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.

[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

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 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.

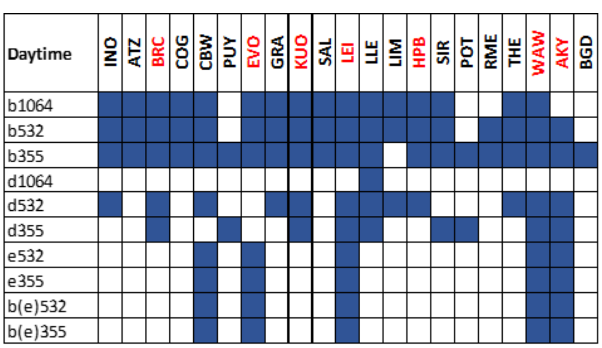
Location	Coordinates
Athens	37.9600 N, 23.7800 E, 212 m
Barcelona	41.3930 N, 2.1200 E, 115 m
Belsk	51.8300 N, 20.7800 E, 180 m
Bucharest	44.3480 N, 26.0290 E, 93 m
Cabauw	51.9700 N, 4.9300 E, 0 m
Clermont-Ferrand	45.7610 N, 3.1110 E, 420 m
Evora	38.5678 N, -7.9115 E, 293 m
Granada	37.1640 N, -3.6050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

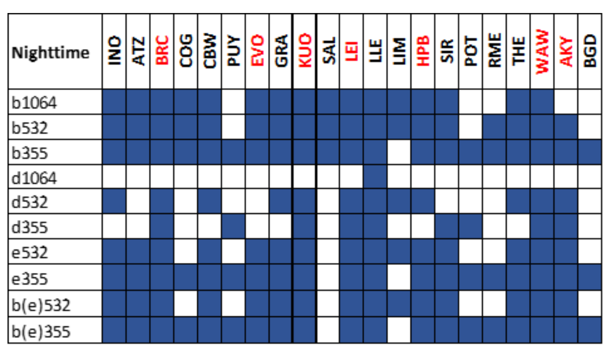
The data products calculated by the Single Calculus Chain depend on the configuration of the lidar system (i.e. the available channels):

- **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.

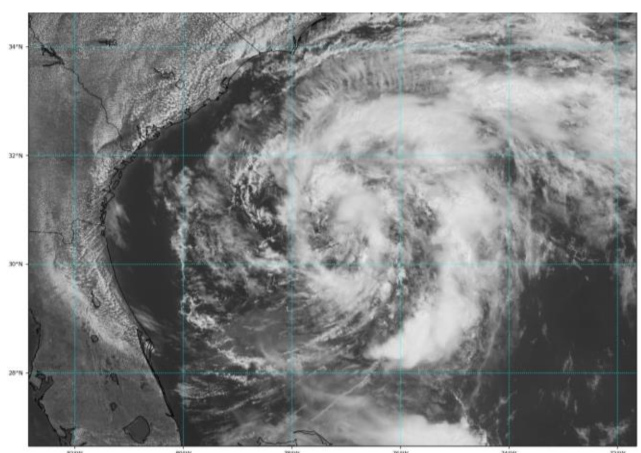


Data products calculated for each station during nighttime; in red, stations providing quasi-continuous measurements.

Report for 15 – 21 May 2020

Meteorological context of the week

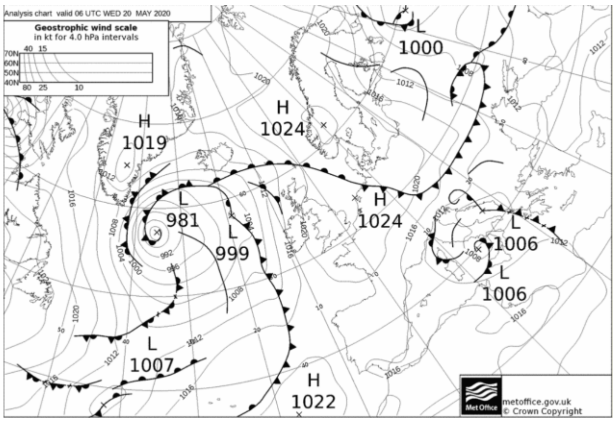
On Friday 15th of May, an extreme heatwave that expanded across the southern Mediterranean from North Africa, spread into south Italy, southern Balkans, and Turkey. On Saturday 16th, dry foehn winds contributed in pushing the peak temperatures locally above 40 °C in many places over southeast Europe. Especially on Sunday 17th May, the heat intensified further, having reached 43.0 °C in Antalya-Bolge, 42.5 °C in Paphos airport-Cyprus, 41.8 °C in Plora-Greece, and 39.9 °C in Palermo-Sicily. Finally, the heatwave persisted until mid-week, with temperatures near 40 °C and then slowly vanished as the upper-level ridge over the Mediterranean collapsed. At the same time, a tropical storm ("Arthur", the first named storm of the 2020 hurricane season) formed in the Atlantic, with minimum central pressure at 1002 hPa and quite well-organized rain bands. The storm slowly drifted north towards Carolinas.



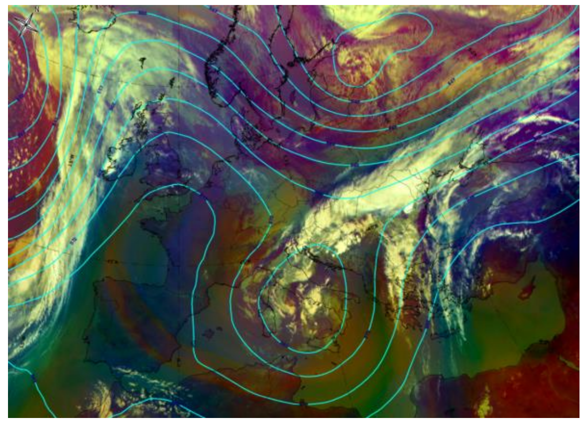
"Arthur Storm" from GOES-16 Visible Channel Reflectance for 17 May 2020 15:47Z (source: https://www.tropicaltidbits.com/)

After the historic and record-breaking heatwave, a huge change occurred for the southern Balkans. On 20 of May, a quite strong and large cold pool pushed from the north, began spreading across the east-southeast Europe into the Balkans and Black Sea region, bringing much colder weather and much lower temperatures than normal long-term average for late May. Moreover, frost recorded over Poland, Ukraine and Belarus, while very large hail fell in Godetch-Bulgaria. There was also interaction with high- and low-pressure fields over western and eastern Europe, respectively. More specifically, a ridge on the Iberian

Peninsula and a trough on top of Balkans, were pushed eastwards, resulting in surface cyclogenesis on the eastern fields of the trough (Italy, Greece) combined with cloud formation on 20-21 of May.

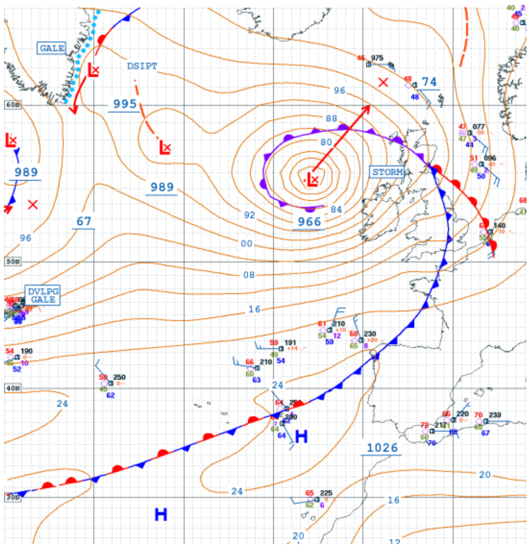


Surface Analysis for 20 May 2020 06UTC *(source: Met Office; Aktuelle Wetterkarten http://www1.wetter3.de/)*

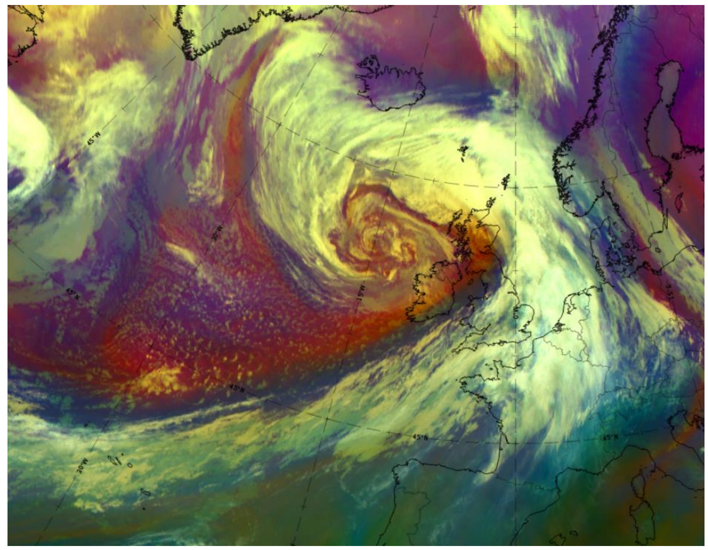


MSG Airmass RGB Satellite Image for 20 May 2020 09 UTC *(source: http://eumetrain.org/ePort_MapViewer/)*

Another large trough with a very deep core (520gpm at 500hPa level), combined with surface cyclogenesis, developed on Thursday 21st May. The cyclone was very large, covering part of the North Atlantic and western Europe, moving towards north-east and passing to the west of the UK and Ireland. The surface-system was rapidly intensifying and reached its peak near 965 hPa in the afternoon. It continued into western Europe on 22nd of May, with its central pressure near 970 mbar. The system delivered severe winds and high waves along the western coasts across Ireland, Wales, and Scotland (115 km/h was reported along western Ireland, 166 km/h in the Scottish Highlands). On May 23rd, the windstorm (unusually strong for late May), reached the UK with wind speeds over 110km/h, along with flooding events.



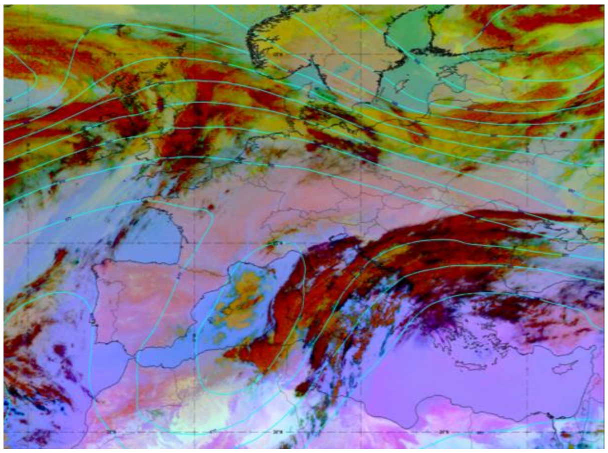
Surface Analysis for 22 May 2020 06UTC
(source: Weather Prediction Center, NOAA; https://www.wpc.ncep.noaa.gov/#page=ovw)



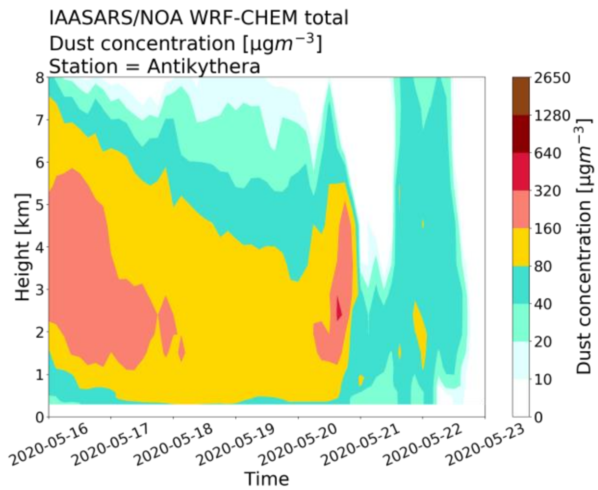
MSG Airmass RGB Satellite Image for 22 May 2020 06 UTC
(source: http://eumetrain.org/ePort_MapViewer/)

Dust outbreaks

On 15th and 16th of May a Surface Low, which was supported by a trough in upper troposphere, led to strong South winds that favored dust transport into Central and East Mediterranean. The most affected regions were The Italian Peninsula, The Balkans, Turkey and Cyprus. The system was slowly moving towards East and was combined by thick cloud cover. On the next days, the system refed with cold air in upper troposphere and the Surface Low formed in Adriatic Sea on 20th of May led to precipitation and dust deposition over Italy, the Balkans and West Turkey. The rest of the week was characterized by an anticyclonic circulation over Mediterranean region that did not favor dust transport towards Europe.



MSG-RGB Dust Satellite Image and Geopotential height at 500hPa for 18 May 2020 06UTC (source: http://eumetrain.org/ePort_MapViewer/)



An example of the week's dust time evolution above Antikythera station

Statistics of the week

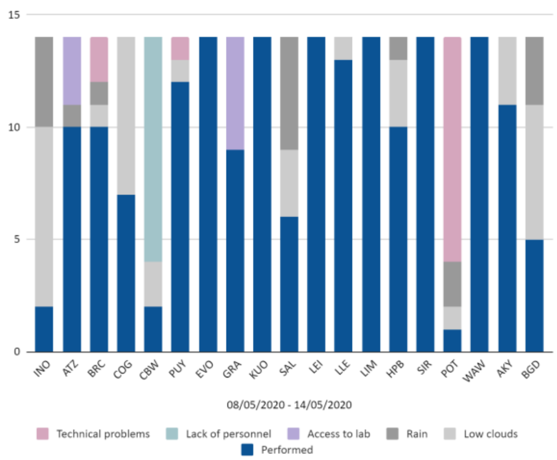
All 21 stations performed measurements, however due to technical problems measurements stopped in Potenza the second day of the reporting period (laser failure). Many of the stations also experienced days with bad weather.

During this week, **65% of the total number of scheduled measurements were performed**. In 20% 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 8% of the cases, while 7% of the measurements could not be performed due to instrument setting and check-ups.

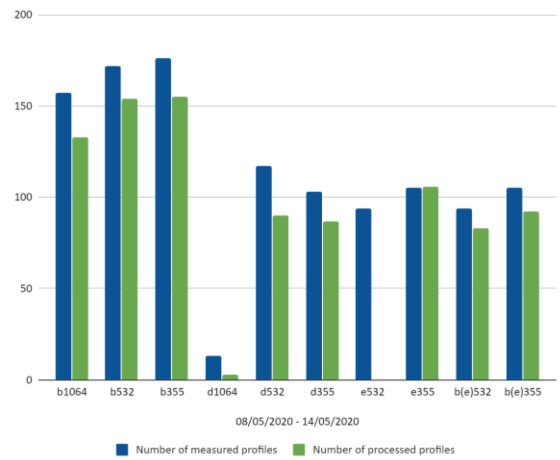
About 88% of the collected datasets were successfully processed by the Single Calculus Chain. Most of the missing data products are due to the presence of low clouds in the measurements, which are screened out by the Cloud Masking module. In case the remaining data is not sufficient to allow a good signal-to-noise-ratio, the optical products are not calculated.

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

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



Measurement statistics

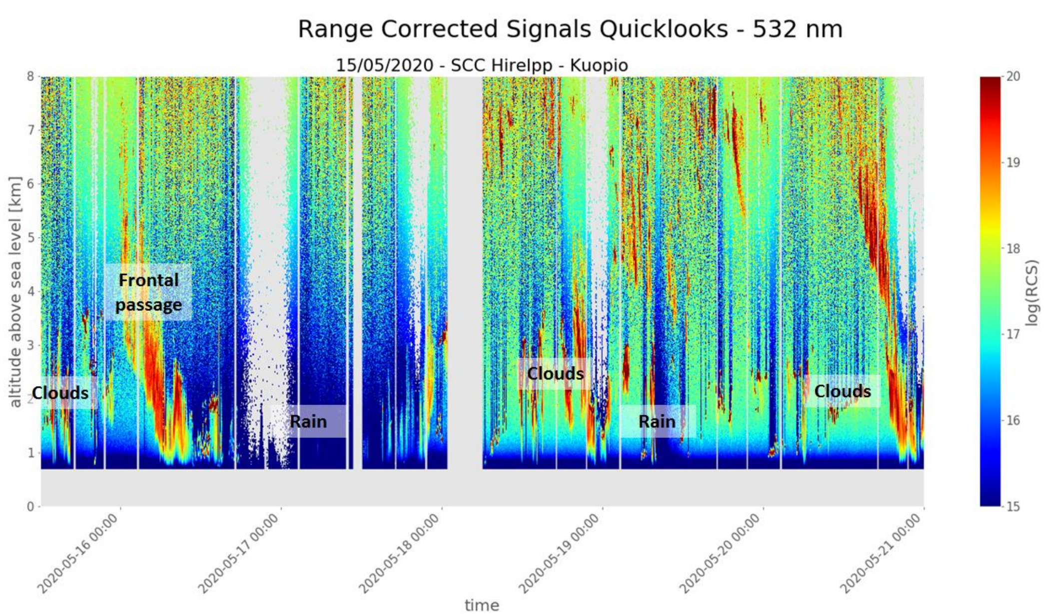


Data products statistics

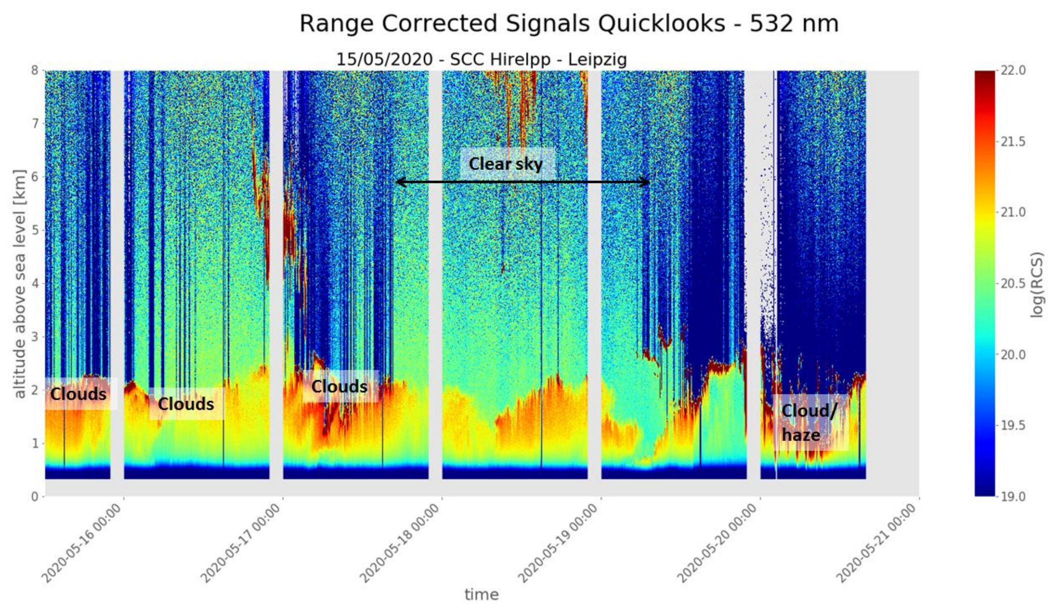
Quicklooks of the week

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. Gray color indicates lack of measurement due to low clouds or precipitation.

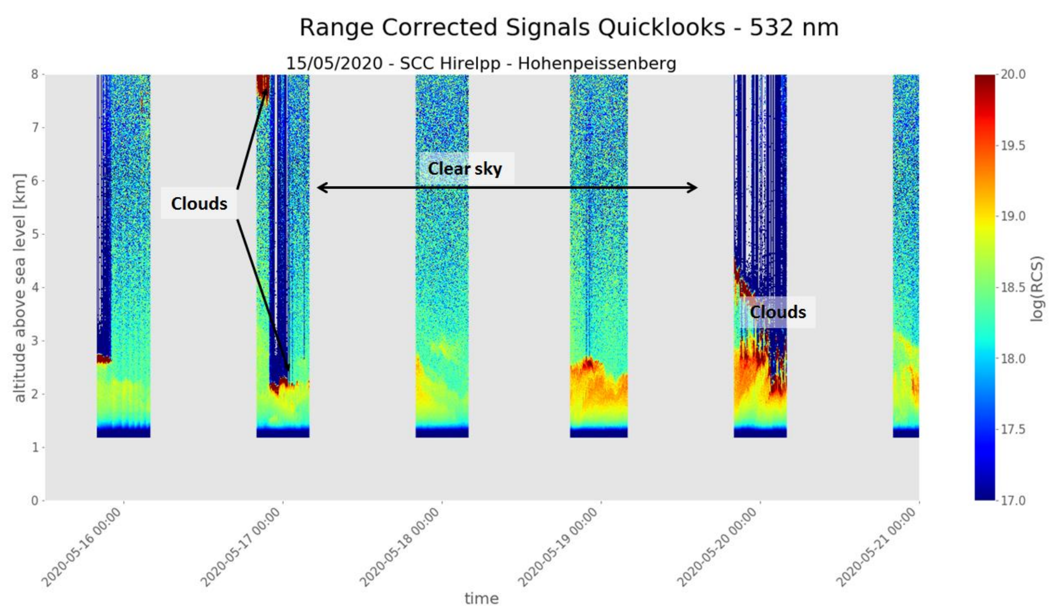
Kuopio



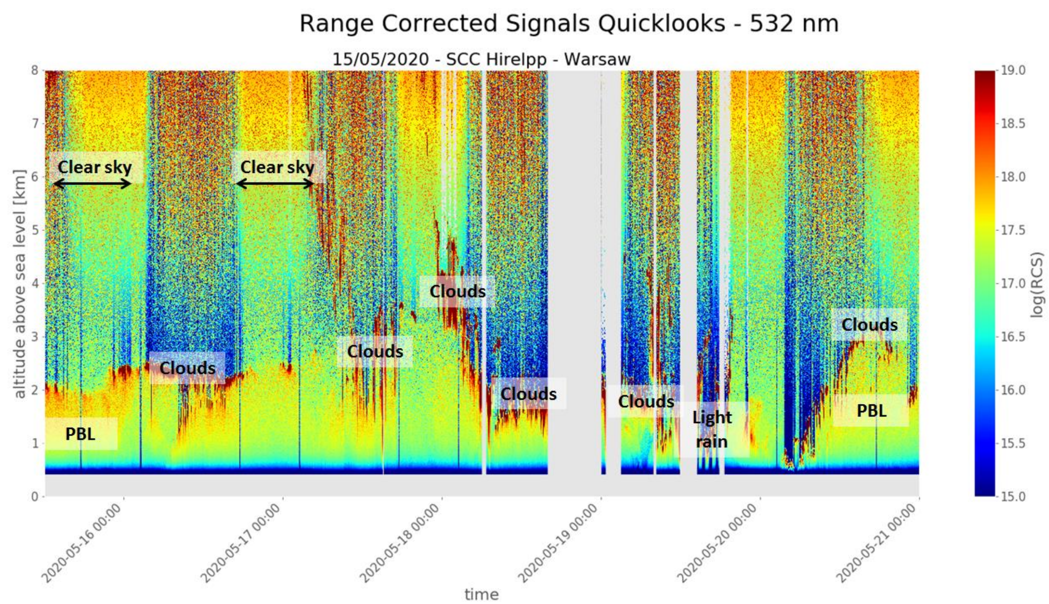
Leipzig



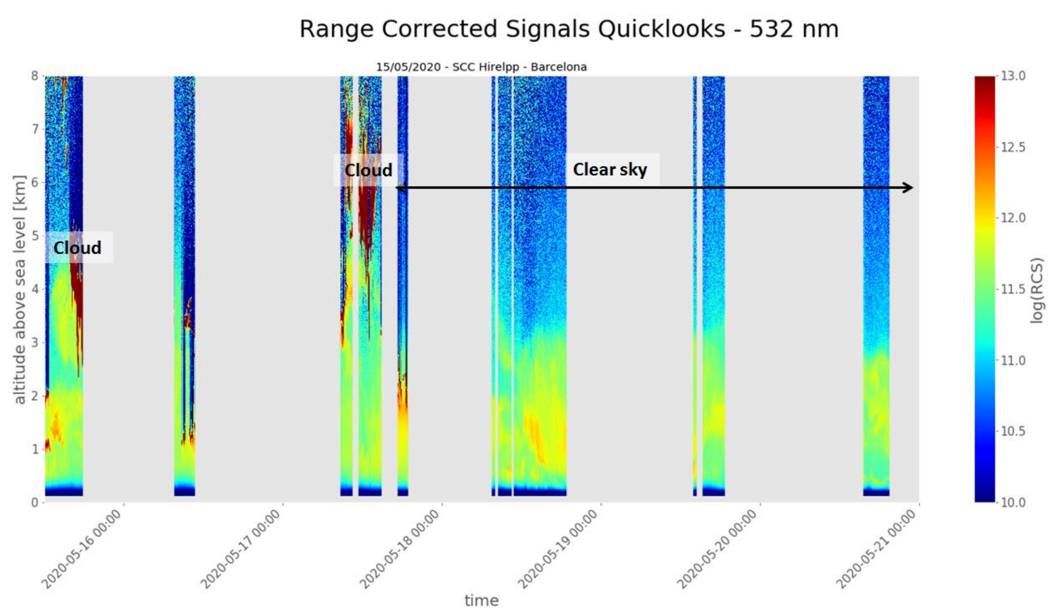
Hohenpeissenberg



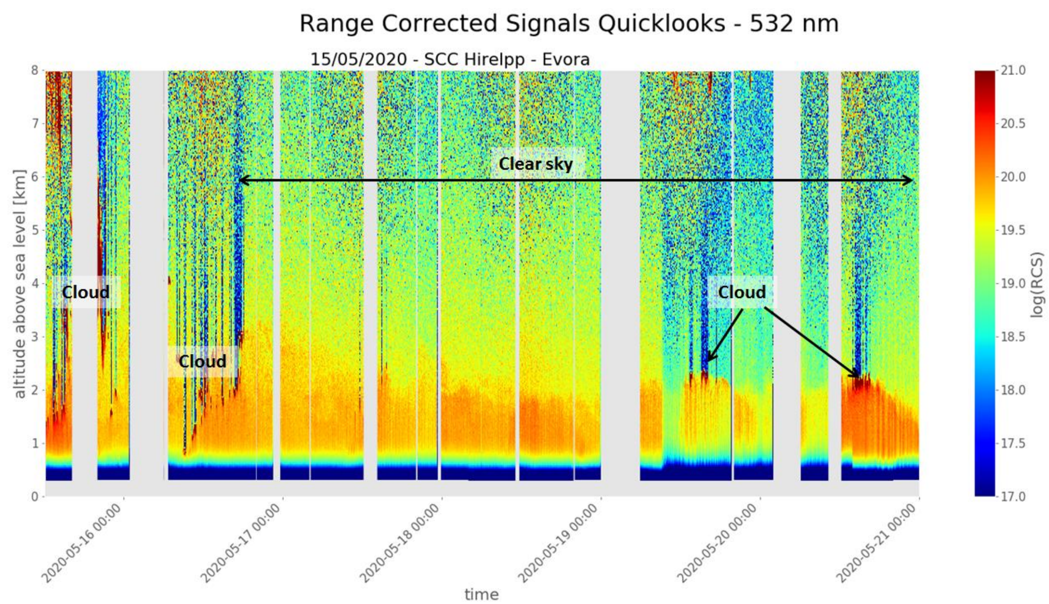
Warsaw



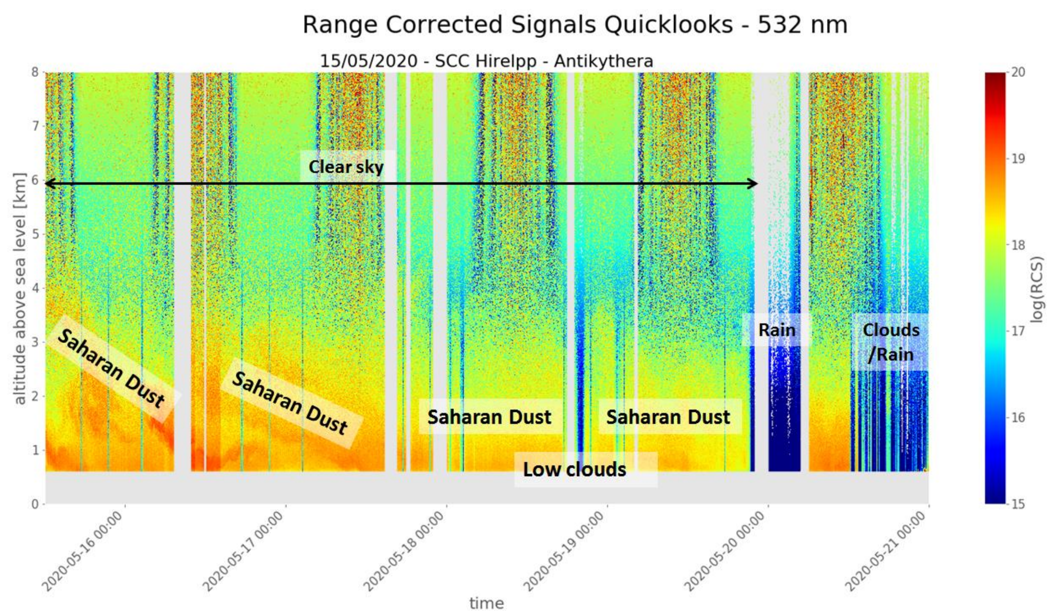
Barcelona



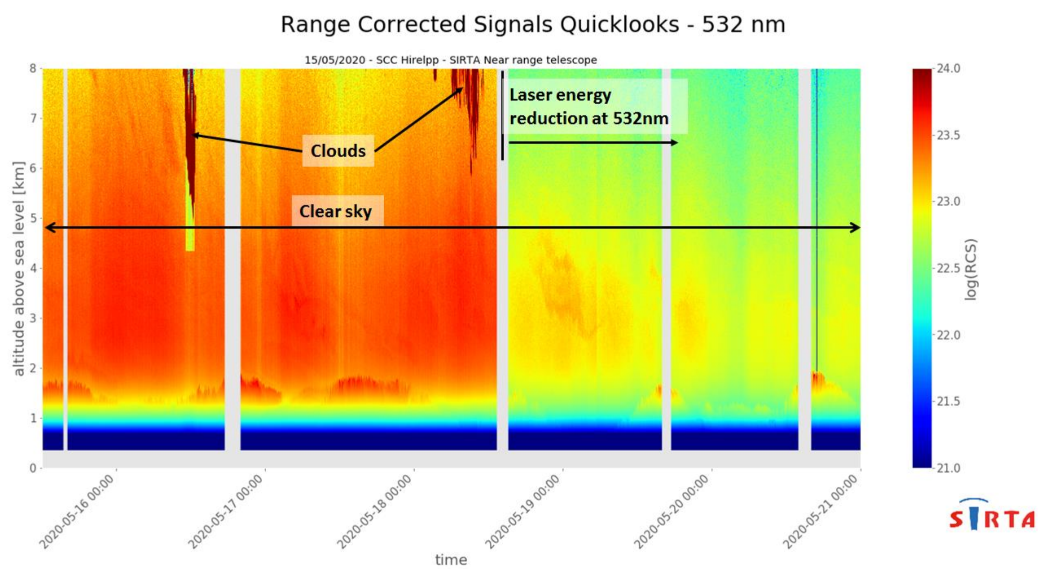
Evora



Antikythera



SIRTA



In Week 3 of the EARLINET NRT campaign, very different atmospheric conditions were observed between North and South Europe at the different stations providing continuous measurements.

Due to an exceptionally strong ridge travelling from North Africa, clear skies and high temperatures were observed in southern Europe accompanied with Saharan dust in the Eastern Mediterranean (Italia, the Balkans, Turkey and Cyprus). This situation is well reflected in Barcelona and Evora where clear skies were present most part of the week. In Evora the PBL diurnal cycle is nicely marked every day, reaching up to 2.5 km above ground level. Multiple thin dust layers were observed above it and in altitudes up to 7.5 km from 17th to 20th of May. In Barcelona the PBL develops up to 3 km height, which is above the usual PBL height for this coastal station. Thermal convection is likely to be the principal factor for such a PBL rising. Further east, in Antikythera clear skies are also observed until 20 May. In the beginning of the week dust was observed above the station at altitudes sometimes as high as 10 km. The observations show similar intensities as the forecasted ones, with the main dust load being up to 5.5 km. The extinction coefficient at altitudes up to 3 km was around 100 Mm^{-1} and it exceeded 150 Mm^{-1} at altitudes between 3 to 4 km. As the advected plume descended slowly during the week, the dust optical depth and the particle depolarization ratio at 532 nm also dropped from 0.5 and 30 % (on 15 May) to 0.3 and 25 % (on 20 May), respectively. On 20 and 21 May, low level clouds were present, on top of the marine boundary layer of the island (altitude < 1 km), connected to the surface low occurred these days over East Balkans. In SIRTA, near Paris, clear skies were observed all week long with sporadic mid-altitude clouds. At this station the PBL diurnal cycle is also nicely marked every day in altitudes up to 2 km a.s.l.

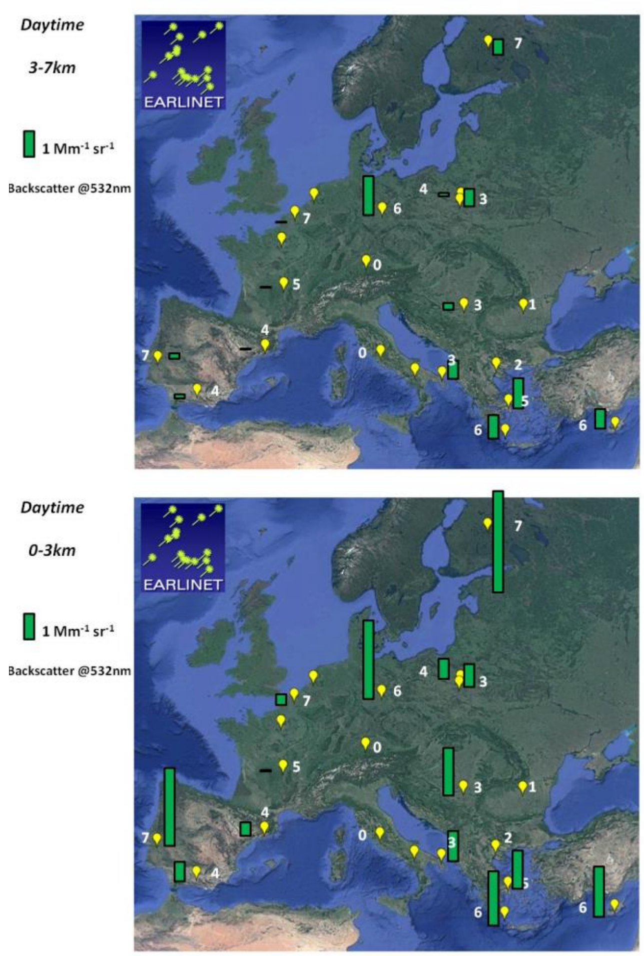
In Northern Europe, clouds were present most of the time. This is particularly visible on Warsaw quicklooks where only two short time slots with clear sky are visible on 15 and 17 May. Most of the cloud formation in Warsaw occurs on top of the PBL. In Leipzig and Hohenpeissenberg a clear-sky window appeared in the middle of the week (17, 18 and 19 May). Low-level clouds were present at the end of the week. Finally, in Kuopio, low and mid-level clouds are visible in the lidar observations on heights 1-5km, and a frontal crossing was captured above the station on 16 and 17 May, on the south sector of the well-shaped cyclone over north Scandinavia. After 17 May, clouds were present most of the week with continuous precipitation, due to a warm front that developed in the east sector of a well-shaped occlusion above England.

Weekly means

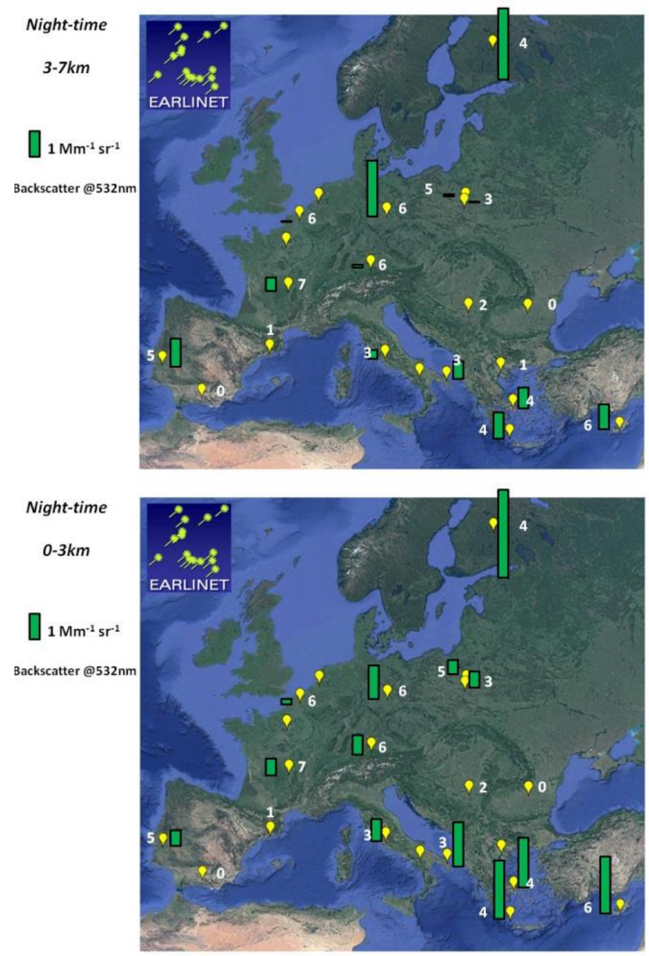
Aerosol backscatter coefficient is a measure of the aerosol load. Linear particle depolarization is a measure of the aerosol non-sphericity. Low troposphere is here defined up to 3 km altitude, where local influences are still possible. High troposphere is defined from 3 km up to 7 km, where typically 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 > $5x10^{-7}$ $m^{-1}sr^{-1}$ 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.



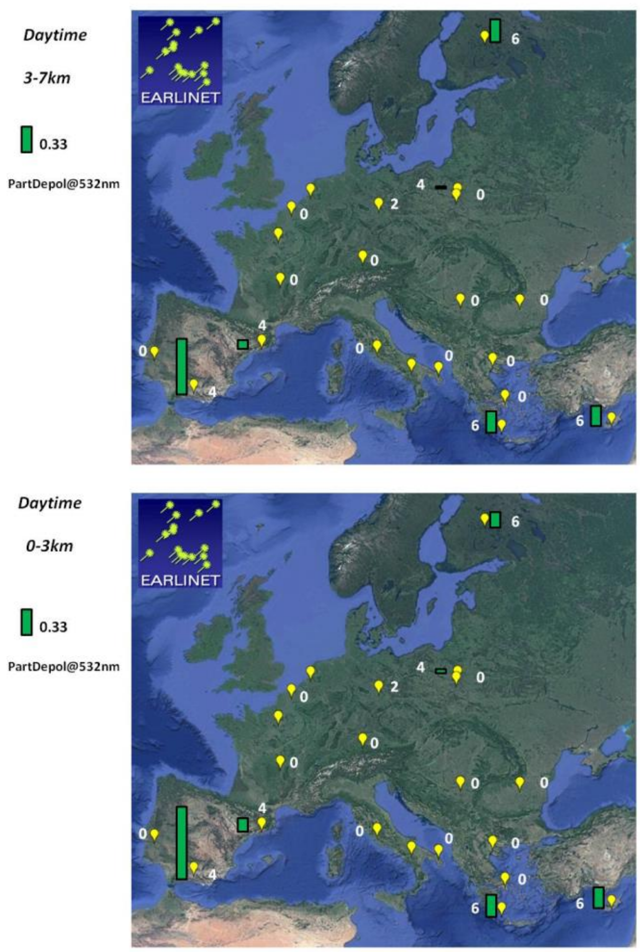
Weekly mean values of the aerosol backscatter coefficient (532 nm) for low troposphere (bottom panel) and high troposphere (upper panel) during daytime.



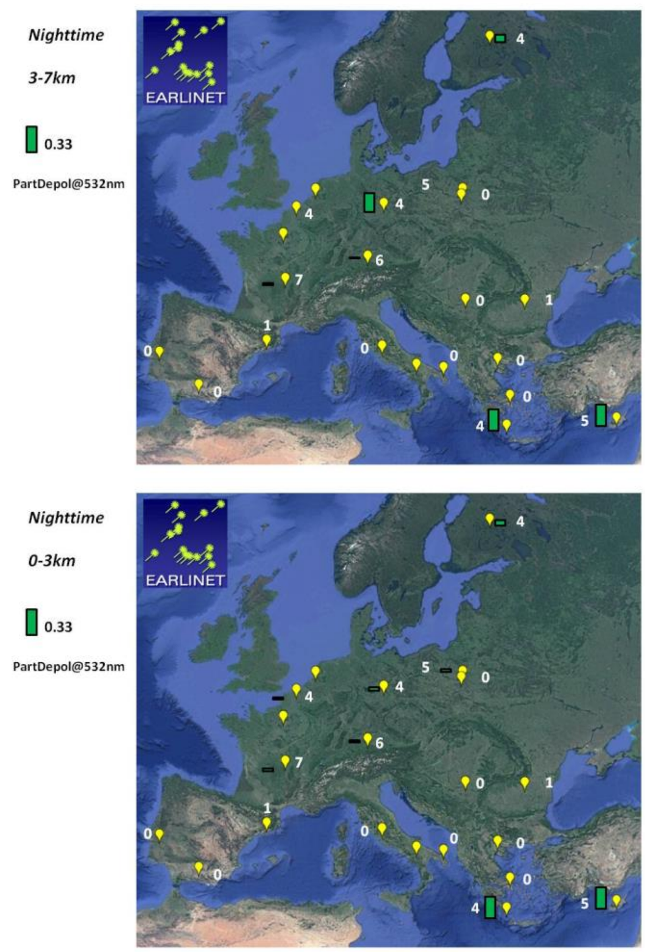
Weekly mean values of the aerosol backscatter coefficient (532 nm) for low troposphere (bottom panel) and high troposphere (upper panel) during nighttime

Aerosol backscatter at 532 is typically higher in the Southern Europe respect to the Central and Northern Europe, because of the dust intrusion described in the Meteorological context reported above. The almost equal mean values reported for daytime and nighttime observation both in the lowest troposphere and FT is another signature of the relevance of the dust intrusion over Eastern Mediterranean stations (Italy, Greece, Cyprus). This is reflected also in the depolarization ratio values reported below, with values on average around 30% both in low and free troposphere. Especially in Antikythera and in Limassol the depolarization ratio remains relatively constant around 0.28 during daytime and nighttime, within both tropospheric layers, in agreement with the vertical distribution and the time evolution of the dust plume transported over this region. On the contrary the big difference in daytime and nighttime backscatter mean value in the 0-3 km altitude range for Evora highlights the absence of dust over there and is the result of the well observed PBL diurnal cycle.

Northern Europe instead is characterized by very low depolarization values and typically low values in the aerosol backscatter values both in low and free troposphere. Some observed high values could be related to a residual cloud contamination in the products, that needs for further investigations beyond the scope of this report and of NRT provision of data.



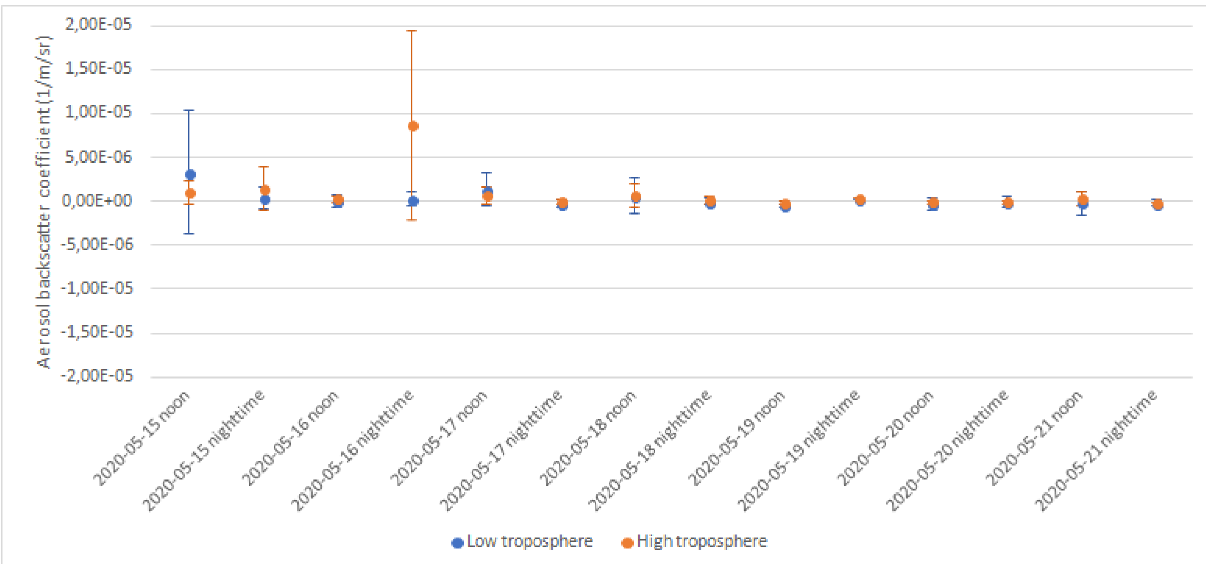
Weekly mean values of the particle linear depolarization ratio (532 nm) for low troposphere (bottom panel) and high troposphere (upper panel) during daytime



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

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

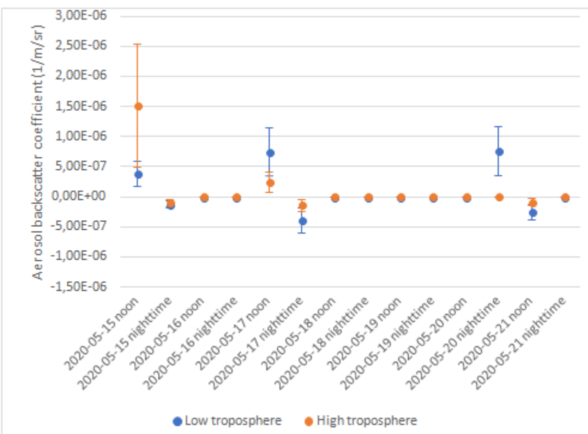
Generally, in Europe during the week 15 – 21 May 2020, the aerosol backscatter coefficient in both upper and lower troposphere are very close to the climatological values. On 15th of May, a certain tendency of higher than climatological values is observed because of the dust intrusion over the Southern Europe, The big value observed in the free troposphere on 16 May is instead caused by individual case of Leipzig, probably related to a residual cloud contamination

In the following, the time evolution of the aerosol backscatter coefficient for 2 sites one in North-eastern Europe (Belsk) and one in Southeast Europe (Athens) are reported as examples.

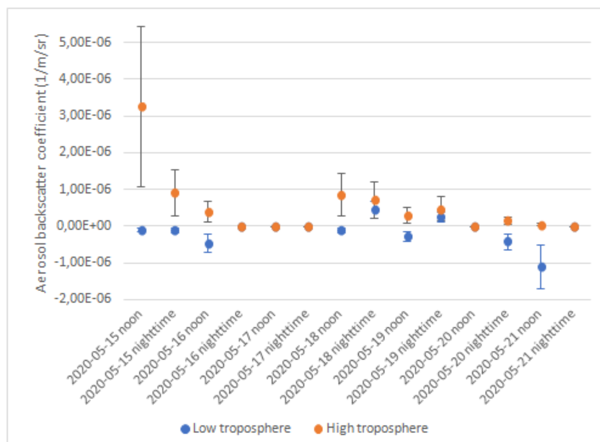
2 Climatological values and profiles are evaluated on the base of 15 years of data (https://doi.org/10.1594/WDCC/EARLINET_All_2000-2015) and are provided as the first release of ACTRIS/EARLINET Level 3 dataset available at https://www.earlinet.org/index.php?id=125 .

Belsk shows no deviance respect to the climatological value in the free troposphere, most days of the week, while in the lower troposphere some deviances are observed but with no a clear tendency, reflecting probably the natural variability of the aerosol content during the month.

Over Athens less aerosol backscatter than climatological is observed in the low troposphere most days of the week, while the values are always higher in the upper troposphere. Especially the maximum increases are related to the dust intrusion over Southern Europe during the first days of the week.



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



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

Preliminary conclusions on the week

During this week, an extreme heatwave that expanded across the southern Mediterranean from North Africa, spread into south Italy, southern Balkans, and Turkey, leading to strong South winds that favored dust transport into Central and East Mediterranean. the heatwave persisted until mid-week. On 20th of May, a quite strong and large cold pool pushed from the North, began spreading across the East-South-East Europe into the Balkans and Black Sea region, bringing much colder weather and much lower temperatures than normal long-term average for late May, even frost in Poland, Belarus and Ukraine. As consequence, atmospheric conditions were completely different in North-Central, and South Europe.

- In North and Central Europe (Finland, Poland, Germany, The Netherlands) clouds were present most of the week with continuous precipitation, and only few time periods with clear sky. Low aerosol backscatter and depolarization ratios were measured both in low and free troposphere.

- In South Europe, clear skies and high temperatures accompanied by Saharan dust were observed in the eastern Mediterranean (Italy, Greece, Cyprus), but also in western Mediterranean (Spain). Aerosol backscatter at 532 was significantly higher than in North and Central Europe, and constant over day and night, both in the low and high troposphere. The depolarization ratio values around 30% both in low and high troposphere are also a typical signature of the Saharan dust over the Mediterranean. Saharan dust was observed in Portugal only as thin layers in the high troposphere.

Generally, in Europe during the week 15 – 21 May 2020, the aerosol backscatter coefficient values in both upper and lower troposphere are very close to the climatological values. On 15th of May, a certain tendency of higher than climatological values is observed because of the dust intrusion over the Southern Europe.