SI-TRACEABLE SURFACE-BASED OBSERVATIONS FOR OZONE AND AEROSOL PROPERTIES RETRIEVAL

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World Radiation Center, PMOD/WRC

QA4EO Phase 1 (2019/11-2022/4)

1) Operate solar spectroradiometers & filter radiometers at PMOD/WRC to retrieve:
    1) Traceable total column ozone from direct spectral solar UV irradiance measurements.
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3) Participation at a field campaign organised by LOA at the Aeronet-Europe calibration site at Observatoire de haute Provence (OHP).

Supplementary tasks:

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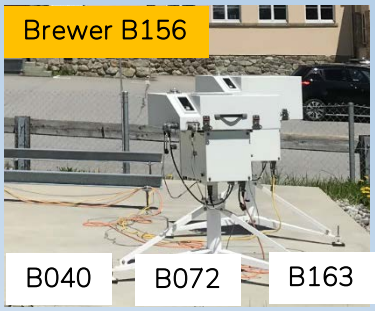
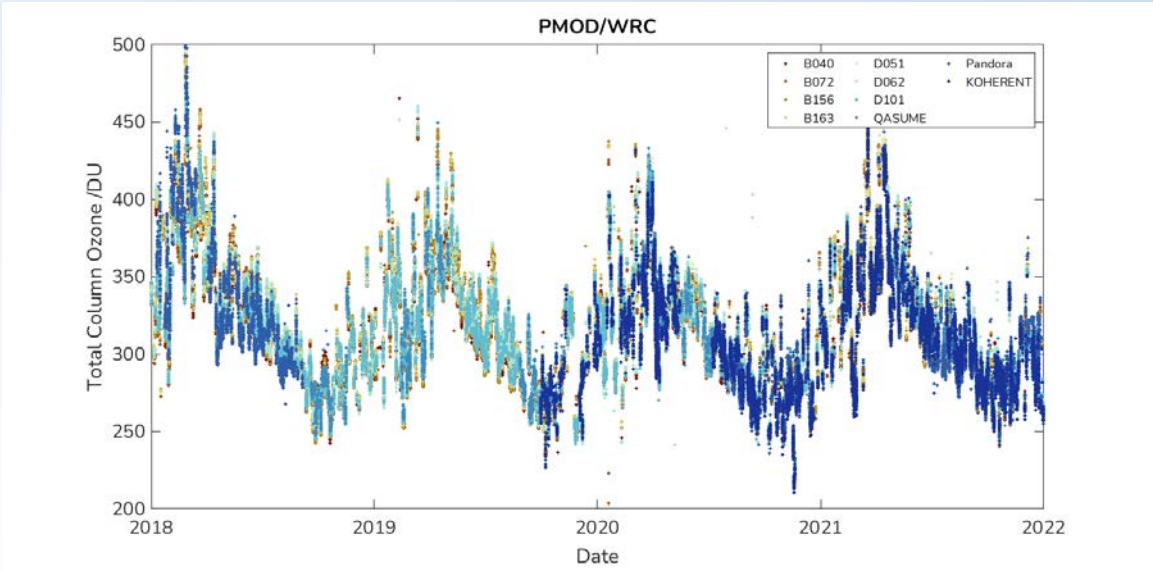
- Characterisation & Calibration of CAL/VAL sensors in the optical laboratory of PMOD/WRC or via cross-calibrations at field campaigns.

Total Column ozone measurements at PMOD/WRC



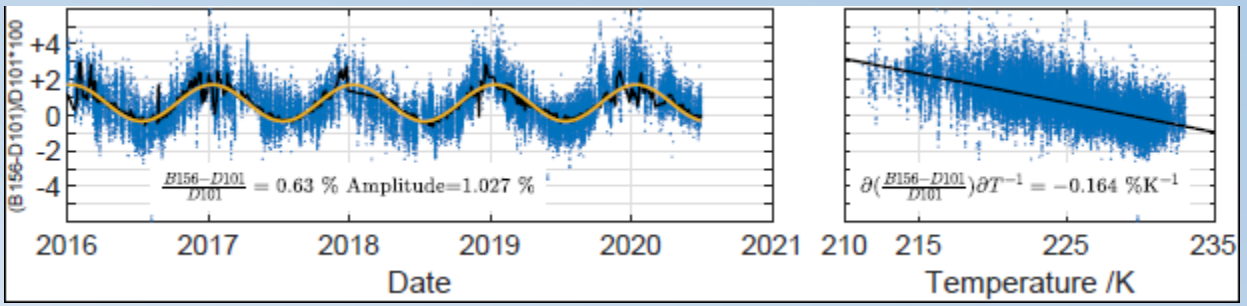
10 Instruments: 4 Brewer, 3 Dobson, 3 Spectroradiometers



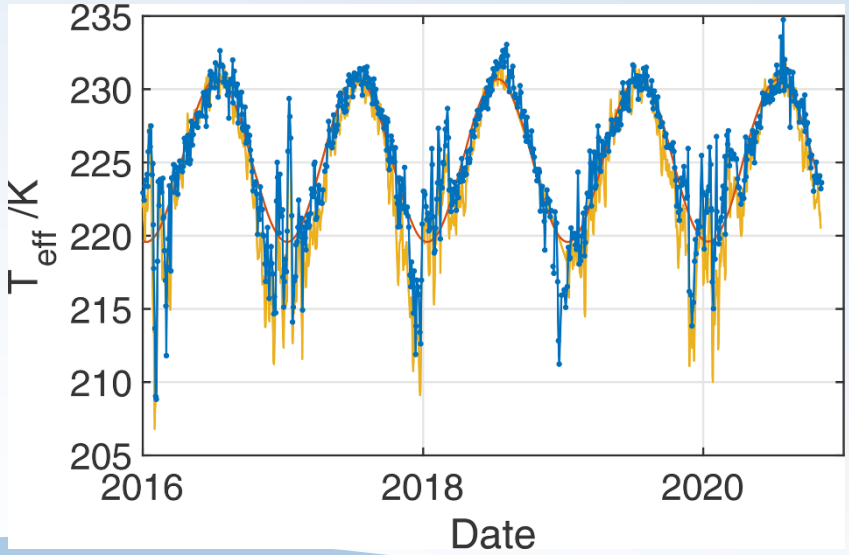
Collaborations with
- MeteoSwiss
- Luftblick, Serco

Finding consistency between Brewer and Dobson

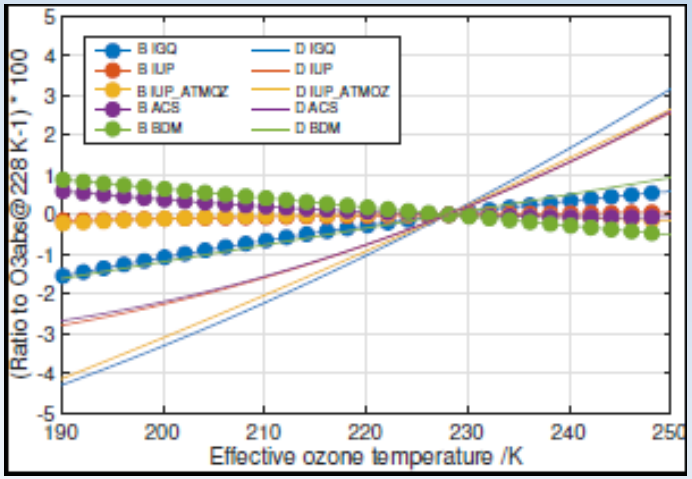
Using the operational methodology



Effective ozone temperature at Davos



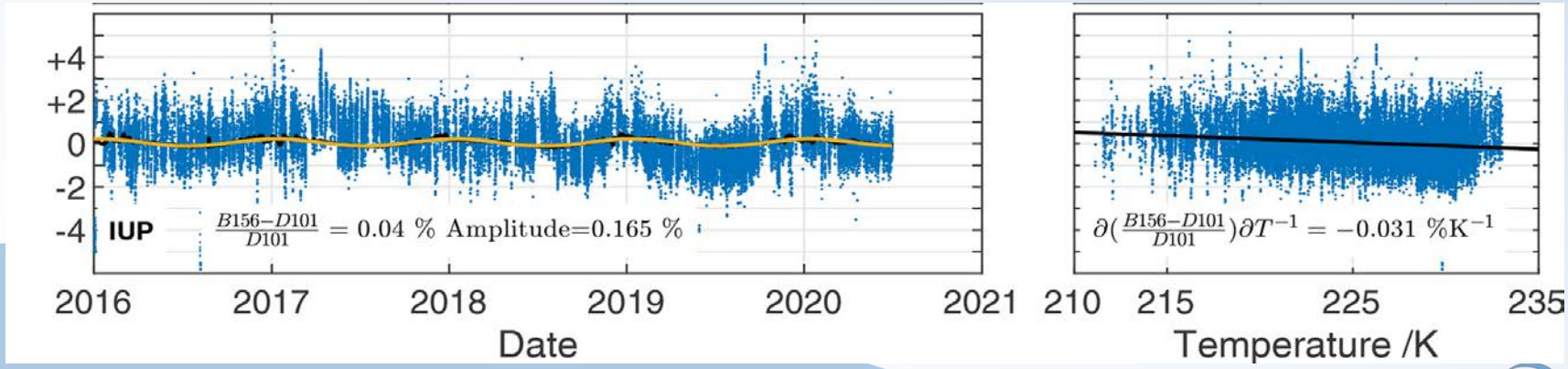
Ozone absorption temperature coefficient



Finding consistency between Brewer and Dobson

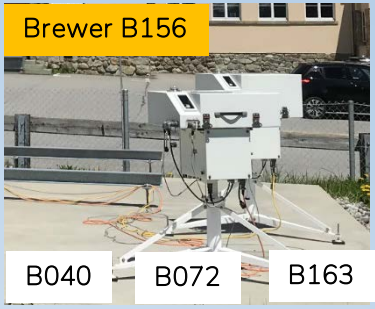
Reprocessing using:

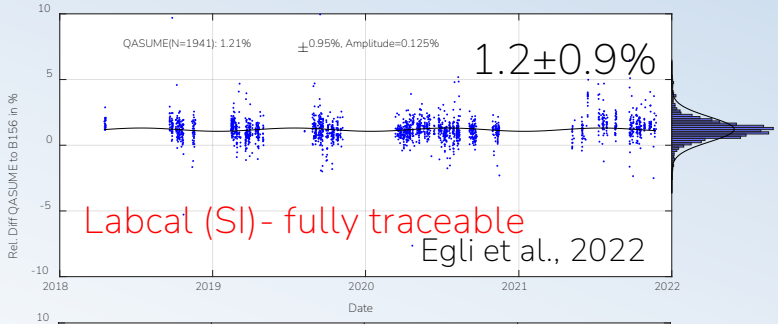
- Ozone absorption cross-sections
  - Bass&Paur, 1985 (IGQ)
  - Daumont, Brion, Malicet, 1993 (DBM)
  - ESA SEOM-IAS, 2020 (ACS)
  - Univ. Bremen, 2017 (IUP_ATMOZ)
  - Univ. Bremen, 2013 (IUP)
- Effective ozone temperature
  - Ozone sondes
  - ECMWF reanalysis
- Measured slit functions of Brewer/Dobson
- Rayleigh scattering coefficients

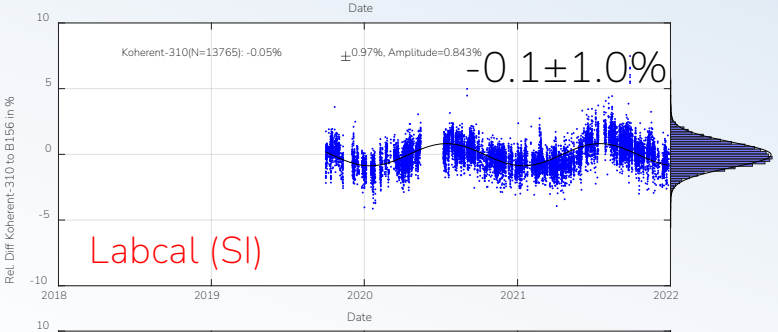


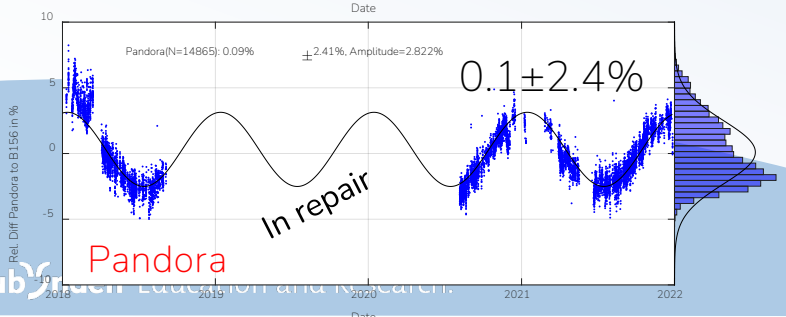
Gröbner et al., AMT, 2021, https://doi.org/10.5194/amt-14-3319-2021, 2021

Total Column ozone measurements at PMOD/WRC

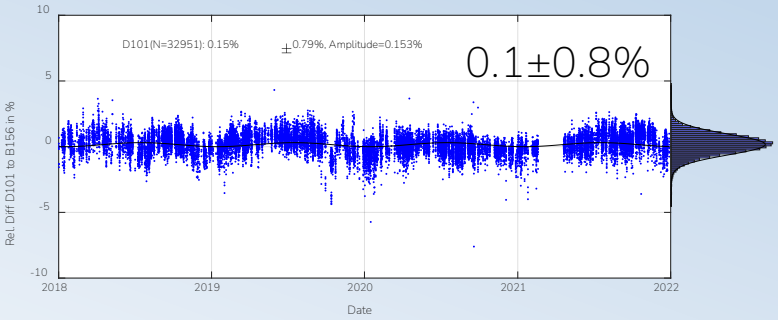




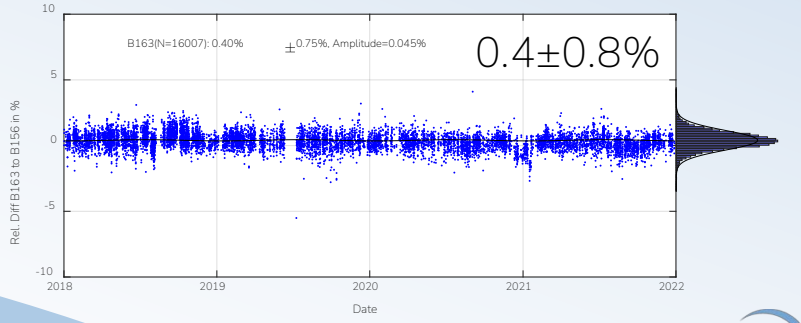




Dobson



Brewer



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19ENV04 MAPP Metrology for aerosol optical properties

EMPIR EURAMET
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

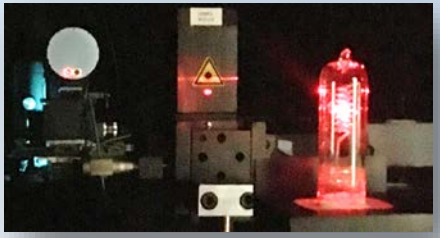
Providing SI-traceability to atmospheric remote sensing of aerosol optical properties.

Project objectives

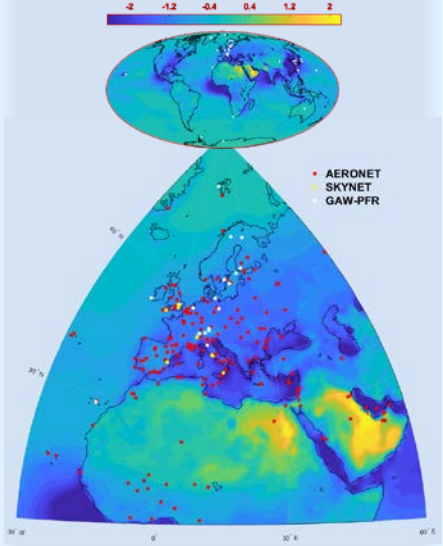
- Spectral irradiance and radiance calibrations in the spectral range 310 nm to 1700 nm with U=1%.
- Derive top-of-the-atmosphere solar and lunar spectra.
- Develop an uncertainty budget for columnar aerosol optical properties (ECVs) and assess its impact on radiative forcing of aerosols in Global Climate Models.
- Create impact by knowledge transfer, training, and uptake and exploitation.

From field calibrations...

... to SI traceability



Aerosol radiative forcing

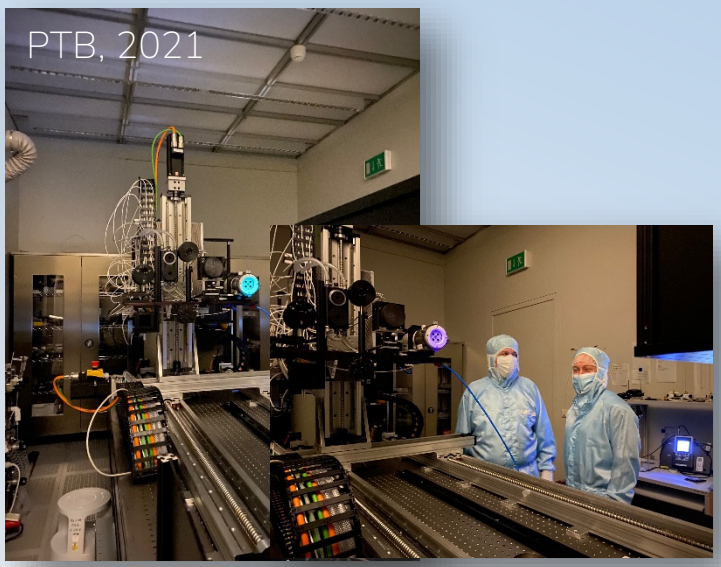


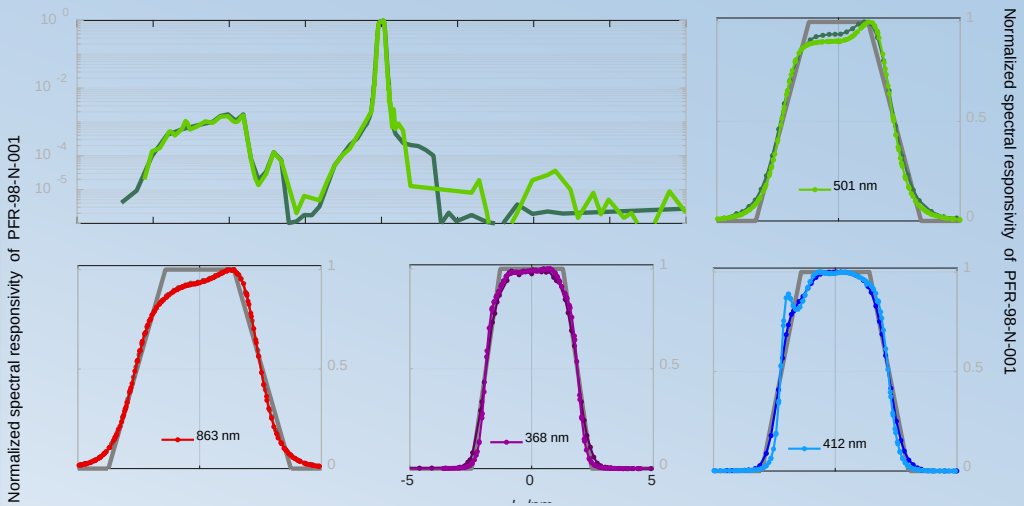
Based on CAMS reanalysis data.

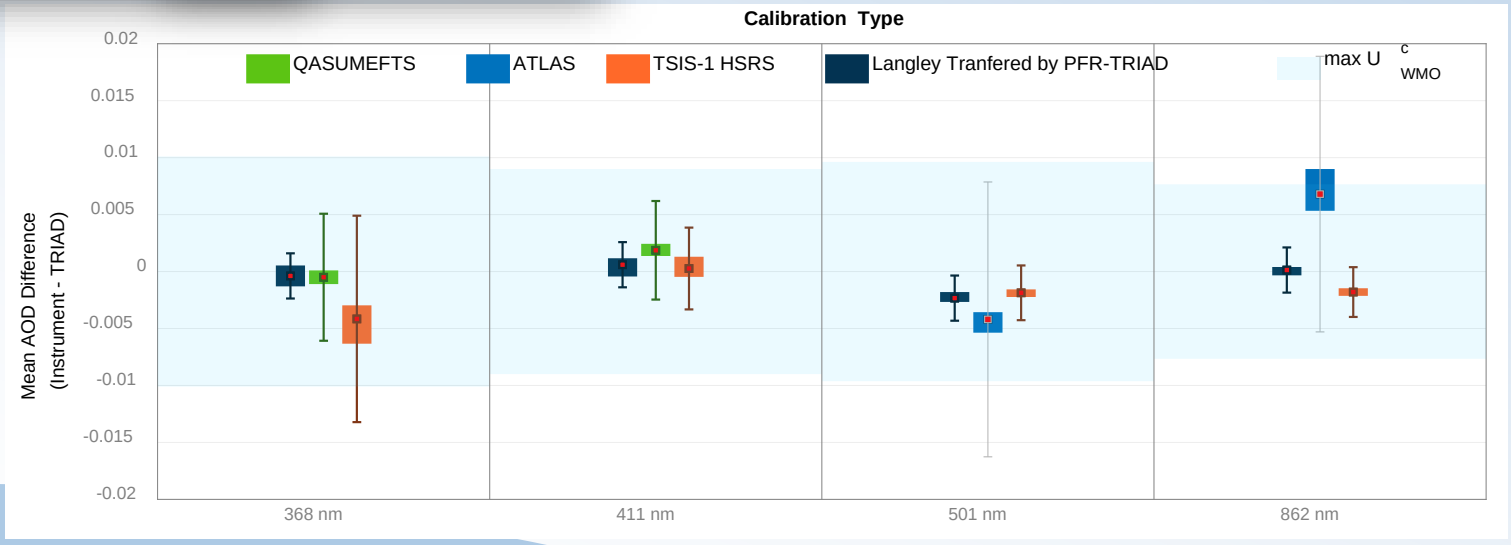
- **Project coordination:** J. Gröbner (pmod wrc)
- **Duration:** 3 years, 2020/6 - 2023/6, Budget: 2.2 M€
- **Aerosol Networks:** GAW-PFR, AERONET Europe, SkyNET Europe
- **Consortium:** 14 Partners, 6 NMI/DI, 8 External partners

pmod wrc · graubünden · PTB · CMI · Aalto University · NPL National Physical Laboratory · VSL Dutch Metrology Institute · AEMet Agencia Estatal de Meteorología · GRASP · Universitat de València · cnrs · Consiglio Nazionale delle Ricerche · University of Reading · Universidad de Valladolid

SI traceable AOD retrieval from filter radiometer PFR







Very good agreement between SI and Langley-based method

EMPIR EURAMET
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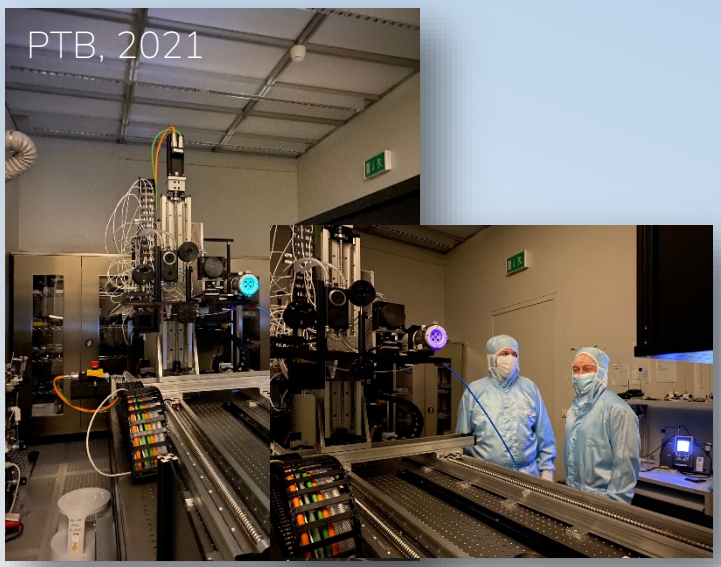
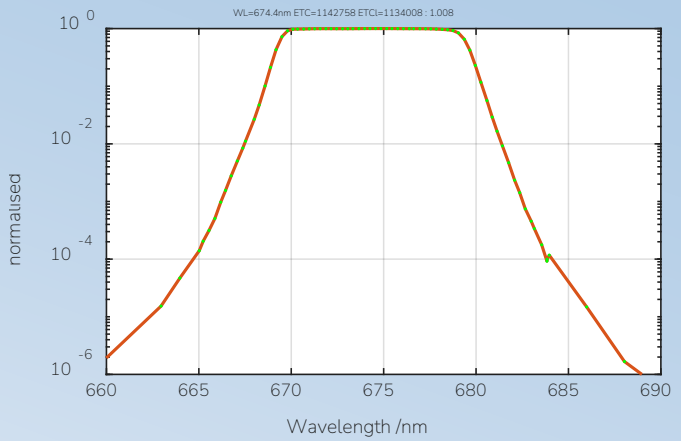
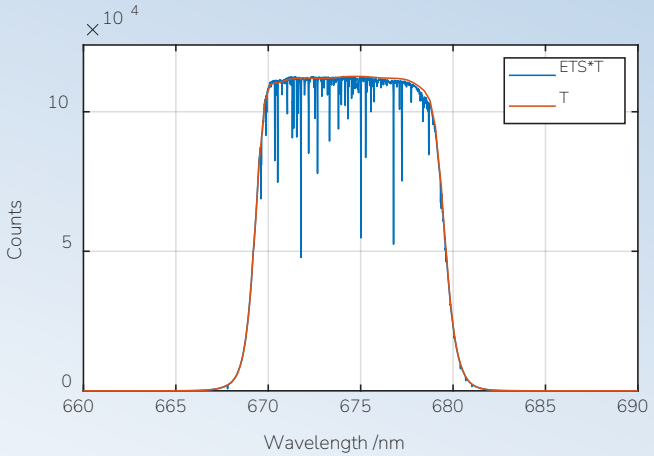
SI traceable AOD retrieval from CIMEL #1270

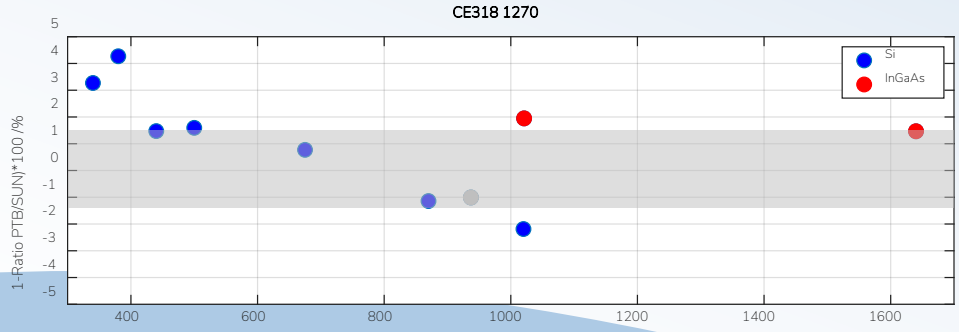


Channel 675 nm





Comparison Langley-calibration (03/2022) and SI-traceable calibration using the solar spectrum TSIS-1



Reasonably good agreement between SI and Langley-based method

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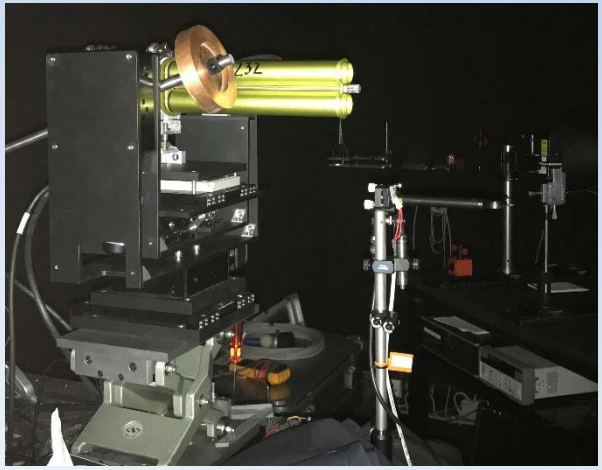
Field of View measurements



Source:

- reflectance plate illuminated with 250 W Xe-lamp.
- Aperture giving an angular size of 0.5°

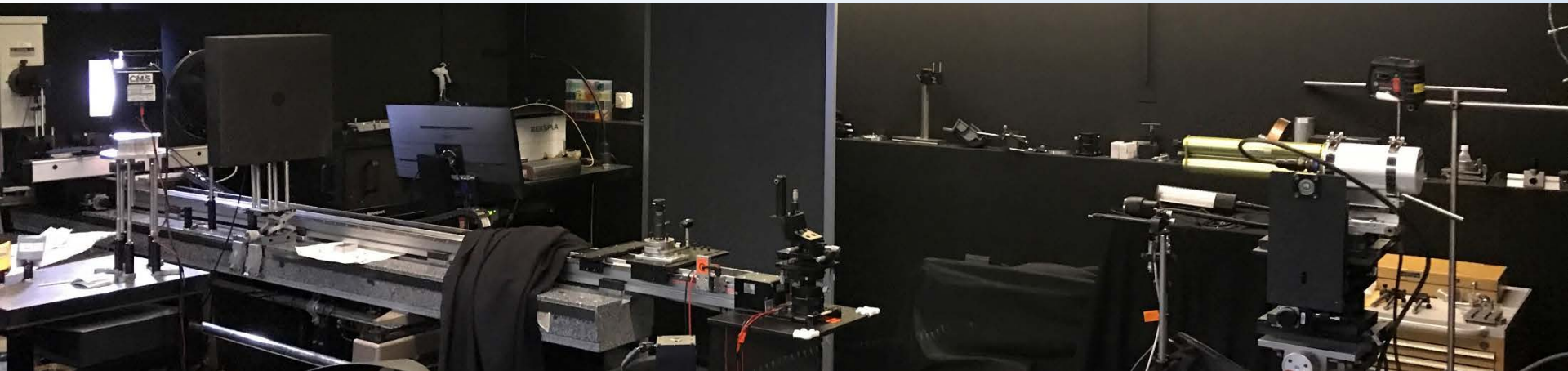
2-axis goniometer:

reference: Gregor Hülsen *et al* 2022 *J. Phys.: Conf. Ser.* **2149** 012001, https://iopscience.iop.org/article/10.1088/1742-6596/2149/1/012001

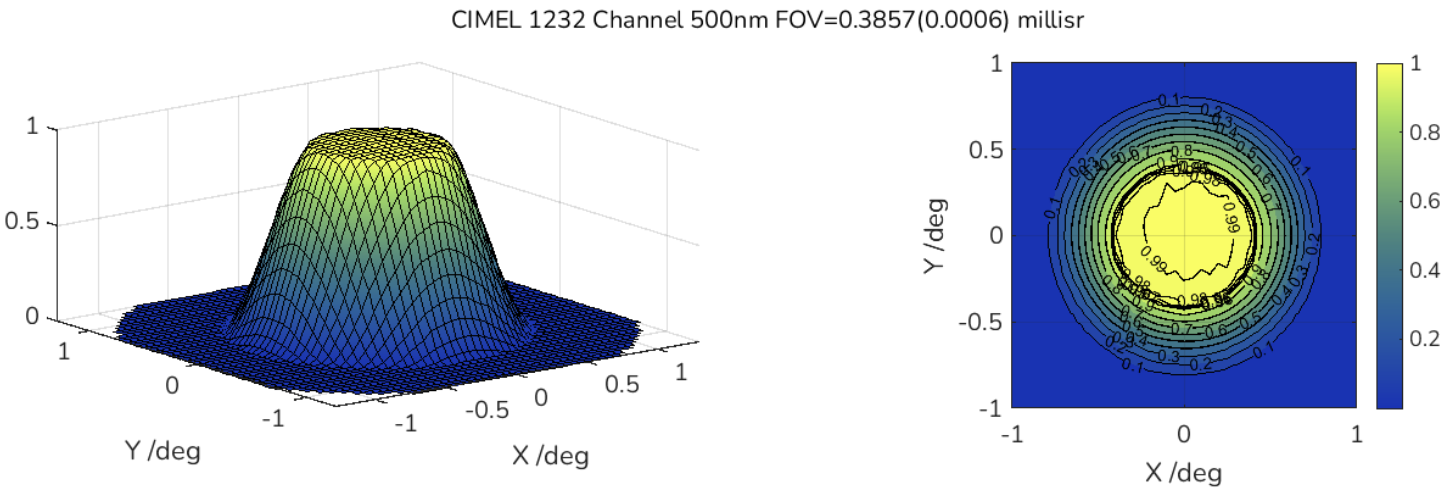
- Calibrated with pointing uncertainty of 0.0003°.
- Resolution 2×10^{-4} °

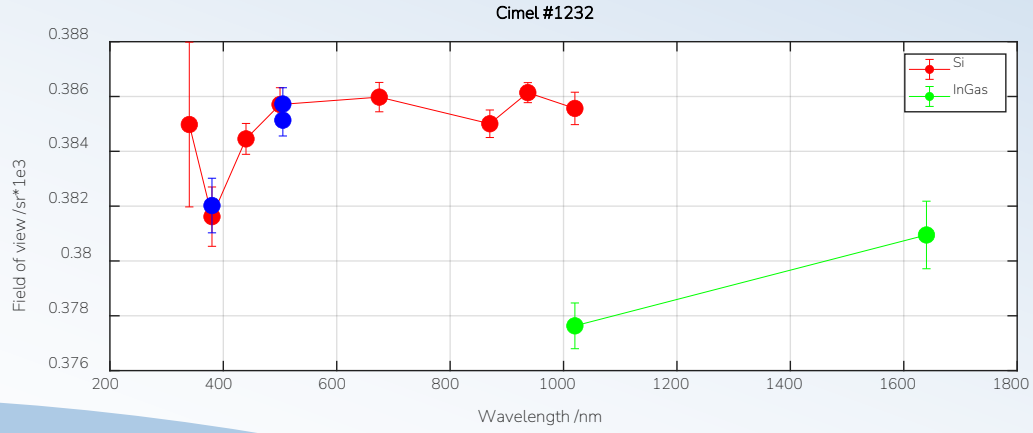
Measurement procedure:

- 1.5 ° x 1.5 ° array with step 0.05°.
- 10 measurements per point.
- repeat reference (0°x0°) every 50 measurements.



Example for the 500 nm channel of Cimel #1232





Collaboration with LOA and NASA

- Error bars represent standard uncertainties
- Blue points are repeat measurements

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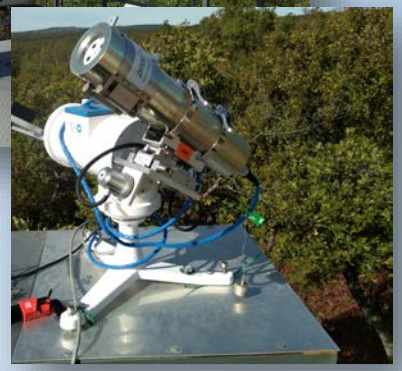
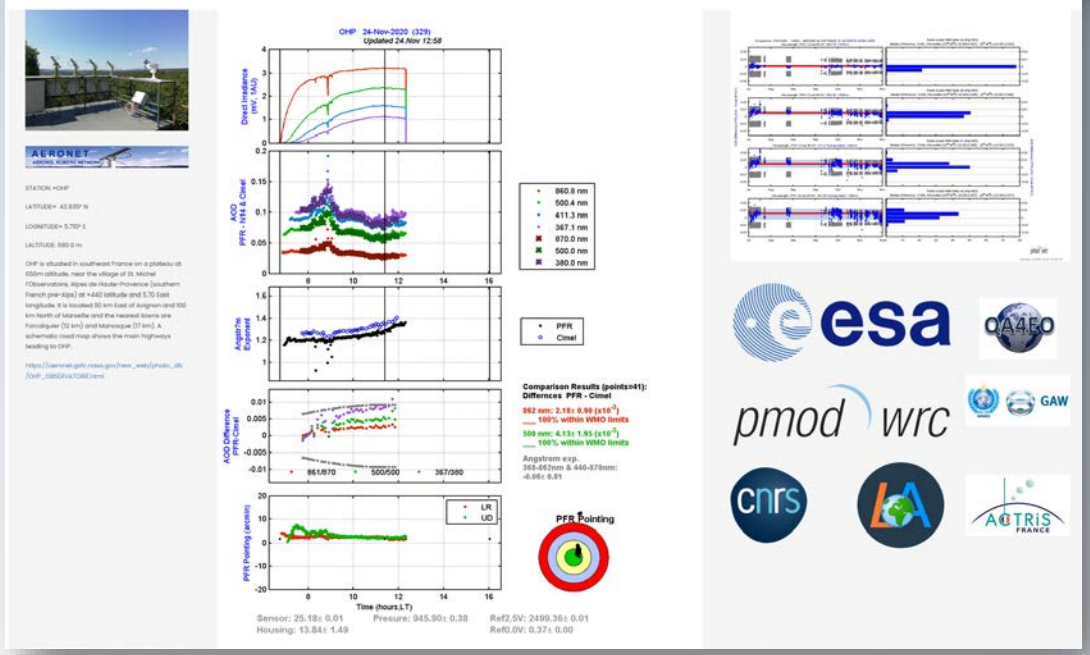
COMPARISON CAMPAIGN AT OHP AERONET-EUROPE, WMO GAWPFR

The PFR instrument (PFR-98-N-014) was installed at the AERONET-Europe calibration site of OHP on 21 July 2020 to provide traceability to the WMO PFR Triad

https://www.pmodwrc.ch/en/world-radiation-center-2/worcc/gaw-pfr/ohp/



Data in realtime on the Internet:



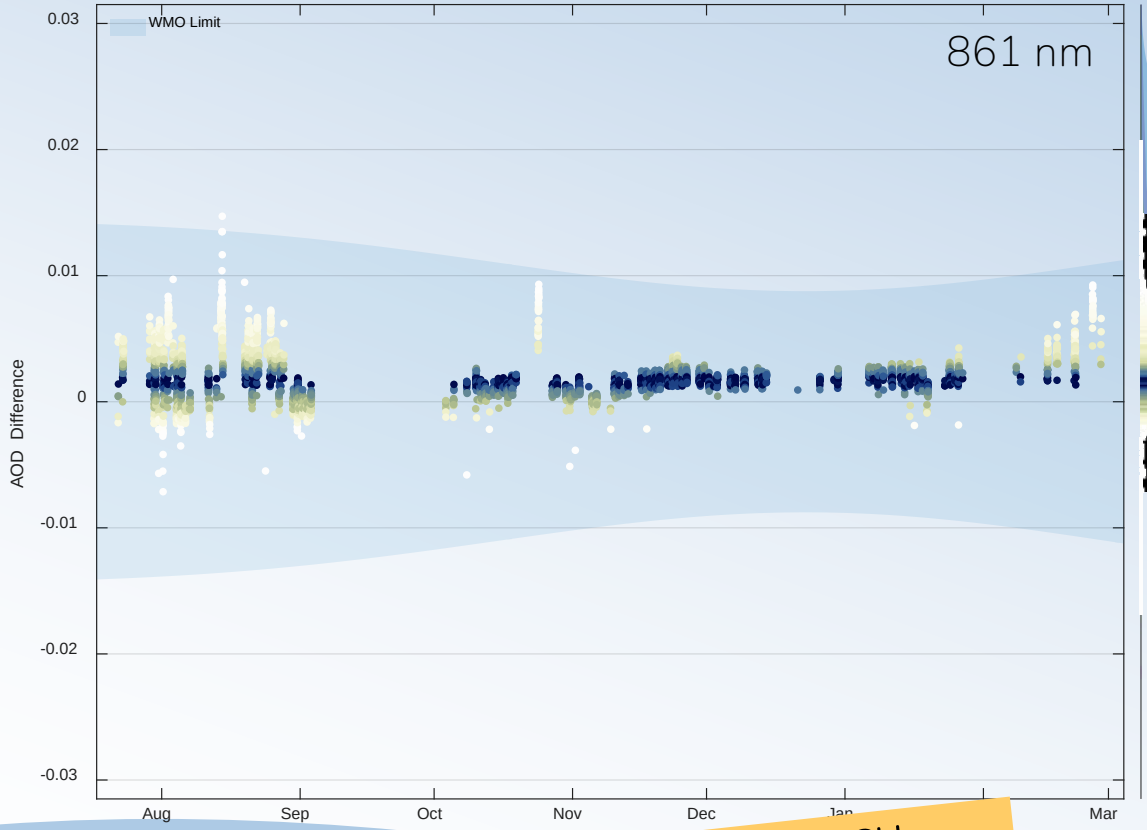
PFR stability before and after the campaign	861.8 nm	500.4 nm	411.3 nm	367.1 nm
	0.2%	0.0%	-0.7%	-1.8%

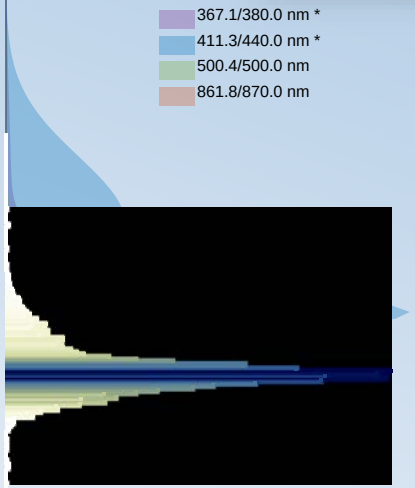
graubünden Education

pmod wrc

COMPARISON CAMPAIGN AT OHP AERONET-EUROPE, WMO GAWPFR

Comparison of Level 2.0 AERONET-Europe and WMO PFR
Triad : 21 July 2020 to 28 Feb 2021





Wavelength PFR/CIMEL in nm	AOD Difference			% in WMO limits
	median	5th percentile	95th percentile	
861/870	0.002	-0.001	0.006	99.9
500/500	0.004	0.002	0.008	98.2
411/440*	0.009	0.004	0.021	59.7
367/380*	0.007	0.002	0.013	83.2

*extrapolated with Angstrom exponent
Number of measurements = 3883

This activity is now supported by ACTRIS-CH
(Swiss funding support until 2024)

Peer-reviewed publications mentioning QA4EO

Published

- Egli, L., Gröbner, J., Hülsen, G., Schill, H., and Stübi, R.: Traceable total ozone column retrievals from direct solar spectral irradiance measurements in the ultraviolet, Atmos. Meas. Tech., 15, 1917–1930, https://doi.org/10.5194/amt-15-1917-2022, 2022.

- Gröbner, J., Schill, H., Egli, L., and Stübi, R.: Consistency of total column ozone measurements between the Brewer and Dobson spectroradiometers of the LKO Arosa and PMOD/WRC Davos, Atmos. Meas. Tech., 14, 3319–3331, https://doi.org/10.5194/amt-14-3319-2021, 2021.

- Zuber, R., Köhler, U., Egli, L., Ribnitzky, M., Steinbrecht, W., and Gröbner, J.: Total ozone column intercomparison of Brewers, Dobsons, and BTS-Solar at Hohenpeißenberg and Davos in 2019/2020, Atmos. Meas. Tech., 14, 4915–4928, https://doi.org/10.5194/amt-14-4915-2021, 2021.

- Kouremeti, N., J. Gröbner, and S. Nevas, Stray-light correction methodology for the Precision Solar Spectroradiometer, J. Phys.: Conf. Ser. 2149 012002, 2022. https://iopscience.iop.org/article/10.1088/1742-6596/2149/1/012002/pdf.

Submitted (in revision)

- Kouremeti, N., S. Nevas, S. Kazadzis, J. Gröbner, P. Schneider and K. Schwind, SI-traceable solar irradiance measurements for aerosol optical depth retrieval, Metrologia, special issue NEWRAD, 2021.

In preparation

- Egli, L., and J. Gröbner, Total Column Ozone Retrieval from Novel Array Spectroradiometer, AMT, 2022.

Outlook for phase 2
1.5.2022-31.10.2024

❖ WP 2220: SI-traceable system development

- Spectral responsivity calibration of Solar/Lunar Precision Filter Radiometer and Precision Solar Spectroradiometer traceable to the SI.
- Measurements of solar & Lunar spectral irradiances with PFR and spectral solar irradiance with PSR at PMOD/WRC and retrieval of spectral AOD.
- Field campaign at pristine measurement site for validation of solar & Lunar spectral irradiance measurements from Solar/Lunar PFR. Location will be selected during the first half of the project.

❖ WP 2230: Ground based instrument calibration

- Development of optimised Total Ozone Column (TOC) retrieval procedure using the double-ratio technique for KOHERENT and Pandora P120.
- Operate Brewer #163, KOHERENT and Pandora P120 at PMOD/WRC to retrieve TOC using the newly developed TOC retrieval procedure. QASUME will be operated on a campaign type basis at selected periods during the project to provide a traceable TOC reference.
- Analyse the TOC measurements of these instruments with respect to the choice of ozone absorption cross section, and their correlation to effective ozone temperature and ozone slant path.