Metrology of Aerosol optical properties; the MAPP project

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+ *MAPP collaborators*

SKYNET Workshop 2021 (Japan, online), 9-11 November, 2021

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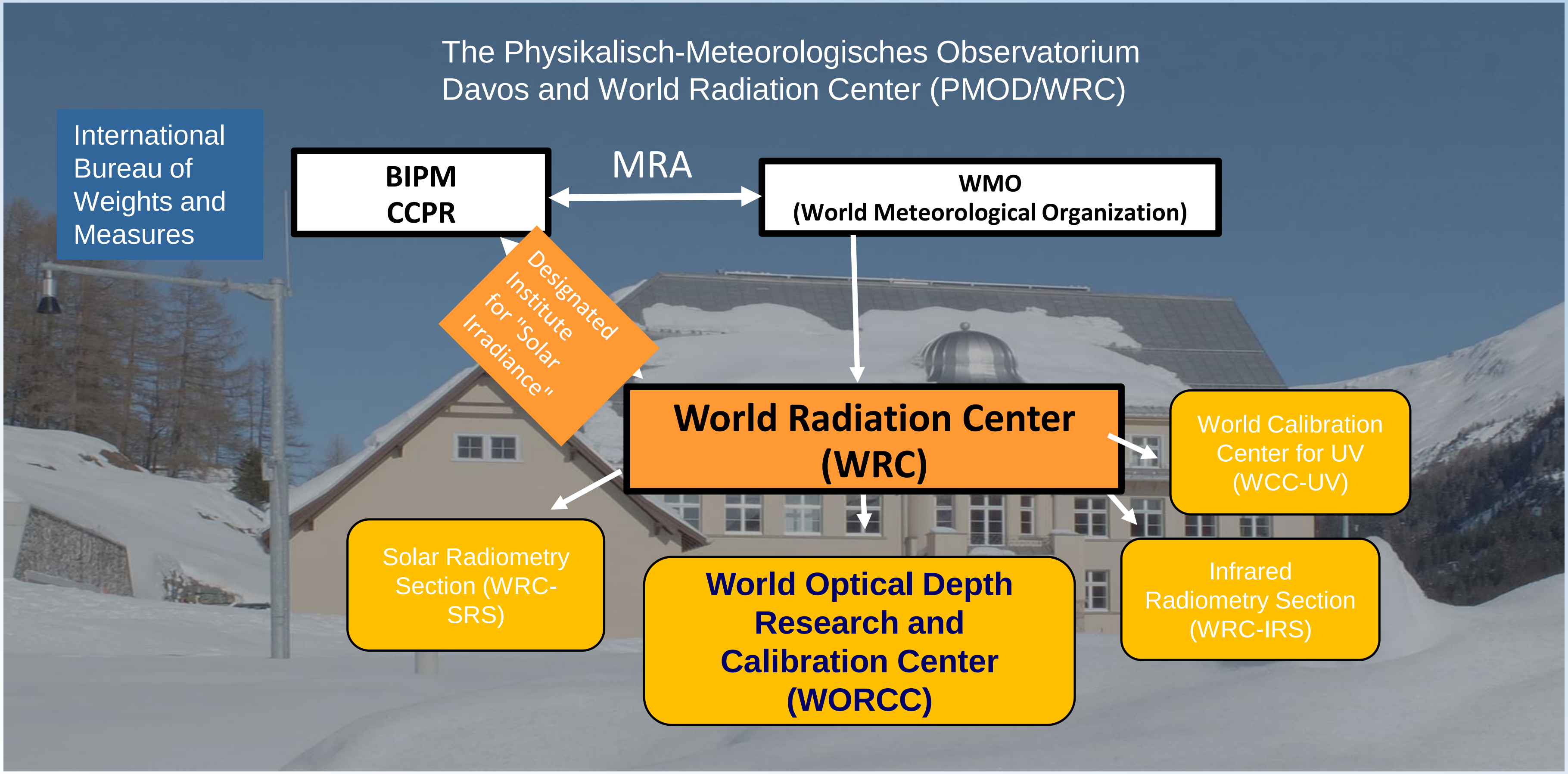
PMOD- WRC aerosol remote sensing - Metrology



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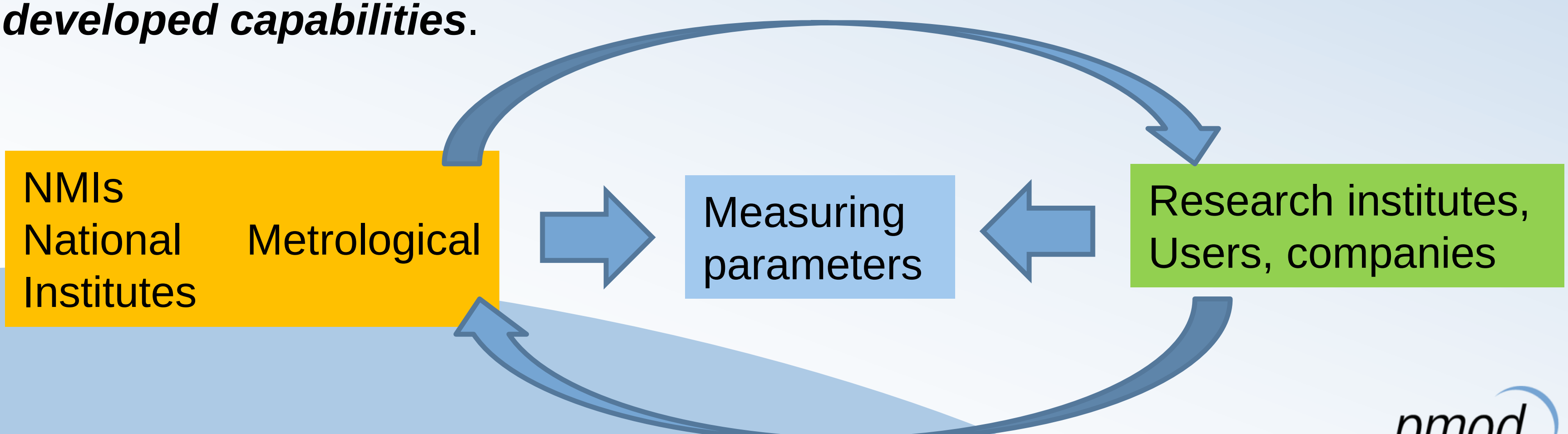
Metrology of Aerosol optical properties; the MAPP project

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

The **European Metrology Programme for Innovation and Research** (EMPIR): coordinates research projects to ***address grand challenges, while supporting and developing the SI system of measurement units***.

There is an increased focus within EMPIR on ***innovation activities to target the needs of industry and accelerate the uptake of research outputs***.

The programs capacity-building projects aim to ***bridge the gap between EU member states with emerging measurement systems and those with more developed capabilities***.



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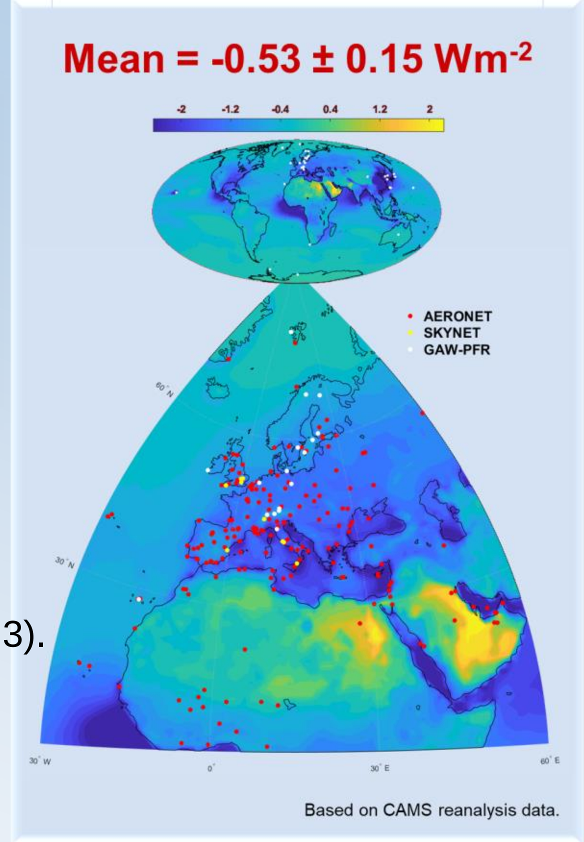
Metrology for Aerosol optical properties (19ENV04 MAPP)

From field calibrations...

...to SI traceability

Aerosol radiative forcing



Project objectives:

- Develop methods and devices for SI-traceable calibrations(WP1).
- Derive top-of-the-atmosphere solar and lunar spectra (WP2).
- Develop an uncertainty budget for columnar aerosol optical properties (WP3).
- Create impact by dissemination, uptake and exploitation (WP4).

- **Project Coordination:** PMOD/WRC J. Gröbner
- **Duration:** 6/2020 – 5/2023
- **Total Budget:** 2.2 M€
- **14 Partners** NMI-DI, Industry, Universities, Research Institutes.

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

Instruments used for passive remote sensing of aerosol optical properties

GAWPFR

PFR (PMOD/WRC)

AERONET

CIMEL

SKYNET

Prede

Sunphotometers

Discrete channels with interference filters,

- Wl range 340 nm - 1640 nm
- Bandwidth 5-10 nm

Emerging technologies

Spectroradiometers, Wavelength range 300 nm up to 2150 nm

QASUME (direct)

PSR (PMOD/WRC)

EKO-EU

BTS(Gigahertz-optic)

Retrieval of aerosol optical properties

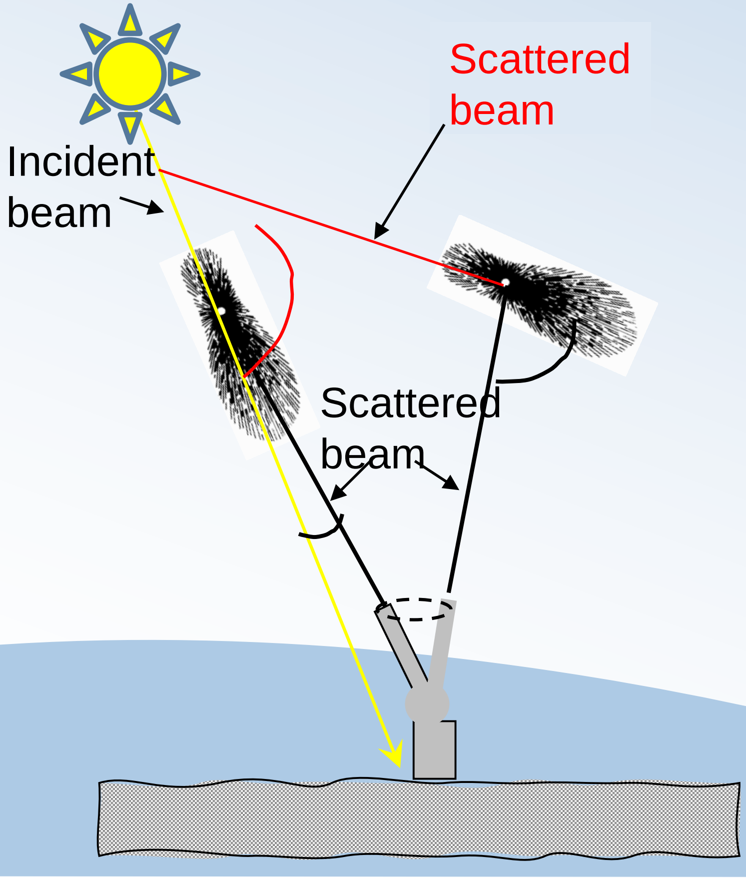
Aerosol products:

- Aerosol optical depth retrieved from <u>direct solar/lunar irradiance</u>

- Size distribution,
- Single scattering albedo,
- Scattering phase function,
- Refractive indices.

} <u>solar radiance</u>

$$\text{AOD} = \frac{\log^{I_0}/_I}{m} - \tau_R - \cdots$$



Aerosol optical depth (AOD) is obtained from transmission measurements of the atmosphere:

Top of the atmosphere irradiance is usually determined by in-situ measurement procedure at high altitude stations (Langley)

Other aerosol properties are obtained from inversion modelling combining direct and scattered solar irradiance.

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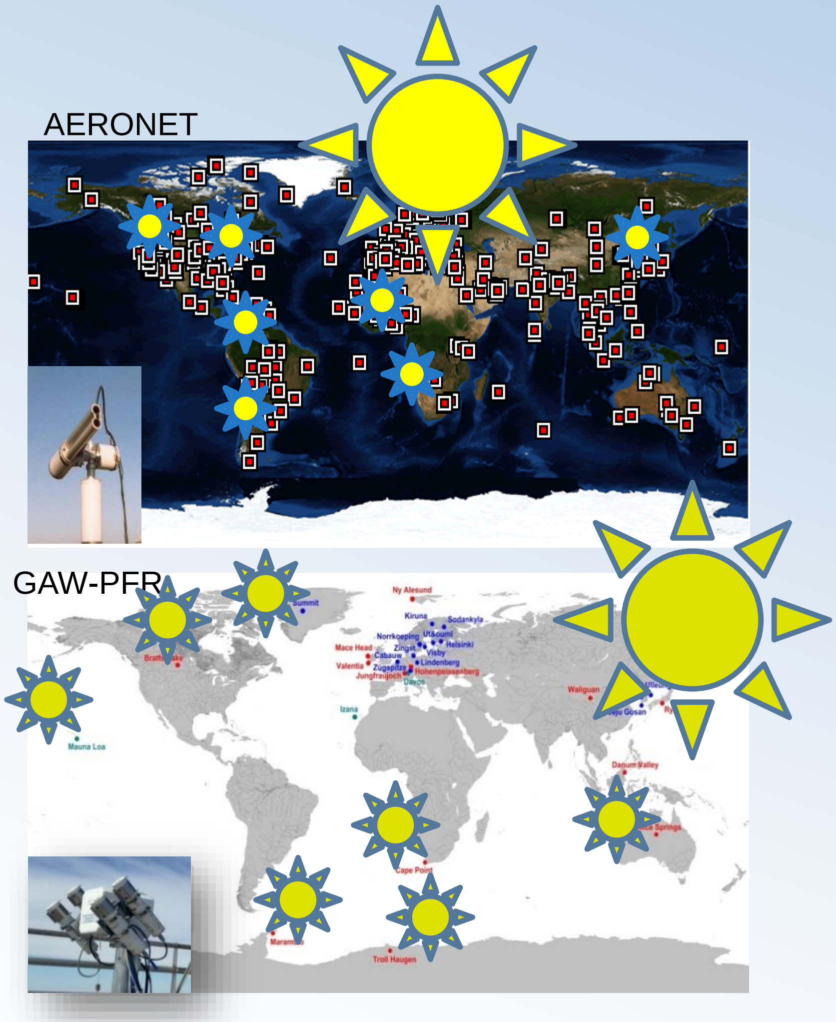
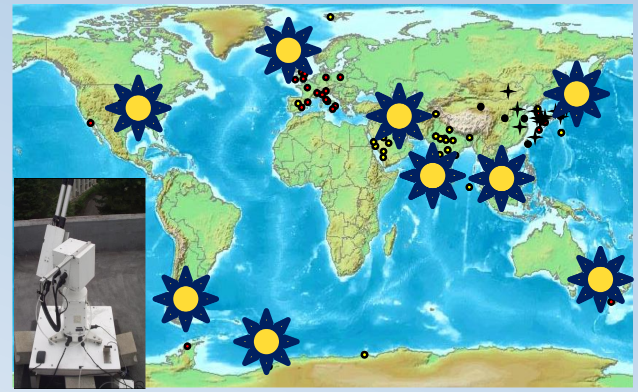
MAPP Objective



SKYNET



- AERONET and GAW-PFR have their own reference "SUNs"
- Each Instrument has its own "little sun"

Aim of MAPP → Harmonize networks, use the same SI

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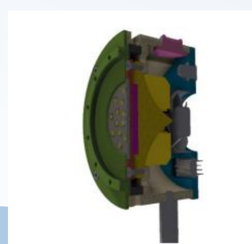
Instrument characterisations

- 4 Tasks
  - Spectral irradiance calibrations
  - Spectral radiance calibrations
  - Field-of-view properties
  - Linearity and temperature coefficients

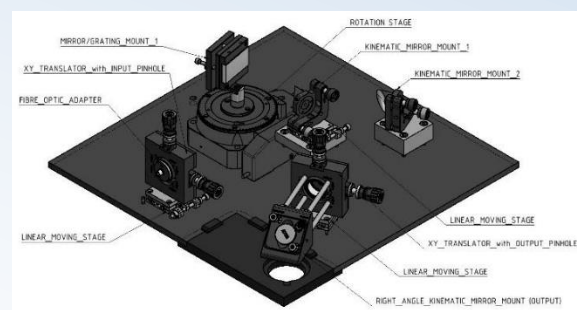
Measure SI-traceable solar (lunar) radiation

Portable monitoring devices (based on previous EMRP projects SolarUV, Atmoz)

Portable LED-based monitoring source (PTB, CNRS)



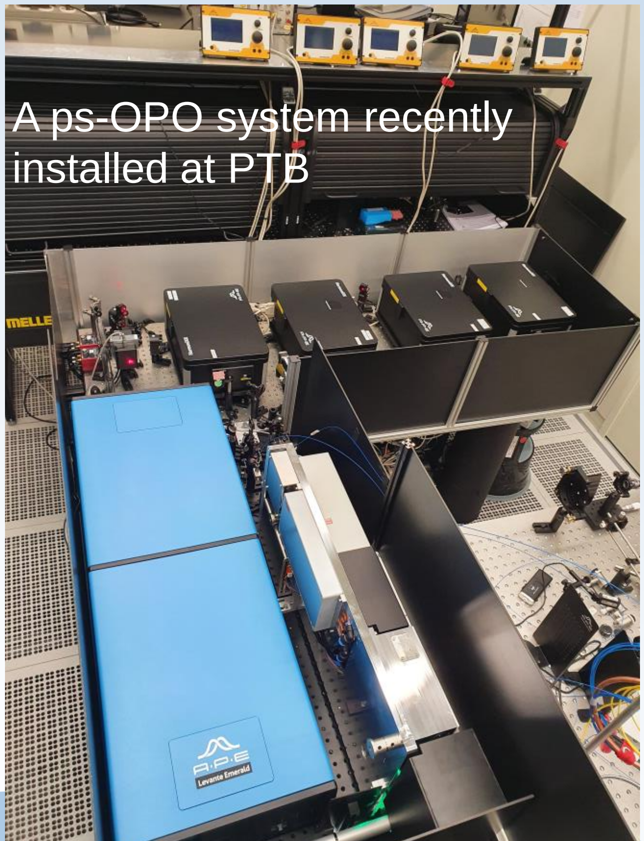
narrowband tunable portable source (TuPS) (CMI, CNRS, UV, PMOD/WRC)

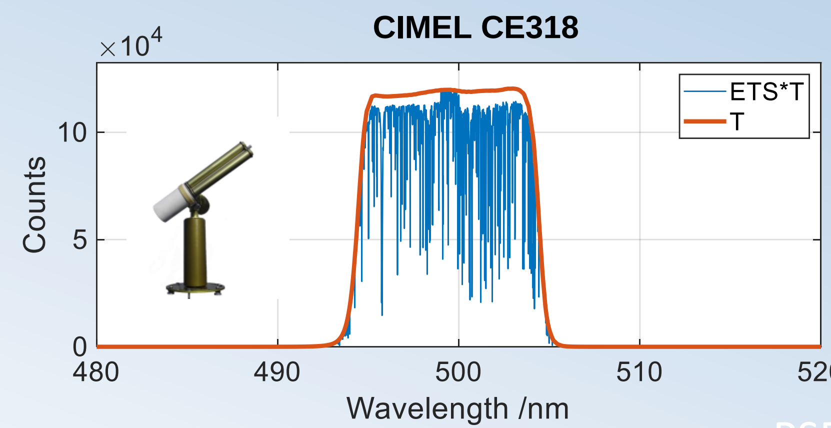


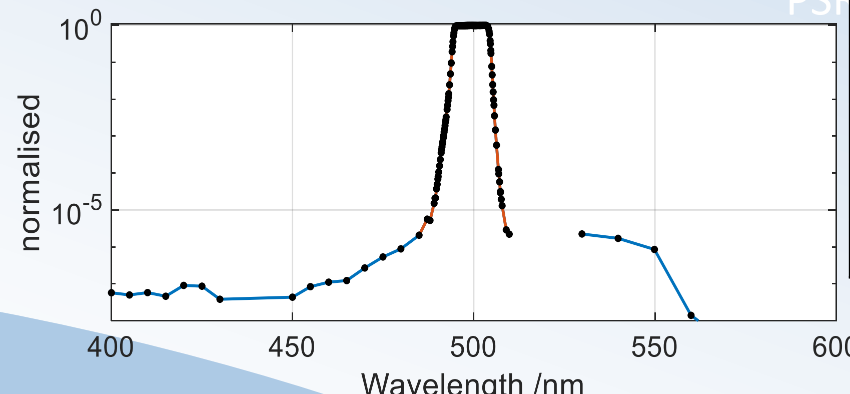
Spectral irradiance calibrations

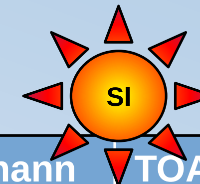
Spectral irradiance responsivity and bandpass functions of radiometers from **GAW-PFR**, **AERONET Europe** and **SKYNET Europe** networks calibrated using the TULIP setup of PTB.

- spectral bands from 340 nm to 1640 nm
- uncertainties 0.1%-0.5%









Channel / nm	TOA/ (Wm^{-2})
339.9	2.204
379.4	5.059
439.5	18.89
499.4	19.61
674.6	15.45
869.7	9.367
936.8	8.305
1019.1	7.318
1938.4	5.630

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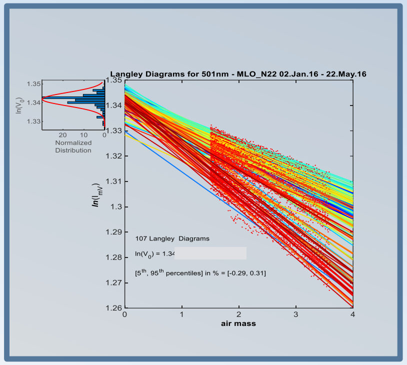
Metrology of Aerosol Optical Properties / Link to SI units

field calibrations
Langley
Relative (signals)
Calibration

Langley : Io= Vo , I=Signal (V)

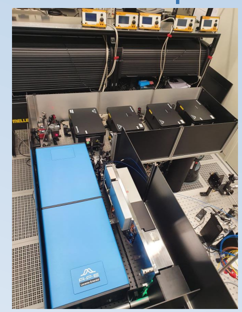


$$I_\lambda = I_\lambda^0 * e^{-\tau_\lambda m}$$

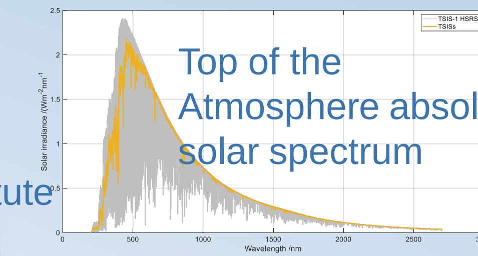
Volts

$$m = 0$$

To **SI traceable absolute calibration** of the PFR
using in addition a Top of the Atmosphere absolute solar spectru



PTB German metrology Institute



Top of the
Atmosphere absolute
solar spectrum

$$I_\lambda = I_\lambda^0 * e^{-\tau_\lambda m}$$

W/m^2*nm

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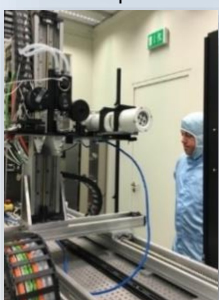
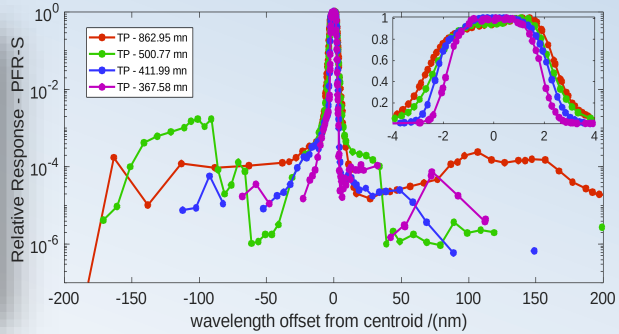
Metrology of Aerosol Optical Properties / Link to SI units

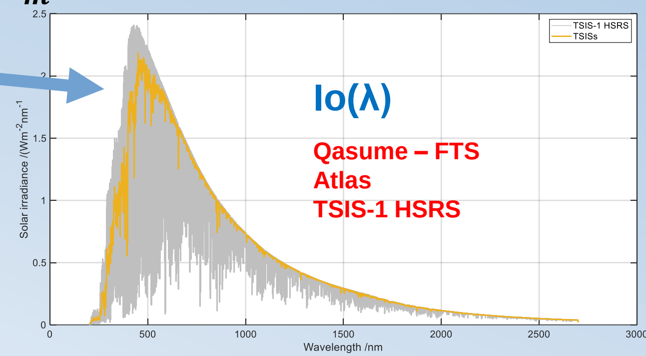
$$I_\lambda = I_\lambda^0 e^{-\tau_\lambda m}$$

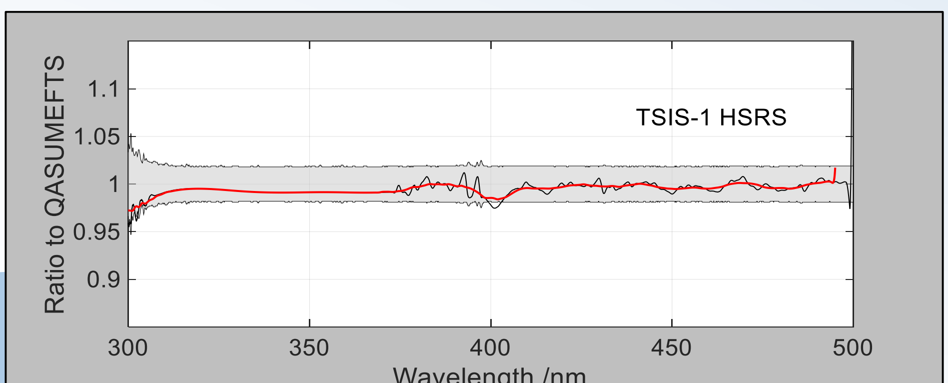
$$AOD = \frac{\ln^{I_0}/_{I}}{m} - \sum_i \tau_{att(i)} m_{att(i)} / m_a$$

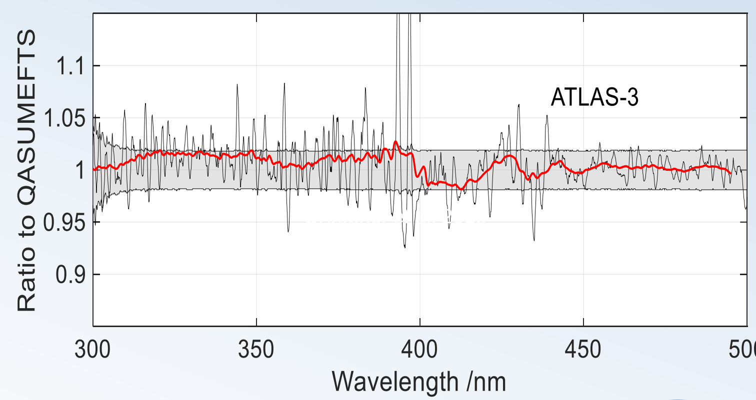
TULIP setup PTB











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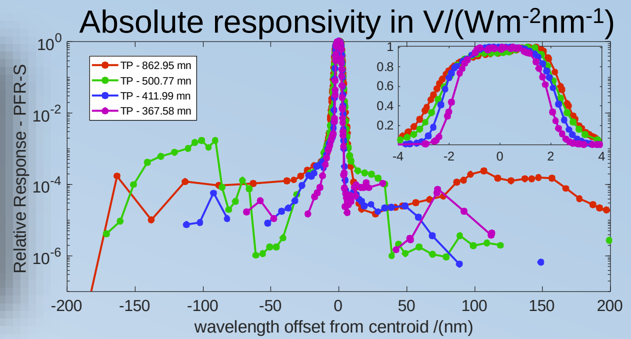
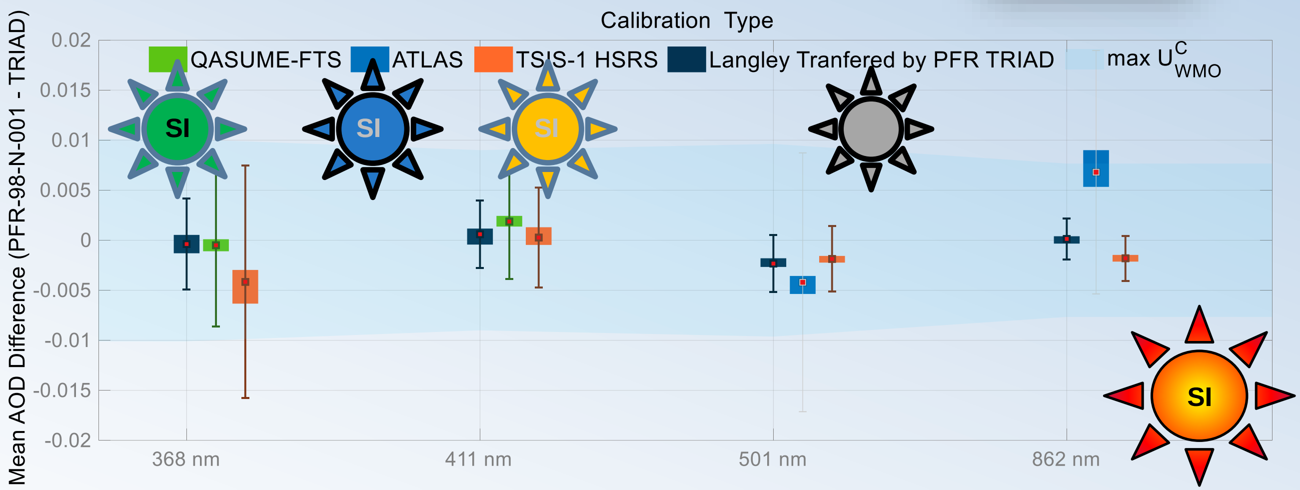
PFR in-situ based (Langley) versus SI traceable calibration

Measurements in collaboration with

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

TULIP setup-PTB





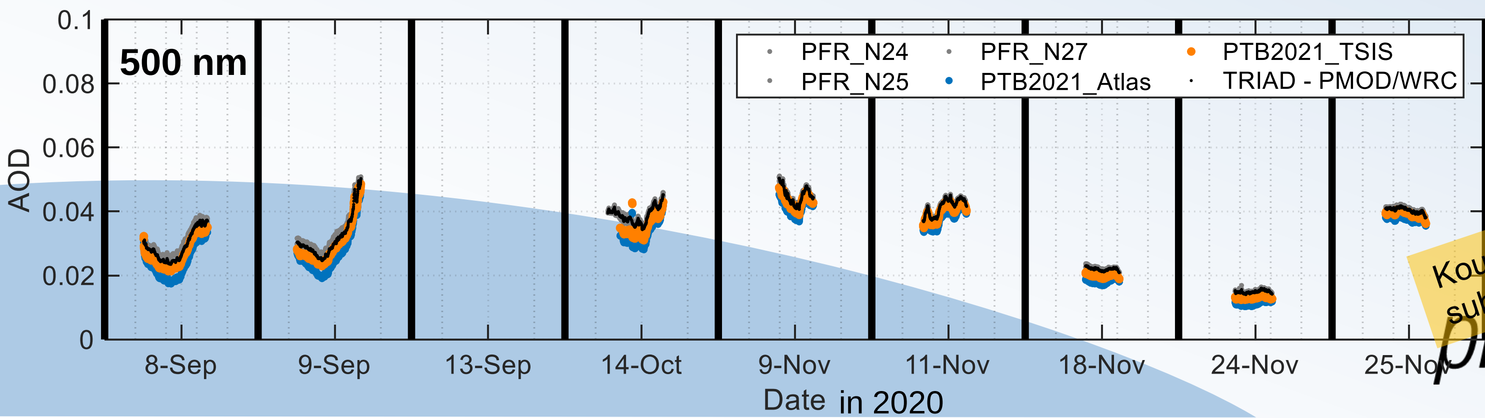
Requirements to achieve WMO AOD limits:

- ➢ Consistency with ETS ≤1%
- ➢ Calibrations with U< 1%

⇨ $U_{AOD} < 0.01$

$$AOD \sim \frac{\log {}^{I_0}/_{I}}{m}$$

Comparison for Langley and SI calibrated AOD retrievals using various top-of-atmosphere spectra



Kouremeti et al., submitted to Metrologia, 2021

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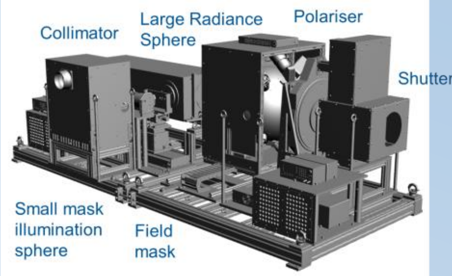
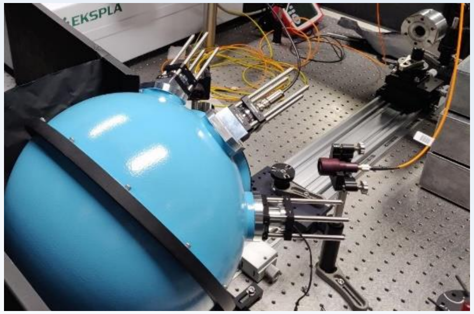
Sky radiance radiometer characterisation

- Characterise a range of sky radiance radiometers, for traceable performance to <0.5% over the 310 – 1700 nm spectral range, covering
  - Bandpass function
  - Spectral radiance response
  - Polarisation sensitivity



- NPL will use part of the STAR-CC-OGSE facility that includes
  - A large integrating sphere source (200 mm diameter exit port) illuminated via a broadband (white light) and a tuneable laser.
  - 360deg rotation polariser assembly
- NPL also providing an integrating sphere calibration for CNRS used within the AERONET network

VSL Dutch Metrology Institute



Narrow-band widely tunable radiance source calibration setup :
- Integrated sphere
- Optical parametric oscillator (OPO)
- Reference trap detector
- Monitor Si detector
- Attenuators, polarizers, laser spectrum analyzer

Radiance source –monochromatic light from an OPO coupled into an integrating sphere
- ✓ Calibrated with calibrated reference trap detector and geometrical measurements

Tunable laser used in both setups are Ekspla NT 242, which emits radiation pulses with a pulse length of 3 ns to 6 ns at a repetition rate of 1 kHz.

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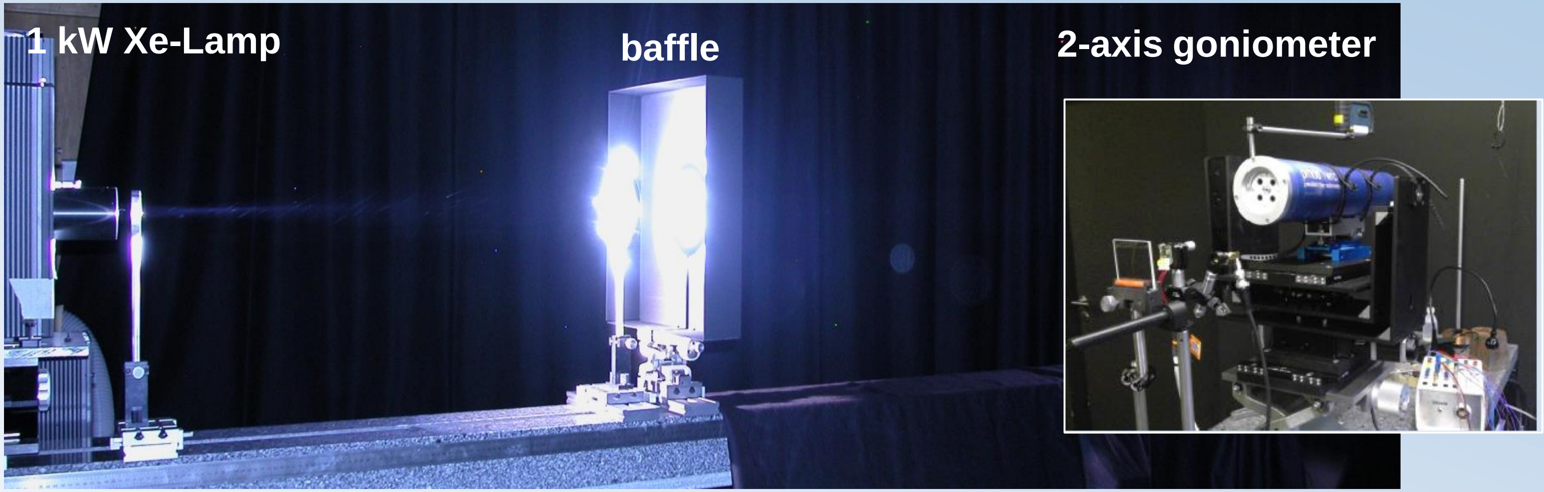
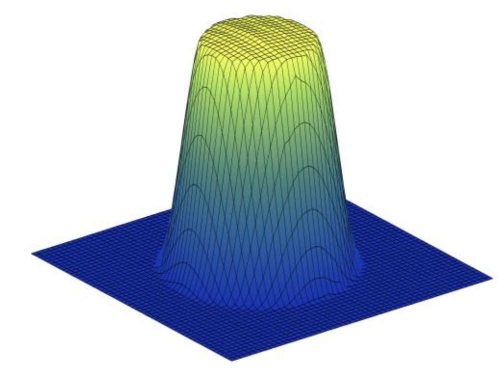
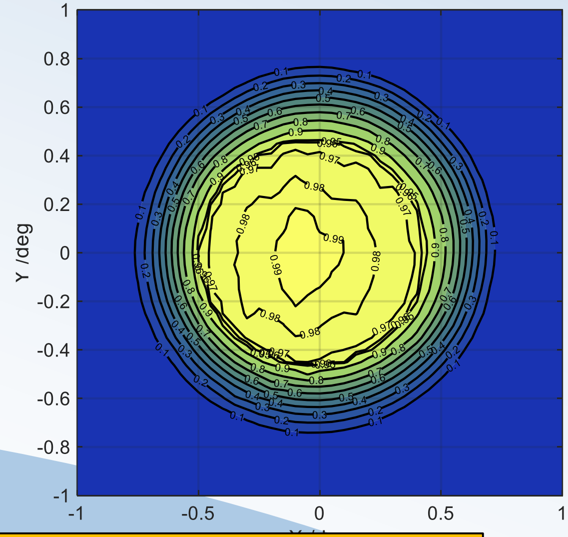
Field of view measurements of solar radiometers

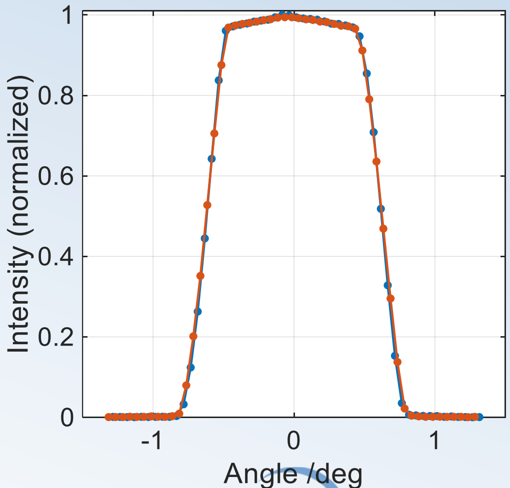
Validate consistency of radiance & irradiance calibrations



CIMEL #1270 440 nm







FOV = 0.3772 (10) millisr (0.3%)

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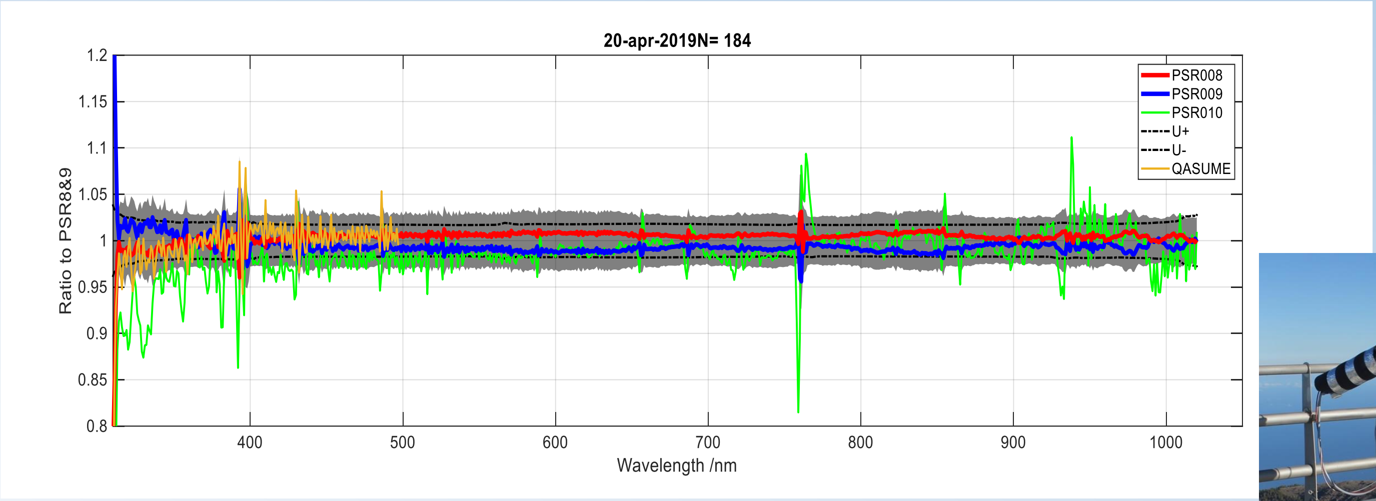
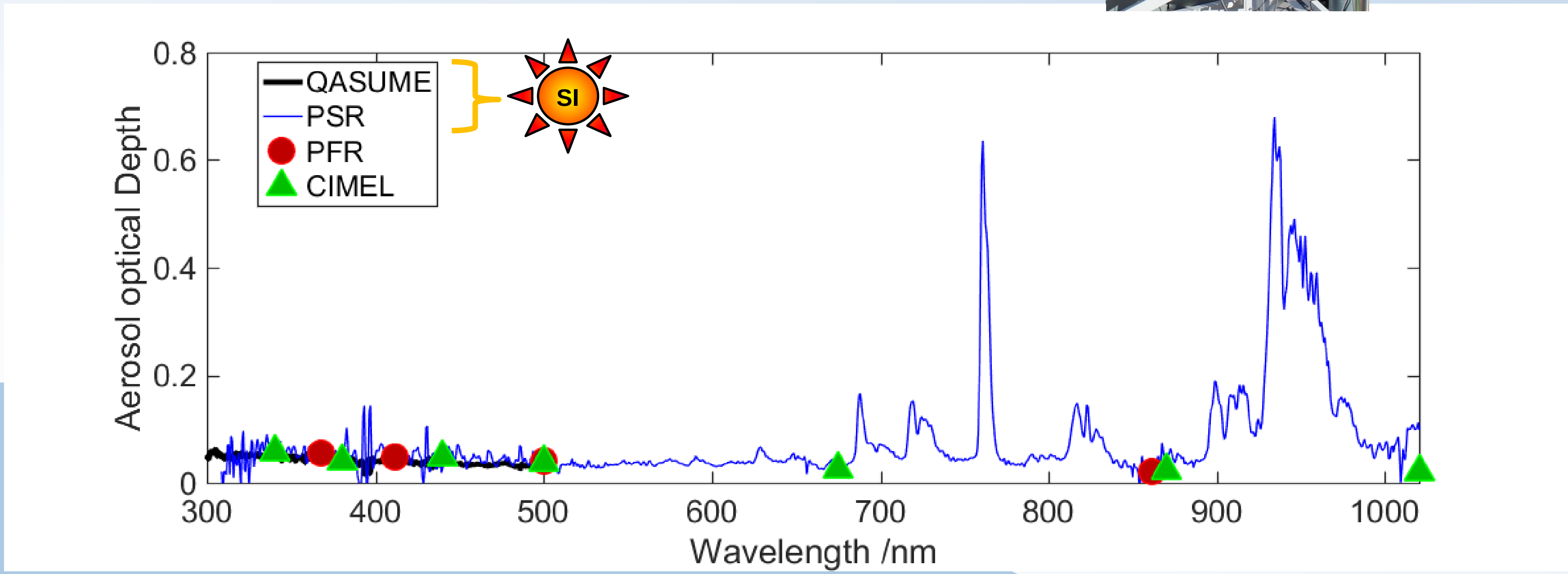
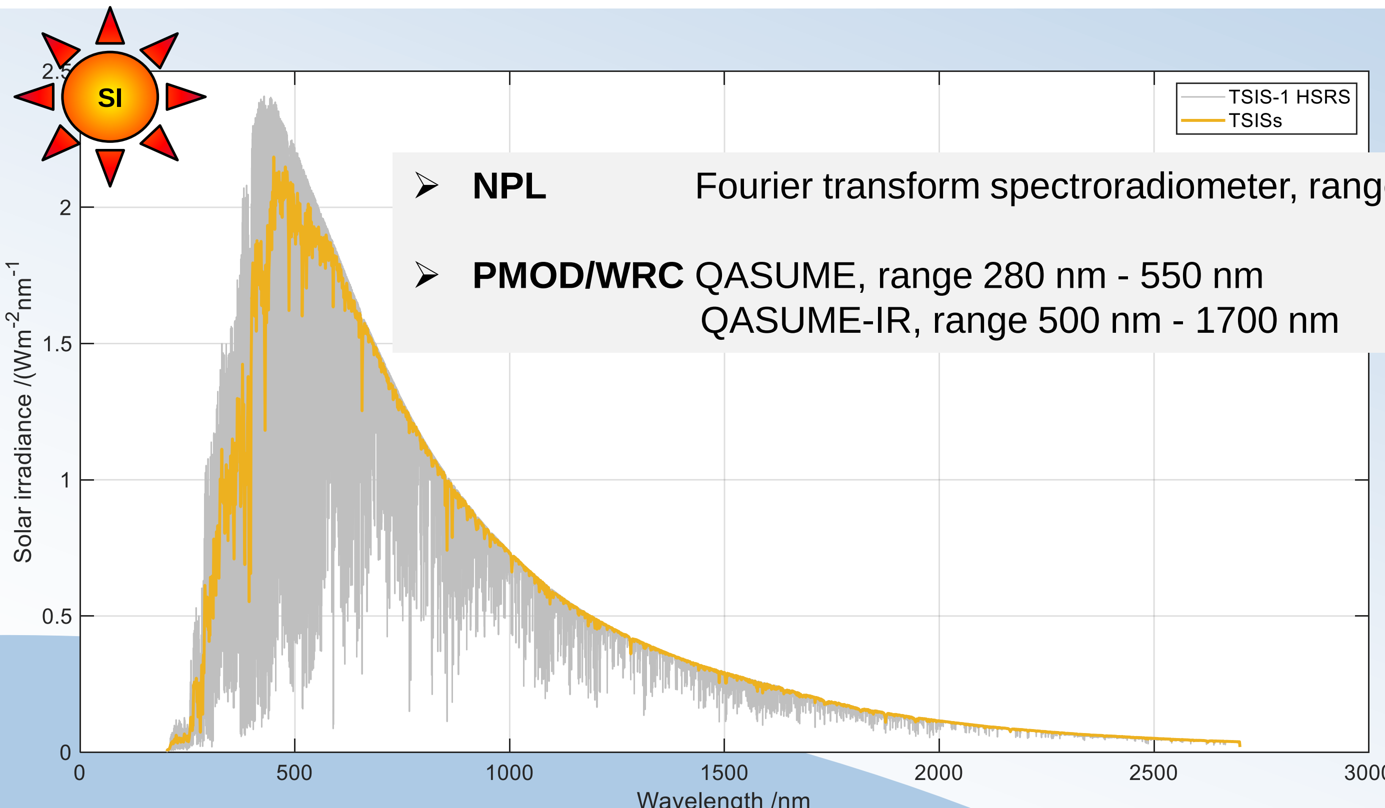
Spectral AOD from Langley and Absolutely calibrated spectroradiometers





Determination of top-of-atmosphere solar and lunar spectra

- Aims
  - to provide a traceable determination of the incoming TOA solar and lunar spectra (UV – NIR) with improved radiometric uncertainties (<1% solar, <2% lunar irradiances).
  - establish metrological comparability of different measurement and analysis methods used to determine the TOA spectrum.



- **NPL** Fourier transform spectroradiometer, range 900 nm - 1700 nm
- **PMOD/WRC** QASUME, range 280 nm - 550 nm
  QASUME-IR, range 500 nm - 1700 nm

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IZAÑA OBSERVATORY: FACILITIES AT IZAÑA, Tenerife, Canary island, Spain

THE SITE (2400 m a s.l.)

3 week Campaign September 2022

CAL LABORATORY

Development of a comprehensive uncertainty budget

- Data generation using advanced measurement techniques
- Development of model for uncertainty estimation of column averaged aerosol properties
- Validation of aerosol optical properties and associated uncertainties
- Global impacts of revised aerosol optical property uncertainties

SORBETTO

SOlar Radiation Based Established Techniques for aTmospheric Observations

SORBETTO

International summer school workshops 13-15 September 2021)

INTERNATIONAL SUMMER SCHOOL CONFERENCE

ABOUT

national Summer School – conference

TOPICS:

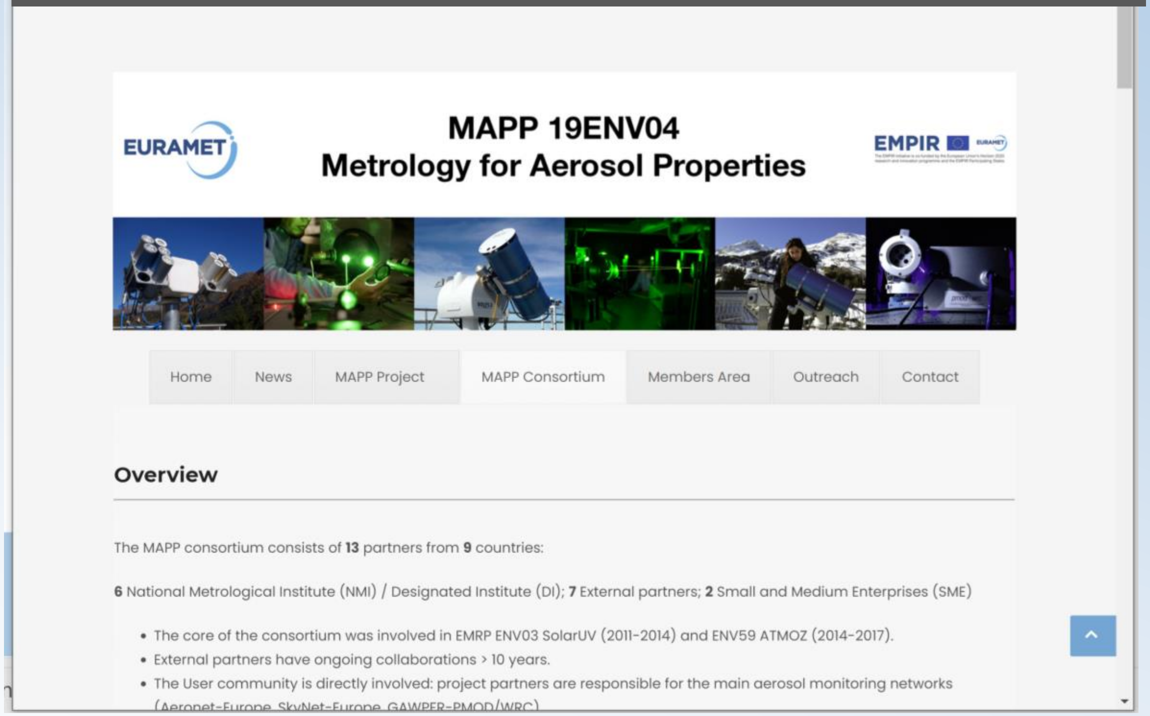
- Radiometry (theory, networks, calibration)
- Photometry (theory, networks, calibration)
- Intercomparison campaigns
- Spectrometry (theory, networks, calibration)
- Calibration and Validation of satellite Missions
- Laboratories

http://sorbetto2.artov.isac.cnr.it/

TRAINING

Further information can be found on our project web-site

https://www.pmodwrc.ch/en/MAPP/



Thank you

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++MAPP collaborators

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EMPIR EURAMET

WORLD METEOROLOGICAL ORGANIZATION
Weather · Climate · Water

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University of Reading

Global impacts of aerosol uncertainties on aerosol radiative forcing

- Propagate new/refined uncertainties in aerosol optical properties through to uncertainties in DARE and DARF
- DARE – Direct Aerosol Radiative Effect – change in radiative flux in an atmosphere with no aerosols. *Quantifies aerosol impacts on present-day radiative budget.*

- DARF – Direct Aerosol Radiative Forcing – change in radiative flux due to a change in aerosol conditions from pre-industrial (typically 1850) to the present day. *Quantifies aerosol impacts on climate change.*
- Identify aerosol optical property uncertainties having most impact on DARE and DARF and confront with results from A3.3.1.

Feed into Climate assessments

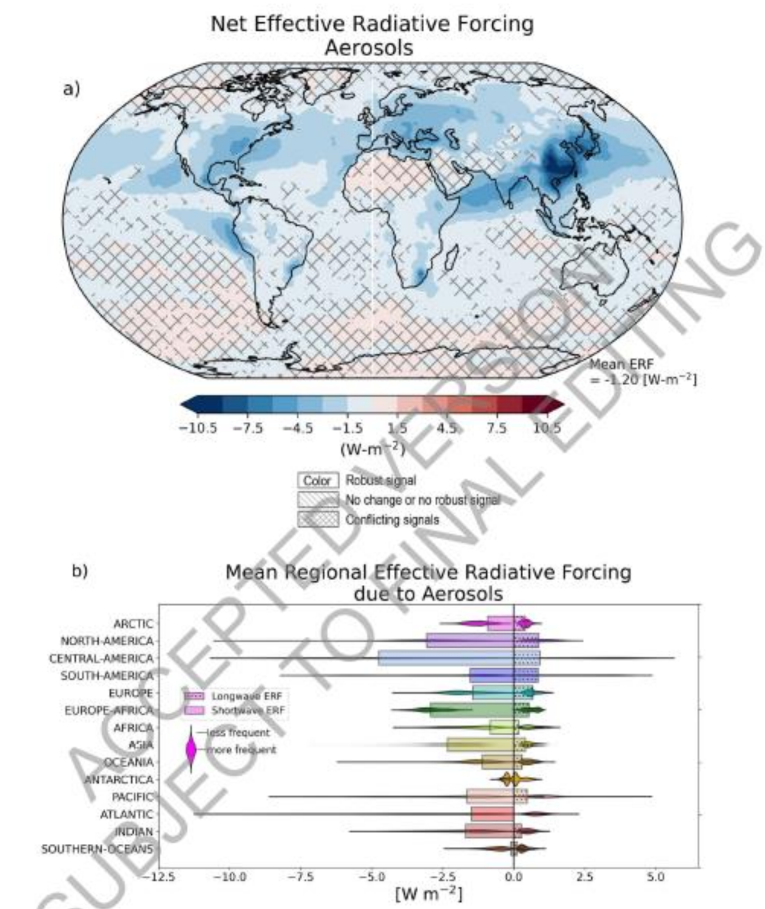

Figure 6.10: Multi-model mean Effective radiative forcings (ERFs) due to aerosol changes between 1850 and recent-past (1995-2014). Panel (a) shows the spatial distribution of the net ERF with area-weighted global mean ERF shown at the lower right corner. Uncertainty is represented using the advanced approach: No overlay indicates regions with robust signal, where ≥66% of models show change greater than variability threshold and ≥80% of all models agree on sign of change; diagonal lines indicate regions with no change or no robust signal, where <66% of models show a change greater than the variability threshold; crossed lines indicate regions with conflicting signal, where ≥66% of models show change

From IPCC AR6, published August 2021