The Physikalisch Meteorologisches Observatorium Davos, World Radiation Center (PMOD/WRC)

Julian Gröbner

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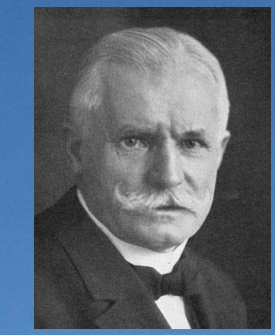
The Physikalisch-Meteorologisches Observatorium Davos and World Radiation Center (PMOD/WRC)



1907 **PMOD founded by Prof. Carl Dorno**

1971 **WMO designates the PMOD "World Radiation Centre" PMOD / WRC**

Non profit foundation, part of the Schweizerische Forschungsinstitut für Hochgebirgsklima und Medizin Davos (SFI Davos)

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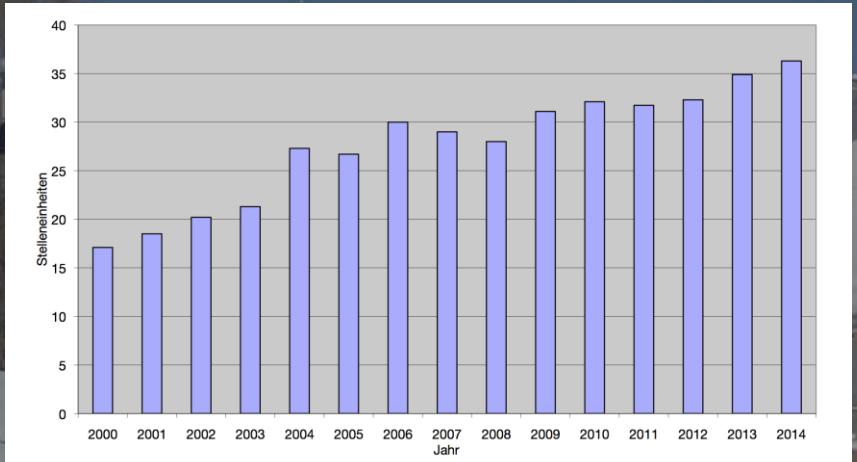
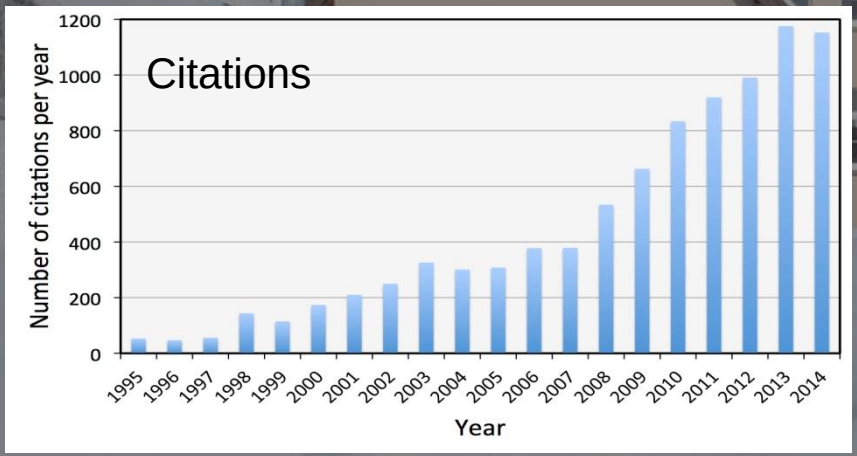
The PMOD/WRC in numbers

41 Employees



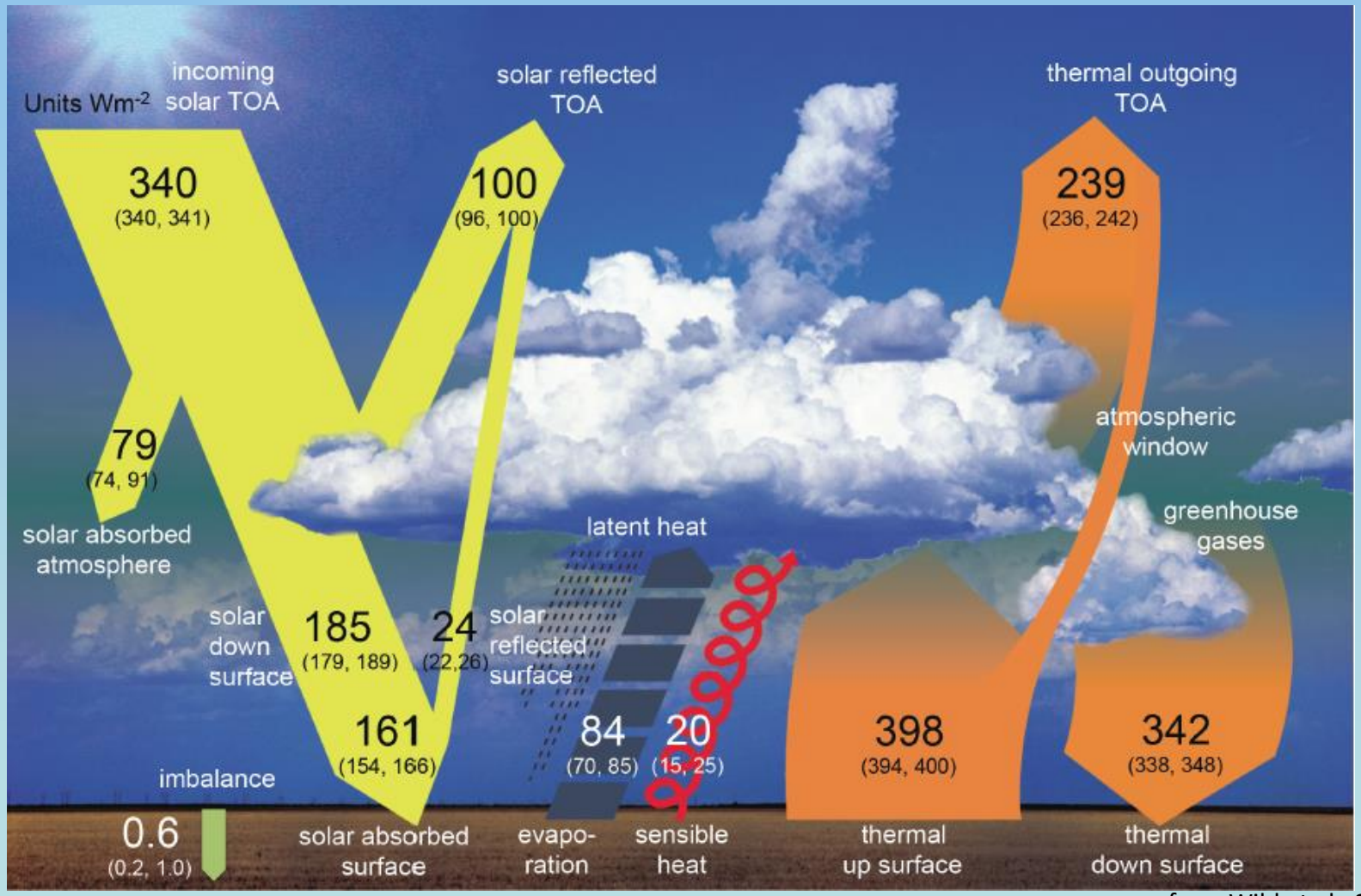
Figur 5. Mitarbeiterbestand per Anfang Jahr des PMOD/WRC in Stelleneinheiten. Anfang 2014 waren 41 Personen am PMOD/WRC angestellt.



Budget (2014)

- Total 5´800´000 CHF
- 44% World Radiation Center
- 48% Third party
- 8% Calibrations & Instrument sales

The global energy balance



from Wild et al., 2013

The role of the PMOD/WRC is to provide reference standards to homogenise radiation measurements world-wide.

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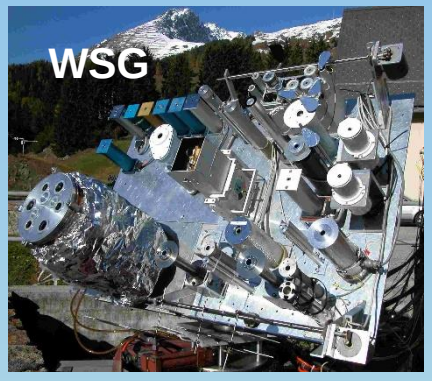
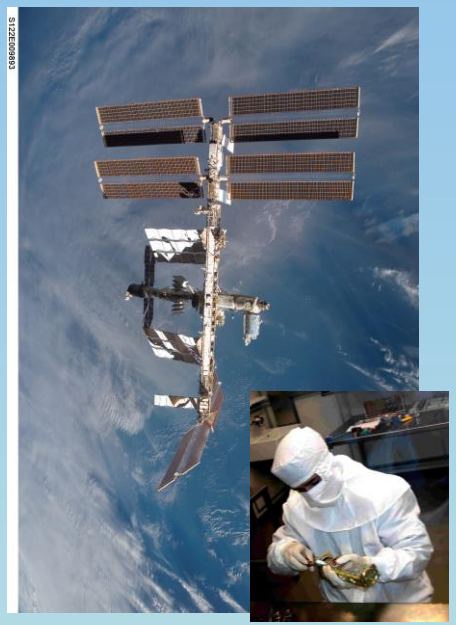
The 4 Pillars of PMOD/WRC

World Radiation Center

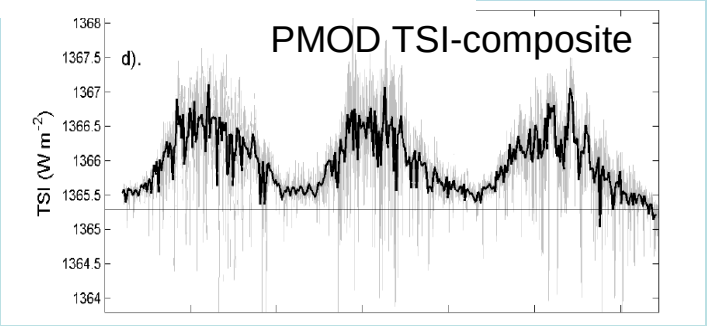


Satellite experiments



Instrument developments

TSI = Total Solar Irradiance



Scientific Research:
Investigating the influence of the Sun on Climate

- Past, present and future climate change
- Climate modelling

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The 2 Worlds of PMOD/WRC

The PMOD/WRC is designated Institute of METAS for solar irradiance:

- Signatory of the CIPM MRA
- Implementation of a Quality System according to ISO 17025
- Holder of 6 CMC's for solar irradiance

Metrology

World Meteorological Organization
Weather • Climate • Water

The PMOD/WRC is designated World Radiation Center by the WMO:

- operates instruments representing radiation quantities accepted as world reference standards by the WMO
- Calibrates meteorological radiation instruments
- Provides traceable measurements to SI
- PMOD/WRC represents WMO in the CIPM MRA for solar irradiance

Meteorology

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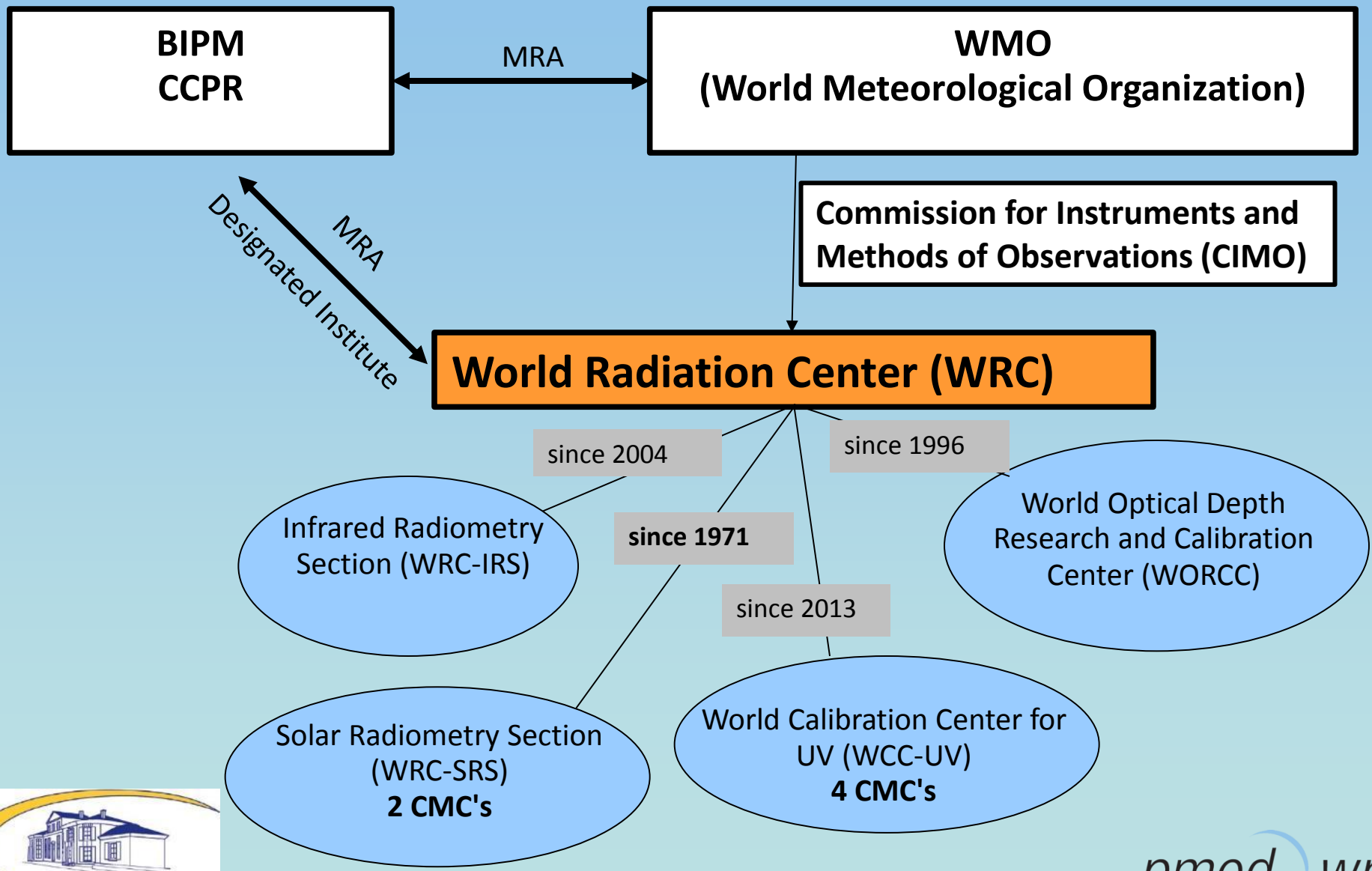
PMOD/WRC as World Radiation Center



CIPM MRA

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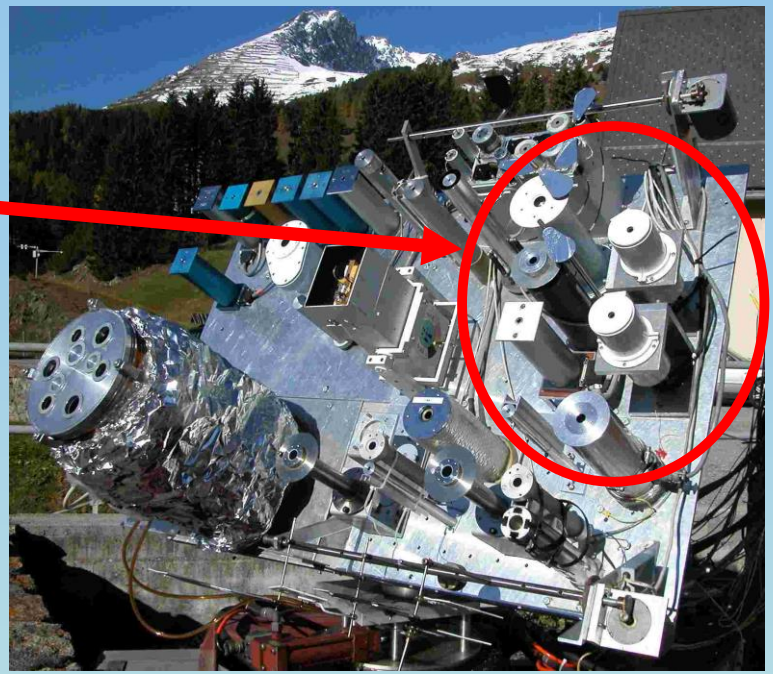
Solar Radiometry Section: World Standard Group (WSG)



The World Radiometric Reference (WRR) is determined by a group of absolute cavity radiometers named the World Standard Group (WSG). At the moment, the WSG is composed of 6 instruments:

PMO-2
PMO-5
CROM-2L
PACRAD-3
TMI-67814
HF-18748

The WRR was established in 1977 as a conventional standard for solar irradiance (conventional "Wm^{-2}").

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Solar Radiometry Section: WSG as a Calibration Standard

WSG Calibration transferred to Instruments at PMOD/WRC

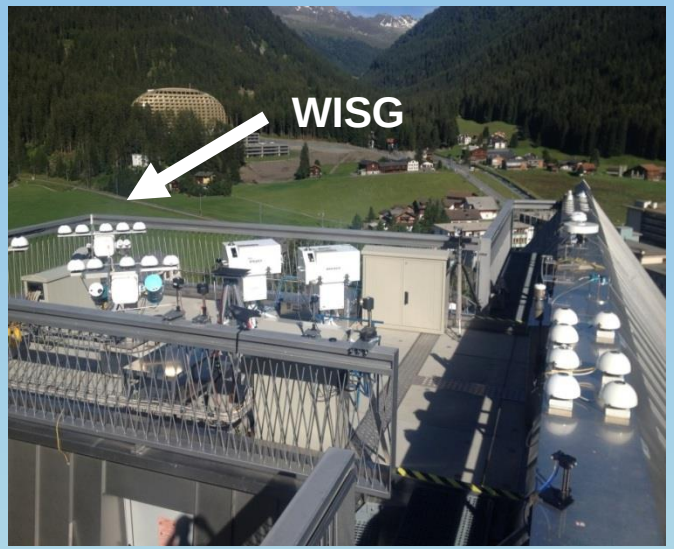
Intl. Pyrheliometer Comp. (IPC)
Every 5 years since 1959

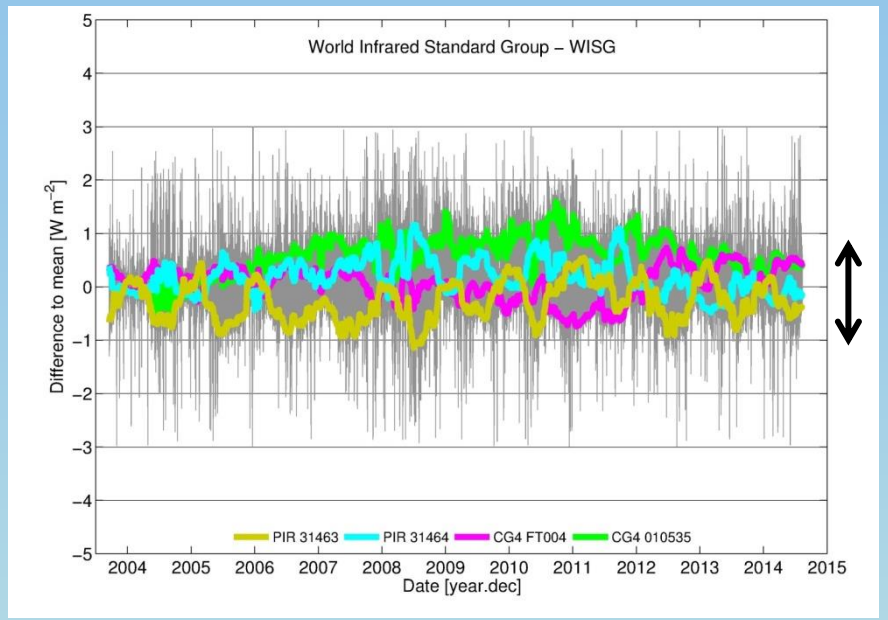
WSG Calibration transferred to Instruments at Regional Centres

WSG Calibration transferred to Instruments at National Centres and customers

IPC XII
28 Sep – 16 Oct 2015
- 120 participants
- 130 pyrheliometers
- 40 countries

The World Infrared Standard Group (WISG)





Consists of 4 Pyrgeometers:

- 2 modified Eppley PIR, s/n 31463, 31464
- 2 Kipp & Zonen CG4, s/n FT004, 010535

The WISG has been stable to ± 1 Wm^{-2} since 2004

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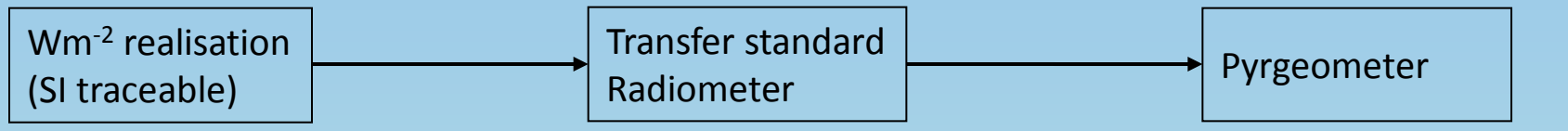
Pyrgeometer traceability to SI

Traceability of longwave infrared irradiance measurements require transfer standard radiometers between the irradiance reference (blackbody cavity) and outdoor measurements



BB2007

- Cylindrical cavity
- effective emissivity 0.99993(33)

Gröbner, AO 2008

IRIS

- Windowless
- Flat Spectral Response
- Nighttime operation only

Gröbner, Metrologia, 2012

Gröbner et al., JGR, 2014

- Si dome & Solarblind Filter
- Thermopile

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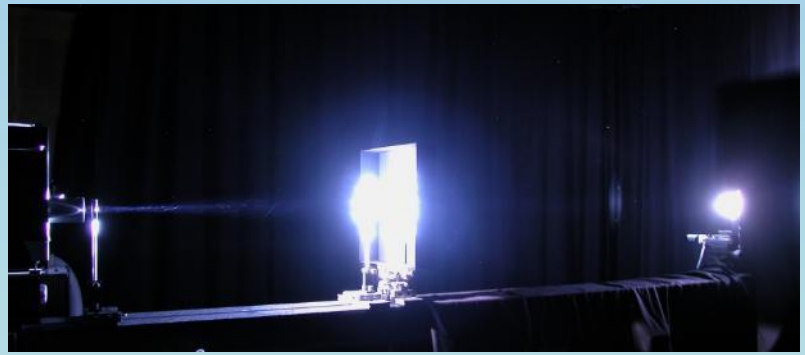
The World Calibration Center for UV (WCC-UV)

- Operational since 2002
- GAW Regional calibration Center for Europe since 2008
- World Calibration Center since 2013

QASUME Spectroradiometer

Broadband Radiometers
4 CMC's

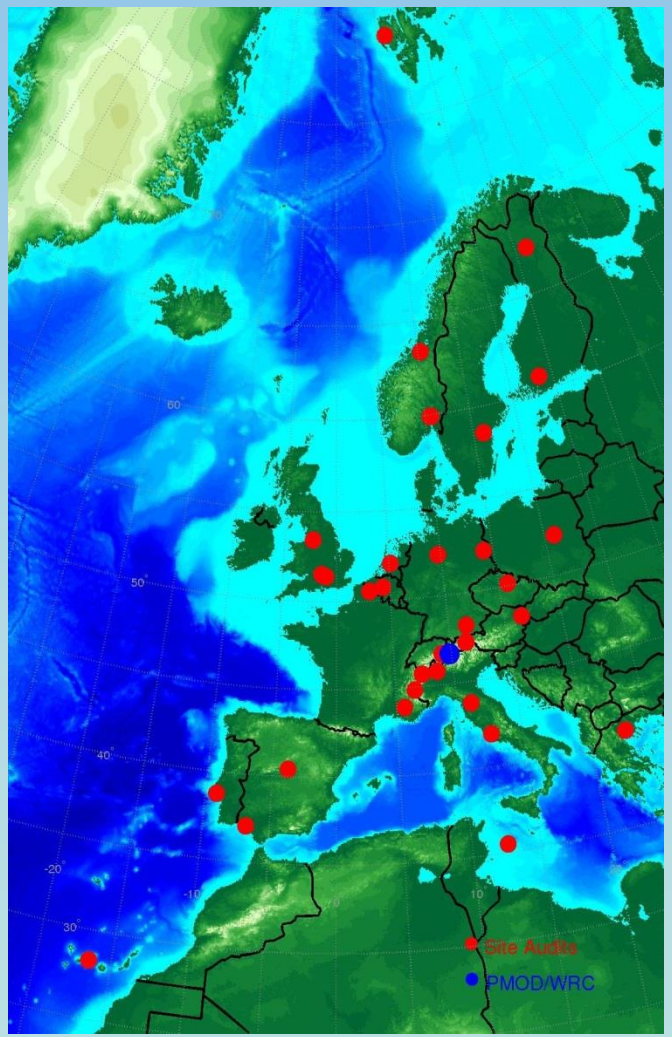


Laboratory facilities

http://pmodwrc.ch/wcc_uv/wcc_uv.html

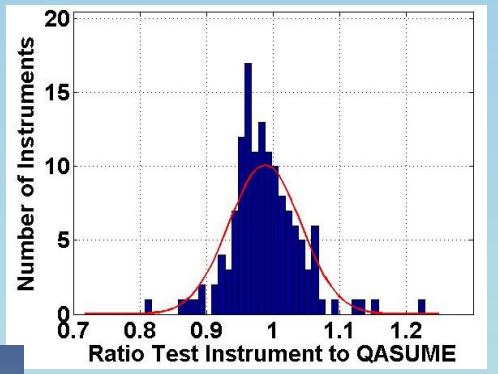
Solar UV Quality Assurance Program

On site comparison with the portable QASUME reference spectroradiometer



Status 2002 - 2015

- **66 site visits**
- **33 sites**
- **> 160 spectroradiometer intercomparisons**



$$\frac{Test}{QASUME} = -1 \pm 14\%$$

http://www.pmodwrc.ch/wcc_uv/?topic=qasume_audit

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EMRP-ENV03 "Solar UV"

http://projects.pmodwrc.ch/env03/

- Enhance the **reliability** of spectral solar UV radiation measured at the Earth surface
- Develop new **techniques and devices** for **traceability** better than 2% (now 5%) and for **cost-effective** array-spectroradiometer in UV monitoring networks
- Intercomparison Campaigns and Workshops

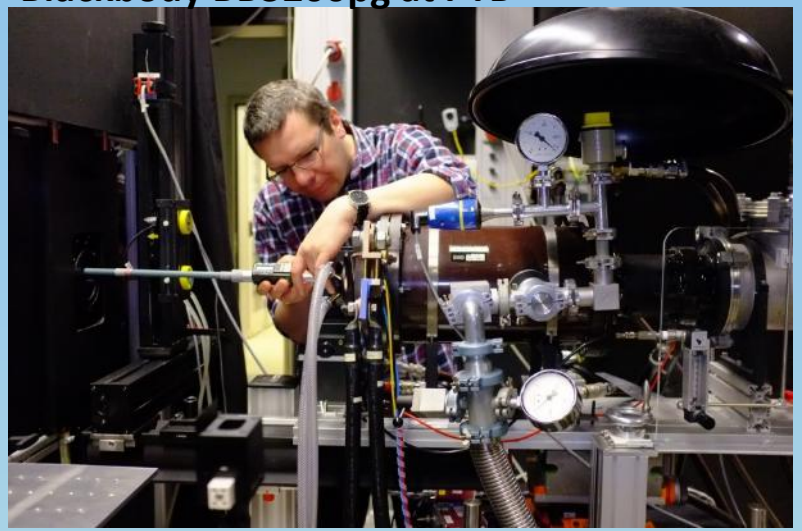
Primary Irradiance Standard | Transfer Standard | Reference Spectroradiometer | End-User Devices | Calibrated UV Network

- **Project Coordination:** pmod wrc *Dr. Julian Gröbner, Davos*
- **Duration:** 2011 - 2014
- **Total Budget:** 3.9 M€
- **8** Partners EU-NMI; **2** Industry; **2** Universities; > **5** Collaborators

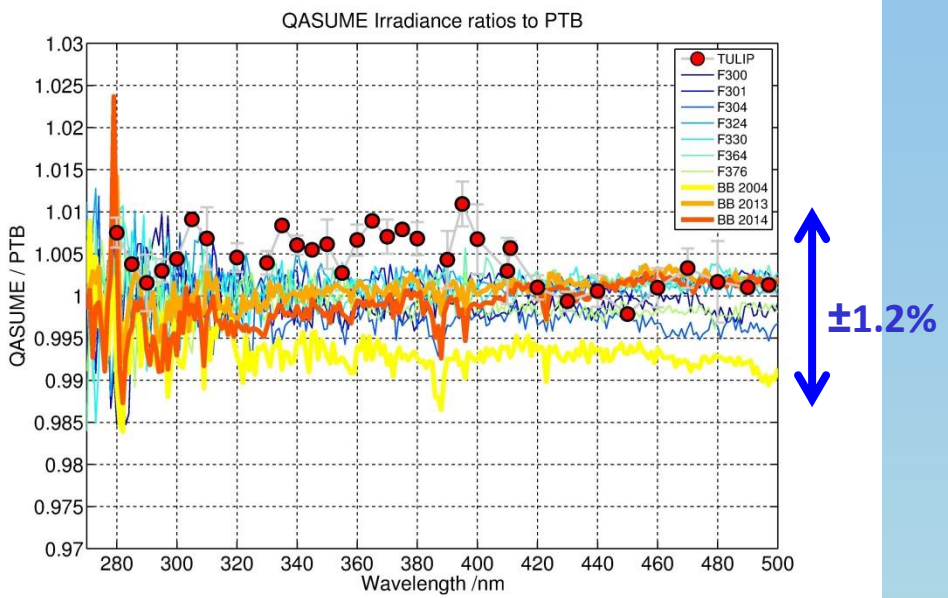
EMRP
European Metrology Research Programme
Programme of EURAMET
The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

Validation of the QASUME irradiance reference at PTB

Blackbody BB3200pg at PTB



QASUME Validations at PTB since 2004



Tuneable Laser facility TULIP

Gröbner J., and **P. Sperfeld**, Direct traceability of the portable QASUME irradiance scale to the primary irradiance standard of the PTB, Metrologia, **42**, 134—139, 2005.

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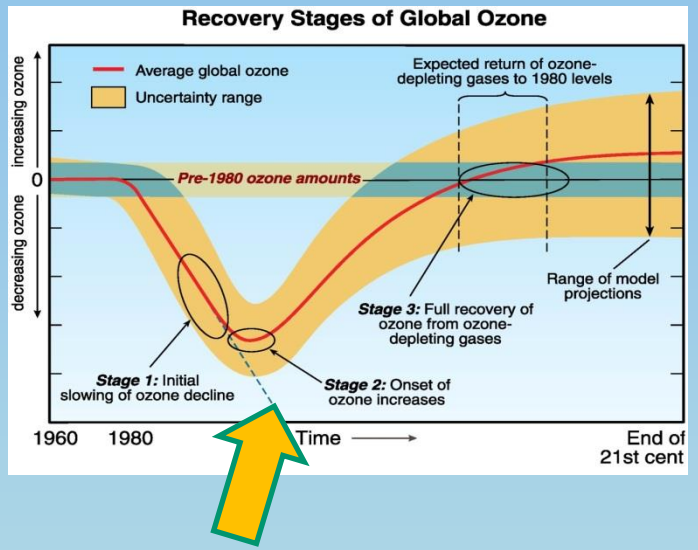
EMRP-ENV59 "ATMOZ"

EMRP
European Metrology Research Programme
Programme of EURAMET
The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

A traceable and harmonized Global Total Column Ozone Network

- Provide traceability of total column ozone to 1%,
- Radiometric characterisation of Dobson and Brewer spectrophotometers,
- Development of array-based solar UV spectroradiometers,
- Improved and consistent ozone absorption x-sections,
- Comprehensive uncertainty budget incorporating instrumental and atmospheric uncertainties



- **Project Coordination:** PMOD/WRC, *Julian Gröbner*
- **Duration:** 10/2014 – 9/2017
- **Total Budget:** 2.5 M€
- **9 Partners** NMI-DI, Industry, Universities

Stakeholders and Collaborators

World Meteorological Organization
Weather • Climate • Water

VSL Dutch Metrology Institute
KIPP & ZONEN SINCE 1830
Aalto University School of Science and Technology
PTB
AEMet Agencia Estatal de Meteorología
Universität Bremen*
ULL Universidad de La Laguna
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World Optical Depth Research and Calibration Center (WORCC)

1999 GAWPFR: First PFR instruments deployed to 3 GAW stations

2006 CIMO XIV recommendation, approved by EC59
Recognition of WORCC as primary WMO reference center for AOD.

2007 Development of a travel standard PFR for on-site Quality Assurance within EUSAAR (8 site visits during 2007-2011)

2009 Izaña Atmospheric Research Center becomes WORCC absolute calibration facility

2014 First 2 Precision Solar Spectroradiometers are deployed

2015 4th Filter Radiometer Comparison
12 countries and 28 instruments

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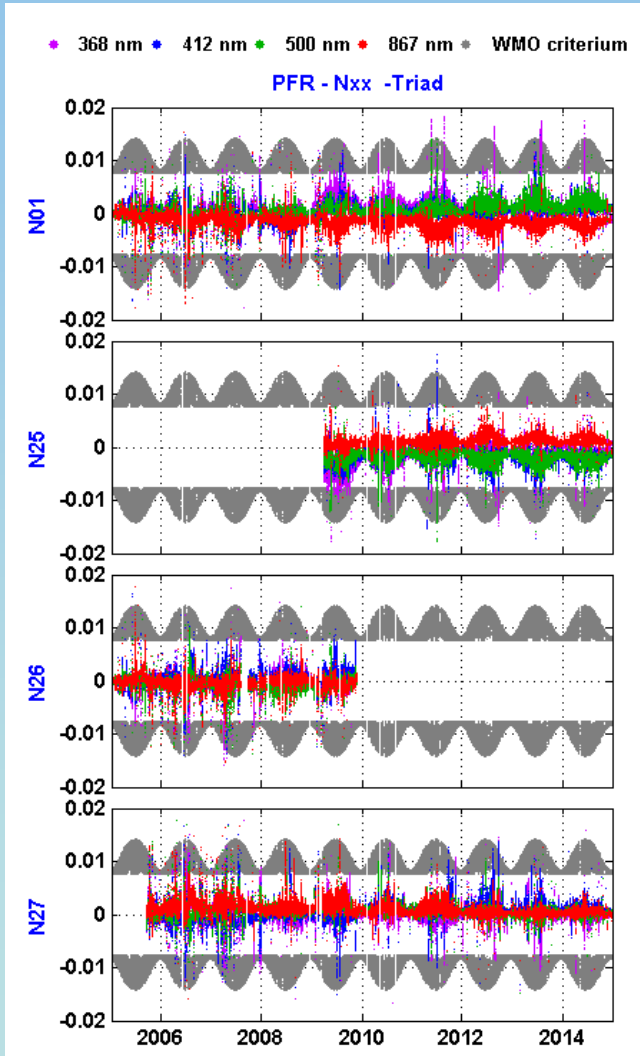
Triad performance 2005-2015

WORCC triad maintenance



MaunaLoa

Long term stability

The PFR reference triad has been operating near continuously since early 2005.

Interruptions were due to recalibrations by the Langley-plot technique at Mauna Loa, Hawaii or Izaña, Canary Islands.

The scatter of aerosol optical depth measurements at 500 nm with the triad sunphotometers is less than **0.0002 ± 0.0011(1σ)** which is well within the WMO criterion of 0.005 + 0.01/m

Yearly calibrations ~20 (2014) instruments

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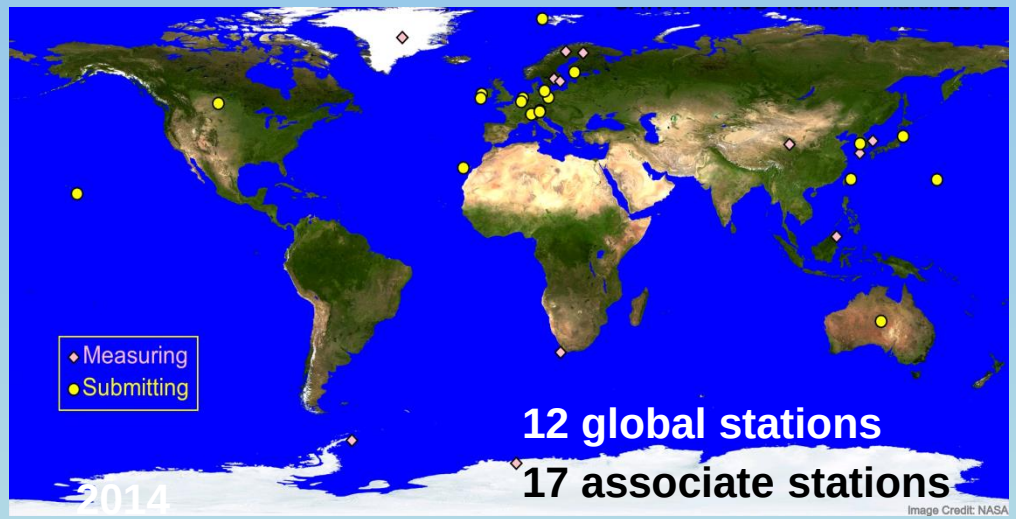
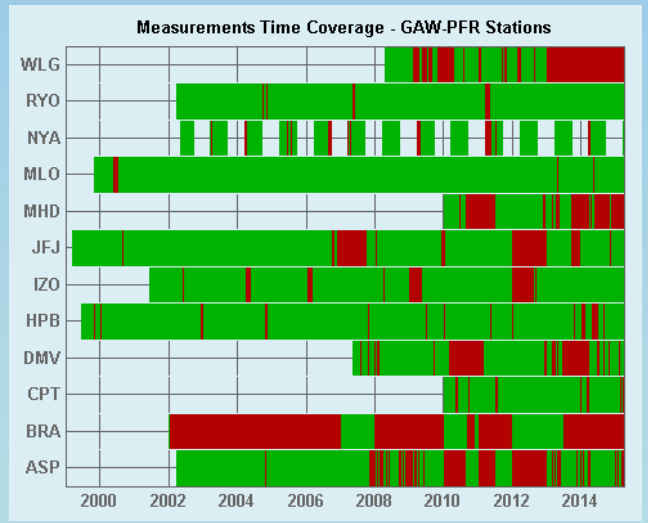
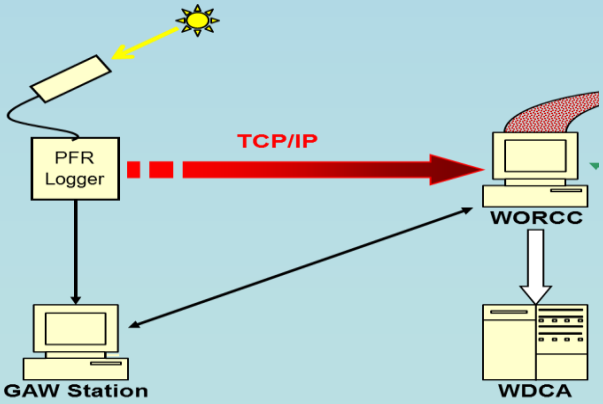
Global Atmospheric Watch PFR Network 1999-

GAW-PFR Network

- Has uniform instrumentation and procedures for AOD measurements
- Uses Precision Filter Radiometers (PFR) with 1 min measurement frequency







Users

Real time sub.
To WDCA: 22

Nearly 90% temporal coverage

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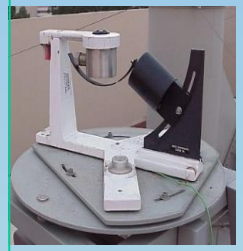
The 4th Filter Radiometer Comparison FRC-IV

PFR	CIMEL	MFRSR	PSR	POM-2	SPO2	SSIM	Microtops
WORCC Triad-CH	PMOD-CH	DWD-DE	DWDa-DE	DWD-DE	BMa-AU	COFa-CA	MIC-GR
SMHI-SE	AERONET-EU	NASA-US1	DWDb-DE	ARPA-IT	BMb-AU	COFb-CA	
DWD-DE	IZANA-ESP	NOAA-US2	PMOD-CH	JMA-JP		COFc-CA	
PMOD-CH (3)		NOAA-US3		KACARE-SA		COFd-CA	
MeteoSwiss-CH							



GAWPFR AERONET SURFRAD SKYNET AUSTRALIA

FRC-IV

- 28 Instruments
- 12 Countries
- 5 Networks

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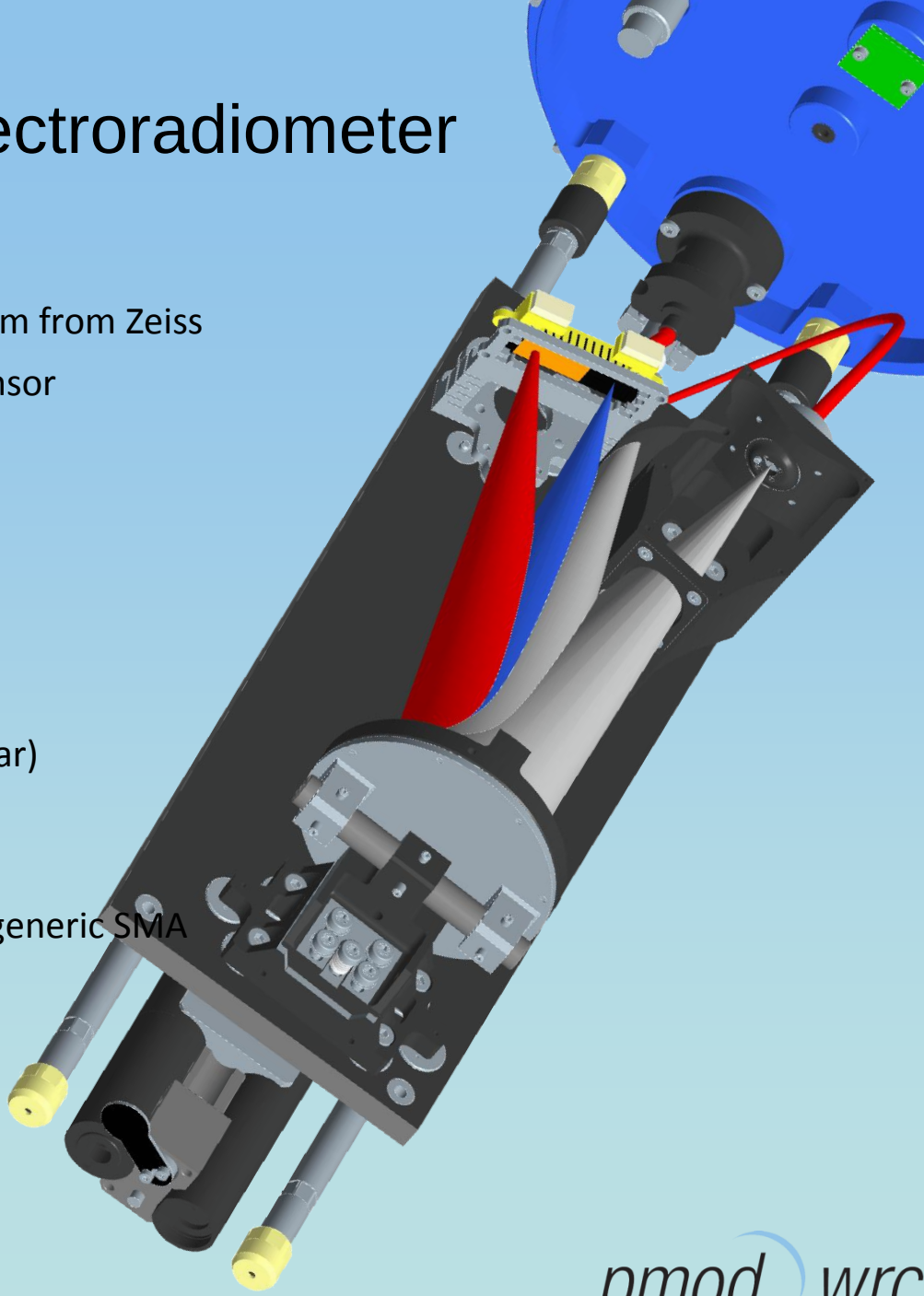
The Precision solar Spectroradiometer (PSR)

- Holographic flat-field grating 200 lines/mm from Zeiss
- Hamamatsu NMOS 1024 linear image sensor
- Wavelength range 300 – 1020 nm
- Resolution 1.5 nm to 6 nm
- Wavelength step 0.7 nm per pixel
- 18 bit ADC (262 kcounts)
- 10 ms to 40 sec integration time
- Temperature stabilised sensor ±0.1K (invar)
- stray-light optimised optical design with zero-order light-trap
- 2 entrance optics , direct irradiance and generic SMA



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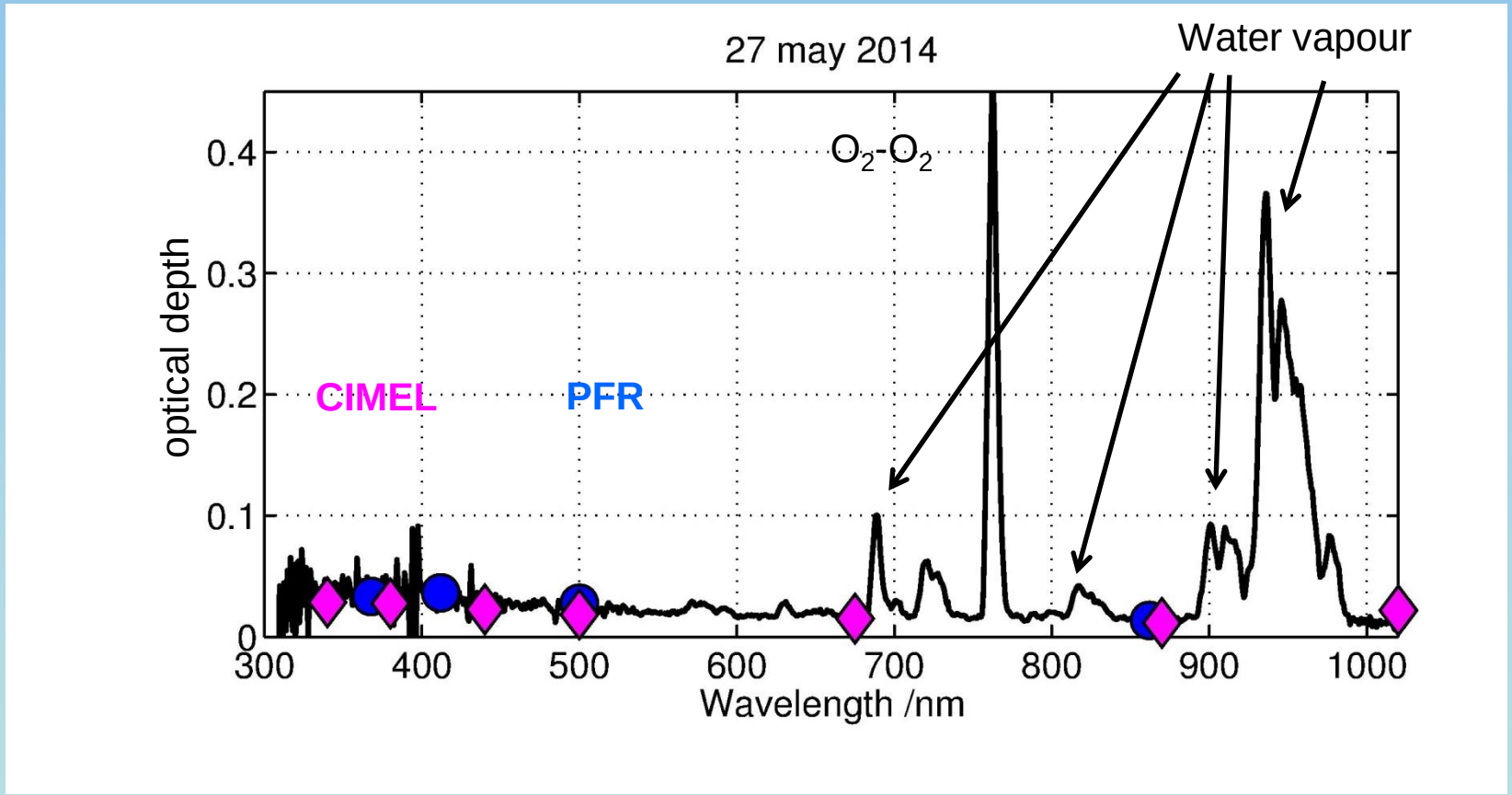
Spectral AOD compared to CIMEL and PFR



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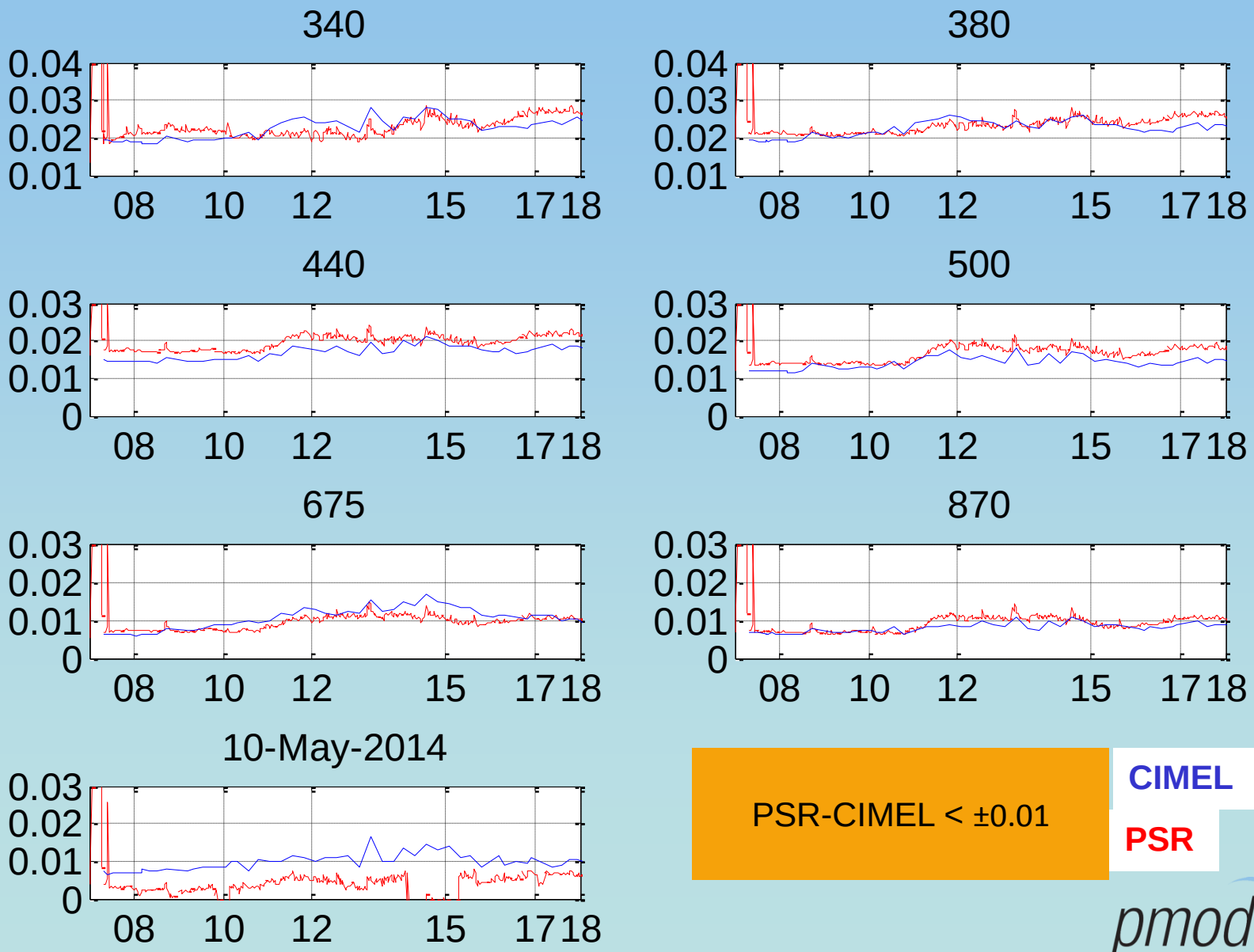
Spectral AOD compared to CIMEL – 10 May 2014



The PMOD/WRC

- Is signatory of the CIPM MRA & Designated Institute for Solar Radiation by METAS
- Implements a Quality Management System after ISO 17025
- Operates four sections within the World Radiation Center
  - Short & Longwave radiation (WRC-SRS & WRC-IRS)
  - Solar UV radiation (WCC-UV)
  - Aerosol optical depth (WORCC)
- Operates the Global GAW-PFR AOD Network
- Has travel Standards for Quality Assurance of
  - Solar UV Radiation
  - Spectral AOD (UV to NIR)
- Designs and sells high quality radiation sensors (Radiometers, Sunphotometers, Spectroradiometers)
- Builds and operates satellite experiments for long-term Total Solar Irradiance monitoring

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