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Solar eclipse of 20 March 2015 and impacts on irradiance, meteorological parameters, and aerosol properties over southern Italy

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ABSTRACT

The effects of the partial solar eclipse of 20 March 2015 on short-wave (SW) and long-wave (LW) irradiance measurements, meteorological variables, and near surface particle properties have been investigated. Measurements were performed at three southern Italy observatories of the Global Atmospheric Watch - World Meteorological Organization (GAW-WMO): Lecce (LE, 40.3°N, 18.1°E, 30 m a.s.l.), Lamezia Terme (LT, 38.9°N, 16.2°E, 50 m a.s.l.), and Capo Granitola (CG, 37.6°N, 12.7°E, 50 m a.s.l.), to investigate the dependence of the eclipse effects on monitoring site location and meteorology. LE, LT, and CG were affected by a similar maximum obscuration of the solar disk, but meteorological parameters and aerosol optical and microphysical properties varied from site to site on the eclipse's day. The maximum obscuration of the solar disk, which was equal to 43.6, 42.8, and 45.1% at LE, LT, and CG, respectively, was responsible for the decrease of the downward SW irradiance up to 45, 44, and 45% at LE, LT, and CG, respectively. The upward SW irradiance decreased up to 45, 48, and 44% at LE, LT, and CG, respectively. Consequently, the eclipse SW direct radiative forcing (DRF) was equal to − 307, − 278, and − 238 W m^{-2} at LE, LT, and CG, respectively, at the maximum obscuration of the solar disk. The downward and upward LW irradiance decrease was quite small (up to 4%) at the three sites. The time evolution of the meteorological parameters and aerosol optical and microphysical properties and their response strength to the solar eclipse impact varied from site to site, mainly because of the local meteorology and geographical location. Nevertheless, the solar eclipse was responsible at the study sites for a temperature decrease within 0.5–0.8 K, a relative humidity increase within 3.5–4.5%, and a wind speed decrease within 0.5–1.0 m s^{-1}, because of its cooling effect. The solar eclipse was also responsible at all the sites for the increase of near surface particle scattering coefficient (σ_{sp}) and scattering color ratio (CR_σ), mainly for the increase of both ultrafine and fine mode particle concentrations. In more detail, σ_{sp}, CR_σ, and number concentration increased up to 2 Mm^{-1}, 0.2, and $9 \cdot 10^3$ cm^{-3}, respectively. The atmospheric turbulence weakening, driven by the eclipse cooling effect and revealed by the decrease of turbulent kinetic energy and potential temperature flux, mainly contributed to the changes of near surface particle concentrations and size distributions.

1. Introduction

Solar eclipses represent a unique opportunity for investigating the atmospheric and environmental response to the large scale and sharply variation of the solar and terrestrial radiation. In fact, during the course of the eclipse, the solar limb darkening produces an abrupt variability in the solar radiation's magnitude and spectral composition. Due to the rarity of the event, few studies have been performed to characterize the phenomenon. In particular, most of them were mainly devoted to the effects of the solar eclipse on the ground-based measurements of irradiance, meteorological parameters, and gas concentrations, since they represent the variables mostly experienced by the observers. For example, Kazadzis et al. (2007) analyzed the spectral effect of the limb darkening on the solar radiation at the surface, during the solar eclipse of 29 March 2006, at the island of Kastelorizo (Greece). Founda et al. (2007) showed a sharply reduction in the incoming global radiation and, consequently, pronounced changes in the surface air temperature at four Greek sites (Athens, Thessaloniki, Kastelorizo, and Finokalia), during the same solar eclipse. In particular, the lowest temperature values occurred about 15 min after the full phase of the solar eclipse. They also observed that the air temperature decrease was not strongly dependent on the percentage of the solar disk's obscuration, since the air temperature variations were also affected by the surrounding environment (mainly the sea influence), the background meteorological

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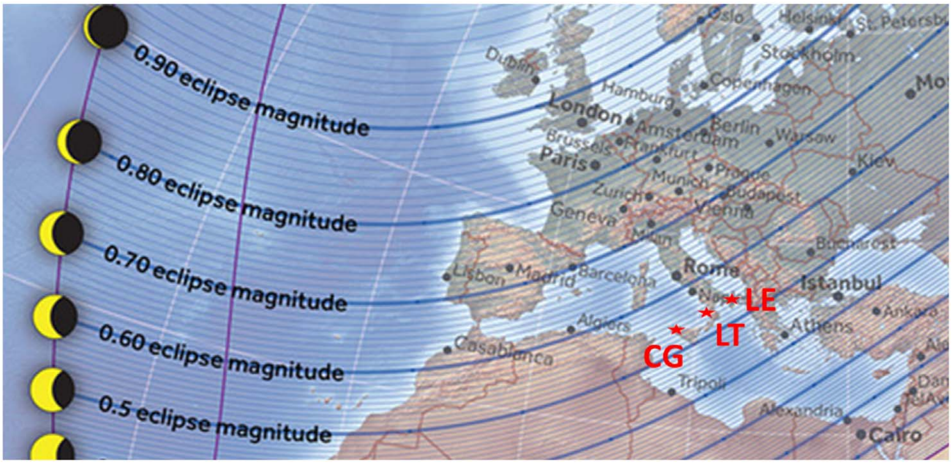

Fig. 1. Map of the solar eclipse magnitude (fraction of the Sun's disk occulted) on 20 March 2015, over Europe and Northern Africa. The geographical locations of the three investigated sites (red stars) are also reported. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

conditions, and the local cloudiness. Surface wind speed decreased because of the cooling and stabilization of the atmospheric boundary layer. The solar eclipse of 29 March 2006 was also investigated by Tzanis et al. (2008) and Kazantzidis et al. (2007). Bala Subrahamanyam and Anurose (2011) studied the solar eclipse's impact on the see/land breeze circulation. Few studies have been devoted to the eclipse effects on the aerosol properties. Sapra et al. (1997) examined the effect of the total solar eclipse occurred on 24 October 1995 on the aerosol concentration, at Trombay (Mumbai, India). The temperature and relative humidity changes, in addition to the suppression of the ground level turbulence, were considered responsible for the increase of the aerosol concentration observed during the studied phenomenon. The 24 October 1995 total solar eclipse was also studied by Dani and Devara (2002): they found that the aerosol optical depth determined by a multi-channel radiometer exhibited a significant enhancement during the course of the eclipse, as a consequence of the increase in relative humidity and the weakening of atmospheric turbulence.

The results presented in this study are related to the 20 March 2015 partial solar eclipse. The effects of this last eclipse on the surface radiation components have been investigated by Maturilli and Ritter (2016) at the high-Arctic site of Ny-Ålesund (78.9°N, 11.9°E, Norway) within the Baseline Surface Radiation Network (BSRN). Scafetta and Mazzarella (2016) monitored the eclipse's impact on the irradiance and main meteorological parameters at the urban area of Naples, central Italy, where the maximum obscuration of the solar disk was of ~50%. Furthermore, Good (2016) analyzed over Europe the behaviour of the remotely sensed land surface temperatures from the Spinning Enhanced Visible and InfraRed Imager (SEVIRI).

The effects of the 20 March 2015 solar eclipse on irradiance, meteorological parameters, and near surface particle properties, by also taking into account the main turbulence parameters changes, have simultaneously been investigated in this paper, unlike most of the previous studies. In particular, the solar eclipse effects on atmospheric aerosol properties have been poorly investigated, to the best of our knowledge. Note also that each solar eclipse is always a unique event, since it is characterized by a particular time of the day, season, location, and synoptic conditions.

Measurements were performed at three southern Italy sites with a rather close percentage of the maximum obscuration of the solar disk, to also investigate the dependence of the eclipse effects on monitoring site location and local meteorology. More specifically, measurements of short-wave (SW) and long-wave (LW) irradiance, air temperature, relative humidity, wind speed and direction were performed at Lecce (LE, 40.3°N, 18.1°E, 30 m a.s.l.), Lamezia Terme (LT, 38.9°N, 16.2°E, 50 m a.s.l.) and Capo Granitola (CG, 37.6°N, 12.7°E, 50 m a.s.l.). The eclipse effects on the turbulent kinetic energy and heat flux have also been estimated by using sonic anemometer measurements at LE. The near surface particle properties have been characterized by scattering coefficients at different wavelengths (e.g. Perrone et al., 2014), particle concentrations, and size distributions. LT and CG are observatories of the Global Atmospheric Watch-World Meteorological Organization (GAW-WMO), while LE is a GAW contributing networks station (https://gawsis.meteoswiss.ch/). Aerosol optical and physical parameters and gas (CH_4, CO_2, and CO) concentrations are provided by the LT station to the GAW-WMO. The LE and CG stations provide aerosol optical parameters. More details on the LT and CG study sites can be found in Cristofanelli et al. (2017). Monitoring sites and instrumentation are described in Section 2. The 20 March 2015 solar eclipse and its impact on the SW and LW irradiance, meteorological and turbulence parameters, and near surface particle properties are analyzed in Section 3. Summary and conclusion are reported in Section 4.

2. Experimental sites and instruments

2.1. Experimental sites description

Fig. 1 (red stars) shows the geographical locations of the three selected monitoring sites that span about 3° in latitude and > 5° in longitude. The Lecce monitoring site is located at the Mathematics and Physics Department of Salento University, on a flat peninsular area of the Apulia region, about 20 km away from both the Ionic and Adriatic Sea. The LE study site can be considered representative of coastal sites of the Central Mediterranean away from large sources of local pollution, according to Perrone et al. (2014), and can be classified as rural background site, according to Larssen et al. (1999). The Lamezia Terme monitoring site is located at the Institute of Atmospheric Science and Climate (ISAC) of the National Research Council (CNR) of Italy on the west coast of Calabria region, at about 600 m from the coastline, on a flat open area at the foot of a mountain chain. Due to the particular location of the site, the local atmospheric circulation is mainly affected by the sea/land breeze effects (Federico et al., 2000). The CNR-ISAC station of Capo Granitola is located directly on the coastline of the Sicily Channel, at the Torretta Granitola coastal site. Therefore, LT and CG are coastal sites away from large sources of local pollution and, like LE, can be classified as rural background sites, according to Larssen et al. (1999).

2.2. Instruments description

An automatic weather station was used at the three sites to monitor meteorological variables. It consists of an electronic thermo-hygrometer (uncertainty of 0.1 K and 1% for temperature and relative humidity, respectively), an anemometer (uncertainty of 0.1 m s^{-1} and 1° for wind speed and direction, respectively), and an electronic pressure