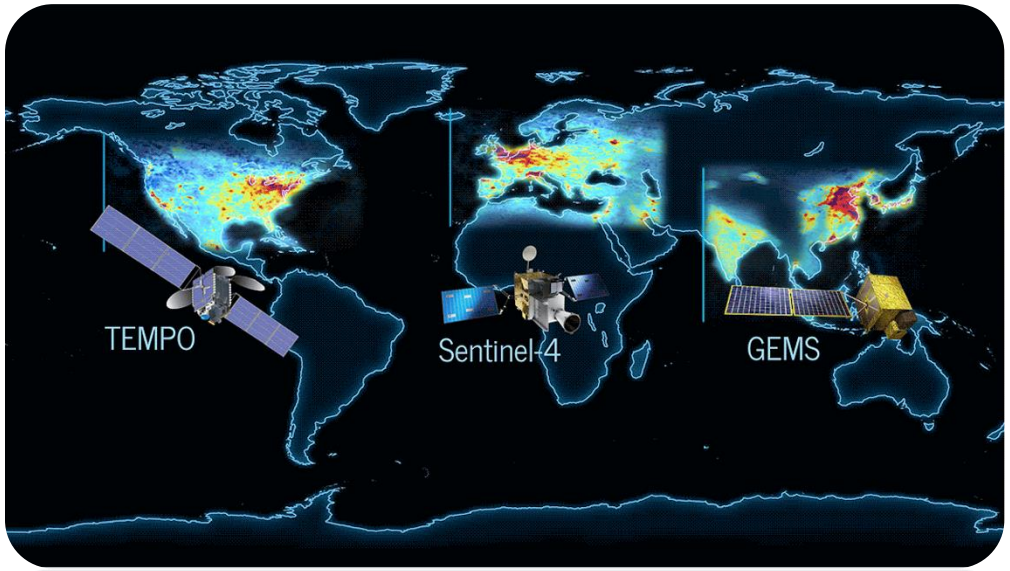


Active: Vertical aerosol backscatter profiles



Passive: Columnar properties of aerosol

Geostationary passive satellites GEMS, TEMPO, Sentinel-4



Able to provide Aerosol Layer height products on high resolution.

GEMS AEH Validation Strategy

- Validation of GEMS Aerosol Layer Height product using passive and active satellite datasets as reference, focusing on the detection of multiple smoke and dust cases over land and ocean.

- Validation Procedures under **PEGASOS Project** for the period (2021-2022)

Three validation chains are performed:

GEMS AEH vs TROPOMI ALH | L2

GEMS AEH vs GOME2/Metop AAH | L2

GEMS AEH vs CALIOP/CALIPSO LH | L2

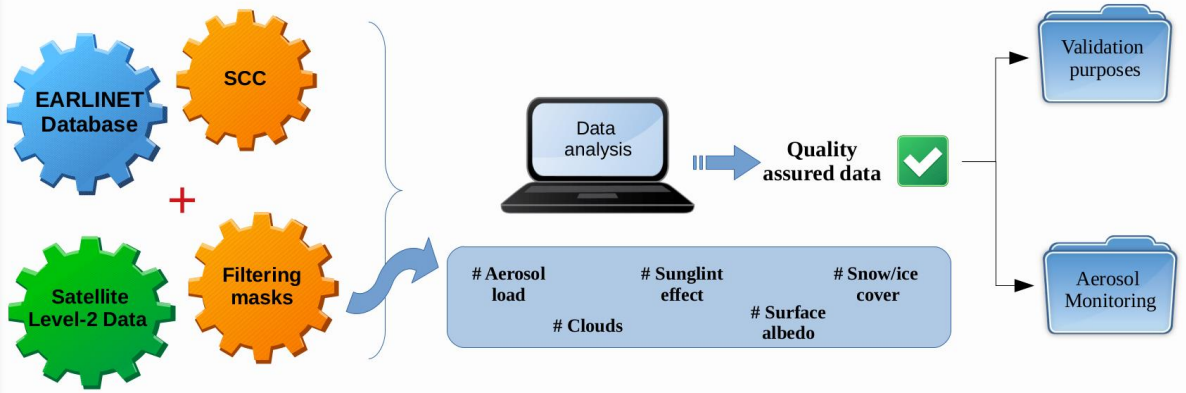
LAP/Auth Validation Background and Activities

Validation Tool by LAP-AuTh: "ATLANTIS"

GOME-2/MetOp are available on the EUMETSAT - ACSAF
https://acsaf.org/

S5P/TROPOMI/S5P are available on the Copernicus Open Data Hub
https://s5phub.copernicus.eu/dhus/#/home

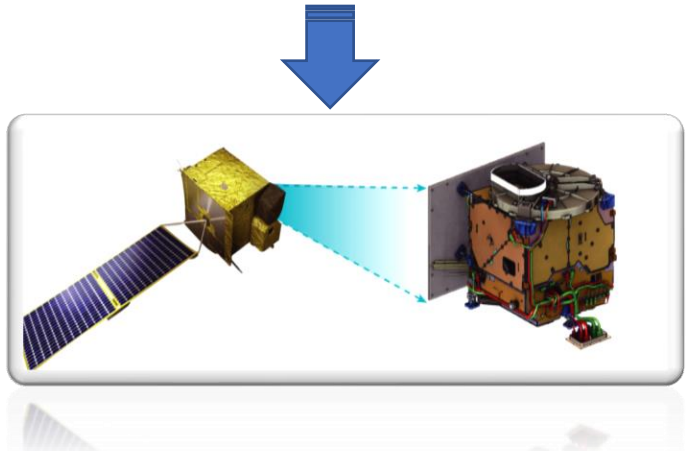
EARLINET Data Portal
https://data.earlinet.org/earlinet/login.zul



An optimal tool has been developed for aerosol monitoring and validation of **GOME-2** & **TROPOMI** aerosol height products

(Read, Map, and Analyze Satellite Data)

We include the GEMS AEH product in the automatic validation procedures of ATLANTIS.

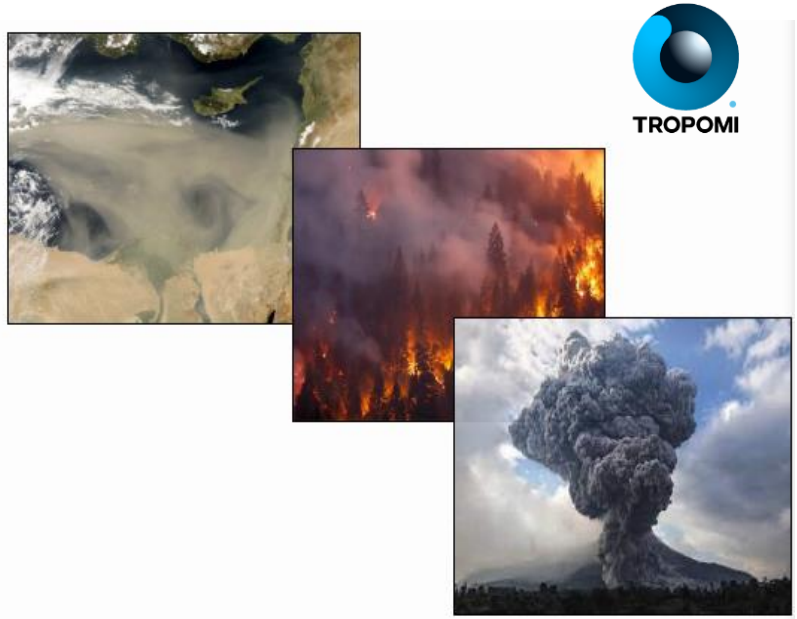


Satellite-to-satellite comparison GEMS vs CALIPSO, S5P, GOME2 is under progress.

The "HARP Toolbox" is used for the validation analysis (https://atmospherictoolbox.org)

Aerosol Layer Height from passive sensors: GOME2 and TROPOMI

ALH product, focuses on retrieval of vertically localized aerosol layers in the FT, such as **desert dust**, **biomass burning** or **volcanic ash** plumes.

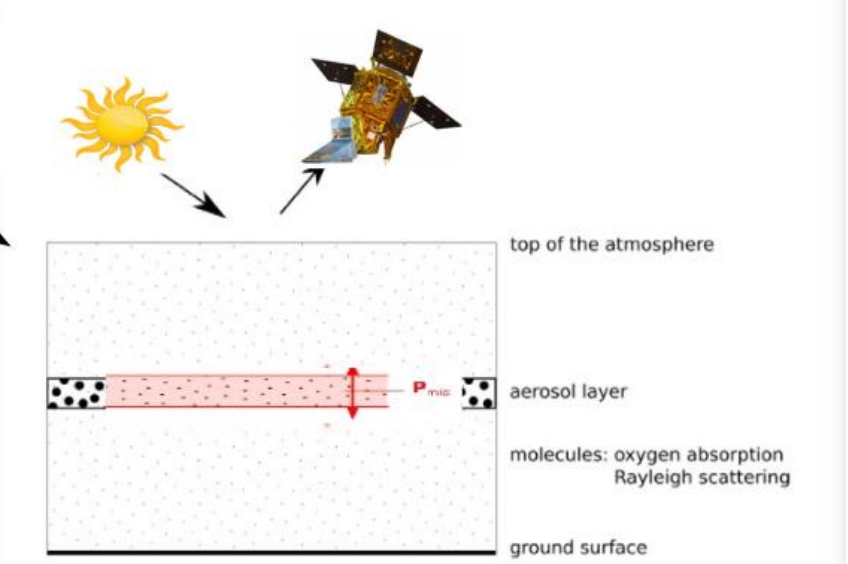


Aerosol Index = indicates the presence of elevated absorbing aerosols in the atmosphere.

AI > 0 : Absorbing aerosols
AI <=0 : non-absorbing aerosols / clouds

Absorbing Aerosol Height (AAH):
from O2 A-band FRESCO cloud retrieval for strong AAI scenes: aerosol height is FRESCO cloud height for AAI > 2. (Wang et al., AMT, 2012).

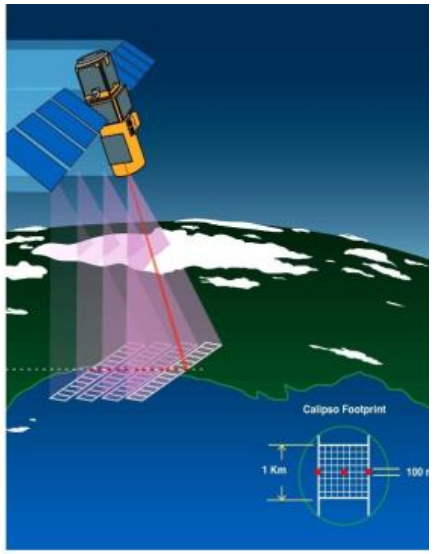
Aerosol Layer Height (ALH):
from O2 A-band using dedicated Optimal Estimation retrieval (Nanda et al., AMT, 2020)



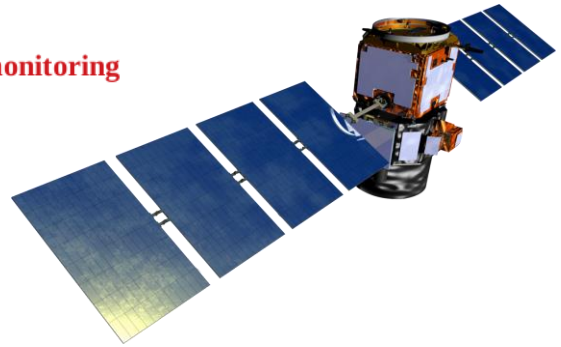
Both of GOME-2 & TROPOMI height products are operational!

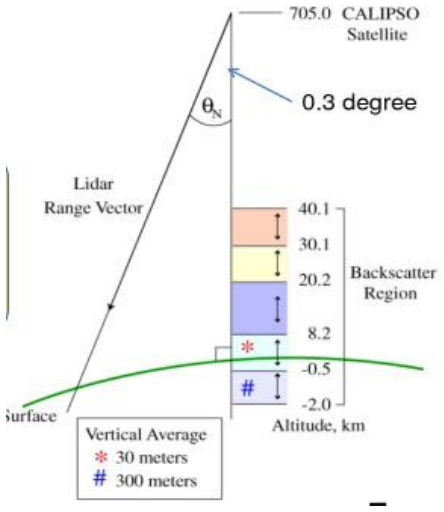
***Important:* Are there any product limitations?**

Aerosol Layer Height from active sensors: CALIOP/CALIPSO



- CALIOP is the main instrument onboard CALIPSO (Operating since 2006)
- Is a dual-wavelength (532, 1064nm) elastic backscatter lidar with the capability of polarization observations
- **High- resolution profiling ability + accurate depol. measurements = Powerful tool for aerosol/clouds monitoring**
- Sun-synchronous polar orbit (705km,16 days repeat cycle)
- Provides information during daytime (13:30ET) and nighttime (01:30ET)
- The footprint of CALIOP measurements is only **100m**.





The final CALIPSO Level 2 product includes:

(a) the vertical location of layers,

(b) the discrimination of aerosol layers from clouds,

(c) the categorization of the aerosol layers in 10 subtypes, and

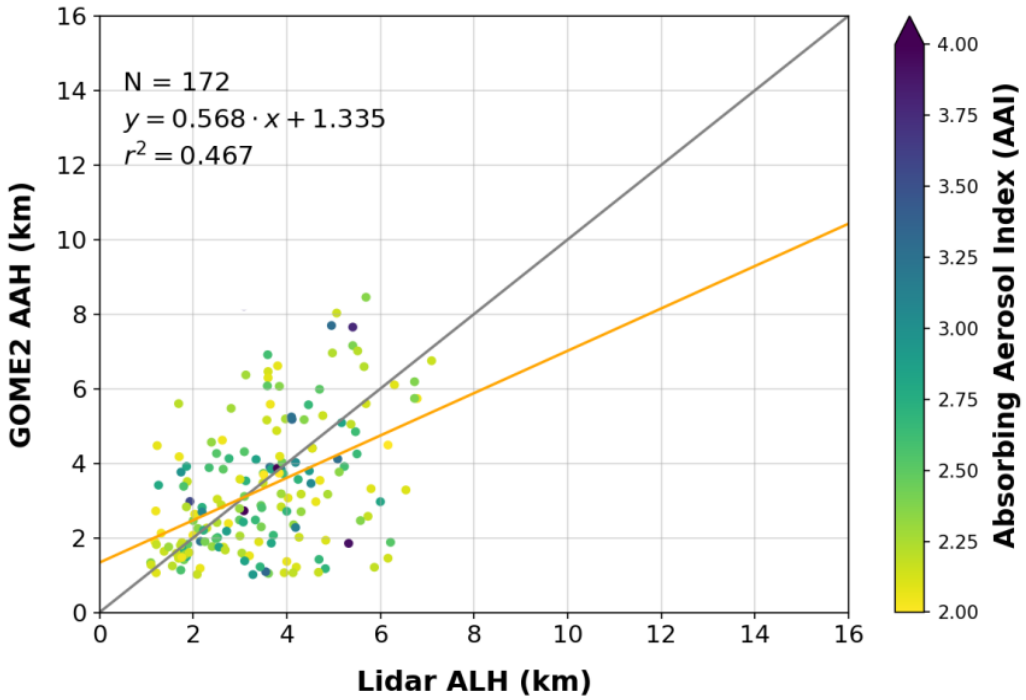
(d) the AOD estimations for each layer detected.

- CAL_LID_L1-Standard (V4) : Total Attenuated Backscatter_532
- CAL_LID_L2-Alay-Standard (V4) : Layer Top Altitude
- CAL_LID_L2-VFM-ValStage1 (V4) : Feature_Classification_Flags

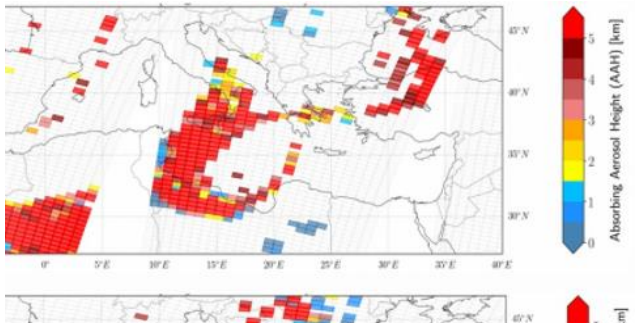
The collocated aerosol extinction profiles at 532 nm from CALIOP level 2 product are used to calculate an extinction weighted aerosol height.

$$Z_{\text{aer}} = \sum_{i-1}^{n} H(i) \left[\frac{B_{\text{sc}}(i)}{\sum_{i=1}^{n} B_{\text{sc}}(i)} \right]$$

Proof of concept: GOME2 Aerosol Height

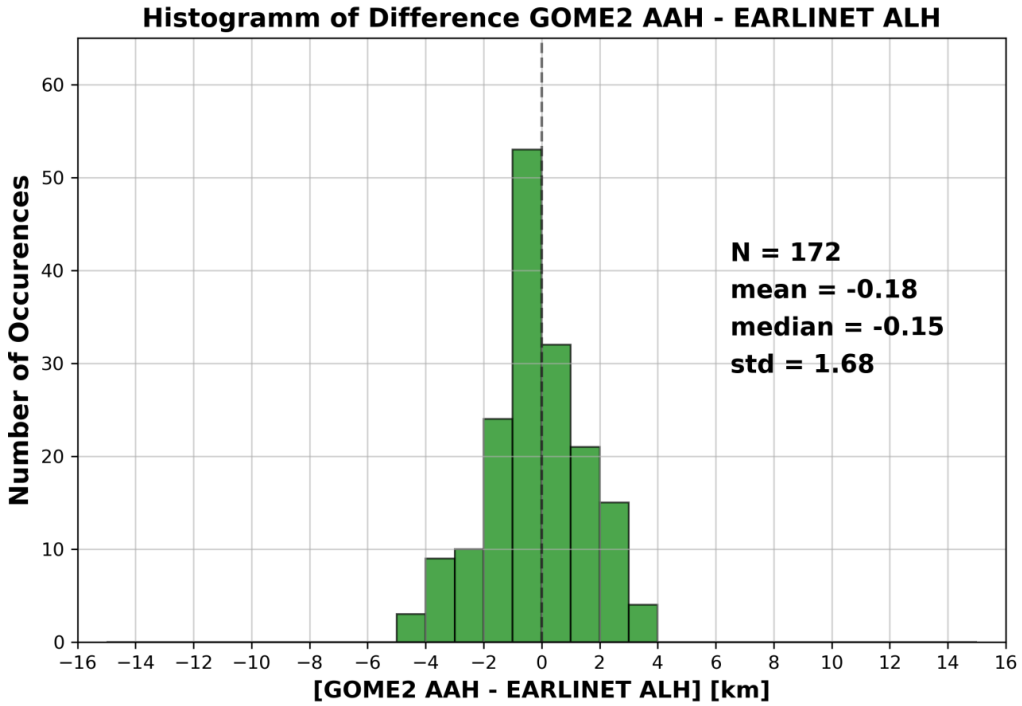


Aerosol Layer Height



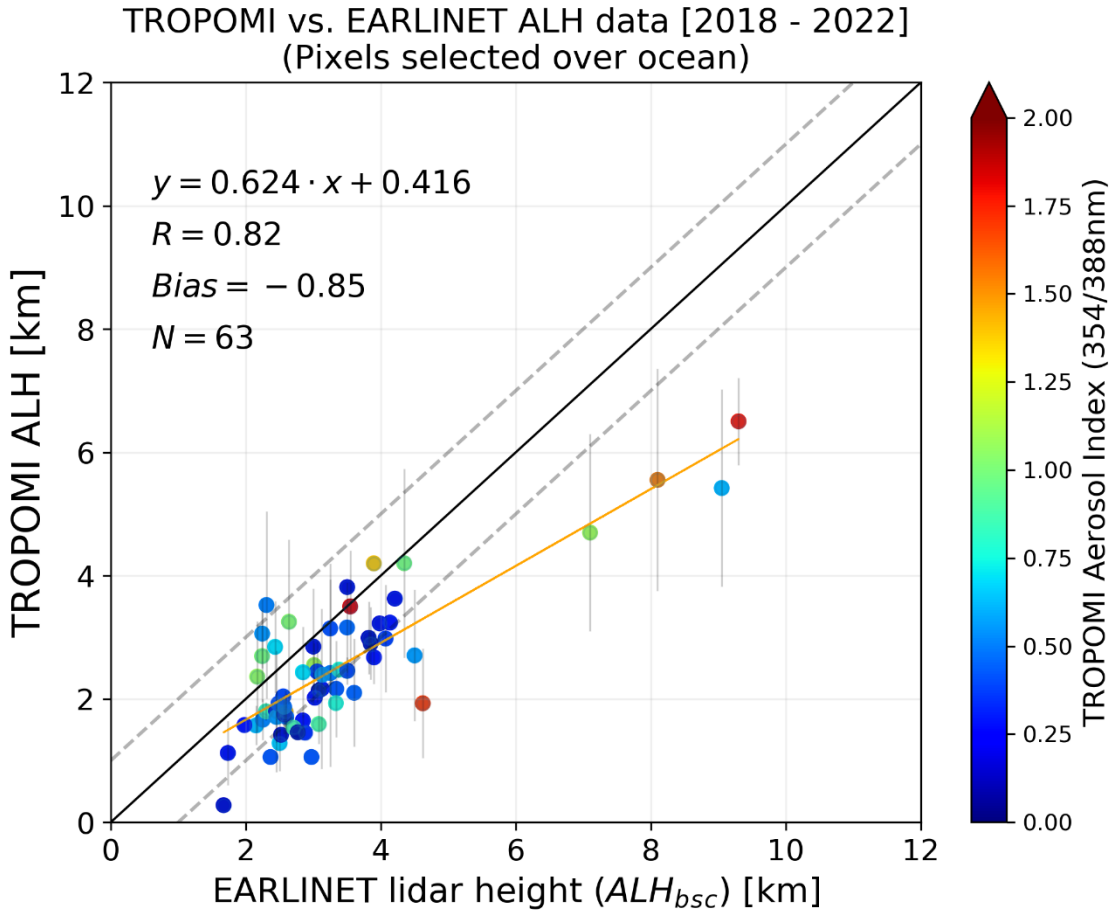
Wildfires raged in California, during the last two weeks of October 2020.

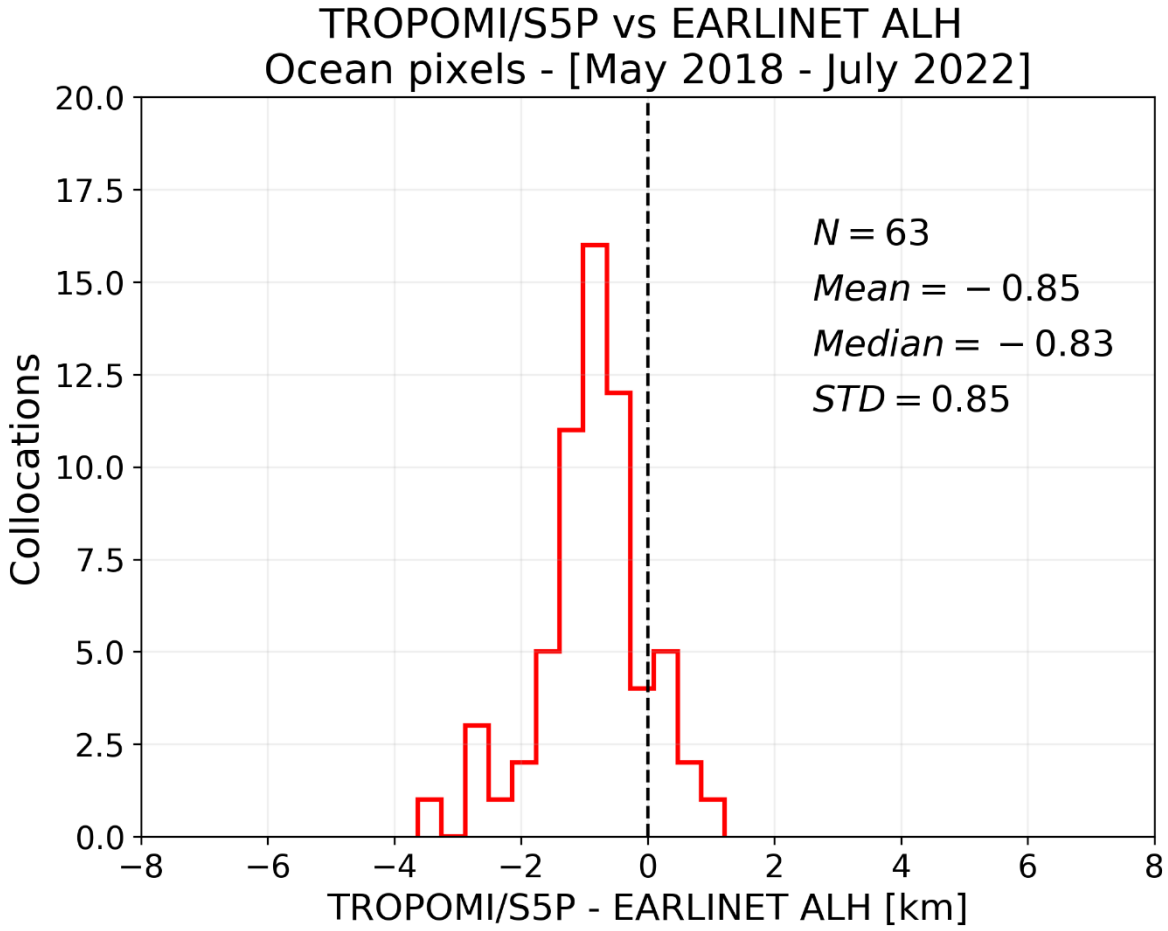
The GOME2 & TROPOMI have been monitoring the long distances smoke plume transport.



Michailidis, K., Koukouli, M.-E., Siomos, N., Balis, D., Tuinder, O., Tilstra, L. G., Mona, L., Pappalardo, G., and Bortoli, D.: First validation of GOME-2/MetOp absorbing aerosol height using EARLINET lidar observations, Atmos. Chem. Phys., https://doi.org/10.5194/acp-21-3193-2021, 2021.

Proof of concept: TROPOMI Aerosol Height



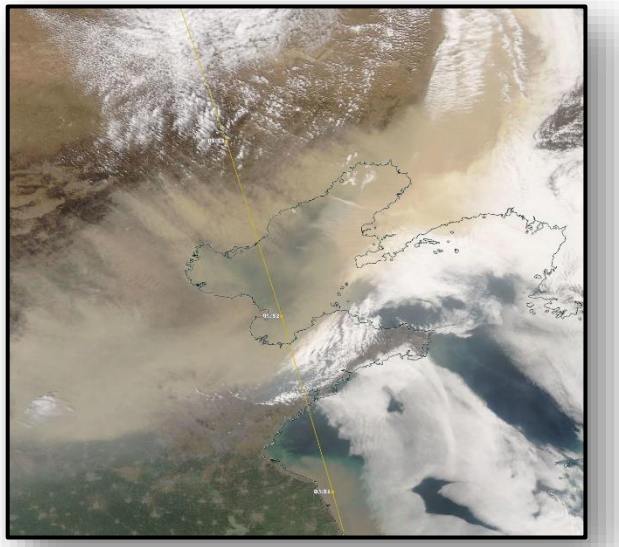


Michailidis, K., Koukouli, M.-E., Balis, D., Veefkind, P., de Graaf, et al.: Validation of the TROPOMI/S5P Aerosol Layer Height using EARLINET lidars, Atmos. Chem. Phys. Discuss, https://doi.org/10.5194/acp-2022-412, in review, 2022.

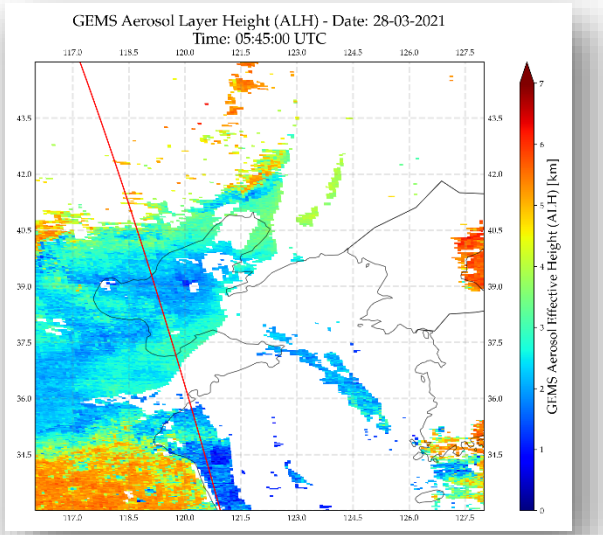
Dust case over the Yellow Sea – 28 March 2021

A dust event occurred on 28 March 2021, over East Asia, originated from the Gobi desert.

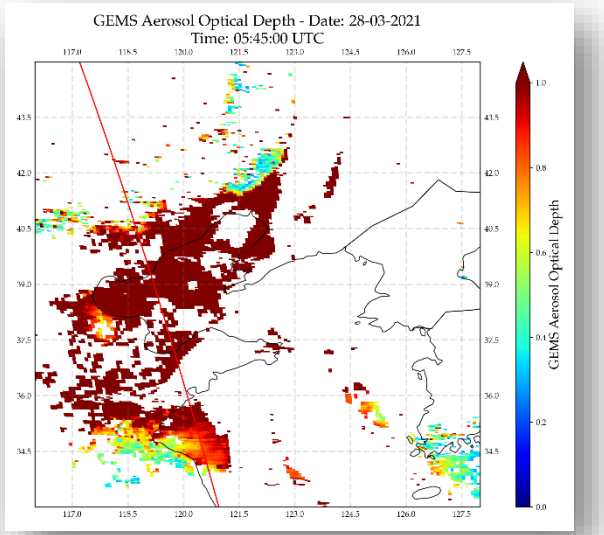
MODIS/Aqua True colour



GEMS Aerosol Effective Height



GEMS Aerosol Optical Depth



CALIPSO Aerosol type:

"Dust"

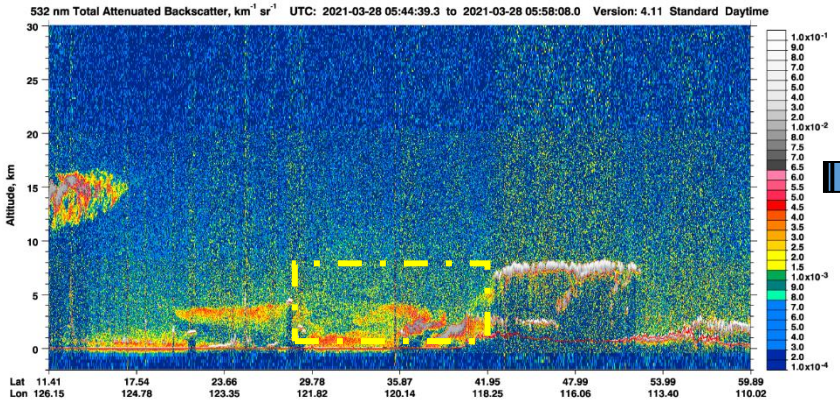
CALIOP Ext. height:

1.2 – 3.3km

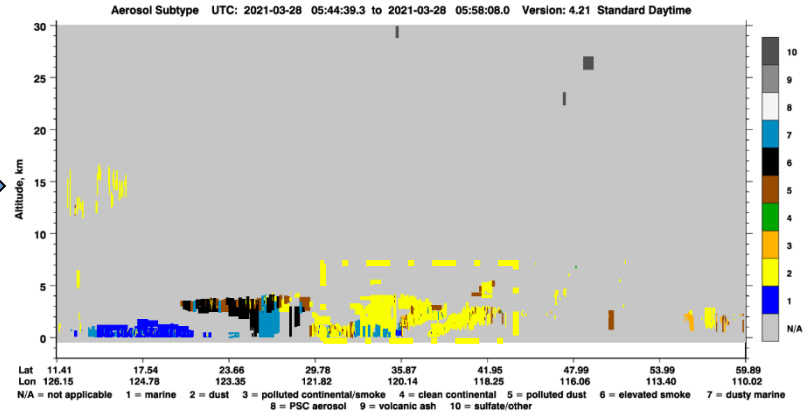
GEMS collocated AEH:

0.9 - 3.5km

CALIPSO Total Att. Backscatter 532nm



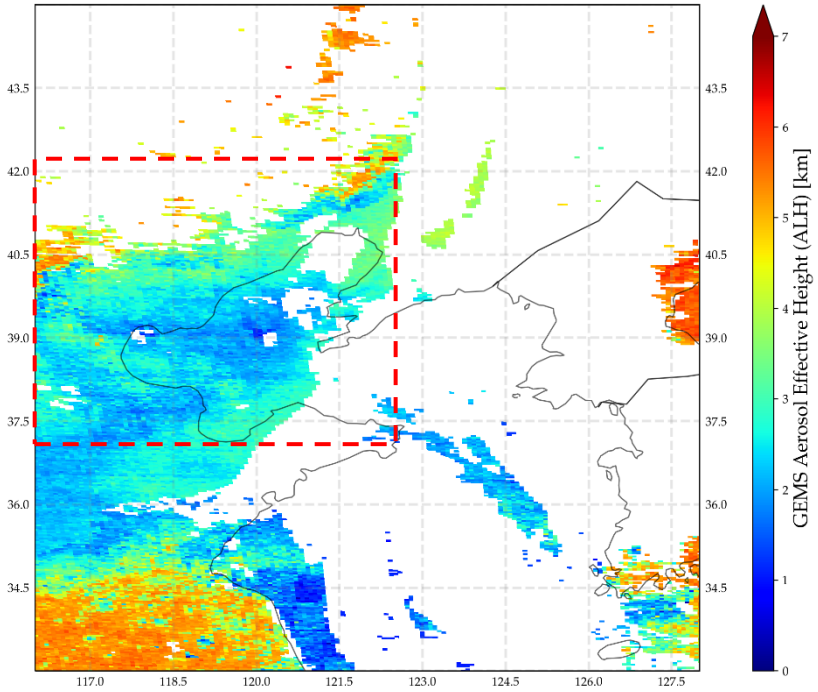
CALIPSO Aerosol subtype



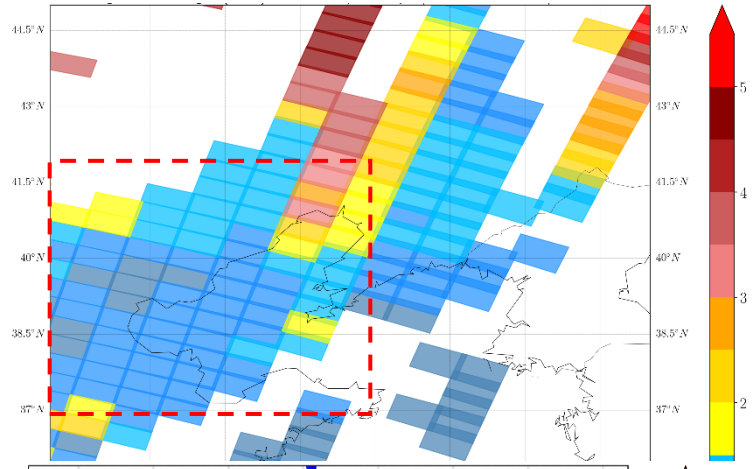
CALIOP/CALIPSO provides aerosol vertical distribution and information on type of particle (size and shape)

Dust case over the Yellow Sea – 28 March 2021

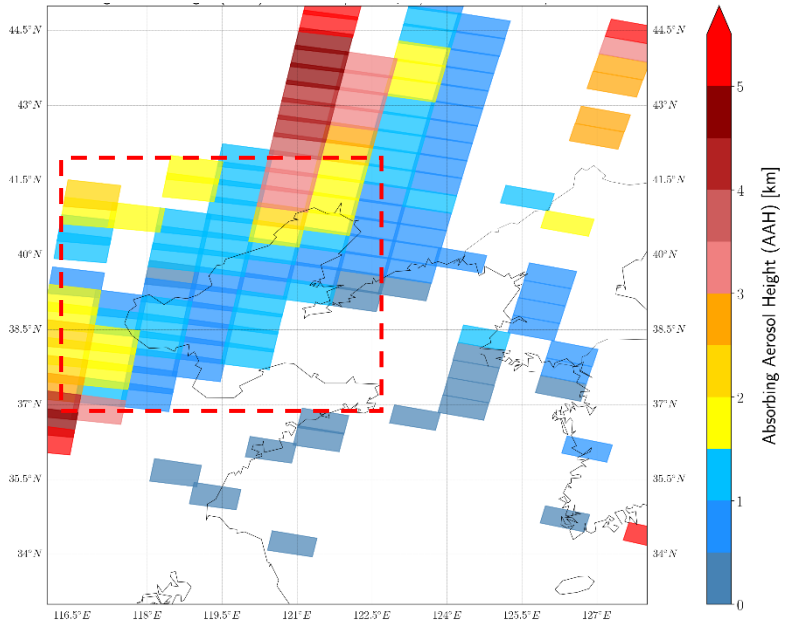
GEMS AEH: 1-5km
(3.5 x 8km^2)



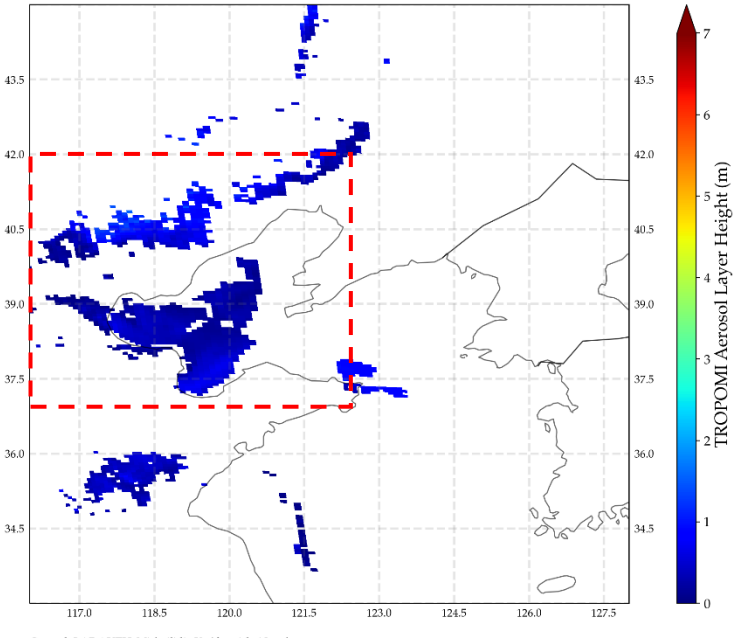
GOME2-B AAH: 0.5-4km
(40x80km^2)



GOME2-C AAH: 0.5-4km
(40x80km^2)



S5P ALH: 0.15 -2km
(5.5 x 3.5km^2)



Summary and Outlook

- Within the ESA Pegasos project, the GEMS ALH is compared to TROPOMI Aerosol Layer Height (AER_LH), GOME-2 (AAH) and CALIOP (Weighted extinction height) data.
- Several aerosol cases were identified to include both dust events and smoke particles.
- On a case base, the GEMS ALH compares favourably with the GOME-2 AAH and the CALIOP weighted extinction height.
- The TROPOMI AER_LH product has known issues over land. A new and improved version of the dataset is expected by December 2022.
- Passive remote sensing of ALH has been made significant progress in the last decade.
- Future retrievals of ALH will be enriched by the GEO Sentinel-4 and the polar Sentinel-5 Copernicus missions.