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VERTICAL VARIABILITY OF AEROSOL ABSORBING PROPERTIES IN THE CARPATHIAN MOUNTAINS

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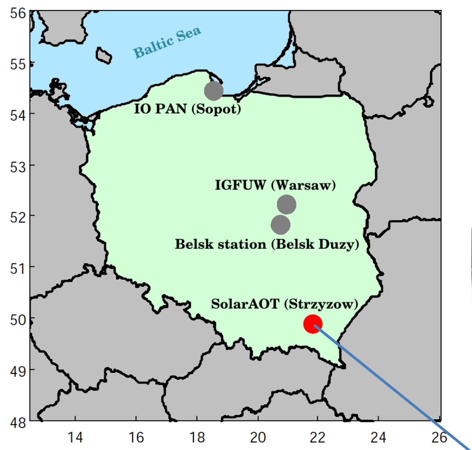
OBJECTIVES

The main goal of this study is to understand the impact of absorbing aerosols on the climate system through: (1) acquiring new knowledge of the vertical variation of aerosol absorbing properties, (2) determining the effect of the vertical variability of the single scattering albedo and absorption coefficient on radiative forcing, (3) determining the impact of vertical distribution of black carbon on radiative heating in the lower troposphere, and (4) comprising of in-situ and lidar measurements of aerosol optical properties.

METHODOLOGY

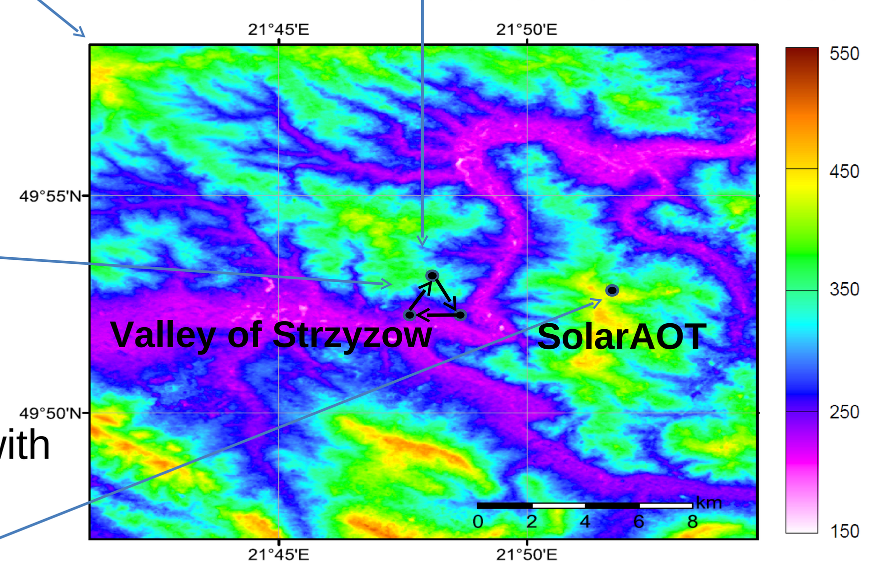


Micro-aethalometer AE-51 (880 nm)

profiles up to 1-1.5 km

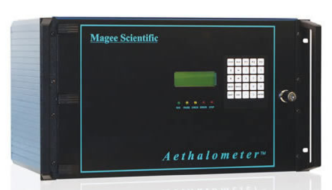
5 kg an unmanned aerial vehicle (UAV) equipped with micro-aethalometer AE-51 and Vaisala radiosonde RS92SGP

1064 nm ceilometer with 250 m overlap range.



MODTRAN code ver. 5.2.1 is used to computed radiative forcing and radiative heating.

Polar Nephelometer Aurora 4000. Light scattering measurements at 450, 525 and 635 nm for 4 scattering sectors: 0-40, 40-70, 70-90, and 90-180°. Retrieved quantities: scattering and backscattering coefficients and asymmetry parameter.



Aethelometer AE-31 to measure filter attenuation and retrieve black carbon concentration and absorption coefficient at 370, 470, 520, 590, 660, 880, 950 nm.

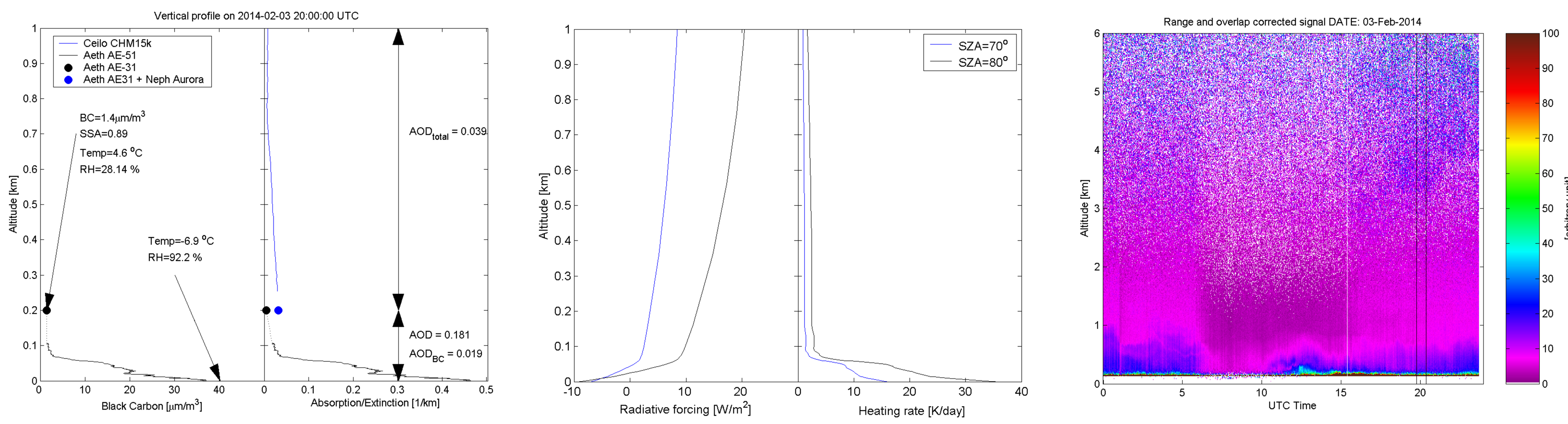
Polar CIMEL 8N-EDPS9 (AERONET station) to measure solar radiance at 340, 380, 440, 500, 675, 870, 936, 1020, 1640 nm and for retrieved aerosol optical depth, column averaged single scattering properties.

The data obtained from micro-aethalometer onboard the UAV includes negative absorption coefficients when sampling is performed at a high time-resolution (1 sec). In this case the instruments noise can cause the attenuation coefficient (ATN) values to remain unchanged or even to decline slightly between time steps. To reduce the signal to noise ratio (SNR) we averaging of the ATN by the run mean filter with time frame of 20 sec. After reduction of ATN noise the aerosol absorbing coefficient and BC concentration are computed from

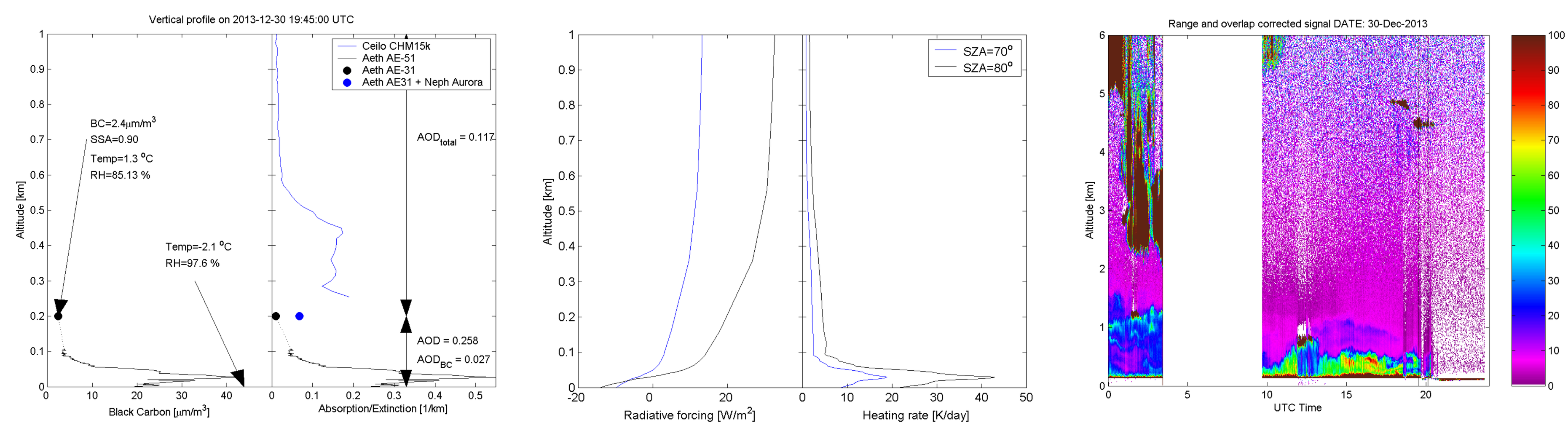
$$\sigma_{ABS} = \frac{dATN}{dt}\,\frac{A}{Q \cdot C \cdot R(ATN)} \qquad BC = \frac{\sigma_{ABS}\, C \cdot R(ATN)}{\sigma_{ATN}}$$

where, A is a sample spot area (7.1·10^{-6} m^2), Q is the volumetric flow rate (2.0·10^{-3} m^3/s), C is the multiple scattering optical enhancement factor (2.05±0.03, Ferrero et al., 2011), R(ATN) is aerosol loading factor, and σ_{ATN} is the apparent mass attenuation cross section (12.5 m^2/g at 880 nm). The R(ATN) term compensates for the nonlinear (loading effect) due to increase of aerosol absorption over time, which in turn results in a reduction in the optical path. Schmid et al. 2006 found that it is needed only when ATN becomes higher than 20. Therefore we changed the filter when the ATN exceed this threshold value. Although this method still may produce negative values the improving of SNR is significant.

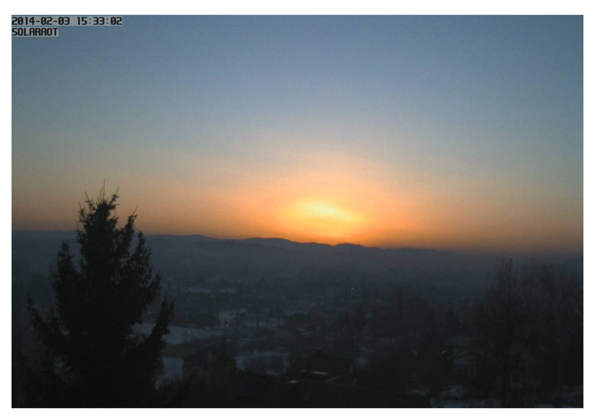
CASE STUDY



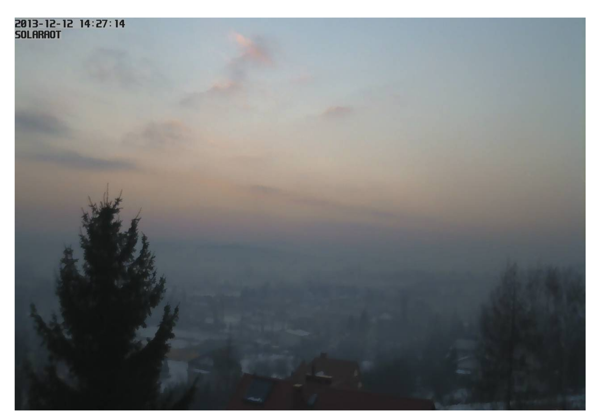
Haze on 3 Feb 2014 during strong inversion condition. The mean temperature gradient in the first 200 m was 6.4°/100m. The relative humidity in the Strzyzow Valley was about 92% while 200 meters above only 28%. The black carbon concentration reached 40 µg/m^3 (20 times larger than long-term mean value) in the Valley causing a high radiative heating (35 K/day for solar zenith angle 70° and 15 K/day for solar zenith angle of 80°).



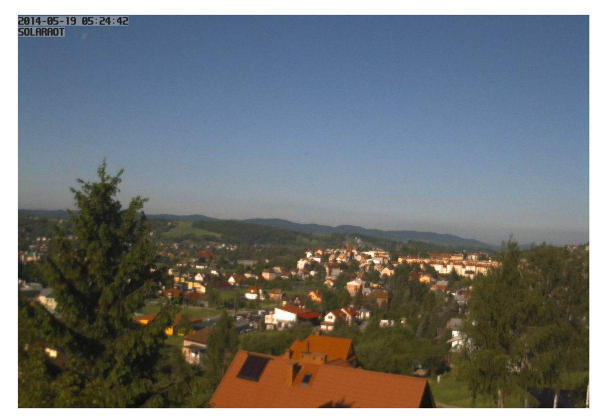
Haze condition on 30 Dec 2013 during moderate inversion (1.9°/100m). The black carbon concentration exceeds 40 µg/m^3 50 meters above the Valley causing a high radiative heating (40 K/day for solar zenith angle 70° and 20 K/day for solar zenith angle of 80°).



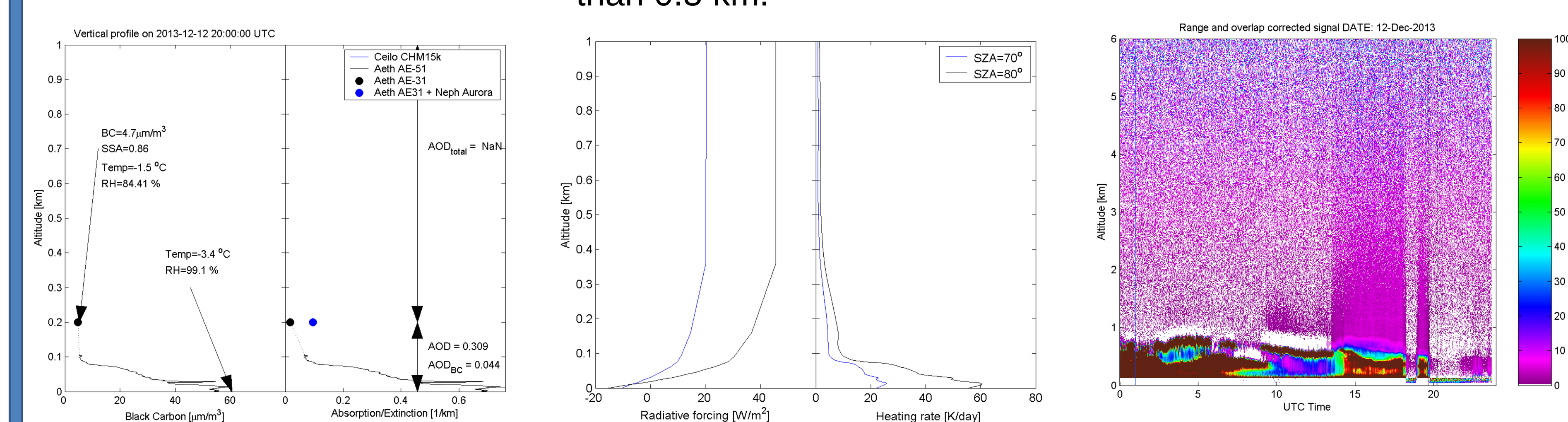
Moderate haze condition on 3 Feb 2014, visibility 10 km.



Extremely haze condition on 12 Dec 2013, visibility less than 0.5 km.

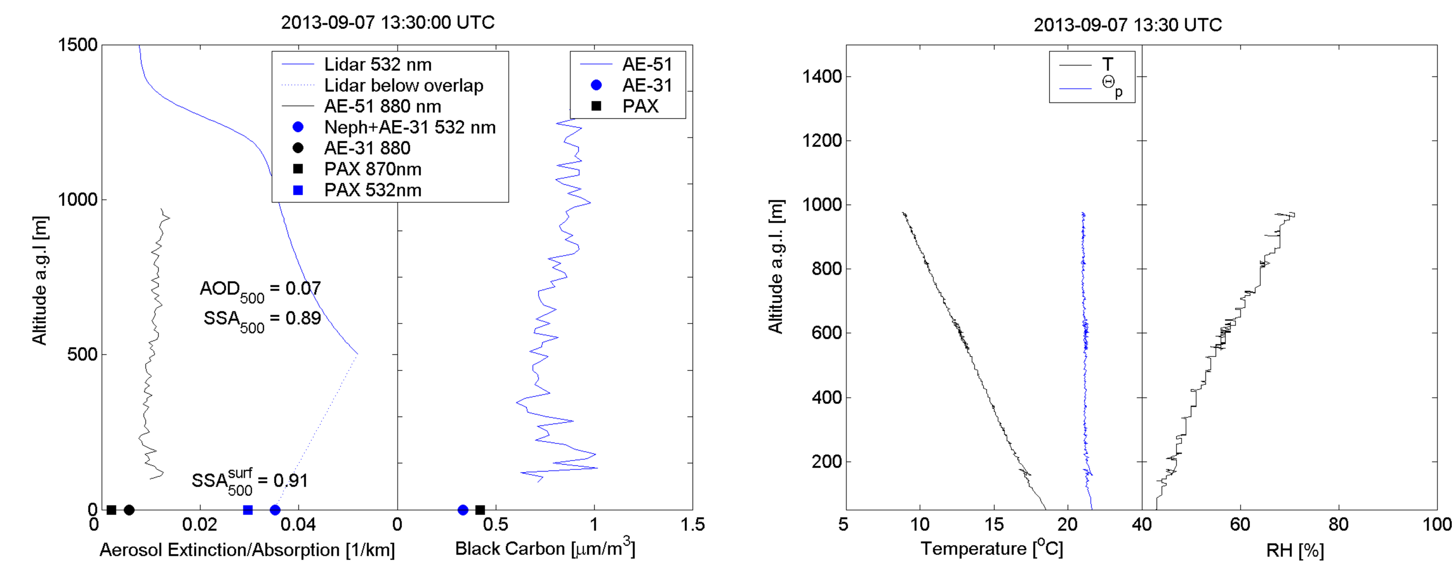


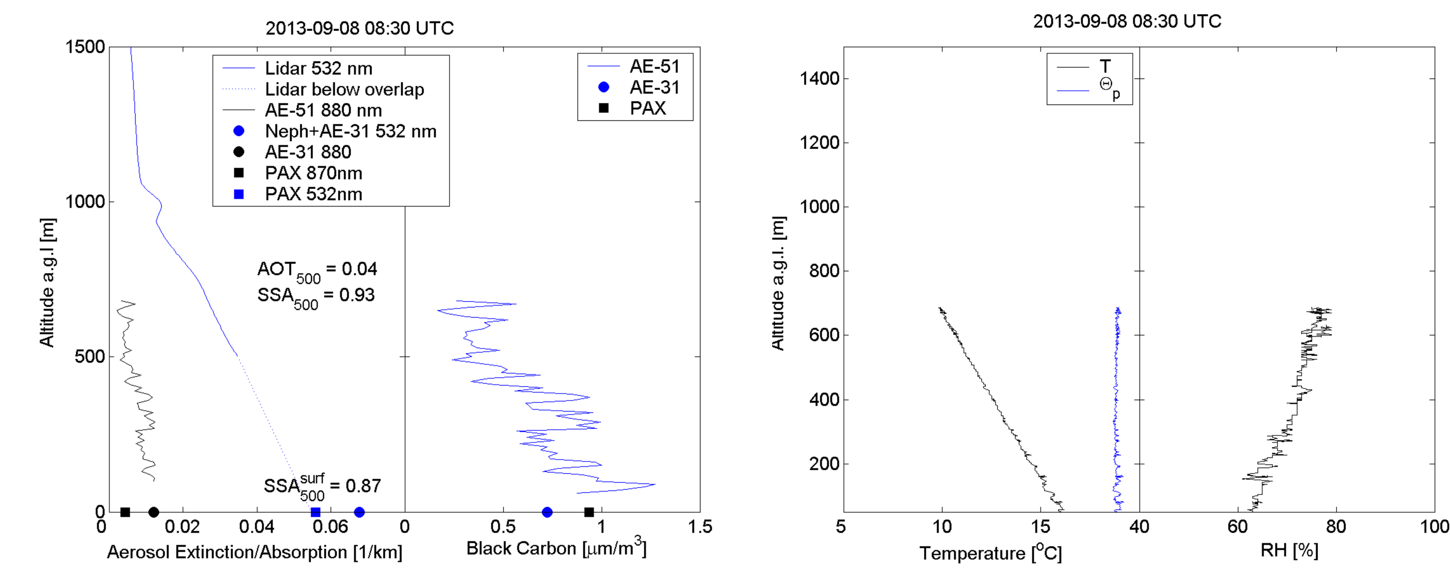
Clean condition on 19 May 2014, visibility 80 km.

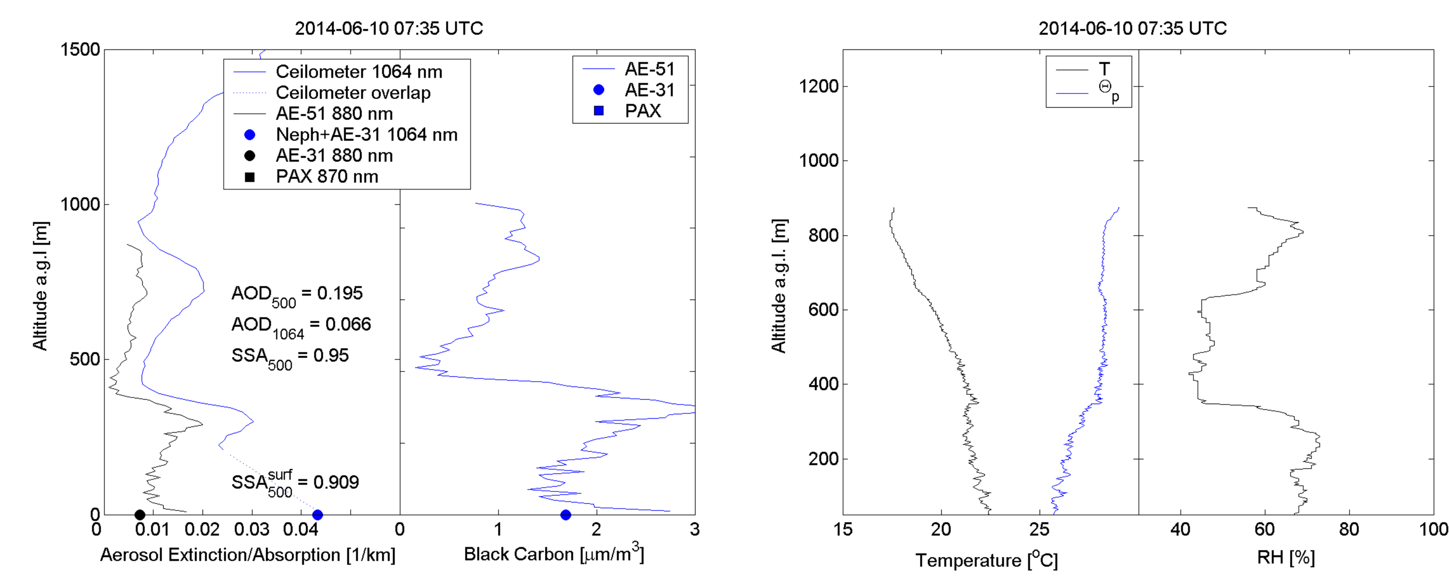


Extremely haze condition on 12 Dec 2013 during weak inversion (1.0°/100m). The black carbon concentration exceeds 60 µg/m^3 close to bottom of the Valley causing a high radiative heating (60 K/day for solar zenith angle 70° and 25 K/day for solar zenith angle of 80°).

FLIGHT EXPERIMENTS IN 2013 AND 2014







CONCLUSION

- We found large variability of black carbon concentration and absorbing coefficient with altitude during inversion conditions.
- The haze layers have usually less than 100 m of depth with maximum of black carbon concentration at the bottom of Valley or several meters above.
- Estimated black carbon optical depth in the first 200 meters was up to 0.04 (at 500 nm) which corresponds to very high (up to 60 K/day) radiative heating during day and strong negative radiative forcing at the surface and positive forcing several meters above.
- The UAV flight tests show that maximum flow rate (0.2 l/min) in the AE-51 is too low to get sufficient SNR during measurements with vertical speed about 3-4 m/s. We plan to increase it up to 0.5-0.7 l/min.
- In addition, due to several hundred meters overlap range in the ceilometer and lidar instruments we are developing a near field optics in the Polly^{XT} lidar to retrieve aerosol optical properties from 50 m above the device. Synergy with AE-51 observation allows to retrieve the profiles of single scattering albedo between 50 and 1000 m.

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