Development of a real-time tool for deriving the optical properties of aerosol particles in PANGEA observatory, using ground-based passive remote sensing measurements

Thesis Supervisor

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Master thesis

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Outline

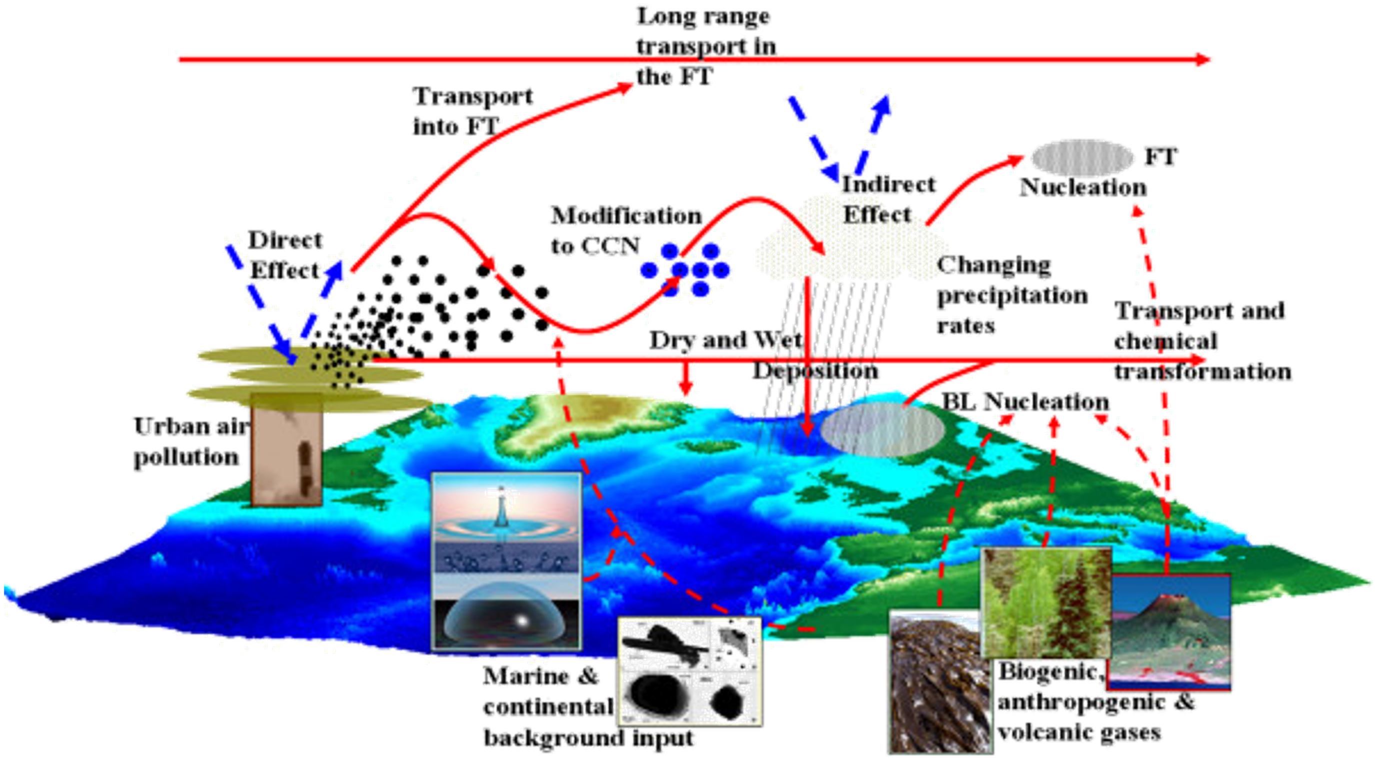
- Thesis Scope
- Aerosol research
- PANhellenic GEophysical observatory of Antikythera (PANGEA)
- AErosol RObotic NETwork (AERONET)
- Developed tool and implementation
- Results
- Future work
- Summary

Thesis Scope

Aerosol Research

Aerosols can affect Earth's energy budget, by directly scattering, absorbing and emitting the incoming solar radiation, and by indirectly influencing the cloud properties.

The atmospheric aerosols play an important role to:



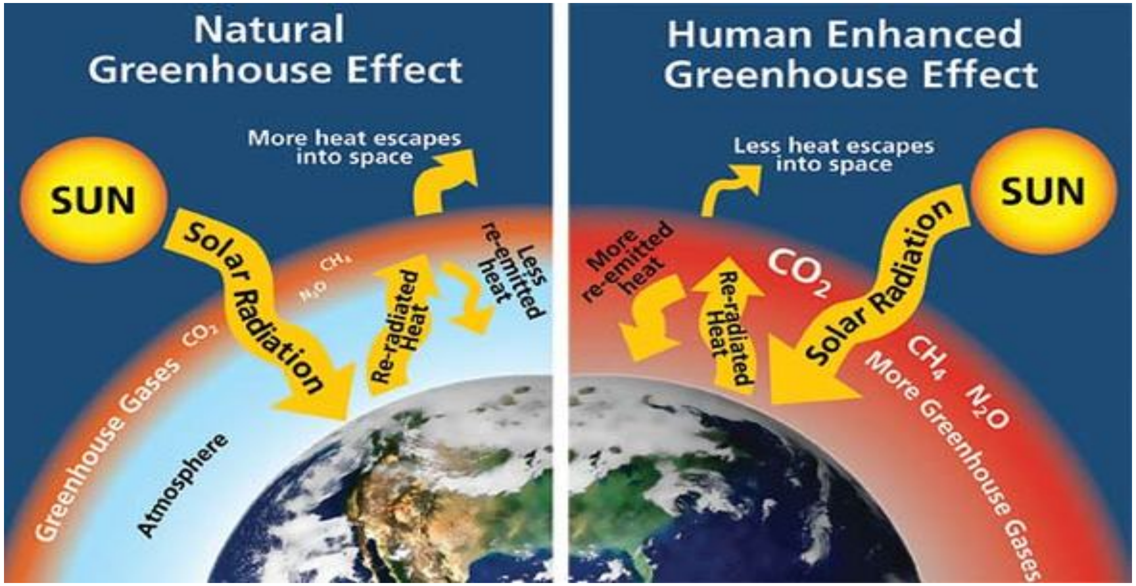
- Weather
- Air quality
- Climate
- Human health
- Ecosystems

Diagram of the life cycle of aerosol in the atmosphere, showing emmission, deposition and transport processes and the action of aerosol while in the atmosphere.
http://www.cas.manchester.ac.uk/resactivities/aerosol/

- This work calculates the optical properties of aerosol particles.
- The **importance** of aerosol optical properties for climate studies.

a) Because aerosol impact the Earth-atmosphere budget

b) Their chemical reaction affect the weather and can harm human health



Tool description

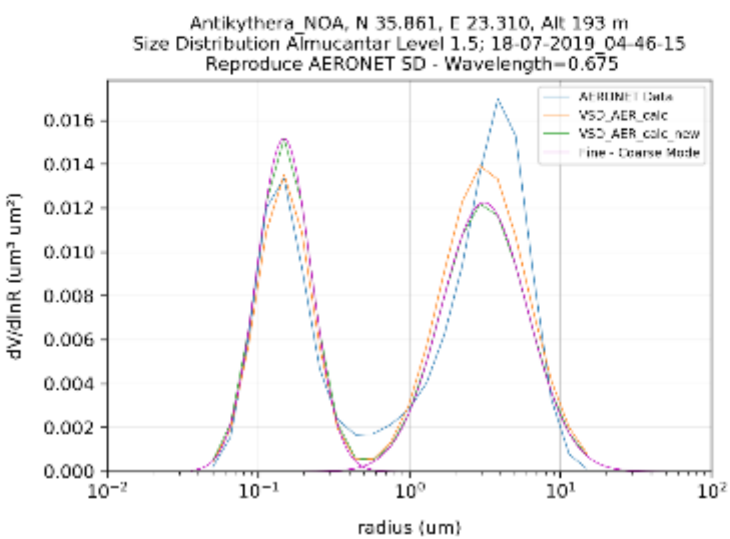
Tool description: Development of a tool for deriving the optical properties of aerosol particles in PANGEA observatory at near-real-time, using ground-based passive remote sensing measurements.

Development steps:

- **Create** a tool that automatically downloads the sun-photometer measurements from the Antikythera AERONET station (at PANGEA), in near real-time.
- **Display** them in graphical plots.
- Use the **Mie scattering code** to calculate the particle optical properties: the extinction, absorption, scattering and backscatter coefficients.

Tool fuctionality

- **Create** a new **tool** that:
  - **Automatically downloads** the AERONET sun-photometer products (size and refractive index of aerosol particles) derived from measurements at PANGEA.
  - **Display** them in graphical plots in near real-time.
  - **Calculate** the optical properties of the particles, when they have spherical shapes.

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abs_f=5.617579533422876e-06 bac_f=1.4251190852857044e-06
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abs_c=3.531313317533394e-06 bac_c=3.1490643817045284e-07
```

Benefit of tool

- It is a **near real-time tool**

The tool can calculate in few seconds the optical properties of aerosols after the data are published in the AERONET

PANhellenic **GE**ophysical observatory of **A**ntikythera

PANGEA

PANGEA observatory in Antikythera island has been installed by the **National Observatory of Athens** (NOA) in order to respond to the scientific need for accurate climatic observations in the Mediterranean.

Why **Antikythera** ?

- crossroad of Europe, Africa and Asia
- anthropogenic activities are very few, due to its population
- ideal place for monitoring natural aerosols
- transported anthropogenic aerosols from big cities in Greece and the surrounding Mediterranean countries

Antikythera NOA equipment
(from National Documentation Centre, www.ekt.gr)

Available instruments in PANGEA:

- **PolyXT lidar** (EARLINET)
- **CIMEL sun-photometer** (AERONET)

What does CIMEL Sun-Photometer do?

- **Provid**es:
  - AOD from **direct-sun measurements**
  - Microphysical properties of the aerosol particles from **diffused light measurements**

How does CIMEL Sun-Photometer **acquire measurements**?

- Every day between sunlight and dawn
- In **nine spectral bands:**
  - 340, 380, 440, 500, 670, 870, 940, 1020 and 1640 nm.

It's a **passive remote sensing** instrument

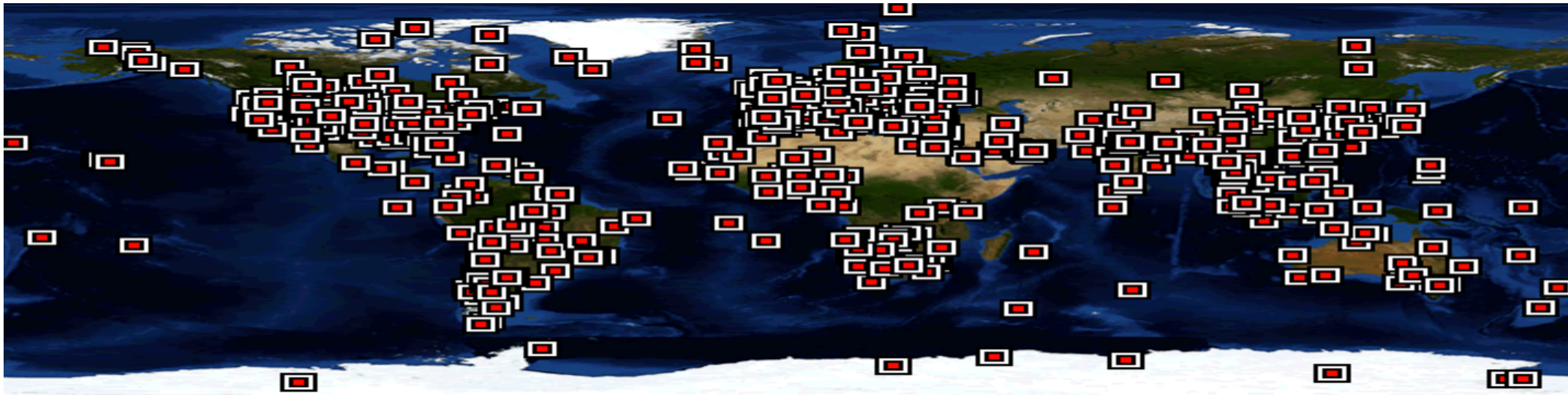
CIMEL sun-photometer (from https://aeronet.gsfc.nasa.gov)

The CIMEL sun-photometer products provide us with the microphysical properties the developed tool uses for the calculation of the aerosol optical properties.

AErosol **RO**botic **NET**work

What is the AERONET?

- It is a network of **ground-based** sun photometers



The worldwide spatial distribution of the AERONET stations

- It provides observations of the **optical** and **microphysical properties** of the atmospheric aerosols

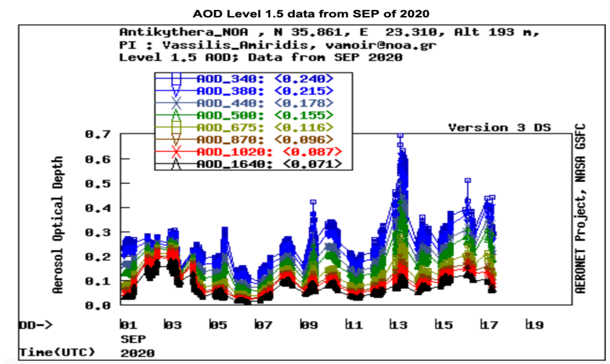
How the AERONET data products **can be accessed** ?

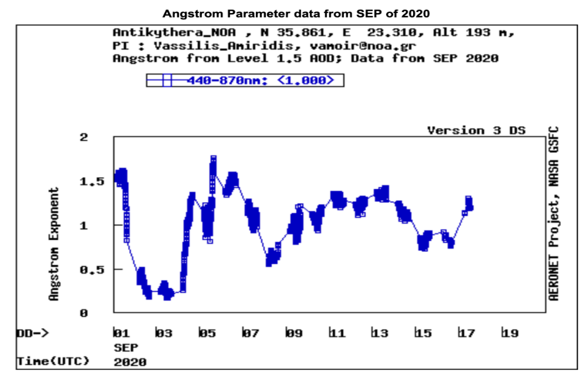
- Through the **AERONET web download tool** in AERONET site https://aeronet.gsfc.nasa.gov/

- Through the **AERONET web services**

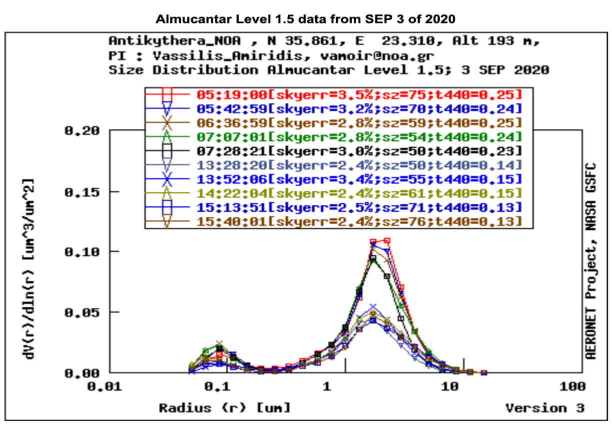
AERONET data display uses a **user-friendly interface** that includes **graphical representations** to display the optical and microphysical properties of the aerosol particles.

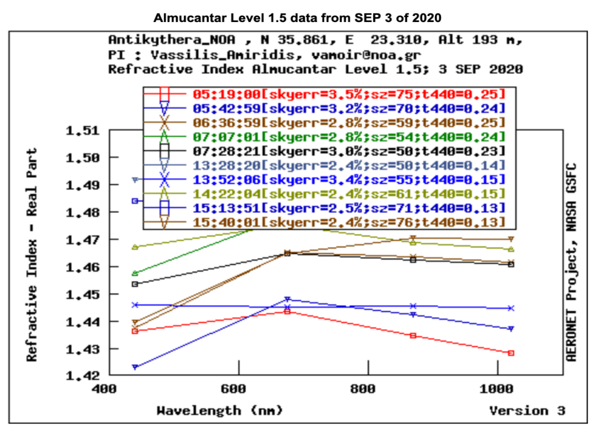
AERONET DATA PRODUCTS

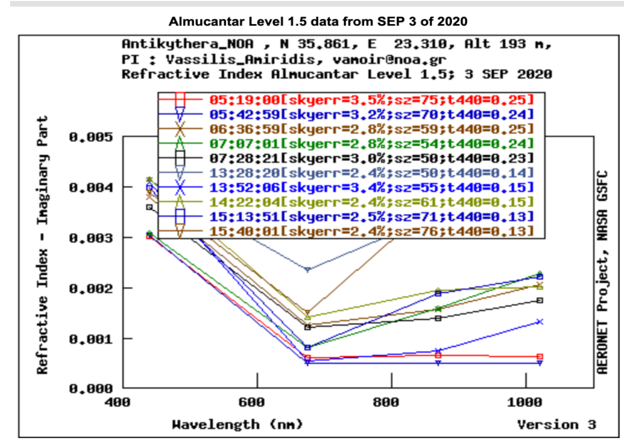




AERONET INVERSION DATA PRODUCTS







Developed tool and implementation

Aim and objectives of the tool

What is our aim?

- To calculate the **optical properties of spherical aerosol particles** in PANGEA observatory based on the AERONET measurements
    - The **scattering** coefficient
    - The **backscatter** coefficient
    - The **absorption** coefficient
    - The **extinction** coefficient

for **fine (**diameter <2.5 μm **) and coarse (**diameter >2.5 μm **)** mode.

Antikythera_NOA AERONET station

- **What** data are used from Antikythera_NOA AERONET station?
  - The **microphysical properties** of the aerosols
    - The **volume size distribution** (dv/dlnr)
    - The **complex refractive index**
    - The **sphericity percentage**
- **How often the station gives data**?

if **there are clouds**

- **What** data are used from Antikythera_NOA AERONET station?
    - The **microphysical properties** of the aerosols
        - The **volume size distribution** (dv/dlnr)
        - The **refractive index**
        - The **sphericity percentage**
- **How often the station gives data**?

Otherwise

UTC /Local time
~ 5:00/8:00
~ 5:25/8:25
~ 6:13/9:13
~ 6:43/9:43
~ 7:34/10:34
~ 8:25/11:25
~ 12:25/15:25

UTC /Local time
~ 13: 34/16:34
~ 14:28/17:28
~ 14:58/17:58
~ 15:49/18:49
~ 16:13/19:13
No data
Until next day

After how many minutes we can **access** the **data**?

~25'

Loading...

- Programming language: **Python version 3.7**

  - Open Source
  - Object Oriented
  - Big Supported Community
  - Easy to learn

- Scientific Python development environment: **Spyder with Anaconda**

ANACONDA® SPYDER

Code analytic description - Algorithm

Download/Read data from AERONET

↓

Plot the dv/dlnr from product "size distribution" of AERONET

↓

Plot the bimodal log-normal fit of dv/dlnr from product "volume concentration" of AERONET

↓

Calculate the dN/dlnr based on dv/dlnr AERONET data

↓

if the particles are spherical call the mie_ code function with inputs the dN/dlnr parameters, the complex refractive indices and the wavelength

↓

In mie_code function, the bhmie() function is called to calculate the optical properties of single particles

↓

At the end, the mie_code function calculates the optical properties of the particle ensemble, i.e., the extinction, scattering, backscatter and absorption coefficient

Code analytic detailed description

Check arguments
(start/end date, wavelength)

The **user** specifies the **wavelength** and the date or the **period** that wants to study.

By **default**, the **wavelength** is equal to **0.44 μm** and the period is the current day.

Web request to Antikythera AERONET server
for AERONET data/web service

Check if there are data for these dates

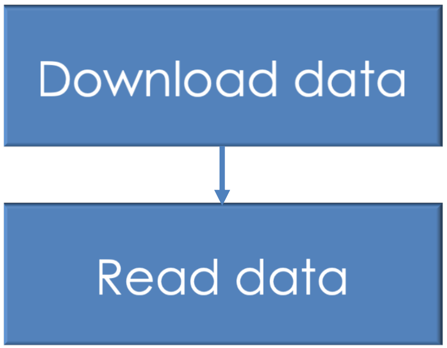
NO

The system **exits** by informing the user that for these dates there are no data.

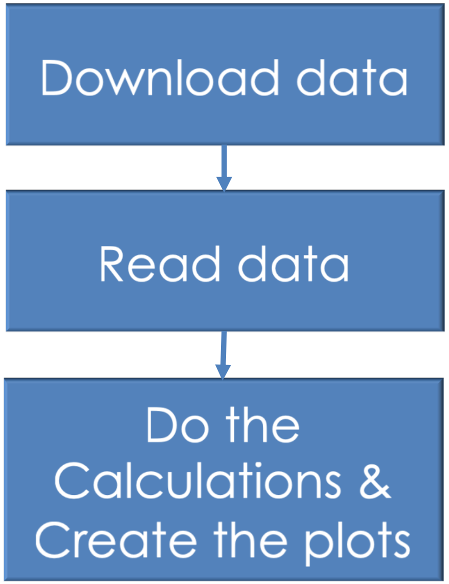
YES

The program **downloads** automatically the relevant **data**.

- In the **case that there are data**, there is an **iteration**, because **there can be more than one measurements (at different times) in the day**.

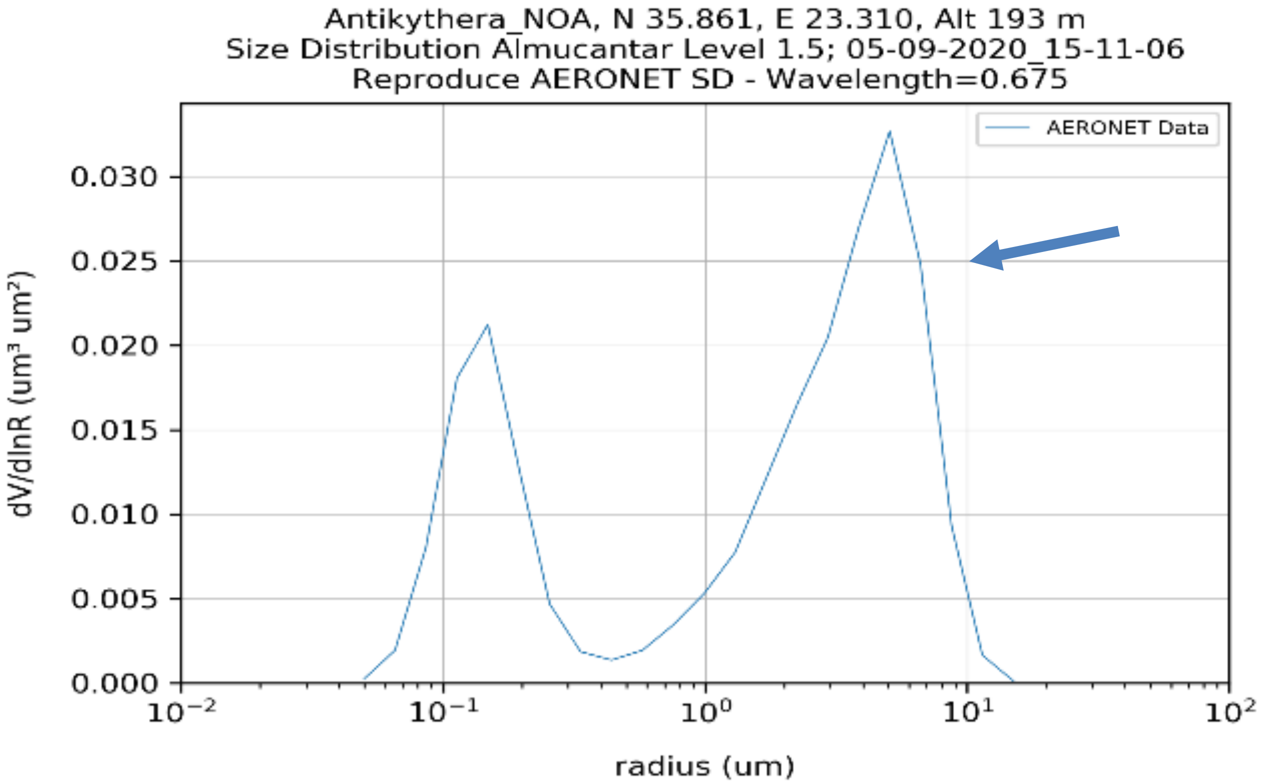


AERONET product	**Parameters**
Product.asy →	**Sphericity_Factor** (%)
Product.rin →	**Refractive_Index Real_Part & Imaginary_Part** (440 nm, 678 nm, 870 nm, 1020 nm)
Product.siz →	**Size distribution at 22 size bins**
Product.vol →	**Parameters of the bimodal log-normal fit of the 22-size-bin volume size distribution**: the geometric standard deviation, total volume concentration, geometric mean volume radius, for both fine and coarse modes

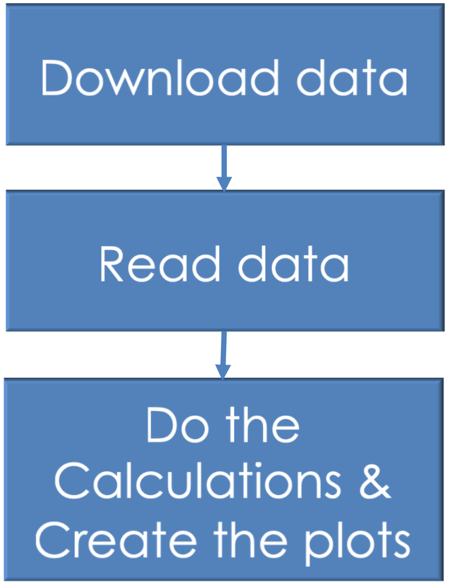


1st step

The **blue line** represents the **22-size-bin Volume Size Distribution** (dv/dlnr) acquired from the AERONET product (product.siz).



Code analytic description



2[nd] step

Based on **the (six) parameters** of the bimodal log-normal fit of the 22-size-bin volume size distribution, we calculate the dv/dlnr_fit:

$$\frac{dV}{dlnr} = \frac{volc\_f}{\sqrt{2\pi}\ln(std\_f)} exp\left(-\frac{(\ln(r) - \ln(vmr\_f))^2}{2\ln(std\_f)^2}\right) + \frac{volc\_c}{\sqrt{2\pi}\ln(std\_c)} exp\left(-\frac{(\ln(r) - \ln(vmr\_c))^2}{2\ln(std\_c)^2}\right)$$

where $\frac{dV}{dlnr}$: the particle volume size distribution
$volc\_f$: the total volume concentration of fine mode
$volc\_c$: the total volume concentration of coarse mode
vmr_f: volume geometric mean radius of fine mode
vmr_c: volume geometric mean radius of coarse mode
std_f: geometric standard deviation of fine mode
std_c: geometric standard deviation of coarse mode

Code analytic description

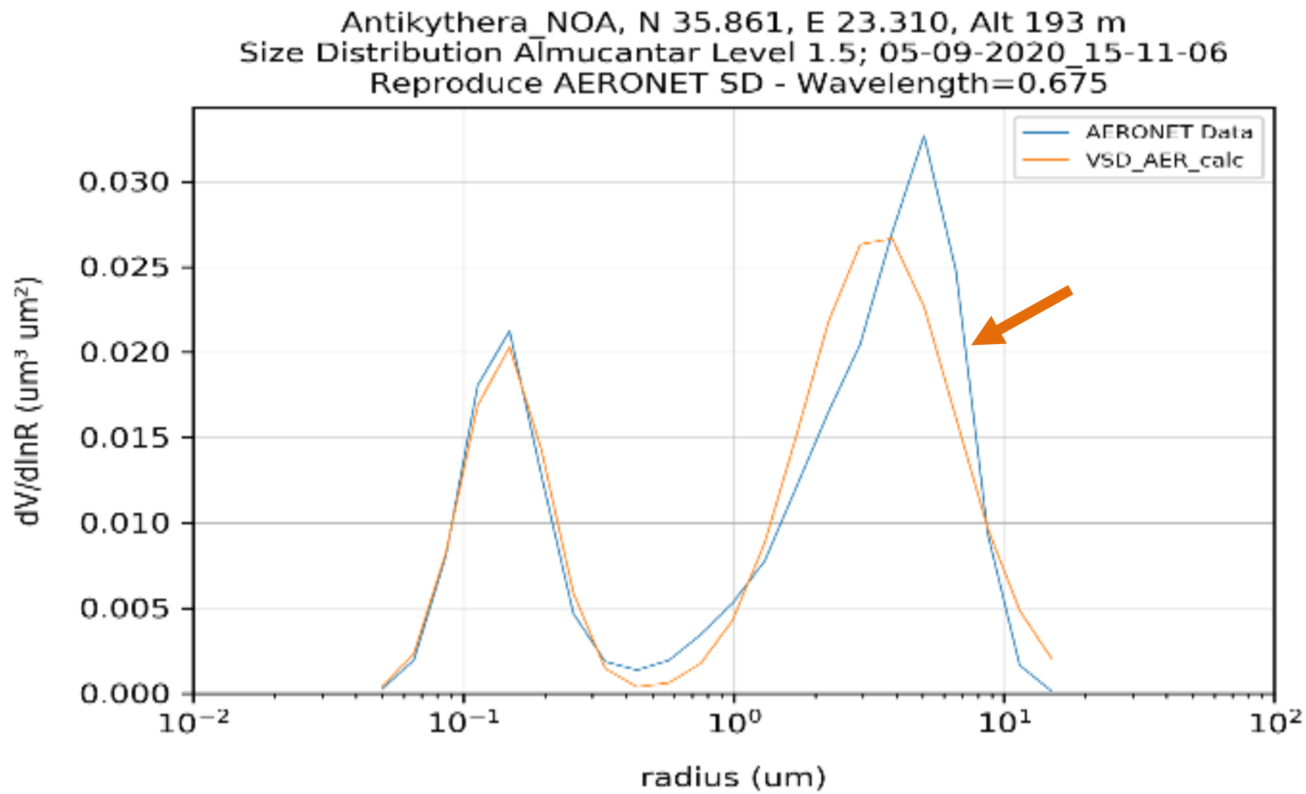
Download data

Read data

Do the Calculations & Create the plots

2nd step

The **orange line** is the **bimodal log-normal fit of the 22-size-bin Volume Size Distribution (dv/dlnr_fit).** **It** fits the blue line using only **six parameters** (volc_f, volc_c, vmr_f, vmr_c, std_f, std_c).



Code analytic description

Download data

↓

Read data

↓

Do the Calculations & Create the plots

2^{nd} step

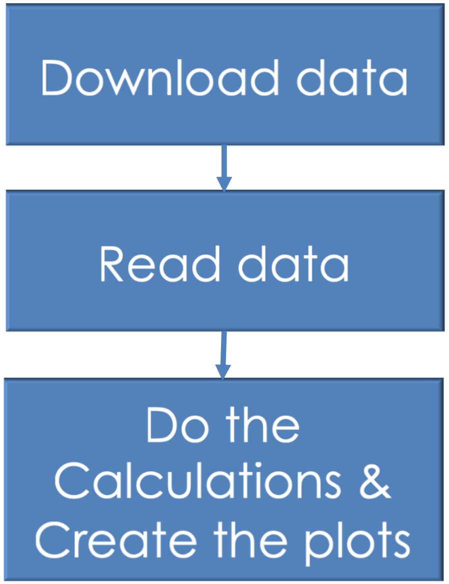
Why we need this step?

Because the **Mie** scattering **code** has as **input** a **bimodal lognormal size distribution**.

This size distribution is described based on these six parameters.

Parameters

- **Total volume concentration** (volc_f, volc_c)
- **Volume geometric mean radius** (vmr_f, vmr_c)
- **Geometric standard deviation** (std_f, std_c)



2nd step

More specifically

The **input** of the **Mie** scattering **code is a bimodal lognormal number size distribution.**

And how can I calculate it?

$$\frac{dN}{dlnr} = \frac{Nc\_f}{\sqrt{2\pi}\ln(std\_f)} exp\left(-\frac{(\ln(r) - \ln(nmr\_f))^2}{2\ln(std\_f)^2}\right) + \frac{Nc\_c}{\sqrt{2\pi}\ln(std\_c)} exp\left(-\frac{(\ln(r) - \ln(nmr\_c))^2}{2\ln(std\_c)^2}\right)$$

Code analytic description

Download data

↓

Read data

↓

Do the Calculations & Create the plots

2nd step

$$\frac{dN}{dlnr} = \frac{Nc\_f}{\sqrt{2\pi}\ln(std\_f)} exp\left(-\frac{(\ln(r) - \ln(nmr\_f))^2}{2\ln(std\_f)^2}\right) + \frac{Nc\_c}{\sqrt{2\pi}\ln(std\_c)} exp\left(-\frac{(\ln(r) - \ln(nmr\_c))^2}{2\ln(std\_c)^2}\right)$$

In order to **calculate the six parameters of the number size distribution** (Nc_f, Nc_c, nmr_f, nmr_c, std_f, std_c) **based on** the six parameters of the **volume size distribution** (volc_f, volc_c, vmr_f, vmr_c, std_f, std_c) we use these formulas:

$$Nc\_f = \sum\left(radius\_AER\_dif \cdot \left(\frac{\frac{1}{radius\_AER\_mean}\frac{volc\_f}{\sqrt{2\pi}std\_f}\exp\left(-\frac{((\ln(radius\_AER\_mean)-\ln(vmr\_f))^2)}{2std\_f^2}\right)}{\frac{4\pi}{3}radius\_AER\_mean^3} \right)\right)$$

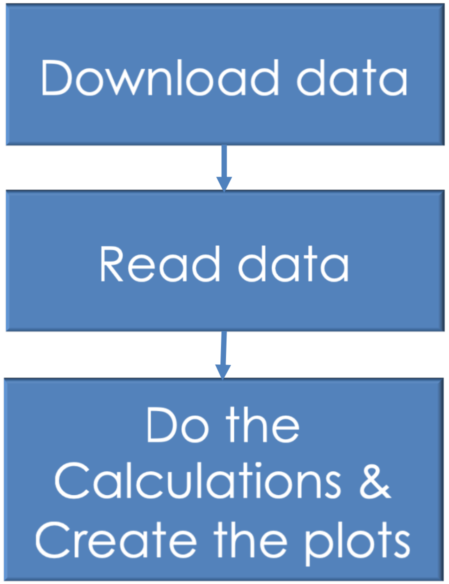
$$Nc\_c = \sum\left(radius\_AER\_dif \cdot \left(\frac{\frac{1}{radius\_AER\_mean}\frac{volc\_c}{\sqrt{2\pi}std\_c}\exp\left(-\frac{((\ln(radius\_AER\_mean)-\ln(vmr\_c))^2)}{2std\_c^2}\right)}{\frac{4\pi}{3}radius\_AER\_mean^3} \right)\right)$$

where

Nc_f: the total number concentration of fine mode

Nc_c: the total number concentration of coarse mod

Code analytic description



2nd step

$$\frac{dN}{d\ln r} = \frac{Nc\_f}{\sqrt{2\pi}\ln(std\_f)} exp\left(-\frac{(\ln(r) - \ln(nmr\_f))^2}{2\ln(std\_f)^2}\right) + \frac{Nc\_c}{\sqrt{2\pi}\ln(std\_c)} exp\left(-\frac{(\ln(r) - \ln(nmr\_c))^2}{2\ln(std\_c)^2}\right)$$

In order to **calculate the six parameters of the number size distribution** (Nc_f, Nc_c, nmr_f, nmr_c, std_f, std_c) **based on** the six parameters of the **volume size distribution** (volc_f, volc_c, vmr_f, vmr_c, std_f, std_c) we use these formulas:

$$nmr\_f = \frac{\exp\left(\ln(2 - vmr\_f) - 3std\_f^2\right)}{2}$$

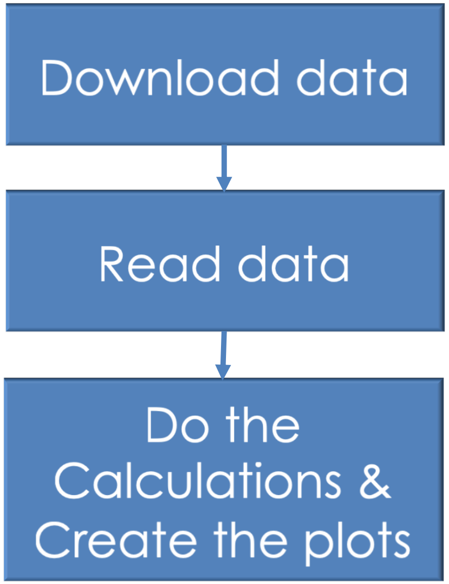
$$nmr\_c = \frac{\exp\left(\ln(2 - vmr\_c) - 3std\_c^2\right)}{2}$$

where

nmr_f, nmr_c:
the number mean radius for fine and coarse mode

The **geometric standard deviation** (“std_f” and “std_c”) **does not change** for number and volume size distributions.

Code analytic description



2nd step

After calculating dN/dlnr with the formulas presented in the previous slides, we calculate the volume size distribution using the following formula:

$$\frac{dV}{d\ln r} = \frac{dN}{d\ln r}\,\frac{4\pi\, radius\_AER\_mean^{3}}{3}$$

This formula uses the assumption **that the size does not change within the size bin and is equal to the mean radius of the size bin (radius_AER_mean)**.

Code analytic description

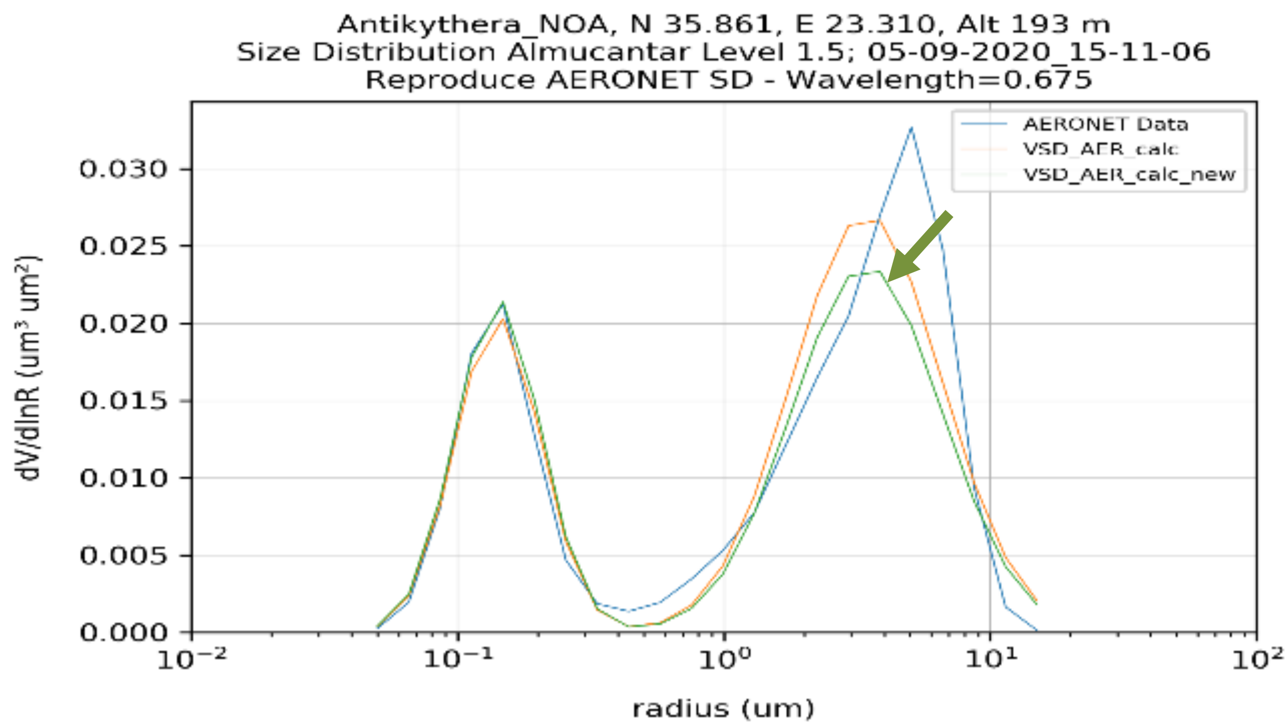
Download data

Read data

Do the Calculations & Create the plots

3ed step

The **green line**, is the **reproduction of the bimodal volume size distribution**, using the calculated number size distribution. This line is used to verify our calculations $\frac{dN}{dlnr}$, since in the ideal case it should coincide with the orange line (i.e. the bimodal log-normal fit of the 22-size-bin volume size distribution).



Code analytic description

Download data

↓

Read data

↓

Do the Calculations & Create the plots

3ed step

This does not happen all the times, mainly due to the limitation in equation to use a representative value for the radius of the size bin.

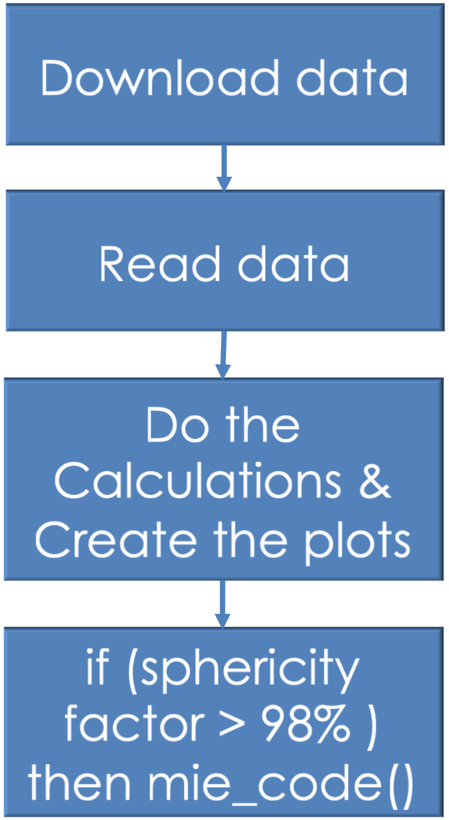
$$\frac{dV}{dlnr} = \frac{dN}{dlnr}\frac{4\pi radius\_AER\_mean^3}{3}$$

$$\frac{dN}{dlnr} = \frac{Nc\_f}{\sqrt{2\pi}\ln(std\_f)} exp\left(-\frac{(\ln(r) - \ln(nmr\_f))^2}{2\ln(std\_f)^2}\right) + \frac{Nc\_c}{\sqrt{2\pi}\ln(std\_c)} exp\left(-\frac{(\ln(r) - \ln(nmr\_c))^2}{2\ln(std\_c)^2}\right)$$

$$Nc\_f = \sum\left(radius\_AER\_dif \cdot \left(\frac{\frac{1}{radius\_AER\_mean}\frac{volc\_f}{\sqrt{2\pi}std\_f}\exp\left(-\frac{(\ln(radius\_AER\_mean)-\ln(vmr\_f))^2}{2std\_f^2}\right)}{\frac{4\pi}{3}radius\_AER\_mean^3}\right)\right)$$

$$Nc\_c = \sum\left(radius\_AER\_dif \cdot \left(\frac{\frac{1}{radius\_AER\_mean}\frac{volc\_c}{\sqrt{2\pi}std\_c}\exp\left(-\frac{((\ln(radius\_AER\_mean)-\ln(vmr\_c))^2}{2std\_c^2}\right)}{\frac{4\pi}{3}radius\_AER\_mean^3}\right)\right)$$

Code analytic description

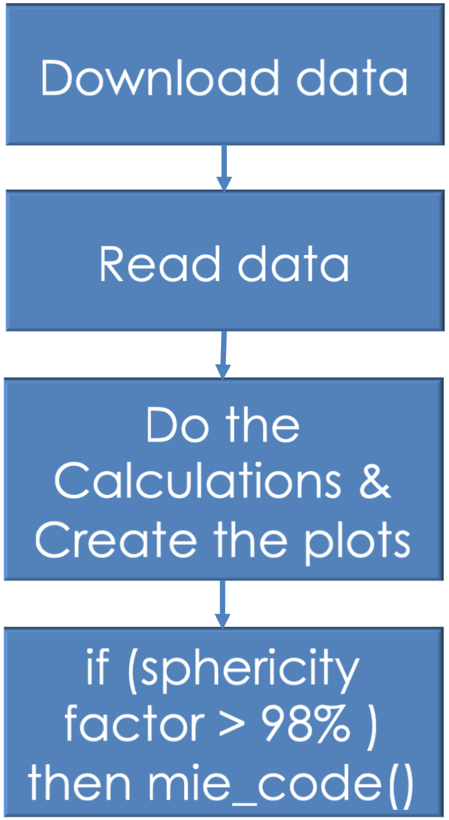


4th step

The Mie Scattering code is valid only for **particles with spherical shapes.**

More specifically

The **sphericity factor needs to be greater than 98%.**



4th step

Mie scattering code

Inputs

- The user-defined wavelength
- The parameters of the number size distribution (Nc_f, Nc_c, nmr_f, nmr_c, std_f and std_c)
- The real and imaginary part of the refractive index (considered to be the same for fine and coarse particles)

Code analytic description

Download data

Read data

Do the Calculations & Create the plots

if (sphericity factor > 98%) then mie_code()

4th step

The mie_code() function **calculate**s:

- The **number concentration in each sub-bin** for fine and coarse mode respectively based on the following formula:

$$dcon\_c = Nc\_c \exp\left(-1\,(ln\frac{r}{nmr\_c})^2/(2\,std\_c^2)\right)\frac{1}{r\,std\_c\,\sqrt{2\pi}}$$

where dcon_c: the number concentration in each bin for coarse mode

Nc_c: the total number concentration of coarse mode

nmr_c: number geometric mean radius of coarse mode

r: bin center radii

std_c: geometric standard deviation of coarse mode

Code analytic description

Download data

↓

Read data

↓

Do the Calculations & Create the plots

↓

if (sphericity factor > 98%) then mie_code()

4th step

$$dcon\_c = Nc\_c \exp\left(-1\,(\ln \frac{r}{nmr\_c})^2/(2\,std\_c^2)\right)\frac{1}{r\,std\_c\,\sqrt{2\pi}}$$

The mie_code() function **calculates**:

- The **volume size distribution** (SD_dv_dlnr) for fine and coarse mode based on the following formula:

$$SD\_dv\_dlnr = r\left(\frac{4\pi}{3}\right)r^3 dcon$$

and a **fourth line** is created in the plot.

Code analytic description

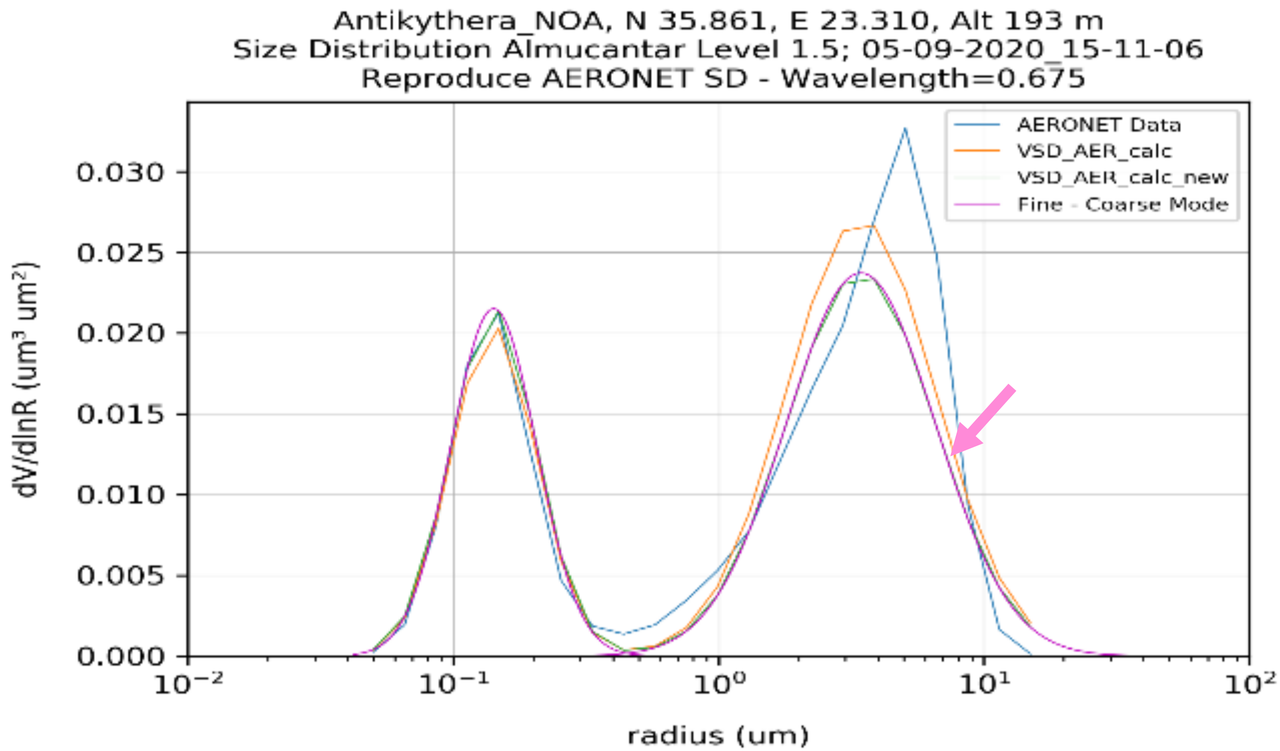
Download data

Read data

Do the Calculations & Create the plots

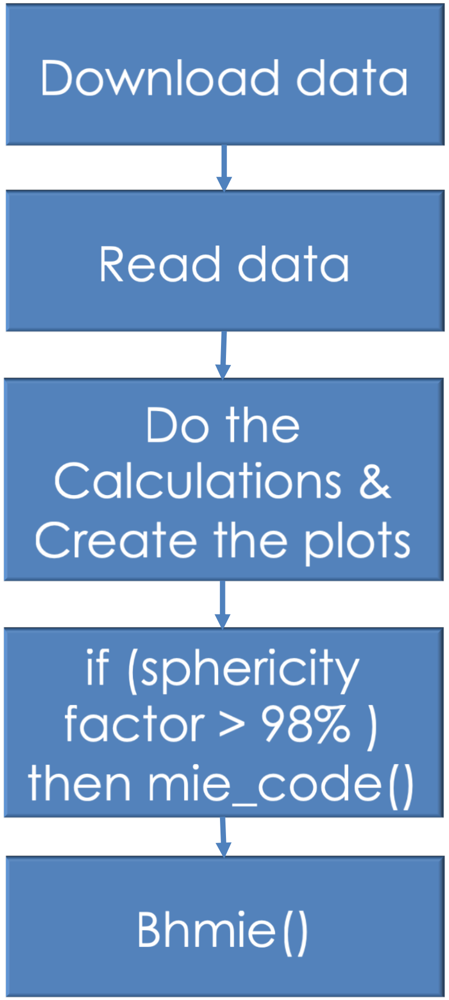
if (sphericity factor > 98%) then mie_code()

4th step



The **pink line** is a **verification** point in the algorithm (it should coincide with the green line), showing that the size distribution we provide in the input is indeed the one that is used in the Mie calculations.

Code analytic description

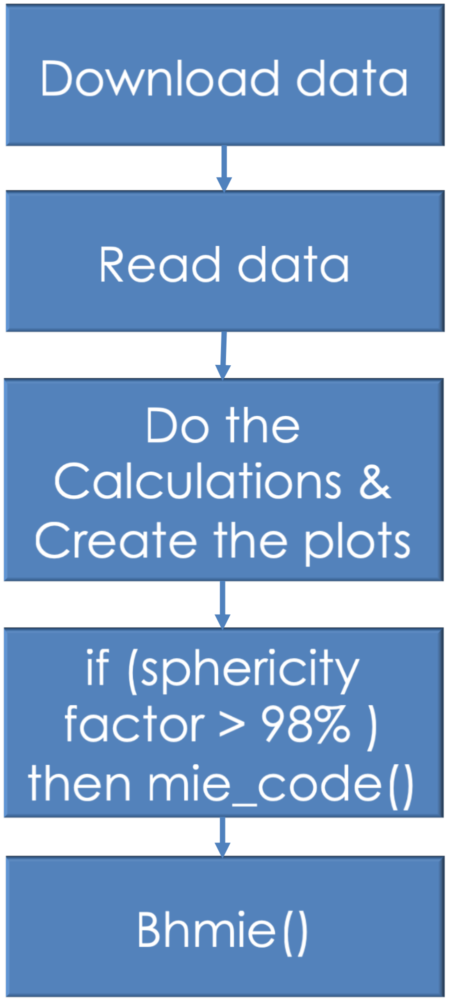


4th step

The mie_code() function uses **the bhmie() function** that calculates the **optical properties** of the **individual particle**, with specific size and refractive index.

The bhmie() function that was used in this thesis, was written in 1983 from **Craig F. Bohren and Donald R. Huffman.**

Code analytic description



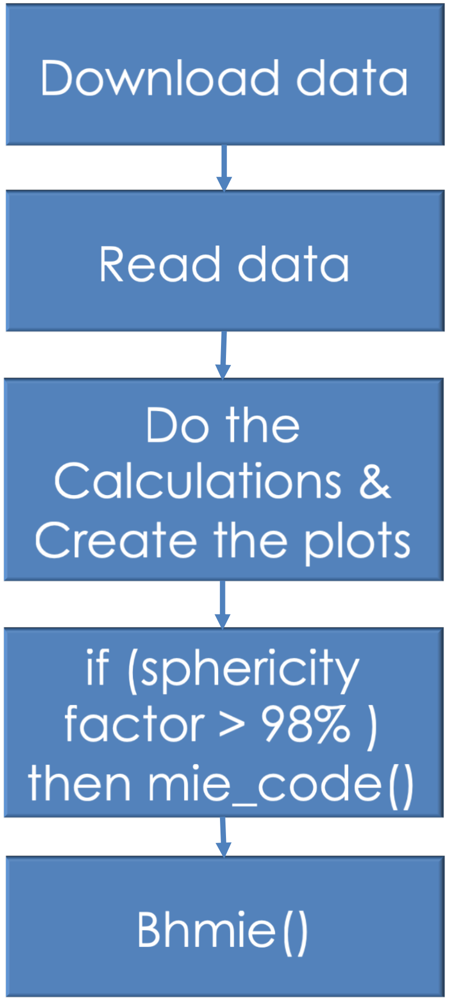
4th step

The mie_code() function uses **the bhmie() function** that calculates the **optical properties** of the **individual particle**, with specific size and refractive index.

Inputs

- The size parameter
- The refractive index
- The number of scattering angles

Code analytic description



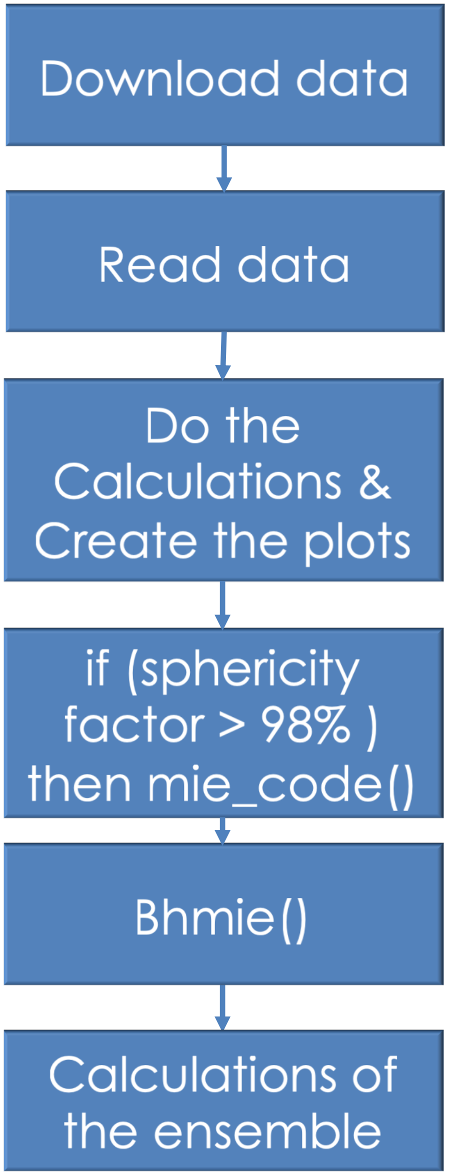
4th step

The mie_code() function uses **the bhmie() function** that calculates the **optical properties** of the **individual particle**, with specific size and refractive index.

Outputs

- The **extinction efficiency**
- The **scattering efficiency**
- The **backscatter efficiency**
- The **absorption efficiency**

Code analytic description



5th step

In this step we calculate the **optical properties** of the **particle ensemble**, taking into account the size distribution of the particles in the ensemble:

- **The extinction coefficient**

$$\varepsilon_{ext} = \int N(r)\sigma_{ext}\,dr = \int N(r)Q_{ext}\,\pi r^2\,dr$$

- **The scattering coefficient**

$$\varepsilon_{sca} = \int N(r)\sigma_{sca}\,dr = \int N(r)Q_{sca}\,\pi r^2\,dr$$

- **The backscatter coefficient**

$$\varepsilon_{bck} = \int N(r)Q_{bck}\left(\frac{\lambda}{\pi r}\right)^2 dr$$

- **The absorption coefficient**

$$\varepsilon_{abs} = \int N(r)\sigma_{abs}\,dr = \int N(r)Q_{abs}\,\pi r^2\,dr$$

Results of the study

Results of 27/04/2020

On the date of 27 of April on 2020, there are **no** available **data** from the Antikythera AERONET station, and the user is informed with the following message:

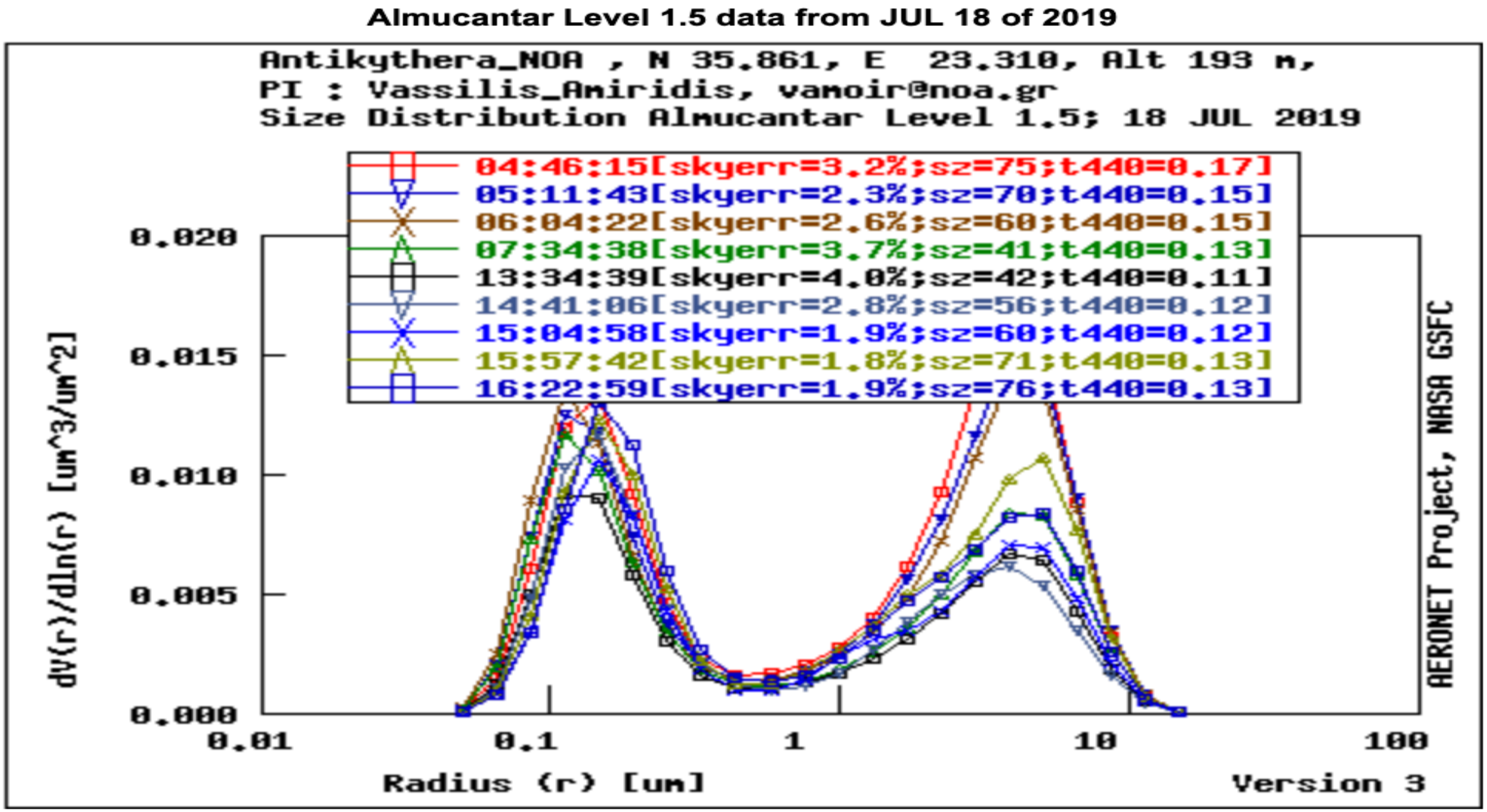
```
Start date is: year=2019&month=4&day=27
End date is: year2=2019&month2=4&day2=27&hour2=23
Wavelength is: 0.675
https://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_inv_v3?
site=Antikythera_NOA&AVG=10&ALM15=1&if_no_html=1&product=SIZ&year=201
9&month=4&day=27&year2=2019&month2=4&day2=27&hour2=23
https://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_inv_v3?
site=Antikythera_NOA&AVG=10&ALM15=1&if_no_html=1&product=VOL&year=201
9&month=4&day=27&year2=2019&month2=4&day2=27&hour2=23
https://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_inv_v3?
site=Antikythera_NOA&AVG=10&ALM15=1&if_no_html=1&product=ASY&year=201
9&month=4&day=27&year2=2019&month2=4&day2=27&hour2=23
https://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_inv_v3?
site=Antikythera_NOA&AVG=10&ALM15=1&if_no_html=1&product=RIN&year=201
9&month=4&day=27&year2=2019&month2=4&day2=27&hour2=23
Site=Antikythera_NO no data is available in this period: starting
date=27/4/2019 and ending date=27/4/2019
```

Results of 25/06/2020

In this case, the **start and end date** are the **same**. The day is the 18th of July on 2019 and the **wavelength of refractive index is equal to 0.675** μm. The data for this date is available as shown in the message below:

```
Start date is: year=2019&month=7&day=18
End date is: year2=2019&month2=7&day2=18
Wavelength is: 0.675
https://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_inv_v3?
site=Antikythera_NOA&AVG=10&ALM15=1&if_no_html=1&product=SIZ&year=2019&month=7&da
y=18&year2=2019&month2=7&day2=18
https://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_inv_v3?
site=Antikythera_NOA&AVG=10&ALM15=1&if_no_html=1&product=VOL&year=2019&month=7&da
y=18&year2=2019&month2=7&day2=18
https://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_inv_v3?
site=Antikythera_NOA&AVG=10&ALM15=1&if_no_html=1&product=ASY&year=2019&month=7&da
y=18&year2=2019&month2=7&day2=18
https://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_inv_v3?
site=Antikythera_NOA&AVG=10&ALM15=1&if_no_html=1&product=RIN&year=2019&month=7&da
y=18&year2=2019&month2=7&day2=18
```

This certain day, based on the AERONET site, there are **nine different retrievals** of the volume size distribution for different times during the day, as shown in the figure below: at 04:46:15, 05:11:43, 06:04:22, 07:34:38, 13:34:39, 14:41:06, 15:04:58, 15:57:42, 16:22:59 UTC



Results of 18/07/2019

Time: 04:46:15

```
Creating plot for SIZ_Antikythera_NO_18-07-2019_04-46-15
SIZ_Antikythera_NO_18-07-2019_04-46-15 Sphericity_Factor 99.00 %
volc_f=0.014000 vmr_f=0.148000 std_f=0.413000 volc_c=0.023000 vmr_c=3.132000
std_c=0.656000 rirp440=1.600000 rirp675=1.541400 rirp870=1.521200
rirp1020=1.524100 riip440=0.007420 riip675=0.006930 riip870=0.006592
riip1020=0.006531
RI 0.675
```

The **AERONET product for this case** provides the following aerosol properties:

- **Total volume concentration** of fine mode (volc_f) : 0.014000 cm^3 cm^{-3}
- **Geometric mean volume radius** of fine mode (vmr_f): 0.148000 μm
- **Geometric standard deviation** of fine mode (std_f): 0.413000
- **Total volume concentration** of coarse mode (volc_c): 0.023000 cm^3 cm^{-3}
- **Geometric mean volume radius** of coarse mode (vmr_c): 3.132000 μm
- **Geometric standard deviation** of coarse mode (std_c): 0.656000

Time: 04:46:15

```
Creating plot for SIZ_Antikythera_NO_18-07-2019_04-46-15
SIZ_Antikythera_NO_18-07-2019_04-46-15 Sphericity_Factor 99.00 %
volc_f=0.014000 vmr_f=0.148000 std_f=0.413000 volc_c=0.023000 vmr_c=3.132000
std_c=0.656000 rirp440=1.600000 rirp675=1.541400 rirp870=1.521200
rirp1020=1.524100 riip440=0.007420 riip675=0.006930 riip870=0.006592
riip1020=0.006531
RI 0.675
```

The **AERONET product for this case** provides the following aerosol properties:

- **Real part of the refractive index** at 440 nm (rirp440): 1.600000
- **Real part of the refractive index** at 675 nm (rirp675): 1.541400
- **Real part of the refractive index** at 870 nm (rirp870): 1.521200
- **Real part of the refractive index** at 1020 nm (rirp1020): 1.524100

- **Imaginary part of the refractive index** at 440 nm (riip440): 0.007420
- **Imaginary part of the refractive index** at 675 nm (riip675): 0.006930
- **Imaginary part of the refractive index** at 870 nm (riip870): 0.006592
- **Imaginary part of the refractive index** at 1020 nm (riip1020): 0.006531

Results of 18/07/2019

Time: 04:46:15

```
ext_all=7.909338890331058e-05 sca_all=7.346999408914502e-05
abs_all=5.623394814165551e-06 bac_all=2.032112840574509e-06
ext_f=6.52076043790471e-05 sca_f=6.241395193588643e-05
abs_f=2.793652443160673e-06 bac_f=1.339195996620889e-06
ext_c=1.388578452426348e-05 sca_c=1.105604215325859e-05
abs_c=2.829742371004884e-06 bac_c=6.929168439536193e-07
```

The calculated **outputs** for this case are the following:

- **Extinction coefficient of the ensemble** (ext_all): 7.909338 Km^{-1}
- **Scattering coefficient of the ensemble** (sca_all): 7.346999 Km^{-1}
- **Absorption coefficient of the ensemble** (abs_all): 5.623394 Km^{-1}
- **Backscatter coefficient of the ensemble** (bac_all): 2.032112 Km^{-1} sr^{-1}

- **Extinction coefficient of the fine mode** (ext_f): 6.520760 Km^{-1}
- **Scattering coefficient of the fine mode**(sca_f): 6.241395 Km^{-1}
- **Absorption coefficient of the fine mode** (abs_f): 2.793652 Km^{-1}
- **Backscatter coefficient of the fine mode** (bac_f): 1.339195 Km^{-1} sr^{-1}

Results of 18/07/2019

Time: 04:46:15

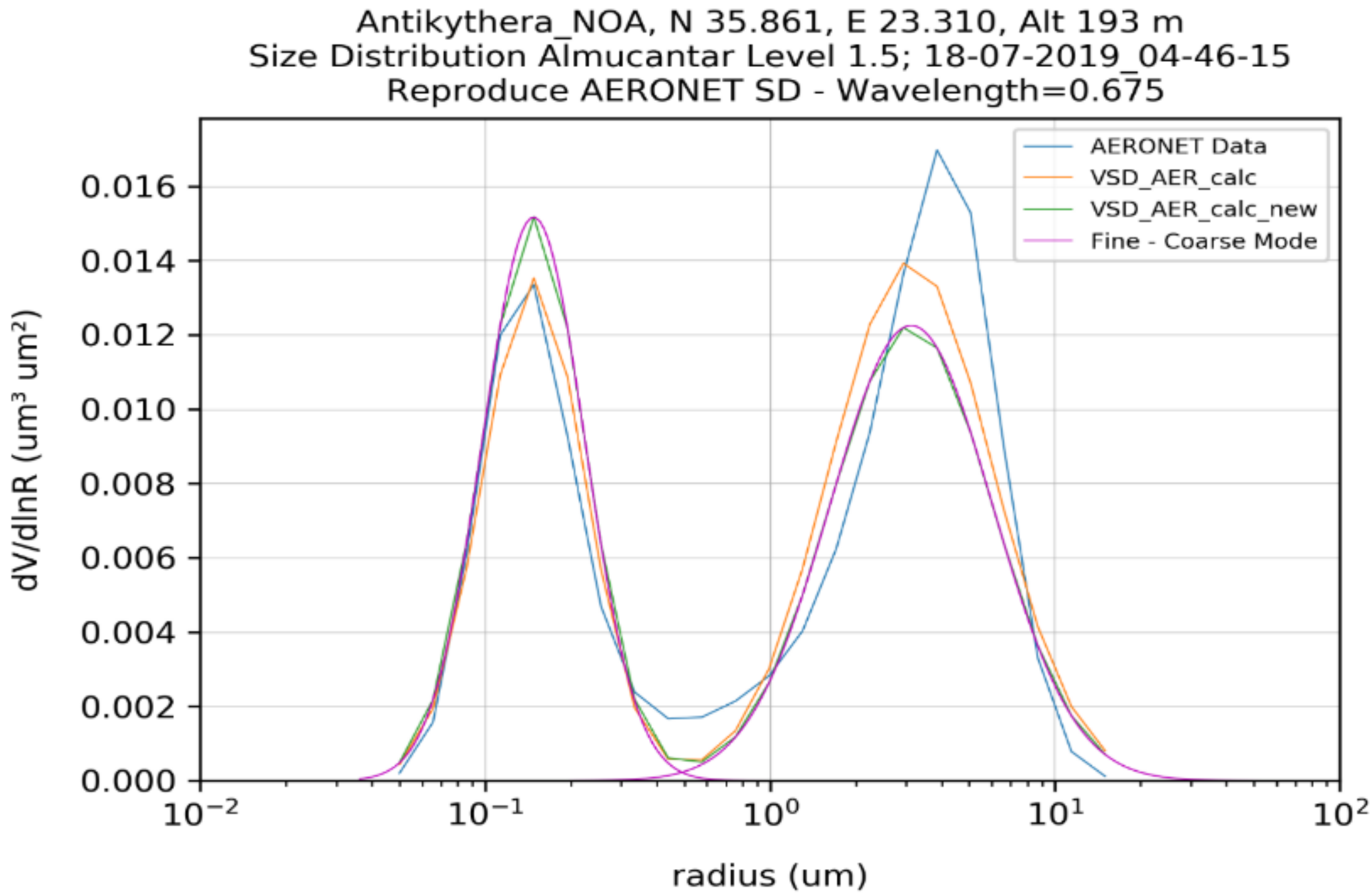
```
ext_all=7.909338890331058e-05 sca_all=7.346999408914502e-05
abs_all=5.623394814165551e-06 bac_all=2.032112840574509e-06
ext_f=6.52076043790471e-05 sca_f=6.241395193588643e-05
abs_f=2.793652443160667 3e-06 bac_f=1.339195996620889 5e-06
ext_c=1.388578452426348e-05 sca_c=1.105604215325859 6e-05
abs_c=2.829742371004884e-06 bac_c=6.929168439536193e-07
```

The calculated **outputs** for this case are the following:

- **Extinction coefficient of the coarse mode** (ext_c): 1.388578 Km^{-1}
- **Scattering coefficient of the coarse mode** (sca_c): 1.105604 Km^{-1}
- **Absorption coefficient of the coarse mode** (abs_c): 2.829742 Km^{-1}
- **Backscatter coefficient of the coarse mode** (bac_c): 6.929168 Km^{-1} sr^{-1}

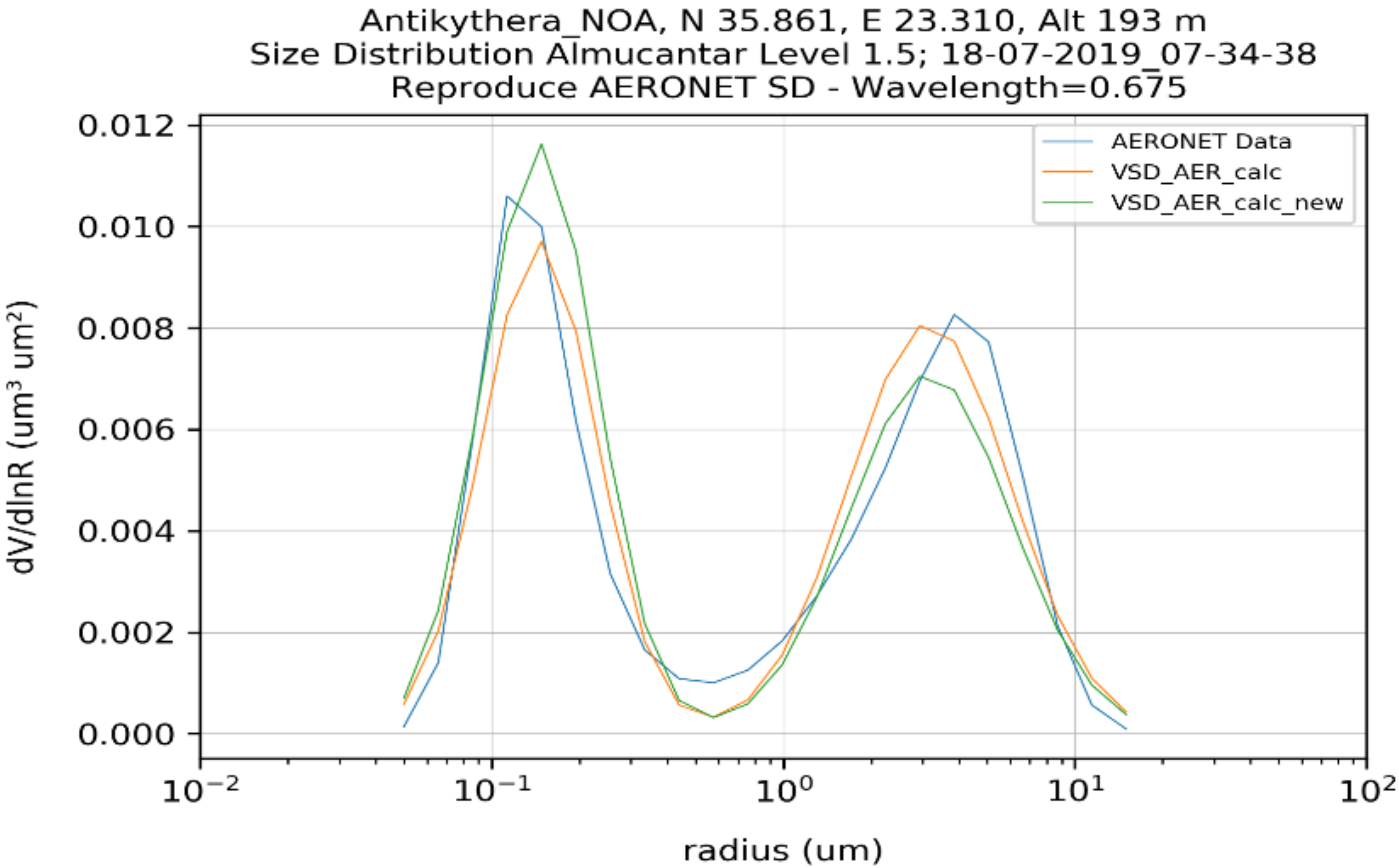
Results of 18/07/2019

Time: 04:46:15



Results of 18/07/2019

Time: 07:34:38



Future work

Future work

The developed tool focuses mainly on the lidar-related optical properties.

These properties can be used in the future step of this work, for combining the sun-photometer with lidar measurements for better characterization of aerosol vertical properties.

Summary

Summary

The goal of this work was to create an **automated tool** that calculates in near **real-time the optical properties** of aerosol particles observed in the **PANGEA observatory**, when the particles have **spherical shapes.** For this scope we use the **sun-photometer measurements** in the station, the **AERONET inversion products** and the **Mie scattering code.**

Thanks for your attention!

- My supervisor **Dr. Vassilis Amiridis**

- The postdoctoral researcher **Alexandra Tsekeri**

Questions ?

Let's try it together...

AERONET

Aerosols

PANGEA

optical properties

Mie code

Remote Sensing

microphysical properties

Backup Slides

AERONET…Aerosol product

AERONET data display uses a **user-friendly interface** that includes **graphical representations** to display the optical and microphysical properties of the aerosol particles.

There are **three versions** available for the **AERONET aerosol product**:

- Version 1.0
- Version 2.0
- Version 3.0

Data quality levels for Direct Sun algorithm:

- Level 1 (unscreened)
- Level 1.5 (cloud-screened and quality controlled)
- Level 2.0 (quality-assured)

Data quality levels for Direct Sun and Inversion algorithm:

- Inversion Level 1.5 (cloud-screened and quality controlled)
- Inversion Level 2.0 (quality-assured)

Results of 30/06/2020

Time: 05:58:11