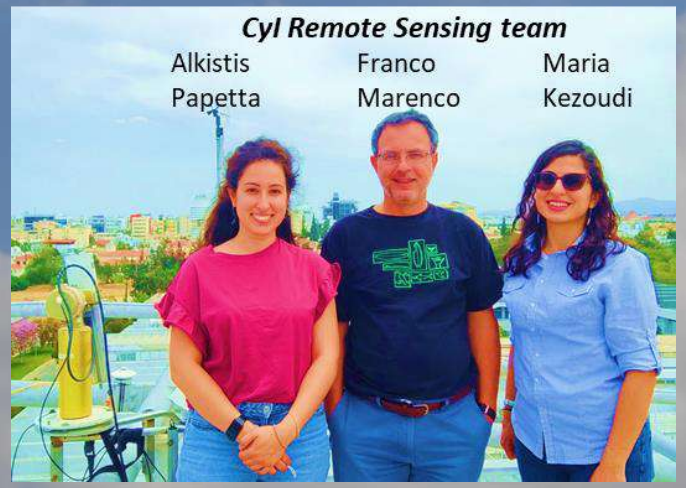


CARE-C

Climate and Atmosphere Research Center.

Observations of the upper atmospheric layers

Autumn school 2022

Observations of the upper atmospheric layers

1. Introduction (Franco Marenco)
2. Ground-based remote sensing datasets (Alkistis Papetta)
3. UAV-based datasets (Maria Kezoudi)

Ground-based remote sensing

A network of ground-based instruments at three **Cyprus Atmospheric Observatory** stations : *sunphotometers, ceilometers, 1 lidar and 1 flux station*.

Remote in-situ sampling

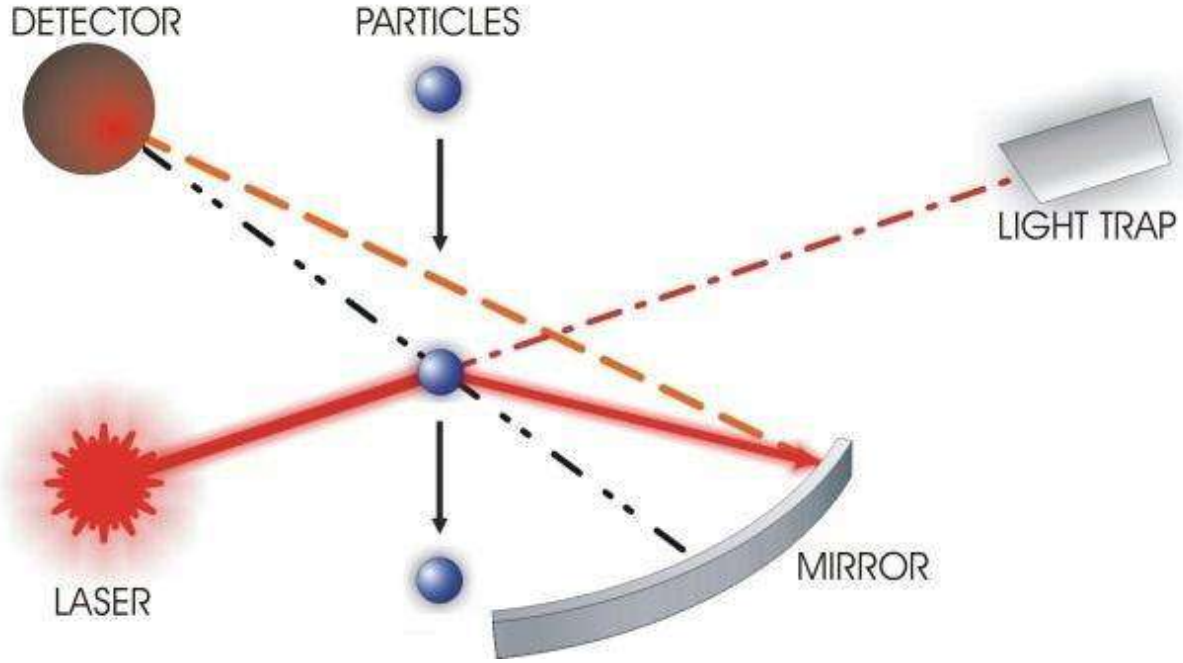
Drone-based aerosol observations using a number of sensors such as POPS, UCASS, COBALD and impactors (work in collaboration with the **Unmanned Systems Research Laboratory**).

SENSOR	UCASS	GPAC	COBALD	POPS
USE	Aerosol size distribution 0.4–20 // 3–40 µm	Impactors (>1µm)	Backscatter ratio (2 orientations)	Aerosol size distribution 0.14–3.3 µm
UAV	Skywalker 2015			I-Soar

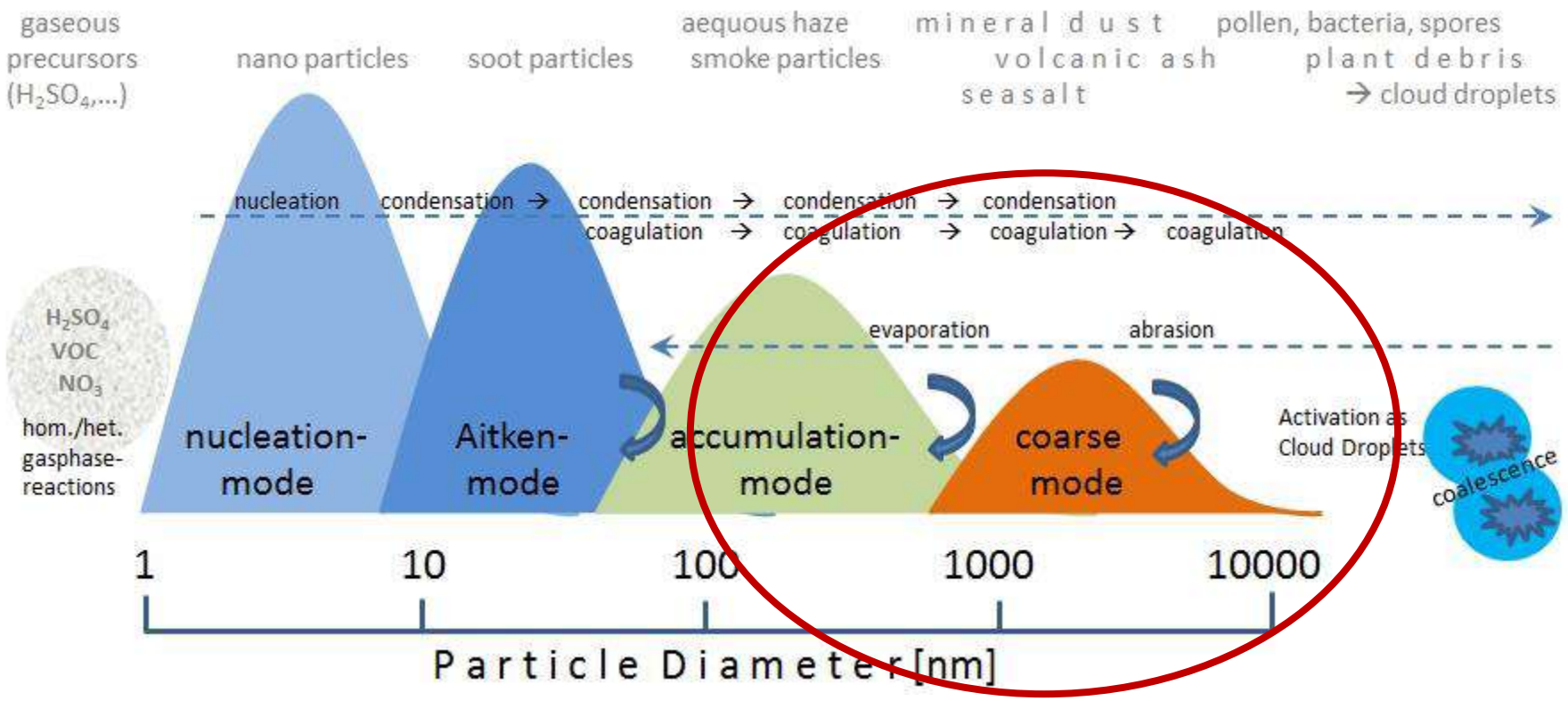
Datasets for summer school

- UAV-based Optical Particle Counter
- Ground-based ceilometer: mixing height
- Ground-based sunphotometer: aerosol optical depth + other properties

Optical Particle Counter (OPC) on-board UAV



Particle Size-Distribution (PSD)



Our OPCs observe accumulation mode and coarse mode particles

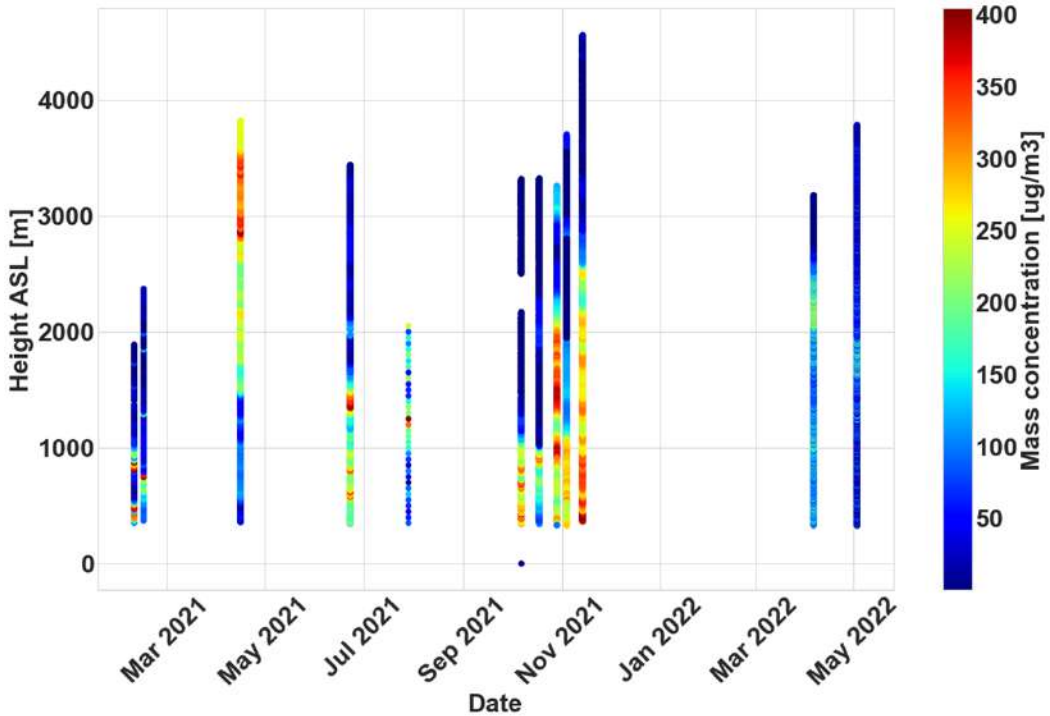
Mass concentration from PSD

PSD
(measured)

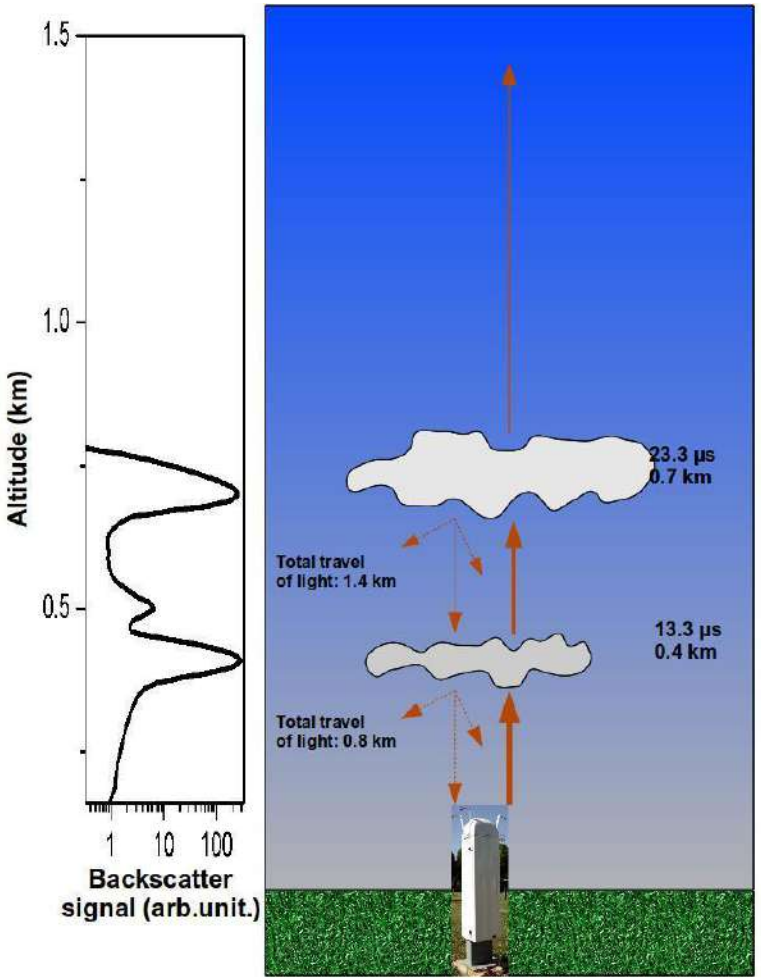
$$M = \frac{4}{3}\pi \int_0^{\infty} N(R)\ \rho\ R^3\ dR$$

Density
(assumed)

Concentration
(µg/m³)

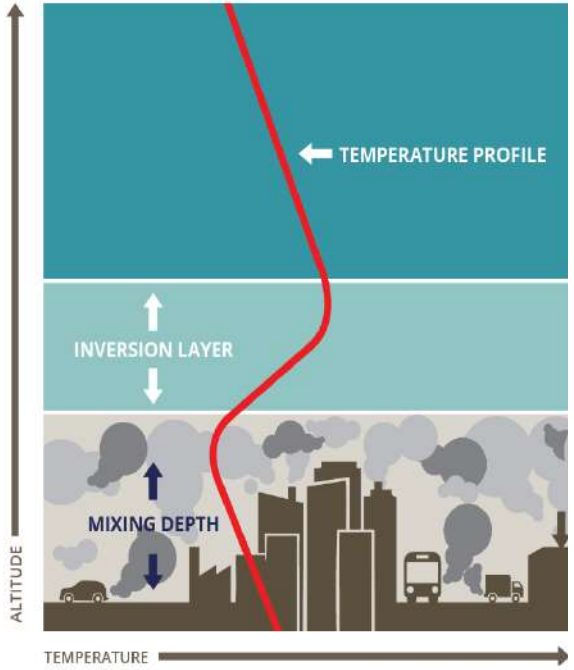


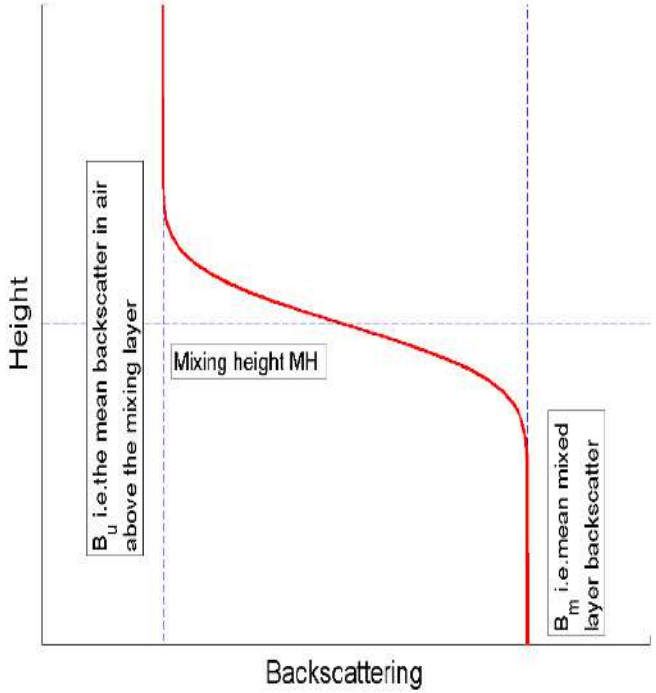
Ceilometer

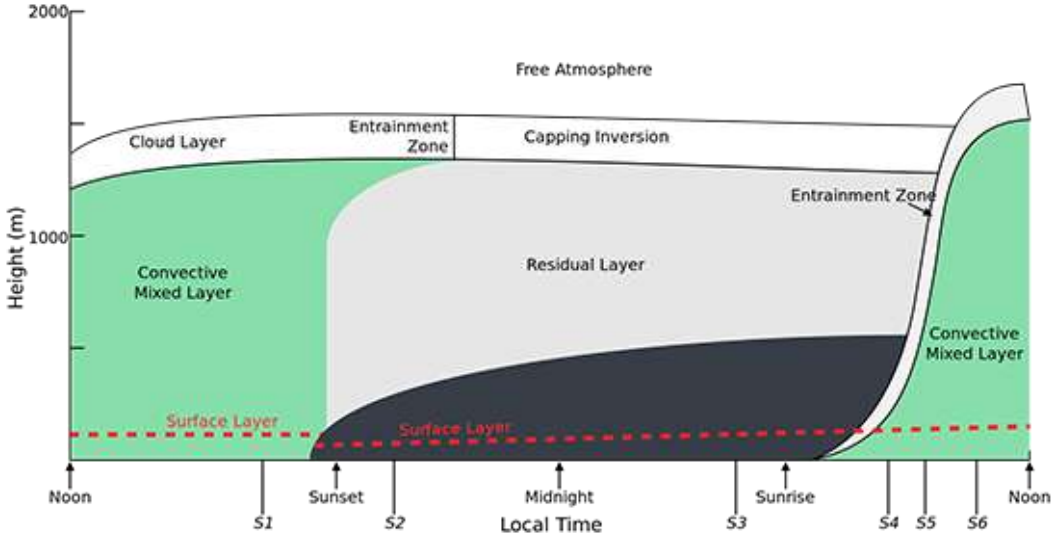

1.5
1.0
0.5
Altitude (km)
1
10
100
Backscatter signal (arb.unit.)
23.3 µs
0.7 km
Total travel of light: 1.4 km
13.3 µs
0.4 km
Total travel of light: 0.8 km

Mixing Layer Height

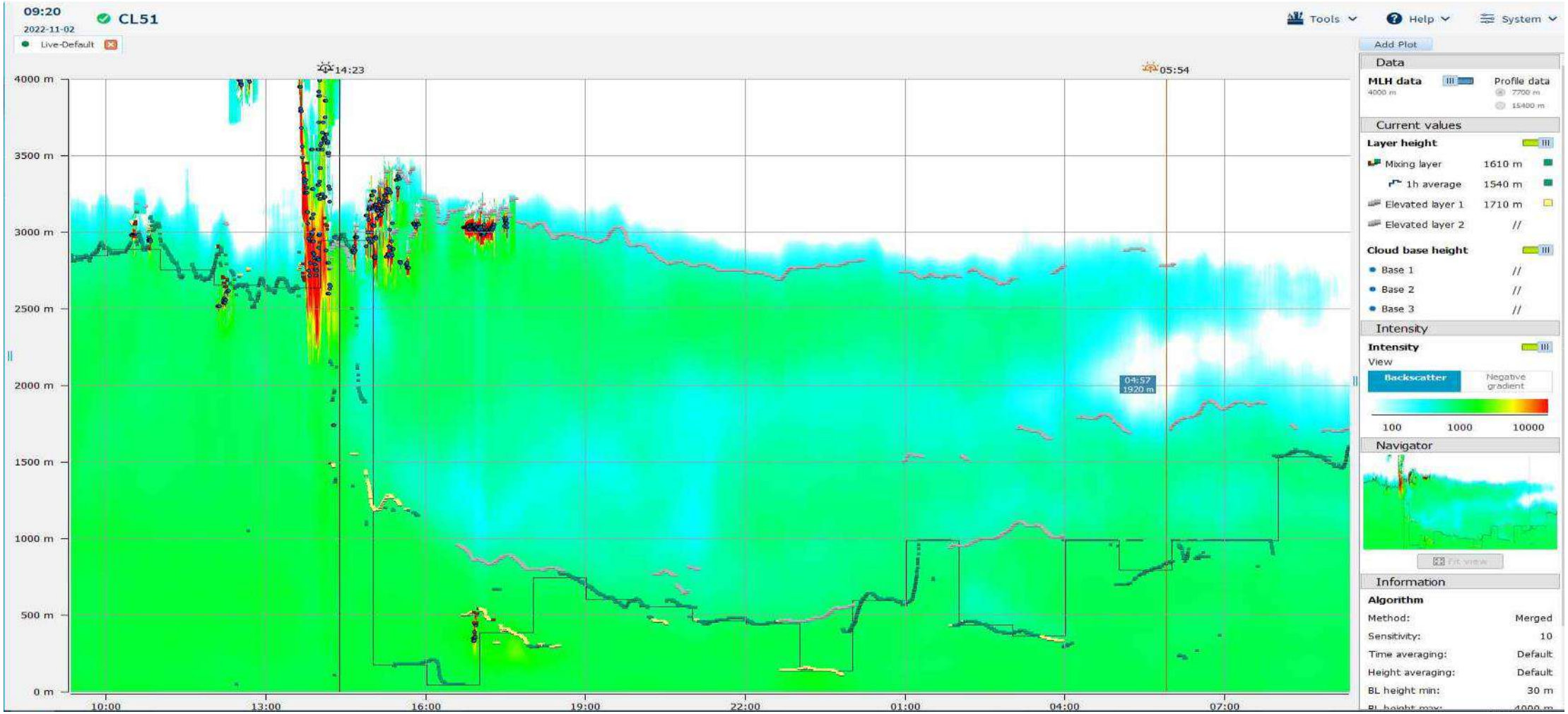
A measure for the vertical turbulent exchange within the boundary layer, and one of the controlling factors for the dilution of pollutants near the ground.



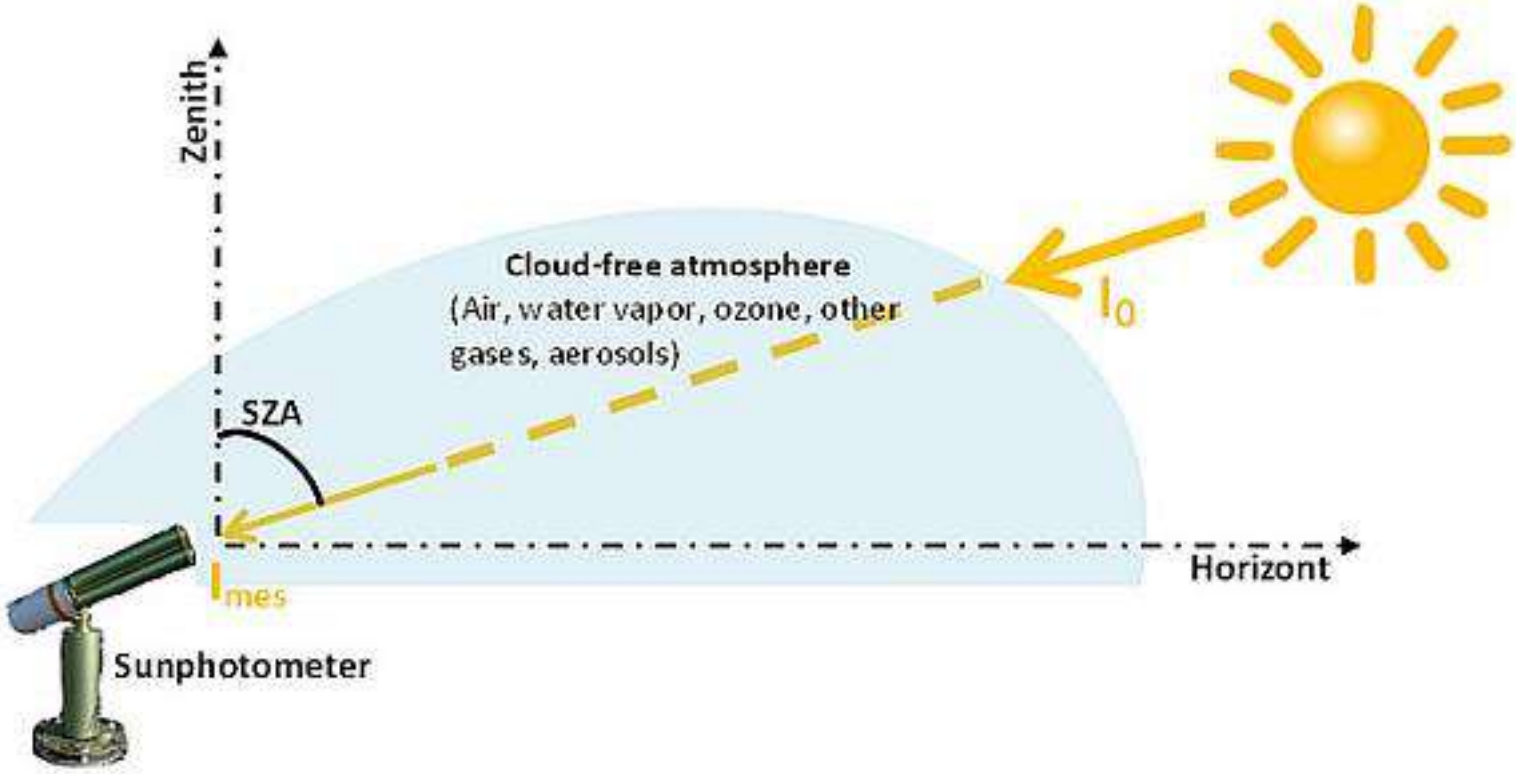




Ceilometer


09:20
2022-11-02
CL51
Tools
Help
System
Live-Default
Add Plot
14:23
05:54
4000 m
3500 m
3000 m
2500 m
2000 m
1500 m
1000 m
500 m
0 m
10:00
13:00
16:00
19:00
22:00
01:00
04:00
07:00
04:57
1920 m
Data
MLH data
Profile data
Current values
Layer height
Mixing layer 1610 m
1h average 1540 m
Elevated layer 1 1710 m
Elevated layer 2 //
Cloud base height
Base 1 //
Base 2 //
Base 3 //
Intensity
Intensity
View
Backscatter
Negative gradient
100
1000
10000
Navigator
Information
Algorithm
Method: Merged
Sensitivity: 10
Time averaging: Default
Height averaging: Default
BL height min: 30 m

Sunphotometer



Aerosol Optical Depth

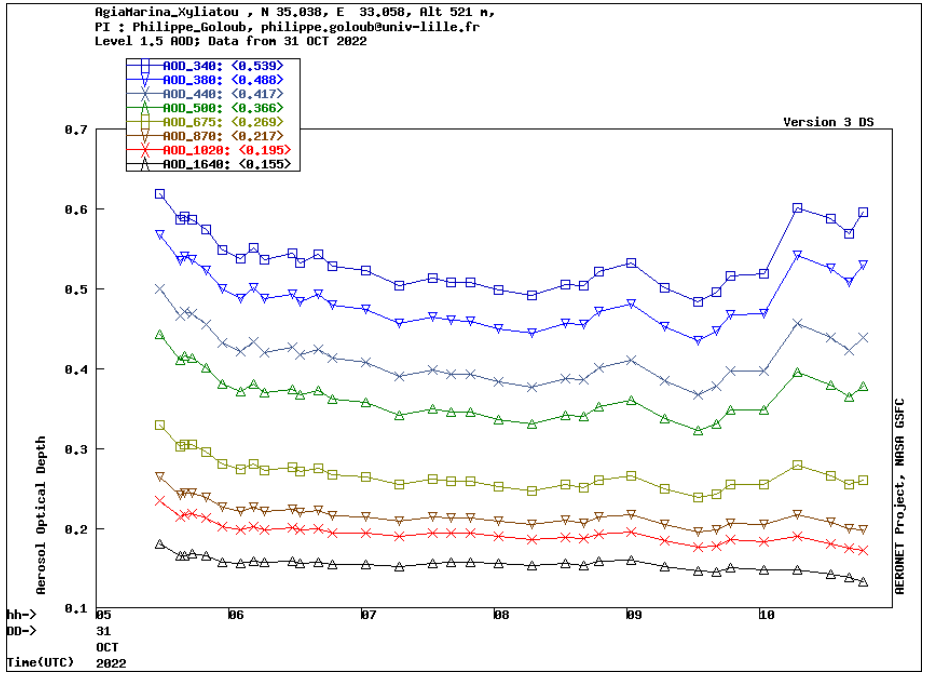
Observed Radiance

Atmospheric Transmittance

Atmospheric Optical Depth

$$I(\lambda) = I_0(\lambda) \cdot T(\lambda) = I_0(\lambda)\, e^{-\tau(\lambda)}$$

Extraterrestrial Irradiance



Molecular Optical depth (Rayleigh scattering)

$$\mathrm{AOD} = \tau_{aer}(\lambda) = \tau(\lambda) - \tau_{mol}(\lambda)$$

IN CLOUD-FREE CONDITIONS

Ångström exponent

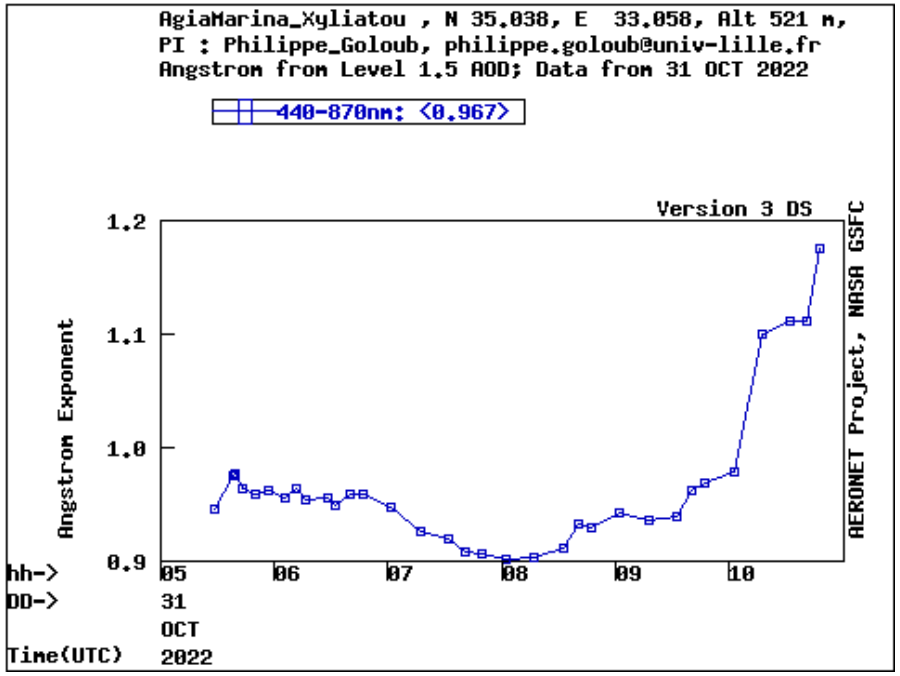
$$\tau_{mol}(\lambda) = \tau_0 \left(\frac{\lambda}{\lambda_0}\right)^{-4}$$

Theoretical relationship
(Rayleigh scattering)

$$\tau_{aer}(\lambda) = \tau_0 \left(\frac{\lambda}{\lambda_0}\right)^{-\alpha}$$

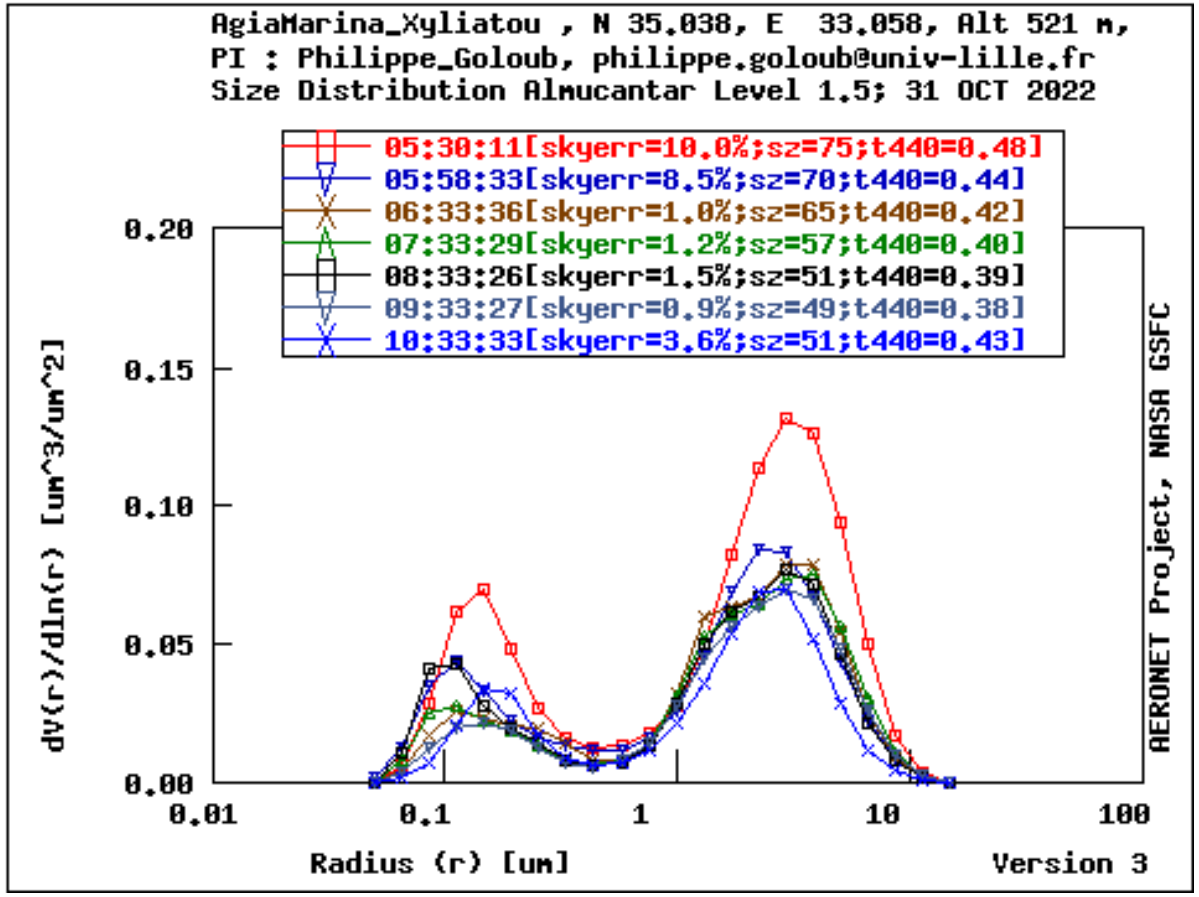
Empirical relationship

Ångström exponent



Fine aerosols (e.g. pollution): $\alpha \approx 1$
Coarse aerosols (e.g. dust): $\alpha \approx 0$

Columnar size-distribution



Sunphotometer: full list of parameters

Direct-sun

- AOD
- Ångström exponent
- Water vapour
- Fine-mode fraction

Inversion

- Size-distribution
- Refractive index
- Absorption optical depth
- Asymmetry parameter
- Phase function

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AERONET (What is it?)

The AERONET (AErosol RObotic NETwork) is a network of ground-based Sun photometers that measure atmospheric aerosol properties

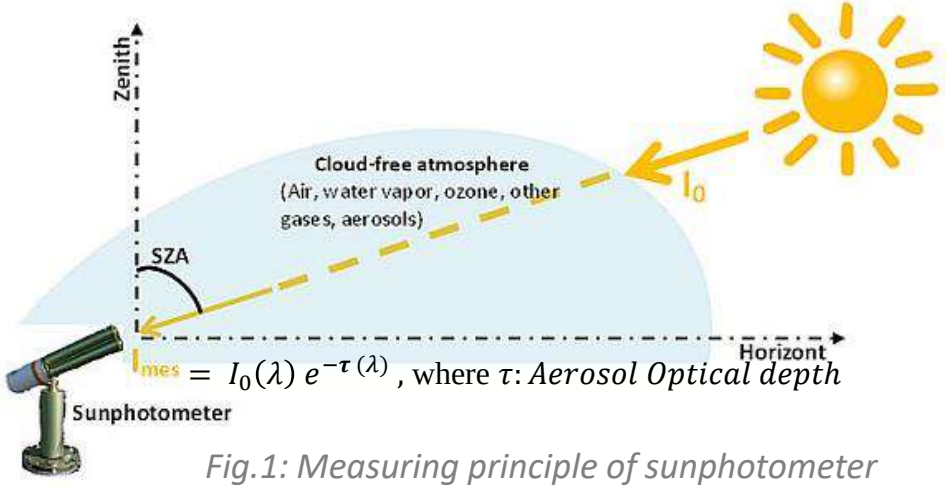

Fig.1: Measuring principle of sunphotometer

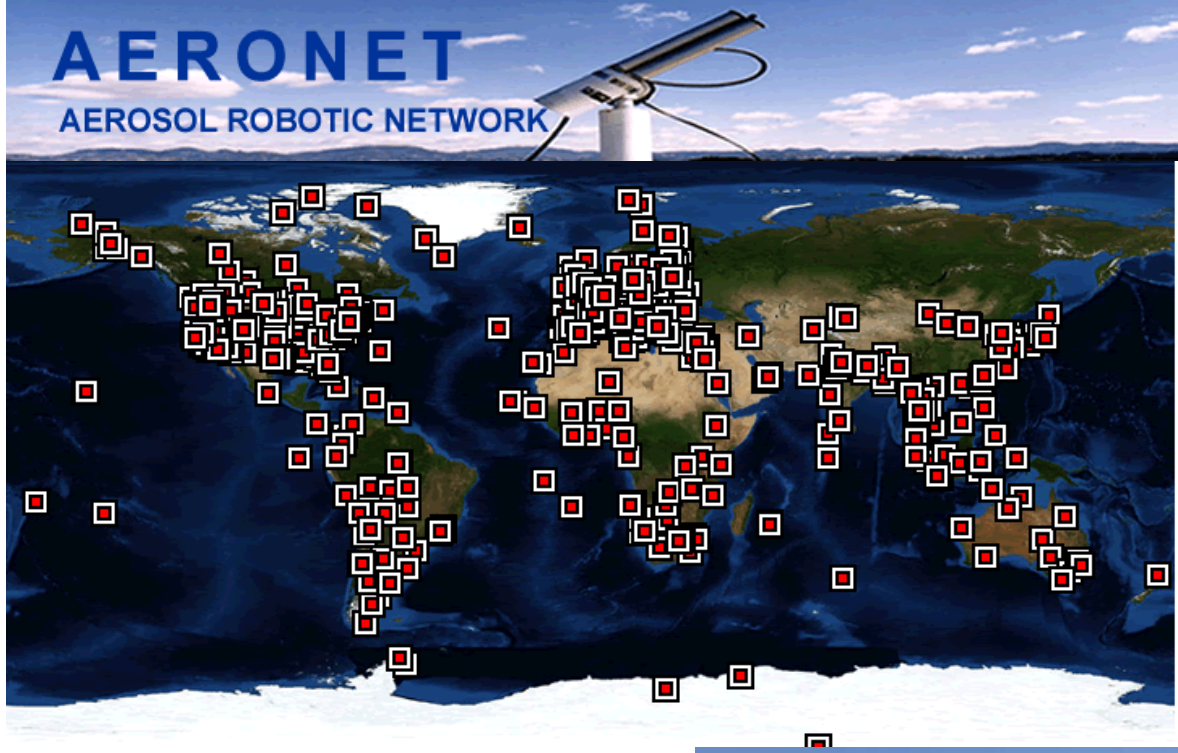

Fig.2: AERONET stations

Fig.3: AERONET station at Troodos, Cyprus→

AERONET (Stations in Cyprus)

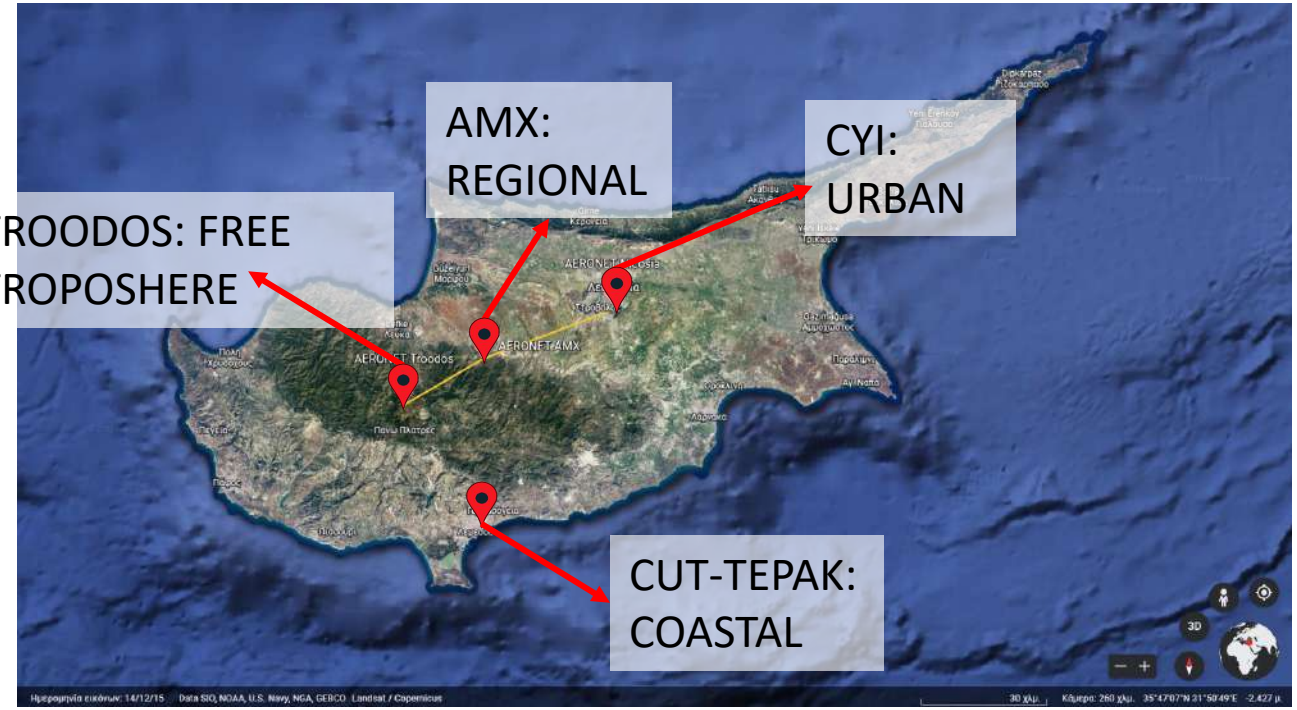

Fig.4: AERONET locations in Cyprus

Fig.5: Elevation profile between the CYI AERONET locations

AERONET (Accessing data)

- Can be downloaded directly via: https://aeronet.gsfc.nasa.gov/cgi-bin/draw_map_display_aod_v3

Or

- Create your own script using input from https://aeronet.gsfc.nasa.gov/print_web_data_help_v3_new.html

Example:

```
#%% Set data dict
data_dict = {
    'endpoint': 'https://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_v3',
    'station':'Nicosia',
    'year': 2021,
    'month': 1,
    'day': 1,
    'year2': 2021,
    'month2': 12,
    'day2': 31,
    'AOD15': 1,
    'AVG': 10,
    'lunar_merge':0
}
url = '{endpoint}?site={station}&year={year}&month={month}&day={day}&year2={year2}&month2={month2}&day2={day2}&AOD15={AOD15}&AVG={AVG}&lunar_merge={lunar_merge}'.format(**data_dict)

wget.download(url, r"C:\Users\a.papetta\Desktop\Python\AERONET_AMX_2021_10.txt")
```

Ceilometer (What is it?)

- Lidar technology that provides vertical profiles of aerosol backscatter up to 15km.
- Output :
  - Cloud base
  - **Boundary layer height**
  - Attenuated backscatter signal

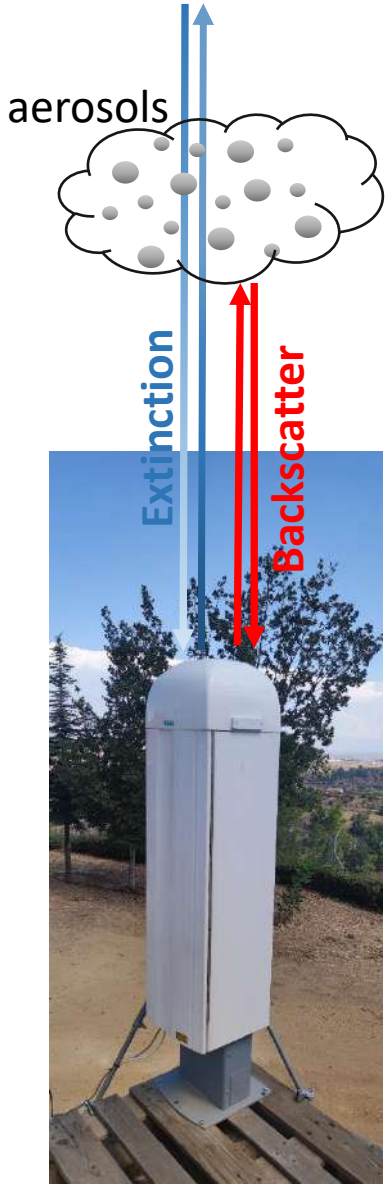

Fig.6: VAISALA CL51 at AMX

Ceilometer (Stations in Cyprus)

Ceilometer (Available data)

- Data available since July 2021
- Files saved under

Cyprus Autumn school data 2022 > AMX Ceilometer

Cyprus Autumn school data 2022 > Cyi Ceilometer

- CSV format

```
timeDim,Mean_Layer_HeightDim,Mean_Layer_Height (m)
2021-07-05 00:00:00,0,480.0
2021-07-05 00:00:16,0,480.0
2021-07-05 00:00:32,0,480.0
2021-07-05 00:00:48,0,480.0
2021-07-05 00:01:04,0,480.0
2021-07-05 00:01:20,0,480.0
2021-07-05 00:01:36,0,480.0
2021-07-05 00:01:52,0,480.0
2021-07-05 00:02:08,0,480.0
2021-07-05 00:02:24,0,480.0
2021-07-05 00:02:40,0,480.0
2021-07-05 00:02:56,0,480.0
2021-07-05 00:03:12,0,480.0
2021-07-05 00:03:28,0,480.0
2021-07-05 00:03:44,0,480.0
2021-07-05 00:04:00,0,480.0
```

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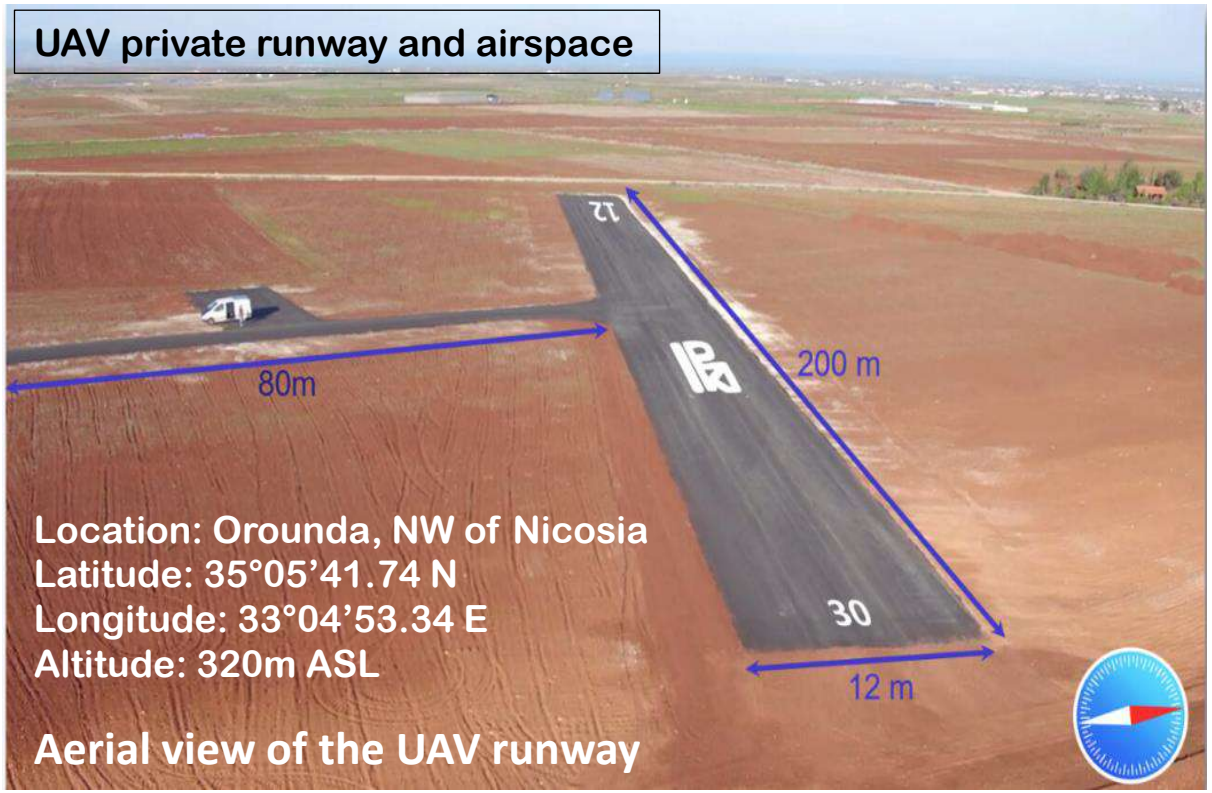
An International Research Facility supported by the European Commission

Unmanned Systems Research Laboratory (USRL) [Kezoudi et al., 2021]*



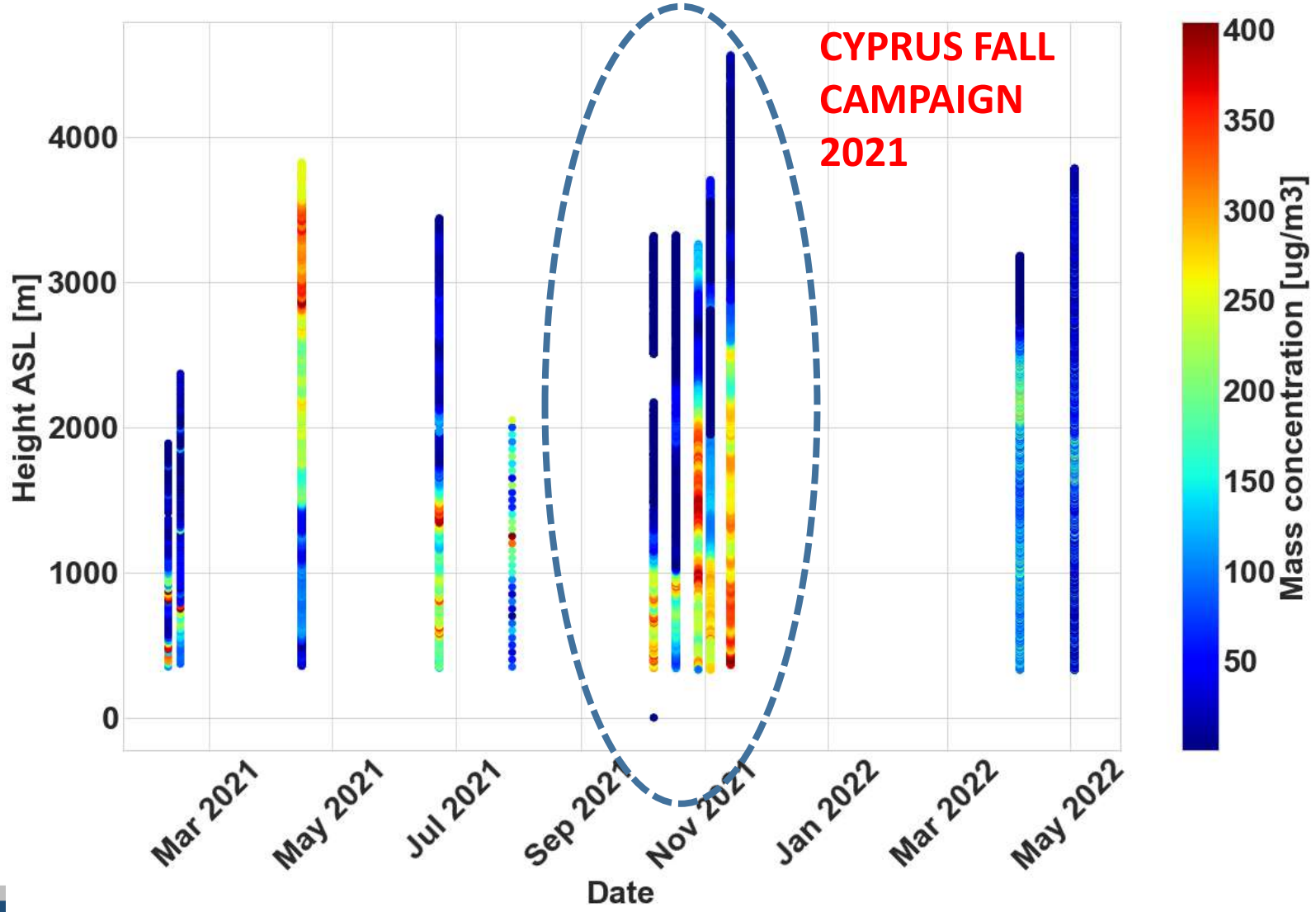
*Kezoudi et al., The Unmanned Systems Research Laboratory (USRL): A New Facility for UAV-Based Atmospheric Observations. *Atmosphere* 2021, *12*, 1042.

USRL UAV fleet

UAS type	Name	Picture	Wingspan / Diameter (m)	MTOW / Payload	Measurement type
Small-size fixed-wing	Skywalker 2015		1.83	4.2 kg / 1.5 kg	Vertical Profiling, Plume Mapping
	Skywalker X8		2.12	5.2 kg / 2 kg	
	I-Soar		2.50	6.5 kg / 2 kg	
	Cobi		2.03	5.5 kg / 2.5 kg	
Small-size multirotor	Stack Emissions Quad Rotor		0.35	1.5 kg / 0.8 kg	Dense Profiling, Stack Emissions, Plume Mapping
	Tarot 650		0.65	3.5 kg / 1.5 kg	
Medium- size fixed- wing	Cruiser		3.80	45 kg / 12 kg	Vertical Profiling

UAV-UCASS OPC take-off

UAV-OPC flights – Seasonality



Example of dataset

	A	B	C	D	E	F	G	H	I	J	K
1	09.02.2021	09.02.2021	09.02.2021	09.02.2021	19.04.2021	19.04.2021	23.06.2021	23.06.2021	29.07.2021	29.07.2021	07.10.2021
2	Height ASL (m)	Mass(µg/m3	Height ASL (m)	Mass2	Height ASL (m)	Mass	Height ASL (m)	Mass	Height ASL (m)	Mass	Height ASL (m)
3	350	205.26946	370	100.89936	355.5	347.37538	358.7	26.0863	350	36.417143	341.9
4	370	338.05988	390	103.3958	356	363.40876	362.1	25.09107	400	31.46	341.5
5	390	591.58847	410	104.92594	357.8	366.6204	365.9	23.92885	450	24.554	344.9
6	410	607.93016	430	109.57031	360.1	369.83204	368.8	25.09107	500	32.354545	348
7	430	641.25853	450	102.05375	361.4	372.32138	371.7	26.0863	550	36.360526	350.8
8	450	270.25648	470	98.73639	362.5	369.83204	373.4	26.84685	600	48.794444	354.2
9	470	724.75177	490	103.16741	364.9	372.32138	376.5	25.96896	650	38.686667	359.7
10	490	717.87392	510	128.59203	367.5	369.83204	379.5	26.84685	700	16.578571	365.9
11	510	459.35603	530	124.86644	369.8	372.32138	381.7	26.96419	750	25.046667	371.6
12	530	230.80682	550	157.26297	372.7	374.81072	383.9	27.08153	800	40.593158	376.6
13	550	139.39151	570	167.78743	375.7	373.1769	386.8	26.96419	850	22.08	379.9
14	570	31.3817	590	145.67538	378.7	371.54307	388.5	26.84685	900	33.661	382.2
15	590	42.18459	610	197.88119	381.8	373.1769	391.1	25.96896	950	42.84	383.3
16	610	35.76158	630	229.01347	384.5	374.81072	392.7	26.84685	1000	56.997895	383.9
17	630	15.23358	650	262.48817	387.2	374.94055	394.8	26.96419	1050	57.386667	384.5
18	650	41.65726	670	210.70814	390	375.07037	392	26.84685	1100	63.728571	385.5
19	670	23.49465	690	187.63328	392.5	382.23729	386.3	26.96419	1150	63.864211	385.9
20	690	39.17002	710	268.83465	394.4	389.4042	387.8	26.84685	1200	96.053333	385.7
21	710	78.46176	730	258.79849	396.2	382.23729	376.2	26.96419	1250	115.976	385.1
22	730	115.95974	750	469.90225	398.6	389.4042	368.4	27.08153	1300	68.207273	385
23	750	101.66255	770	406.29392	401	382.23729	359.3	27.12712	1350	68.529444	385.8
24	770	87.20651	790	66.11795	403.2	382.23729	351.9	27.12712	1400	53.668421	387.5
25	790	151.82016	810	47.63461	405.9	403.47846	352.7	26.96419	1450	32.265	389.6
26	810	788.81454	830	32.51999	408.3	417.89459	360.6	26.96419	1500	32.206071	391.8
27	830	679.28567	850	98.7571	409.3	417.89459	355.4	26.96419	1550	31.286316	394.2
28	850	546.96443	870	73.5025	410	423.77567	353.4	26.96419	1600	70.046316	397.4
29	870	782.53362	890	24.221	410.5	430.38048	362.3	26.57602	1650	25.365714	400.2
30	890	399.06318	910	56.10765	411.1	439.63734	362.6	25.73705	1700	59.391935	402
31	910	209.32366	930	43.17779	412.2	439.63734	362.1	25.73705	1750	51.370526	403.5
32	930	399.80959	950	51.03792	413.1	439.63734	367	26.57602	1800	67.592222	405.6
33	950	395.1589	970	59.82097	414.9	439.63734	367.3	26.57602	1850	54.605333	409.5
34	970	408.15169	990	59.86723	417.2	452.45959	353.7	27.00978	1900	42.358261	412.9
35	990	244.54251	1010	55.75296	419.6	452.45959	346.7	28.45321	1950	53.6515	417.2

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Thank you for your attention.