



# Raman Lidar Observations of a MCS in the frame of the Convective and Orographically-induced Precipitation Study

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## INTRODUCTION

The Raman lidar system *BASIL* was deployed in Achern (Supersite R, Lat: 48.64 °N, Long: 8.06 °E, Elev.: 140 m) in the frame of the *Convective and Orographically-induced Precipitation Study-COPS*. On 20 July 2007 a frontal zone passed over the COPS region, with a Mesoscale Convective System (MCS) imbedded in it. *BASIL* was operated continuously during this day, providing measurements of temperature, water vapour, particle backscattering coefficient at 355, 532 and 1064 nm, particle extinction coefficient at 355 and 532 nm and particle depolarization at 355 and 532 nm. The MCS reached the measurement site at 8:45 UTC; the thunderstorm approaching determined the lowering of the anvil clouds, which was captured by lidar. A cloud deck was present at 2 km, which represents a mid-level outflow from the thunderstorm/MCS. The mid-level outflow gave out hydrometeor-debris (mostly virga) and was recycled back into it. The MCS modified the environment at 1.6-2.5 km levels directly (outflow) and the lower levels through the virga/precipitation. Wave structures were observed in the particle backscatter data. The wave activity seems to be a reflection of the shear that is produced by the MCS and the inflow environmental wind. Measurements in terms of particle backscatter and water vapour mixing ratio will be discussed at the Workshop to illustrate the above phenomena.

## BASILICATA LIDAR (BASIL)

The Raman lidar system *BASIL*, shown in figure 1, deployed in Achern (Supersite R, Lat: 48.64 °N, Long: 8.06 °E, Elev.: 140 m) in the frame of the Convective and Orographically-induced Precipitation Study, was operated continuously during 20 July 2007, providing measurements of temperature, water vapour, particle backscattering coefficient at different wavelengths. The major feature of *BASIL* is represented by its capability to perform high-resolution and accurate measurements of atmospheric temperature and water vapour, both in daytime and night-time, based on the application of the rotational and vibrational Raman lidar techniques in the UV. Besides temperature and water vapour, *BASIL* is capable to provide measurements of particle backscatter at 355, 532 and 1064 nm, particle extinction coefficient at 355 and 532 nm and particle depolarization at 355 and 532 nm. Here in the present study, range corrected signals at 1064 nm and water vapor measurements are shown and discussed.



Figure. 1: BASIL - Interior of the sea-tainer with the laser in the background and the receiver system in the foreground.

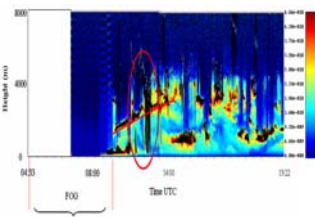


Figure. 1: Range corrected signals at 1064 nm during the day

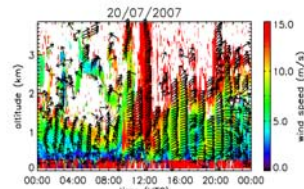


Figure.2: Wind speed and wind direction from the co-located wind profiler

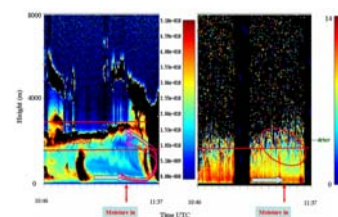


Figure. 3: . Range corrected signals at 1064 nm and water vapour mixing ratio in the timeframe 10:46-11:37 UTC, 20 July 2008 during the passage of the MCS.

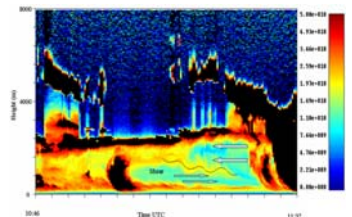


Figure. 4: Range corrected signals at 1064 nm. This colour scale allows to highlight a wave train, travelling horizontally associated with shear between, inflow or outflow regions.

Figure 1 shows the range corrected signals at 1064 nm during the day. There was presence of low clouds or fog in the valley till 09:30 UTC and development of convective clouds during the afternoon with different precipitation intervals throughout the day. The lidar visualized the interaction of the MCS with the prevailing pre-storm environment and also how it was modified. A signature of thunderstorm approaching is present in the 1064 nm range corrected lidar signals in figure 1, visible in the lowering of the anvil clouds up high. Low level wind below about 1km was towards the centre of the thunderstorm during the time period 10 to 12 UTC as seen in figure 2. The highest wind speed observed was around 15 m/s. Figure 3 shows the range corrected signals at 1064 nm and water vapor data during the MCS. An interesting fact is the cloud deck at 2km, which represents the mid-level outflow from the Thunderstorm/MCS. The wind flow at higher levels is opposite with respect to low level winds. The effect of this is to moisten that level and precipitate (mostly virga). So, we can see a conveyor belt of things here where the thunderstorm mid-level outflow spits out hydrometeor-debris and it is recycled back into it. In the water vapor mixing ratio we observe the moist layer below about 1 km and a drier layer about 2 km. This means that the MCS was modifying the environment at 1.6-2.5km levels directly (outflow) and the lower levels through the virga/precipitation. In addition, the MCS can only survive by pulling in moisture from a large area (~100km radius or more) around it (below about 1km), which is somewhat modified by the virga. Figure 4 shows the range corrected signals at 1064 nm during the passage of the frontal zone, with the imbedded MCS. A wave train travelling horizontally appears in the figure.

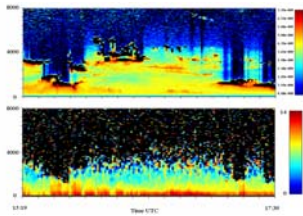


Figure. 5: Range corrected signals at 1064 nm and water vapor during the convective activity.

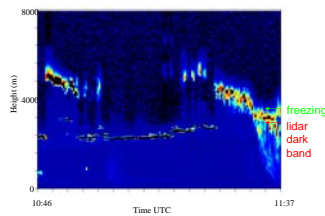


Figure. 7: Dark-band phenomenon

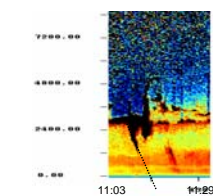


Figure.6: Rain speed calculated from lidar back-scattering data

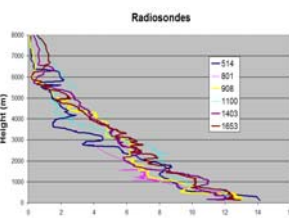


Figure. 8: Radiosondes launched during the day

The waves like structures seen in the data just prior to the arrival of the thunderstorm are due to shear between inflow or outflow regions. These waves affected the environment prior to the arrival of the MCS. Two primary processes stand out: the elevated outflow region above the BL (2-3.5km) and the presence of associated shear. Shear and mid-tropospheric moistening are important parameters to consider in convection: shear can inhibit convection but also aid if the waves break and create self sustaining turbulence at the right level. Moistening of the mid-levels allows for a rising moist air parcel to travel higher in altitude with out being depleted by drier air aloft. Figure 5 shows the range corrected signals at 1064 nm and water vapor during the afternoon when the convective activity was higher. The water vapor is averaged for one min interval. This figure highlights the variability of the humidity field beneath the cloud deck. Figure 6 shows the rain speed calculated during the precipitation episode (virga). Figure 7 illustrates the time evolution of the particle backscatter ratio at 1064 nm over a period of approx. 40 minutes from 10:48 UTC to 11:27 UTC; this figure is in a different colour scale than figure 4 in order to highlight the precipitation episode. Around 11:20 UTC melting hydrometeors start precipitating from clouds, with the cloud base at approx. 3 km and the freezing level at about 3.4 km (indicated by green arrow). A dark band appears in the figure: this is the horizontal line of lower particle backscatter values observed for a period of 5-10 minutes indicated by red arrow. Finally, figure 8 represents all the radiosondes launched on 20 July. The 09:08 UTC radiosonde clearly represents a moist layer below about 1 km and a drier layer in the region 1-2 km: this was the time when the MCS entered the COPS area. Results shown here demonstrate the excellent capability of Raman lidars in visualizing the detailed vertical and temporal structure of the atmosphere. Fine-scale structures of the boundary layer and between air masses at different altitudes were detected allowing, to explain the dynamic processes involved.

**ACKNOWLEDGEMENT** The participation of BASIL to COPS was supported by the COPS *International Science Steering Committee* and the *EUFAR* Program through the H2Olidar project. We would like to thank Emily Norton from University of Manchester for the clear air wind profiler quick-look data in figure 2.