Deployment of an EZ backscattering Lidar in Asia to detect Aeolian dust events and studying aerosol optical properties in the frame of future global Lidar networks

S. Lolli[1], L.Sauvage[1], S. Loaec[1]

[1]Leosphere, 76 Rue Monceau, Paris, France(slolli@leosphere.fr)

INTRODUCTION

During these last years, scientific community agrees about the central role played by the atmospheric aerosols, directly in forcing radiative transfer by heating or cooling and indirectly in acting as Cloud Condensation Nuclei that affect lifetime and amount of clouds. Cheung et al., 2005[1] and Yu et al, 2006[3] quantified the global aerosol impact on the radiative energy balance of Atmosphere and Earth calculating the direct radiative effect due to the anthropogenic and natural aerosols. The North East Asia and Korean Peninsula are often hit by dust particles that originate in Gobi desert in central Asia. This study describes the results obtained during a measurement campaign realized in Seoul, Korea from March 23 to May 8 2009 with an EZ Lidar™, produced by the French company Leosphere. A synergy between Lidar data satellite imagery and NOAA analytical back trajectories by HYSPLIT calculation scheme and Barcelona Supercomputing Center DREAM dust forecast model permits to detect and study the advection over south Korea of large dust particles, very hazardous for health and transportation when hit the ground level.

THE MEASUREMENT CAMPAIGN, EXPERIMENTAL SET-UP AND DATA PROCESSING

A 48 days long measurement campaign has been realized in Seoul (37.48N, 126.9E), in South Korea from the 23^{rd} of March 2009 to the 8^{th} May 2009. The campaign was supported by Leosphere that deployed an EZ Lidar ALS450 on the roof of Kweather building. The EZ Lidar ALS 450 involved in this campaign is an elastic Lidar whose light source is a tripled Neodymium-Yag laser that emits a pulse of duration of 10ns at 355nm with maximum energy of 16 mJ and repetition rate of 20Hz. The ALS450 EZ Lidar has been designed to derive vertical profiles of aerosol extinction (α_{aer}) , aerosol backscattering (β_{aer}) , depolarization ratio (δ) and Planetary Boundary Layer (PBL) height. The Lidar is completely eye-safe and reaches full overlap at 200m.

CHARACTERIZATION OF ADVECTION PATTERNS BY BACK TRAJECTORIES AND SATELLITE IMAGES

The 5-day analytical back trajectories by the HYSPLIT calculation scheme [3] have been used to infer source regions of the air masses advected over South Korea, in Seoul during the measurement campaign. The incertitude accompanying HYSPLIT generated trajectories can be estimated to be anywhere around 15%-30%. For the purpose of this study the accuracy of back trajectories is sufficient to infer the source of the air masses advected over Seoul. In Figure 1 and 2 the 3 levels back trajectories respectively at 1km, 2km, 3km are estimated at 03.00 UTC, (12.00pm local time) and at 12.00UTC (9pm local time) on May 1^{st}, 2009

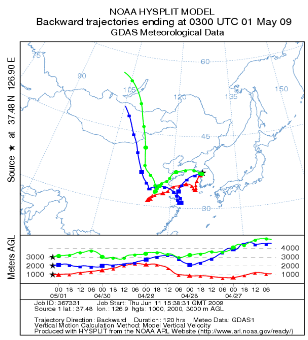

Figure 1 HYSPLIT Back trajectories on May 1^{st} , 2009 12UTC

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In Figure 1 the air masses advected over Seoul at 2km and 3km are continental from Siberia. The starting point height of the modeling is over 4 km that means that probably the air mass is travelling and it doesn't originate in the desert region, then it contains no dust, while in Figure 2, the air mass at 3km start point originates on ground in the Gobi desert, a high source of mineral dust.

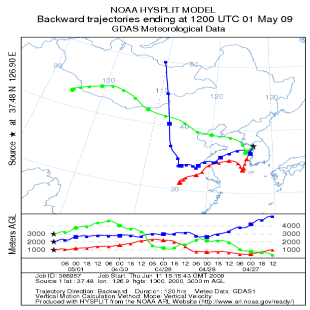


Figure 2 HYSPLIT Back trajectories on May 2nd, 2009 12UTC

It is very probable that this air mass contains large dust particles; while at higher altitudes back trajectories come from Arctic region in Siberia where no dust particles are present. The hypothesis is validated by MODIS satellite on April 26th that put in evidence the dust storm that originates in desert areas between China and Mongolia and is moving eastward, as shown in Figure 3:

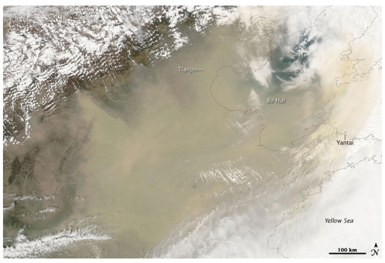


Figure 3 MODIS satellite image on 26th April 2009. Dust storm over China east propagating

and reaches Seoul on 1st May 2009.

Moreover, the Barcelona Supercomputing Center DREAM model computes world dust forecast for an altitude of 3km. At 12.00UTC of May 1st, the situation was:

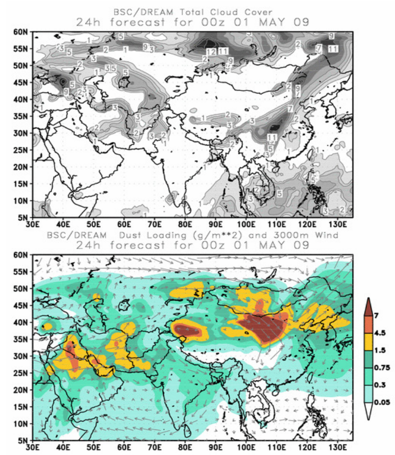


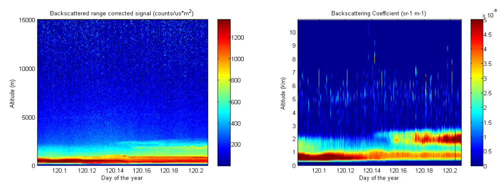
Figure 4 BSC/Dream forecast at 0.00UTC over Asia

We can observe a clear sky over Seoul with a dust transit.

AEROSOL VERTICAL DISTRIBUTIONS BY LIDAR MEASUREMENTS

From back trajectories and satellite analysis, from 30th April to 2st May 2009 it should be observed a dust event over South Korea with a change in spatial and temporal aerosol optical and microphysical proprieties. Aerosol vertical profiles have been monitored from 29th of April (day 120) to 2nd of May (day 121). The attenuated backscatter coefficient is retrieved calculating the instrumental constant in a region free of aerosols. The Aerosol Optical Depth (AOD) and backscattering coefficient are retrieved using Fernald backward inversion [4],[5]. The Lidar Ratio should be assumed under these hypotheses. Automated software build a Lidar Ratio profile based on temperature and pressure of measurement site and latitude and longitude. By the way, for the purpose of this work, it is interesting the relative variation of this value.

On 30th of April, the aerosol backscattering coefficient measured by the lidar shows a transit of a dust aerosol layer between 2 and 3km from 3am local time (Figure 5), that is advected, according to Modis satellite, DREAM forecast and back trajectories from the desert areas between China and Mongolia.



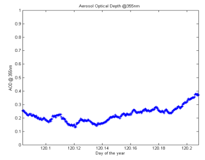


Figure 5 a) Backscattered range corrected Signal b) Aerosol Backscattering coefficient c)Aerosol Optical Depth on 30th of April, from 2am to 5am Seoul local time.

The dust layer transit continues until 9am of May 1st , as shown in Figure 6. The evolution shows that the dust particles are decreasing

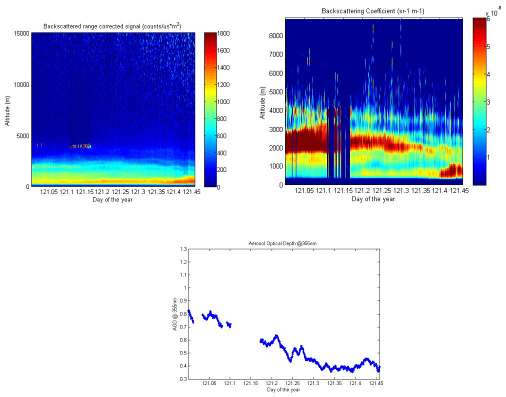


Figure 6 a) Backscattered range corrected Signal b) Aerosol Backscattering coefficient c)Aerosol Optical Depth on 1st of May, from 0am to 11am Seoul local time

This is a classical situation for Seoul with the aerosol load confined at altitudes below 1.2 km (figure 7)

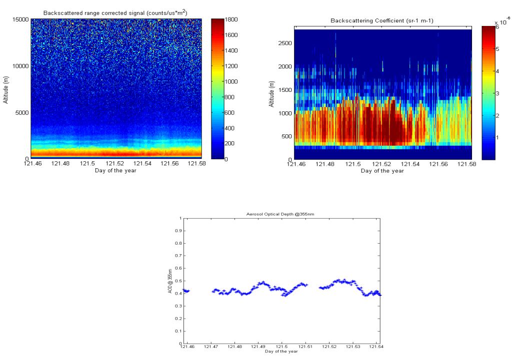


Figure 7a) Backscattered range corrected Signal b) Aerosol Backscattering coefficient c)Aerosol Optical Depth on 1st May, from 11am to 2pm Seoul local time.

In this time period advection pattern over Seoul from back trajectories reveals air masses probably coming from central Siberia (Continental). In figure 8, the following three hours, from 2pm to 5pm show again the aerosol load up to 1.5 km due to the convection activity during the warmer hours.

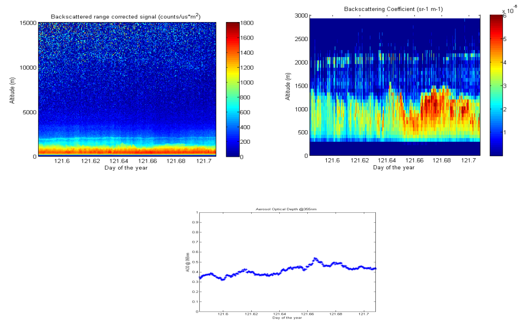


Figure 8 a) Backscattered range corrected Signal b) Aerosol Backscattering coefficient c)Aerosol Optical Depth on 1st May, from 2pm to 5pm Seoul local time.

with AOD around 0.45

From 5pm to 8pm, there it can be noticed the usual aerosol load up to 1.3km and the presence of an extra aerosol layer from 1.5km to 3km.

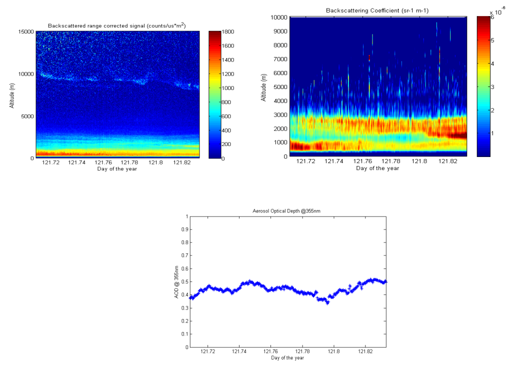


Figure 9a) Backscattered range corrected Signal b) Aerosol Backscattering coefficient c)Aerosol Optical Depth on 1st May, from 5pm to 8pm Seoul local time.

From 8pm to 11pm the layer is out breaking over Seoul as showed in Figure 10 at an altitude between 2 and 3 Km. :

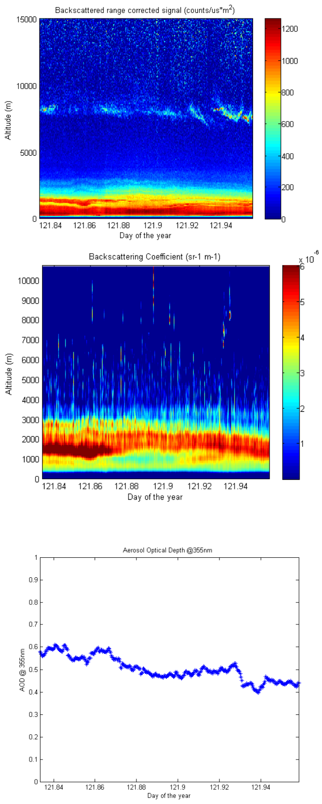


Figure 10a) Backscattered range corrected Signal b) Aerosol Backscattering coefficient c)Aerosol Optical Depth on 1st May, from 8pm to 11pm Seoul local time

The source region of the air mass at that altitude for that time is situated in the Gobi desert. Also the MODIS satellite pictures put the dust event in evidence around 25-26 of April 2009.

SUMMARY AND CONCLUSIONS

Data from measurement campaign held in Seoul, South Korea from 23rd of March to 8th of May 2009 have been analyzed in order to characterize dust phenomena events that affect atmospheric particulate properties and their variation with time and space due to the advection of air masses from desert areas. It is shown that the synergy of an elastic Lidar with HYSPLIT back trajectories generator, MODIS satellite images and DREAM forecast model, have allowed understanding and characterizing aerosol properties both in specific layers and on overall atmospheric column down to the ground. Aerosol backscatter coefficient, Atmospheric Optical Depth (AOD) have revealed that dust particles from Gobi desert have been advected over the monitoring site on 30th of April and 1st of May 2009, in accordance with HYSPLIT, DREAM and MODIS images. The EZ Lidar is then capable to detect dust particles transit, and outdoor and unattended use capabilities added to its measurements performances define then this instrument as a good candidate for deployment into growing global aerosol and dust monitoring networks and research measurement campaigns.

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