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Origin of atmospheric aerosols at the Pierre Auger Observatory using studies of air mass trajectories in Southern America

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Abstract

The Pierre Auger Observatory is making significant contributions towards understanding the nature and origin of ultra-high energy cosmic rays. One of its main challenges is the monitoring of the atmosphere, both in terms of its state variables and its optical properties. The aim of this work is to analyze aerosol optical depth $\tau_a(z)$ values measured from 2004 to 2012 at the observatory, which is located in a remote and relatively unstudied area of the Pampa Amarilla, Argentina. The aerosol optical depth is in average quite low – annual mean $\tau_a(3.5\text{ km}) \sim 0.04$ – and shows a seasonal trend with a winter minimum – $\tau_a(3.5\text{ km}) \sim 0.03$ –, and a summer maximum – $\tau_a(3.5\text{ km}) \sim 0.06$ –, and an unexpected increase from August to September – $\tau_a(3.5\text{ km}) \sim 0.055$). We computed backward trajectories for the years 2005 to 2012 to interpret the air mass origin. Winter nights with low aerosol concentrations show air masses originating from the Pacific Ocean. Average concentrations are affected by continental sources (wind-blown dust and urban pollution), while the peak observed in September and October could be linked to biomass burning in the northern part of Argentina or air pollution coming from surrounding urban areas.

Keywords: cosmic ray, aerosol, air masses, atmospheric effect, HYSPLIT, GDAS.

1. Introduction

Modelling of aerosols in climate models is still a challenging task, also due to the lack of a complete global coverage of long-term ground-based measurements. In South America, only few studies have been done, usually located in mega-cities (Carvacho et al., 2004; López et al., 2011; Morata et al., 2008; Reich et al., 2008; Zhang et al., 2012). Astrophysical observatories need a continuous monitoring of the atmosphere, including aerosols, and thus offer an unique opportunity to get a characterisation of aerosols in the same locations over several years. Here we report on seven years of aerosol optical depth measurements carried out at the Pierre Auger Observatory in Argentina.

The Pierre Auger Observatory is the largest operating cosmic ray observatory ever built (Abraham et al., 2004, 2010a). It is conceived to measure the flux, arrival direction distribution and mass composition of cosmic rays from 10^{18} eV to the very highest energies. It is located in the Pampa Amarilla ($35.1° - 35.5°$ S, $69.0° - 69.6°$ W, and $1\,300 - 1\,700$ m above sea level), close to Malargüe, Province of Mendoza. Construction was completed at the end of 2008 and data taking for the growing detector array started at the beginning of 2004. The observatory consists of about 1660 surface stations – water-Cherenkov tanks and their associated electronics – covering an area of 3000 km^2. In addition, 27 telescopes, housed in four fluorescence detector (FD) buildings, detect air-fluorescence light above the array during nights with low-illuminated moon and clear optical conditions. The atmosphere is used as a giant calorimeter, representing a detector volume larger than 30 000 km^3. Once cosmic rays enter into the atmosphere, they induce extensive air showers of secondary particles. Charged particles of the shower excite atmospheric nitrogen molecules, and these molecules then emit fluorescence light mainly in the $300 - 420$ nm wavelength range. The number of fluorescence photons produced is proportional to the energy deposited in the atmosphere through electromagnetic energy losses undergone by the charged particles. Then, from their production point to the telescope, photons can be scattered by molecules (*Rayleigh scattering*) and/or atmospheric aerosols (*Mie scattering*). A small component (at shorter ultra-violet wavelengths) of the fluorescence light can be absorbed by some atmospheric gases such as ozone or nitrogen dioxide.

The aerosol component is the most variable term contributing to the atmospheric transmission function. Thus, to reduce as much as possible the systematic uncertainties on air shower reconstruction using the fluorescence technique, aerosols have to be continuously monitored. An extensive atmospheric monitoring system has been developed at the Pierre Auger Observatory (Abraham et al., 2010b; Louedec and Losno, 2012). The different facilities and their locations are shown in Figure 1. Ae-