Lidar detection of Canadian forest fires over Europe in June and July 2013

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Abstract

Lidar is an active range-resolving optical remote sensing technique which allows for the measurement of a wide range of atmospheric parameters. The Raman backscatter lidar station in Cork is part of the European lidar network, EARLINET, which aims to provide a comprehensive database of aerosol distribution on a continental scale. Aerosol from Canadian forest fires were detected at the Cork lidar station and several other EARLINET stations between June 2013 and July 2013. Selected measurements from Cork at 532 and 607 nm, are discussed and compared to those taken by other EARLINET stations. HYSPLIT air-mass back trajectory models were used to trace the origin of the detected aerosol layers. An aerosol forecast model, MACC, was used to further investigate and verify the origin and presence of the smoke to be from wildfires in Quebec. Lidar ratios for the smoke were determined to be between 33 sr and 62 sr.

Lidar Principle

The basic setup of a Raman lidar is shown in **Figure 1**. Pulsed laser light propagates into the atmosphere and the elastic and inelastic backscattered light is detected by the receiver optics. The Klett or Raman methods outlined in [1,2] can then be used to calculate the backscatter coefficient, extinction coefficient, and lidar ratio.

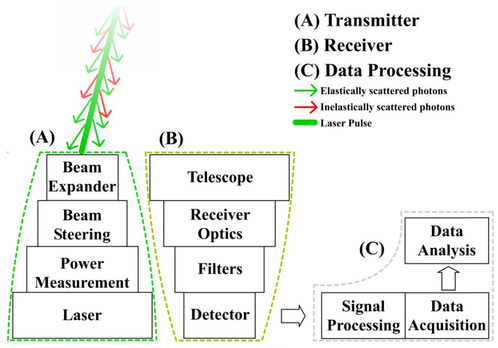


Figure 1: Basic Raman lidar setup. The transmitter unit (A) contains a Nd:YAG laser with a beam expanding Galilean telescope and a beam steering mirror. The receiver unit (B) contains a Newtonian telescope with receiving optics, two narrow band filters and two detectors. The data processing unit (C) contains components to process the signals, acquire data, and analyse data. [3]

4th July 2013

A large aerosol load was detected over Ireland with lidar ratios that were indicative of forest fire smoke (47 - 66 sr). These aerosol layers were transported over Europe and were detected at Minsk station on the 8th July 2013. Only elastic backscatter measurements were available for Minsk station. Backscatter coefficients decreased between Cork and Minsk stations possibly due to a lower aerosol concentration.

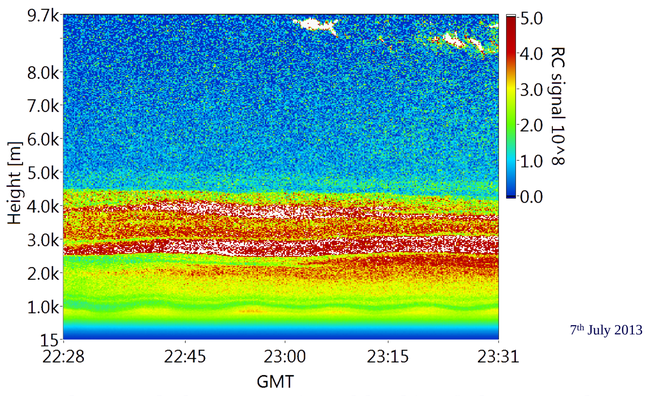
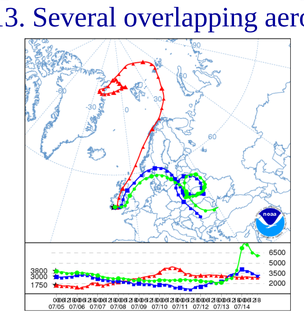


Figure 2: Colour-coded images (quicklook) of the time-dependent range corrected backscatter signal profiles at 532 nm for the 4th July 2013. Several overlapping aerosol layers are observed up to 5 km.



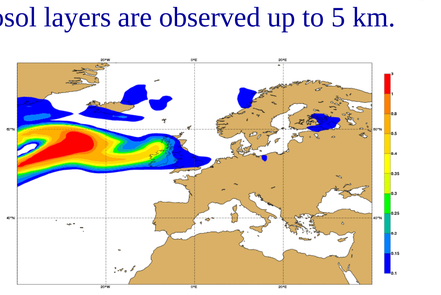


Figure 3: Left: HYSPLIT air-mass forward trajectory (9 days) from Cork station (00:00 UTC 4th July to 00:00 UTC 14th July). Right: MACC model forecast indicating the optical depth of biomass burning aerosols at 550 nm.

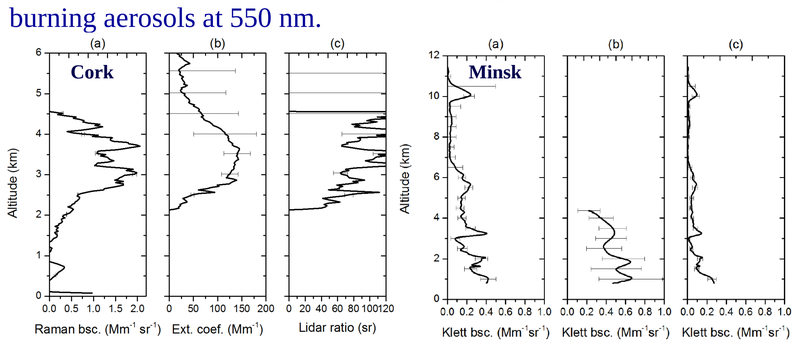


Figure 4: Cork station measurement (23:30 – 23:50 UTC) on 4th July 2013: (a) Raman backscatter. (b): Extinction coefficient. (c) Lidar ratio. Minsk measurement on 8th July 2013 (07:47 – 08:17 UTC). (a): 532 nm emission wavelength. (b): 355 nm emission wavelength. (c): 1064 nm emission wavelength. Station altitude: 200 m.

7-9th July 2013

Data measured at Cork between the 7th and 9th of July were compared with those measured at Cabauw. The MACC model showed a high pressure system blocking some of the aerosol over Ireland, but a higher concentration was forecasted for Cabauw. This was confirmed in the lidar measurements with larger backscatter coefficients at Cabauw. Only data measured at Cork on the 7th July could be compared quantitatively to data measured at Cabauw because a change in overlap occurred between the 8th and 9th of July at Cork. The lidar ratio values in both stations were mainly indicative of forest fire smoke mixed with marine aerosol.

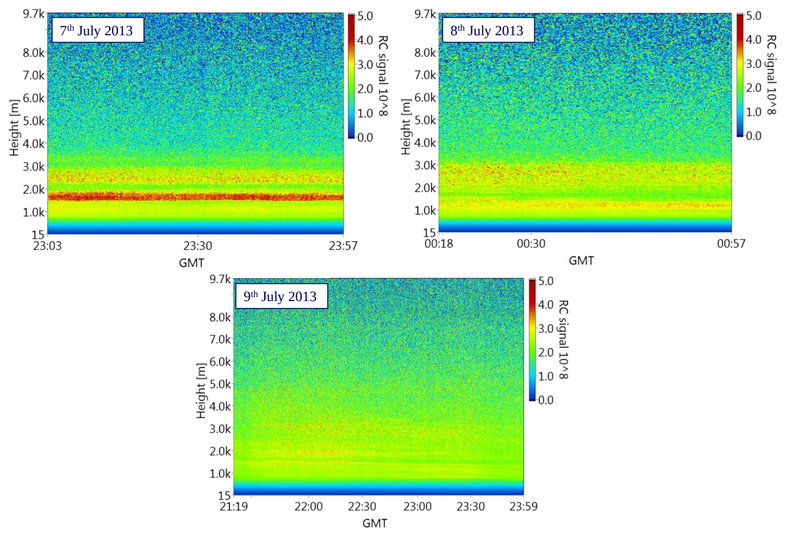


Figure 5: Colour-coded images (quicklook) of the time-dependent range corrected backscatter signal profiles at 532 nm for 7th, 8th and 9th July respectively. Blurring of aerosol layers between approximately 500 m and 4 km is apparent over 72 hours.

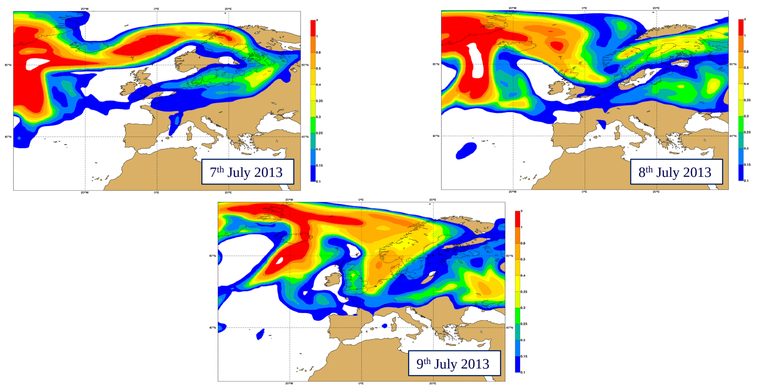


Figure 6: MACC forecasts 7th to 9th July 2013. The high pressure system around Ireland at this time may have prevented the aerosol from fully penetrating Irish air space.

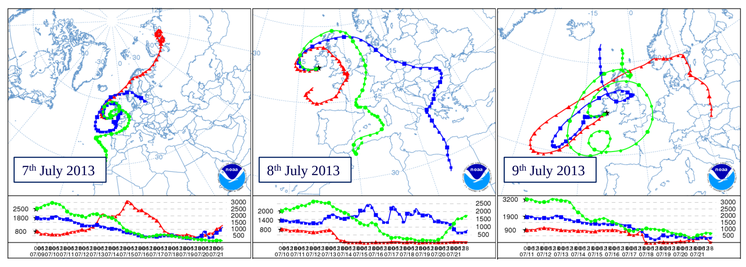


Figure 7: HYSPLIT air-mass forward-trajectory (11 days) from Cork for 7th to 9th July 2013. Layers measured at Cork do not exactly correspond to the measurement days in Cabauw.

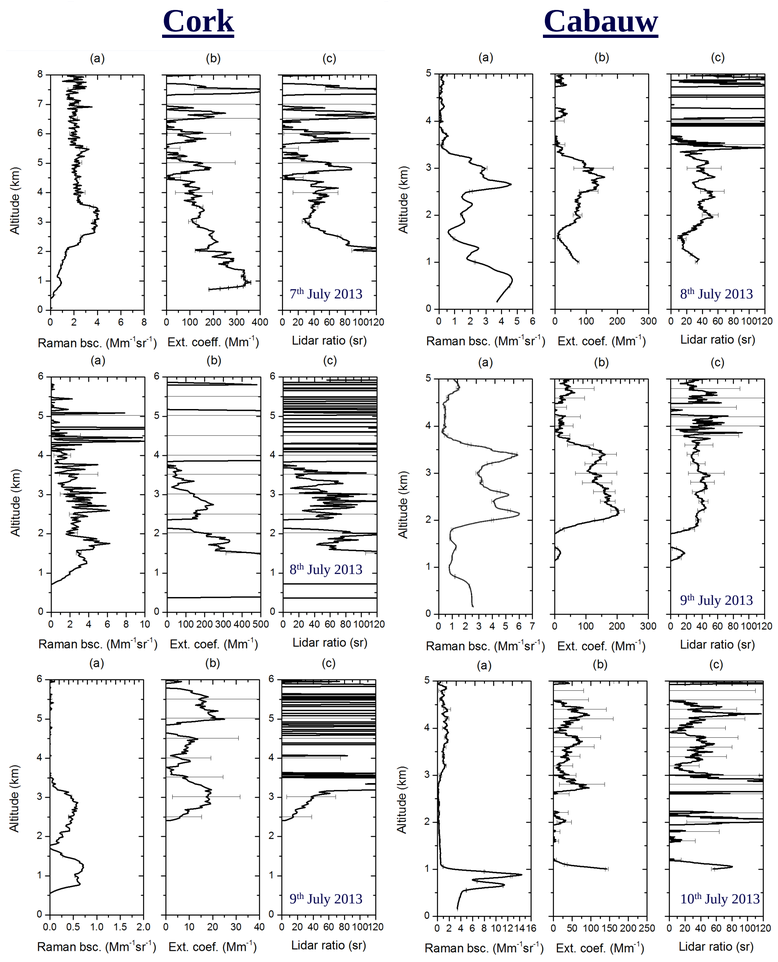


Figure 8: Measurements from Cork station (Left) and Cabauw station (Right) between 7th and 9th July 2013. (a) Raman backscatter. (b): Extinction coefficient. (c) Lidar ratio. Error bars correspond to the standard deviation of the photon noise in the measurement. Cabauw extinction wavelength: 355 nm. Station altitude: 1m.

11th July 2013

Measurements in Cork on the 11th July were compared with those from Bucharest, Granada, Sofia and Garmisch station. Extinction values were available for Bucharest and Granada and only elastic backscatter measurements were available for Sofia and Garmisch. Sofia detected the largest backscatter coefficients, followed by Granada, then Garmisch, Bucharest, and Cork. Lidar ratio values at Granada were indicative of forest fire smoke mixed with urban haze and some marine aerosol. Bucharest had lidar ratio values that were likely to be forest fire smoke mixed with urban haze.

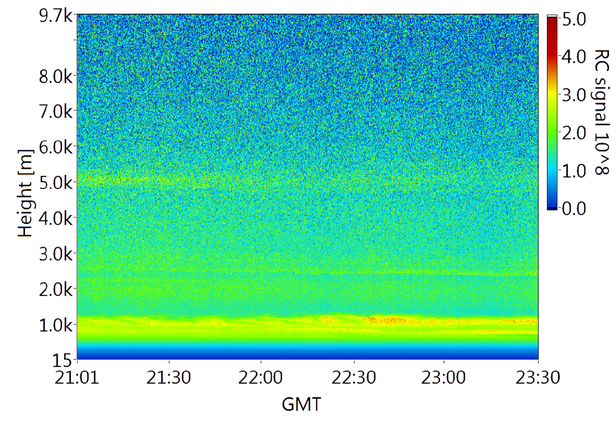


Figure 9: Colour-coded image (quicklook) of the time-dependent range corrected backscatter signal profiles at 532 nm for 11th July 2013. Aerosol layers can be seen at 2 km, 2.8 km and 5 km.

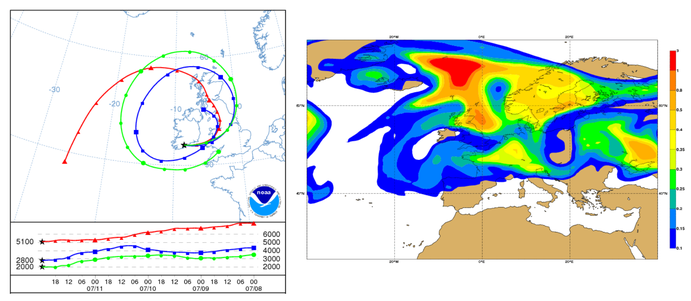


Figure 10: Left: HYSPLIT model backward trajectory (3 days) from 00:00 11th July 2013 to 00:00 8th July 2013. The aerosol layers are circulating over the UK and the Atlantic Ocean. Right: MACC model forecast for 11th July 2013 indicating the optical depth of biomass burning aerosols at 550 nm progressing from North America towards Europe.

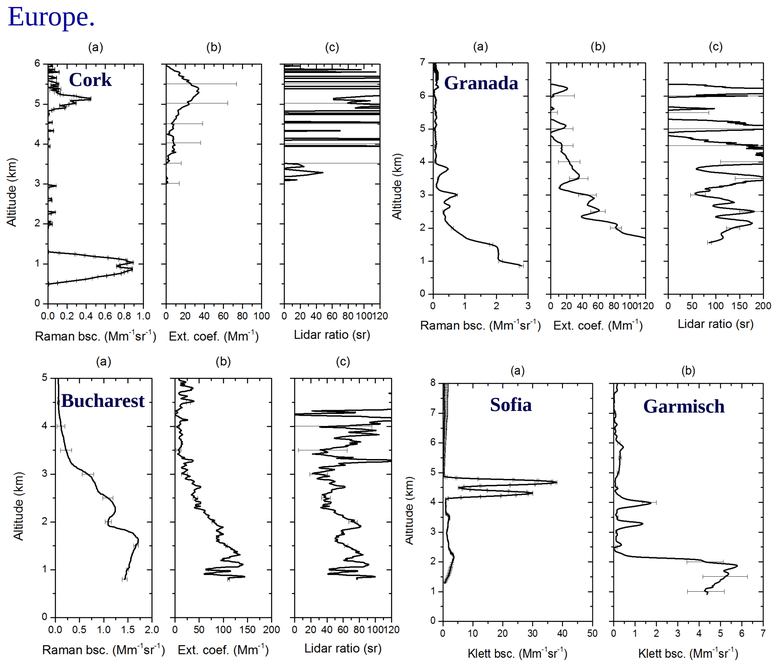


Figure 11: Measurements over Europe during forest fire event on 11th July 2013. (a) Raman backscatter. (b): Extinction coefficient. (c) Lidar ratio. Error bars correspond to the standard deviation of the photon noise in the measurement. Only selected error bars are shown. **Cork**: (21:40 – 22:10 UTC). Smoothing window lengths: 240 m up to 840 m, 390 m up to 2190 m, 1050 m upwards. **Granada**: Measurement from Granada station on 12th July (02:00 – 02:30 UTC). Laser wavelength: 532nm. Station altitude: 680 m. **Bucharest**: (18:58 – 19:28 UTC). Emission wavelength: 532 nm. Station altitude: 93 m. **Sofia (a)**: Emission wavelength: 510 nm (17:16 – 17:46 UTC, station altitude 550 m), **Garmisch (b)**: Emission wavelength: 313 nm (12th July 07:30 – 08:00 UTC.) station altitude 730 m.

Acknowledgements

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