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Aerosol optical properties in central Argentina

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ABSTRACT

This work presents the analysis of the long-term observations of aerosol optical properties in the central region of Argentina. Monitoring of aerosol parameters was carried out at the Cordoba-CETT AERONET site (31° 31′ S, 64° 27′ W, 730 m.a.s.l.) from November 1999 until December 2010. Long-term measurements of aerosol optical depth, Ångström exponent, fine mode fraction and single scattering albedo were analyzed and compiled to describe the climatology of the optical properties of the aerosols of the region. The knowledge of the optical properties of aerosols and their spatial distribution is required to evaluate aerosol effects on the climate system. This information provides an opportunity for understanding how aerosols might influence the regional radiation budget. Results show that aerosol optical depth at 340 nm is characterized by low values from February to April (monthly average of 0.15 ± 0.05), very low values from May to June (monthly average of 0.08 ± 0.03) and a sustained increase from July to September (monthly average of 0.20 ± 0.09) reaching a value of 0.26. From this dataset, no long-term trends are observable. Results of the inter-annual variations of the Ångström exponent between 440 and 870 nm reflect an important difference in the year 2004 compared to the other 11 years of the study. A possible explanation of this fact is elaborated with the help of back trajectory analysis. Finally, three episodes are described and analyzed, as they produced important increases of the daily aerosol optical depth value. We explained these episodes with a combination of air mass trajectory analysis, meteorology and the MODIS fire counts product.

1. Introduction

Atmospheric aerosols and pollutants absorb and scatter shortwave solar radiation and these interactions have resultant impacts on atmospheric radiative transfer balance (Solomon et al., 2007). Atmospheric aerosol particles in the boundary layer can also significantly change air quality either directly or by affecting the rate of tropospheric ozone formation (Flynn et al., 2010). Scattering by aerosols increases the actinic flux and the rates of photochemical reactions in the upper parts of the planetary boundary layer, while aerosol absorption reduces the amount of UV radiation available for chemical reactions within and below the aerosol layer. Therefore, without accurate knowledge of aerosol UV absorption, the magnitude and even the sign of the aerosol effect on tropospheric photochemistry will remain highly uncertain (Palancar et al., 2013).

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When aerosols are emitted into the atmosphere from some natural or anthropogenic sources, it is important to know its further behavior. The questions to answer are: how far and how fast particles can be transported? What are the dimensions of the plume during the transport? If we measure the aerosol properties at a given site, how much of these properties are determined by local sources and how much by distant ones? Since many of the involved parameters are highly dependent on weather conditions and on the topography of terrain, all these questions are not easy to answer.

In order to analyze the association between trajectories and air mass composition arriving at a site, a multitude of methods to carry out trajectory classifications has been devised (Fleming et al., 2012) and references therein. Over the last decades, trajectory analysis has been widely used to examine the dynamical processes and the patterns of the air mass transport. In a review of recent aerosol studies in Europe it was found that 11% of all studies used back trajectory methods to cluster aerosol levels according to their origins and transport pathways (Viana et al., 2008).

Optical properties of aerosols transported by an air mass can be obtained either from satellite or surface measurements. Satellite data can provide the required space-time coverage of aerosol optical depth (AOD) but the retrieval of aerosol absorption, in the form of single scattering albedo (SSA), is not reliable compared to the ground-based measurements (Zawadzka et al., 2013). Ground-based measurements of aerosol properties are more accurate than the satellite observations and have a better temporal resolution, but they are limited in the spatial distribution. In the last two decades, a large number of studies dealing with the analysis, retrieval, or estimation of aerosol optical properties from ground measurements have been published (e.g. Dubovik et al., 2000; Srivastava et al., 2012).

In spite of its importance, only a few works dealing with optical properties of aerosols have been published for the central region of Argentina. In one of these studies, Andrada et al. (2008) used their irradiance dataset, the AERONET (AErosol Robotic NETwork) database, and the TUV (Tropospheric Ultraviolet and Visible) model (Madronich, 1987) to analyze the effects of aerosols on surface Ultraviolet B irradiance (UV-B, 280–315 nm) on cloudless days in Córdoba city, Argentina, during the period 1999–2006. More recently Achad et al. (2013) used individual particle analysis and experimental UV-B irradiance measurements together with radiative transfer calculations to retrieve and compare the relative contribution of aerosol types at an urban site of the Córdoba city. Beyond the few works about aerosol optical properties published for Córdoba region, at present and as far as we know, there are no studies relating their optical properties with the pathways of the air masses arriving to this region.

In this work, we first present a comprehensive analysis of the aerosol optical properties measured at the Cordoba-CETT (Centro Espacial Teófilo Tabanera) AERONET site in the period of 1999–2010 and then the correlation of these properties with the pathway of the air masses arriving at the site during a long period of anomalous values. As the instrument measuring in this AERONET station was deployed at another place in 2010, the analyzed period represents the whole and only dataset of ground-based aerosol properties for the central region of Argentina. Back trajectories calculated for this period by using the Hybrid Single-Particle Lagrangian Integrated Trajectory model (HYSPLIT 4) were clustered to show the climatology of the air masses arriving to the region according to both position and frequency. In addition, the analysis of the daily, monthly, annual, and inter annual variation of the aerosol optical properties allowed to detect episodes, which are explained considering the meteorology of the region and the origin and transport of the air masses.

2. Materials and methods

2.1. Site and meteorology

The measurement site is a rural area located 20 km to the West of Córdoba city. A few kilometers to the West of the site, the so-called *Sierras Chicas* range of hills runs in the North-South direction for 490 km, with an average height of 800 m.a.s.l. and a few peaks, no higher than 2000 m.a.s.l.

The aerosol optical parameters were measured with a CIMEL Electronique 318A Sun photometer deployed at Cordoba-CETT AERONET station (31° 31′ S, 64° 27′ W, 730 m.a.s.l.) in 1999. This instrument provides AOD values at seven spectral bands (340, 380, 440, 500, 670, 870, and 1020 nm). The station was operative until December 2010, when the Sun photometer was deployed at another region away from Córdoba. A detailed description of the instruments, data acquisition procedure, and calibration is given by Holben et al. (1998, 2001), and an accurate assessment of the AERONET retrievals can be found in the work of Dubovik et al. (2000). The combined effects of uncertainties in calibration, atmospheric pressure, and ozone amount result in a total uncertainty in the derived AOD values of 0.01–0.02, with the largest errors in the UV region (Eck et al., 1999). Except for the single scattering albedo at 441 nm (SSA_{441}), all the aerosol optical parameters used in this work were level 2.0.

The meteorology in central Argentina is characterized by dry winters with average minimum daily temperature of about 6 °C and rainy summers with an average maximum daily temperature of about 30 °C. The climate is sub-humid with a mean annual precipitation of 790 mm (concentrated mainly in summer time), a mean annual temperature of 17.4 °C and prevailing winds from NE (National Weather Service). The monthly variation of the mean wind speed, average temperature, and total precipitation for the region is shown in Fig. 1, for the 12-year period under study (1999–2010). The soil of the region is loessic and due to the presence of erosive agents it shows weak waves (Kröhling, 1999). During the dry season (April–September) the surrounding hills and mountains are prone to the existence of fires, produced not only accidentally but also intentionally, especially during winter–spring time. In Argentina, available fire databases indicate that, in the average, the burned area covers a wide range of vegetation types, including grasslands (53%), shrub lands (27%) and natural