

Aerosol optical depth ground-based sensors, homogenization activities between different networks

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Overview

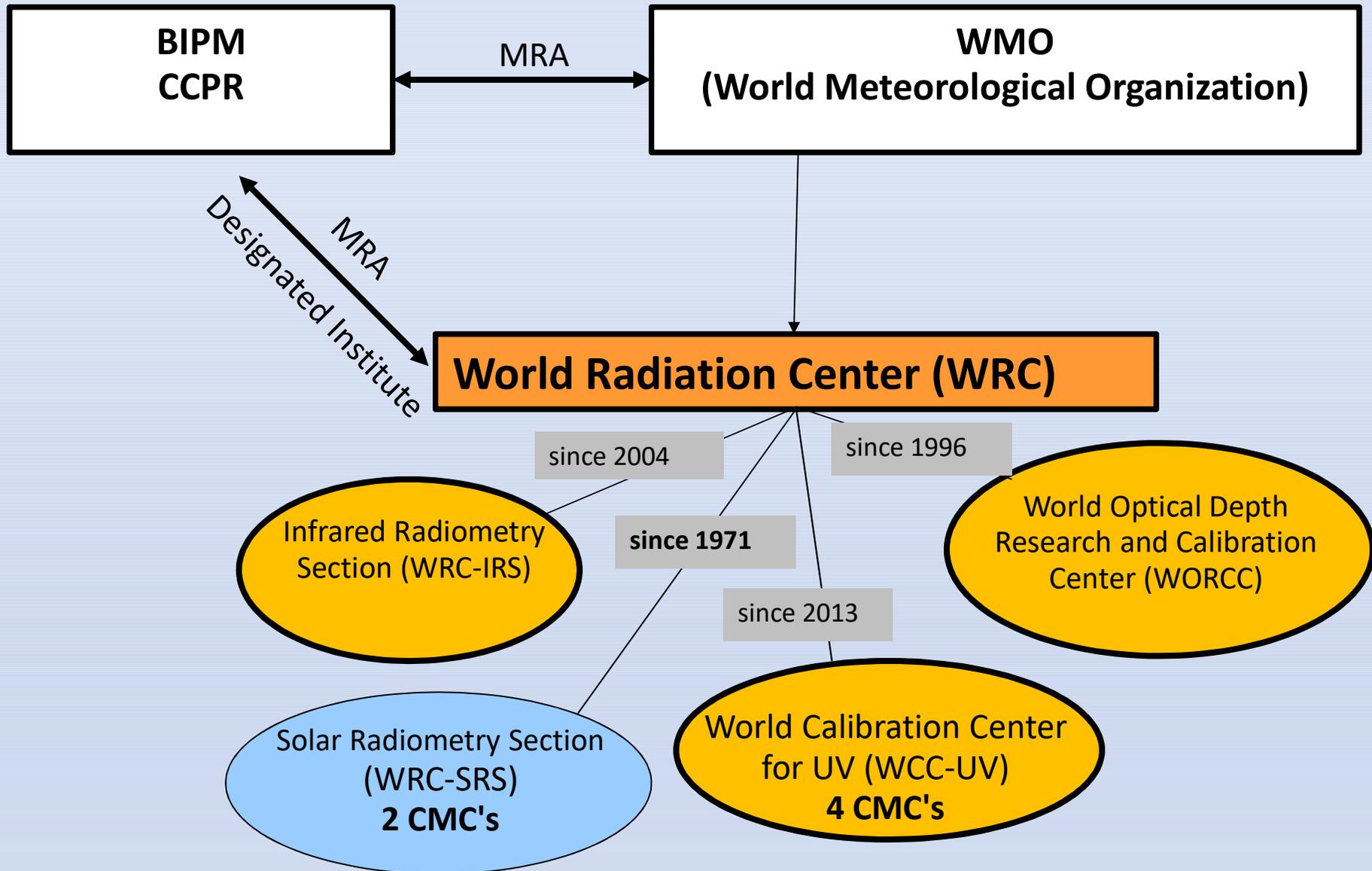
Aerosols and radiative forcing

Aerosol Optical Depth

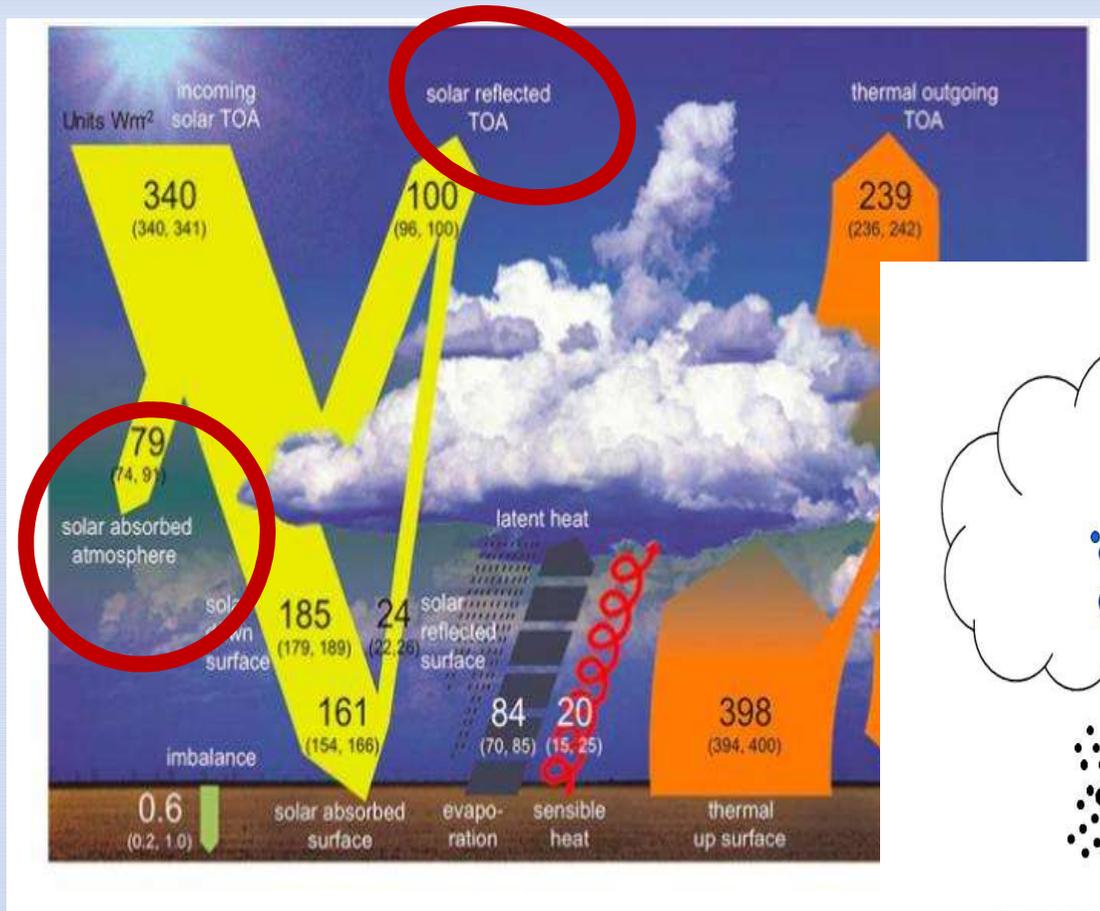
Surface based AOD networks

Homogenization activities

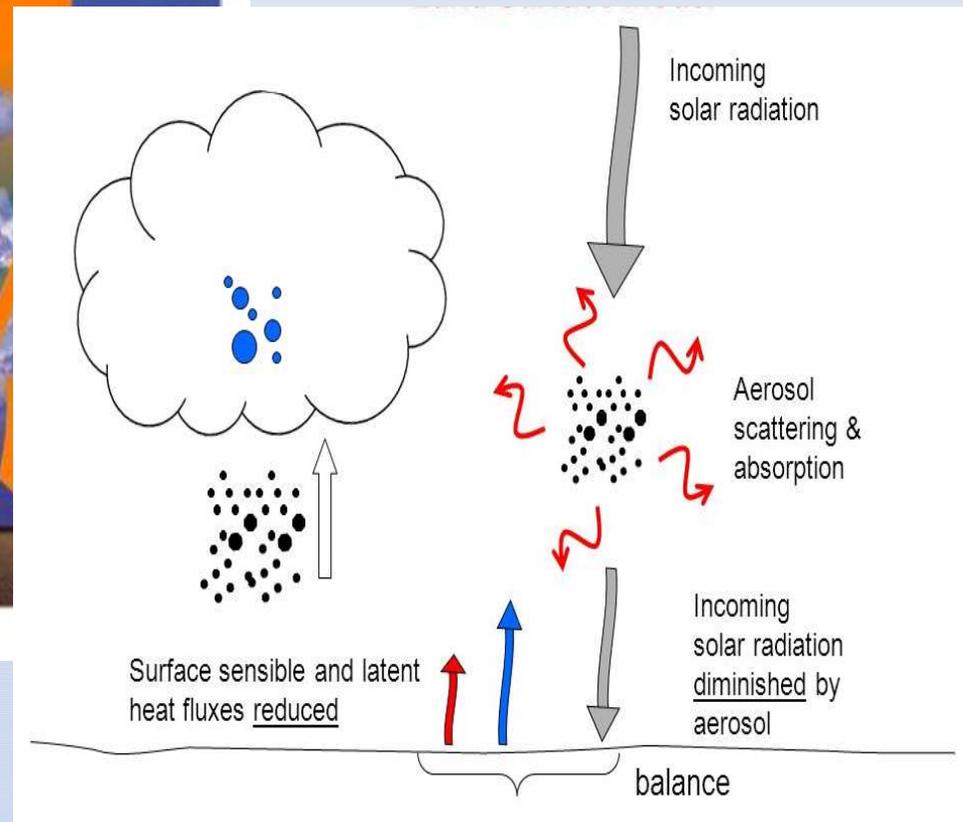
PMOD/WRC as World Radiation Center



Aerosols and radiative forcing



Aerosols:
absorption scattering
Interaction with clouds



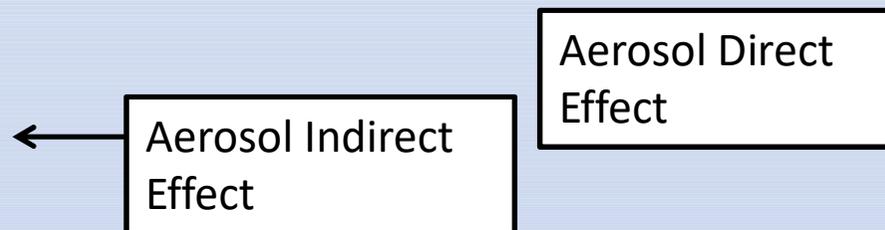
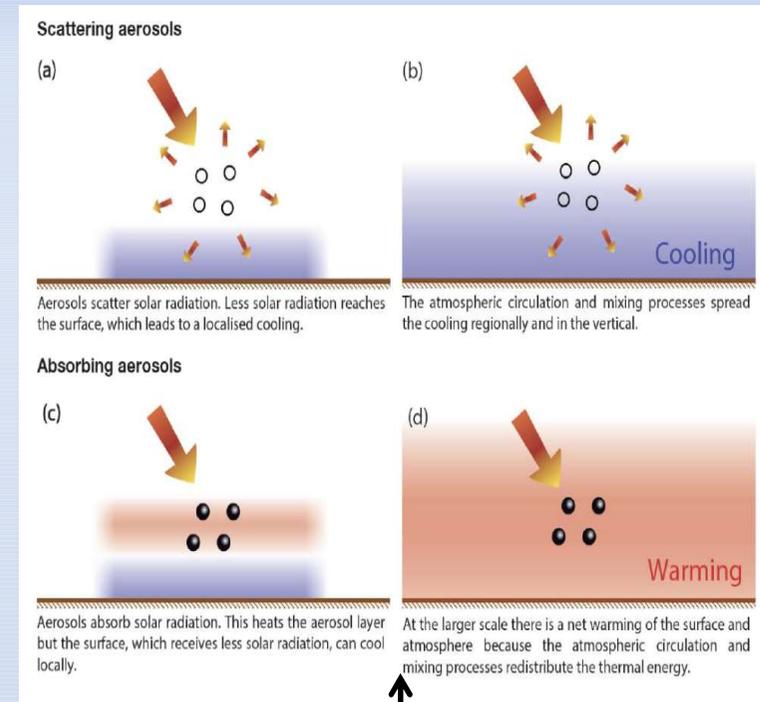
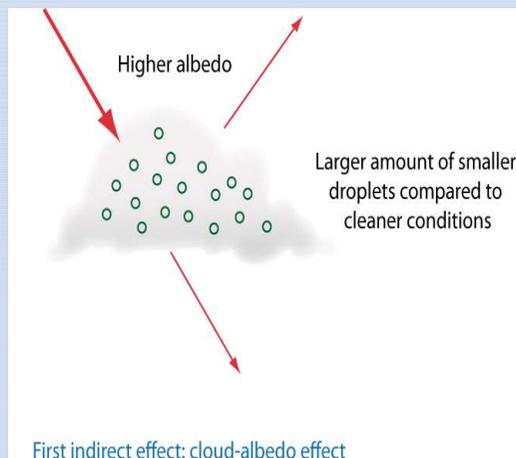
Wild et al, 2013

Aerosols and radiative forcing

Why are aerosols important?

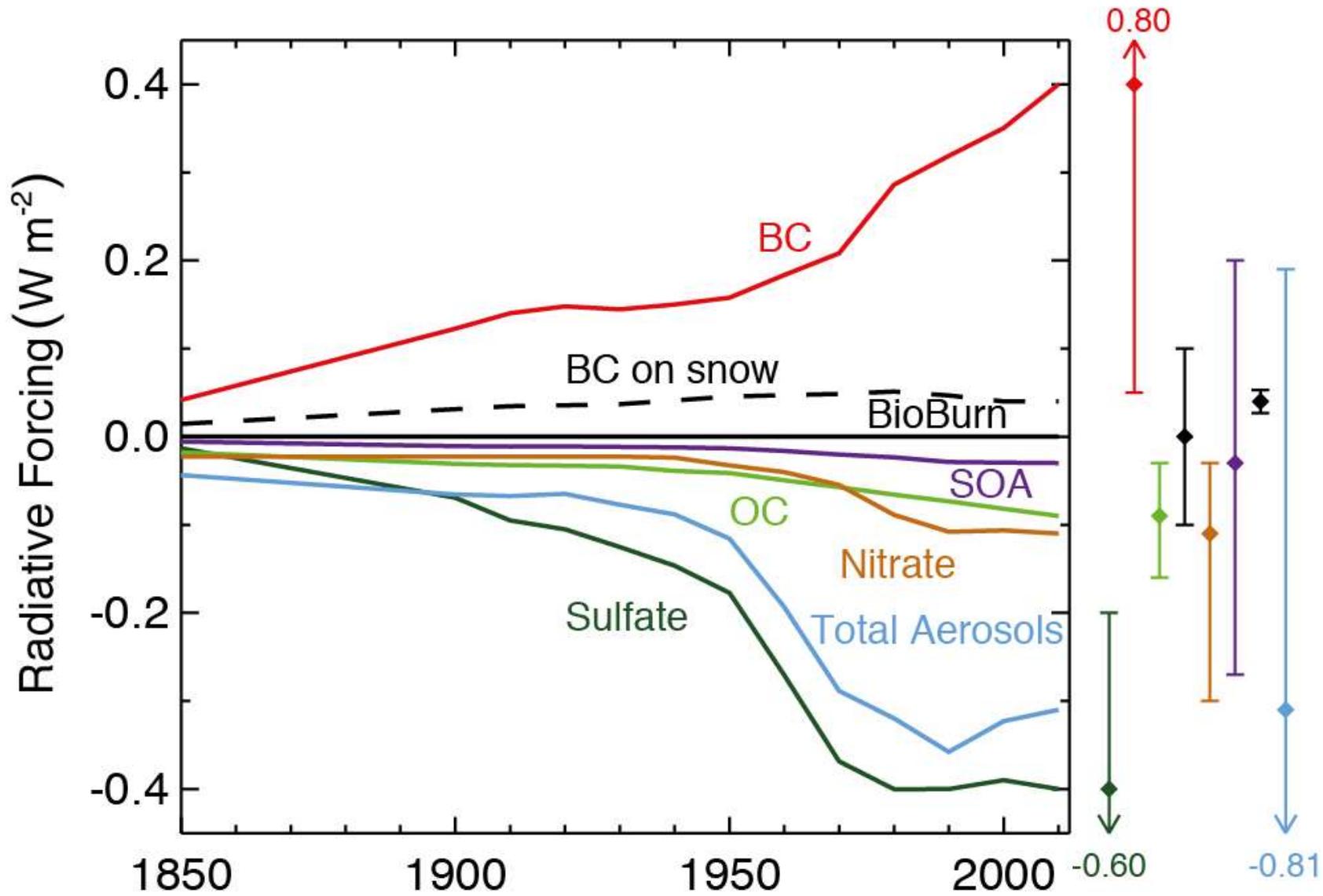
Because aerosols have much shorter lifetimes and more varied distributions than greenhouse gases, the net effect on global climate is hard to predict.

Aerosols can increase the reflectance of clouds. They also may modify the lifetime of clouds by affecting precipitation.



Source: IPCC, Fifth Assessment Report, 2013

Aerosols and radiative forcing

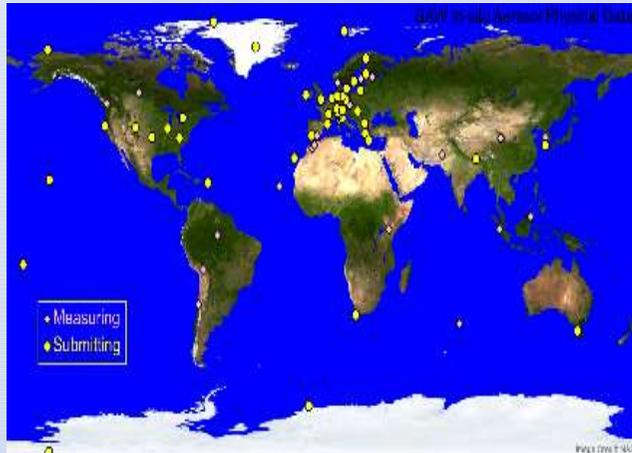


Aerosols and radiative forcing

IN-SITU

AEROSOL OPTICAL DEPTH

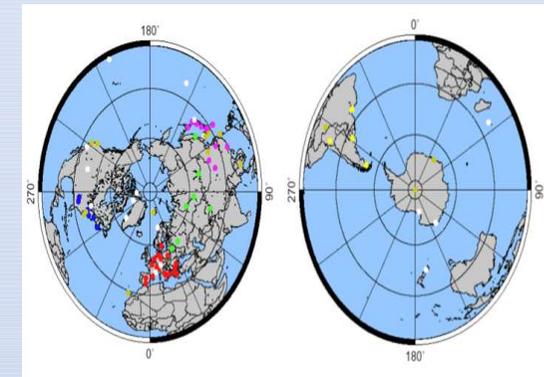
LIDAR



Surface level
Health effects



Columnar
Radiative forcing



Columnar profiles

Aerosol measurements / Intro Aerosols

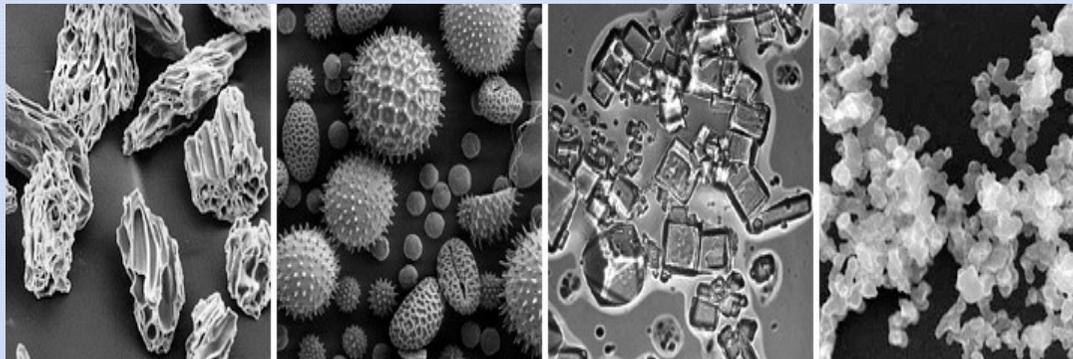
Aerosols ?

Suspended particles in the atmosphere

Ranging in size from a few molecules to tens of micrometers

Our main interest is aerosols with $0.1 < r < 20 \mu\text{m}$

$1 \mu\text{m}$ is an approximate separation between “fine” and “coarse” aerosols



volcanic ash

pollen

sea salt

soot.

Optical Properties

Optical properties are important for several reasons

- Their effect on the radiative balance of the Earth's environment
- Their effect on heating of the atmospheric column which can change circulation and affect the water cycle
- Effect on visibility

What columnar aerosol properties are retrieved / used for studying their radiative effects ?

Aerosol Optical Depth (AOD) ~ aerosol amount

These **optical measurements** of light extinction are used to represent aerosol amount in the entire column of the atmosphere.

AOD is a unitless value and wavelength dependent.

Sample AOD values (visible):

0.02 - very clean isolated areas.

0.2 – fairly clean urban area

0.4 – somewhat polluted urban area

0.6 – fairly polluted area

1.5 – heavy biomass burning or dust event

What is Aerosol Optical Depth?

“AOD is a quantitative measure of the extinction of solar radiation by the integrated columnar aerosol load”

“AOD is the single most comprehensive variable to remotely assess the aerosol burden in the atmosphere”

“AOD is a key variable in climate modelling, aerosol closure experiments and satellite verifications”

Aerosol Optical depth

Optical Depth is not Optical Thickness

Definitions in AMS Glossary of Meteorology

(consistent with WMO CIMO Guide or GAW#162 Report)

optical thickness : The dimensionless line integral of extinction coefficient along any path in a scattering and absorbing medium.

optical depth: The optical thickness measured vertically above some given altitude.

Turbidity and Visibility

Turbidity (AOD) optical extinction along vertical path

Ångström turbidity \approx AOD@1 μ m **AOD = b * $\lambda^{-\alpha}$**

Volz, Schüepp turbidity \approx AOD@500nm

Visibility (meteorological range) along horizontal path

$$V = 1/\tau \ln(1/\epsilon) = 1/\delta * 3.912 \quad (\text{Koschmieder formula})$$

	$\text{\AA}(\beta)$	AOD (500nm)	V(km)
Clean	0.02	0.05	80
Clear	0.1	0.25	16
Hazy	0.2	0.5	8
Turbid	0.4	1.0	4

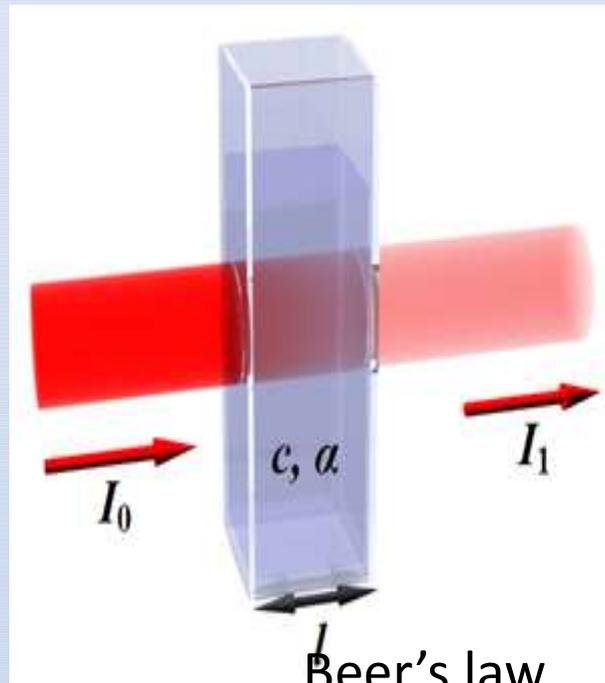
Extinction of Sunlight

- **Absorption** in specific spectral domains by molecular (H_2O , CO_2 , O_3 , ...) and particulate matter (aerosols) Radiative energy is deposited in the atmosphere in form of heat or chemical reactions.
- **Scattering** by particles of a wide range in size from molecules to cloud droplets.
Scattering is a continuous process, redistributing radiation in all directions for all wavelengths, but does not transfer energy.
- **Extinction** = Absorption + Scattering

What columnar aerosol properties are retrieved / used for studying their radiative effects ?

Aerosol Optical Depth (AOD) ~ aerosol amount

$$I = I_0 * e^{-m\tau}$$



I = measurement
 I_0 = TOA / calibration
 τ = total extinction

$$\tau_{(wl)} = \tau_{o_3} + \tau_{aer} + \tau_{Ray} + \tau_{cl} + \tau_{gas}$$

Aerosol Optical Depth

$$I(\lambda, \theta, r) = \frac{I_0(\lambda)}{r^2} * e^{-\left[\delta_R * m_R(\theta) + \delta_A * m_A(\theta) + \delta_G * m_G(\theta) \right]}$$

where I is the measured irradiance (in arbitrary units), I_0 the calibration constant, ε the diffuse light scattered into field-of-view, r the Sun-Earth distance (in astronomical units), m_x are the respective air masses for molecular scattering, ozone absorption and aerosol extinction with corresponding optical depth δ_x , ϑ is the apparent solar zenith angle, p is the actual and p_0 the standard atmospheric pressure.

$$\delta_A(\lambda) = \frac{\log\left(\frac{I_0(\lambda)}{I * r^2}\right) - \frac{p}{p_0} m_R(\theta) \delta_R(\lambda) - m_{O_3}(\theta) \delta_{O_3}(\lambda)}{m_A(\theta)}$$

Air mass approximations

Definition: (relative) Air mass is the density integral of an extinction component along a slant path through the atmosphere related to its vertical integral which defines unit air mass.

For a plane-parallel and homogeneous atmosphere all air masses would be equal to $m=1/\cos(sza)$, but for a curved and refracting atmosphere a numerical integration must be performed for each solar zenith angle sza using a realistic atmospheric model of vertical density and refractive index distribution.

Tabulated results of such calculations were published by several authors together with fitted approximation formulas such as those given below:

$$\text{Rayleigh air mass } m_R = \frac{1}{\sin(e) + 0.50572(e + 6.07995)^{-1.6364}} \quad (\text{Kasten, 1989})$$

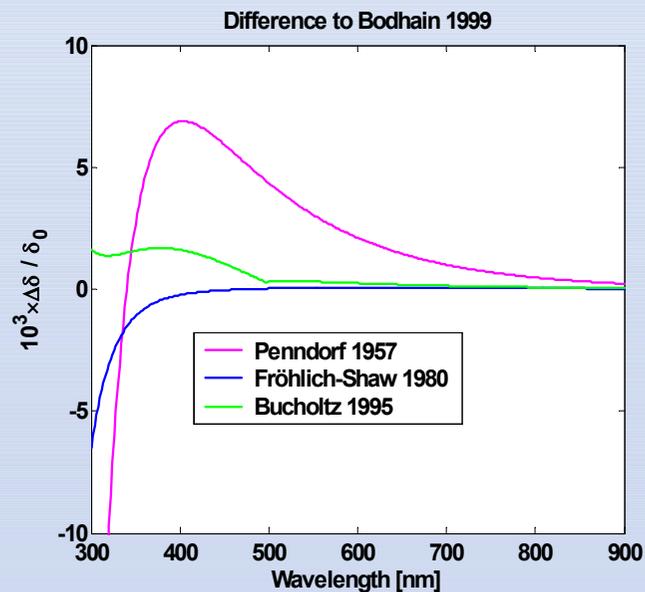
$$\text{Ozone air mass } m_{O_3} = \frac{R + h}{\sqrt{(R + h)^2 - (R + r)^2 \times \cos^2(e)}} \quad (\text{Komhyr, 1980})$$

$$\text{Aerosol air mass } m_a \approx m_{H_2O} = \frac{1}{\sin(e) + 0.0548 \times (e + 2.65)^{-1.452}} \quad (\text{Kasten, 1966})$$

Where e is the apparent solar elevation angle, $R=6370\text{km}$ the mean Earth radius, r the station height above sea level in km and h the height ($\approx 22\text{km}$) of the ozone layer. The aerosol air mass is further approximated by water vapour air mass, which has similar scale height.

Rayleigh optical depth

- Rayleigh optical depth δ_R is proportional to atmospheric pressure
- Refractive index of air is wavelength dependent
- King depolarisation factor depending on air composition (CO_2)
- Explicit integrations fitted in wavelength by several authors



Approximation by Fröhlich & Shaw

$$\delta_R(\lambda) = 0.00864 \times \lambda^{-\left(3.916 + 0.074\lambda + \frac{0.050}{\lambda}\right)} \times \frac{p}{1013.5}$$

[wavelength λ in μm]

Extraterrestrial Calibration I_0

I_0 can be determined from:

- A. Extrapolation through the atmosphere: Langley methods.
- B. Comparison to reference instrument
- C. Laboratory calibration combined with solar spectrum.

Calibration and AOD errors

$$\delta(\lambda) = \frac{1}{m} [\ln(I_0) - \ln(I) - 2 \ln(r)]$$

$$\frac{1}{m} \left[\ln \left(I_0 \times \left(1 + \frac{\Delta I_0}{I_0} \right) \right) - \ln(I) \right] = \delta + \frac{1}{m} \ln \left(1 + \frac{\Delta I_0}{I_0} \right) = \delta + \Delta\delta$$

Calibration
error

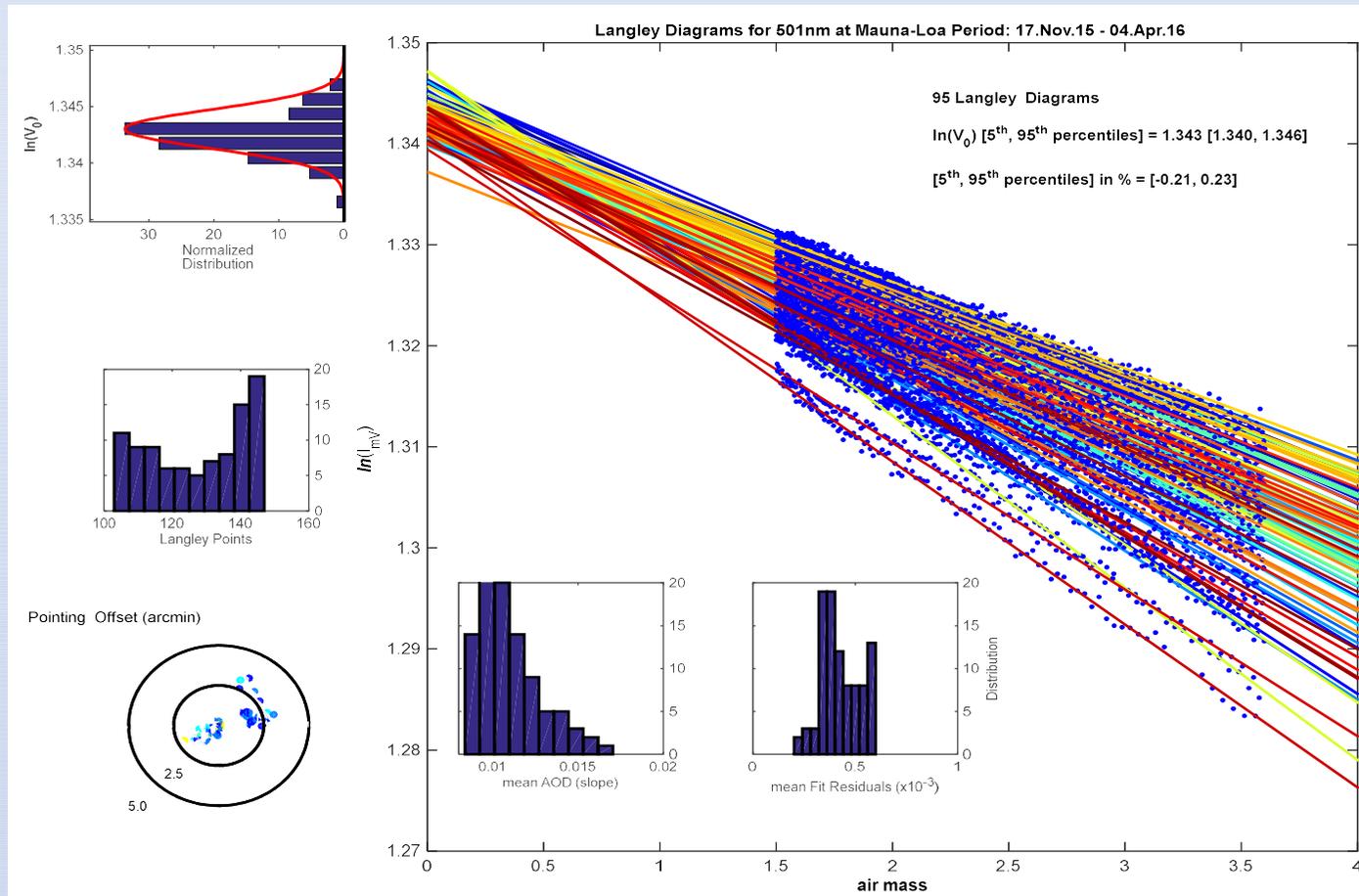
AOD
error

$$\Delta\delta \approx \frac{1}{m} \left(\frac{\Delta I_0}{I_0} \right)$$

$$WMO-GAW: \Delta\delta = 0.005 + \frac{0.01}{m}$$

An uncertainty of Calibration of 1% is required in GAW

Langley calibration



Langley plots for Mauna Loa observatory from November 2015 to April 2016.

Measurement Techniques

- **Pointed spectral radiometers (Sunphotometers)**

Solar irradiance in narrow field-of-view

Calibration of extra-terrestrial irradiance

Requires two-axis sun tracker

Atmospheric transmission

- **Shaded hemispherical radiometers**

Solar global and diffuse hemispherical irradiance

Calibration of extra-terrestrial value and cosine response

Rotating shadow band

Atmospheric transmission

- **Sun and Sky-scanning radiometers**

Solar irradiance and Sky radiance in narrow field-of-view

Calibration of extraterrestrial value and absolute radiance

Requires two-axis pointing robot

Atmospheric transmission, scattering phase function

Instrument pictures



Specifications for Sun photometers

- Handheld instruments are inadequate for contemporary needs.
- Sampling rate: 1 observation/minute
- Timing accuracy <10 second, time reporting in UTC
- Site coordinates accuracy of 15arcsec
- Measurements resolution 1/5000 of full scale or better
- Full Field_of_View 2.5°, slope angles 1°; tracking <0.25°
- Primary channels 368±2/<6nm 412±2/<6nm
 (center/bandwidth) 500±3/<11nm 862±4/<11nm
 (additional channels) 778±2/5; 675±3/11; 610±2/11nm
- Ancillary data for air pressure, temperature and humidity
- Daily ozone total column at station or at nearby Dobson site
- Raw measurements should be archived with results

According to WMO CIMO Guide (1996), BSRN (2000) and GAW specifications.

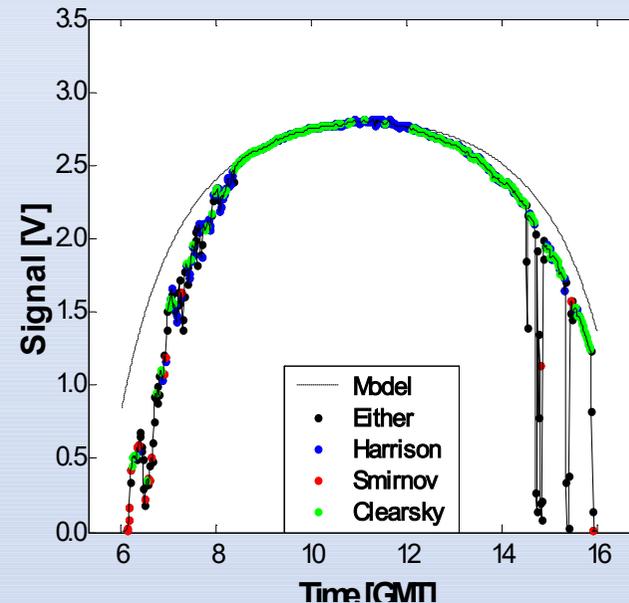
Available Instruments

Commercially available spectral Radiometers for Aerosol measurements						
Model	Manufact.	Channels	Viewangle	Network	Remarks	Software
Pointed Sunphotometers						
SP02 (-L)	Carter-Scott	4: 412, 500, 675, 862	5° (2.5°)			
PFR	PMOD	4: 368, 412, 500,862	2.5°	GAW-PFR	incl. DAQS	
PSR	PMOD	Spectral	2.5°		incl. DAQS	
SPUV-6 (10)	YES	6: 368, 500, 615, 778, 870, 940	2.5°		incl. DAQS	optional
Rotating Shadowband Radiometer						
MFR-7	YES	6: 415, 500, 615, 673, 870, 940	$2\pi / 3.5^\circ$		incl. DAQS	optional
Sky-Scanning Radiometers						
CE318-1	Cimel	5: 440, 670, 870, 936, 1020	1°	AERONET	Filterwheel, tracker incl.	basic incl.
POM-01L	Prede	7: 315, 400, 500, 675, 870, 940, 1020	1°	SKYNET	Filterwheel, requires PC	free UNIX SW
SP1A	Schulz	18 WMO +	1° imaging		Filterwheel, requires PC	included

List is not exhaustive, further instruments may be available from other companies

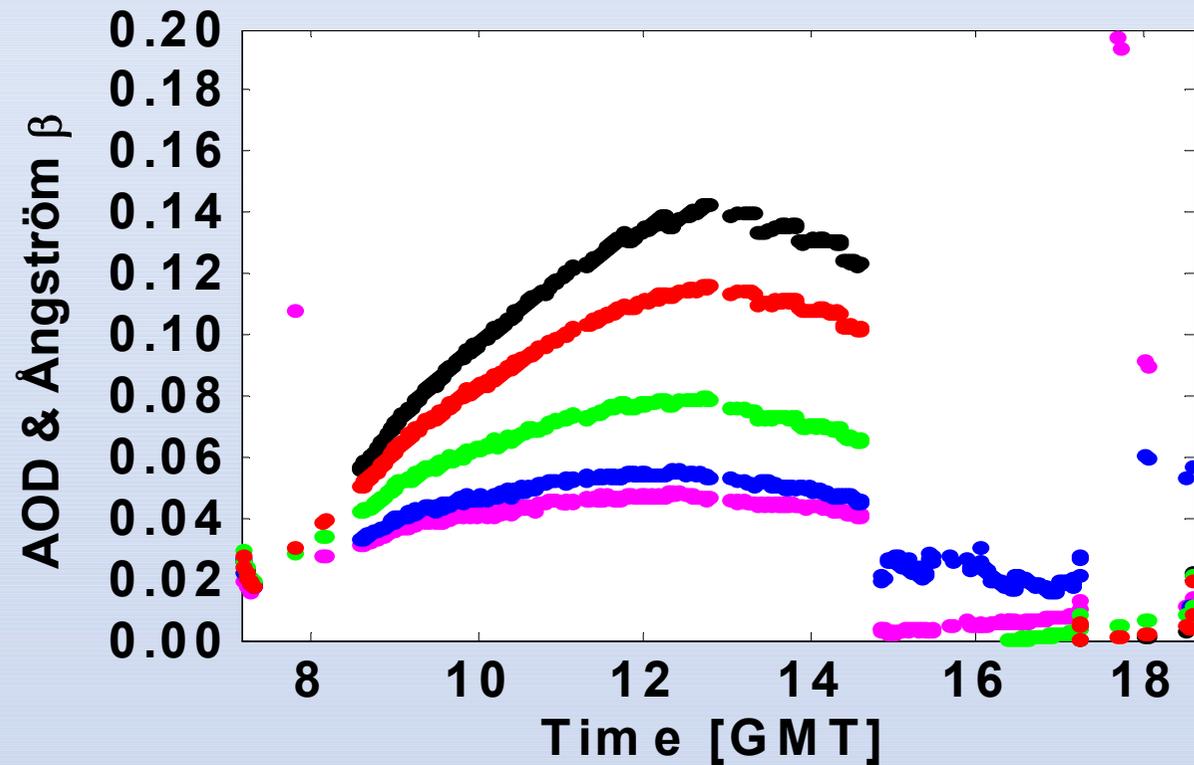
QC: Cloud Filtering

- Automated measurements need objective cloud filtering algorithm
- Thin cirrus clouds are hard to detect
- Harrison: $\Delta I / \Delta m < 0$ under clear sky works well while air mass changes quickly, most useful for Langley calibrations
- Smirnov: AOD varies more slowly than cloud perturbations based on rapid 'Triplet' measurements
- Additional smoothness filtering using second derivatives of signal or AOD.



Cloud filtering example with broken thin clouds in the morning, haze and thicker clouds in the afternoon.

QC: Cleaning

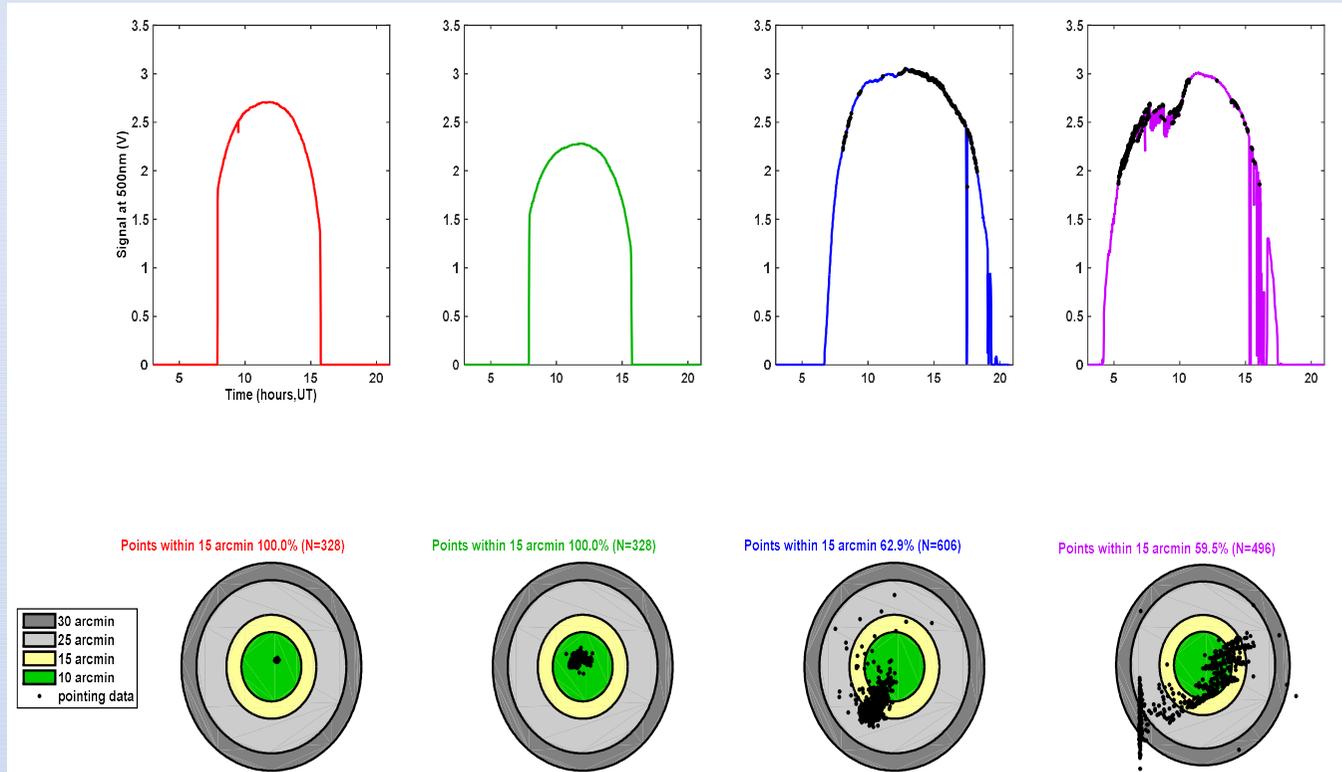


Neglected maintenance (cleaning) → erroneous results

Often hard to detect – always awkward to correct

Limited capability of automated tests → manual checks required

QC: Sun tracking

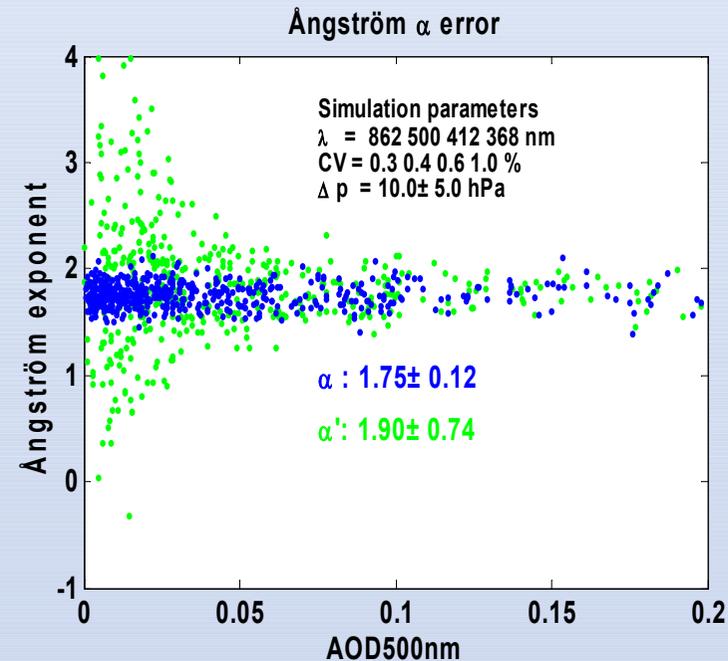
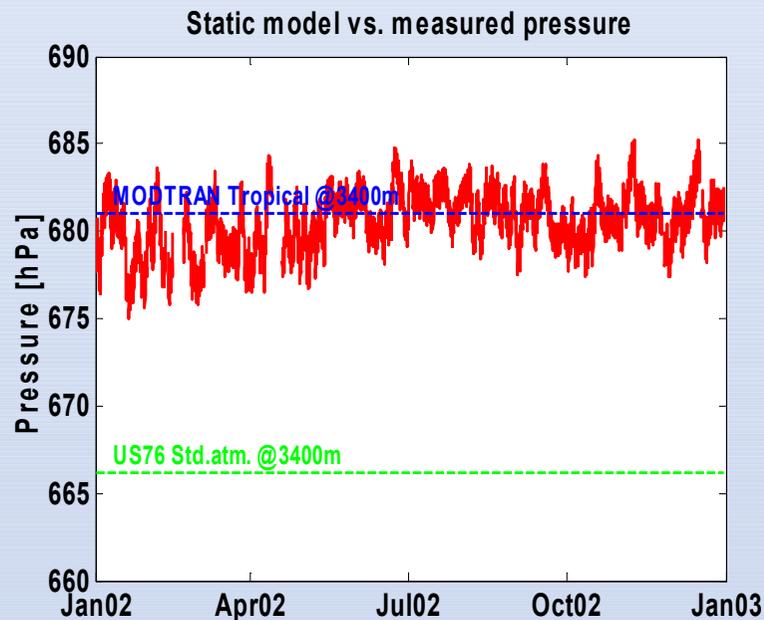


Sun tracker misalignment & hysteresis causing AOD artefacts

Individual checks and tight filtering required, possible with PFR!

QC: Atmospheric Pressure

- Rayleigh $\delta_R(\lambda, p) \gg \delta_A(\lambda)$ in UV-VIS range U95(p) $< \pm 2$ hPa
- Davos station mean vs. sunny measurement: $\Delta p \approx 3 \pm 6$ hPa
- Differences among MODTRAN models (1km): $\Delta p = 7$ hPa



➤ small error in AOD $< 0.005 \Rightarrow$ larger error & scatter in α for small AOD

Reason: $\delta_R(862) \approx \delta_A(862)$, but $\delta_R(368) = 0.35$, $\rho = 4.0$; $\delta_A(368) = 0.05$, $\alpha = 1.5$

Instruments

Precision Filter Radiometer



PFR N21 at Riory, Japan

PFR specifications

- Automated, solar spectral radiometer
- 4 simultaneous channels at 862, 500, 412, 368nm using IAD interference filters
- Field of View: $\pm 2.5^\circ$, slope angle 0.7°
- Dimensions: $\text{Ø}90 \times \text{L}300\text{mm}$, Mass 3 kg
- Continuous, high cadence measurements
- Sensor at $20 \pm 0.1^\circ\text{C}$ in range $-25 \div 35^\circ\text{C}$;
internal shutter; airtight N_2 flushed housing
- built-in pointing and barometric sensor
- Data logger with 30 day storage capacity

3 different cloud flags are determined for individual samples:

1. Harrison & Michalsky algorithm, modified for air masses < 2
2. Triplet algorithm applied as moving filter on continuous samples
3. Optical thick ($\text{OD} > 3$) clouds

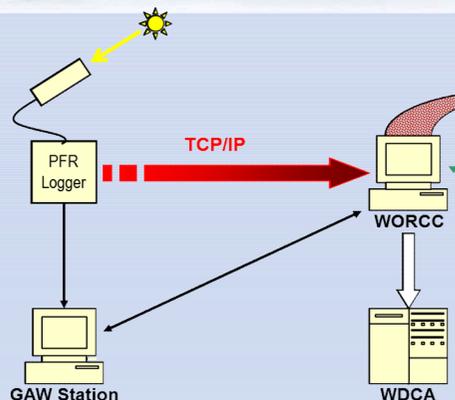
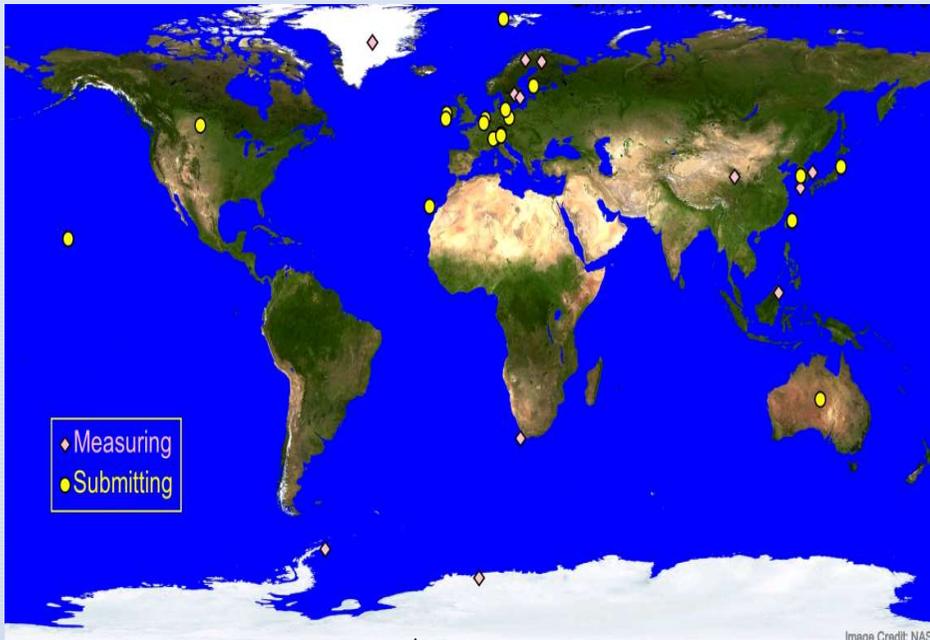
GAW – PFR measurements

GAW-PFR Network

- Has uniform instrumentation and procedures for AOD measurement

12 global stations (PMOD)

17 associate stations (PFRs)



Users

**Real time sub.
To WDCA: 22**

Europe

- Davos, CH
- Hohenpeissenberg, DE
- Tenerife, ES
- Mace Head, IR
- Ny Alesund, NO
- Jungfraujoch, CH
- Sodankylä, FI
- Summit, Gr
- Jokioinen, FI
- Kiruna, SE
- Norrköping, SE
- Visby, SE
- Valentia, IR
- Cabauw, NL
- Zingst, DE
- Lindenberg, DE
- Zugspitze, DE

Asia

- Danum Valley, (MA)
- M. Walliguan (CN)
- Anmyeon (SK)
- Jeju Gosan (SK)
- Ryori (JP)
- Ulleungdo
- Dokdo (SK)

N. America

- Mauna Loa, (US)
- Bratts Lake (CA)

Australia

- Alice Springs, (AU)

Africa

- Cape Point (SA)

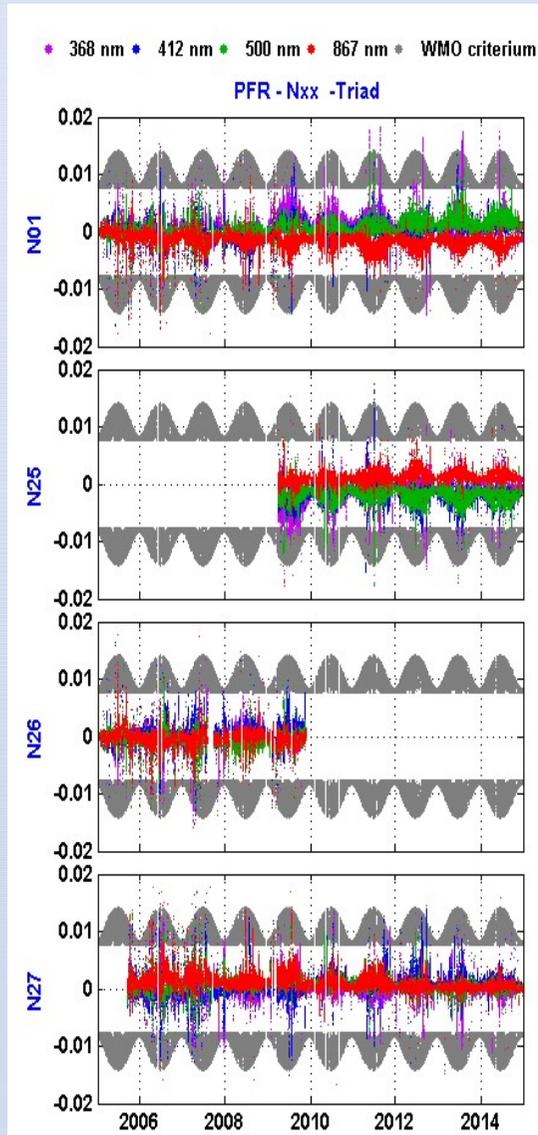
Antarctica

- Marambio (FI)
- Troll (NO)

PMOD WRC triad

Long term stability

WORCC triad maintenance



Davos



Izana



Mauna Loa

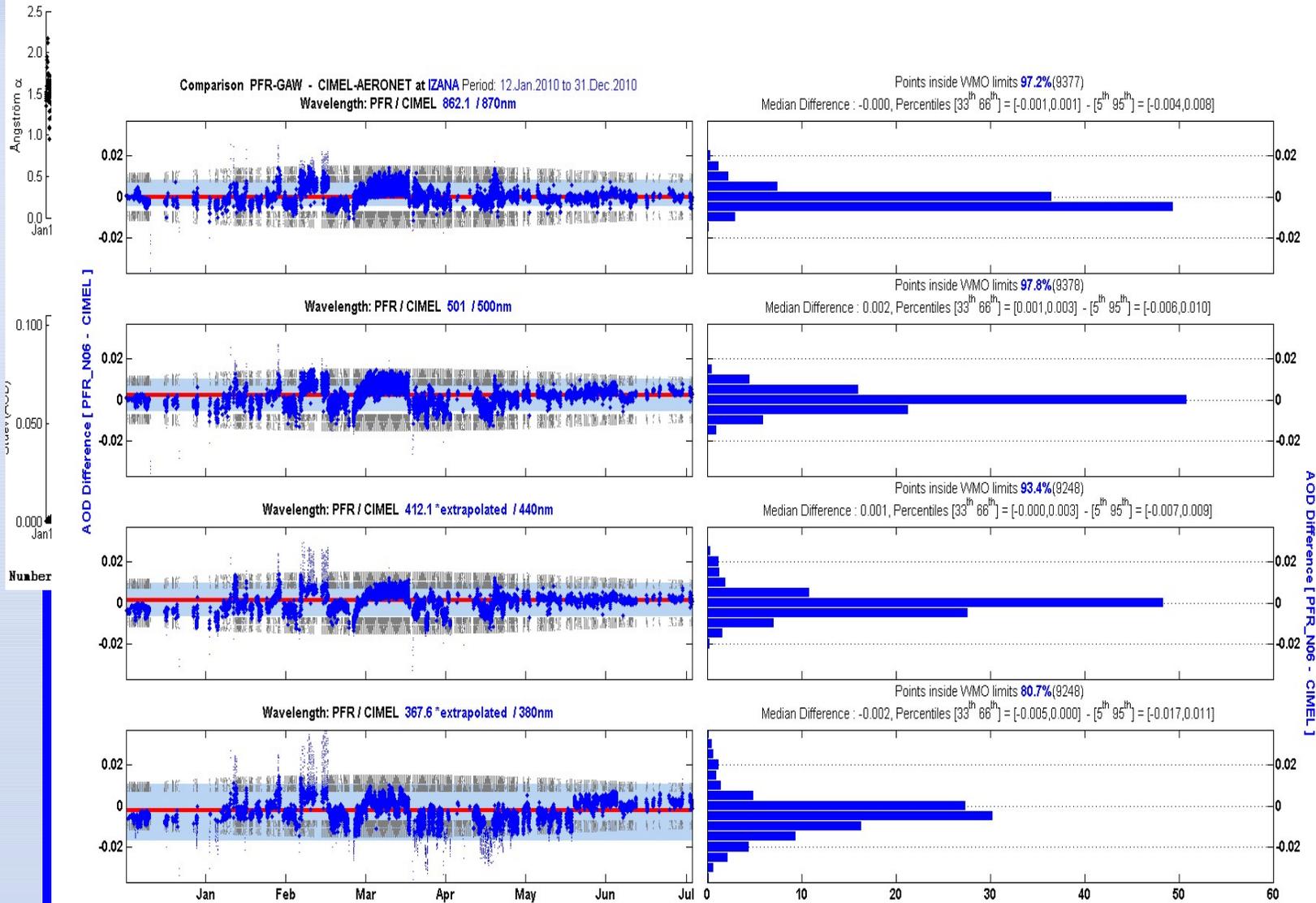
The PFR reference triad has been operating near continuously since early 2005.

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

The scatter of aerosol optical depth measurements at 500 nm with the triad sunphotometers is less than

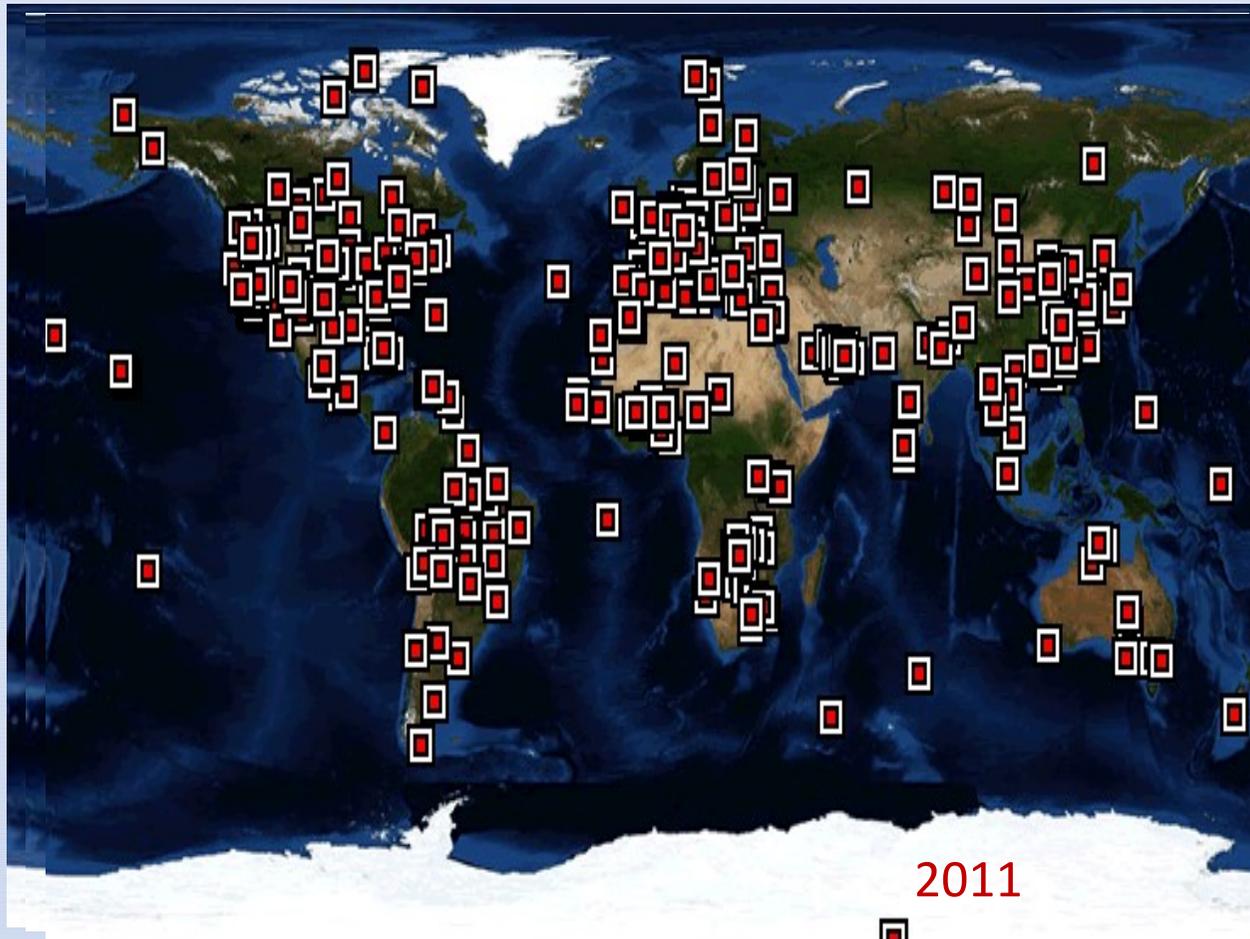
$$0.0002 \pm 0.0011(1\sigma)$$

which is well within the WMO criterion of $0.005 + 0.01/m$



Sunphotometer Networks

Aeronet Network



CIMEL Sun-photometer

Open data access via website: <http://aeronet.gsfc.nasa.gov/>

Sunphotometer Networks

Aerosol Robotic Network (AERONET) Homepage

NASA GODDARD SPACE FLIGHT CENTER [+ Visit NASA.gov](#)

AERONET AEROSOL ROBOTIC NETWORK

+ AEROSOL OPTICAL DEPTH + AEROSOL INVERSIONS + SOLAR FLUX + OCEAN COLOR + DATA SYNERGY TOOL

Home

MISSION

The AERONET (Aerosol Robotic Network) program is a federation of ground-based remote sensing aerosol networks established by NASA and LOA-PHOTONS (CNRS) and greatly expanded by collaborators from national agencies, institutes, universities, individual scientists, and partners. The program provides a long-term, continuous and readily accessible public domain database of aerosol optical, microphysical and radiative properties for aerosol research and characterization, validation of satellite retrievals, and synergism with other databases. The network imposes standardization of instruments, calibration, processing and distribution.

AERONET collaboration provides globally distributed observations of spectral aerosol optical depth (AOD), inversion products, and precipitable water in diverse aerosol regimes. Aerosol optical depth data are computed for three data quality levels: Level 1.0 (unscreened), Level 1.5 (cloud-screened), and Level 2.0 (cloud-screened and quality-assured). Inversions, precipitable water, and other AOD-dependent products are derived from these levels and may implement additional quality checks.

The processing algorithms have evolved from Version 1 to Version 2.0 (fully released in July 2006) and are available from the AERONET and PHOTONS web sites. Version 1 data may be downloaded from the web site through 2006 and thereafter upon special request. New AERONET products will be released as new measurement techniques and algorithms are adopted and validated by the AERONET research community. The AERONET web site also provides AERONET-related news, a description of research and operational activities, related Earth Science links, and an AERONET staff directory.

DATA ACCESS

AEROSOL OPTICAL DEPTH

- + Data Display
- + Download Tool
- + Download All Sites
- + Climatology Tables
- + Climatology Maps

AEROSOL INVERSIONS

- + Data Display
- + V2 Download Tool
- + V1 Download Tool

SOLAR FLUX

- + Data Display

OCEAN COLOR

NEWS

7 November 2006

<http://aeronet.gsfc.nasa.gov/> (1 of 2)20.11.2006 13:52:04

ECARS
10 Apr



<http://aeronet.gsfc.nasa.gov/>

Site: Davos - Additional Site Information

DISCLAIMER AERONET Level 1.0 Real Time Data.
The following AERONET data are unscreened and may not have final calibration applied.

The principal investigator(s) of the Davos site: Christoph Wehrli
If you intend to use the following data please contact principal investigator(s) via e-mail: christoph.wehrli@cam.ac.uk

Operational Time at Davos site
1752 Days [4.800 Years]
Start Date: 05-JUL-2001, Latest Date: 06-APR-2011

Total Processed Data (years represent total data equivalent)
Level 1.0 AOD: 1373 Days [3.762 Years]
Level 1.5 AOD: 1183 Days [3.241 Years]
Level 2.0 AOD: 583 Days [1.597 Years]

[Return to the World Map](#) | [Switch to Version 2 Inversions](#) | [Switch to Version 1 Direct Sun and Inversions](#)

AERONET Data Type:
AOD
Water Vapor
440-570 Angstrom
SCA Fine Coarse AOD
SCA Fine Mode Fraction

Data Display Controls

Related Product Availability for Davos (select each day below):

- SCA Trajectory Analyses - Availability - More information
- MPANET Images - Availability - More information
- Show TERRA-MODIS | AQUA-MODIS Rapid Response Images - Availability - More information
- Landsat Image
- Visible Satellite Images (Check Availability) - More information
- Infrared Satellite Images (Check Availability) - More information

SELECT CHARTS FOR LARGER IMAGES

Choose year: 2001 2004 2005 2006 2007 2008 2009 2010 2011
 Choose month of 2011: JAN FEB MAR APR

Choose day of APR 2011:
 1 2 3 4 5 6 7 8 9 10 11 12
 13 14 15 16 17 18 19 20 21 22 23 24
 25 26 27 28 29 30

AOD Level 1.0 data from APR of 2011
 Davos, N 46°48'46", E 09°50'59", Alt 1596 m, PI : Christoph.Wehrli, christoph.wehrli@podarc.ch
 Level 1.0 AOD; Data from APR 2011

AOD Level 1.0 data from APR 5 of 2011
 Davos, N 46°48'46", E 09°50'59", Alt 1596 m, PI : Christoph.Wehrli, christoph.wehrli@podarc.ch
 Level 1.0 AOD; Data from 5 APR 2011

AERONET DOWNLOAD

- AOD Level 1.0
- AOD Level 1.5
- SCA Level 1.0
- SCA Level 1.5
- Raw Altimeters
- Raw Principal Planes
- More AERONET Downloadable Products...

AERONET DOWNLOAD

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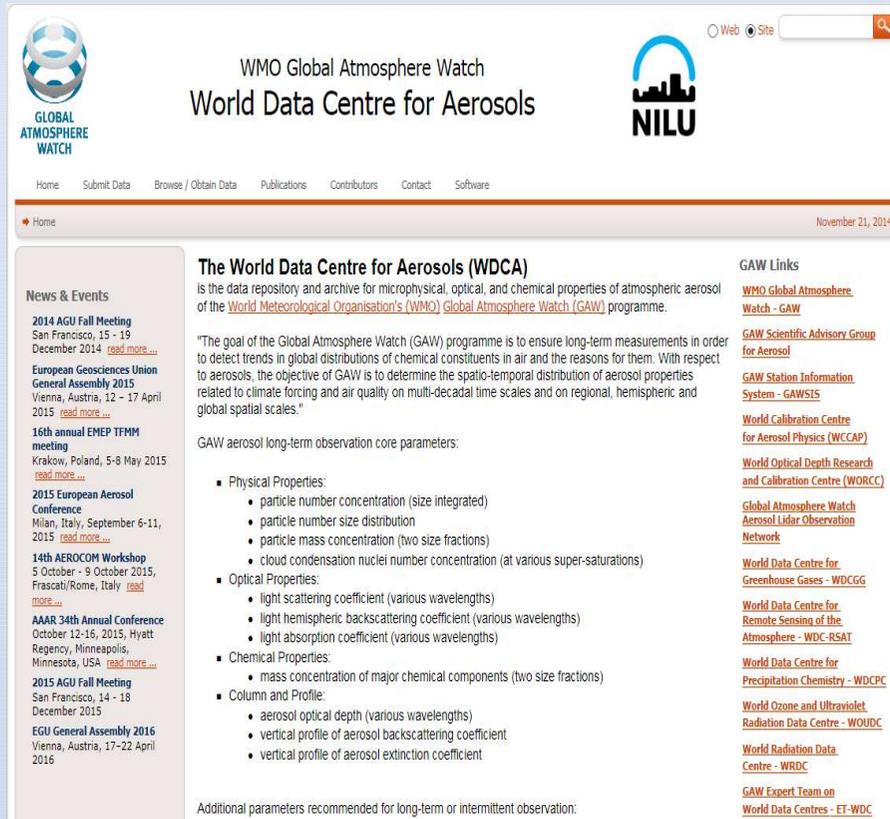
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+ Privacy Policy and Important Notices

NASA
 Curator: David M. Giles
 NASA Official: Brent N. Holben
 Generated: 04/07/2011

Sunphotometer Networks

World Data Center for Aerosols



WMO Global Atmosphere Watch
World Data Centre for Aerosols

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November 21, 2014

The World Data Centre for Aerosols (WDCA)

is the data repository and archive for microphysical, optical, and chemical properties of atmospheric aerosol of the [World Meteorological Organisation's \(WMO\) Global Atmosphere Watch \(GAW\)](#) programme.

"The goal of the Global Atmosphere Watch (GAW) programme is to ensure long-term measurements in order to detect trends in global distributions of chemical constituents in air and the reasons for them. With respect to aerosols, the objective of GAW is to determine the spatio-temporal distribution of aerosol properties related to climate forcing and air quality on multi-decadal time scales and on regional, hemispheric and global spatial scales."

GAW aerosol long-term observation core parameters:

- Physical Properties:
 - particle number concentration (size integrated)
 - particle number size distribution
 - particle mass concentration (two size fractions)
 - cloud condensation nuclei number concentration (at various super-saturations)
- Optical Properties:
 - light scattering coefficient (various wavelengths)
 - light hemispheric backscattering coefficient (various wavelengths)
 - light absorption coefficient (various wavelengths)
- Chemical Properties:
 - mass concentration of major chemical components (two size fractions)
- Column and Profile:
 - aerosol optical depth (various wavelengths)
 - vertical profile of aerosol backscattering coefficient
 - vertical profile of aerosol extinction coefficient

Additional parameters recommended for long-term or intermittent observation:

GAW Links

- [WMO Global Atmosphere Watch - GAW](#)
- [GAW Scientific Advisory Group for Aerosol](#)
- [GAW Station Information System - GAW/SIS](#)
- [World Calibration Centre for Aerosol Physics \(WCCAP\)](#)
- [World Optical Depth Research and Calibration Centre \(WORCC\)](#)
- [Global Atmosphere Watch Aerosol Lidar Observation Network](#)
- [World Data Centre for Greenhouse Gases - WDCGG](#)
- [World Data Centre for Remote Sensing of the Atmosphere - WDC-RSAT](#)
- [World Data Centre for Precipitation Chemistry - WDCPC](#)
- [World Ozone and Ultraviolet Radiation Data Centre - WOUDC](#)
- [World Radiation Data Centre - WRDC](#)
- [GAW Expert Team on World Data Centres - ET-WDC](#)



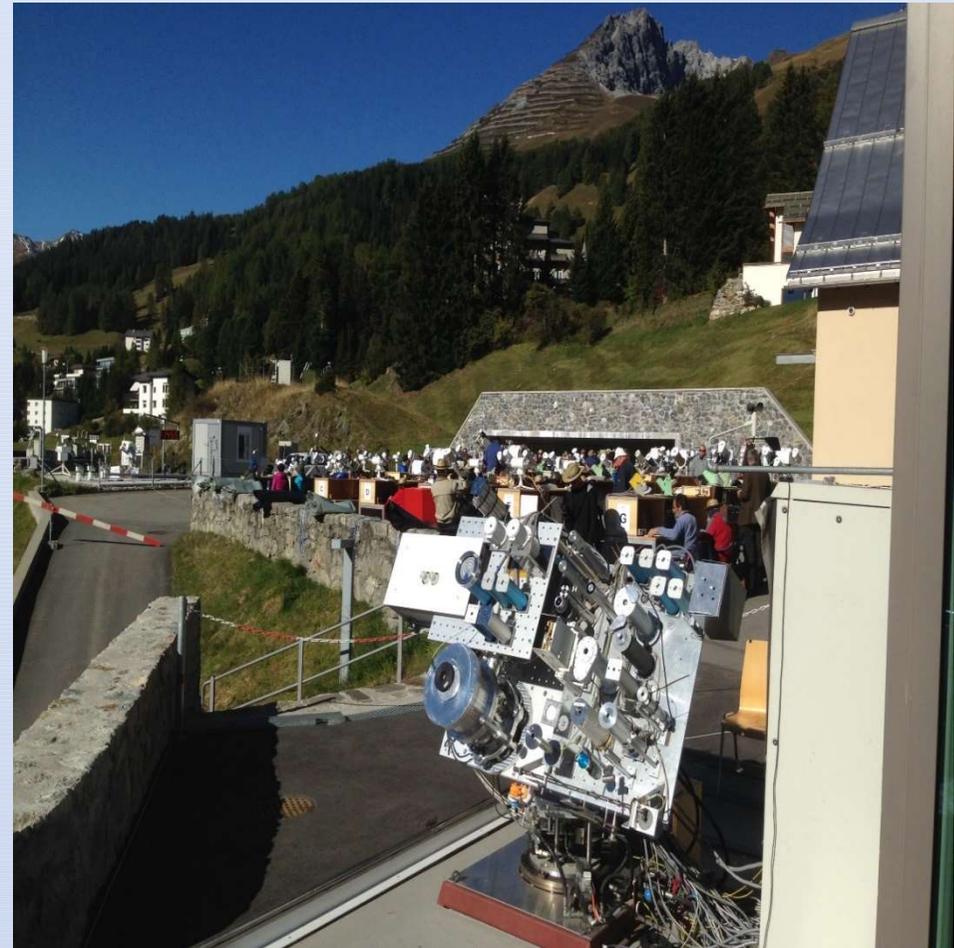
(IPC-XII) / 4th Filter-Radiometer Comparison (2015, Davos)

Sep, 28-Oct to 16, 2015, PMO Davos

- 12th International Pyrheliometer Comparison (IPC-XII)
- **4th Filter-Radiometer Comparison (FRC-IV)**
- 2nd International Pyrgeometer Comparison (IPgC-II).

organized by the World Radiation Center (WRC) on behalf of the World Meteorological Organization (WMO).

<http://projects.pmodwrc.ch/ipc-xii/>



History ..

2000: FRC – I

Instrument signal comparison

7 wavelengths, 17 radiometers, 1 day measurements

common processing $\rightarrow \delta\delta \approx 0.016$ @ 500nm (N=8)

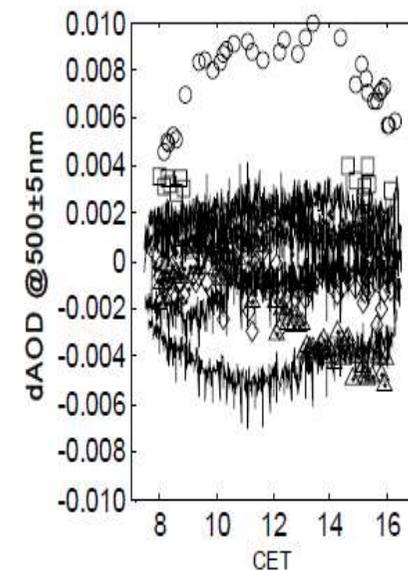
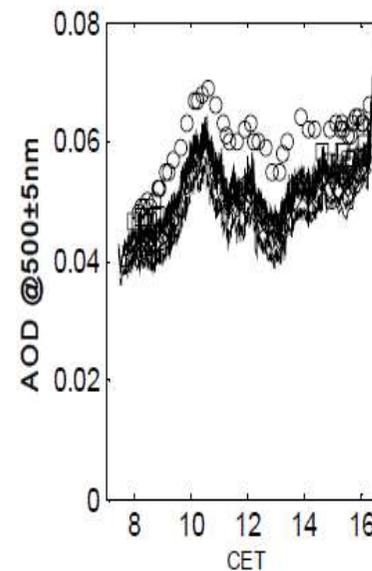


2005: FRC – II AOD results

12 instruments at wavelengths $500 \pm 3\text{nm}$ & $865 \pm 5\text{nm}$,

specific processing

comparison according to WMO recommendations (2004)

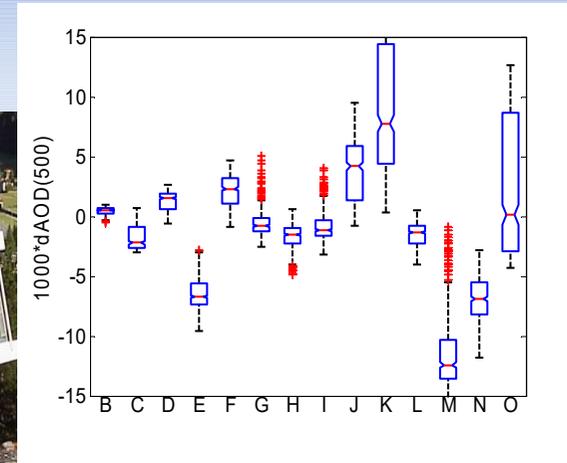
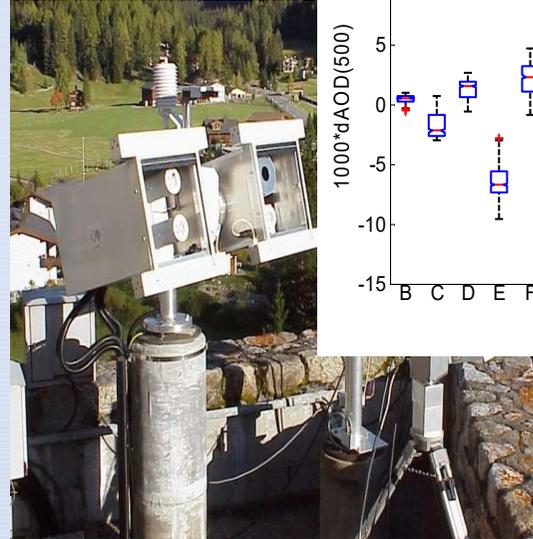


History ..

2010: FRC – III AOD results

17 instruments at wavelengths
 $500 \pm 3 \text{ nm}$ & $865 \pm 5 \text{ nm}$,

Individual processing



FRC-IV 2015

AOD Comparison at wavelengths $367 \pm 5 \text{ nm}$, $412 \pm 5 \text{ nm}$, $500 \pm 3 \text{ nm}$ & $865 \pm 5 \text{ nm}$, Ångström exponents

specific processing by participants comparison according to WMO recommendations (2004)

30 Instruments, 12 countries



Assessment of AOD Quality

WMO Report No. 162 (2005) discusses criteria for AOD quality:

“The ability to trace calibration to a primary reference(s) (i.e. traceability) not currently possible based on physical meas. systems. Hence, traceability based on AOD difference criteria”

- an inter-comparison or co-location traceability will be established if AOD difference between networks is within specific limits
- Inter-comparisons should be long enough such that:
 - a) ≥ 1000 coincident AOD data points
 - b) Minimum 5 sunny days
 - c) AOD (500 nm) $\sim 0.040 - 0.200$
- For traceability, 95% of AOD difference should lie within:
$$U_{95} < \pm(0.005 + 0.010/\text{airmass})$$

FRC/Participating Instruments 30 instruments – 15 groups – 12 countries

PFR	CIMEL	MFRSR	PSR	POM-2	SPO2	SSIM	Microtops
WORCC Triad-CH (3) SMHI-SE DWD-DE PMOD-CH (3) MeteoSwiss-CH	PMOD-CH AERONET-EU IZANA-ESP	DWD-DE NASA-US1 NOAA-US2 NOAA-US3	DWDa-DE DWDb-DE PMOD-CH	DWD-DE ARPA-IT JMA-JP KACARE-SA	BMa-AU NOAA-US	COFa-CA COFb-CA COFc-CA COFd-CA	MIC-GR
GAW-PFR	AERONET-EU	SURFRAD	DWD	SKYNET	AU-NET		
							
Direct sun wl: 368, 412, 500, 863 nm Fwhm: 3.8- 5.4nm FOV=2.5 deg Meas: 1 minute	Direct sun wl: 340, 379, 440, 500, 670, 870, 1021 nm Fwhm: 10 nm FOV=1.2 deg Meas: ~15 minute	Global+diffuse wl: 415, 500, 610, 665, 860, 940 nm Fwhm: 10 nm FOV = variable Meas: 1 minute	Direct sun spec wl: 320-1000 nm Fwhm: 1.5-6 nm FOV=1.5 deg Meas: ~10 sec	Direct sun spec wl: 315, 340, 380, 400, 500, 675, 870, 940, 1020, 1627, 2200 nm Fwhm: 10 nm FOV=1 deg Meas: 1 min	Direct sun spec wl: 368, 412, 502, 675, 778, 812, 862nm Fwhm: 5 nm FOV=2.4 deg Meas: 1 min	Direct sun spec wl: 6 filters Fwhm: 5 nm FOV=2 deg Meas: 1 min	Direct sun spec wl: 6 filters Fwhm: 10 nm FOV=2.5 deg Meas: 1 min

Participating Instruments - Networks

AERONET

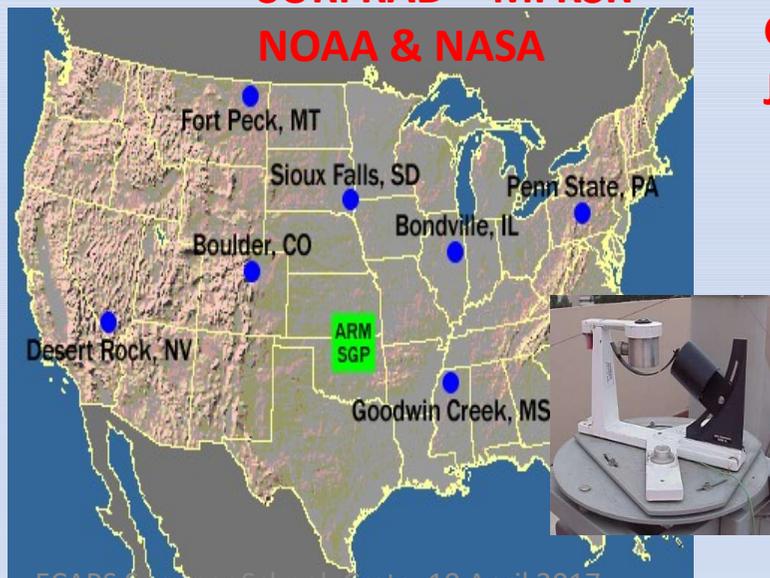


GAW-PFR



National Networks:
Australia
USA
Germany
Japan

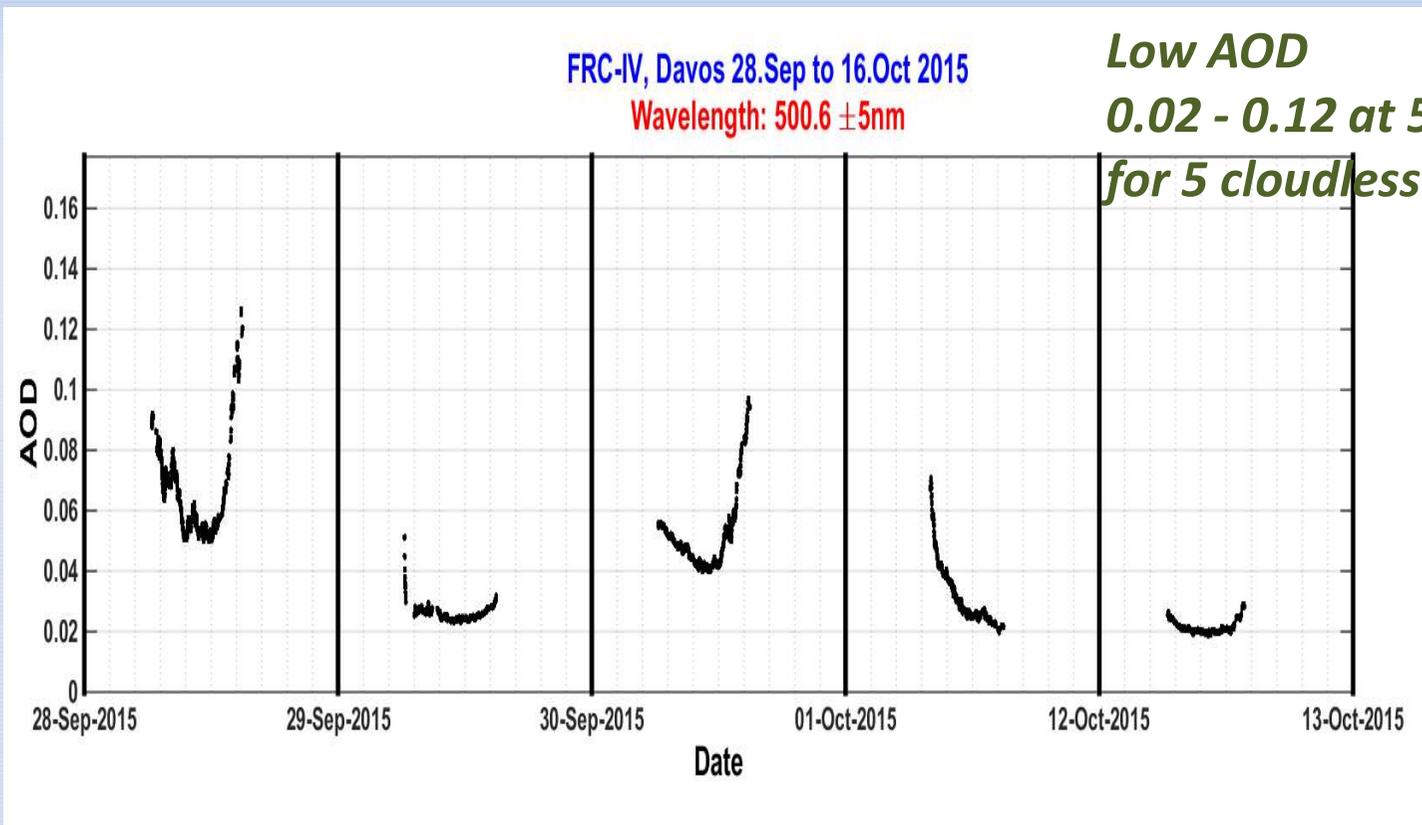
SURFRAD – MFRSR NOAA & NASA



Skynet



AOD variability during the campaign



samples at 500nm (PFR, POM-2, SPO, MFRSR, PSR, SIM: 1100-2000, CIMEL: ~300, 750, MIC: 350)

Duration ≥ 5 days OK

AOD₅₀₀ within 0.040 ÷ 0.200 OD .. OK

U95: dAOD ≤ 0.005 + 0.01/m

Reference triad performance

WORCC triad

Izana, Tenerife, Spain

Mauna Loa, Hawaii, USA



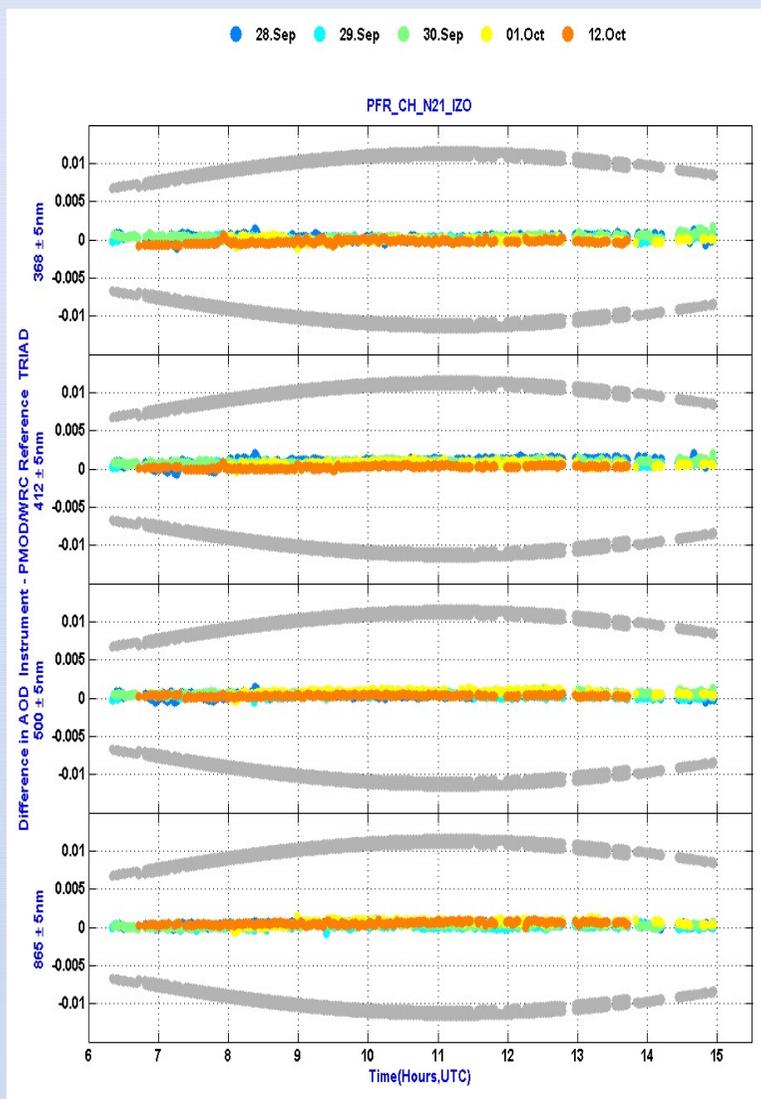
N06, N21

N24



Davos, CH

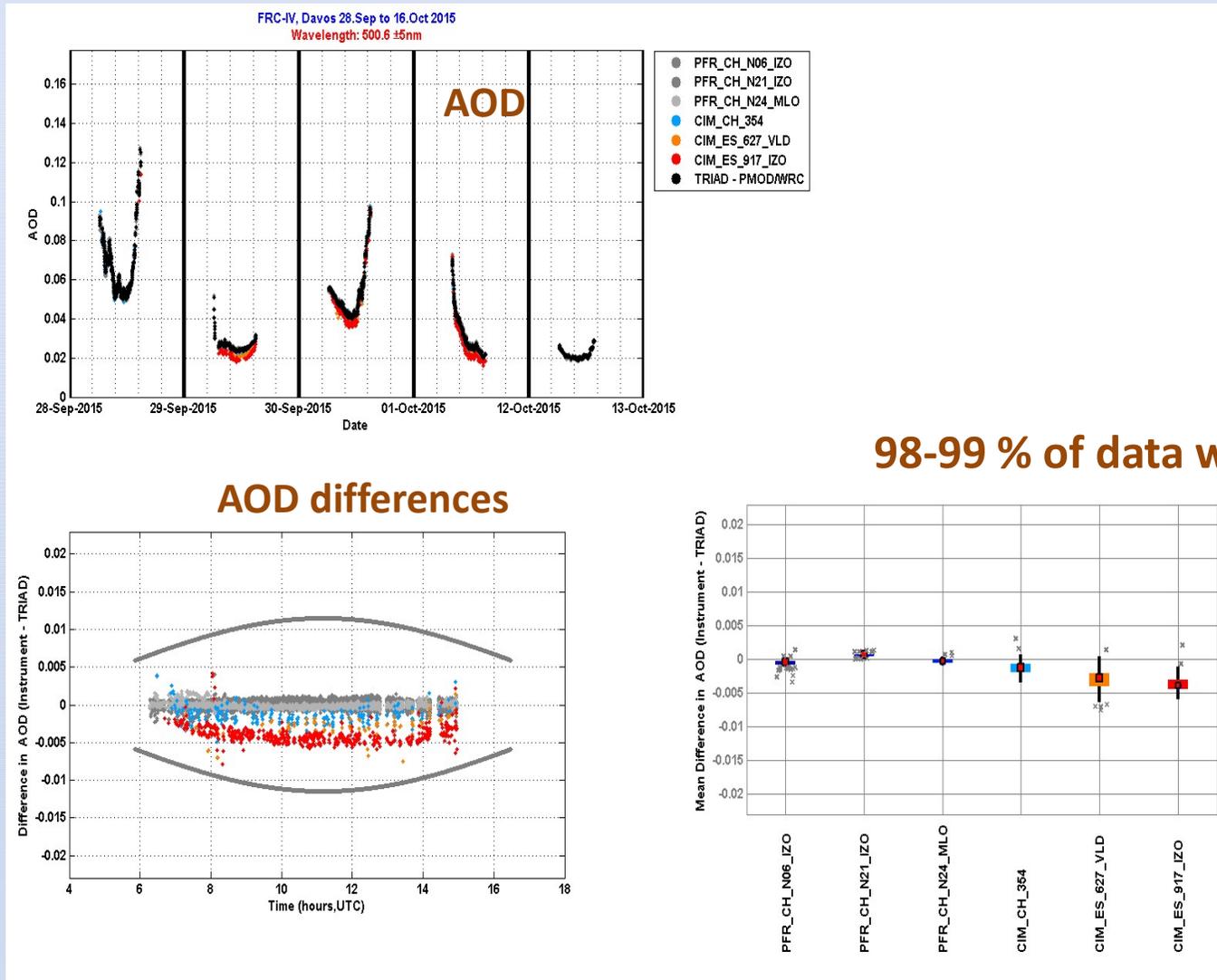
Triad recalibration
Before the campaign



AOD dif < 0.001

The 4th Filter Radiometer Comparison

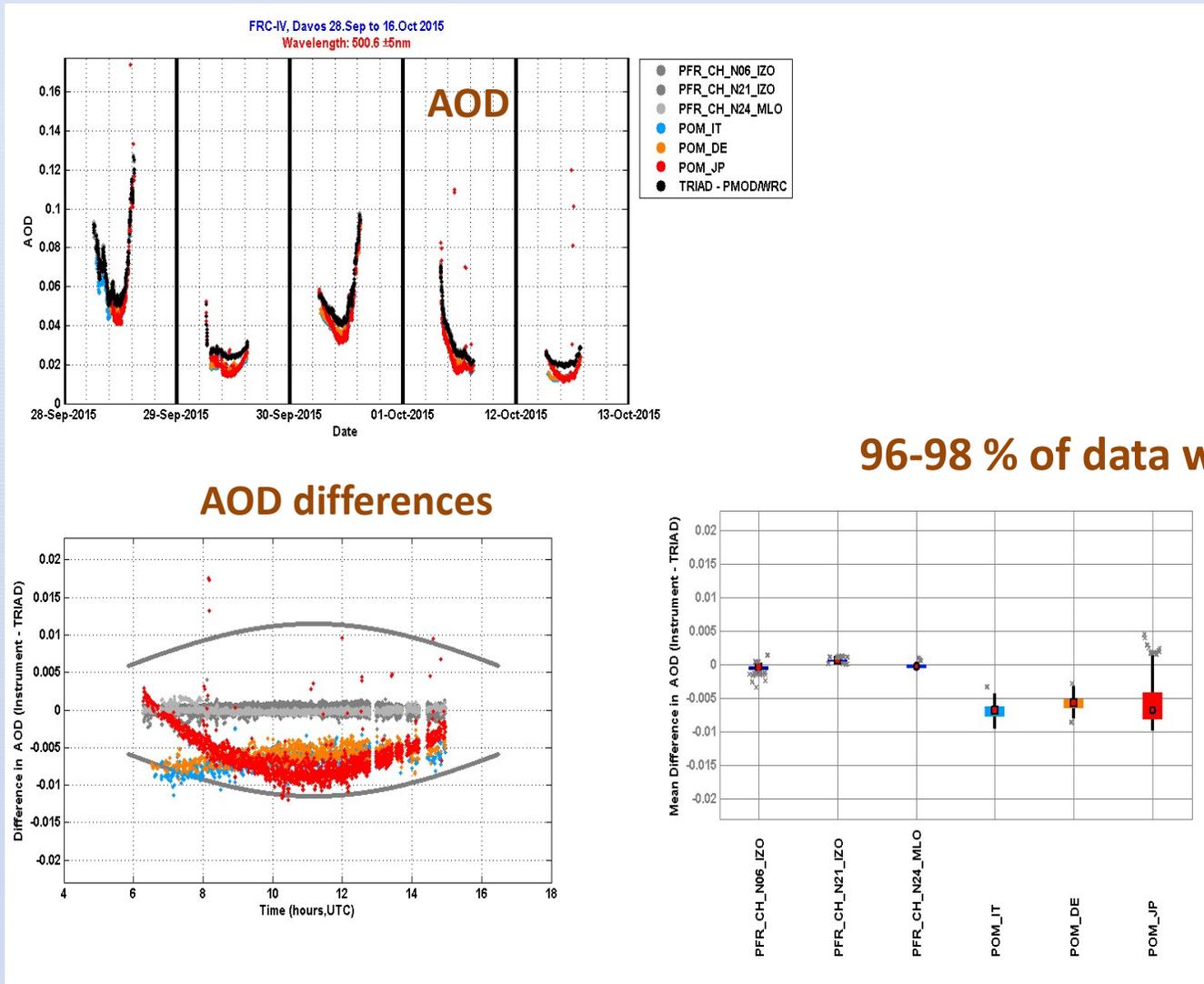
CIMEL (AERONET) instrument comparison at 500nm



98-99 % of data within WMO limits

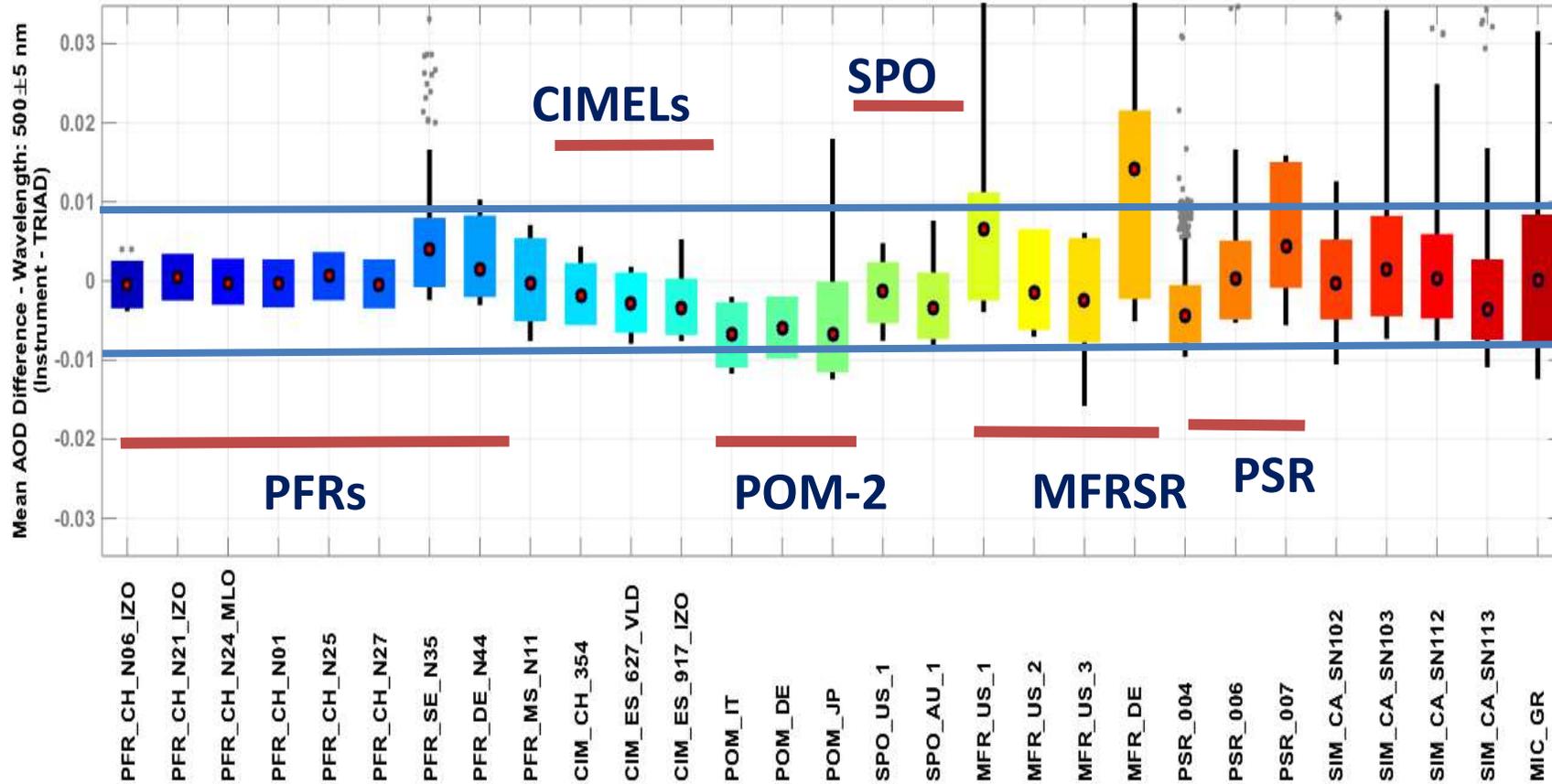
The 4th Filter Radiometer Comparison

POM-2 (SKYNET) instrument comparison at 500nm



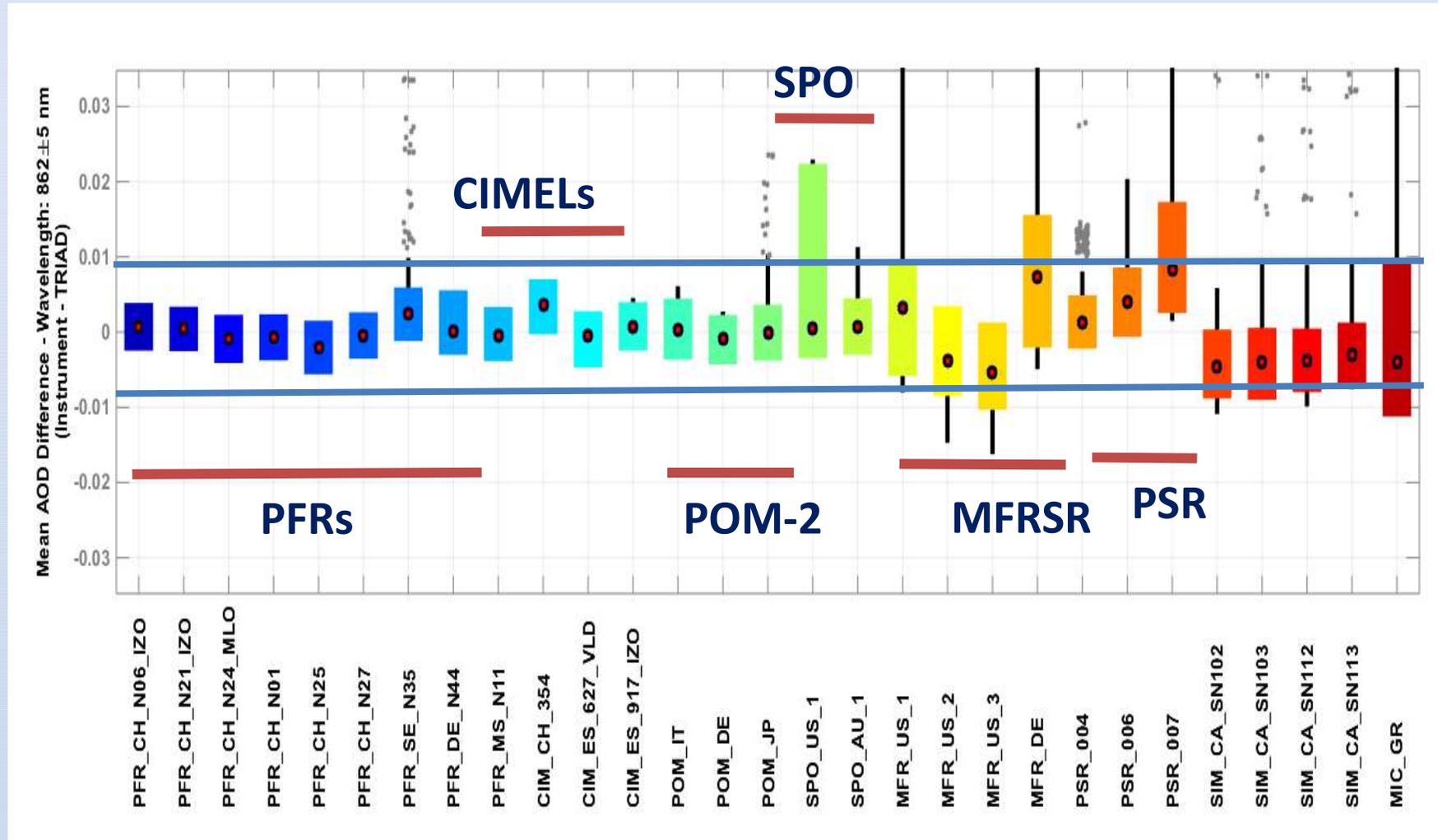
The 4th FRC results

AOD differences at 500 nm

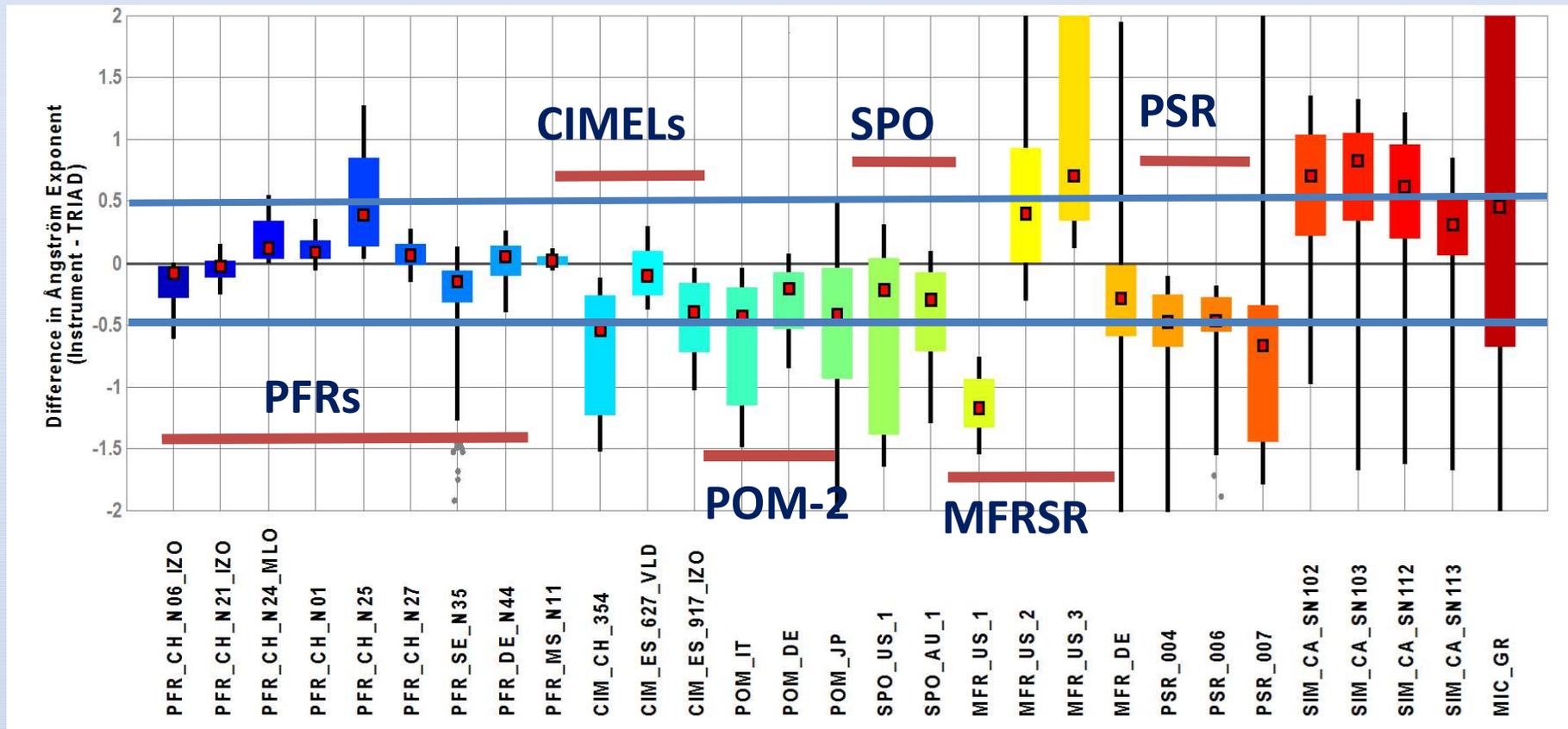


The 4th FRC results

AOD differences at 865 nm

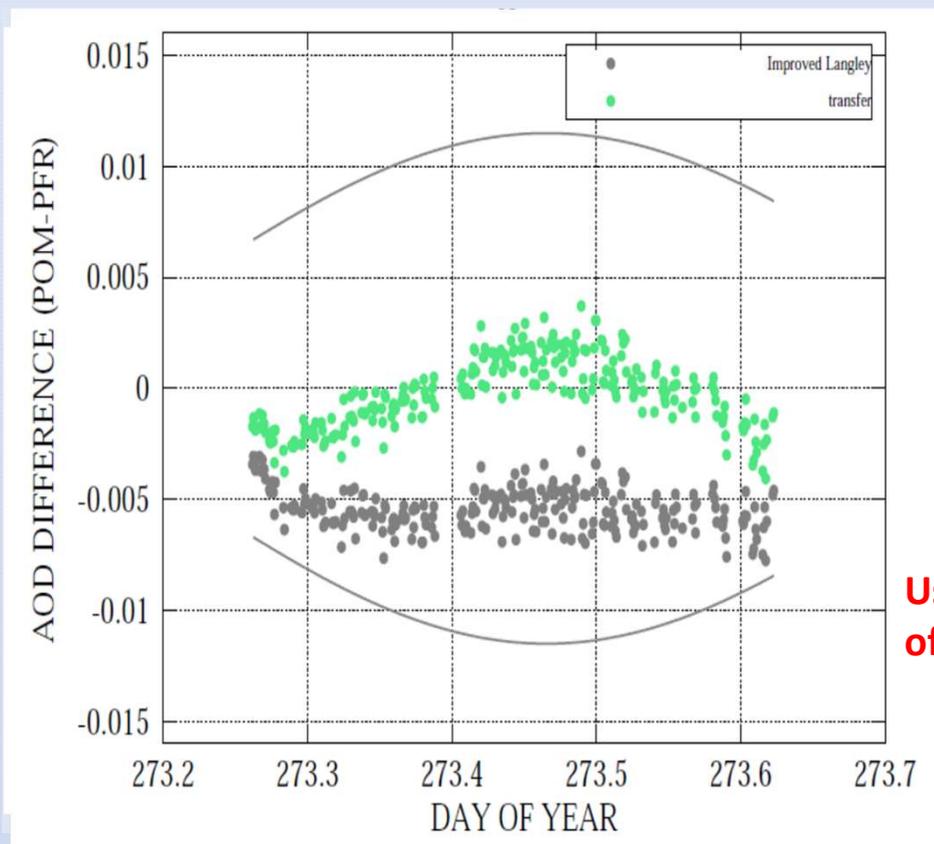


Ångström Exponents



Conclusions

- Calibration uncertainties, methods used for calibration and AOD retrieval, instrument measuring principles contribute to the observed dispersions



POM2 – triad at 500nm offset ~ 0.008

**Using GAW-PFR algorithm
offset ~ 0.005**

**Using GAW-PFR algorithm & calibration
offset ~ 0.002**

Conclusions

- Agreement for AOD at 500nm and 865nm
- Angstrom Exponent still doubtful for AOD ~ 0.1
- Cloud screening differences
- Processing differences (ozone, NO₂ ..)
- High AOD comparisons (field of view + issues)
- Long term comparisons
- Results could be used as a starting point for global AOD homogeneity initiatives among different Networks

WMO report

https://www.wmo.int/pages/prog/arep/gaw/documents/GAW_Report_No_231_7_Nov.pdf

Google: WMO report 231 FRC

Permanent Cimel-PFR comparison at Izaña



Period: from 20/01/2005 to 9/11/2014

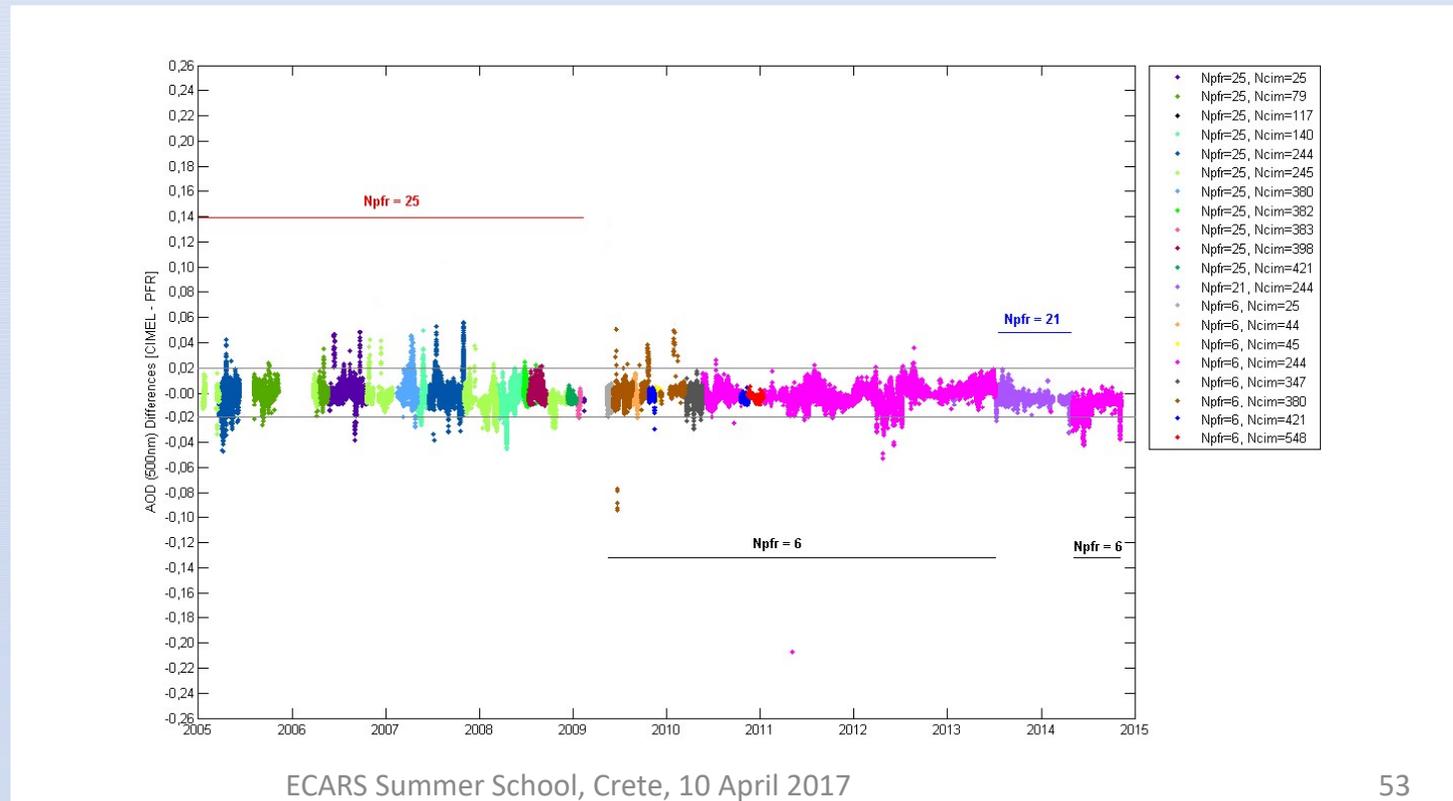


Long-term Intercomparison Cimel/AERONET – PFR/GAW at Izaña

1' minute simultaneous Cimel-PFR AOD data at 4 channels (2 actual channels)

15 CIMELs and 3 PFRs were used in this period

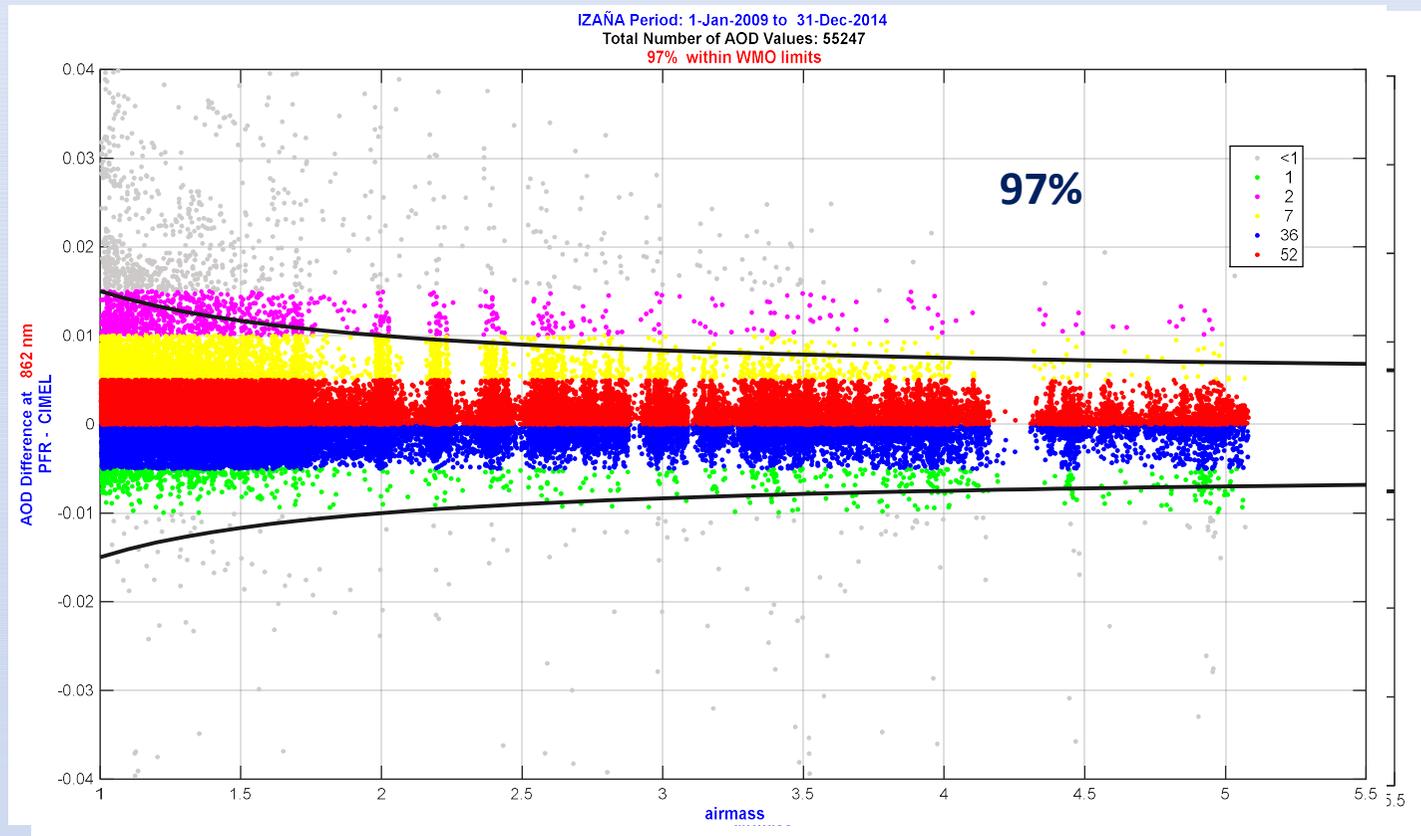
CIMELs	PFRs
25	N25
44	N06
45	N21
79	
117	
140	
244	
245	
347	
380	
382	
383	
398	
421	
548	



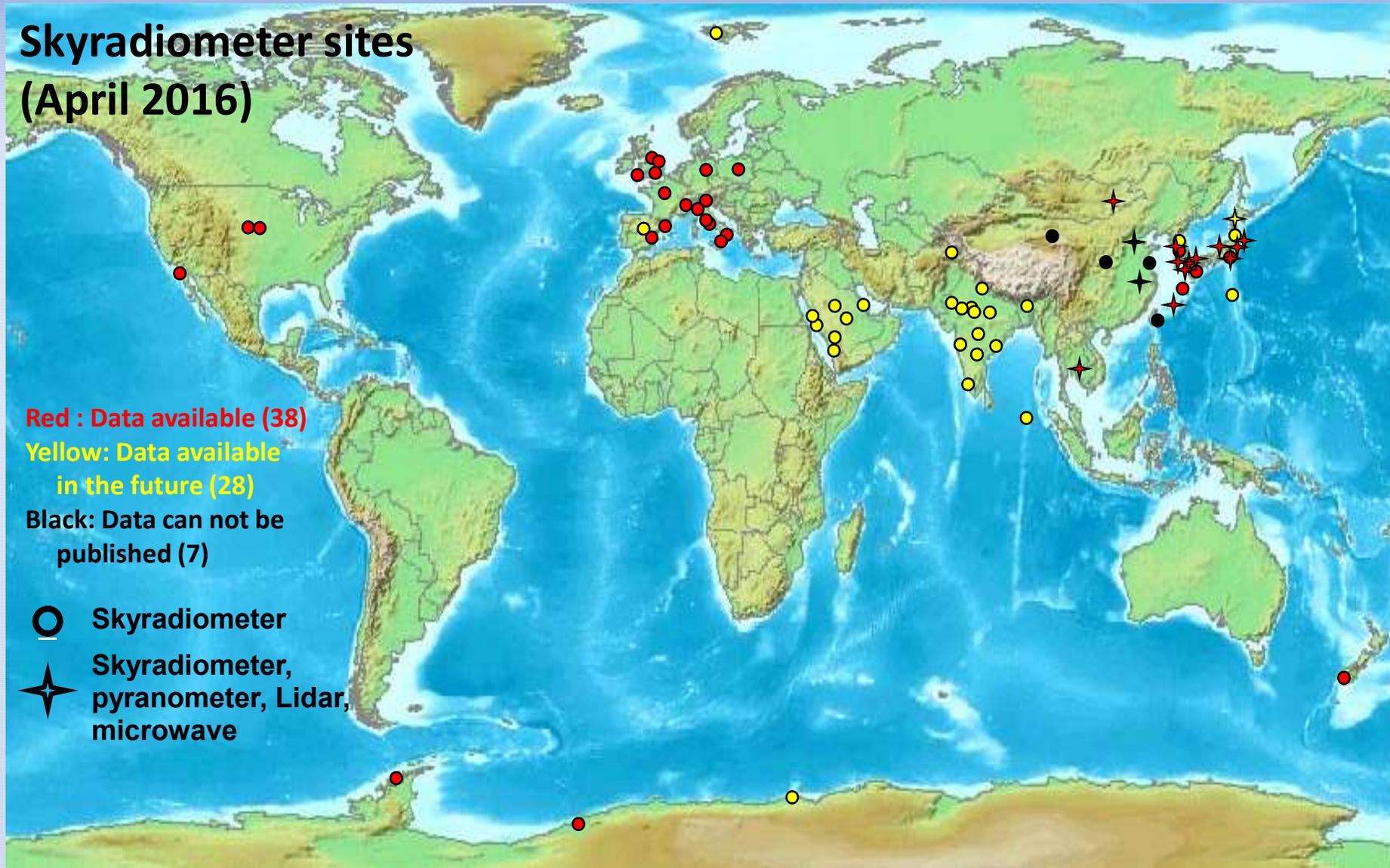
WORCC and AERONET / EUROPE

Collaboration of PMOD/WORCC with Izaña observatory:

- Langley calibration of PFRs and triad calibration transfer
- Calibration PSR, lunar PFR, UV-PFR
- Long term comparison of CIMEL and PFR
- Link long term traceability of GAW-PFR and AERONET/Europe



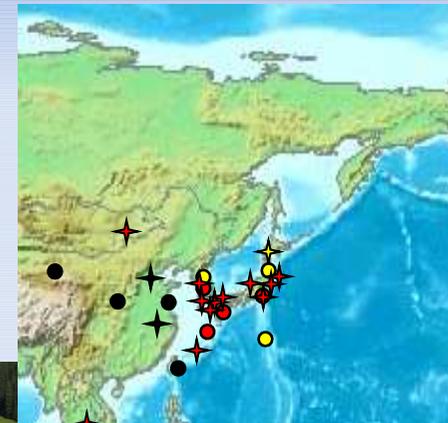
Skyradiometer sites (April 2016)



SKY-NET / POM-2 instruments: looking for permanent traceability to WORCC

Chiba – Japan: 1/2016 – today

PFR vs CIMEL



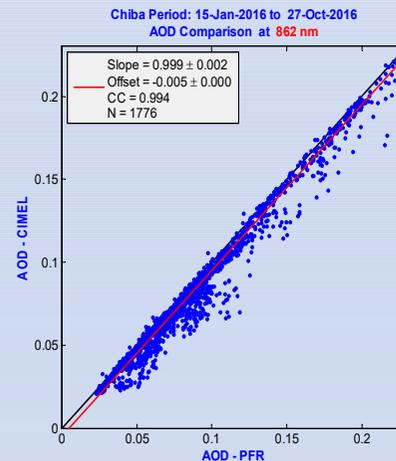
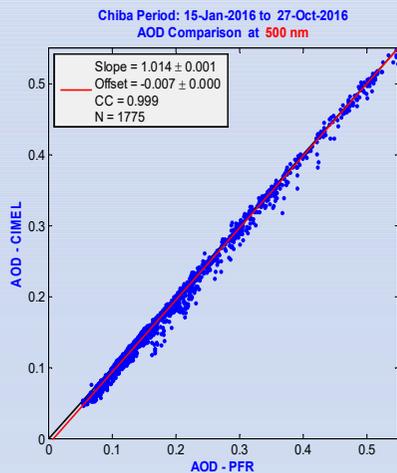
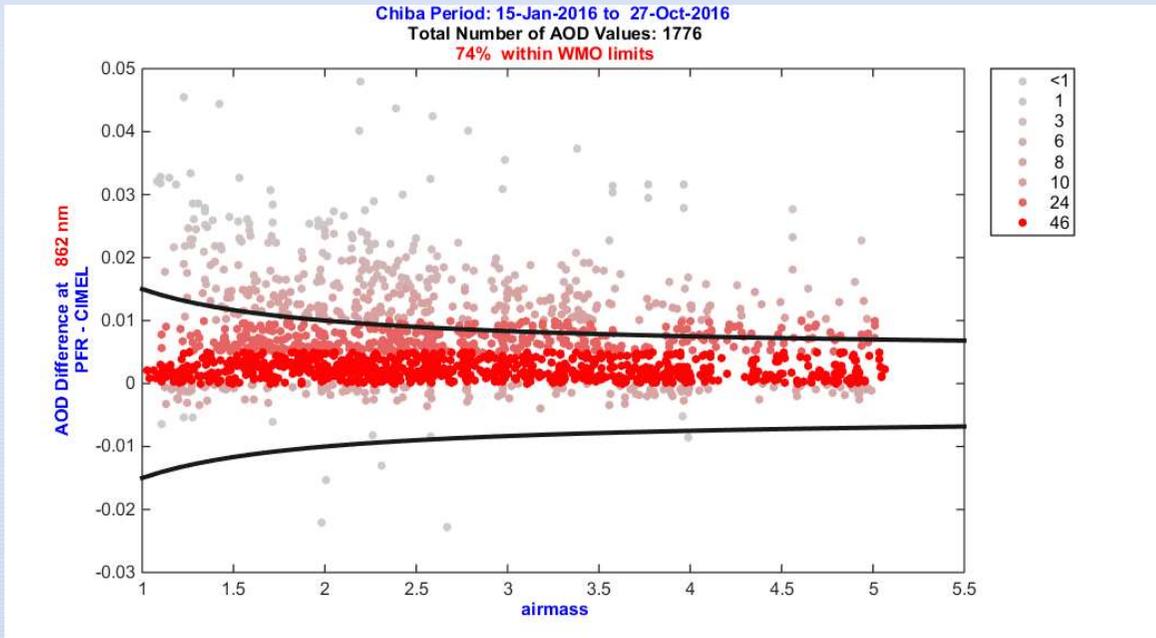
PFR



CIMEL

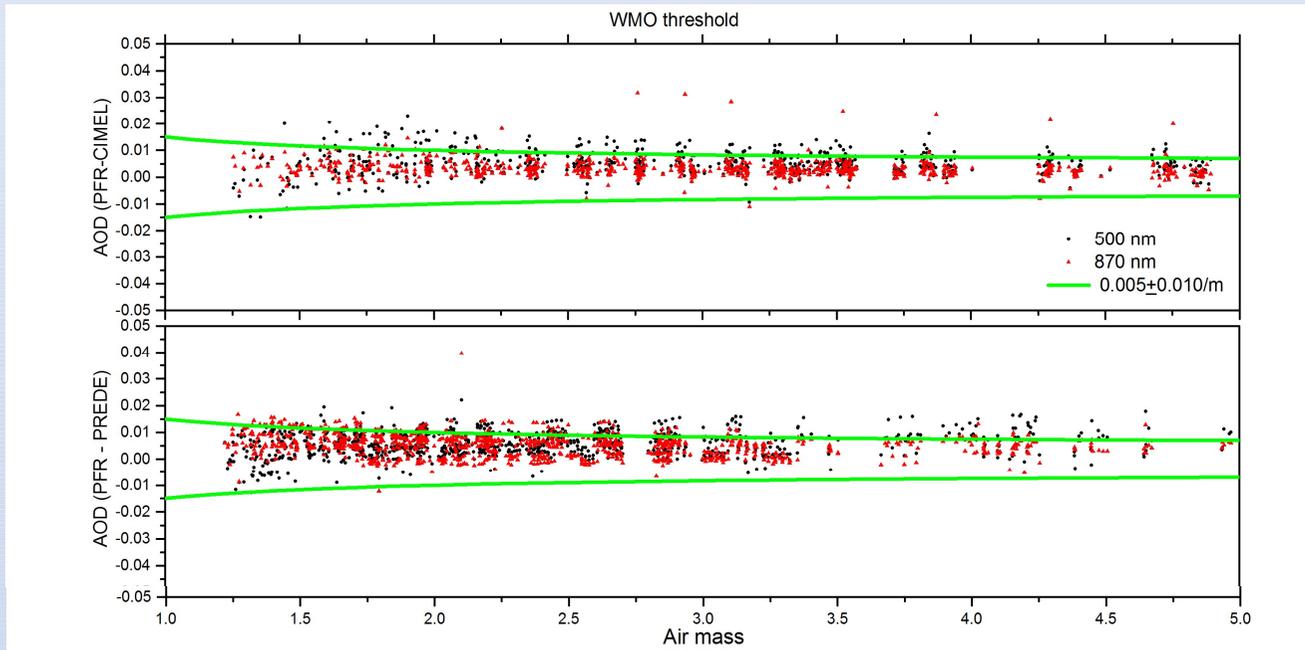
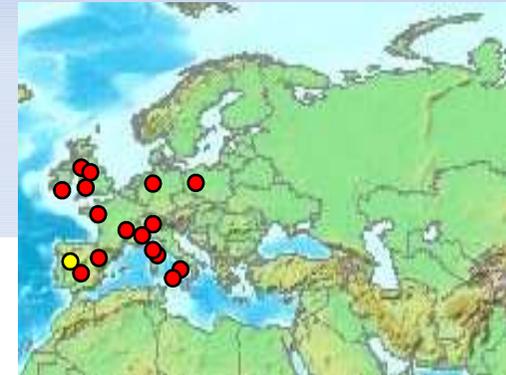


POM-2



SKY-NET / POM-2 instruments: looking for permanent traceability to WORCC

Valencia – Spain: 2/2015 – 1/2016



Campanelli, Kazadzis, et al.,: The SKYNET radiometer Network: Aerosol Optical Depth retrieval performance at the FRC-IV campaign and long-term comparison against GAW-PFR and AERONET standard instruments, WMO-TECO, 2016



Atmospheric Aerosol Eddies and Flows NASA GSFC Space Science Full HD Video.mov



Thank you