Installation and performance of instrumentation to measure aerosols in the frame of MACCLIMA

(MAC2/3.5b/380)

África Barreto

PI Aerosol Group, Izaña Atmospheric Research Center – AEMET

03/02/2023

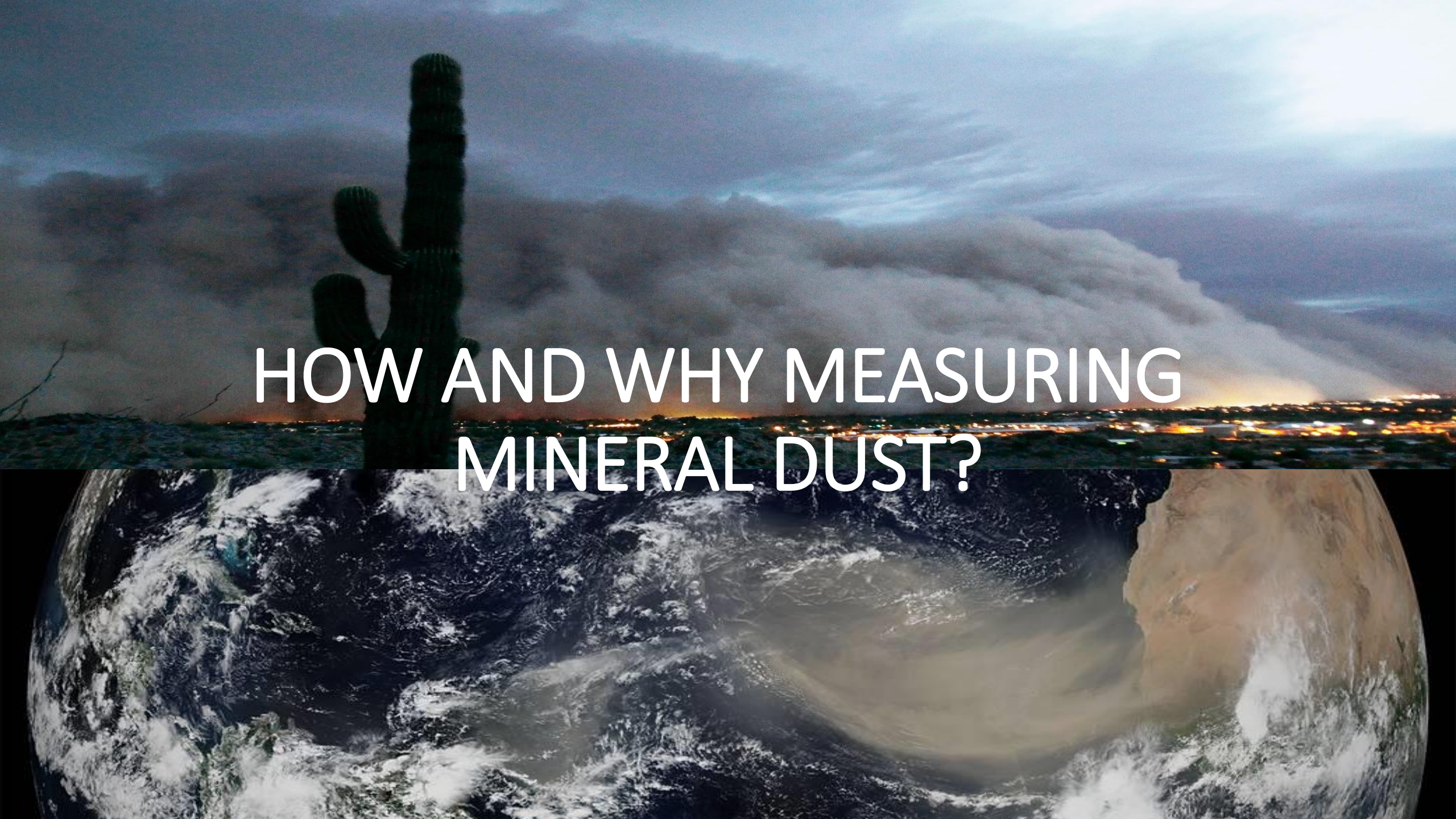
Activity 2.1.2 Increase the technical and human training of actors responsible for meteorological and oceanographic observation of the phenomenon of climate change in the cooperation area, framed in the MAC-CLIMA Project (MAC2/3.5b/254) approved in the framework of the INTERREG VA-Madeira-Açores-Canaries (MAC) territorial cooperation program 2014-2020, 85% co-financed with ERDF funds.

MACCLIMA

OBJECTIVE: Increase the technical and human training of the actors responsible for meteorological and oceanographic observations of the climate change phenomenon as a cooperative project within the Macaronesian Region.

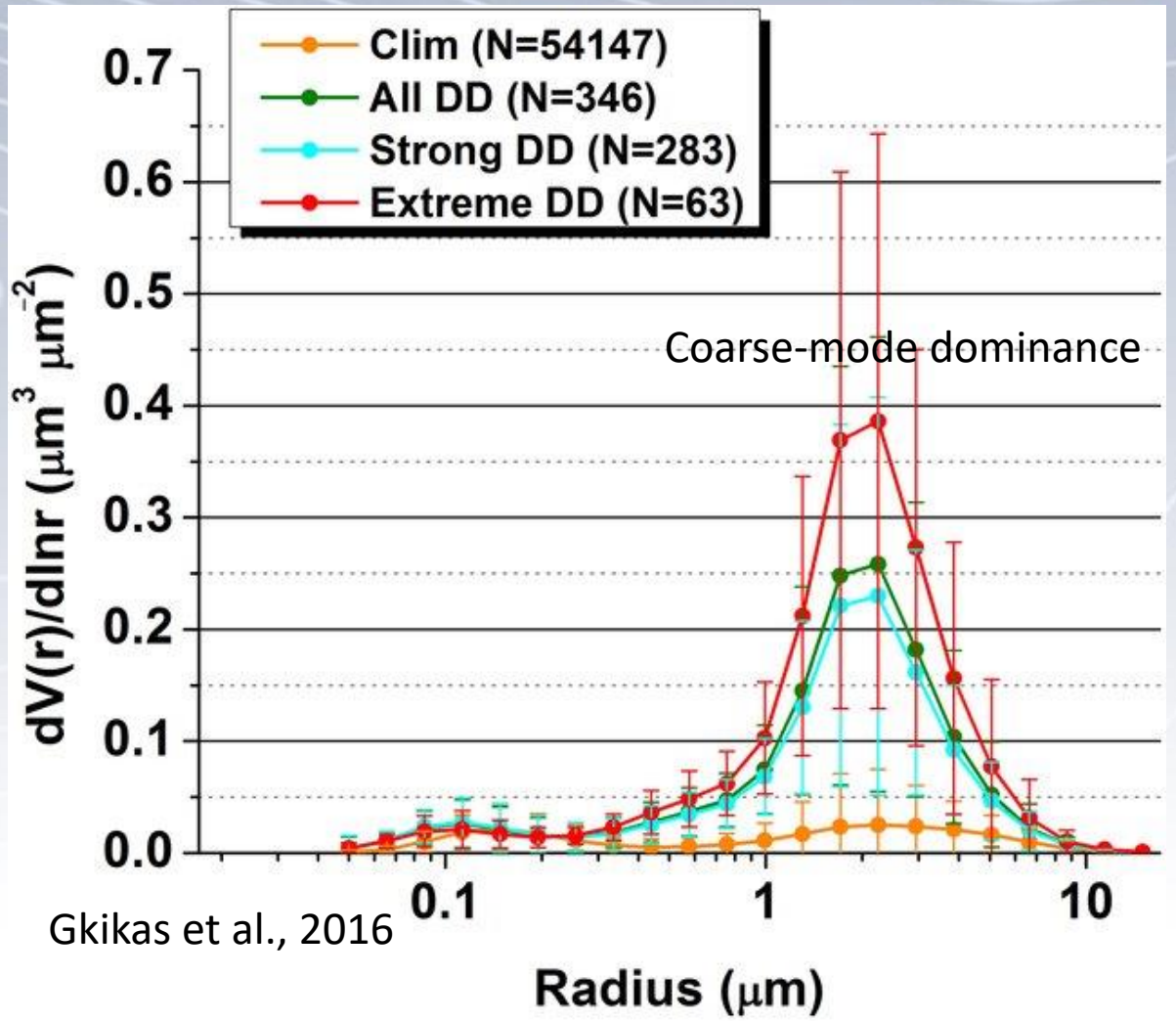
OUTPUT: Warning Advisory products for airborne dust for specific regions in order to mitigate those hazards impacting on vulnerable sectors (agriculture, public health, aviation, etc).

NEEDS: Provide observational data to validate the model outputs – Operate and provide aerosol information with the two instruments selected for MACCLIMA.



HOW AND WHY MEASURING MINERAL DUST?

Lindqvist et al. (2014)



Coarse-mode dominance

Gkikas et al., 2016

coarse mode increased by factors ≈10

Typical ranges in the size of mineral dust particles

In terms of Air Quality: Particulate Matter PM

PM10 mass concentration (µg/m^3) of all aerosols smaller than 10 µm (particles with Ø < 10 µm)

PM2.5 mass concentration (µg/m^3) of all aerosols smaller than 2,5 µm (particles with Ø < 2,5 µm)

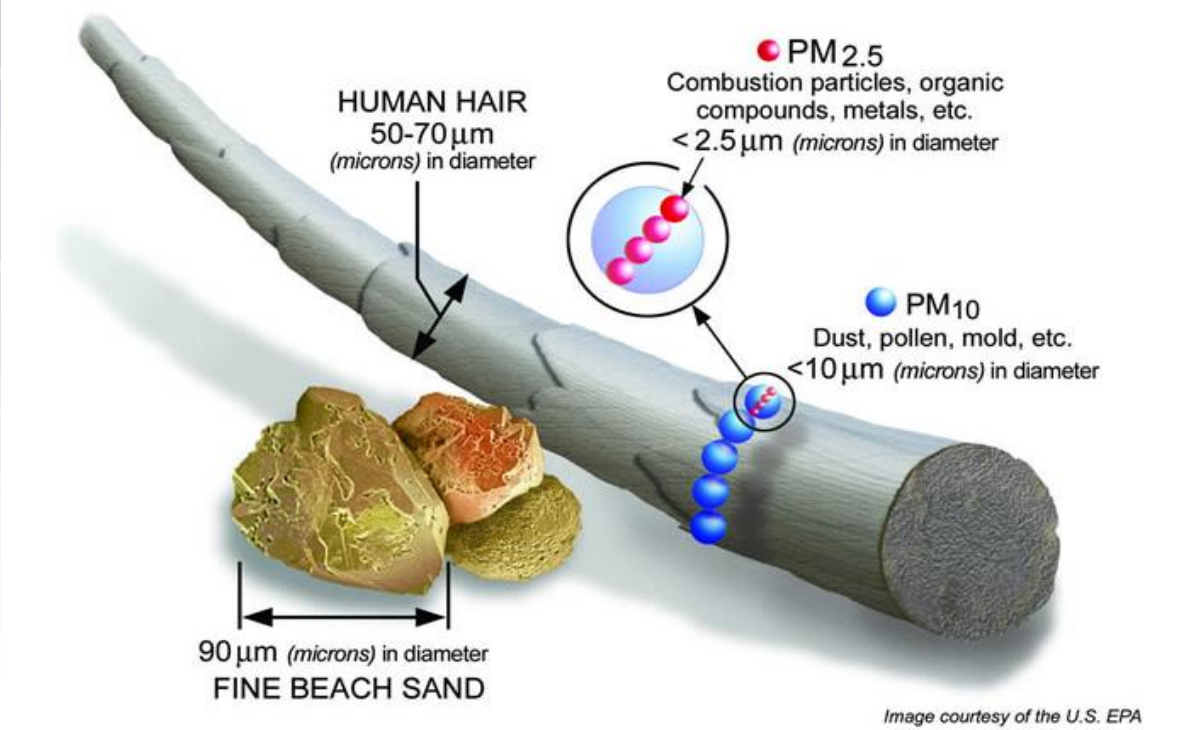


Image courtesy of the U.S. EPA

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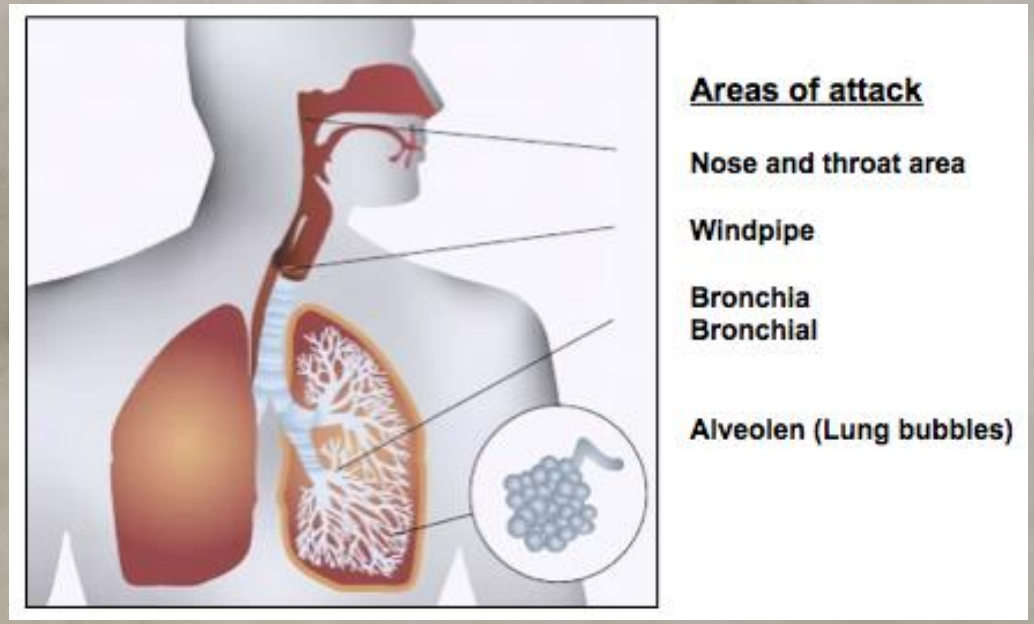
Aerosols and Health

- Particles suspended in the air enter our body when we breathe
- Associated hazard depend on chemical composition and where they deposit within the respiratory system
- These effects include **infectious diseases** (meningitis and valley fever), **respiratory problems** or **cardiovascular diseases**, sometimes even leading to cancer



Aerosols (Dust) ground-based detection

REMOTE SENSING

IN-SITU

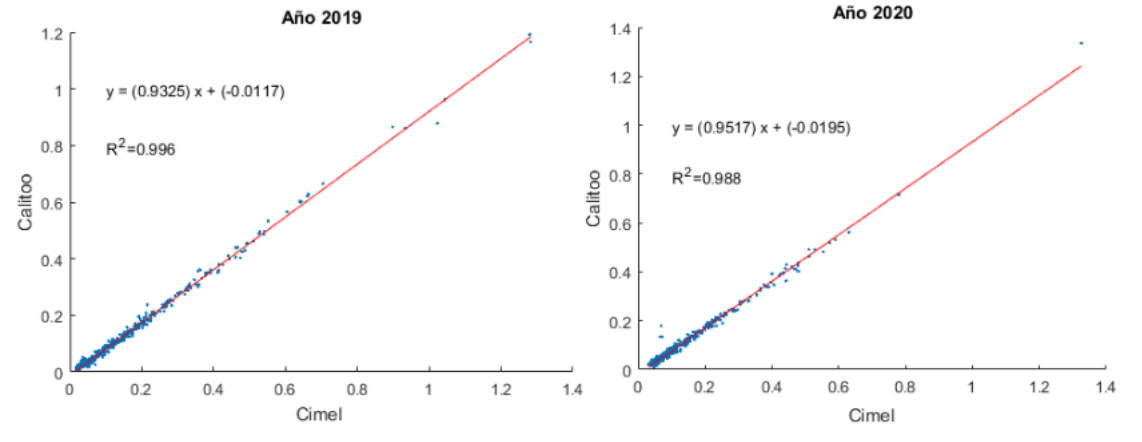
LOW-COST SENSORS VALIDATED WITH REFERENCE INFORMATION

PHOTOMETRY: Hand-held photometer Calitoo – AOD & AE

PARTICLE MATTER SENSOR + WEATHER STATION: IMDS – PM10 & PM2.5

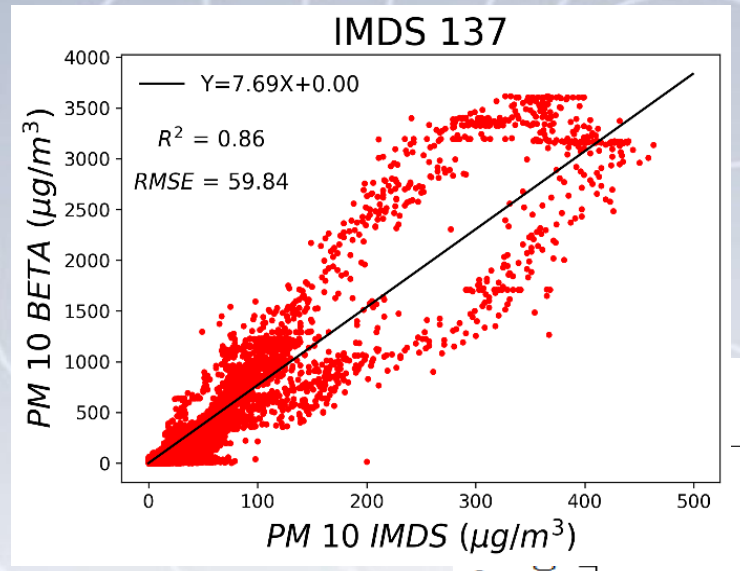
MACCLIMA

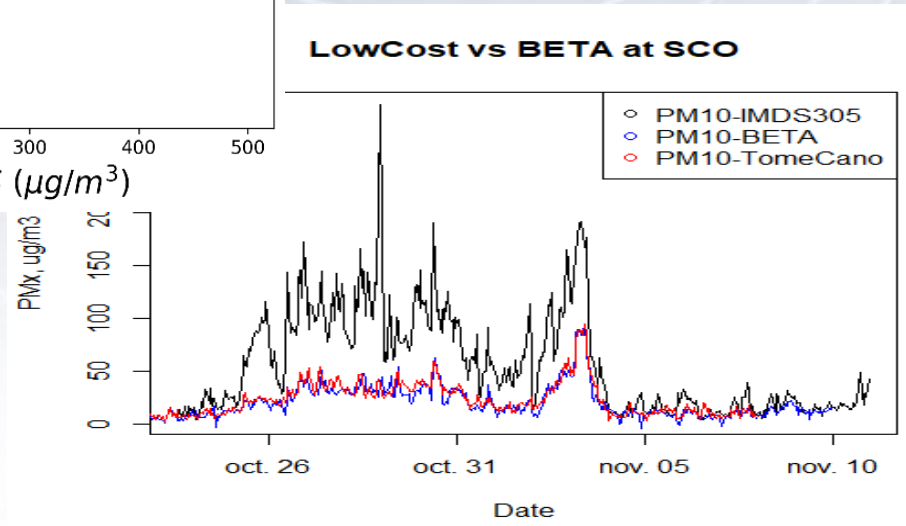
Photometry: Calitoo evaluation at Tamanrasset (Argelia) using AERONET



	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic
Datos	308	138	252	82	72	60	206	151	186	131	134	243
MSE	0.0003	0.0003	0.001	0.002	0.002	0.001	0.001	0.0006	0.006	0.0006	0.0005	0.0004
RMSE	0.016	0.019	0.031	0.030	0.039	0.042	0.033	0.035	0.024	0.026	0.022	0.020
Pearson(R^2)	0.933	0.963	0.982	0.995	0.993	0.986	0.996	0.995	0.988	0.988	0.954	0.873

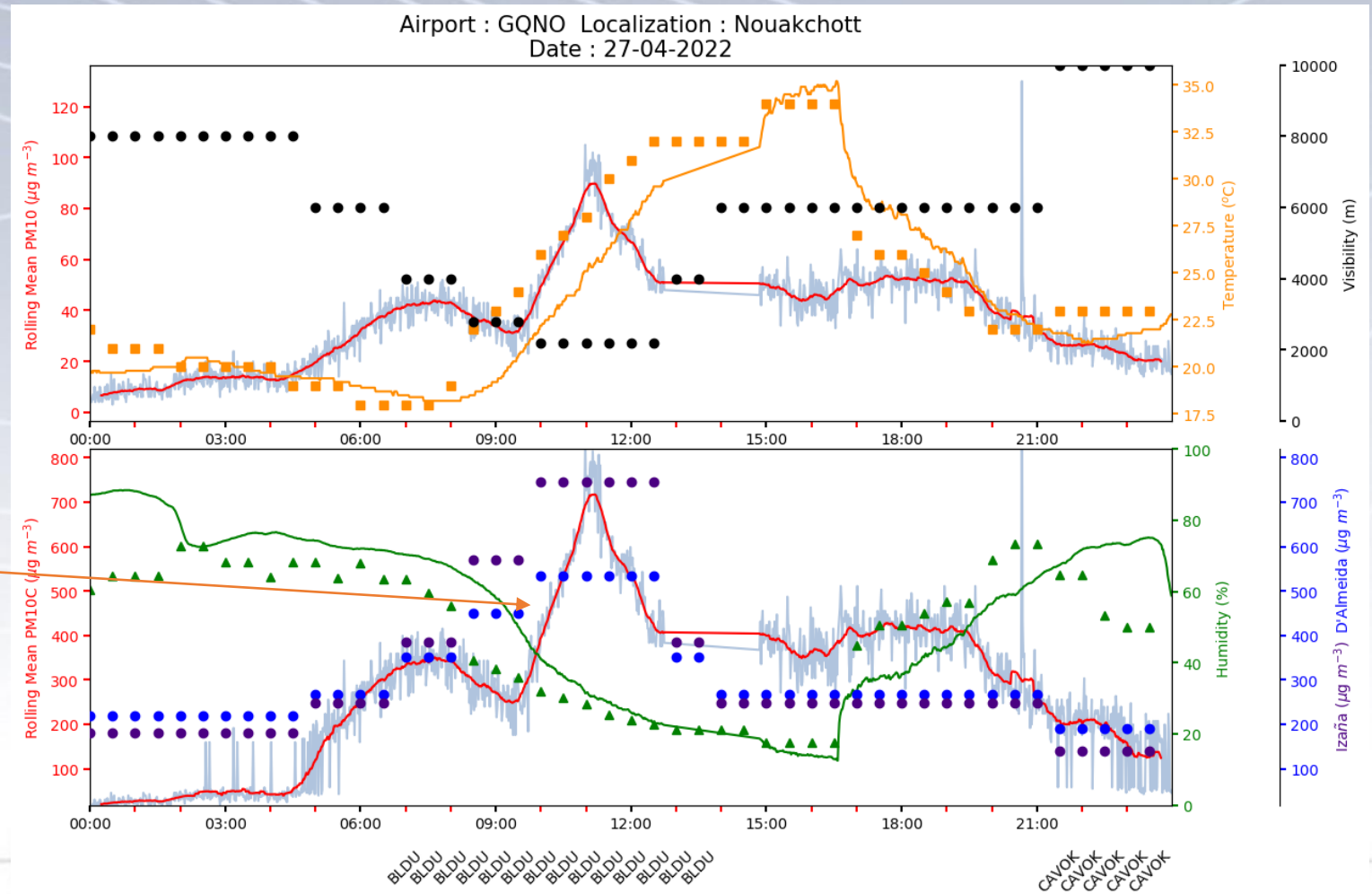
IN SITU: IMDS evaluation at Santa Cruz (Spain) using reference in-situ data (BETA attenuation monitor)





PM10 Evolution measured by IMDS at Mauritania

Good agreement between PM10 IMDS and the expected PM10 values according to visibility measurements



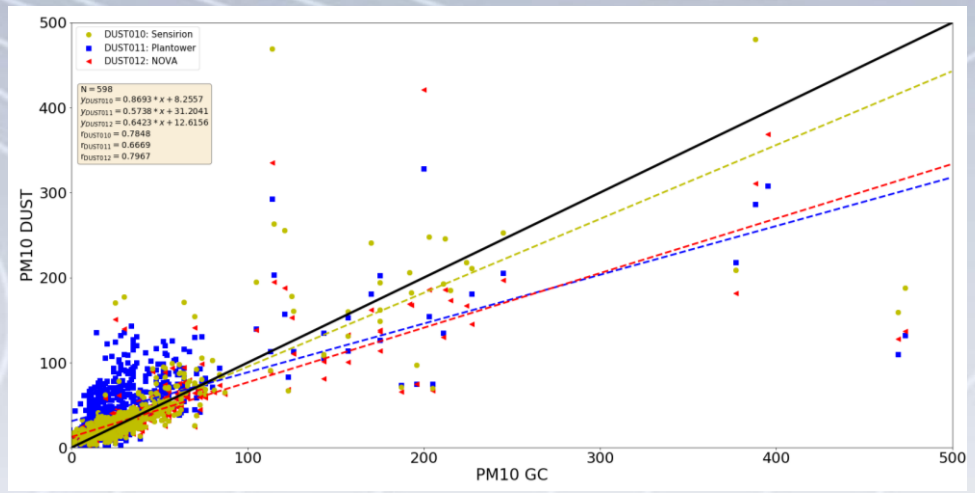
PM10

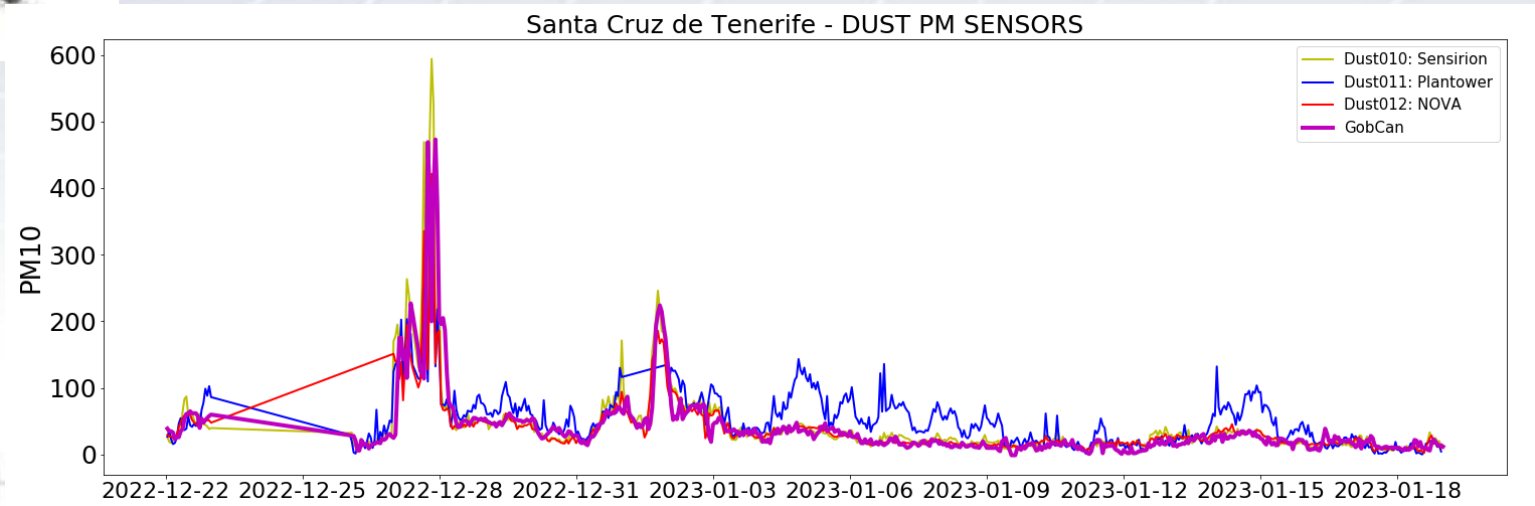
IN SITU: multi-sensor PM10 evaluation at Santa Cruz (in progress)

NOVA SDS011

SENSIRION SPS30

PLANTOWER PMS5003





MEASUREMENTS TECHNIQUES

AOD Observations at your site: Sun Photometry (Remote Sensing)

Beer's Law

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

$$(I_\lambda < I_{0,\lambda})$$

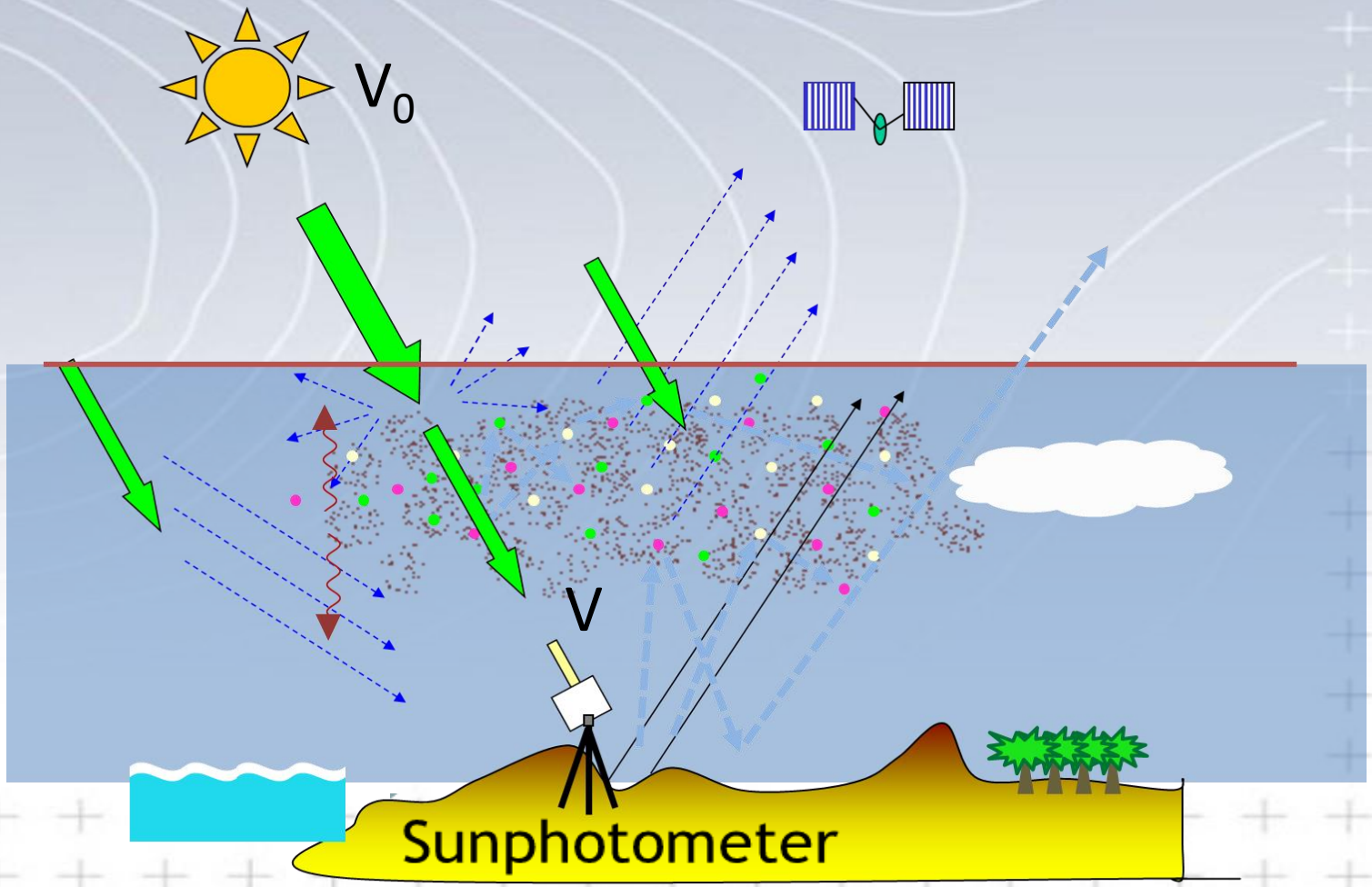
$$\tau_\lambda = AOD_\lambda$$

Angstrom Eq.

$$\tau_\lambda = \beta \cdot \lambda^{-\alpha}$$

α = Angstrom Exponent

α↓ large particles
α↑ fine particles



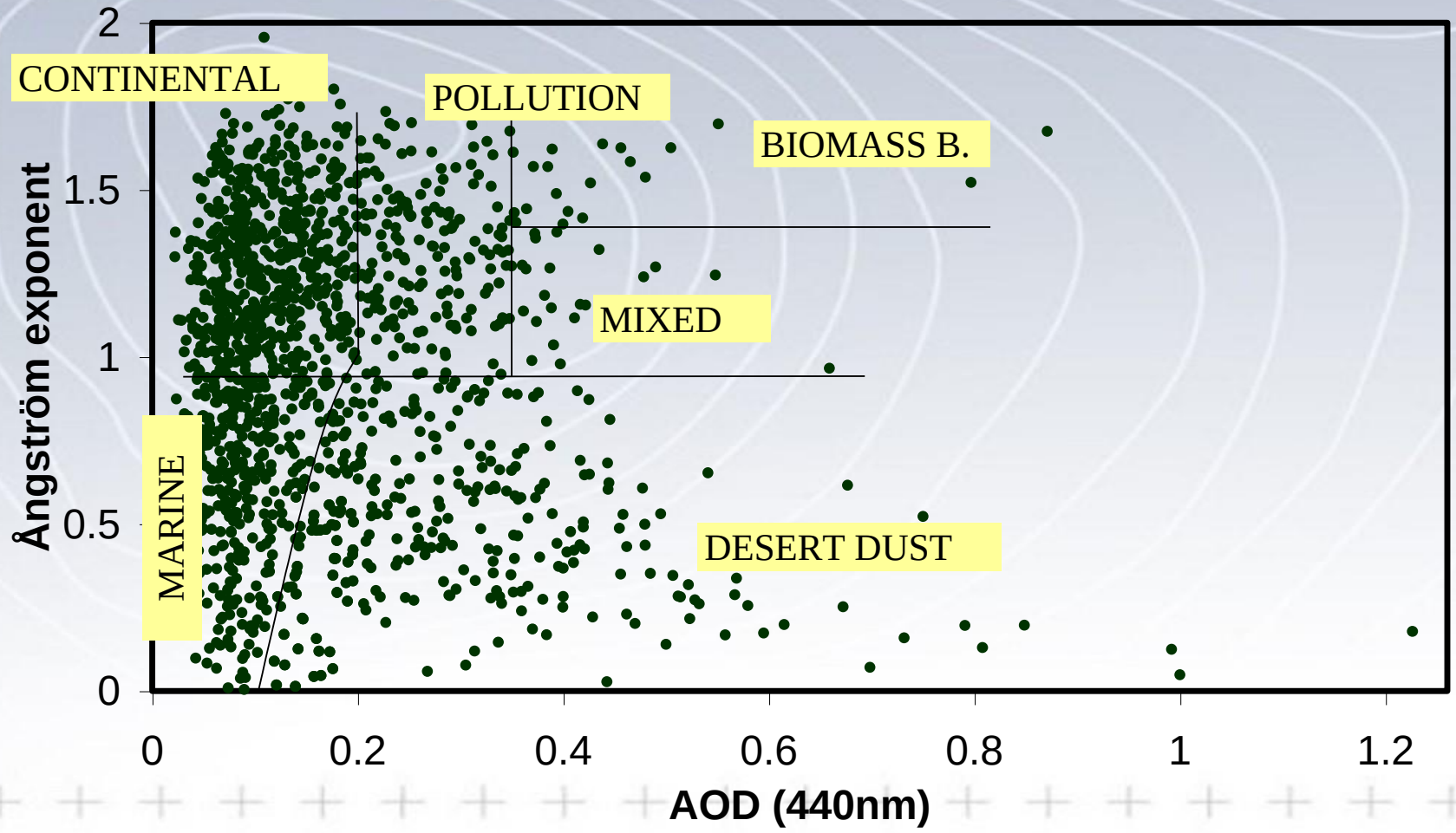
More aerosols in the atmosphere cause more extinction and less energy transmitted to the surface. AOD is the degree to which aerosols prevent the transmission of light.

Typical AOD ranges

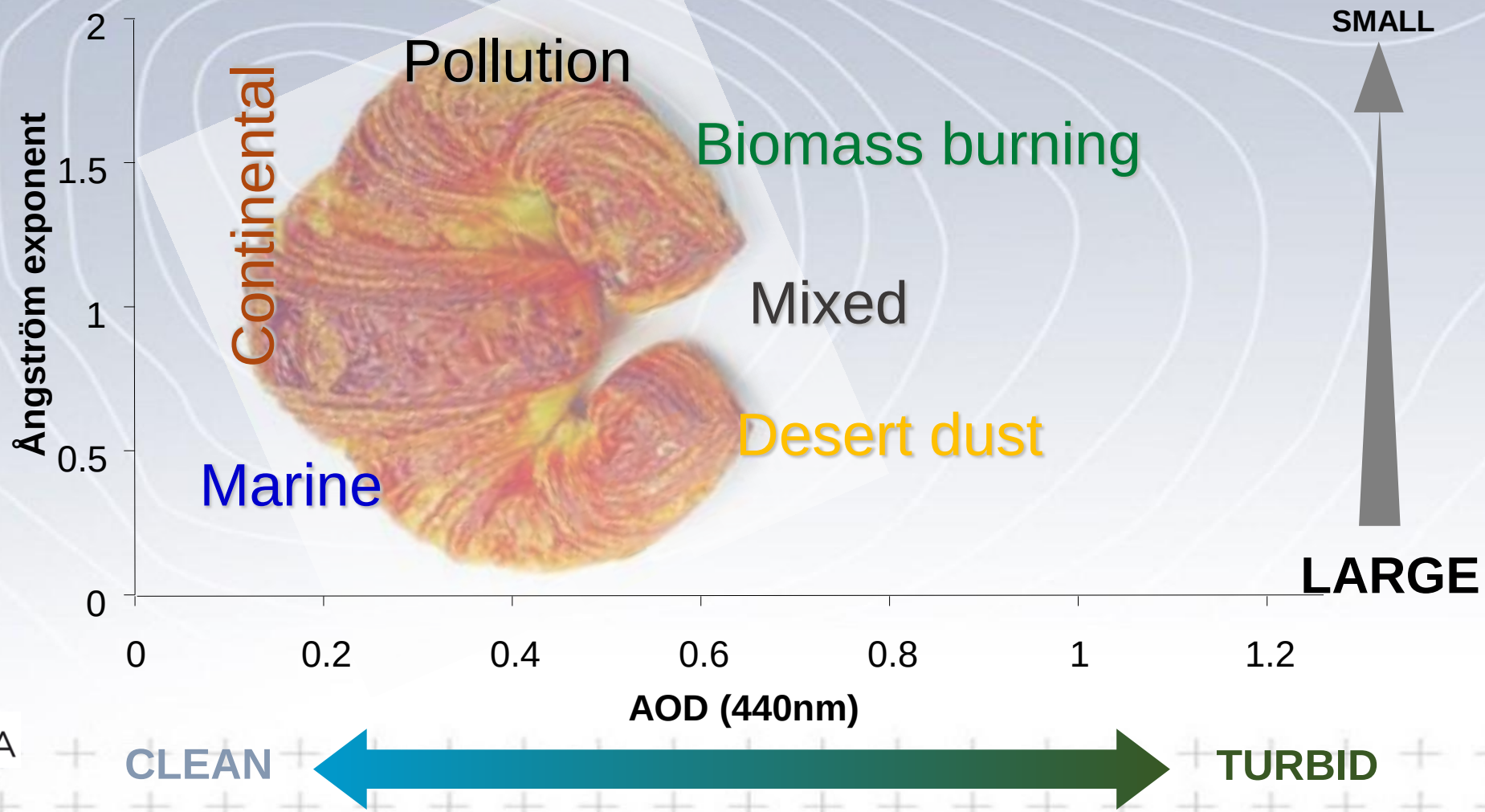
Sky conditions	500 nm	870 nm
Extremely clear (pristine)	0.03 - 0.05	0.02 - 0.03
Clear	0.05 - 0.10	0.03 - 0.07
Somewaht hazy	0.10 - 0.25	0.07 - 0.20
Hazy	0.25 - 0.5	0.20 - 0.40
Extremly hazy	> 0.5	> 0.4

Note that red AOD values are typically less than green AOD values. This is due to the fact that typical aerosols scatter green light more efficiently than red light.

Aerosol Type with diagram AOD-α

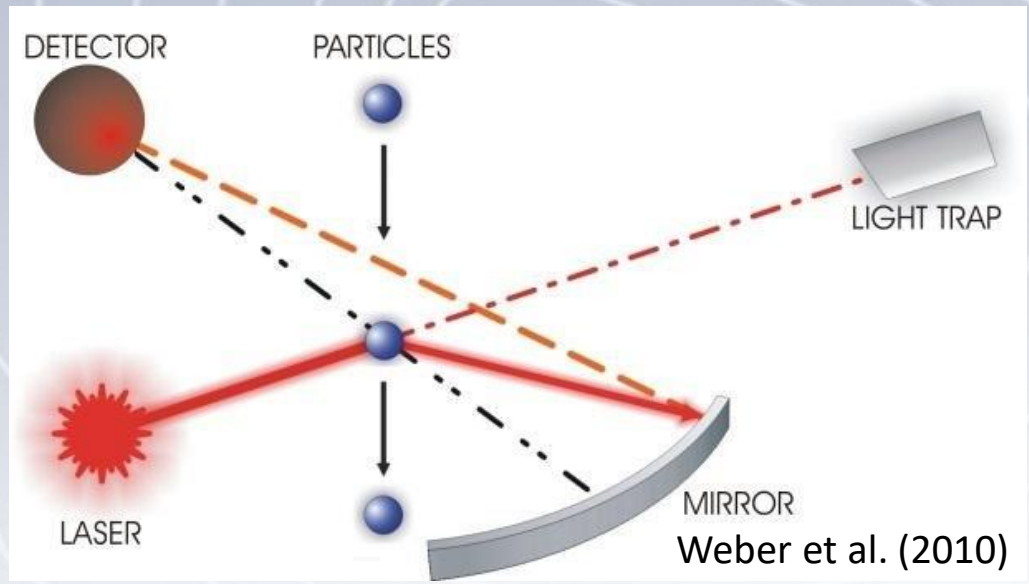


Aerosol Type with diagram AOD-α



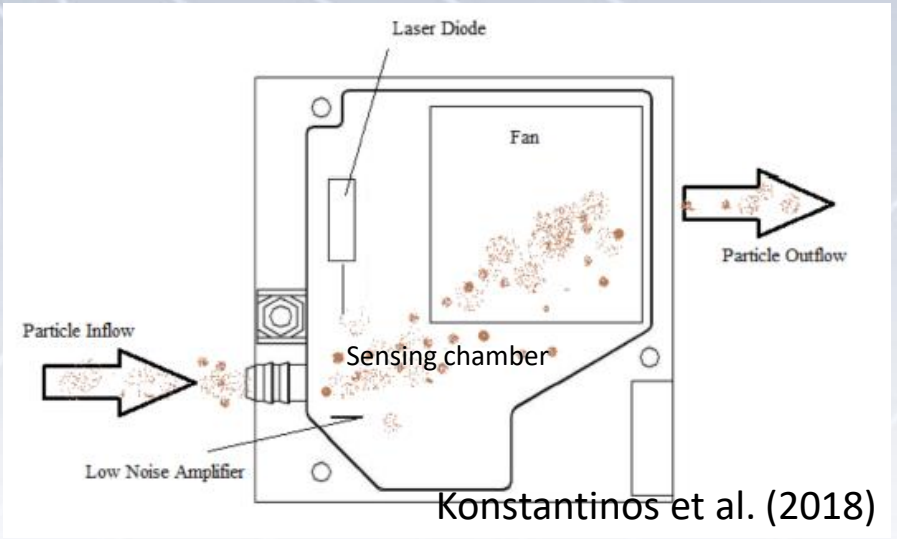
PM Observations at your site: PM sensors (In-Situ)

Principle of operation



Weber et al. (2010)

NOVA SDS011 low cost sensor



Konstantinos et al. (2018)

Mass concentration (PM) is proportional to the scattered light intensity assuming particle density and size distribution. Possible interferences with enviromental humidity and temperature.

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source: https://atmosphere.copernicus.eu/dust-outbreak-over-senegal-and-cape-verde-islands

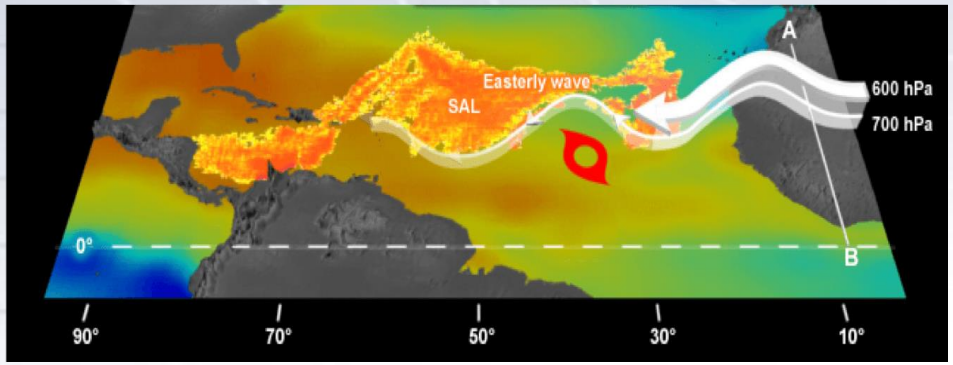
CAPE VERDE SITE

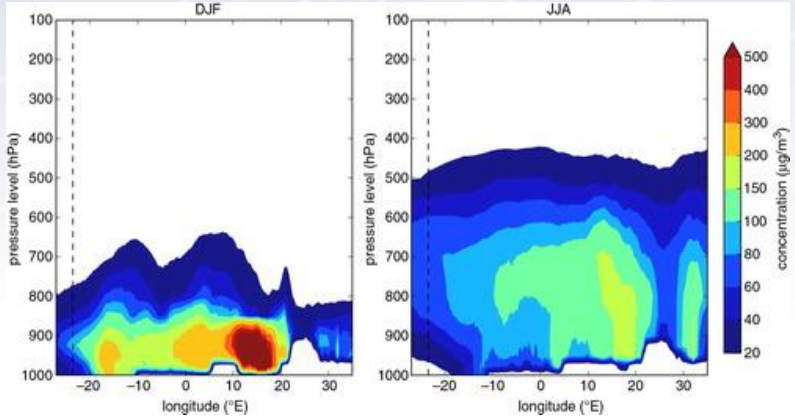
One of the best places to study Saharan dust and its transport in an elevated layer off the West African coast towards the Atlantic.

Interesting climatology of dust (seasonality also affecting the vertical extent of the Saharan layer):

- Maximum dust concentration at surface level in Oct-March (max. PMs) due to a low-level dust intrusions in winter.
- Lower dust concentrations at surface in summer Jun-Aug but high AODs due to a high-level dust transport.

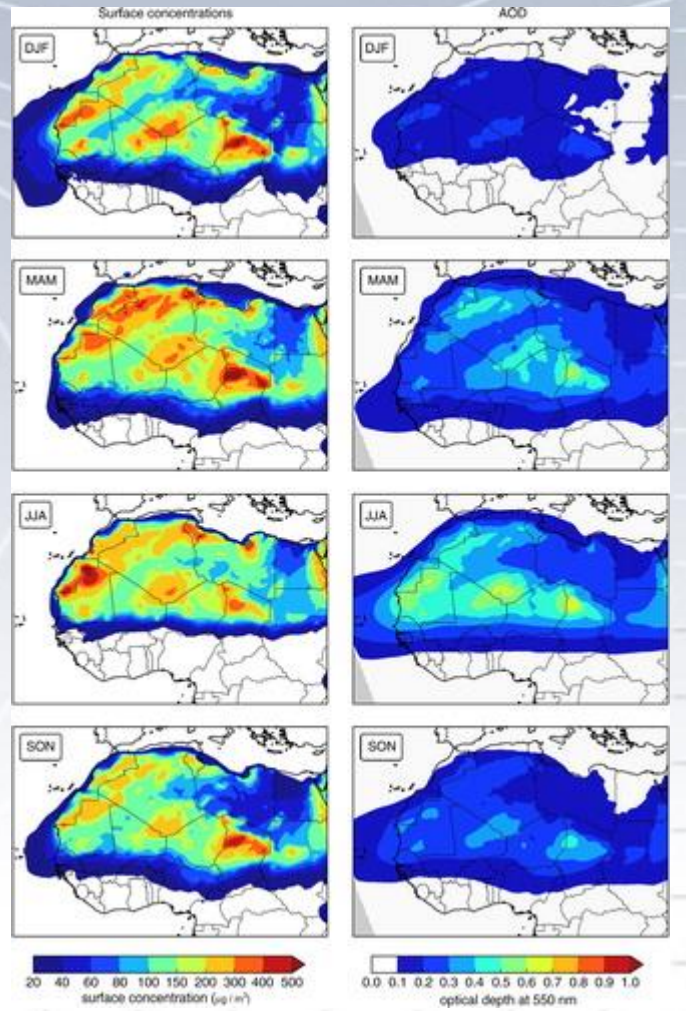
https://www.aoml.noaa.gov/saharan-air-layer/





Gama et al. (2015)

Gama et al. (2015)



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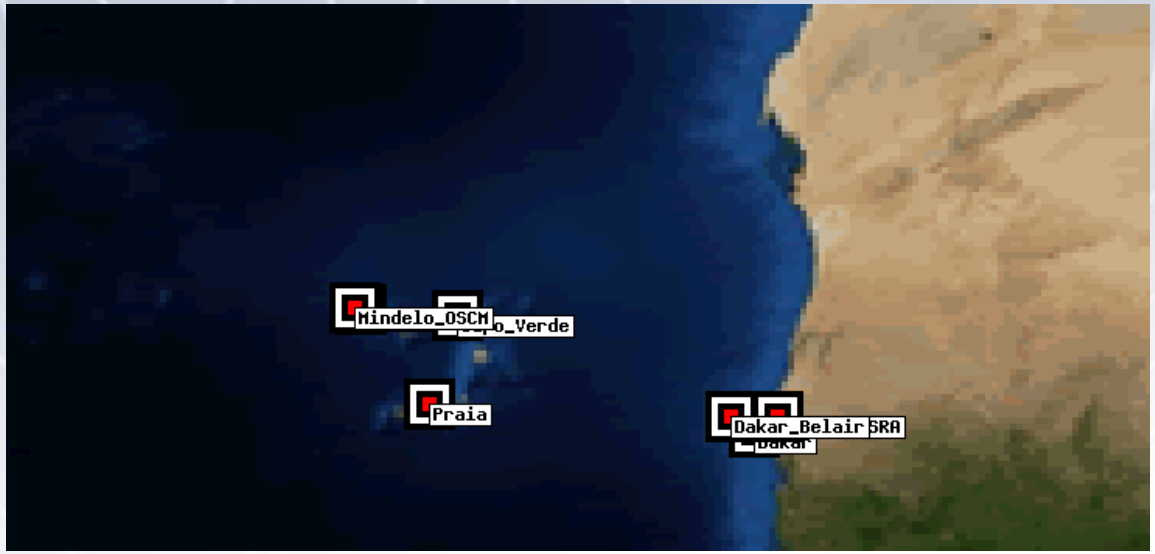
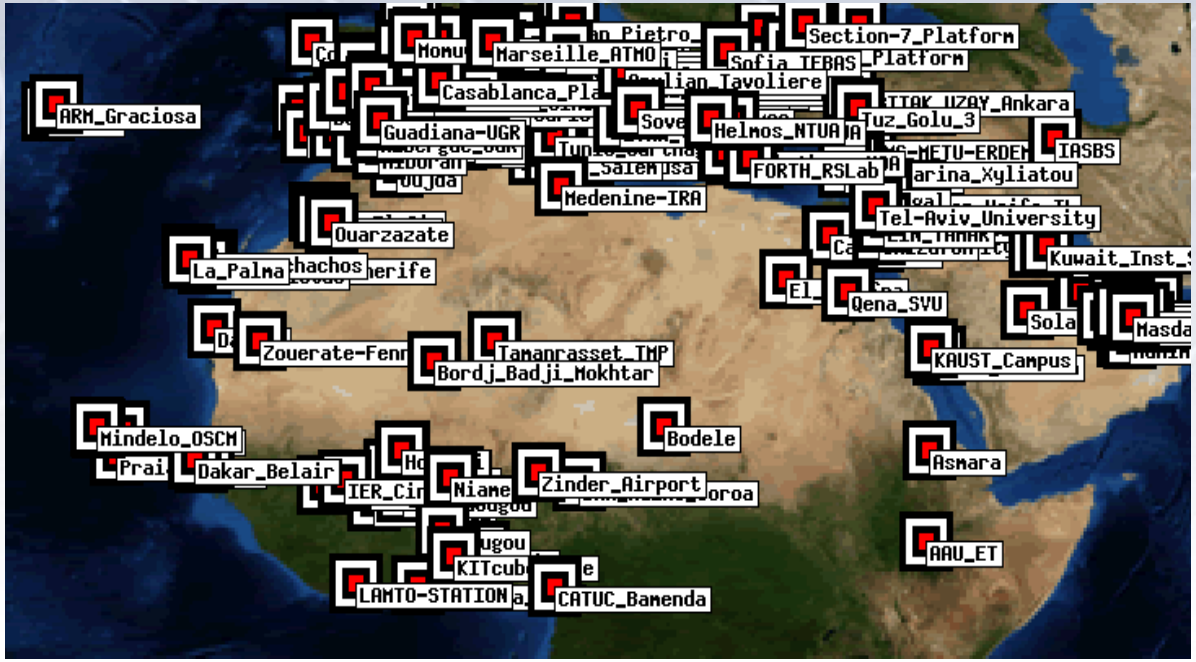
AERONET:

1 long-term site since 1994 (Cape Verde, Sal, co-managed by INMG)

1 mid-term site since 2021 (TROPOS)



Lack of photometric coverage in North Africa (central Sahara) providing information of dust source processes and dust transport over the Atlantic corridor



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JATAC and ASKOS experimental campaigns

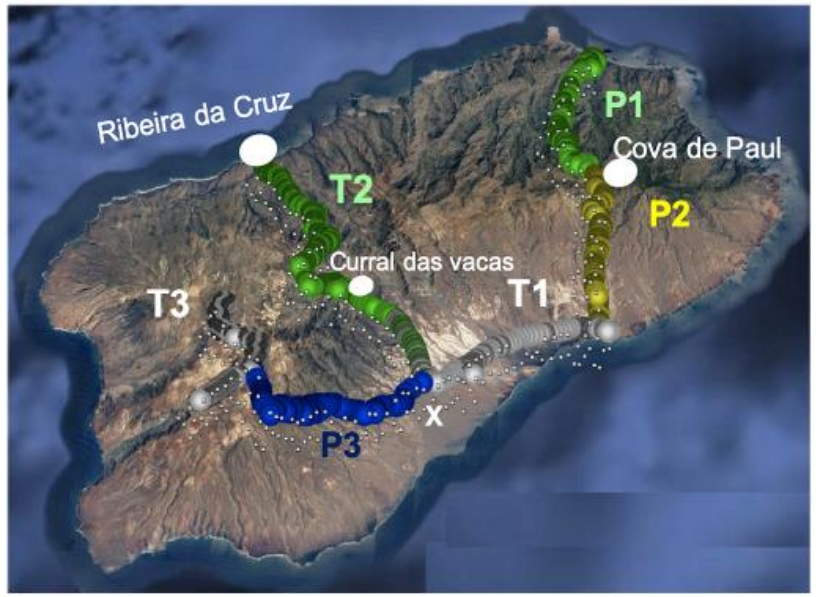
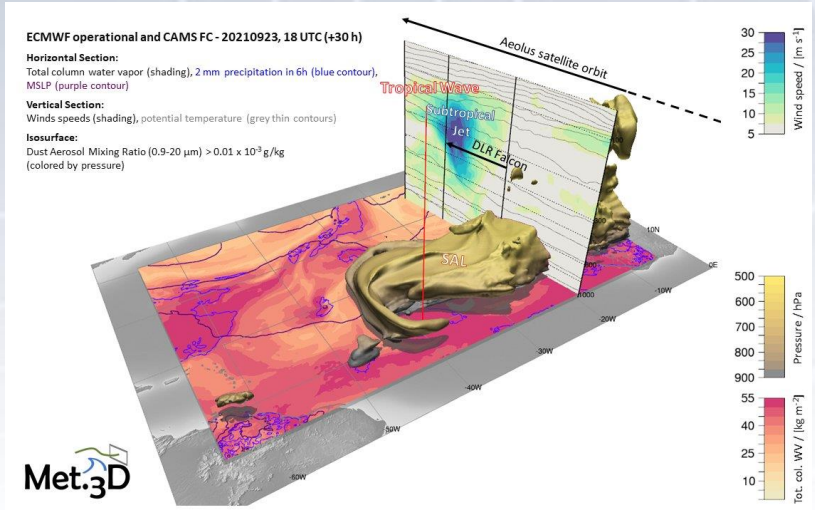
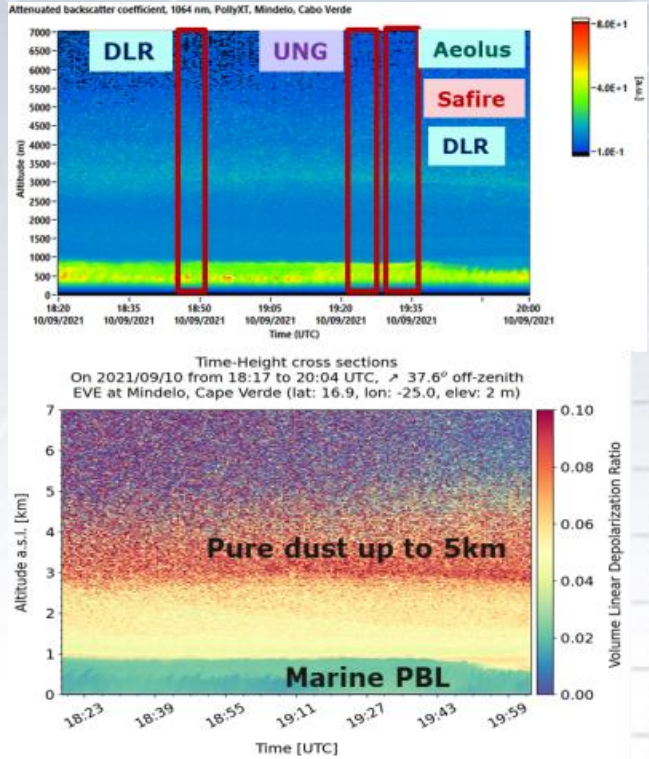


Fig. 2. Santo Antão island. Routes of the transects (Tx) and vertical profiles (Px) along which PM_x was measured. Crosspoint of T1, T2 and P3 is highlighted as x.

Rodríguez et al. (2021)





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CREWS CLIMATE RISK & EARLY WARNING SYSTEMS

WORLD METEOROLOGICAL ORGANIZATION

MACCLIMA

Interreg

Fondo Europeo de Desarrollo Regional

EUROPEAN UNION

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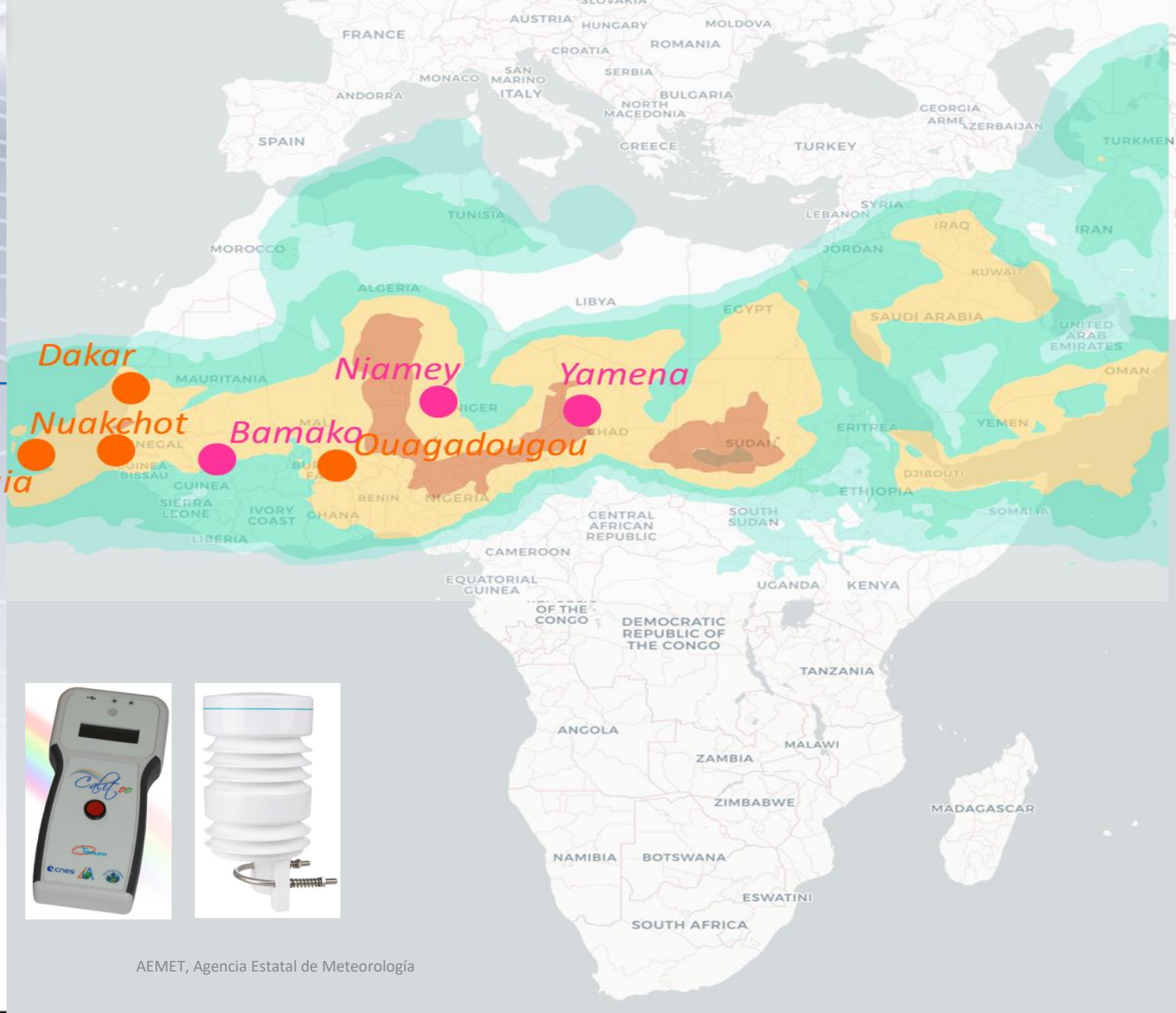

AEMET, Agencia Estatal de Meteorología

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Barcelona Dust Regional Center

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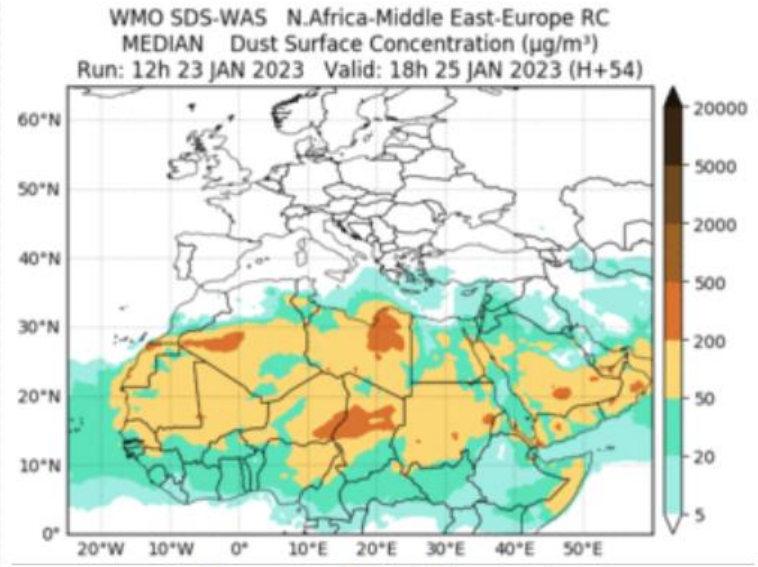
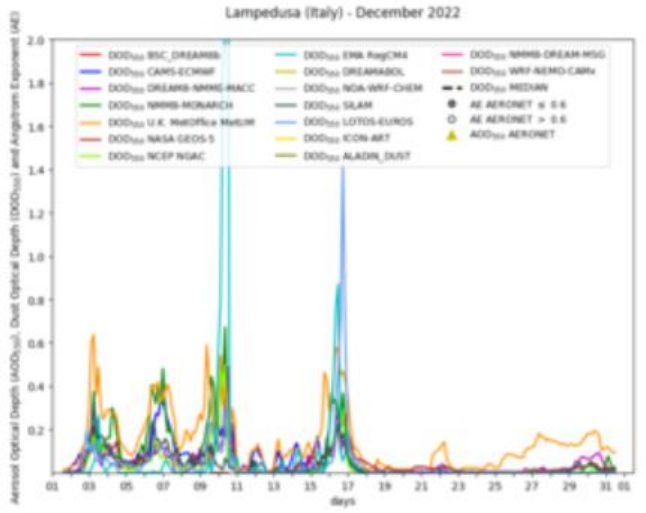
WMO SDS-WAS Regional Center for Northern Africa, Middle East and Europe, conducting research and providing operational products

Dust forecasts



Compared Dust Forecasts



Forecast Evaluation

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Possibilities to perform Calitoo measurements?

STEP 1: near 1-year measurements at Sal or Midelo to verify operation and instrumental performance with AERONET nearby stations?

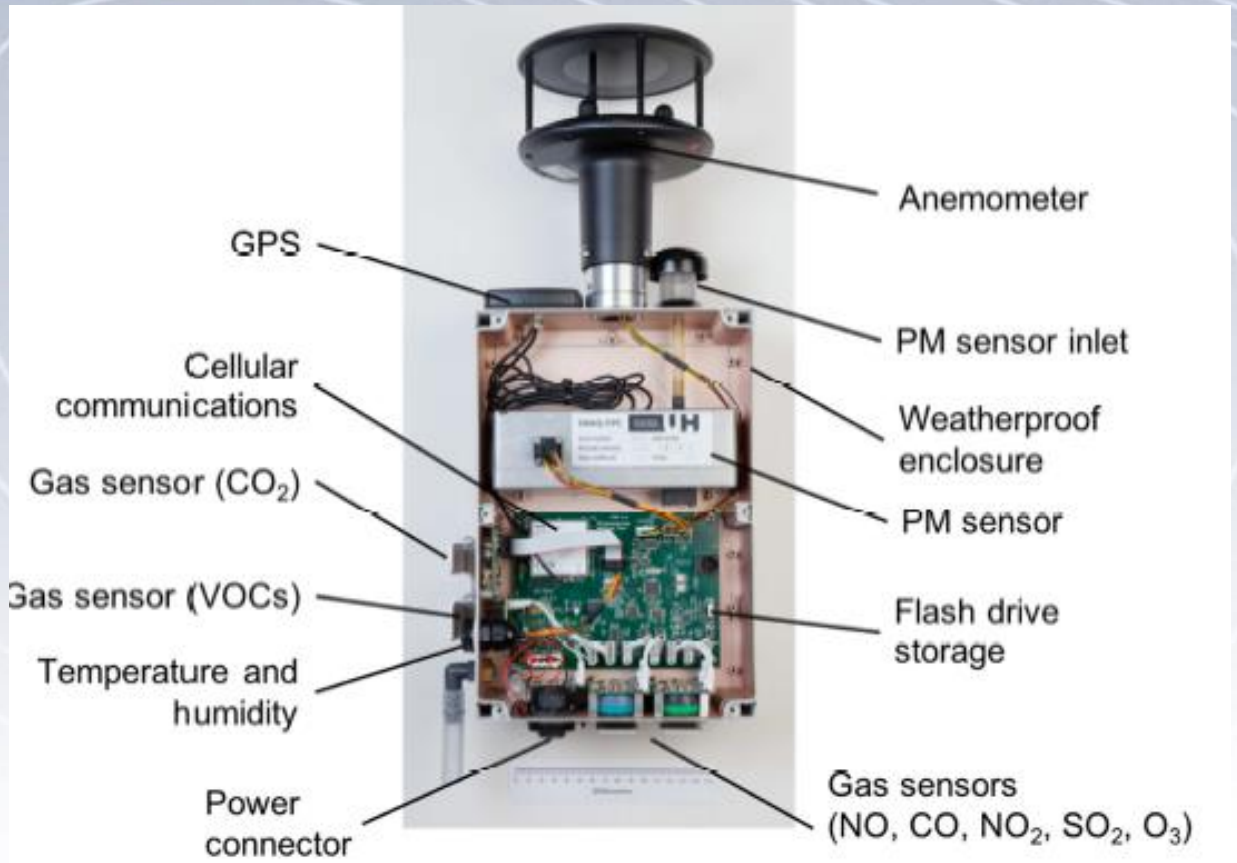
STEP 2: operate the Calitoo at another Island (maybe at the Sotavento Islands?)

STEP 3: New information available for SDS product verification

INSTRUMENTAL DESCRIPTION

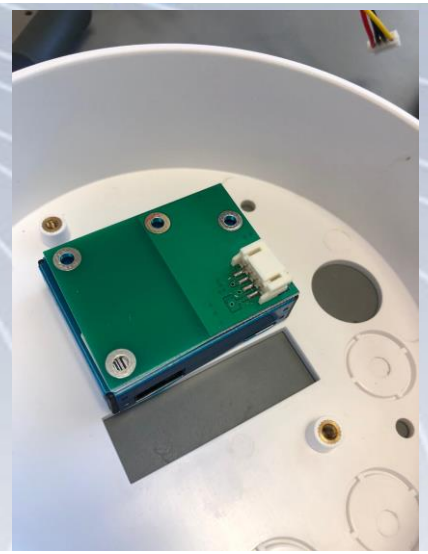
Low Cost PM Sensor

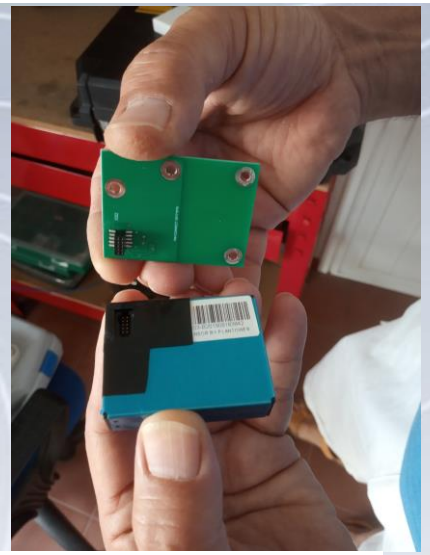
Low-cost sensors for the measurement of atmospheric composition: overview of topic and future applications (WMO, 2018)



Low Cost PM Sensor

IMDS





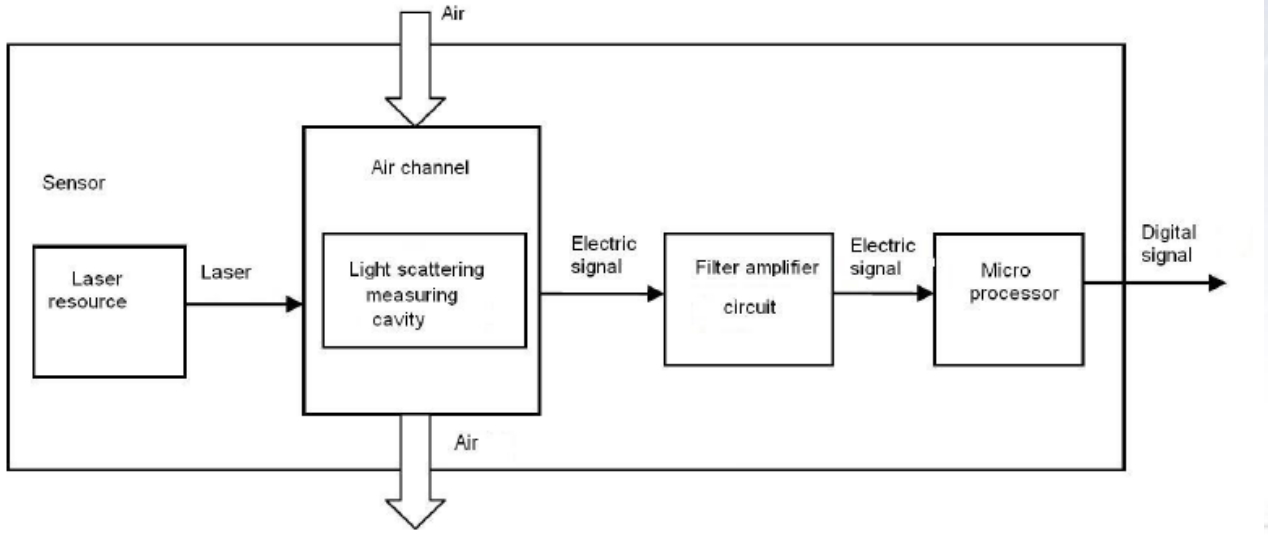
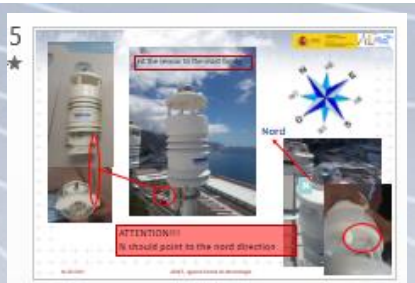
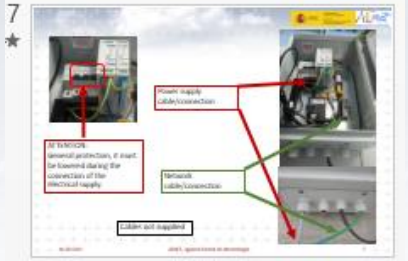


Figure 1 Functional block diagram of sensor

IMDS





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Photometry: Calitoo handheld sun photometer

Technicals characteristics:

- Light channels: 465 (B), 540 (G) and 619 (R) nm
- Possible 999 measures stored in memory
- AOD calculated in real-time
- USB data download
- Free software on web site.
- Supply : 4 batteries AA (1,5V)
- Dimensions : 210 x 100 x 35 mm
- Weight : 400 g (With batteries)
- Operating temperature : -20°C to 55°C

http://www.calitoo.com

How to use it?
https://www.youtube.com/watch?v=4wCzw4rY9Hs

Photometry: Calitoo handheld sun photometer

Products:

AOD @ 465, 540 et 619 nm

Angstrom Exponent

Calibration provided!!!

(at Izaña WMO testbed)

First pilot experiments at:

Tamanrasset GAW Station (Algeria)

Tehran (Iran)

Aminabad Mt. Firoozkoh GAW station (Iran)

Photometry: Calitoo handheld sun photometer

Measurements

The measurement principle is to point the Sun and search for the maximum reading. The photometer keeps only the maximum measured and then calculated the optical depth.

The Sun alignment is done manually. It is facilitated by the sighting device located above the display of the Calitoo.

The calculation of optical depth use raw brightness measurements, calibration coefficients, date and GPS position as well as atmospheric pressure.

CALITOO

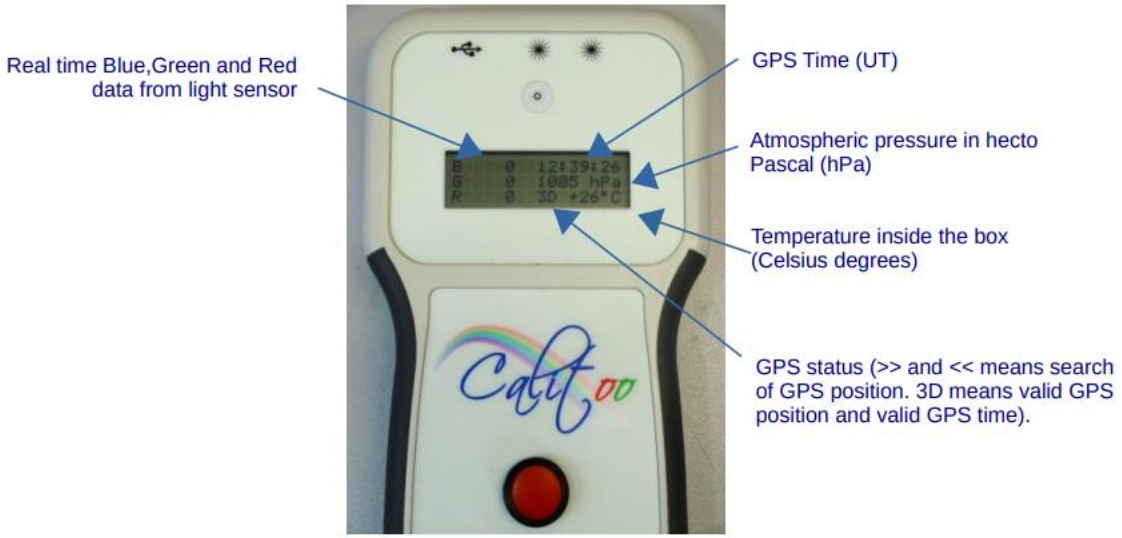
How to use it?
https://www.youtube.com/watch?v=4wCzw4rY9Hs

How to take measurements? See the manual at http://www.calitoo.fr/uploads/documents/en/usermanual_2020_en.pdf

Power ON by pressing for a few seconds on the red button

1.3 First measurements

After turning the welcome page, the photometer indicates that it is in measuring mode and displays basic information :



Once the GPS photometer is 3D, you can start measuring.
If the GPS is not in 3D, you cannot make a recordable measurement

CALITOO

How to use it?
https://www.youtube.com/watch?v=4wCzw4rY9Hs

How to take measurements? See the manual at http://www.calitoo.fr/uploads/documents/en/usermanual_2020_en.pdf

1.4 Point to the Sun

Pointing the photometer is manual, it is facilitated by the sighting device located above the LCD screen.

Video tutorial on YouTube : How to measure aerosols ?

You have to stand facing the Sun stably and quickly bring the bright spot in the middle of the target pointer and keep the same time measures.

The Sun spot is on the center of the target : the photometer is pointed.

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CALITOO

How to use it?
https://www.youtube.com/watch?v=4wCzw4rY9Hs

How to take measurements? See the manual at http://www.calitoo.fr/uploads/documents/en/usermanual_2020_en.pdf

1.5 Maximum

The goal is to get the maximum value in three colors during about 1mn of search.

Click the button on the photometer and you go to the page maximum measurements (assuming of course that you had stayed on the base page described above).

While keeping an eye on the target, you monitor the numerical measured values on the screen. When maximums do not change, after about one minute, you go on to the next step.

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CALITOO

How to use it?
https://www.youtube.com/watch?v=4wCzw4rY9Hs

How to take measurements? See the manual at http://www.calitoo.fr/uploads/documents/en/usermanual_2020_en.pdf

1.6 AOT display

After displaying maximum values page, by pressing one more time on red button, Calitoo computes AOT and displays results on a new page.

If results seems be wrong for you, you can choose to do not recording it (see section 1.8)

1.7 Alpha display

Click on the button again and you are on the fourth page, the page of the Alpha parameter or Angstrom coefficient.

This coefficient, the calculation of which is explained in Appendix 4.2., makes it possible to characterize the type of particles detected.

R2 is a certitude index. 1.00 is a total certitude with the calculated Alpha while 0.50 is 50% of certitude.

R2 calculation is explained in Appendix 4.2.

CALITOO

How to use it?
https://www.youtube.com/watch?v=4wCzw4rY9Hs

How to take measurements? See the manual at http://www.calitoo.fr/uploads/documents/en/usermanual_2020_en.pdf

1.8 Memorization

Click the button again and you are on the fifth page that is recording. You can read the complete sequence of operation of the button in the Appendix 4.6.

The photometer will ask if you want to record (the measures).

Be sure you store the measurement!!!

If this is the case, you should always press the button, but this time hold it down until **Recorded !** appears at the bottom of the screen.

Then you release the button and find yourself on the base page for a new round of measures.

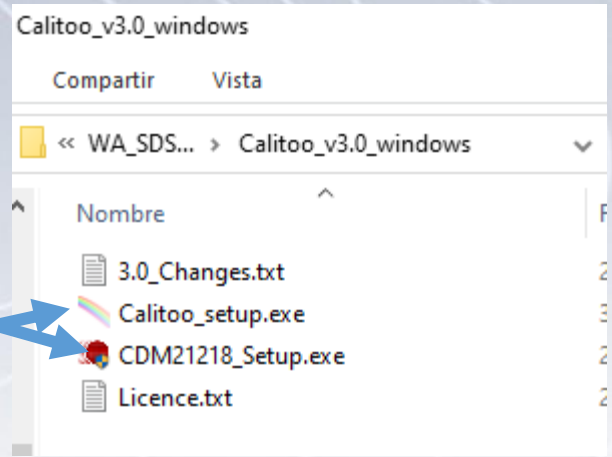
If you are not satisfied with your measurement and you do not want to save, a single click will cancel the operation and you find yourself back on the base page for a new measurement cycle.

MACCLIMA

How to upload data?
First, software download: http://www.calitoo.fr/index.php?page=software

1º execute (install)

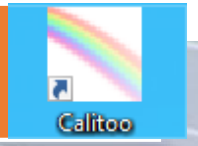
2º execute (install)



CALITOO

Data Visualization

How to upload data?
Plug calitoo to PC in “Reading mode” with USB cable and open the Calitoo software



Automatic recognition

Go to “Data” label

Press the Green row to downlado data (in this case 11 measurements

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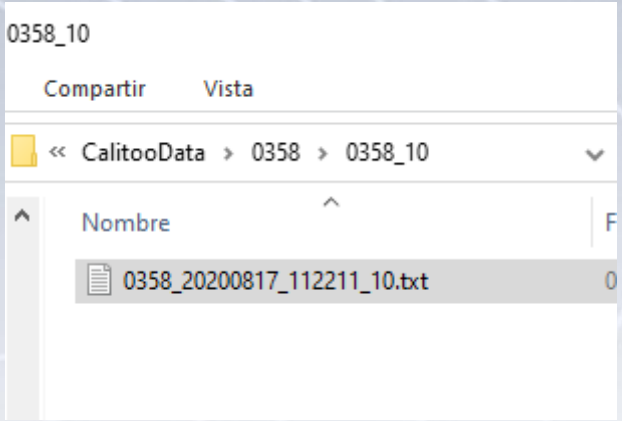
CALITOO

Data Visualization

How to upload data?
Where are the data?

You need to look for the “CalitooData” folder, and there you will find .txt files with downloaded data



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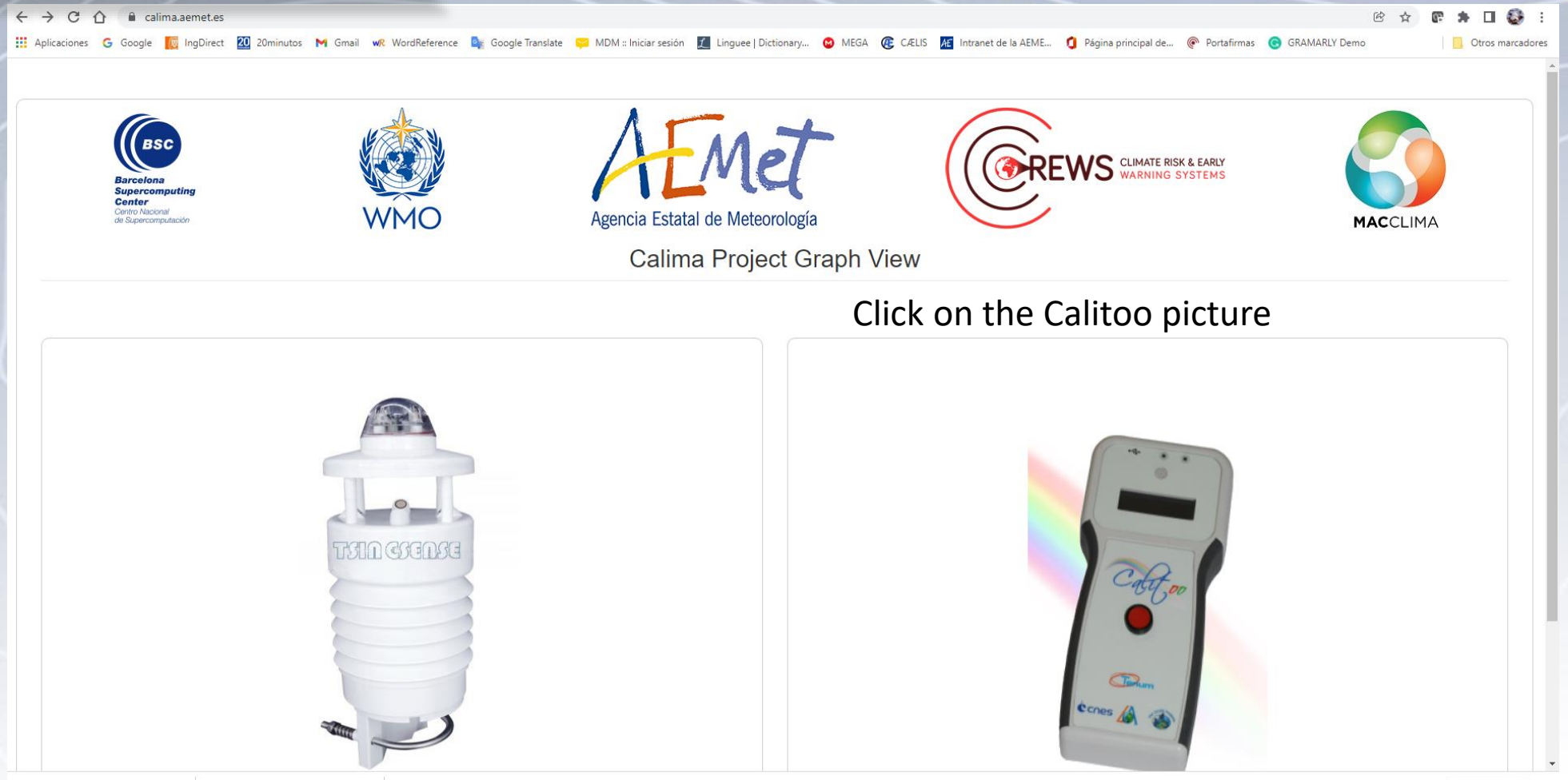
CALITOO

How to upload data?
Go to https://calima.aemet.es/



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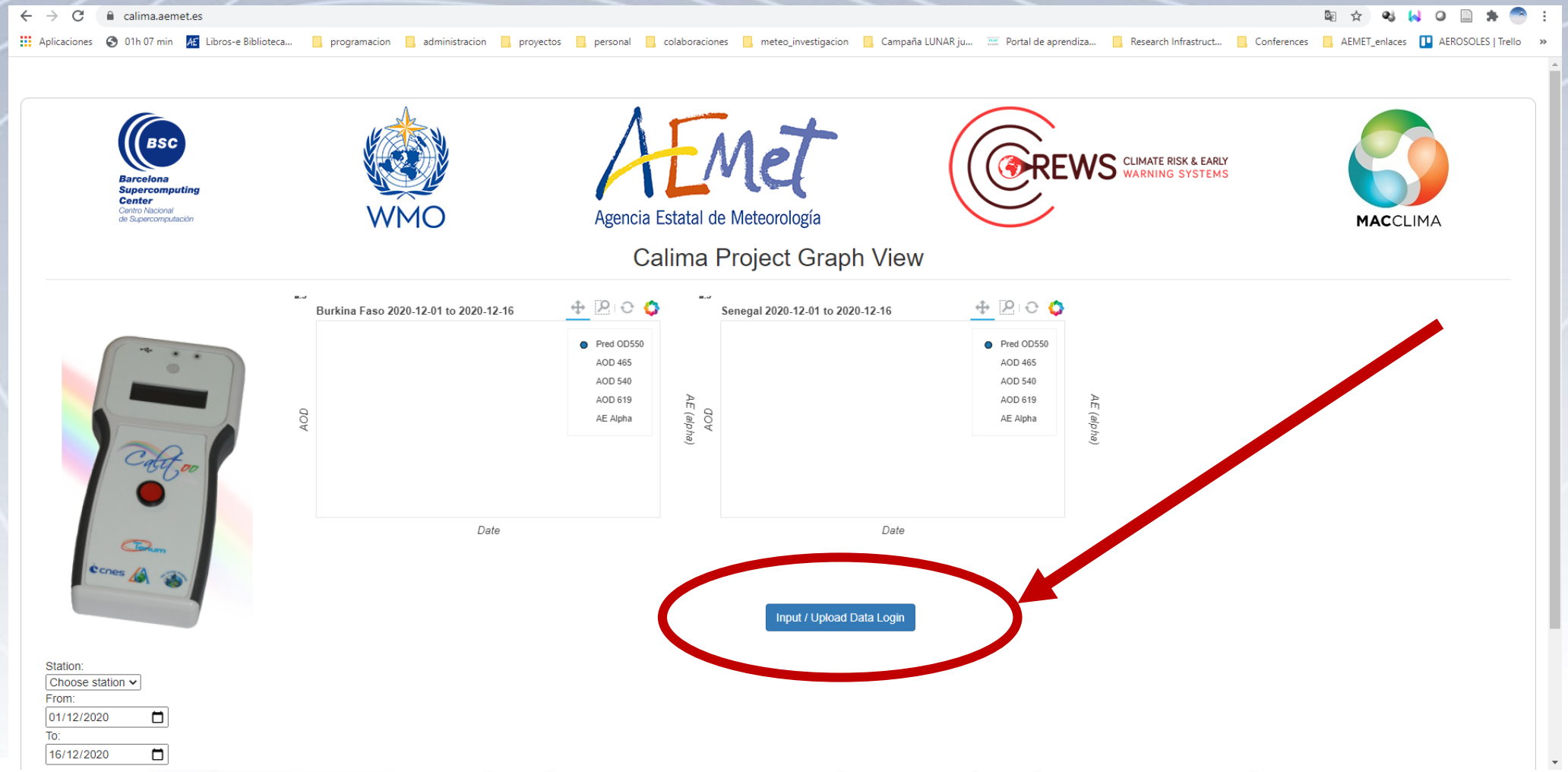
CALITOO

How to upload data?
Go to https://calima.aemet.es/

Input / Upload Data Login

Click on “Input/Upload Data Login”



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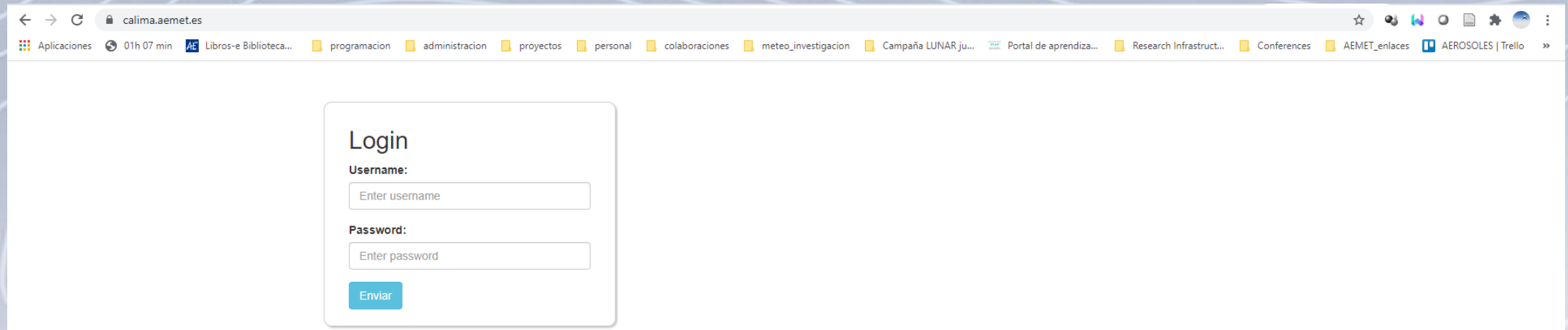
How to upload data?

Enter username and password



CALITOO

How to upload data?

Click on “Click to upload Calitoo TXT data file”

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

WMO

Agencia Estatal de Meteorología

CREWS CLIMATE RISK & EARLY WARNING SYSTEMS

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Calima Project

Senegal

Last data:

Date	dd/mm/aaaa
Time UTC	--:--
Atmospheric Pressure hPa	Enter pressure
AOD Blue 465	Value between 0 and 3
AOD Green 540	Value between 0 and 3
AOD Red 619	Value between 0 and 3
Alpha	Value between 0 and 4

Submit

Click to upload Calitoo TXT data file

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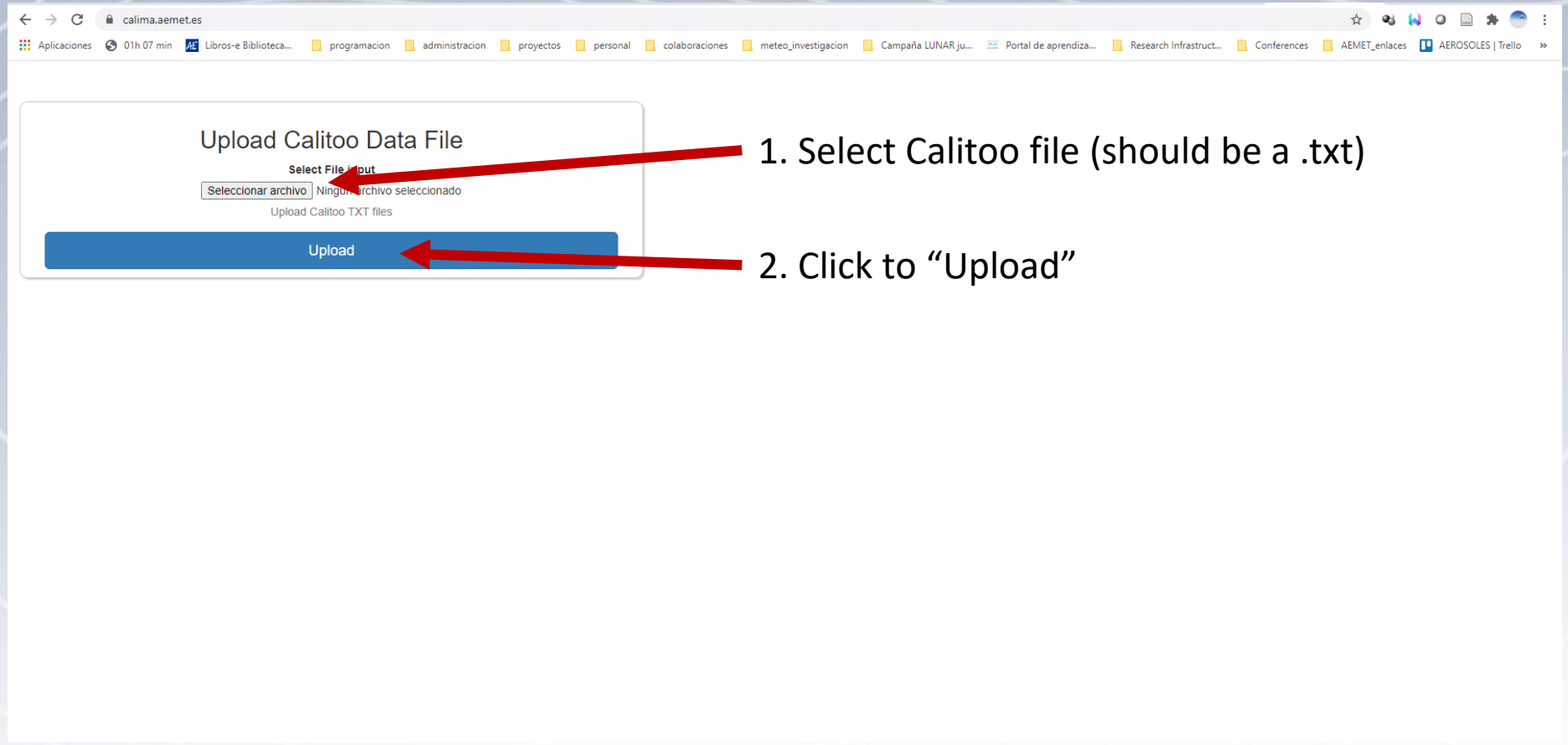
CALITOO

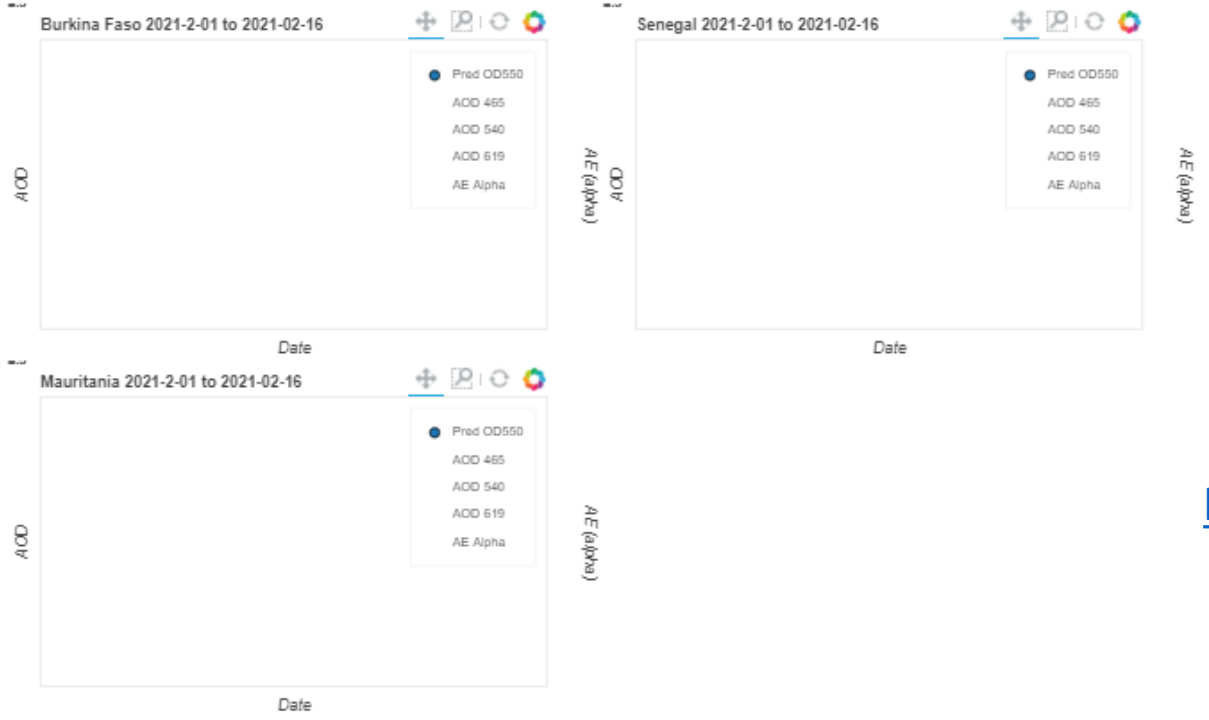
How to upload data?



1. Select Calitoo file (should be a .txt)

2. Click to “Upload”

Station:
Choose station
From:
mm/dd/yyyy
To:
02/16/2021
Plot Graph



https://calima.aemet.es/

Some considerations to take into account when measuring aerosols with the Calitoo

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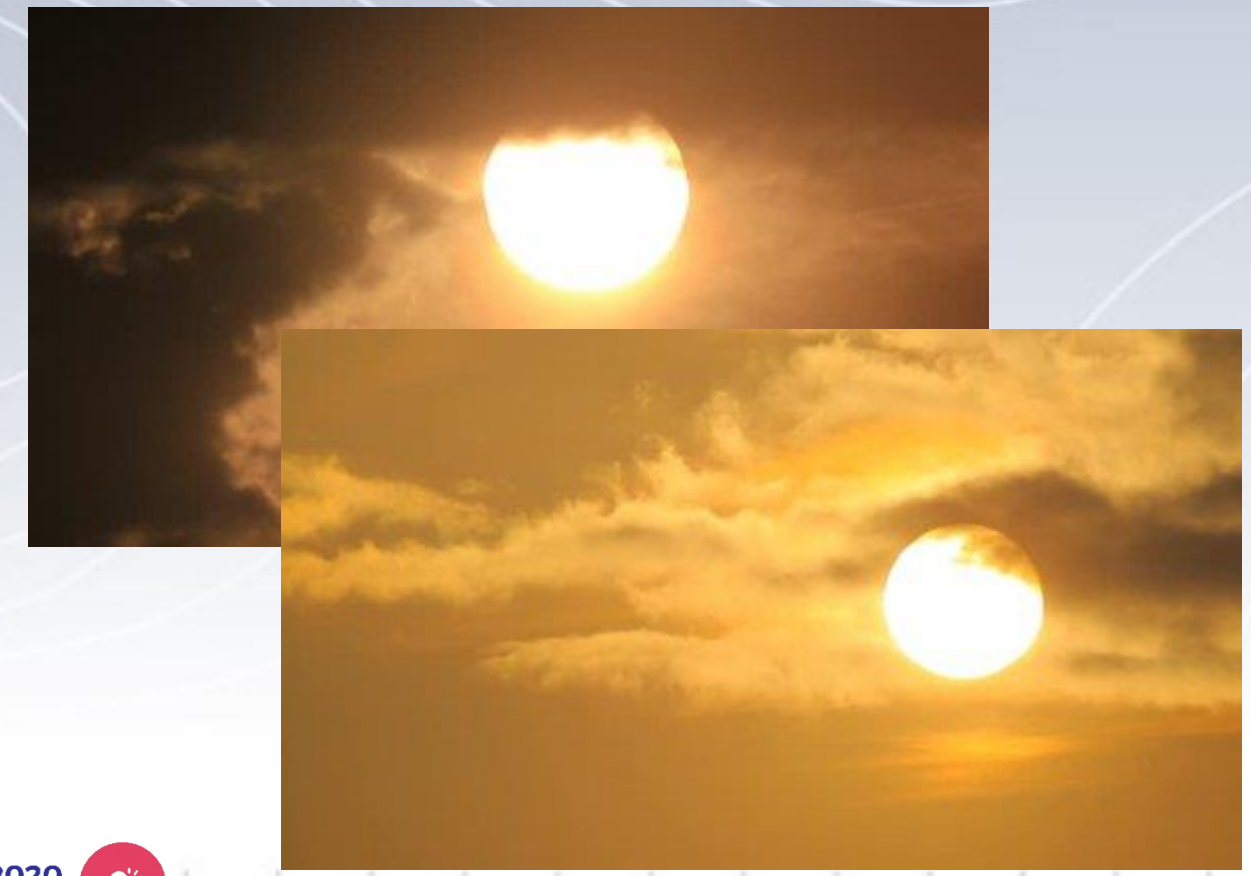
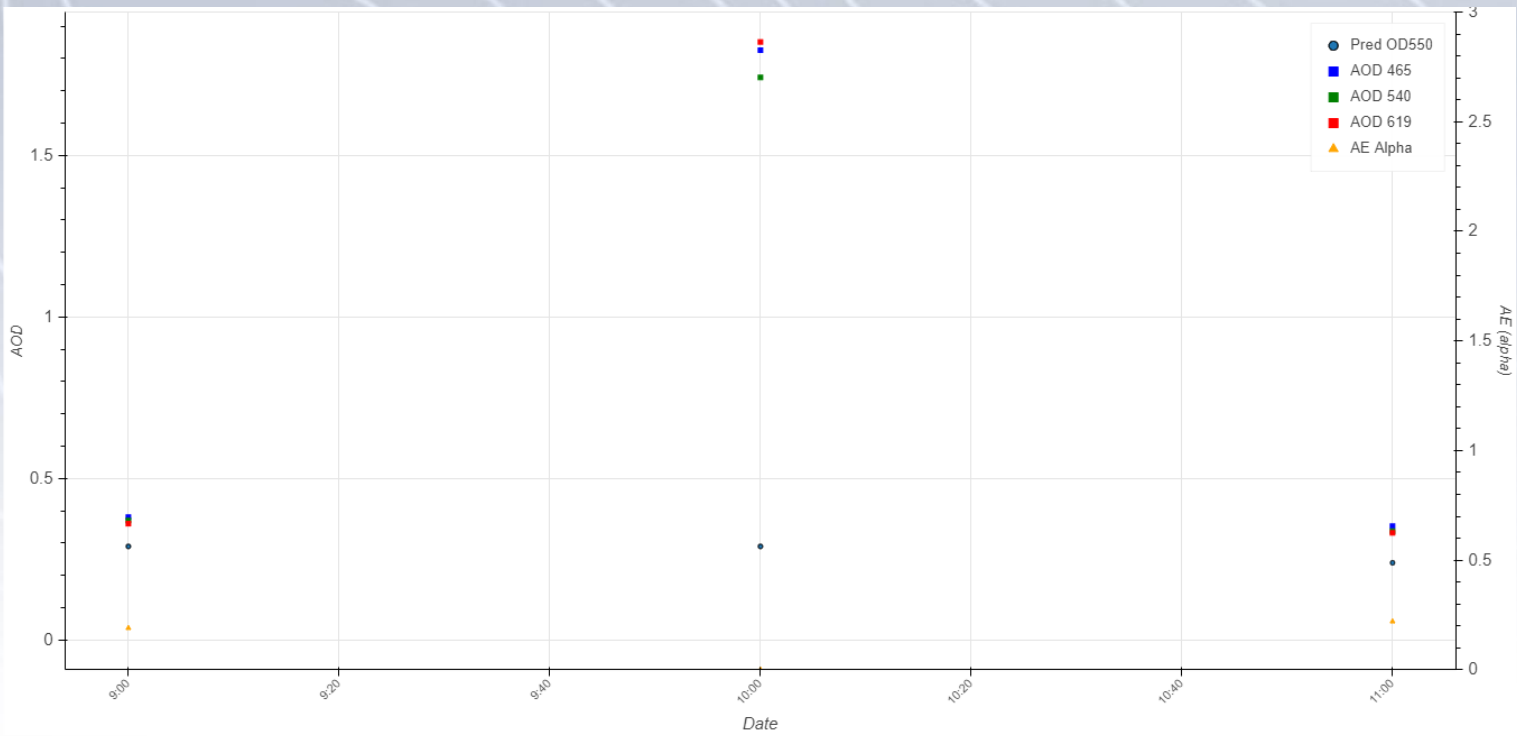
Cloud-free observations

Please note that it is not possible to perform measurements with the Calitoo in the presence of any type of cloud cover. Beware of veil-like clouds (cirrostratus) or clouds that partially cover the solar disk, as this will give erroneous readings



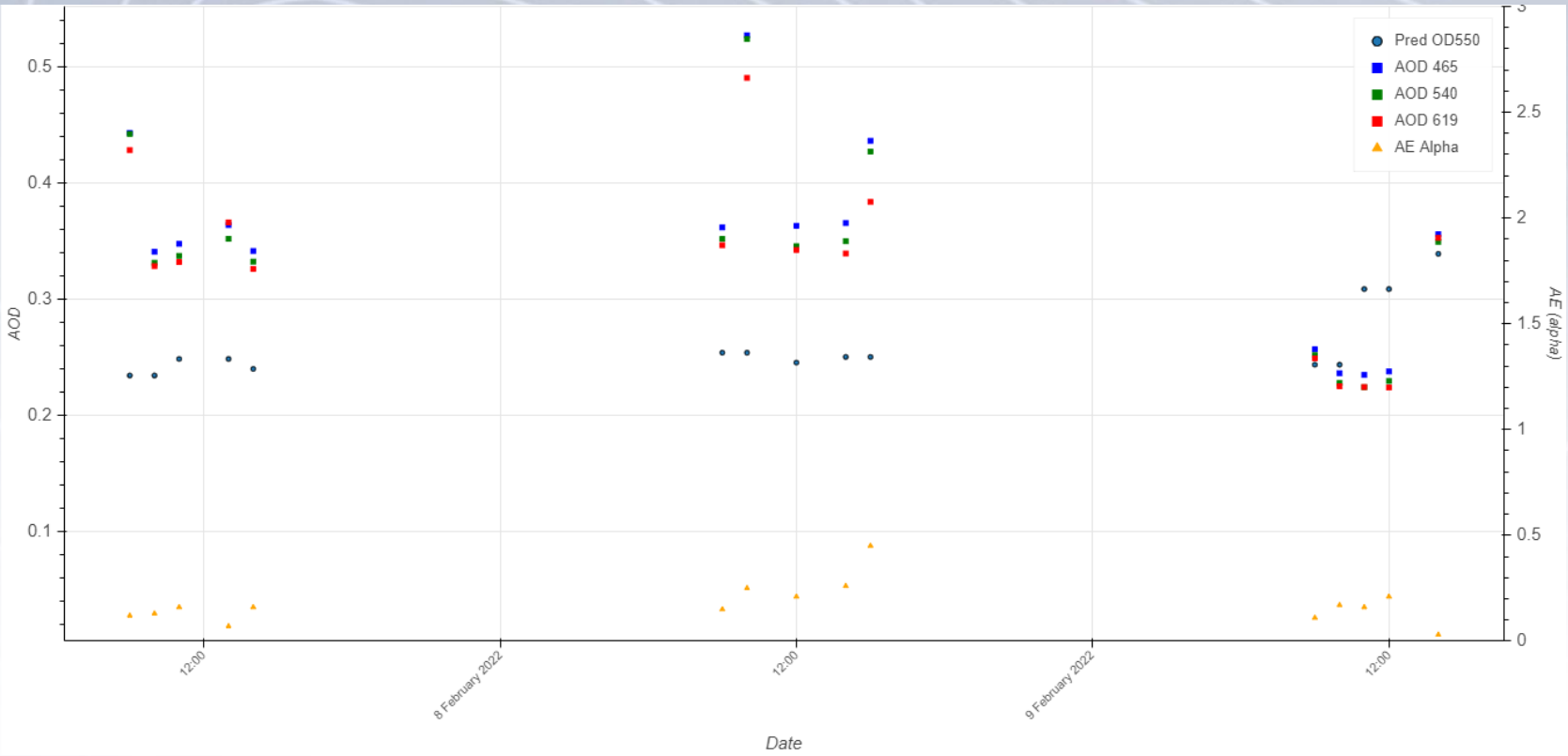
Consequence of misreading

Either due to the presence of clouds or due to a poor pointing, the reading may be erroneous and lead to abnormal AOD values, as shown in the following figure. In it, we can check how the AOD undergoes a variation in 1 hour from values close to 0.5, normal under conditions of the presence of mineral dust, to values of 1.7, to decrease again in 1 hour at values of 0.5. This intermediate measure is probably wrong.



Correct measurements

In this case, the expected **spectral consistency** of AOD between consecutive measurements as well as similar values between observations (**temporal consistency** of close in time observations) are observed. It should be expected that the AOD will not vary abruptly between measurements unless atmospheric conditions change markedly.



REMEMBER this slide!!!!! Note that red AOD values are typically less than green AOD values. This is due to the fact that typical aerosols scatter green light more efficiently than red light.

Typical AOD ranges

Sky conditions	500 nm	870 nm
Extremely clear (pristine)	0.03 - 0.05	0.02 - 0.03
Clear	0.05 - 0.10	0.03 - 0.07
Somewaht hazy	0.10 - 0.25	0.07 - 0.20
Hazy	0.25 - 0.5	0.20 - 0.40
Extremly hazy	> 0.5	> 0.4

Check the readings before saving the data: criterion R^2

1.6 AOT display

After displaying maximum values page, by pressing one more time on red button, Calitoo computes AOT and displays results on a new page.

If results seems be wrong for you, you can choose to do not recording it (see section 1.8)

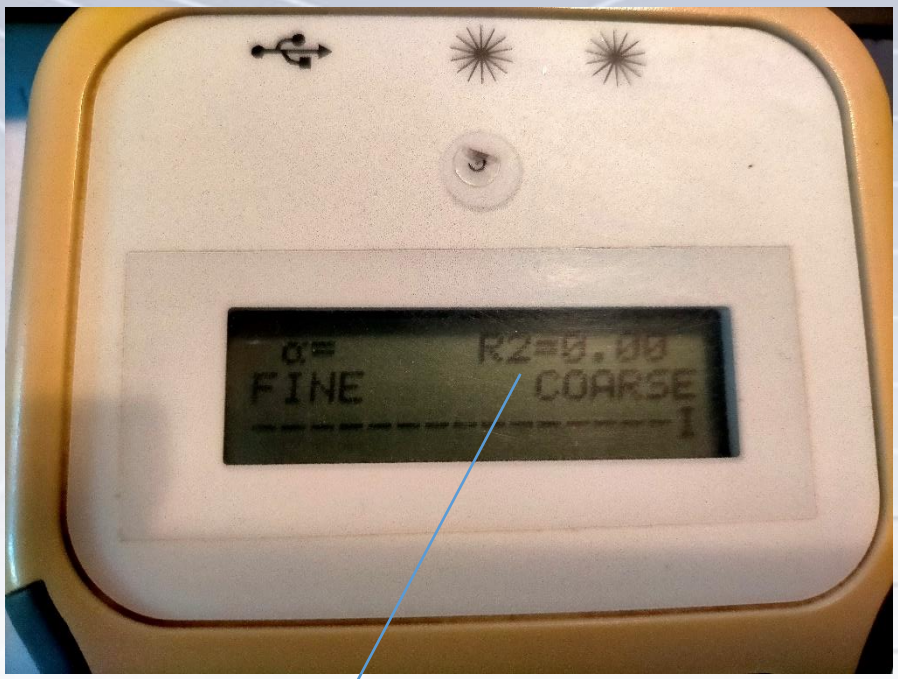
1.7 Alpha display

Click on the button again and you are on the fourth page, the page of the Alpha parameter or Angstrom coefficient.

This coefficient, the calculation of which is explained in Appendix 4.2., makes it possible to characterize the type of particles detected.

R2 is a certitude index. 1.00 is a total certitude with the calculated Alpha while 0.50 is 50% of certitude.

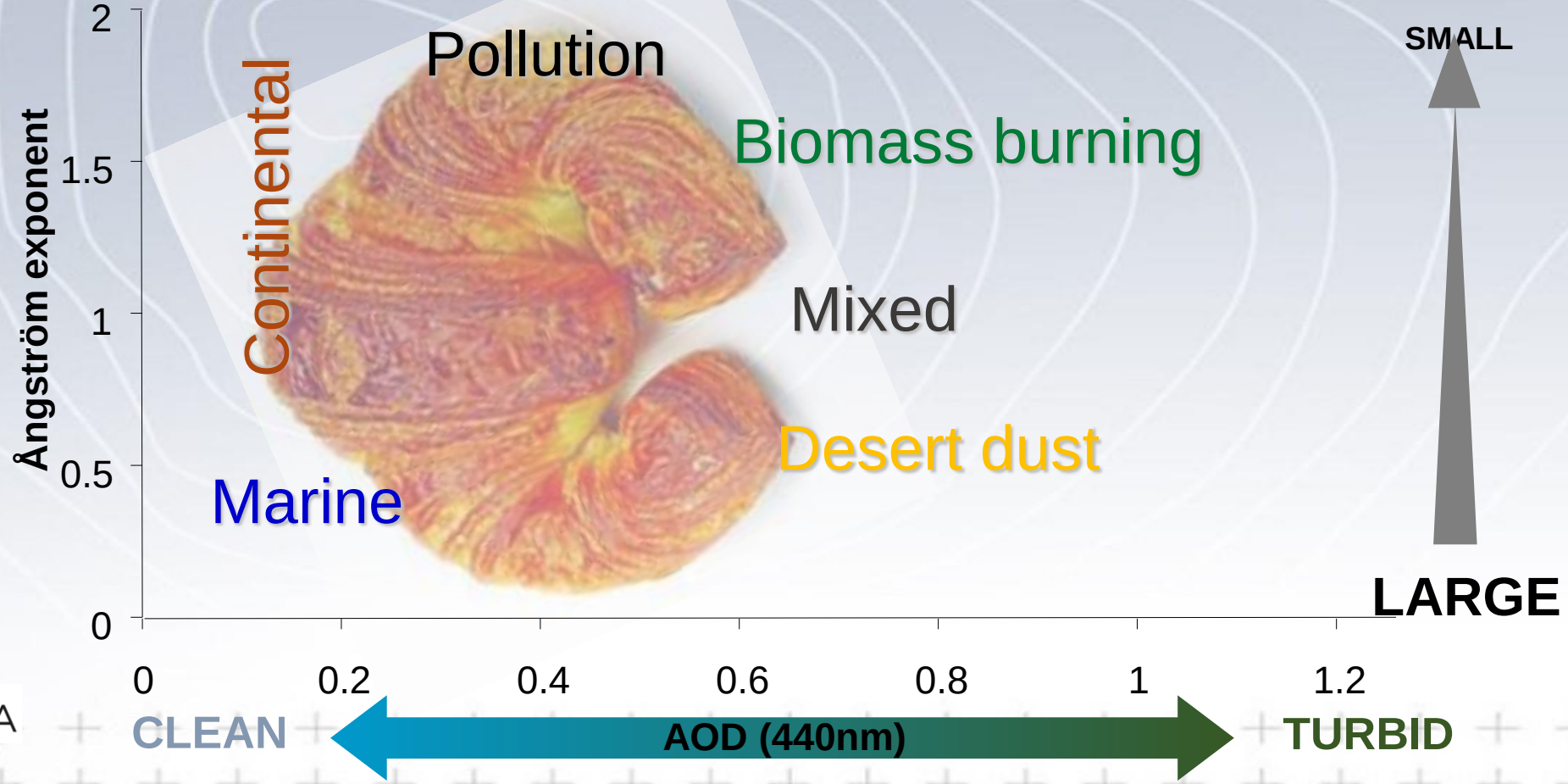
R2 calculation is explained in Appendix 4.2.



$R^2 > 0.6$

$$\tau_\lambda = \beta \cdot \lambda^{-\alpha}$$

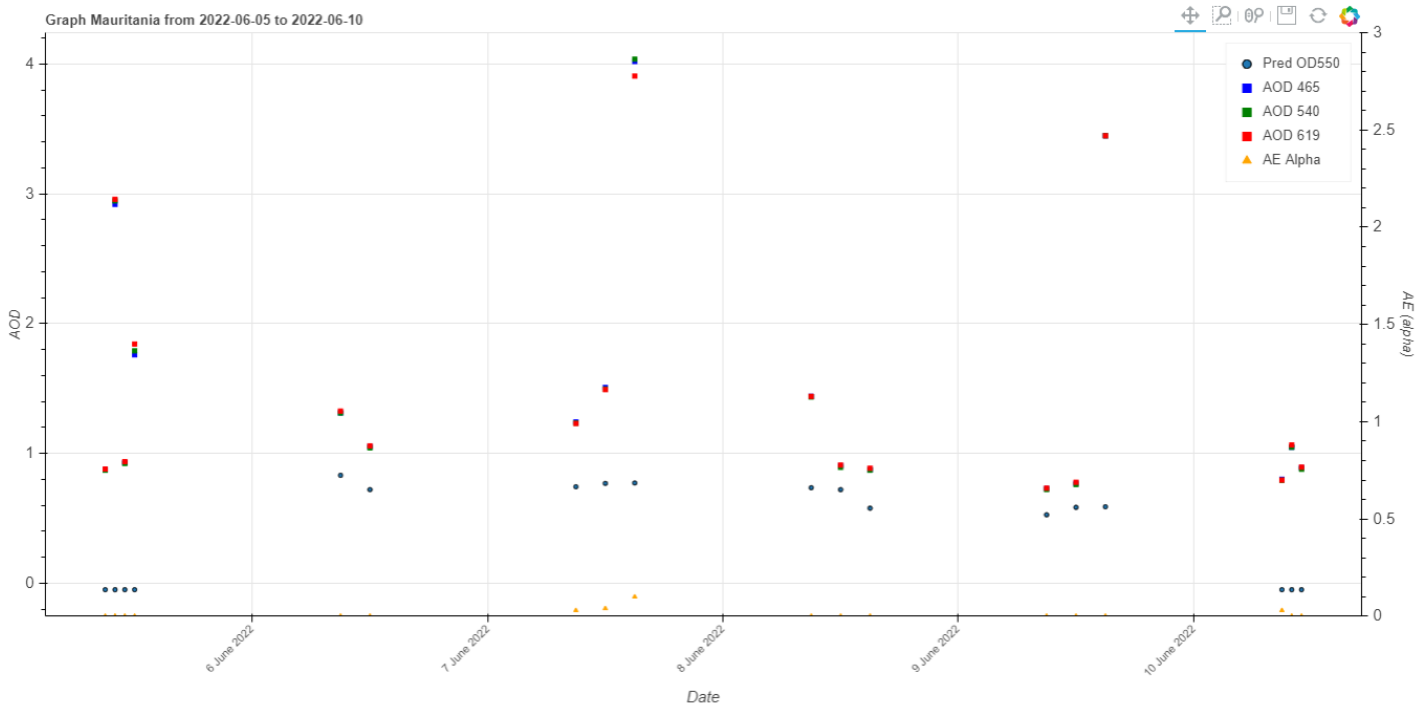
REMEMBER this slide!!!!! Note that alpha or AE is calculated by means of the linear regressions of spectral AOD with their corresponding wavelengths, so that a correct measurement is characterized by a good regression (R^2) of this fitting analysis. Typical AE for dust is very low (<0.5) – coarse particles



Examples of measures in Mauritania

Calima Project Graph View

Station:
Choose station
From:
05/06/2022
To:
10/06/2022
Plot Graph



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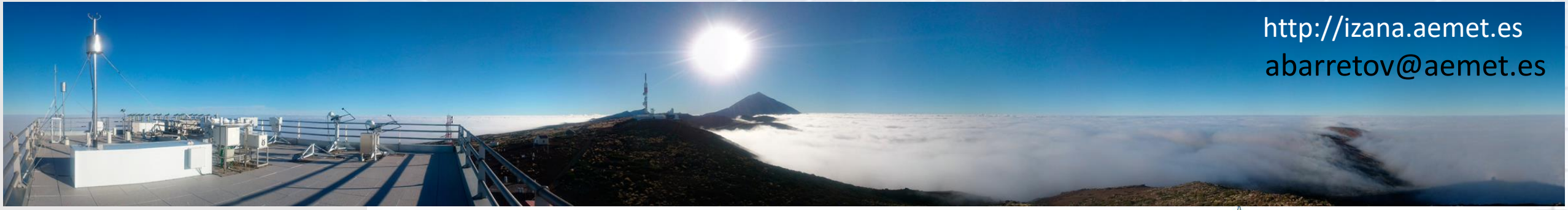
Thanks for your attention!



http://izana.aemet.es
abarretov@aemet.es

AEMet Agencia Estatal de Meteorología

INMG INSTITUTO NACIONAL DE METEOROLOGIA E GEOFÍSICA

WORLD METEOROLOGICAL ORGANIZATION