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Short-term effects of desert and non-desert PM_{10} on mortality in Sicily, Italy

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ABSTRACT

Background: Increased PM_{10} concentrations are commonly observed during Saharan dust advections. Limited epidemiological evidence suggests that PM_{10} from anthropogenic and desert sources increase mortality. We aimed to evaluate the association between source-specific PM_{10} (non-desert and desert) and cause-specific mortality in Sicily during 2006–2012 period.

Methods: Daily PM_{10} concentrations at 1-km^2 were estimated in Sicily using satellite-based data, fixed monitors and land use variables. We identified Saharan dust episodes using meteorological models, back-trajectories, aerosol maps, and satellite images. For each dust day, we estimated desert and non-desert PM_{10} concentrations. We applied a time-series approach on 390 municipalities of Sicily to estimate the association between PM_{10} (non-desert and desert) and daily cause-specific mortality.

Results: 33% of all days were affected by Saharan dust advections. PM_{10} concentrations were 8 $\mu g/m^3$ higher during dust days compared to other days. We found positive associations of both non-desert and desert PM_{10} with cause-specific mortality. We estimated percent increases of risk (IR%) of non-accidental mortality equal to 2.3% (95% Confidence Interval [CI]: 1.4, 3.1) and 3.8% (3.2, 4.4), per 10 $\mu g/m^3$ increases in non-desert and desert PM_{10} at lag 0–5, respectively. We also observed significant associations with cardiovascular (2.4% [1.3, 3.4] and 4.5% [3.8, 5.3]) and respiratory mortality (8.1% [6.8, 9.5], and 6.3% [5.4, 7.2]). We estimated higher effects during April–September, with IR% = 4.4% (3.2, 5.7) and 6.3% (5.4, 7.2) for non-desert and desert PM_{10}, respectively.

Conclusions: Our results confirm previous evidence of harmful effects of desert PM_{10} on non-accidental and cardio-respiratory mortality, especially during the warm season.

1. Introduction

A large number of epidemiological studies has investigated the association between air pollution and health during the last decades. The latest update of the Global Burden of Disease (GBD) estimated that almost 4.2 million deaths were attributable to air pollution in 2016 (Cohen et al., 2017). Only in Europe, long-term exposure to air pollution causes 356,000 deaths every year (European Environment Agency, 2017). The current level of awareness on this topic of governments and national and local policy makers is still insufficient and the goal to decrease deaths attributable to air pollution to a minimum is still far from being achieved.

The harmful effect of short-term exposure to air pollution on human health has been well established worldwide (Analitis et al., 2006; Samoli et al., 2013; Zanobetti et al., 2003). Particulate matter (PM), one of the principal pollutants investigated, is a mixture of solid and liquid particles in the air produced by different sources. In urban settings, human activities such as vehicular traffic and biomass combustion sources have a large impact on PM emissions (Viana et al., 2008). A large body of literature provides evidence regarding the effect of traffic-related PM on morbidity and mortality (Baccarelli et al., 2009; Gruzieva et al., 2017; Krämer et al., 2010; Rosenlund et al., 2009) but less is known about PM produced by other sources such as forest fires, volcanic eruptions and desert dust advections.

A few studies focused on this issue in the last years. The European project "MED-PARTICLES" (Samoli et al., 2013, 2014; Stafoggia et al.,

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2013) explored the short-term effects of fine and coarse PM in Southern Europe and found evidence of health effects even for the coarse fraction (e.g. PM between 2.5 and 10 µm, $PM_{10-2.5}$). The authors also explored the role of desert dust from Saharan advections (Pey et al., 2013; Stafoggia et al., 2015). Specifically, they were able to identify desert dust episodes in 14 cities across Southern Europe, and for each day impacted by desert dust, they separated the desert contribution to ground-level PM_{10} concentrations from the anthropogenic sources. The results of that project underlined that Saharan dust events affect the Mediterranean area over a large percentage of days each year, and that the health effect from the desert component of PM is at least as large as the effect from the anthropogenic-derived PM_{10} concentrations.

Recent studies from Eastern Asia, Australia and the Middle East (Chan et al., 2008; Chen and Yang, 2005; Chiu et al., 2008; Lee et al., 2013; Merrifield et al., 2013; Vodonos et al., 2014, 2015; Yang et al., 2005) confirmed the main findings from earlier studies in Southern Europe, the Caribbean and North America (Crooks et al., 2016; Faustini et al., 2015; Gyan et al., 2005; Stafoggia et al., 2013).

In Italy, we recently evaluated the effect of total and source-specific (anthropogenic and desert) PM_{10} on cause-specific mortality in the four major cities of Sicily (Palermo, Catania, Messina, and Syracuse) (Renzi et al., 2017) using fixed monitors for exposure assessment.

In the last years, sophisticated models based on satellite observations and land-use regression (LUR) have been used to quantify daily PM surface concentrations. Satellite data allow to predict daily concentrations of PM over wide geographical areas, therefore they enable to estimate associations with health outcomes even in locations with no monitored air quality data. In particular, a recent analysis by Stafoggia et al. (2016) estimated daily PM_{10} concentrations over Italy during 2006–2012 at a spatial resolution of 1-km^2.

The aim of this study is to expand our previous analysis (Renzi et al., 2017) by evaluating the association between source-specific (non-desert and desert) PM_{10} and cause-specific mortality in the whole Sicily region using satellite-based spatiotemporal PM_{10} estimates. As a secondary objective, because of the concurrency of desert episodes with high summer temperatures, we performed season-specific analyses and evaluated whether air temperature might confound the desert dust-mortality association by fitting models with increasing level of adjustment for such a potential confounding factor.

2. Methods

2.1. Study setting

Sicily is the largest island in the Mediterranean (5 million of inhabitants). It is divided into 390 municipalities belonging to nine Provinces: Agrigento, Caltanissetta, Catania, Enna, Messina, Palermo, Ragusa, Syracuse, and Trapani. Due to its proximity to North Africa, it is often impacted by desert dust episodes, which can increase PM_{10} levels up to several hundred µg/m^3 on some days (Pey et al., 2013). In addition to desert sources, several anthropogenic sources need to be acknowledged, including emissions from large industrial sites (ARPA Sicilia, 2016; Pirastu et al., 2010) and household and traffic-related emissions in the main urban settings (Biggeri et al., 2005).

2.2. Health data

We collected daily counts of mortality events by using health regional databases from 1 January 2006 to 31 December 2012. In particular, we collected information about deaths from non-accidental (International Classification of Diseases, 9th – ICD9 codes: 1–799), cardiovascular (ICD9 codes: 390–459) and respiratory causes (ICD9 codes: 460–519) for the population above 35 years of age. We created separate time-series for each of the 390 municipalities in Sicily.

2.3. Environmental data on PM_{10}

We used the 1-km^2 grid net for which satellite-based PM estimates are available with the Sicily region (Stafoggia et al., 2016) for a total of 26,600 different grid cells. The estimates are based on Aerosol Optical Depth (AOD), a measure of light extinction (scattering plus absorbance) from columnar suspended aerosol. In a previous work, we have used data on 1-km^2 AOD and other spatiotemporal variables to predict daily PM_{10} values in each cell of Italy for the period 2006–2012 (Stafoggia et al., 2016). Briefly, the methodology used to estimate daily PM_{10} concentrations at 1-km^2 resolution is a three-step approach where AOD data were first calibrated to PM_{10} concentrations, while adjusting for land-use and meteorological variables (stage 1), the resulting model was then applied to predict daily PM_{10} over cells-days with available AOD (stage 2), and then an imputation model has been applied for grid cells and days with no AOD retrievals (stage 3) (Stafoggia et al., 2016).

We attributed daily values of PM_{10} estimated concentrations for all grid cells in Sicily, and we derived daily mean concentrations at the municipality level by averaging PM_{10} values of the grid cells intersecting each municipality.

2.4. Desert dust detection

The methodology used for identifying desert dust episodes has been described in a previous study (Pey et al., 2013). It enables the identification of almost all desert dust episodes, independently of their intensity and duration, and consists in the interpretation of several tools: meteorological products (NCEP/NCAR: http://www.esrl.noaa.gov/psd/data/composites/hour/), aerosol maps (BSC-DREAM: http://www.bsc.es/projects/earthscience/DREAM/; NAAPSNRL: http://www.nrlmry.navy.mil/aerosol/; MODIS: http://modis.gsfc.nasa.gov/), and air masses back-trajectories (HYSPLIT: http://ready.arl.noaa.gov/HYSPLIT%20traj.php). Firstly, back-trajectories of air masses were viewed to include only episodes of air masses transported from North Africa, Arabian Peninsula or Negev-Middle Eastern deserts. Secondly, aerosol maps and satellite images were evaluated. Finally, meteorological maps were calculated to verify the existence of favorable scenarios for the transport of desert-blown dust. We applied these methods on the whole region to characterize each day as desert-free or desert-affected.

2.5. Desert dust contribution to PM

Once desert dust days were identified, we applied a statistical approach on the time series of daily background PM_{10} concentrations in order to quantify daily contribution of desert dust at ground level. To this aim, we divided Sicily into three macro-areas (Fig. 1), and we named “Area-1” the northwest region (where Palermo is located), “Area-2” the southern region (which includes Syracuse and Catania), and “Area-3” the northeast region (where Messina is located). The purpose to divide Sicily in three region was to minimize desert dust exposure measurement error as compared to the alternative approach of having a global assessment of dust advections over the whole region.

EC-Guidelines in EU Air Quality Directive (2008/50/EC) prescribed to use a Regional Background site (RB), defined as stations located at least 20 km from urban and industrial areas and away from local emission, as reference to calculate the dust contribution on PM_{10} levels during dust days. However, in Sicily RBs are not available, so we identified three remote rural municipalities, one per each macro-area, where human activities were assumed to play a negligible contribution to PM_{10} concentrations, and we used satellite-derived PM_{10} estimates for these municipalities in place of (missing) observed PM concentrations.

The EU method consists in the application of a 30-day moving 40th percentile over the PM_{10} data series, after exclusion of days impacted by desert dust (Pey et al., 2013; Querol et al., 2009). For these days, the