EVOLUTION OF THE PLANETARY BOUNDARY LAYER IN THE PRESENCE OF FOG AND PLUME

Longlong Wang[1,*], Samo Stanič[1], Asta Gregorič[1], Klemen Bergant[1,2], Maruška Mole[1] and Marko Vučković[1]

[1]University of Nova Gorica, Nova Gorica, Slovenia
[2]Slovenian Environment Agency, Ljubljana, Slovenia

1 Introduction

Planetary boundary layer (PBL) is the lowest part of atmosphere, directly influenced by the Earth's surface. It is characterized by turbulent transport of moisture, aerosols and energy exchange with the surface. PBL height is one of the key parameters governing aerosol concentrantions, since vertical mixing within the PBL controls dilution of both aerosols and gaseous pollutants (Quan et al., 2013). Investigation of the evolution of PBL can help us understand temporal fluctuations of aerosol concentrations. Vertical strucutre of the PBL and its temporal evolution can be monitored using a lidar, a remote sensing tool with high space-time resolution.

PBL and backscatter coefficient of aerosols were investigated in November 2015 in the central part of Vipava valley (Ajdovščina, 45.93 °N, 13.91 °E) using lidar as the main detection tool. This period was characterized by temperature inversion and high atmospheric stability. There were several episodes of fog, combined with periods of high aerosol loading due to sources of biomass burning within the valley. The evolution of the PBL was investigated under different weather conditions and in the presence of plume.

2 Methods

a. Lidar setup

Figure 1: Photo of Mie scattering lidar system.

- Lidar was set up at the town of Ajdovščina in the Vipava valley. Measurements were performed 4–12 Nov. 2015.
- Lidar scans: elevation angle: 30°, each event is an average of 10 laser shots.

Table 1: Specifications of the Mie scattering lidar system.

Transmitter	Nd:YAG pulsed laser	Receiver	Newtonian telescope
Wavelength	1064 nm	Diameter	300 mm
Pulse energy	40 mJ	Focal length	1500 mm
Pulse duration	9 ns	Data recorder	Licel TR40-160
repetition rate	10 Hz	Data inversion	PC
Detectors	APD	Complete overlap	150 m

b. Water vapour measurements

Absolute average humidity within the valley was extracted from the differential measurement of the tropospheric wet delay of GPS signals between two receivers (Novatel), located at the valley rim (965 m a.s.l.) and floor (127 m a.s.l.) using GIPSY OASIS software package (NASA JPL). Horizontal distance between the receivers was 6 km.

c. Weather conditions

Weather conditions were determined based on the data from the meteorological station at Dolenje, 2 km from the lidar site.

Table 2: Daily values of meteorological parameters (temperature, relative humidity, wind speed) in the Vipava valley in November 2015.

Date	Weather	T [°C]		RH [%]		WS [m/s]	
		Min	Max	Min	Max	Min	Max
04/11	plume	2.7	18.3	37	91	0	0.6
05/11	fog	3.3	18.6	61	99	0	1.7
06/11	fog	3.7	22.0	42	97	0	1.9
09/11	plume	3.4	20.9	50	98	0	0.5
10/11	fog	5.9	17.1	68	99	0	0.4
12/11	clear	3.0	18.9	59	99	0	2.4

3 Results

a. Optical properties of the atmosphere

Aerosol loading information was obtained from back-scattered laser pulses. Far end part of the return signal was taken as background noise. After its subtraction, the range square corrected signal from lidar can be defined as

$$S(r) = C + ln\beta(r) - 2\int_0^r \alpha(r'), \tag{1}$$

where C is the constant of lidar system. By assuming a fixed extinction (α) to backscatter (β) of 50, the extinction coefficient at range $r < r_m$ can be written as (Klett, 1981)

$$\alpha(r) = \frac{exp[S(r) - S(r_m)]}{\alpha^{-1} + 2 \cdot \int_r^{r_m} expS(r') - S(r_m)dr'}. \tag{2}$$

Aerosol optical depth (AOD) at a given height can be decribed as

$$\tau(h) = \int_0^h \alpha(h')dh'. \tag{3}$$

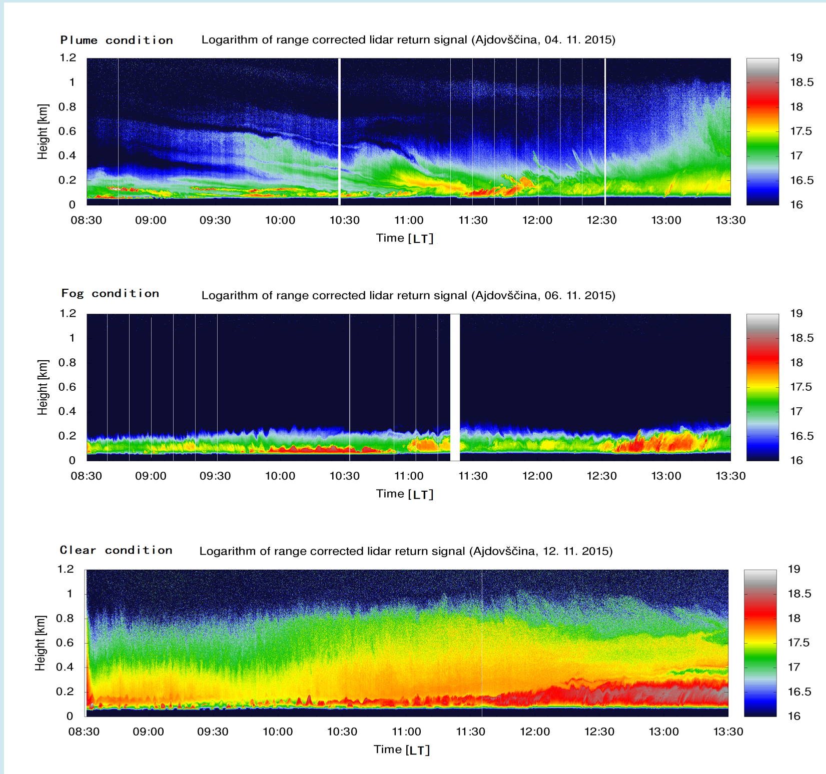

Figure 2: Evolution of PBL from range corrected lidar signal over Ajdovščina from morning to noon for different weather conditons.

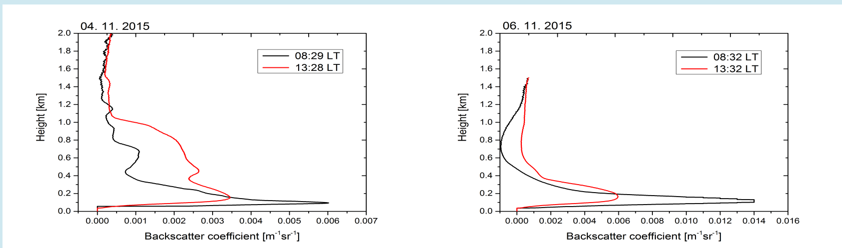

Figure 3: Vertical backscatter coefficient profiles, taken around 08:30 and 13:30 on November 4 (defined as plume weather, left) and November 6, 2015 (defined as fog weather, right).

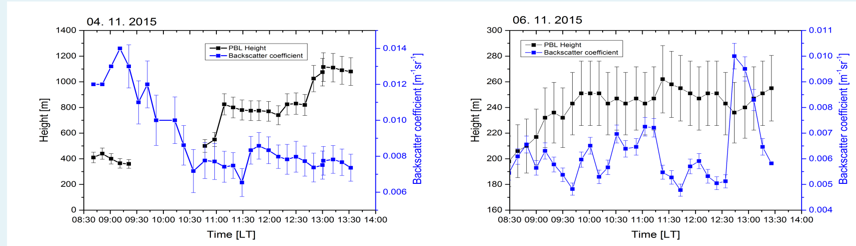

Figure 4: Comparison between backscatter coefficient at the height of 200 m above the ground and the PBL height on November 4 (defined as plume weather, left) and November 6, 2015 (defined as fog weather, right).

b. Correlation between AOD and absolute humidity

High water vapour content in the PBL can cause hygroscopic growth of wettable particles or the formation of droplets due to hygroscopic particles, which act as cloud condensation nuclei (CCN). The correlation between AOD (obtained from lidar measurements) and absolute humidity (obtained from GPS signal delays) was therefore investigated for different weather conditions.

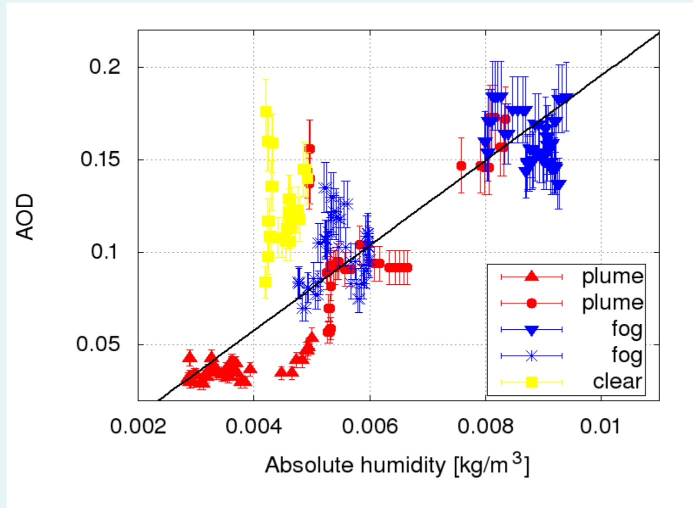

Figure 5: The correlation between the AOD below 1000 m and the absolute humidity within the valley. Colours represent different weather conditions. For the five days of observations presented in this study, the correlation coefficient between AOD and absolute humidity was found to be 0.78 (black line).

4 Conclusions

The relationship between the PBL height and backscatter coefficient, obtained from lidar measurements, shows the dependence of the PBL evolution on weather conditions. In the presence of fog, PBL height remained constant during the day at around 200 to 300 m above ground, whereas in the case of plume it was increasing during the morning and reached its maximum soon after noon. Backscatter coefficient decreased from morning to noon in both cases, presumably governed by the rising PBL height in the case of plume and the level of absolute humidity in the case of fog. Good correlation between AOD and absolute humidity indicates possible influence of water vapour on aerosol aging processes within the PBL.

References

1. Quan, Jiannong, et al. "Evolution of planetary boundary layer under different weather conditions, and its impact on aerosol concentrations." Particuology 11.1 (2013): 34-40.
2. Klett, James D. "Stable analytical inversion solution for processing lidar returns." Applied Optics 20.2 (1981): 211-220.

* Corresponding author: longlong.wang@ung.si

Acknowledgements: The research was funded by the Slovenian Research Agency through the P1-0385 Remote sensing of atmospheric properties research program and through the Young researchers training program