Validation of Sentinel-2 Auxiliary Data: Focus on Aerosol Optical Depth at 550 nm and Total Column of Water Vapour

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Since the beginning of the **Sentinel-2** mission in 2015, in complement of Sentinel-2 imagery files, meteorological auxiliary data from **European Centre for Medium-Range Weather Forecasts** (ECMWF) are provided to the users within L1C and L2A products. Since the 25th of January 2022 (PB 04.00), the number of ECMWF meteorological parameters has been extended with three additional parameters and a new set of 10 atmospheric parameters from the **Copernicus Atmosphere Monitoring Service** (CAMS).

This poster describes the format and contents of this meteorological and atmospheric auxiliary data. It also presents the methodology and the results of the monitoring of two parameters (Aerosol Optical Depth at 550 nm & Total Column of Water), on 24 different locations distributed over all continents and all climate zones using 24 AERONET stations. The period covers about 19 months of data.

Sentinel-2 Auxiliary Data Format

Since processing baseline 04.00 and in Sentinel-2 Collection-1 product the following auxiliary files are available with each L1C and L2A product. Those files are located at granule level in the AUX_DATA folder:
- AUX_**ECMWFT** (GRIB);
- AUX_**CAMSFO** (GRIB), AUX_**CAMSRE** (GRIB) for Collection-1

AUX_**ECMWFT**

AUX_**CAMSFO**
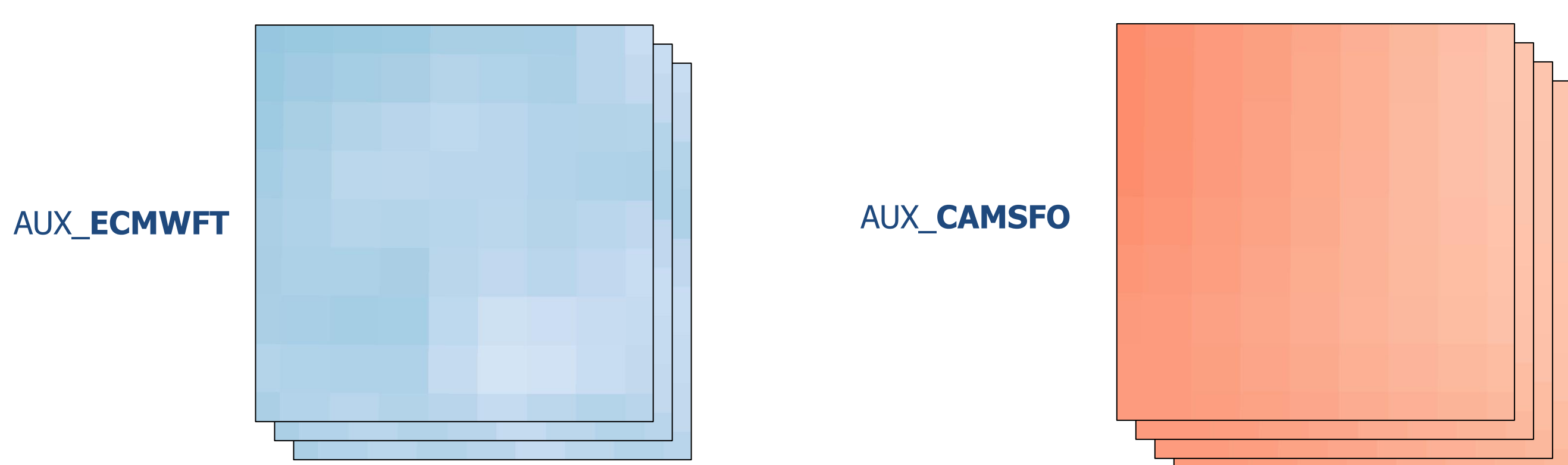
- Total column ozone (TCO3) [Kg/m2];
- Total column water vapour (TCWV) [Kg/m2];
- Mean sea level pressure (MSL) [hPa].
- 10-meter V wind component (10v) [m/s]
- 10-meter U wind component (10u) [m/s]
- Relative Humidity @ Isobaric Surface [%]

Correspondence table between CAMS variable name and physical parameter name is given in Table 4 of the Sentinel-2 Annual Performance Report – Year 2022

- Geopotential (at the surface = orography) [m²/s²];
- Total Aerosol Optical Depth at 469nm (aod469)
- Total Aerosol Optical Depth at 550nm (aod550)
- Total Aerosol Optical Depth at 670nm (aod670)
- Total Aerosol Optical Depth at 865nm (aod865)
- Total Aerosol Optical Depth at 1240nm (aod1240)
- Black Carbon Aerosol Optical Depth at 550nm (bcaod550)
- Dust Aerosol Optical Depth at 550nm (duaod550)
- Organic Matter Aerosol Optical Depth at 550nm (omaod550)
- Sea Salt Aerosol Optical Depth at 550nm (ssaod550)
- Sulphate Aerosol Optical Depth at 550nm (suaod550)

The format (GRIB V1) and contents of this file are identical in L1C and L2A products. This auxiliary data is provided in a gridded format which results from a temporal (linear) and spatial interpolation (bilinear with a Ground Sample Distance of 12.5km) of the raw ECMWF global forecast dataset into a geographical area covering the Level-1C tiles footprint. Grid points are provided in latitude/longitude using WGS84 reference system.

Source and usage of Auxiliary Data

The parameters in AUX_CAMS_FO originate from ECMWF through the Copernicus Atmosphere Monitoring Service that generates every day, five-day forecasts of aerosols, atmospheric pollutants, greenhouse gases, stratospheric ozone, and the UV-Index.

The Aerosol Optical Depth at 550 nm from AUX_CAMS_FO can be used as atmospheric information fallback in the L2A processor when performing the atmospheric correction for certain Sentinel-2 tiles when not enough dark dense vegetation pixels are present to perform an independent aerosol retrieval.

The parameters in AUX_ECMWFT originate from ECMWF that generates every day global meteorological forecasts.

The Total Column of Water from AUX_ECMWFT is not used in the L2A processor when performing the atmospheric correction. However, it is interesting to check how its performance compares with the L2A processor outputs.

Material and Methods

The monitoring is performed on 24 different locations distributed over all continents and all climate zones using 24 AERONET stations.

The data period covers about 19 months of data, between 25/01/2022 to 17/08/2023, starting with Sentinel-2 PB 04.00, since the AUX_CAMS_FO files are embedded in the L1C and L2A products.

The values of AUX_CAMS_FO and AUX_ECMWFT are extracted at the AERONET site location using its geographic coordinates.

The Aerosol Optical Depth at 550 nm AERONET values are spectrally and temporally interpolated to the Sentinel-2 acquisition time. The Precipitable Water AERONET values are temporally interpolated to the Sentinel-2 acquisition time.

Credits: We would like to express our gratitude to the Principle Investigator(s) and Co-Investigator(s) as well as all the persons involved for establishing and maintaining the 24 sites used in this analysis: 'Lille', 'Kyiv', 'Kangerlussuaq', 'NEON_UNDE', 'Toravere', 'MetObs_Lindenberg', 'NEON_CVALLA', 'Medenine-IRA', 'Valladolid', 'XiangHe', 'OHP_OBSERVATOIRE', 'Gangneung_WNU', 'NEON-Disney', 'Tamanrasset_INM', 'Kanpur', 'Dhaka_University', 'Ilorin', 'Silpakorn_Univ', 'Huancayo-IGP', 'Jambi', 'Rio_Branco', 'Mongu_Inn', 'Fowlers_Gap', 'CEILAP-RG'.
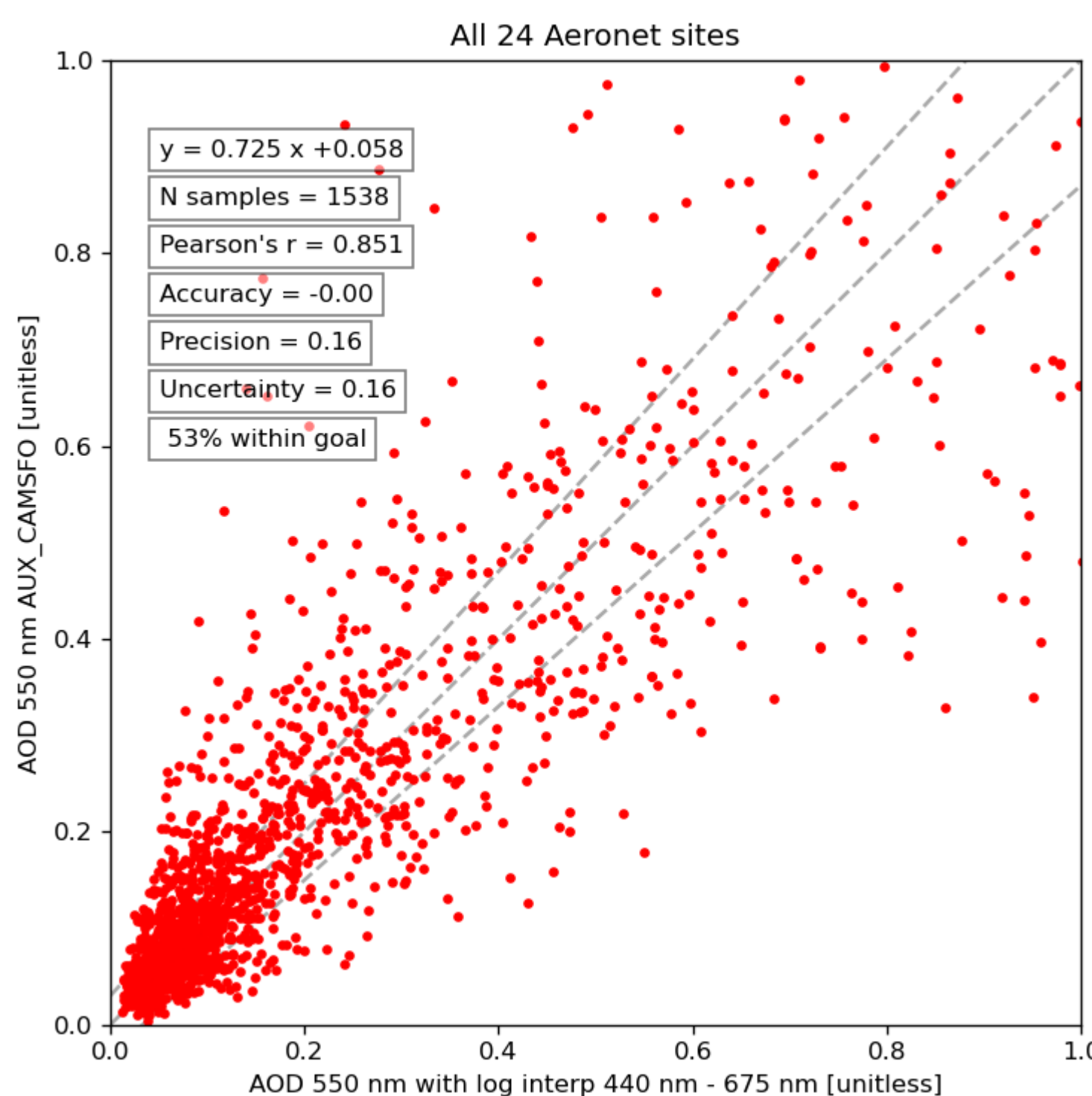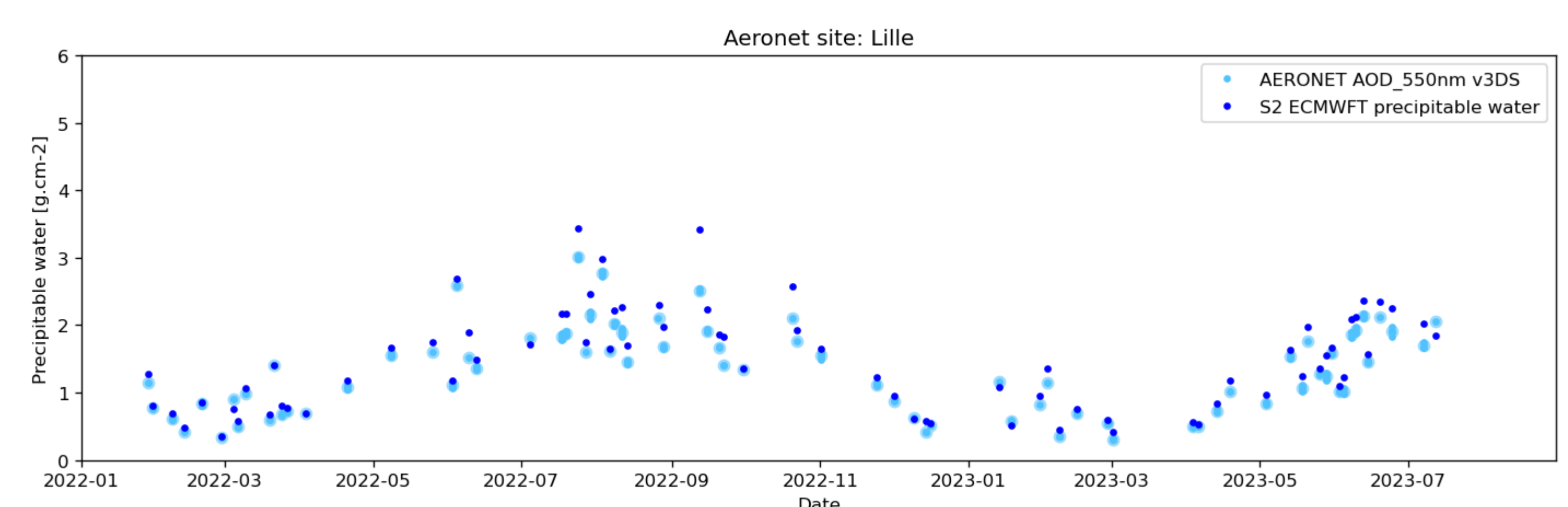
Aerosol Optical Depth at 550 nm
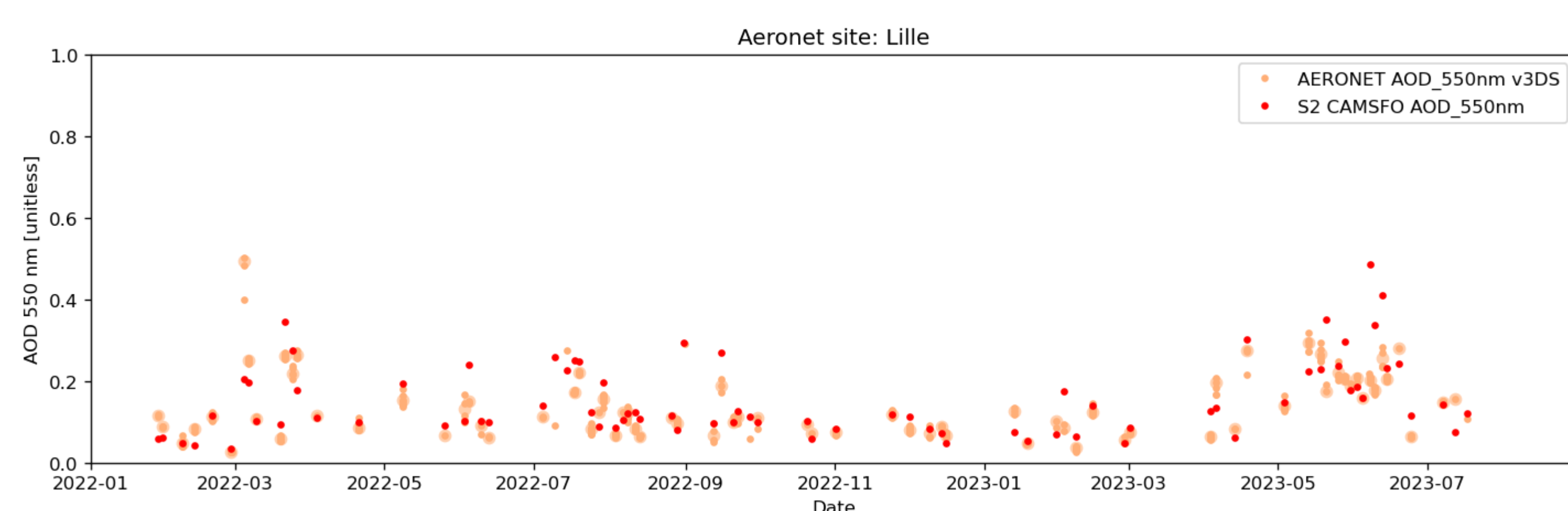
The temporal plot above shows all the concomitant Sentinel-2 auxiliary CAMS data (in red) with the AERONET data (in light red), for one AERONET site: Lille, France. .

The adjacent scatter plot shows all the concomitant Sentinel-2 auxiliary CAMS data with respect to the AERONET data for all the 24 AERONET test sites.

These consolidated statistics on all test sites show that 53% of CAMS data is within the uncertainty goal with an overall uncertainty of 0.16 without significant bias. It should be noted however that depending on the test site this value can range from 23% for the lowest agreement (Ilorin) up to 84% for the best agreement (Kangerlussuaq). In general, the agreement is better for test sites with lower aerosol load. .

y = 0.725 x +0.058
N samples = 1538
Pearson's r = 0.851
Accuracy = -0.00
Precision = 0.16
Uncertainty = 0.16
53% within goal

Total Column of Water

The temporal plot above shows all the concomitant Sentinel-2 auxiliary ECMWF data (in blue) with the AERONET data (in light blue), for one AERONET site: Lille, France. A seasonality can be observed with an atmosphere wetter in summer and dryer in winter.

The adjacent scatter plot shows all the concomitant Sentinel-2 auxiliary ECMWF data with respect to the AERONET data for all the 24 AERONET test sites.

These consolidated statistics on all test sites show that 87% of ECMWF data is within the uncertainty goal with an overall uncertainty of 0.27 g.cm-2 with a slight positive bias of 0.15 g.cm-2 . It should be noted however that depending on the test site, this value can range from 75% for the lowest agreement (OHP_OBSERVATOIRE) up to 98% for the best agreement (Kangerlussuaq). In general, the agreement is better for test sites with dryer atmosphere.

y = 1.054 x +0.057
N samples = 1542
Pearson's r = 0.99
Accuracy = 0.15 g.cm-2
Precision = 0.23 g.cm-2
Uncertainty = 0.27 g.cm-2
87% within goal