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Study on the Variability of Extinction Coefficients of Atmospheric Aerosol Over LHAASO

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We investigate the extinction coefficients of atmospheric aerosol over the Large High Air Shower Observatory (LHAASO), located at the Haizi Mountain, Daocheng County, China. The Aerosol Optical Depth(AOD), the column-integrated extinction coefficient(EC), is obtained by MODerate-resolution Imaging Spectroradiometer(MODIS) from 2011−2018. The data of extinction coefficients over LHAASO have been analyzed by Infrared Pathfinder Satellite Observations (CALIPSO) satellite during 2011-2017. Our results show that the AOD and EC have a yearly variation with the peak values in July, August and September, and less in the other months, which suggests that the atmospheric aerosols over LHAASO has its special characteristics. Over LHAASO the EC of the atmospheric aerosols are very small, which is consistent with other studies. The maximum values of EC occurred around 6∼7km altitude. Due to the bigger error of EC, more CALIPSO data to be utilized for the variability of EC over LHAASO.

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1. Introduction

The Large High Altitude Air Showers(LHAASO), one of the Major National Science and Technology Infrastructures, is located at Haizi Mountain, Daocheng County, Sichuan Province. It is composed of the Square Kilometer Array(KM2A),Water Cherenkov Detector Array(WCDA) and Wide Field of view Cherenkov Telescope Array(WFCTA) and expected to be the highest sensitivity instruments in the gamma ray detection, ultra-high gamma survey, the primary cosmic ray spectra and anisotropy[1, 2]. WFCTA, consisting of 18 telescopes, has been designed to fulfil the measurement of the primary cosmic rays with the energy of 10^{13}-10^{17}eV and transfer the energy scales from the direct measurement to the extreme high energy measurement, with different lay-out in different observation mode and energy range[3, 4].

To meet the requirement of the calibration of WFCTA, to select effectively the good shower events and correct the raw data, to improve the quality of the data and decrease the systematic errors, it is importance to investigate the variation of extinction coefficients from surface atmospheric aerosol in the field view of LHAASO-WFCTA.

LHAASO ($29°21'31''$ N, $100°08'15''$) is located in the east-south of Tibetan Plateau, and the western Sichan Province. This region is mainly covered by the alpine grassland in summer, and snow in cold winter. In the Tibetan Plateau, the atmospheric aerosols are usually taken as a whole and the geographical ranges are from 30^0-36^0 in latitude, and 80^0-100^0 in longitude. The chemical composition and optical properties, like extinction coefficients together with aerosols optical depth have been investigated by many atmospheric researchers[5, 6, 7]. Daily average of online PM2.5 at southeast Tibetan Plateau, where LHAASO belongs, is $11.7 \pm 4.7 \mu gm^{-3}$, but the ratio of PM2.5 to the total suspended particles was higher than that at Ngri, Qomolangma and Nam Co, which probably origin from the Sichuan Basin with dense PM2.5[8]. The model of atmospheric aerosol have been explored [9], However, so far the variation on the extinction coefficients over LHAASO have not been reported. In this talk, we will study on the variation of the extinction coefficients of atmospheric aerosol based on the experimental data by CALIPSO/CALIOP and MODIS, to provide the references for laser lidar calibration of LHAASO.

2. Experimental Data

2.1 CALIPSO Data

The CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation), which was launched by NASA in April 2006, works at 705*km* above the earth at sun-synchronous orbit. The orbital inclination is 98.2 degrees. It gets three-dimensional distribution of global regional clouds and aerosols every 16 days. CALIOP(Cloud-Aerosol Lidar with Orthogonal Polarization) is the most important equipment carried by CALIPSO and provides high-resolution vertical profiles of aerosols and clouds. It has three receiver channels, one measures the 1064*nm* backscatter intensity and two channels measure orthogonally polarized components of 532*nm* [10].

The data is selected from 99.6 to 100.6 degrees east longtitude, 29.0 to 30.0 degrees north latitude where the whole area of LHAASO is located. To insure that the good quality of data, the cloud-aerosol distinguish index is required to be within the range of -100 to -50 to differentiate cloud and aerosol better. Meanwhile, the uncertainty of extinction coefficient should be less than

10 and the aerosol particle type should be determined, the coefficient *Ectinction_QC_532* is set 0 or 1. Besides, because of the distraction of sunlight during the daytime, a higher threshold is determined for daytime than for night. It is worth noting that all CALIPSO data in this analysis are observed at night, for the WFCTA of LHAASO will be calibrated during in the clear nights.

2.2 MODIS Data

Aerosol optical depth(AOD), which is a key measure of aerosol optical properties, is the column-integrated extinction coefficient, representing the attenuation of solar radiation by aerosol scattering and absorption. The AOD is usually obtained from ground-based and space-based observations. Compared with the ground-based observation, space-based AOD retrievals have high spatial resolution and global coverage, and widely been used in the study of aerosol radiative forcing on regional and global climate, in spite of their relatively complicated and less accurate disadvantage.

Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument aboard the Terra (originally known as EOS AM-1, launched on the Dec. 18,1999) and Aqua (originally known as EOS PM-1, launched on the May 5, 2002) satellites. Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths. These data will improve our understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere. So far, the MODIS AOD have been widely adopted by environmental researchers [11, 12, 13, 14], also have been confirmed to be validated in China[15, 16].

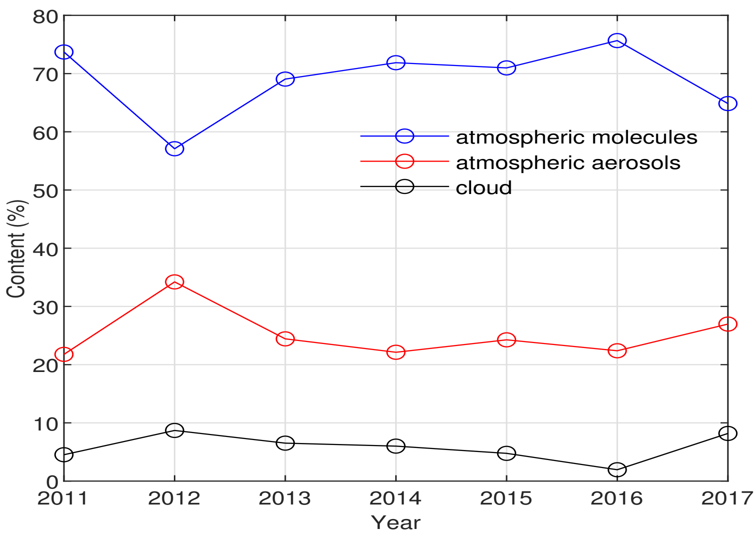

Figure 1: Content(%) for atmospheric molecules(blue), aerosols(red), and cloud(black) in the air during 2011-2017 over LHAASO

3. Results and Discussion

3.1 Yearly content of atmospheric aerosols in the air Over LHAASO

In generally, the particles with total attenuated backscattering intensity(TABI) of 0.0045$\sim$0.1km^{-1}sr^{-1} are believed to be cloud, the particles with TABI of 0.0001$\sim$0.0008km^{-1}sr^{-1} are atmospheric molecules, the particles with the range of TABI of 0.008$\sim$0.0045km^{-1}sr^{-1} are atmospheric aerosols. According to this classification, the content of different kind of particles in the air over LHAASO is shown in the Figure 1. The content in the air for atmospheric molecules, clouds and atmospheric aerosols are $\sim$70%, $\sim$10%,$\sim$20%, separately. The contents of the atmospheric aerosols was $\sim$ 33% in 2012, maybe the construction of Aden Daocheng Airport destroyed the vegetation, more dust particles were carried to the air. The content of atmospheric aerosols had a trend to turn larger in 2017.

3.2 Monthly mean AOD from MODIS

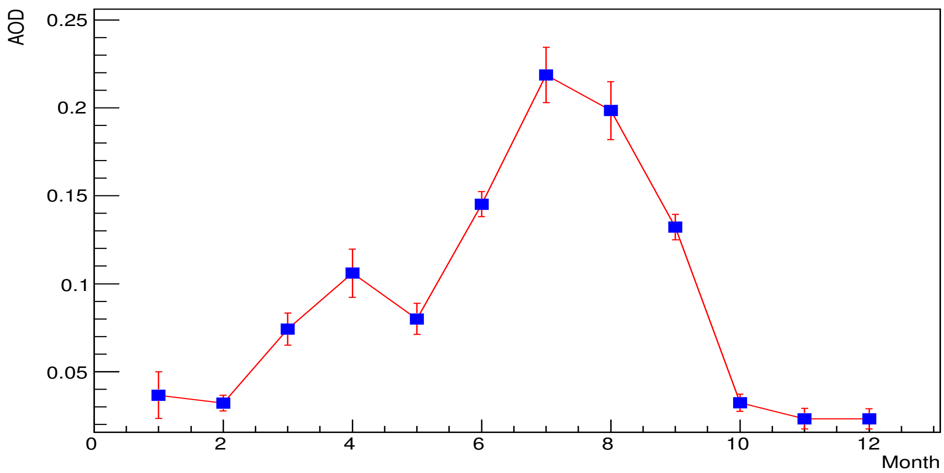

Figure 2: monthly mean AOD variability in one year at LHAASO

Figure 2 shows the monthly averaged AOD values from MODIS observation during 2011-2018. Each point is the average of the AOD in the corresponding months and the errors are the standard deviation of the average. At the LHAASO site the AOD changes from 0.02 to 0.23, with the double peak characteristics. The most prominent peak appears in the July, while the AOD value in June, August and September are also bigger. The second most prominent peak, much less than in the July, is in April, which is probably correlated the Taklimakan Desert. The AOD values in October, November, December, January and February are similarly small. The temporal characteristics of AOD during one year indicates the same variation of the extinction coefficients over LHAASO.

3.3 monthly mean EC from CALIPSO

Figure 3 shows the monthly mean EC of atmospheric aerosols among 4km-10km during 2011-2017 from CALIPSO. The each point is the average of EC in the related months if the data had been survived after selection. The errors are the standard deviation of the mean values. EC appeared bigger in July, August and September, smaller in October, November, December, January and February. It is also clear that EC was bigger in Summer and Fall, smaller in Winter and Spring. This trend of EC is different with the AOD, mostly because of the different sensors, different inversion method of data, different sample space for measurement and time resolution and so on[5].

MODIS and CALIOP are both sensors that carried by A-Train series satellites. The difference of their transit time is only 90 seconds, so the change of the extinction coefficient of aerosol at the same place observed by the two detectors can be ignored. The observation of aerosol optical depth in the data shows that the signal-to-noise ratio(SNR) of laser transmitted by CALIOP sensor on the ground is reduced[5], which probably leads to the smaller value of the extinction coefficient. Compared with MODIS data the extinction coefficients of the two significant peaks of EC is not so prominent because of less statistics, which need to be more observation data.

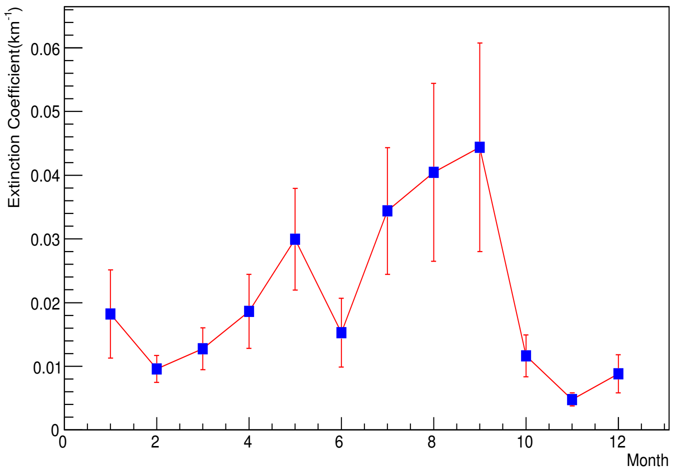

Figure 3: the monthly mean EC during 2011-2017 from CALIPSO. The horizontal axis gives the EC(km$^-1 \cdot sr^-1$) and the vertical axis is month

3.4 Vertical profile of EC during 2011-2017

Figure4 shows the vertical profile of EC during 2011-2017. The year corresponds to upper plots from left to right : 2011, 2012, 2013, 2014, and lower plots from left to right: 2015, 2016, 2017. In each plot the horizontal axis gives the EC(km^{-1}) and the vertical axis is the altitude(km). The vertical axis starts from about 4km because of the average altitude of 4410m above sea level(a.s.l.) of LHAASO site. There is no experimental data for the ∼6.4km and lower altitude in 2013. The largest EC values in these years appeared in the around 6-7km of altitude. In the other altitude the EC occurred small fluctuation, and more the EC appeared almost evenly when the altitude is higher than 8km a.s.l., suggesting that the aerosol concentration is very small in these altitudes. The climate characteristics at LHAASO is as follows: the winter is long, no summer, no frost. At the 6-8km altitude, transparent cirrus often exist with a little opaque deep convective. The snow covers from the end of September through the start of May, rainfall is much less than evaporation. It is windy and dusty in this regionlab17. That the surface mineral aerosol particles are brought to the high altitudes by huge wind probably result from the high-values of the EC in the about 6∼ 7km altitude. The largest value of EC in 2017 was almost 2 times bigger than peaks in other years. Maybe there were more dusts to be carried to these altitudes in 2017, when LHAASO started to make civil engineering.

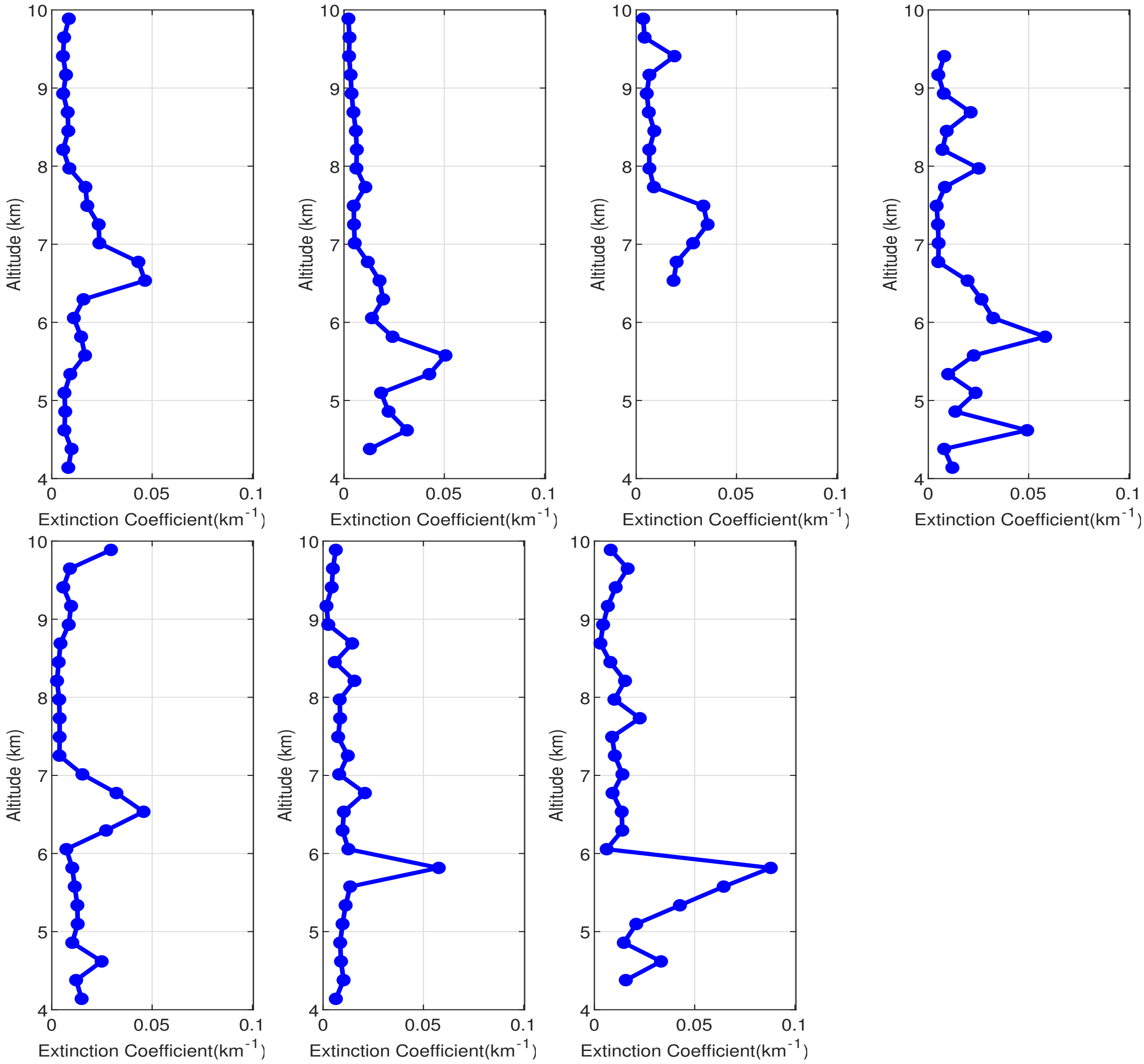

Figure 4: the vertical profile of yearly mean EC over LHAASO. The horizontal axis gives the EC(km^{-1}) and the vertical axis is the altitude(km), upper plots from left to right:2011, 2012, 2013, 2014, lower plots from left to right: 2015, 2016, 2017

3.5 EC distribution

The normalised distribution of the EC over LHAASO from 2011-2017 in 4∼6km, 6∼8km, 8∼10km are shown in the Figure5. The width of the distribution of the EC appeared smaller at higher altitude. For the altitudes of 6−8km, 8−10km, the EC occurred in the range of, 0∼0.289km^{-1}, 0∼0.106km^{-1}, separately. These distributions indicate that in the lower altitude of LHAASO there was some aerosol particles with high scattering ability. Overall, the EC over LHAASO are small, with 80% being less 0.126km^{-1} compared with that in Sichuan Basin.

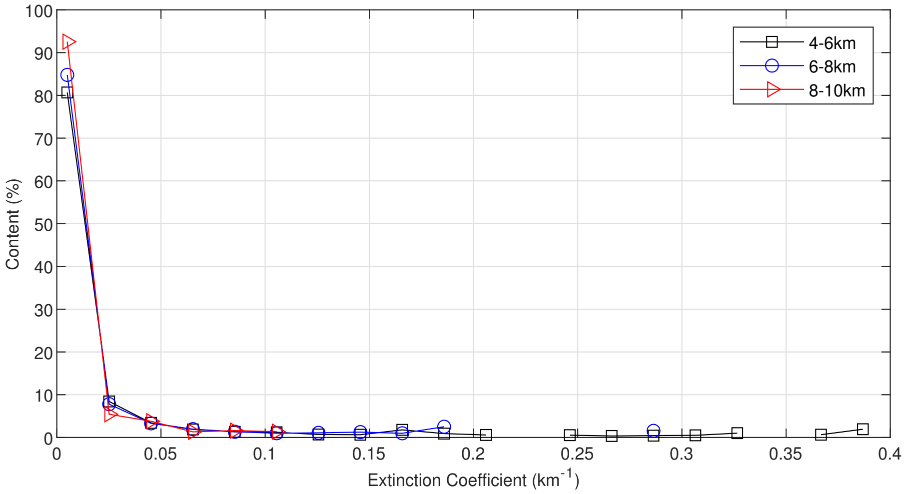

Figure 5: the distribution of EC as a function of altitude over LHAASO. The horizontal axis gives the EC(km^{-1}) and the vertical axis is the normalised distribution, black color presents 4-6km, blue color means 6-8km and red color is 8-10km

4. Summary and Discussion

The variability of the extinction coefficients of atmospheric aerosol over the LHAASO have been investigated in detail by CALIPSO and MODIS data. The high-values of extinction coefficients is in July, August and September, and lower-values is in October, November, December, January and February. The profiles of EC from 2011-2017 indicate the prominent high-values center is about 6∼7km a.s.l. and the distributions of EC suggest the extinction coefficient over LHAASO is relatively smaller than in other regions of China.

In this proceeding the EC's statistics errors are bigger, we need to make analysis on more CALIPSO data to get the more precise variation of the extinction coefficient over LHAASO.

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