ACTRIS – Aerosols, Clouds and Trace gases Research Infrastructure (www.actris.eu)

EARLINET – European Aerosol Research Lidar NETwork (www.earlinet.org)

# EARLINET/ACTRIS analysis of aerosol profiles during the COVID-19 lock-down and relaxation period

## About EARLINET/ACTRIS

The European Aerosol Research Lidar Network, EARLINET, was established in 2000 as a research project with the goal of creating a quantitative, comprehensive, and statistically significant database for the horizontal, vertical, and temporal distribution of aerosols on a continental scale. Since then EARLINET has continued to provide the most extensive collection of ground-based data for the aerosol vertical distribution over Europe.

EARLINET is part of ACTRIS (Aerosols, Clouds and Trace gases Research Infrastructure). ACTRIS is a pan-European initiative consolidating actions amongst European partners producing high-quality observations of aerosols, clouds and trace gases. ACTRIS was accepted into ESFRI Roadmap in 2016 and is now in the implementation phase.

## The NRT Campaign in May 2020

This campaign is organized as part of the ACTRIS initiative for studying the changes in the atmosphere during the COVID-19 lockdown. The scope of the campaign is twofold: a) to monitor the atmosphere's structure during the lockdown and early relaxation period in Europe; b) to identify possible changes due to decreased emissions, by comparison to the aerosol climatology in Europe.

Lidars measure at least two-times per day (minimum two hours at noon, and minimum two hours after sunset). Depending on the setup of the instrument, various data products are produced by a centralized processing system (Single Calculus Chain)[1]: vertical profiles of the aerosol backscatter and extinction coefficients, and of the linear depolarization ratios. With their high temporal and vertical resolution, lidars give comprehensive information on the atmospheric structure, its dynamics, and its optical properties.

In this study the near-real time (NRT) is used. Measurements are submitted and processed in maximum 12h after the end of the mandatory noon and nighttime measurements. Quality control of the

[1] D'Amico, G., Amodeo, A., Baars, H., Binietoglou, I., Freudenthaler, V., Mattis, I., Wandinger, U., and Pappalardo, G.: EARLINET Single Calculus Chain – overview on methodology and strategy, Atmos. Meas. Tech., 8, 4891–4916, https://doi.org/10.5194/amt-8-4891-2015, 2015

measurement is performed by each station, while the SCC embeds subroutines for automatic quality control of the processed data. However, this is still preliminary data until the full set of QA/QC procedures is applied and the re-analysis is done.

## Contacts

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- [Lucia Mona](), ACTRIS Data Centre, Aerosol Remote Sensing Unit (ARES)

## Participating lidar stations

EARLINET currently has 31 active stations. Out of these, 21 participate in this campaign, covering different regions over Europe. These stations operate either automatic / remotely controlled instruments, or are located in regions where complete lock-down is not effective.


*Lidar stations providing measurements of the aerosol profiles daily: a) in yellow, stations measuring 2 times per day; b) in red, stations providing quasi-continuous measurements. No measurements are performed during precipitation.*

| **Location** | **Coordinates** |
|---|---|
| Athens | 37.9600 N, 23.7800 E, 212 m |
| Barcelona | 41.3930 N, 2.1200 E, 115 m |
| Belsk | 51.8300 N, 20.7800 E, 180 m |
| Bucharest | 44.3480 N, 26.0290 E, 93 m |
| Cabauw | 51.9700 N, 4.9300 E, 0 m |
| Clermont-Ferrand | 45.7610 N, 3.1110 E, 420 m |
| Evora | 38.5678 N, -7.9115 E, 293 m |
| Granada | 37.1640 N, -3.6050 E, 680 m |
| Kuopio | 62.7333 N, 27.5500 E, 190 m |
| Lecce | 40.3330 N, 18.1000 E, 30 m |
| Leipzig | 51.3527 N, 12.4339 E, 125 m |
| Lille | 50.6117 N, 3.1417 E, 60 m |
| Limassol | 34.6700 N, 33.0400 E, 10 m |
| Hohenpeissenberg | 47.8019 N, 11.0119 E, 974 m |
| Palaiseau | 48.7130 N, 2.2080 E, 156 m |
| Potenza | 40.6000 N, 15.7200 E, 760 m |
| Roma-Tor Vergata | 41.8330 N, 12.6500 E, 110 m |
| Thessaloniki | 40.6300 N, 22.9500 E, 50 m |
| Warsaw | 52.2100 N, 20.9800 E, 112 m |
| Antikythera | 35.8600 N, 23.3100 E, 193 m |
| Belgrade | 44.8557 N, 20.3913 E, 89 m |

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# Data products

The data products calculated by the Single Calculus Chain depend on the configuration of the lidar system (i.e. the available channels):

- **b1064** – the aerosol backscatter coefficient at 1064nm, calculated from the elastic channel (1064nm) with the Fernald-Klett algorithm; assumption of the lidar ratio at 1064nm is required
- **b532** – the aerosol backscatter coefficient at 532nm, calculated from the elastic channel (532nm) with the Fernald-Klett algorithm; assumption of the lidar ratio at 532nm is required
- **b355** – the aerosol backscatter coefficient at 355nm, calculated from the elastic channel (355nm) with the Fernald-Klett algorithm; assumption of the lidar ratio at 355nm is required
- **d532** – the linear particle depolarization ratio at 532nm, calculated from the combination of polarization channels at 532nm
- **d355** – the linear particle depolarization ratio at 355nm, calculated from the combination of polarization channels at 355nm
- **e532** – the aerosol extinction coefficient at 532nm, calculated from the Raman signals at 607nm with the Raman algorithm
- **e355** – the aerosol extinction coefficient at 355nm, calculated from the Raman signals at 387nm with the Raman algorithm
- **b(e)532** – the aerosol backscatter coefficient at 532nm, calculated from the combination of elastic (532nm) and Raman (607nm) channels
- **b(e)355** – the aerosol backscatter coefficient at 355nm, calculated from the combination of elastic (355nm) and Raman (387nm) channels

Depending on the design of the lidar, Raman channels can be operated during daytime (if the rejection of the sky background is sufficiently good), or only during nighttime. As such, the data products differ from day to night, as follows:

| Daytime | INO | ATZ | BRC | COG | CBW | PUY | EVO | GRA | KUO | SAL | LEI | LLE | LIM | HPB | SIR | POT | RME | THE | WAW | AKY | BGD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| b1064 | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | | |
| b532 | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | |
| b355 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| d1064 | | | | | | | | | | | | ■ | | | | | | | | | |
| d532 | ■ | | ■ | | ■ | | | ■ | ■ | | ■ | ■ | ■ | ■ | | | | ■ | ■ | ■ | |
| d355 | | | ■ | | | ■ | | | ■ | | ■ | ■ | | | ■ | ■ | | | ■ | ■ | |
| e532 | | | | | ■ | | | | | | ■ | | | | | | | | ■ | ■ | |
| e355 | | | | | ■ | | | | | | ■ | | | | | | | | ■ | ■ | |
| b(e)532 | | | | | ■ | | | | | | ■ | | | | | | | | ■ | ■ | |
| b(e)355 | | | | | ■ | | | | | | ■ | | | | | | | | ■ | ■ | |

*Data products calculated for each station during daytime; in red, stations providing quasi-continuous measurements.*

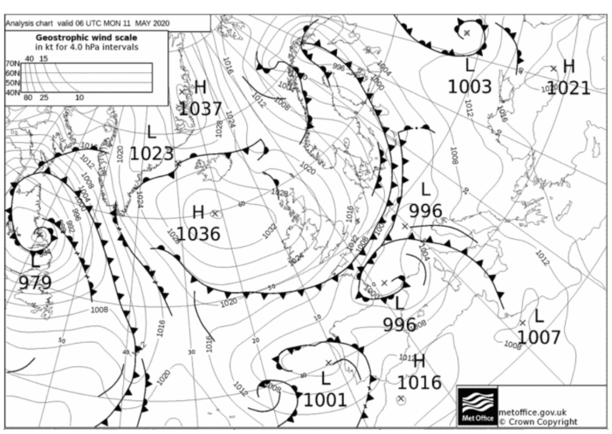
| Nighttime | INO | ATZ | BRC | COG | CBW | PUY | EVO | GRA | KUO | SAL | LEI | LLE | LIM | HPB | SIR | POT | RME | THE | WAW | AKY | BGD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| b1064 | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | | |
| b532 | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | |
| b355 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| d1064 | | | | | | | | | | | | ■ | | | | | | | | | |
| d532 | ■ | | ■ | | ■ | | | ■ | ■ | | ■ | ■ | ■ | ■ | | | | ■ | ■ | ■ | |
| d355 | | | ■ | | | ■ | | | ■ | | ■ | ■ | | | ■ | ■ | | | ■ | ■ | |
| e532 | ■ | ■ | ■ | | ■ | | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | ■ | |
| e355 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| b(e)532 | ■ | ■ | ■ | | ■ | | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | ■ | |
| b(e)355 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |

*Data products calculated for each station during nighttime; in red, stations providing quasi-continuous measurements.*

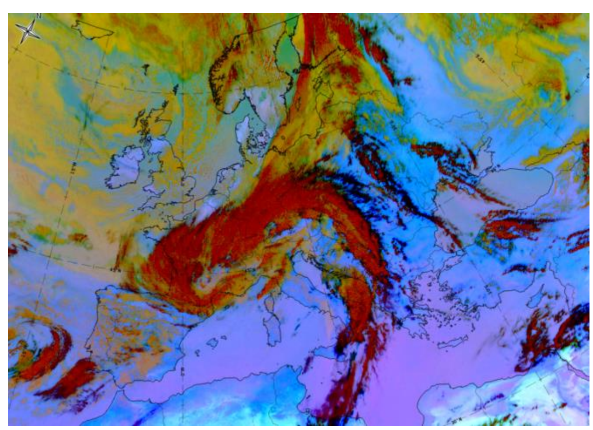
# Report for 8 – 14 May 2020

## Meteorological context of the week

Following up last week's meteorological aspect, circulation above Europe from 8 to 10 May, can be described by upper high-pressure fields above Balkans and deep trough/low over western Iberian Peninsula, while cold arctic air-masses aloft over north Europe. On the 11th of May according to the surface pressure analysis, a cold front is shaped, on the southeastern side of the North Atlantic anticyclone (with surface pressure-center 1036hPa), blocking these colder airmasses from the Arctic. The frontal system moved across central Europe, with relatively slow speed and storms along the leading frontal boundary. On the 12th of May the sharp surface cold front, extending from northwest Russia across northeast Europe into the Alpine region, can be discerned by thick, high and cold ice clouds (dark red in SEVIRI image) above mainly France, Germany and Poland. As a result, much colder weather is spread behind the front, but very warm temperatures remain in front of it. During that morning, temperatures several degrees of Celsius below zero were recorded over Germany (Sugspitze -7,7$^{o}$C), UK (Cairngorms -7,3$^{o}$C) and Poland (Sniezka -8.7$^{o}$C). Moreover, snowfall occurred in some regions along the front, especially over Poland and Belarus. As for dynamics, the baroclinic structure of the system is characterized by the tilting between surface low and 500 hPa trough. The surface system is on the southwestern side of the trough, indicating the vertical slope and thus contributing to the upper level dynamics. Similar atmospheric circulation is observed from 12 to 13 of May, with the large cold pool remaining over north-central and eastern Europe and gradually vanishing towards 15-16 of May.



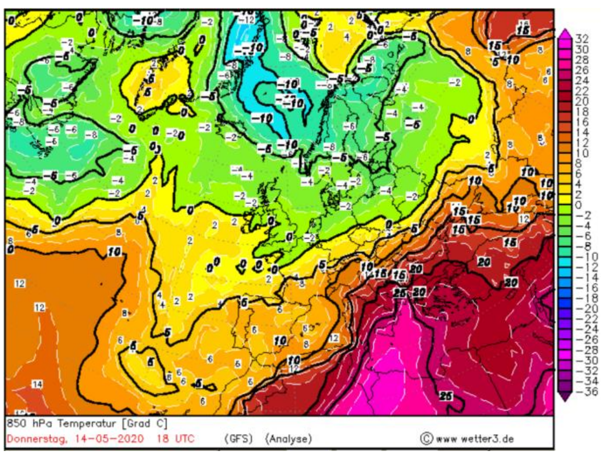

Surface Analysis for 11 May 2020 06UTC (source: Met Office; AktuelleWetterkarten[http://www1.wetter3.de/](http://www1.wetter3.de/))



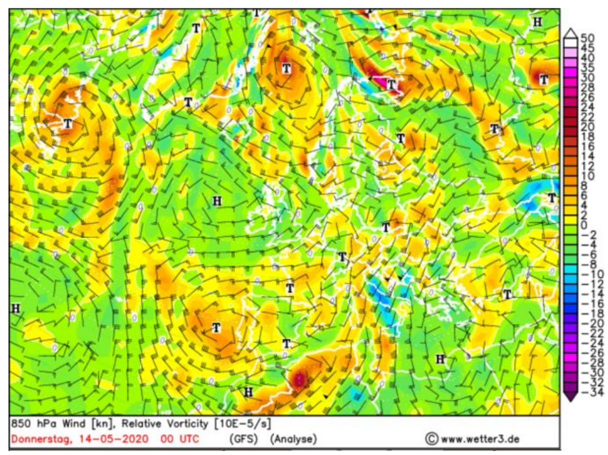
SEVIRI Dust RGB Satellite Image for 11 May 2020 12 UTC (source:[http://eumetrain.org/ePort_MapViewer/](http://eumetrain.org/ePort_MapViewer/))

Ahead of the frontal line, warm air-mass in the Southeastern Mediterranean affected the area causing completely different weather conditions. On Friday 14th of May, the large-scale dynamics provoked a very rare heat-wave for mid-May over Greece and western Turkey, endured for several days. Different temperature levels are obvious above Europe, with the 0ºC isotherm line, spreading across central Europe and separating the area in two different temperature fields. Extremely high temperatures, apropos the season, were observed in meteorological stations in central and south Greece, leading to new records for mid-May (41,8ºC Plora, Herakleion 16/5/2020).

From 14th of May onwards, atmospheric conditions in Europe were characterized by a well-organized pressure low, spinning anti-clockwise above Azores and a pressure-high spinning clockwise over north Africa, causing a quite strong wind field, associated with the surface circulation, locally resulting in severe south winds (50 knots) enriching central and east Mediterranean with dust loads from Africa. The extremely warm air-mass remained over the Southeastern Mediterranean until the end of the week.




850hPa Temperature for 14 May 2020 18UTC (source: AktuelleWetterkartenhttp://www1.wetter3.de/)

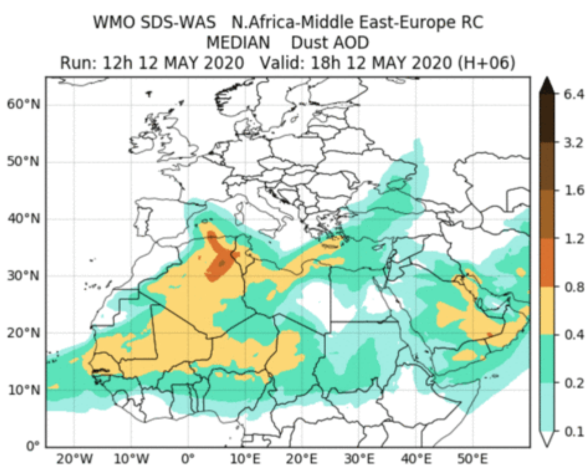



850 hPa Winds for 14 May 2020 00UTC (source: AktuelleWetterkartenhttp://www1.wetter3.de/)

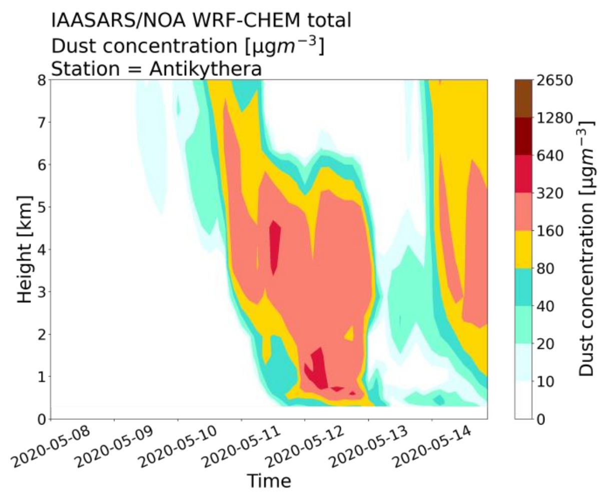
* 850hPa isobaric level corresponds approximately to 1457m height above mid-latitude areas

## Dust outbreaks

On 8th of May, the upward atmospheric currents above the North–West Sahara, initiated Saharan dust transport towards the Eastern coastline of Spain. In the next days, the system moved North-East and dust was spread to Central, North and East Europe with highest concentrations above south Italy and the Balkans. Another dust event, with the main dust sources from North and Central Sahara and affected the Mediterranean on 12th and 13th of May with high dust concentrations above the Italian and Balkan Peninsulas. The station of Antikythera in Greece was affected from both events with the main dust plume being up to 6km and dust being present in altitudes even higher than 8km. Both dust events are associated with Sharav cyclones over North Africa which are typical transport pathways towards Mediterranean for the spring and summer period.




*Ensembled Dust Optical Depth (source: WMO SDS-WAS;[https://sds-was.aemet.es/forecast-products/dust-forecasts/ensemble-forecast](https://sds-was.aemet.es/forecast-products/dust-forecasts/ensemble-forecast))*

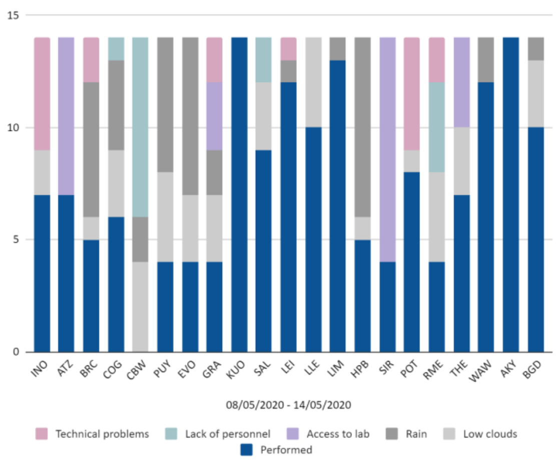



*An example of dust time evolution above Antikythera station for the 2 events of the week*

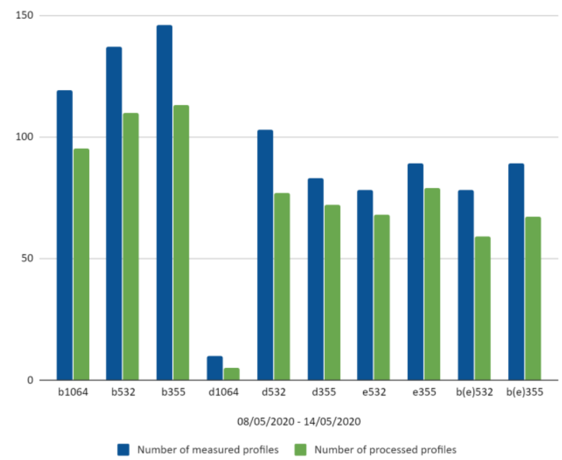
## Statistics of the week

All 21 stations were ready to perform measurements, however meteorological conditions (low clouds saturating the signals, or rain) made it impossible to perform measurements at Cabaw. Most of the stations also experienced days with bad weather.

During this week, **54% of the total number of scheduled measurements were performed**. In 27% of the cases, measurements could not be performed due to the weather conditions (rain or very low clouds), access to the laboratory and lack of personnel made the measurements impossible in 13% of the cases, while 6% of the measurements could not be performed due to instrument setting and check-ups.




*Measurement statistics*




*Data products statistics*

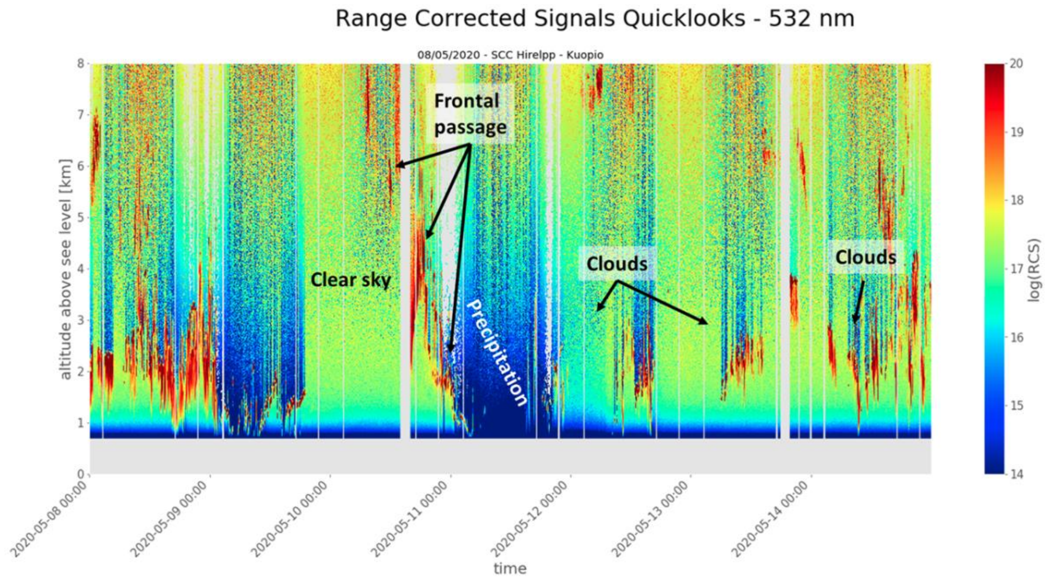
**About 80% of the collected datasets were successfully processed by the Single Calculus Chain**. Most of the missing data products are due to the presence of low clouds in the measurements, which are screened out by the Cloud Masking module. In case the remaining data is not sufficient to allow a good signal-to-noise-ratio, the optical products are not calculated.

## Quicklooks of the week

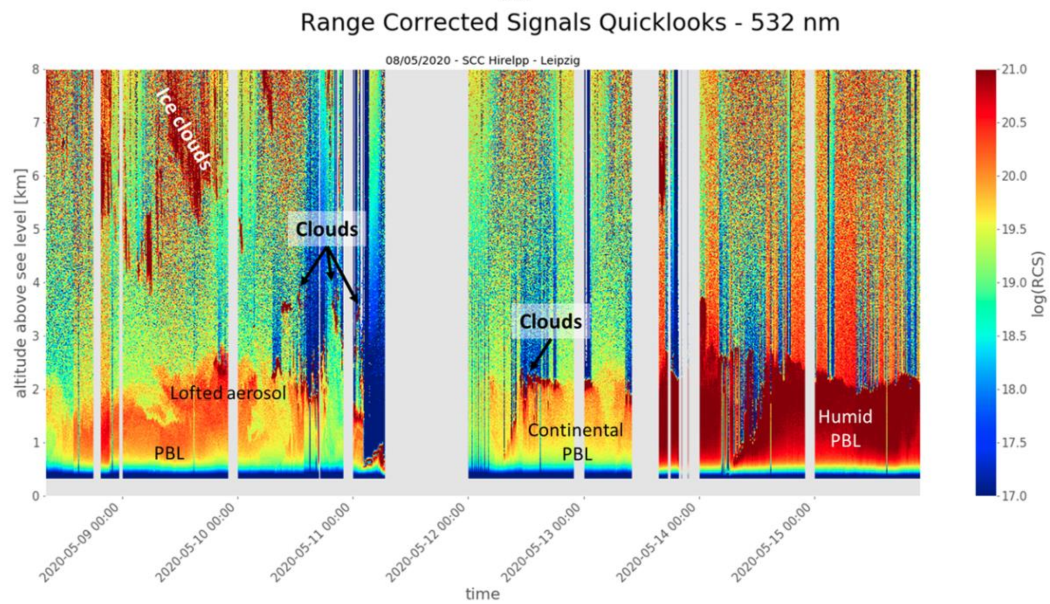
Quicklooks below show the temporal variability of the aerosol layers in the vertical. Regions in the atmosphere with high content of aerosols or clouds are identified in red colors, while “clean” regions are shown in blue. Grey color indicates lack of measurement due to low clouds or precipitation.

**Note:** Quicklooks from Hohenpeissenberg are not included in this report because it was raining almost the whole-time, therefore the quicklooks are not relevant.

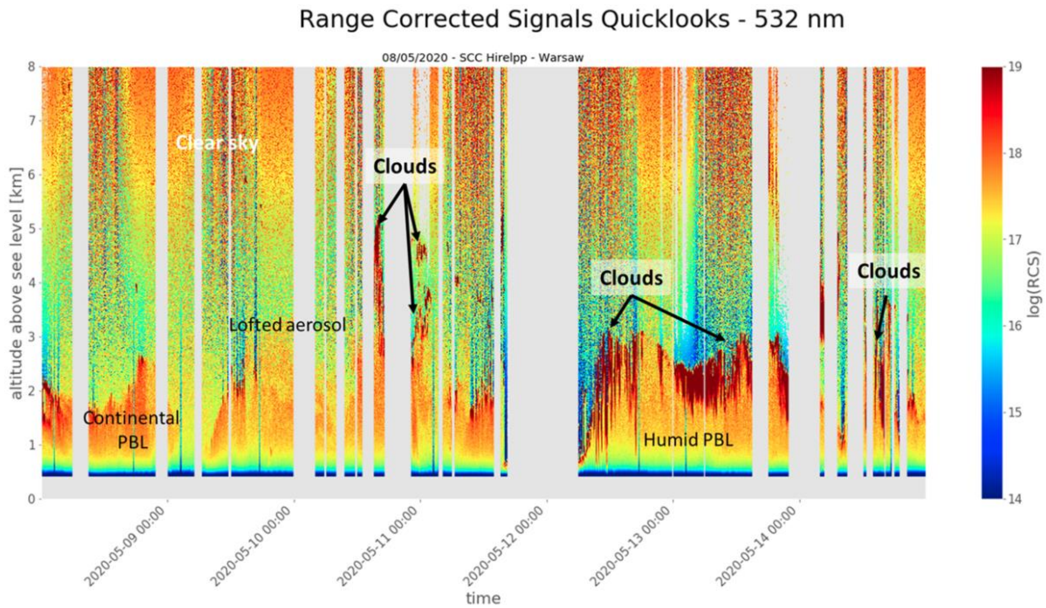
**Kuopio**



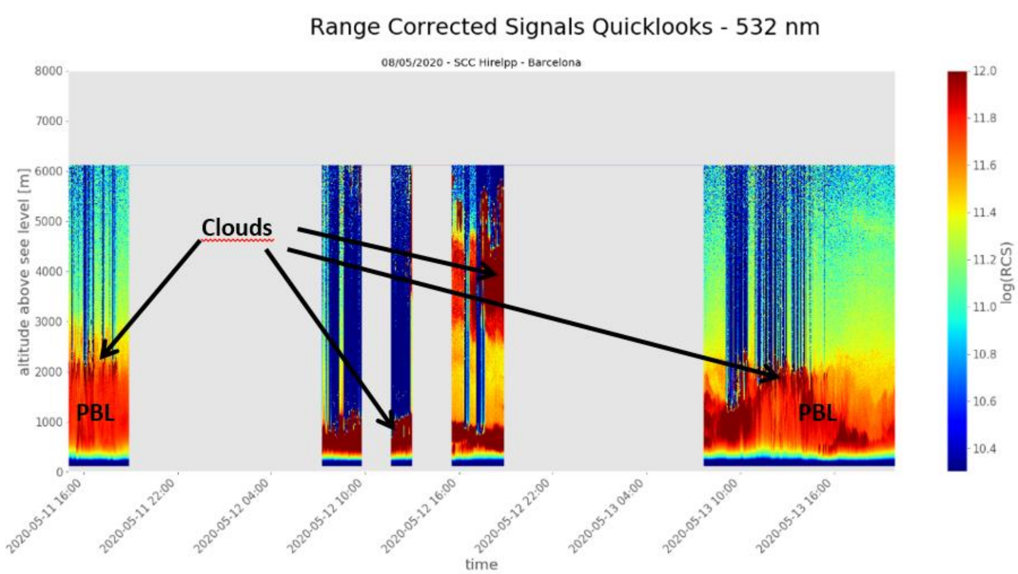

**Leipzig**



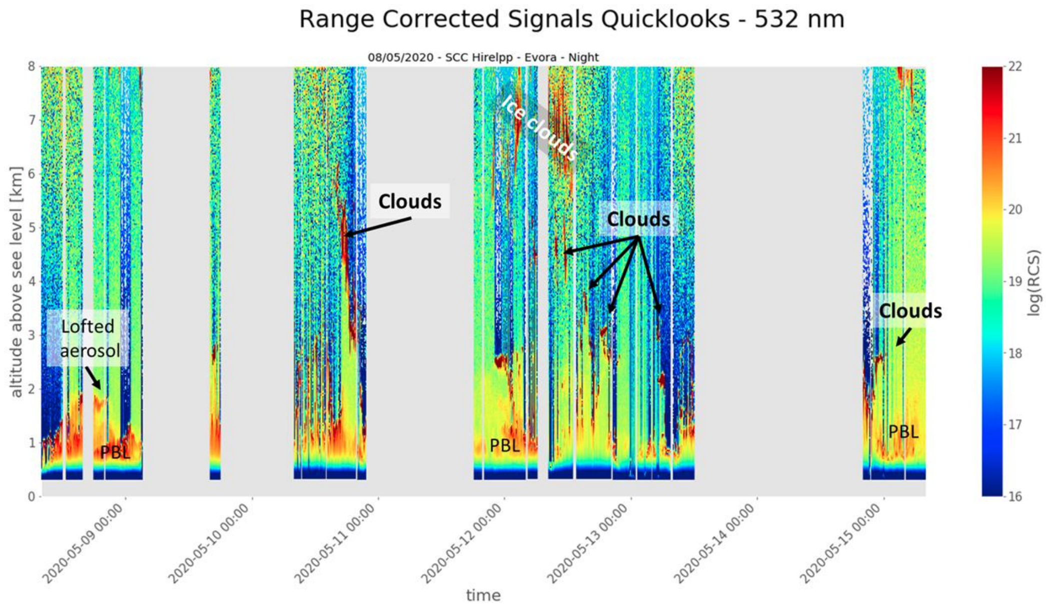
**Warsaw**



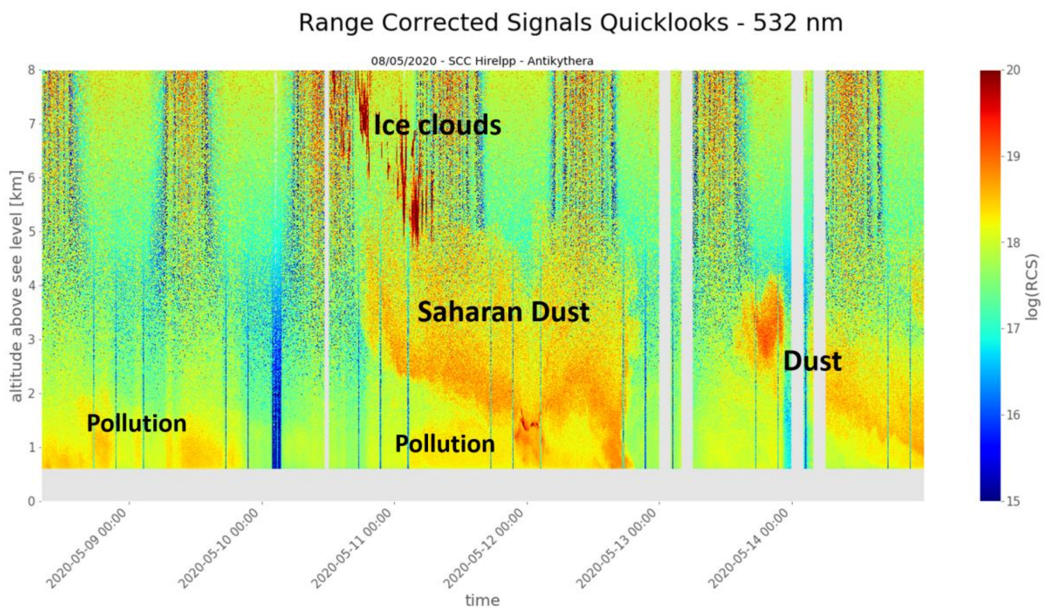

**Barcelona**



**Evora**




**Antikythera**




In Week 2 of the EARLINET NRT campaign, very different atmospheric conditions were observed at the different stations providing continuous measurements.

In Leipzig, for example, a mix of everything, namely clear sky, clear sky with high ice clouds, lofted aerosol layers, low clouds, precipitation, a typical continental dry PBL, and a humid PBL after precipitation was observed. In Warsaw, another continental station, on the other hand, mostly clear sky conditions with pronounced PBL development was found in the first half of the week. In the second half of the week, the PBL got more humid like in Leipzig and was consequently frequently cloud-topped. Later in the week, cloud occurrence got more frequent and partly showers (precipitation) were observed.

At the Nordic station of Kuopio, alternating phases of low clouds with precipitation and phases of clear sky conditions were observed. During the clear sky conditions, a very clean atmosphere with virtually no aerosol in the entire troposphere and no PBL was observed.

In the western Mediterranean in Barcelona, a Saharan dust event was observed until 8 May. After that, low clouds/rain occurred on 9 and 10 May. A mix of broken clouds since 11 May. Similar observations with comparably frequent cloud occurrences were made for the second station in the Western Mediterranean (Evora, Portugal) during the week.

In the Eastern Mediterranean in contrast, pollution from the big Greek metropolitan areas (Athens, Thessaloniki) and the Balkan were observed on Antikythera island in the lowermost troposphere on 8 and 9 May. Pronounced aerosol layers were observed since 11 May with pollution aerosol from northern Africa in the lowermost 2 km. Above, diverse Saharan dust layers occurred up to 5 km asl. The dust touched the ground at the end of the reporting week.

## Weekly means

Aerosol backscatter coefficient is a measure of the aerosol load. Linear particle depolarization is a measure of the aerosol non-sphericity. Low troposphere is here defined up to 3 km altitude, where local influences are still possible. High troposphere is defined from 3 km up to 7 km, where typically long-range transport of aerosols occurs and no local influences are present. For sites for which only backscatter at 355 nm was available, the values were scaled to 532 nm considering a backscatter Angstrom exponent of 1. No wavelength dependence has been considered for the particle depolarization ratio. Number of profiles used for the mean calculation is reported in white, for the others not all info necessary for the average calculations are available at the weekly report release time.

Being an intensive parameter, the particle depolarization values are considered significant only when the aerosol load is such to allow the depolarization characterization. Specifically, the depolarization values satisfying the following criteria, satisfied simultaneously, are considered for the averaging procedures: backscatter > $5 \times 10^{-7}$ $m^{-1} sr^{-1}$ and error_backscatter/abs(backscatter) < 50% and error_depolarization/abs(depolarization) < 50%.

Weekly means are reported only for parameters measured at least 3 times for the considered slot of measurement.

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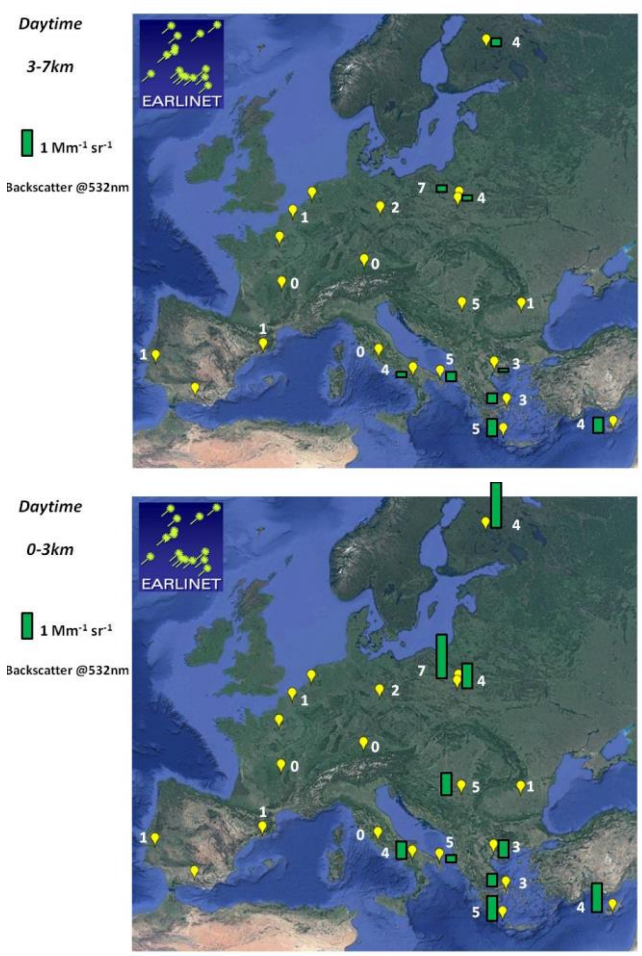
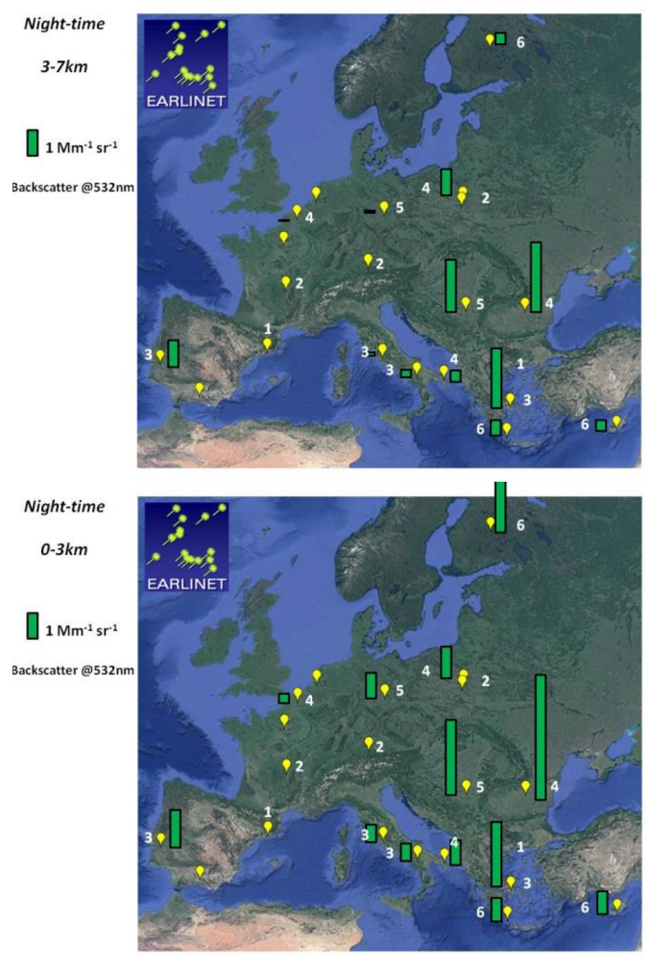
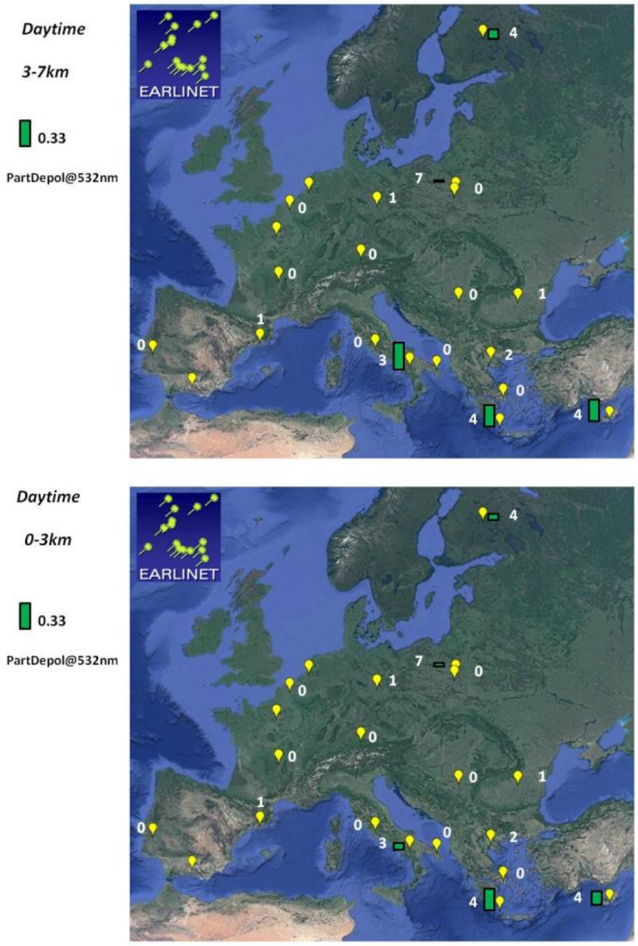



*Weekly mean values of the aerosol backscatter coefficient (532 nm) for low troposphere (bottom panel) and high troposphere (upper panel) during daytime.*

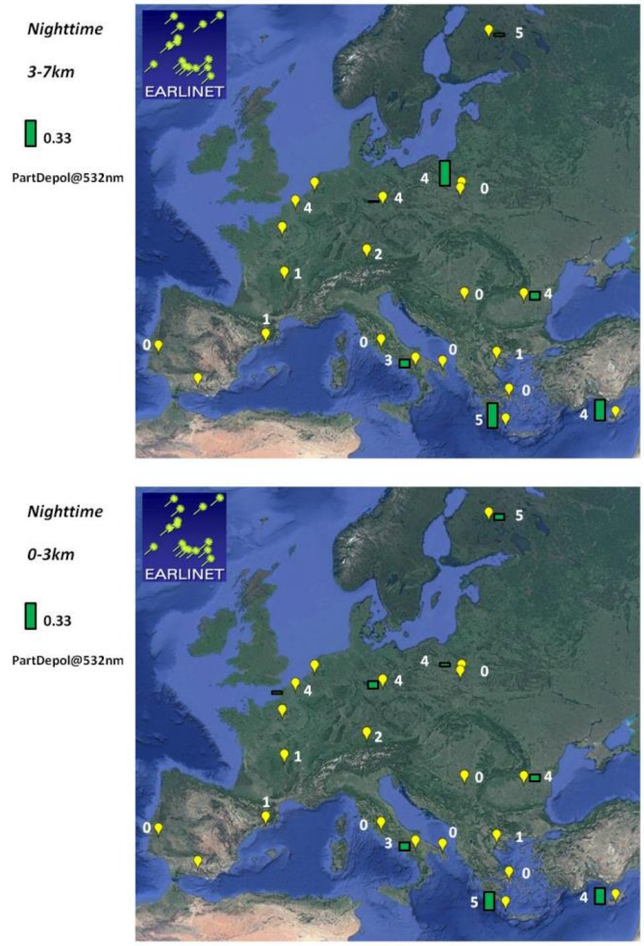



*Weekly mean values of the aerosol backscatter coefficient (532 nm) for low troposphere (bottom panel) and high troposphere (upper panel) during nighttime*

Backscatter values below 3 km are typically higher than those in the upper part of the troposphere and values are also typically higher in daytime than in nighttime.




*Weekly mean values of the particle linear depolarization ratio (532 nm) for low troposphere (bottom panel) and high troposphere (upper panel) during daytime*



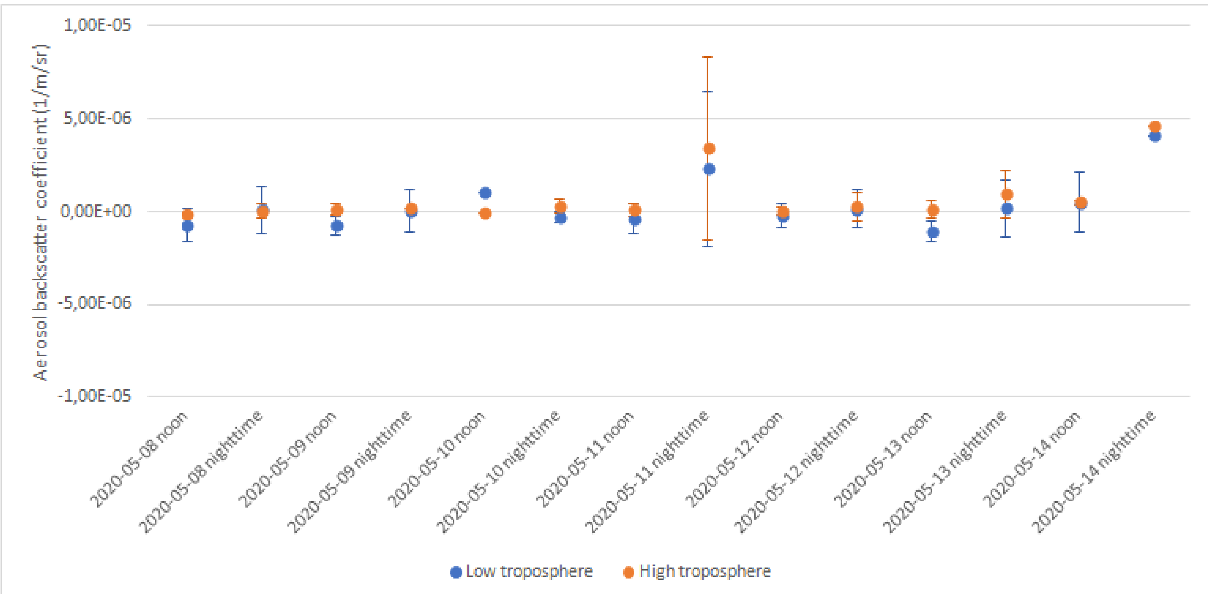

*Weekly mean values of the particle linear depolarization ratio (532 nm) for low troposphere (bottom panel) and high troposphere (upper panel) during nighttime*

In the low troposphere, the values of the linear particle depolarization ratio are relatively low in all regions typical for continental aerosols, with slightly higher values in Southern Europe.

In the Southern Europe, the aerosol load in the free troposphere is rather high in particular over Antikythera and Limassol, where also high depolarization ratio values are measured. This is probably the effect of the dust outbreak which affected the most southern sites of EARLINET, as described in the meteorological section of this report. Similarly, high values are observed on average in the other Southern stations like Barcelona and Lecce. Slightly lower values on average are observed over Potenza where only the starting of the dust arrival where observed because measurement where stopped on 13 May for a laser failure.

## Evolution with time

The graphs below show changes of the aerosol backscatter coefficient in the low and high troposphere during the week of interest. They are calculated as a difference to the climatological values for May between 2000 – 2015[2]. Positive values indicate higher aerosol load than the climatological mean.




*Time evolution of the aerosol backscatter coefficient (532 nm) in the low and high troposphere, as difference to the climatological values; average for all stations*

Generally, in Europe during the week 8-14 May 2020, an insignificant decrease of the aerosol backscatter coefficient in the lower troposphere and no decrease in the high troposphere can be seen in comparison to climatological values. An increase of backscatter values with respect to climatological values both in the low and high troposphere sometimes observed after 10 May, are partly related to the advection of Saharan dust from North Africa to Europe.

In the following, the time evolution of the aerosol backscatter coefficient over the sites in Central-North Europe (Leipzig) and in Southern Europe (Potenza) are reported.

For Leipzig station, a typical climatological situation is seen in the lower troposphere. In the higher troposphere variations are more significant but scattered. No clear conclusion can be provided.

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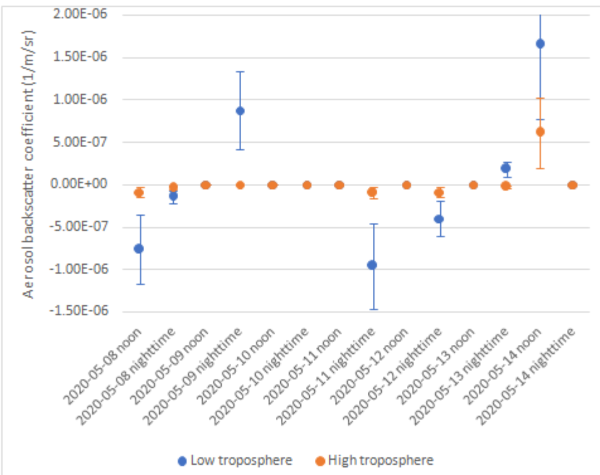
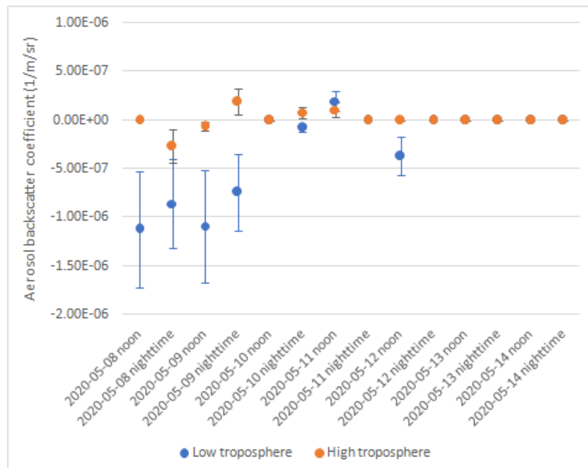
[2] Climatological values and profiles are evaluated on the base of 15 years of data (https://doi.org/10.1594/WDCC/EARLINET_All_2000-2015) and are provided as the first release of ACTRIS/EARLINET Level 3 dataset available at https://www.earlinet.org/index.php?id=125 .

Over Potenza, less aerosol backscatter than climatological is observed in the low troposphere in the first days of the week, then the values increase likely due to the arrival of dust from Northern Africa. At the same time, the higher troposphere value increased from "almost climatological value" to "higher than climatological".




*Time evolution of the aerosol backscatter coefficient (532 nm) in the low and high troposphere as difference to the climatological values; Leipzig station (Central-North Europe)*




*Time evolution of the aerosol backscatter coefficient (532 nm) in the low and high troposphere as difference to the climatological values; Potenza station (Southern Europe)*

## Preliminary conclusions on the week

In the week of 08-14 May 2020, very different atmospheric conditions were observed at the different lidar stations, driven by changing air mass circulations:

- The vertical structure of the atmosphere in **Central Europe** was highly variable, from observed clear sky, clear sky with high ice clouds, lofted aerosol layers, low clouds, precipitation, a typical continental dry PBL, and a humid PBL after precipitation.
- During clear sky conditions, a very clean atmosphere with virtually no aerosol in the entire troposphere and no PBL was observed in **North Europe**.
- Frequent cloud occurrences and rain characterized this week in the **Western Mediterranean**, after a dust episode ended on 8th May.
- In the **Eastern Mediterranean**, pollution from the big Greek metropolitan areas (Athens, Thessaloniki) and the Balkan were observed in the lowermost troposphere on 8 and 9 May. Pronounced aerosol layers were observed since 11 May with pollution aerosol from northern Africa in the lowermost 2 km and up to 5 km.

In the week of 08-14 May 2020, two dust outbreaks were observed in Europe. Both dust events are associated with Sharav cyclones over North Africa which are typical transport pathways towards Mediterranean for the spring and summer period:

- On 8th of May, the upward atmospheric currents above the North–West Sahara, initiated Saharan dust transport towards the Eastern coastline of Spain. In the next days, the system moved North-East and dust was spread to **Central, North and East Europe** with highest concentrations above south Italy and the Balkans.
- On 12th and 13th of May another dust event, with the main dust sources from North and Central Sahara and affected the **Mediterranean** on 12th and 13th of May with high dust concentrations above the Italian and Balkan Peninsulas.

**Overall,** in Europe an insignificant decrease of the aerosol backscatter coefficient in the lower troposphere and no decrease in the high troposphere can be seen during the week 8-14 May 2020, by comparison to climatological values. An increase of backscatter values with respect to climatological values both in the low and high troposphere sometimes observed after 10 May, and are partly related to the advection of Saharan dust from North Africa to Europe.