Events of intense aerosol pollution over the Paris Area during winter 2016-2017 observed by Raman lidar

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During winter cold spells over the Paris area, the top of the atmospheric boundary layer (ABL) is lower than 500 m and promotes the accumulation of pollutants near the surface. This effect is enhanced with the presence of high pressures that are generally associated with low mean wind speeds of a few m.s⁻¹. Winter aerosol pollution events are generally sampled using in-situ measurements of PM₁₀ and PM₂.₅ (i.e. aerosol mass concentration for particle aerodynamic diameters of less than 2.5 and 10 μm, respectively), which are carried out by the network of ground-based stations managed by AIRPARIF. They are poorly documented by lidar observations because the particles are trapped in the first hundred meters of the troposphere.

The compact 355 nm Lidar for Automatic Atmospheric Surveys Using Raman Scattering (Fig.1, Fig. 2 & 6), LAASURS, Chazette et al., 2017, with low minimum measurement altitude, has been deployed at University Pierre and Marie Curie. Our main goal was the study of the temporal evolution of aerosol optical properties within the ABL between end of September 2016 and end of January 2017.

A significant increase of particulate pollution is observed during the winter 2016-2017 (Fig. 3) due to a colder meteorology associated with an increased occurrence of high pressure.

During winter 2016-2017 ten days exceeded the normative information threshold of 50 μg.m⁻³ (see Fig. 3 & 4) with respect to the European directive 2008/50/EC of 21 May 2008.

Among those days, two major pollution events stand out: the first one centered around 1 December 2016 and the second one centered around 21 January 2017.

Aerosol extinction and ground concentrations

Fig. 7 & 8 reveal a good agreement between the Aerosol Optical Thickness (AOT) Raman derived, the intensity of the Aerosol Extinction Coefficient (AEC) and the ground concentration variations for both events.

For the first event (Fig. 7), severe concentrations occur during the afternoon of the 30 November with an already high ABL. They are accentuated on the morning of 1 December when the ABL slims down.

In January (Fig. 8), ground concentrations, AOT and AEC levels are significant but not over the alert threshold on 20 January. A drop of temperature (°C to -4°C) during the night of 20 to 21, lowering the ABL, explains the later increase of concentration, reaching above 120 μg.m⁻³.

These two pollution events share high concentration levels but the conditions of their occurrence are different.

Spaceborne measurements

Spaceborne instruments dedicated to Earth observations corroborate ground-based lidar measurements. The spectroradiometer MODIS on board Terra and Aqua satellites operates a synoptic view of the AOT (Fig. 9). An AOT of 0.2 at 550 nm corresponds to 0.37 at 355 nm in agreement with the ground-based lidar retrieval.

The spaceborne lidar CALIOP on board CALIPSO passed close to Paris area on 21 January 02:00 UTC. CALIOP data inversion allows access to both the AEC and the aerosol typing (Burnet et al., 2015).

(a) The pollution is characterized by a AEC higher than 0.3 km⁻¹, standing about 300 km in latitude and centered 1 km above the mean sea level (Fig. 10).

(b) The aerosol typing above Paris area is mainly polluted continental or smoke, which is consistent with a winter pollution episode (Favez et al., 2009).

Pollution origins

Backward trajectories were simulated in ensemble mode by the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYPLIT) model*.

As shown in Fig. 11 for the first event, the air mass came from Southern England after having passed through Northern France, Ile de France region, Rhone region and western Germany. Regions including highly industrialized zones known to be aerosol emitters.

In January (Fig. 12) the air parcel is mainly confined in the center-south of France and Rhione valley for three days.

Conclusion: The first event in December is at least partially due to an advection phenomena from industrial regions, whereas the January episode seems to be caused by the accumulation of local pollutants in a strong weather blocking situation.

Prospect: Further analysis coupling chemistry composition and transport models will be conducted to better understand the origins. This long lidar over Paris will be used for a statistics of the aerosol optical properties in the ABL and above during winter. Lidar technology has shown its potential as a complementary tool with ground stations to discriminate causes of pollution events and help public authorities with implementing suitable countermeasures.