

Laser remote sensing of tropospheric aerosol over Southern Ireland using a backscatter Raman LIDAR

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Abstract

Raman backscatter coefficients, extinction coefficients and lidar ratios were measured with a ground based Raman Lidar system at University College Cork, Ireland [1], during the periods of July 2012 – August 2012, April 2013 – December 2013 and March 2014 – May 2014. Statistical analysis of these parameters in this time provided information about seasonal effects of Raman backscatter coefficients and the altitude of the top of the planetary boundary layer.

The mean of the altitude of the top of the planetary boundary layer over these time periods is 950 ± 302 m. The values are larger in summer, 1206 ± 367 m, than in winter, 735 m. The altitude of the top of the planetary boundary layer measured at Cork is lower than most EARLINET stations. Raman backscatter coefficients above and altitude of 2 km are highest in summer and spring where the values are greater than $0.28 \text{ Mm}^{-1} \text{ sr}^{-1}$. Winter values of Raman backscatter coefficient are less than $0.06 \text{ Mm}^{-1} \text{ sr}^{-1}$. These seasonal effects are consistent with most EARLINET stations [1,2].

Large aerosol loads were detected in July 2013 due to a Canadian forest fire event. HYSPLIT air-mass back trajectory models were used to trace the origin of the detected aerosol layers. The aerosol forecast model, MACC, was used to further investigate and verify the propagation of the smoke. The Lidar ratio values and Klett and Raman backscatter coefficients at Cork, for the 4th July, the 7th to 9th of July and the 11th July were compared with observations at Cabauw, Minsk, Granada, Bucharest, Sofia and Garmisch. Lidar ratio values for the smoke detected at Cork were determined to be between 33 sr and 62 sr.

Seasonal Effects

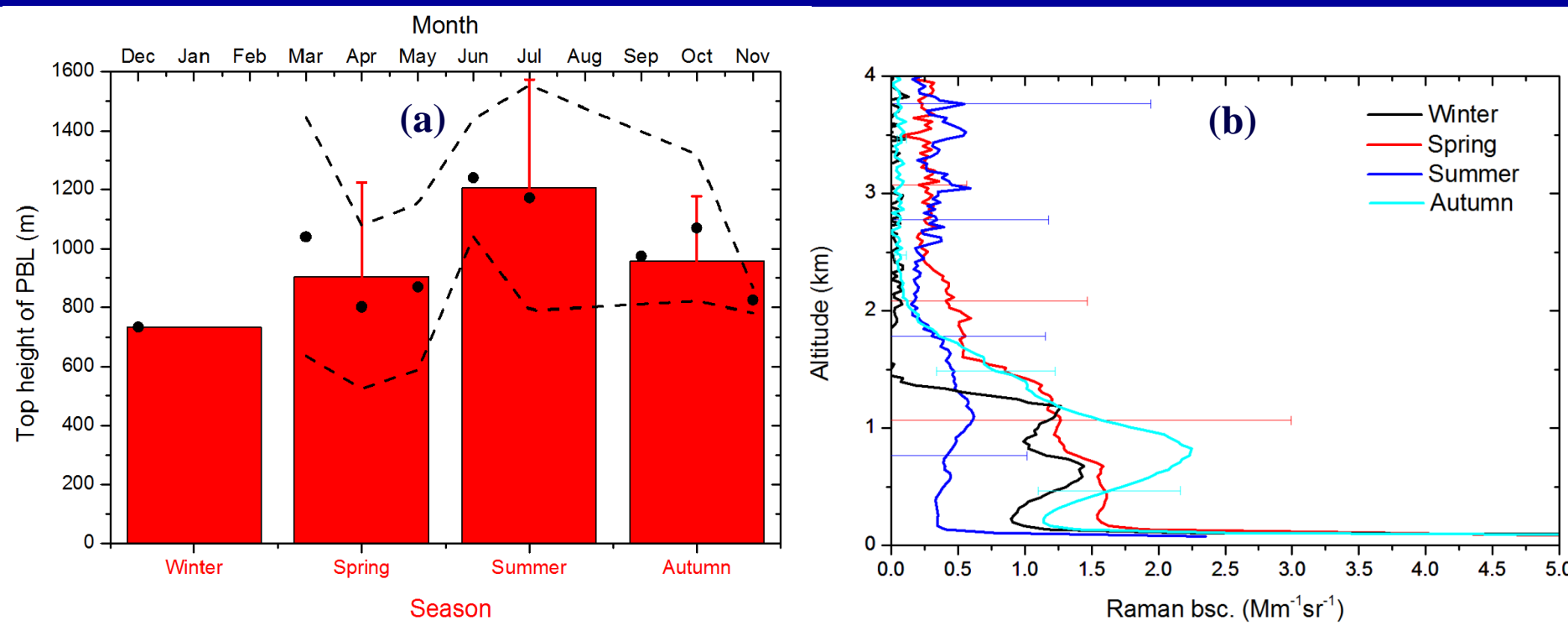


Figure 1: (a): Average altitude of top of PBL over Cork city between 1st July 2012 and 30th June 2014 separated for the four different seasons. Red bars: Mean seasonal altitude of top of PBL. Red error bars: Standard deviation of mean seasonal altitude of top of PBL. Black circles: Mean monthly altitude of top of PBL. Dashed black line: Standard deviation of monthly average for altitude of top of PBL. (b): Mean seasonal Raman backscatter coefficients measured with UCLID. Black line: Winter, Red line: Spring, Blue line: Summer, Cyan: Autumn. Error bars indicate the standard deviation of the seasonal backscatter coefficients.

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.

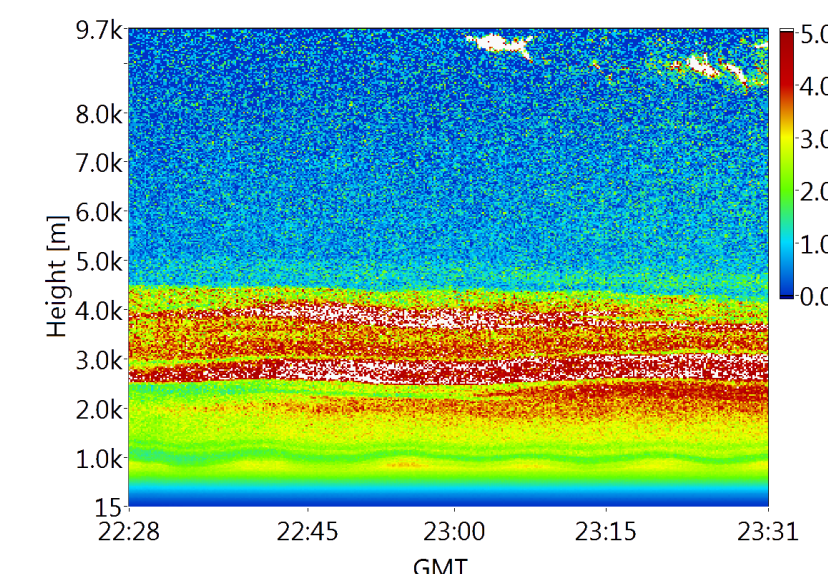


Figure 2: Colour-coded images (quicklook) of the time-dependent range corrected backscatter signal profiles at 532 nm for the 4th July 2013. Several overlapping aerosol layers are observed up to 5 km.

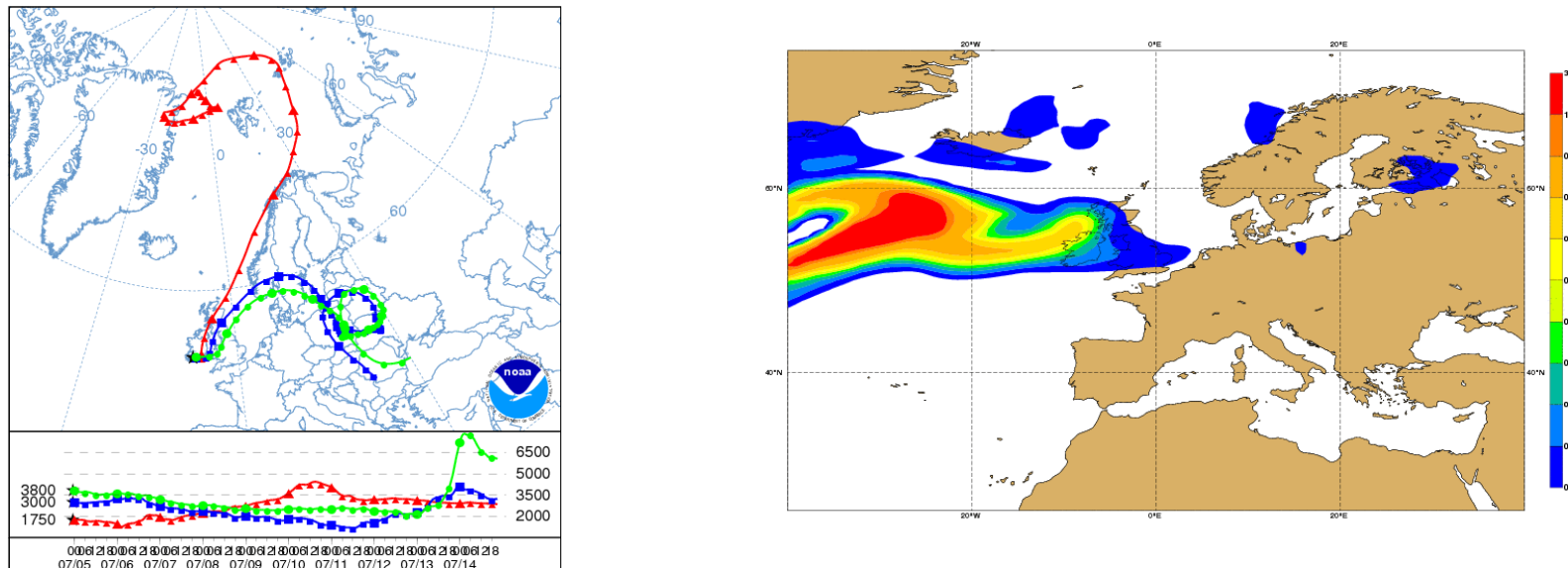


Figure 3: Left: HYSPLIT air-mass forward trajectory (9 days) from Cork station (00:00 UTC 4th July to 00:00 UTC 14th July). Right: MACC model forecast indicating the optical depth of biomass burning aerosols at 550 nm.

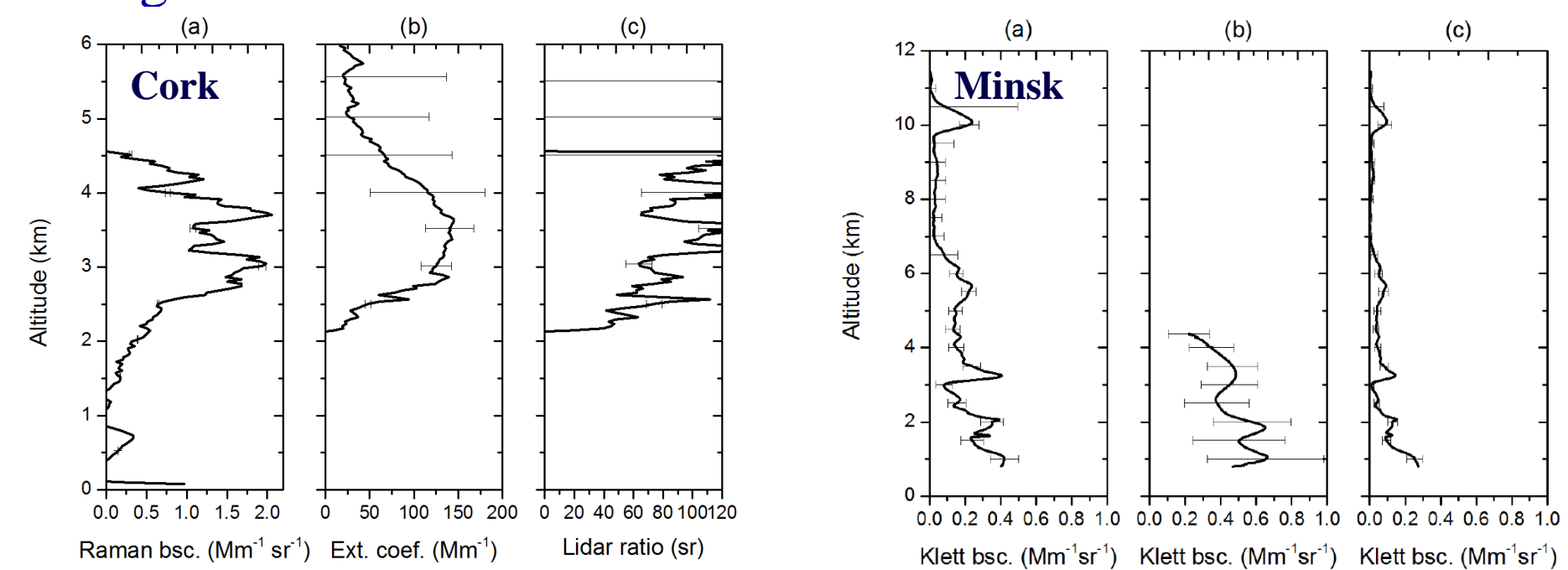


Figure 4: Cork station measurement (23:30 – 23:50 UTC) on 4th July 2013: (a) Raman backscatter. (b): Extinction coefficient. (c) Lidar ratio. Minsk measurement on 8th July 2013 (07:47 – 08:17 UTC). (a): 532 nm emission wavelength. (b): 355 nm emission wavelength. (c): 1064 nm emission wavelength. Station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

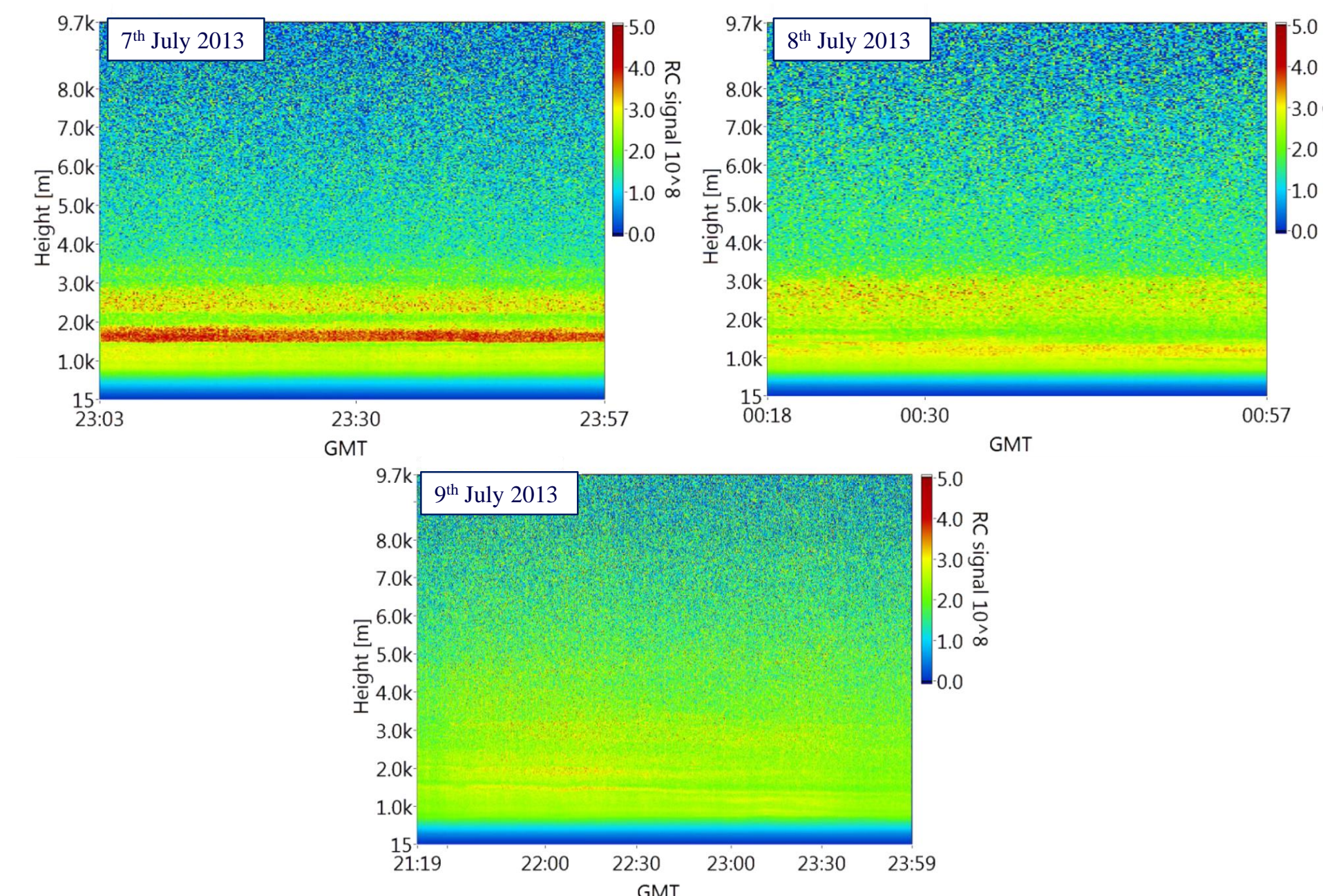


Figure 5: Colour-coded images (quicklook) of the time-dependent range corrected backscatter signal profiles at 532 nm for 7th, 8th and 9th July respectively. Blurring of aerosol layers between approximately 500 m and 4 km is apparent over 72 hours.

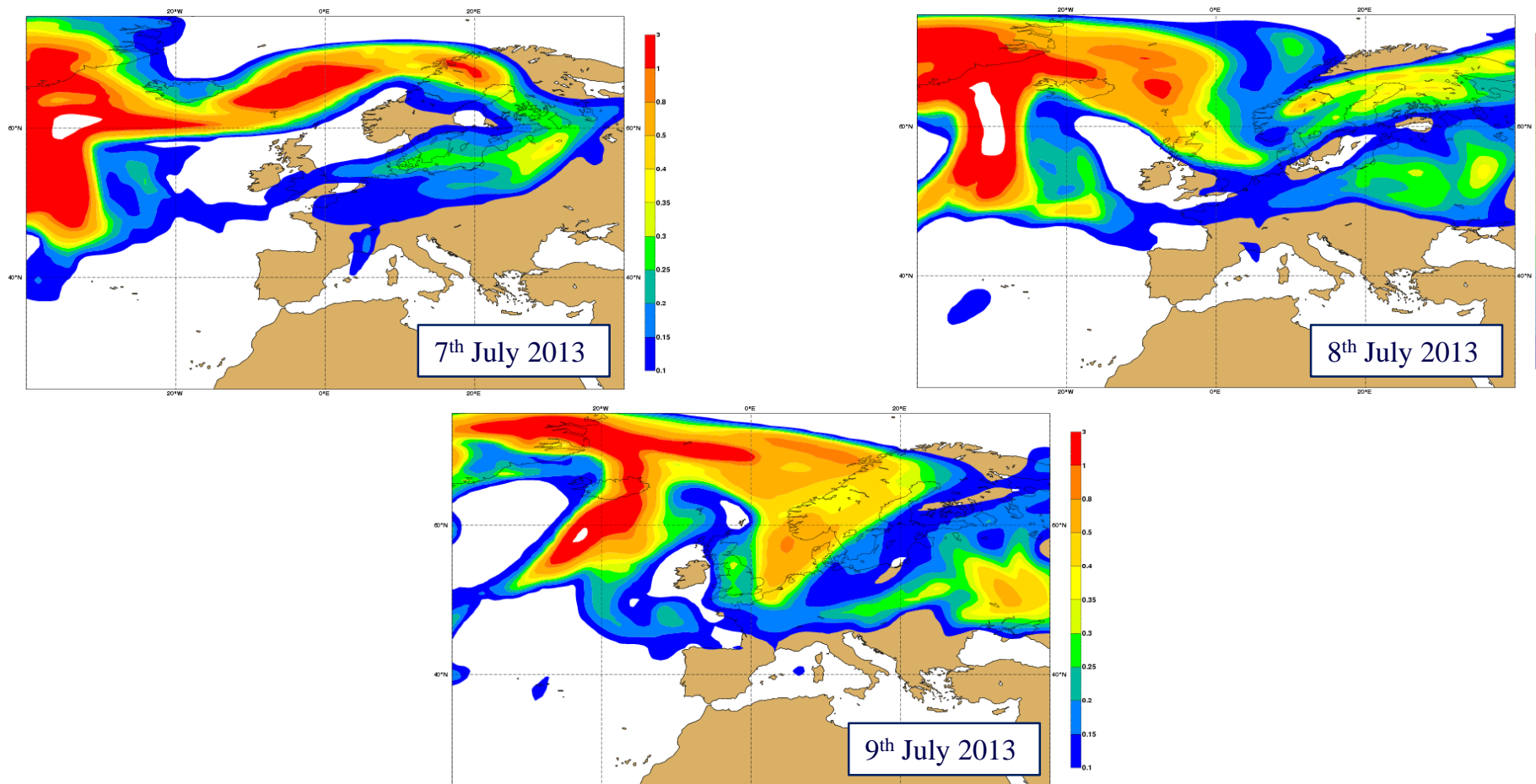


Figure 6: MACC forecasts 7th to 9th July 2013. The high pressure system around Ireland at this time may have prevented the aerosol from fully penetrating Irish air space.

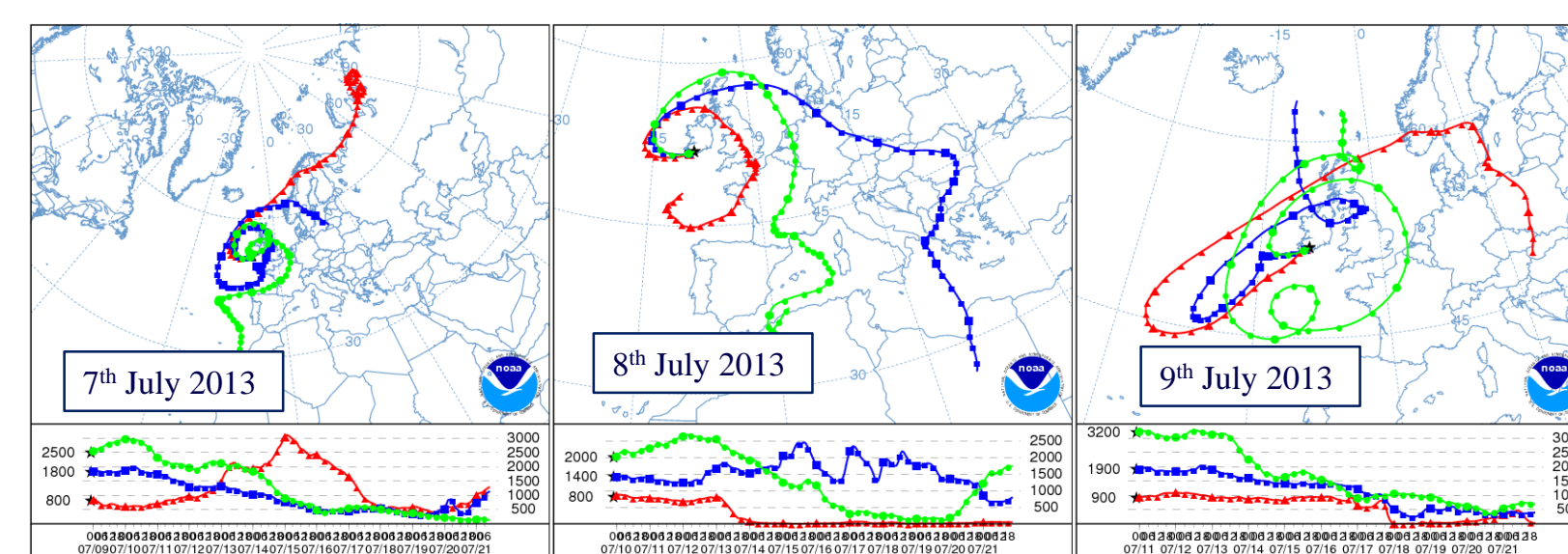


Figure 7: HYSPLIT air-mass forward-trajectory (11 days) from Cork for 7th to 9th July 2013. Layers measured at Cork do not exactly correspond to the measurement days in Cabauw.

Cork

Cabauw

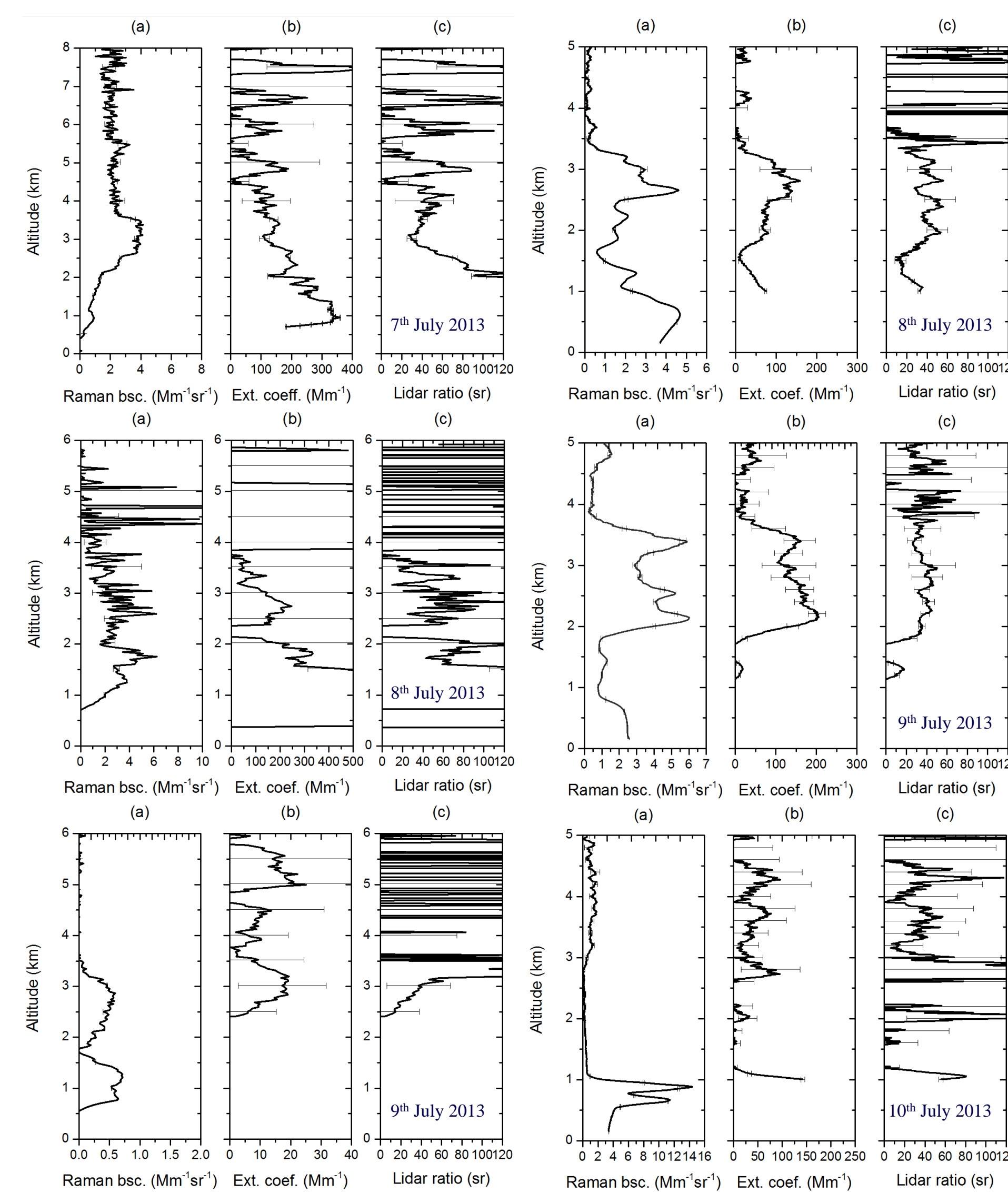


Figure 8: Measurements from Cork station (Left) and Cabauw station (Right) between 7th and 9th July 2013. (a) Raman backscatter. (b): Extinction coefficient. (c) Lidar ratio. Error bars correspond to the standard deviation of the photon noise in the measurement. Cabauw extinction wavelength: 355 nm.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

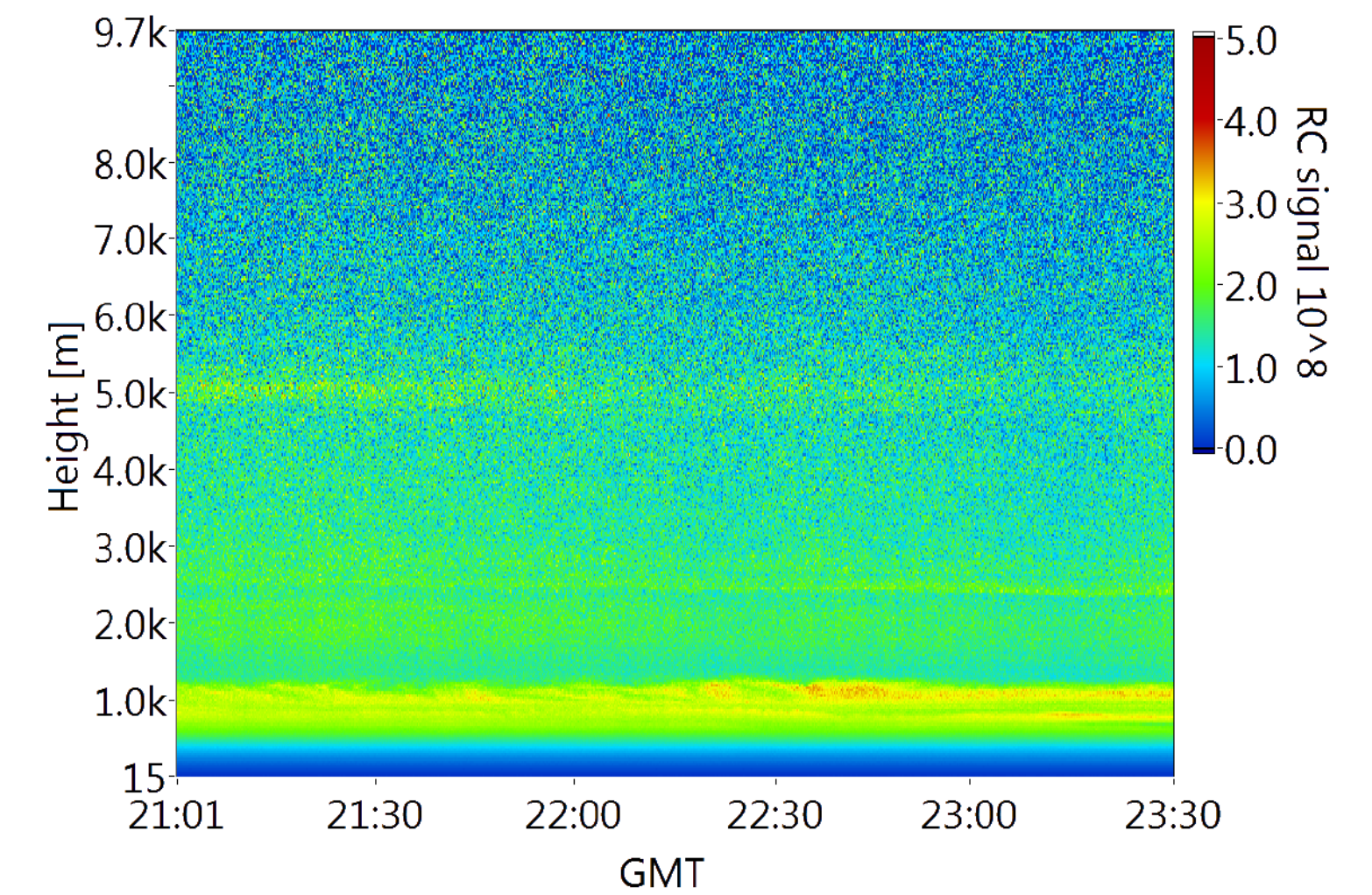


Figure 9: Colour-coded image (quicklook) of the time-dependent range corrected backscatter signal profiles at 532 nm for 11th July 2013. Aerosol layers can be seen at 2 km, 2.8 km and 5 km.

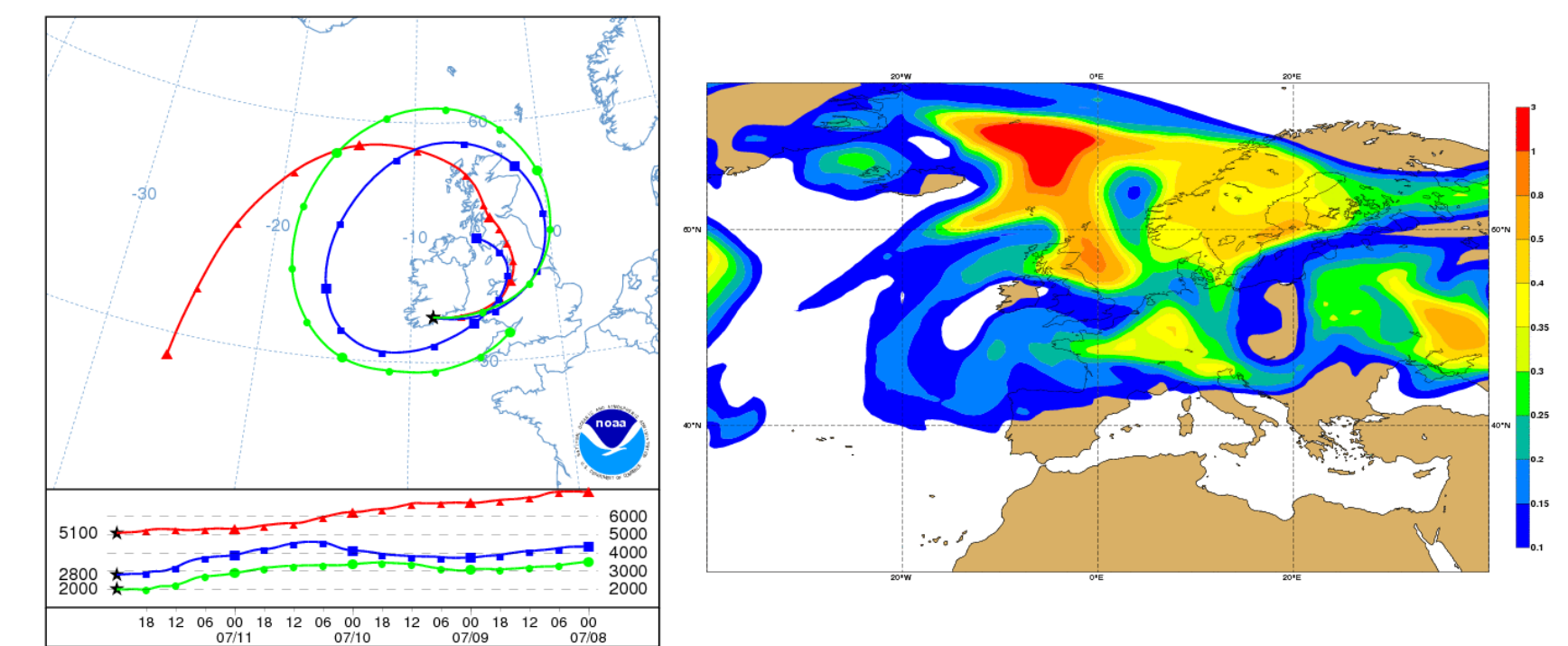


Figure 10: Left: HYSPLIT model backward trajectory (3 days) from 00:00 11th July 2013 to 00:00 8th July 2013. The aerosol layers are circulating over the UK and the Atlantic Ocean. Right: MACC model forecast for 11th July 2013 indicating the optical depth of biomass burning aerosols at 550 nm progressing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

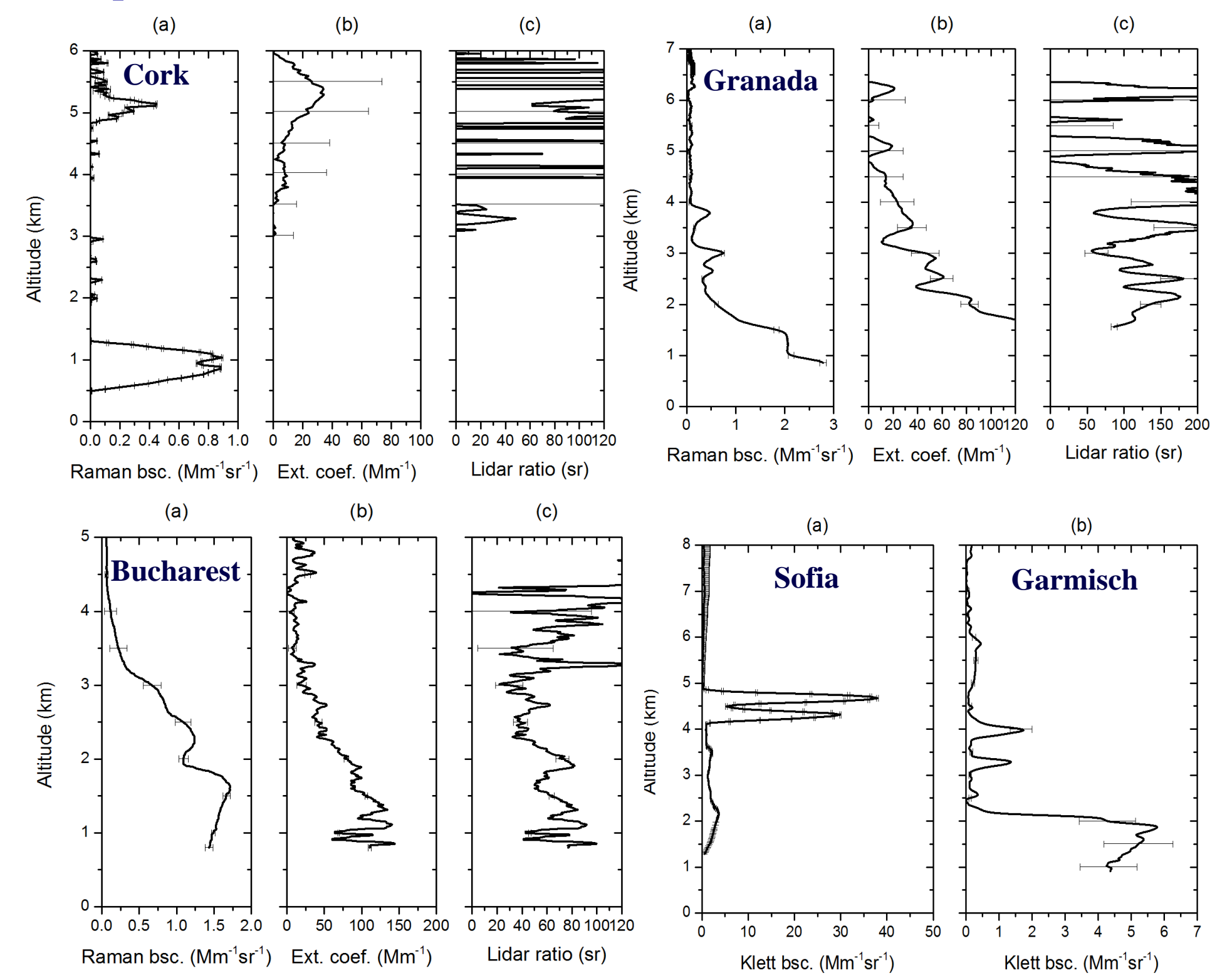


Figure 11: Measurements over Europe during forest fire event on 11th July 2013. (a) Raman backscatter. (b): Extinction coefficient. (c) Lidar ratio. Error bars correspond to the standard deviation of the photon noise in the measurement. Only selected error bars are shown. **Cork:** (21:40 – 22:10 UTC). 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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References

- [1] M.A.P. McAuliffe, A.A. Ruth, Typical tropospheric aerosol backscatter profiles for Southern Ireland: The Cork Raman lidar. Atmos. Res. 120/121 (2013) 334-342.
- [2] V. Matthias et al., Vertical aerosol distribution over Europe: Statistical analysis of Raman lidar data from 10 European Aerosol Research Lidar Network (EARLINET) stations. J. Geophys. Res. 109 (2004) D18201.