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

- Doina Nicolae, ACTRIS Centre for Aerosol Remote Sensing (CARS)
- 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.

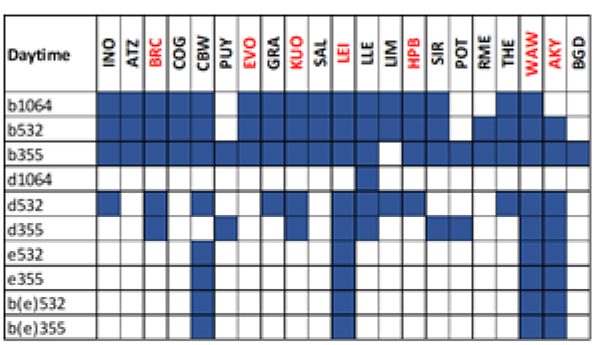
Location	Coordinates
Athens	37.9600 N, 23.7800 E, 212 m
Barcelona	41.3930 N, 2.1200 E, 115 m
Belsk	51.8300 N, 20.7800 E, 180 m
Bucharest	44.3480 N, 26.0290 E, 93 m
Cabauw	51.9700 N, 4.9300 E, 0 m
Clermont-Ferrand	45.7610 N, 3.1110 E, 420 m
Evora	38.5678 N, -7.9115 E, 293 m
Granada	37.1640 N, -3.6050 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

Data products

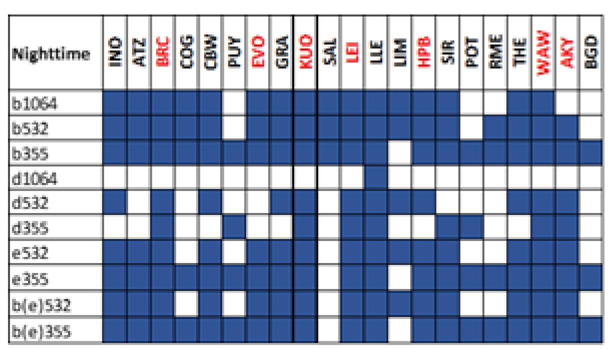
The data products calculated by the Single Calculus Chain depend on the configuration of the lidar system (i.e. the available channels):

- 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:



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



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

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

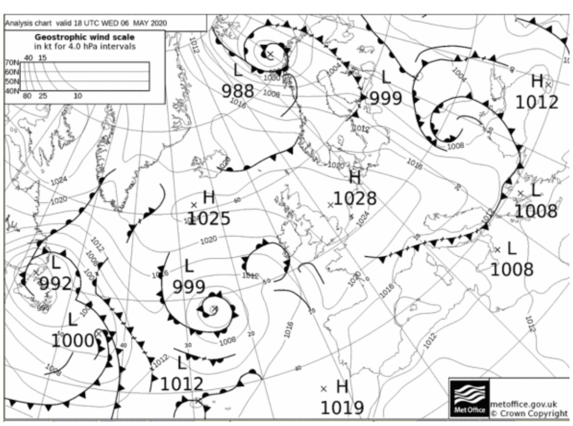
EARLINET – European Aerosol Research Lidar NETwork (www.earlinet.org)

Report for 1 – 7 May 2020

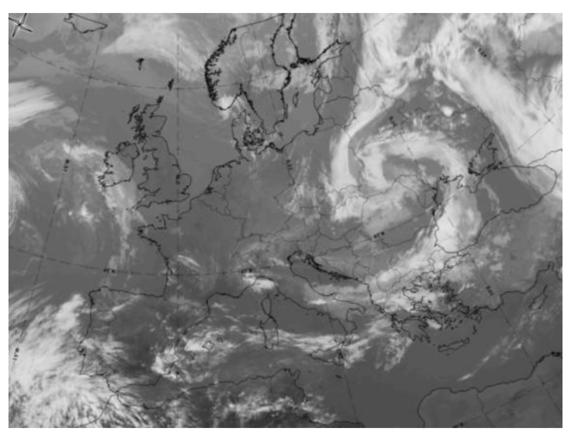
The first week of the campaign was dedicated to the adjustment of the instruments, performance of the quality assurance tests, and implementation of the specific measurement and data processing procedures. During this week, low clouds were generally present above Europe, therefore only part of the scheduled measurements has been performed and processed. Due to the small number of processed files, no detailed analysis of the resulting data is possible. Several examples are presented below.

Meteorological context during the week

April 2020 was an exceptionally dry month and also the sunniest April on record according to provisional statistics from the Met Office. During the 2 first days of May, atmospheric circulation is described by zonal flow above Europe and surface low-pressure around the frontal occlusions over Scandinavia interacting with cold arctic airmasses. No large horizontal temperature or pressure gradients were observed through Europe. At 3rd of May, higher pressure field around a 500hPa ridge, occur above west, while at the same time lower pressure fields around a trough, occur above east Europe. These conditions reserved dry and settled weather. At 4th of May, high pressure from the northwest England interacted with low pressure from southwest, resulting to increasingly brisk easterly winds (50mph) in the English Channel. At the same time in eastern Europe, a surface warm front, extending from Belarus across southeast Europe into the eastern Mediterranean, moves with slow speed causing rain and locally thunderstorms for several days. At May 5th, a well-organized low-pressure system from Atlantic, makes progress in northeast Europe, running into the block of high pressure in central areas. Finally, during 6 and 7 of May, high pressure fields slide eastward and a well-shaped frontal occlusion occurs through central and east Europe.



Surface Analysis for 6 May 2020 18UTC (source: Met Office; Aktuelle Wetterkarten http://www1.wetter3.de/)



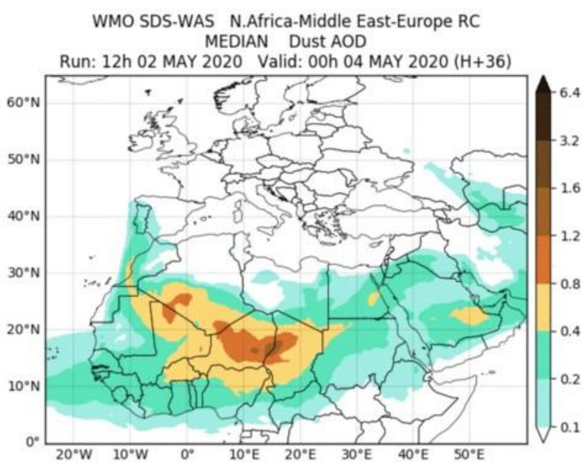
Infrared MSG Satellite Image for 6 May 2020 18 UTC (source: http://eumetrain.org/ePort_MapViewer/)

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

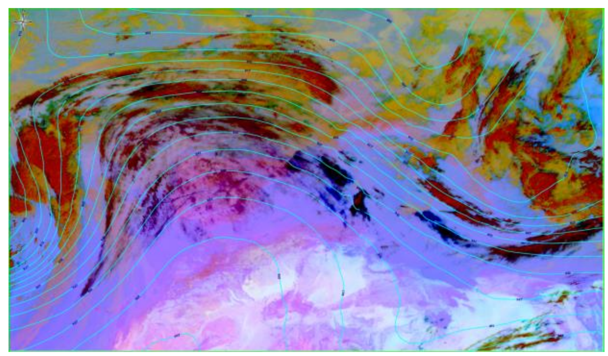
EARLINET – European Aerosol Research Lidar NETwork (www.earlinet.org)

Dust outbreaks

Driven by a surface low pressure system that was enhanced by a well structured trough in the upper troposphere, dust was transported to the Iberian Peninsula on 3rd of May. At first, dust mass spread to the area of Portugese and, gradually, extended towards East affecting Spain. The mean modeled Dust Optical Depth in the affected regions, was around 0.4. On 7th of May a low pressure system in North Africa started to form leading to dust transport on the next days.

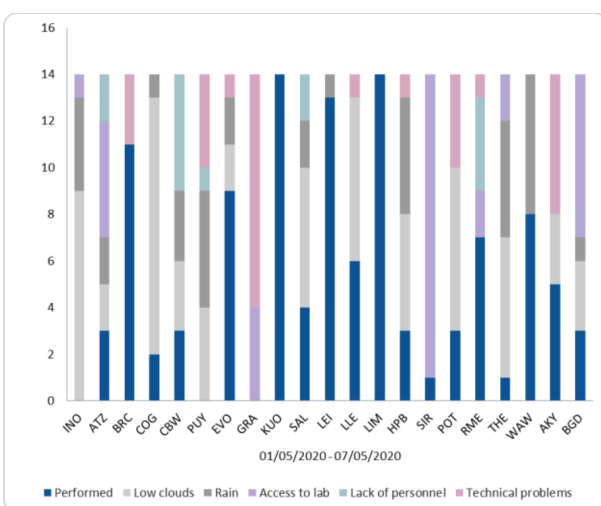


Ensembled Dust Optical Depth (source: WMO SDS-WAS;https://sds-was.aemet.es/forecast-products/dust-forecasts/ensemble-forecast)

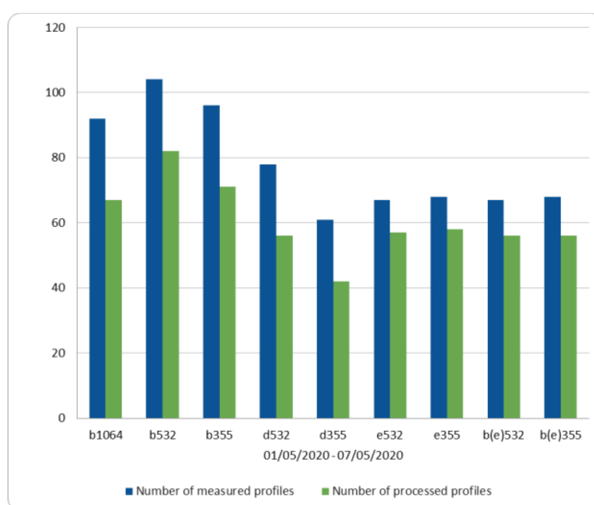


SEVIRI Dust RGB Satellite Image for 3 May 2020 06:45 UTC (source:http://eumetrain.org/ePort_MapViewer/)

Statistics of the week



Measurement statistics



Data products statistics

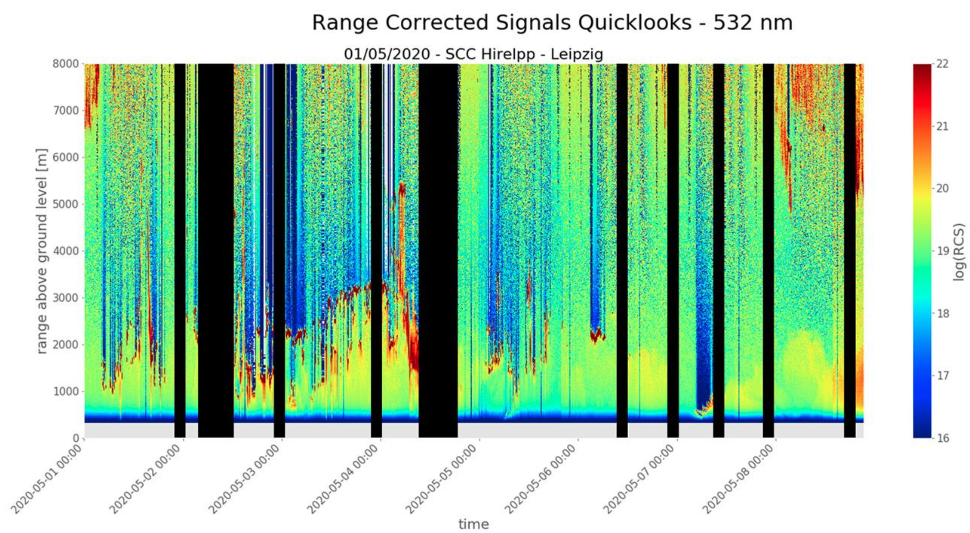
During this week, 37% of the total number of scheduled measurements were performed. In 36% of the cases, measurements could not be performed due to the weather conditions (rain or very low clouds), access to the laboratory and lack of personnel made the measurements impossible in 16% of the cases, while 11% of the measurements could not be performed due to instrument setting and check-ups.

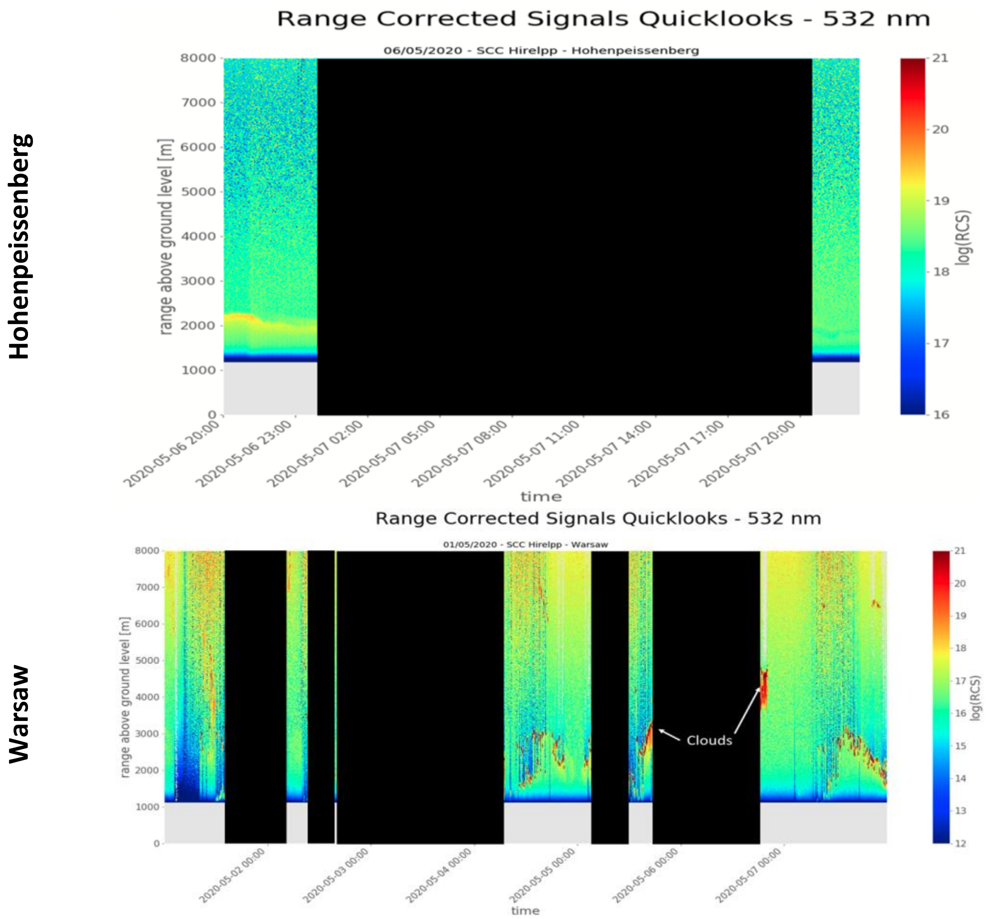
More than 77% of the collected datasets were successfully processed by the Single Calculus Chain. Most of the missing data products are due to the presence of low clouds in the measurements, which are screened out by the Cloud Masking module.

Quicklooks of the week

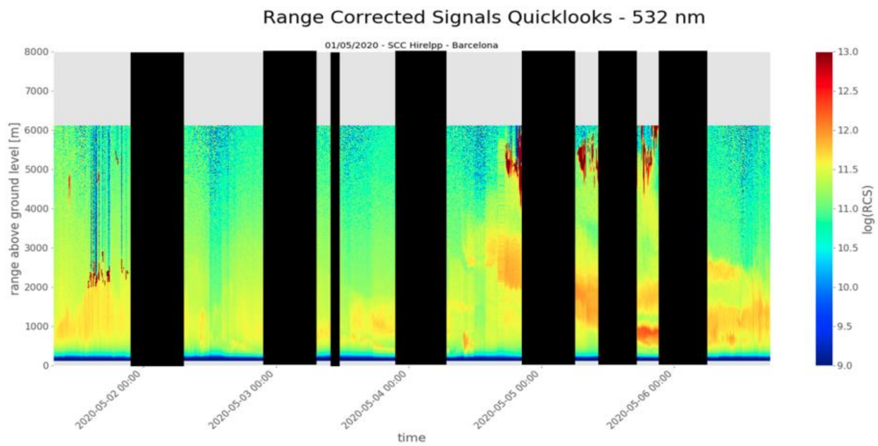
Quicklooks below show the temporal variability of the aerosol layers in the vertical. Regions in the atmosphere with high content of aerosols or clouds are identified in red colors, while "clean" regions are shown in blue. Black color indicates lack of measurement due to low clouds or precipitation.

Leipzig

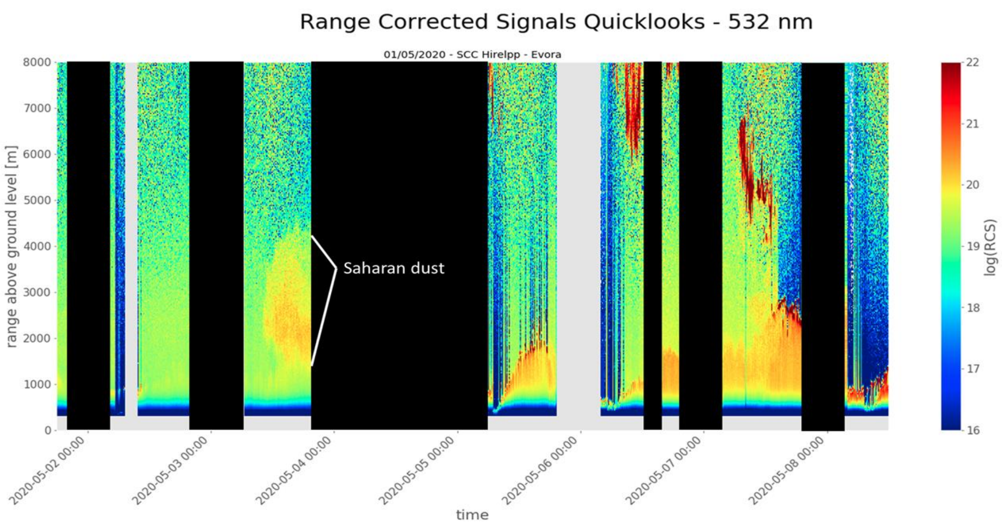



Range Corrected Signals Quicklooks - 532 nm
06/05/2020 - SCC Hirelpp - Hohenpeissenberg
Hohenpeissenberg
range above ground level [m]
log(RCS)
time
Range Corrected Signals Quicklooks - 532 nm
01/05/2020 - SCC Hirelpp - Warsaw
Warsaw
range above ground level [m]
Clouds
log(RCS)
time

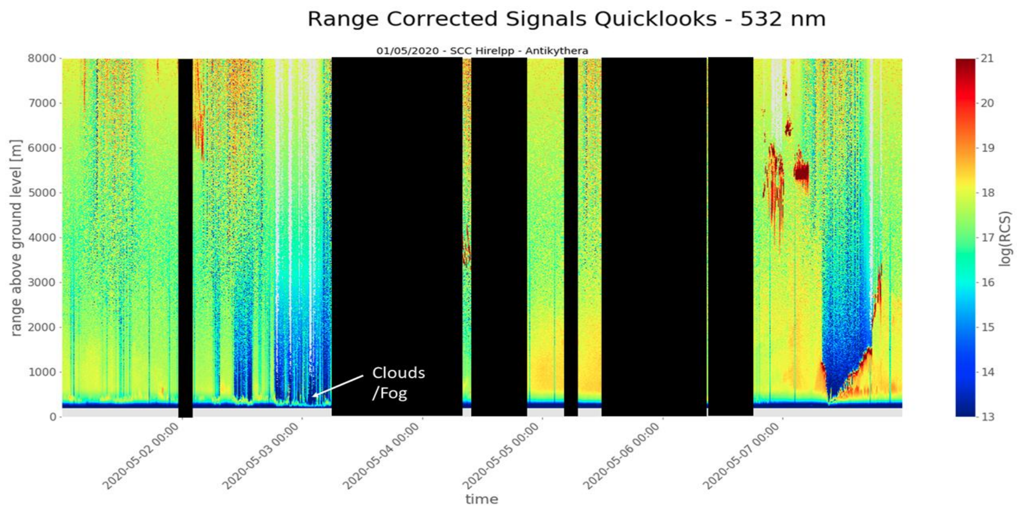
Barcelona



Evora



Antikythera



For the lidar stations in central Europe (Warsaw, Leipzig, Hohenpeissenberg), the week of 1 to 7 May was dominated by low-level clouds with rain events. The cloud bottom height varied from 1 to 3 km in Warsaw and thus was mostly connected to the local PBL. A similar pattern was observed in Leipzig, but in the end of the week, low-level clouds dissolved and aerosols were observed up to 2.5 km. Above 7 km, mainly Cirrus clouds were present. The aerosol load was significantly intensified from afternoon to the night of 7 May. In the Western Mediterranean - Evora - the week started under clear sky conditions with low aerosol load. In the middle of the week, a dense Saharan dust plume was observed between 1.5 and 4.5 km. This plume was observed later in the week in Barcelona up to 6 km with clouds forming on its top. After the mid of the week it started to get cloudier in Evora and aerosols coupled to the PBL were observed up to 2.5 km. Similar observations were made in Barcelona.

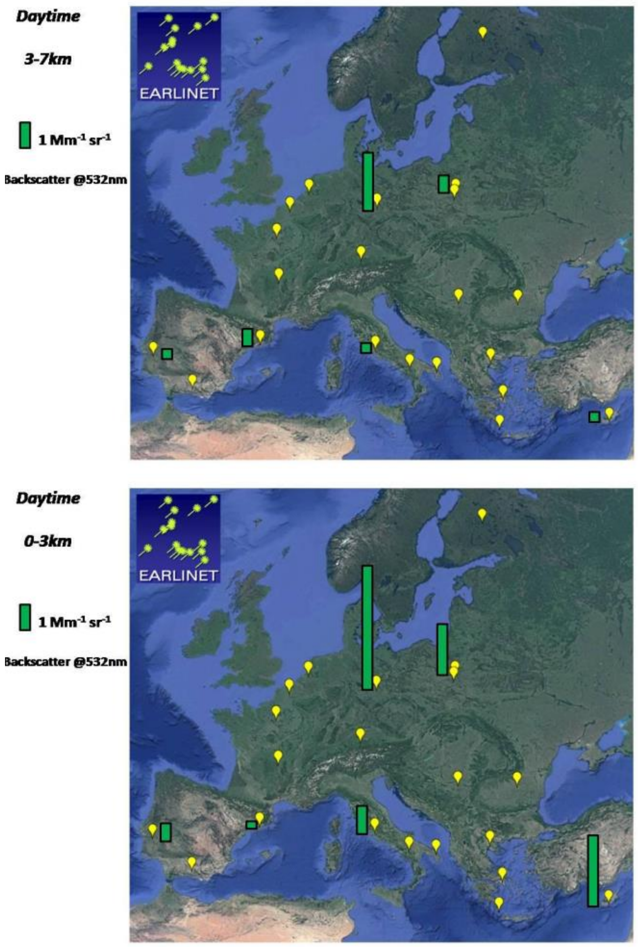
A different picture was drawn in the Eastern Mediterranean on the island of Antikythera. There, the first half of the week was dominated by low-level clouds and/or fog. During clear sky conditions in the middle of the week, aerosols most probably coupled to the PBL were observed up to 2.5 km. The end of the observing week was again dominated by a frontal passage with low clouds and probably a bit of precipitation.

In contrast to April 2020, in which high pressure over central Europe lead to clear sky conditions and the occurrence of multiple aerosol layers in the troposphere (most probably caused by biomass burning in Eastern Europe), the first week of May 2020 was characterized by changing weather patterns with significant low clouds and rain, but also some dust from the Saharan desert reaching the Iberian Peninsula.Weekly means

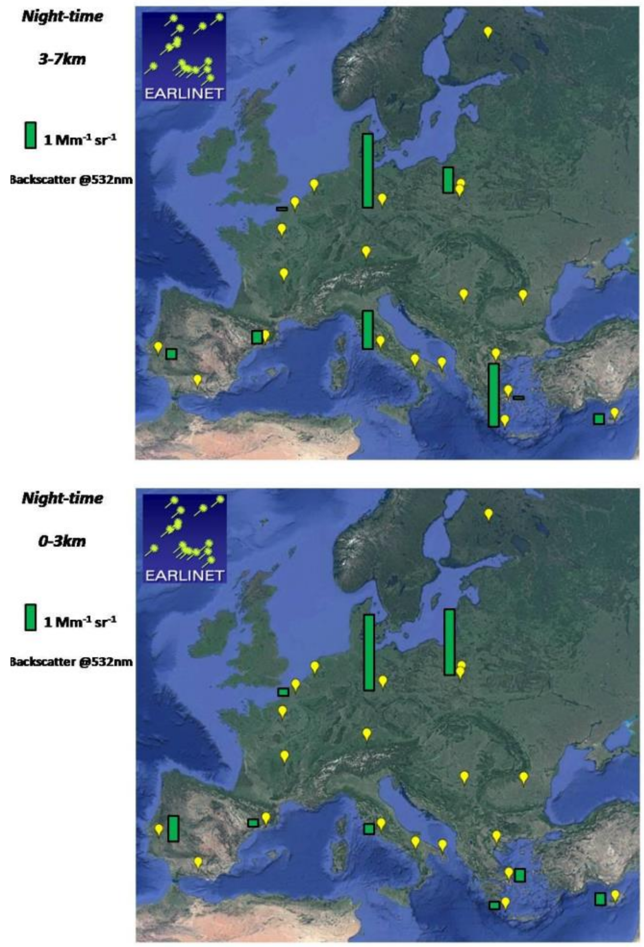
Aerosol backscatter coefficient is a measure of the aerosol load. Linear particle depolarization is a measure of the aerosol non-sphericity. Low troposphere is here defined up to 3 km altitude, where local influences are still possible. High troposphere is defined from 3 km up to 7 km, where typically 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.

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 > $5x10^{-7}$ $m^{-1}sr^{-1}$ 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.

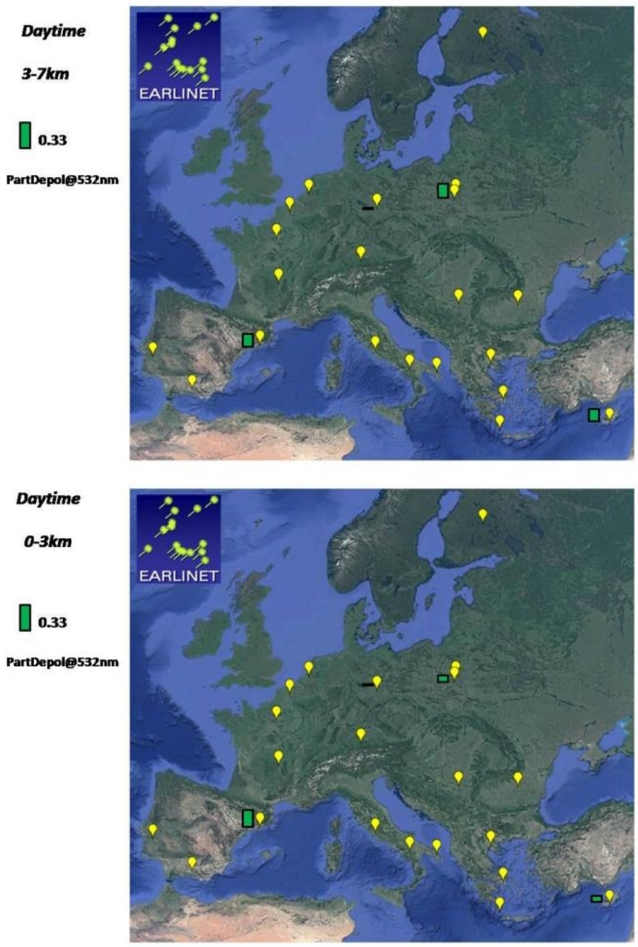


Weekly mean values of the aerosol backscatter coefficient (532 nm) for low troposphere (bottom panel) and high troposphere (upper panel) during daytime

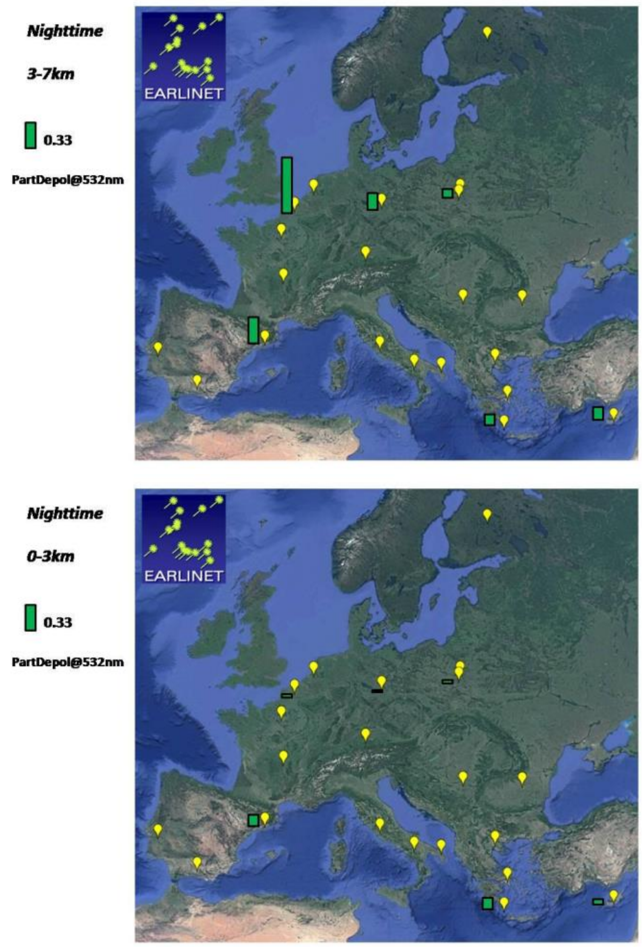


Weekly mean values of the aerosol backscatter coefficient (532 nm) for low troposphere (bottom panel) and high troposphere (upper panel) during nighttime

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. However, significant differences between regions are also visible. Systematic high values are measured in Central-North Europe (Leipzig and Warsaw) both at night and day, in the low and in the high troposphere. For the Southern stations the pattern changes from day to night: higher values in the low troposphere during daytime, and higher values in the high troposphere during nighttime.



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

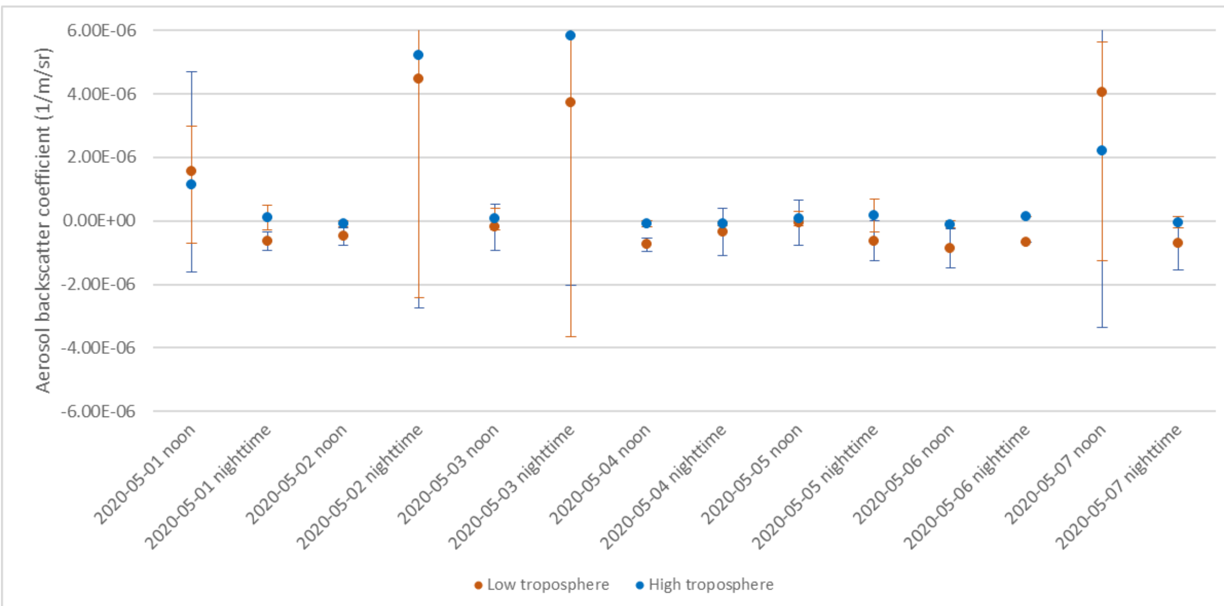


Weekly mean values of the particle linear depolarization ratio (532 nm) for low troposphere (bottom panel) and high troposphere (upper panel) during nighttime

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 high troposphere, the values of the linear particle depolarization ratio are higher for Central-North stations, as well as for Barcelona. This may be related to an episode of long-range transport of dust particles at altitudes higher than 3km.

Evolution with time

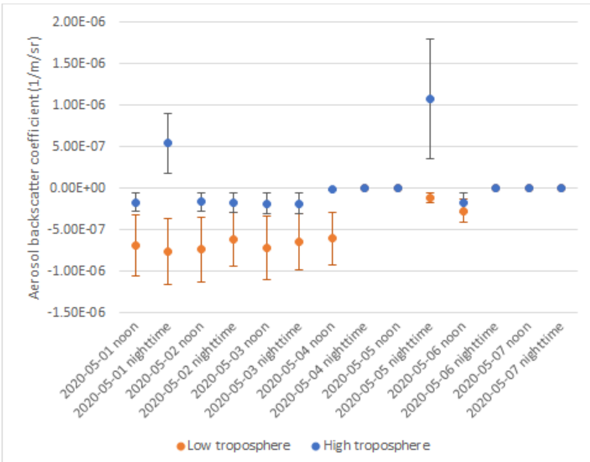
The graphs below show the changes during the week of the aerosol backscatter coefficient in the low and high troposphere, as a difference to the climatological values for May between 2000 – 2015[2].



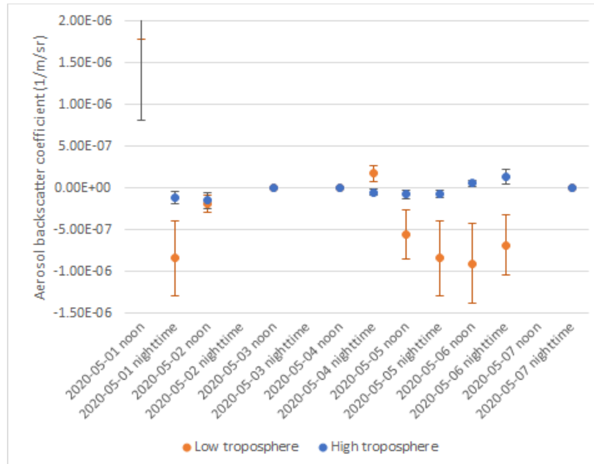
Time evolution of the aerosol backscatter coefficient (532 nm) in the low and high troposphere, as difference to the climatological values; average for all stations

Generally, in Europe a small decrease of the aerosol backscatter coefficient in the lower troposphere and no decrease in the high troposphere can be seen. However, the day to day variability is high, especially for the lower troposphere, due to particular meteorology during Spring time. Measurements on 2nd, 3rd and 7th of May show especially high values for both vertical regions, probably associated with long range transport of aerosols in Central-North Europe.

[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 .



Time evolution of the aerosol backscatter coefficient (532 nm) in the low and high troposphere as difference to the climatological values; Barcelona station (South-West Europe)



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)

As shown in the examples above, the values of the aerosol backscatter coefficient in the low troposphere are lower than the climatological values for almost the entire time interval presented, both in South-West and in Central-North Europe. The high troposphere, however, shows some time intervals with increased values of the aerosol backscatter coefficient, different for South-West Europe (1st May nighttime, 5th of May nighttime) and Central-North respectively (1st May noon). This may be associated to the specific patterns of the long range transported aerosols in the free troposphere.

Preliminary conclusions on the week

In contrast to April 2020, the first week of May 2020 was characterized by changing weather patterns with significant low clouds and rain, but also some dust from over Sahara reaching the Iberian Peninsula.

Generally, in Europe a small decrease of the aerosol backscatter coefficient in the lower troposphere and no decrease in the high troposphere was noticed by comparison with the climatological values (2000-2015).

The weekly-averaged aerosol backscatter coefficient and linear particle depolarization ratios are highly dependent on the region and the specific air mass transport, both in the low troposphere and high troposphere.