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Meteorologically adjusted urban air quality trends in the Southwestern United States

Erika K. Wise*, Andrew C. Comrie

Department of Geography and Regional Development, University of Arizona, Harvill Building, Box 2, Tucson, AZ 85721, USA

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Abstract

Cities in the Southwestern United States (Southwest) are often close to violating tropospheric ozone (ozone) and particulate matter (PM) federal air quality standards, and local climate and weather conditions play a large part in determining whether or not pollutant levels exceed the federally mandated limits and by what magnitude. The Kolmogorov–Zurbenko (KZ) filter method has been used in a number of studies in the Eastern United States to determine meteorological controls on ozone concentrations and to separate out those effects in order to examine underlying trends. The Southwest, however, experiences a different climate regime than other parts of the country, and atmospheric controls on air quality in the region have not been examined in this manner. This paper determines which meteorological variables most influence ozone and PM in the Southwest and examines patterns of underlying pollutant trends due to emissions.

Ozone and PM data were analyzed over the time period 1990–2003 for the Southwest's five major metropolitan areas: Albuquerque, NM; El Paso, TX; Las Vegas, NV; Phoenix, AZ; and Tucson, AZ. Results indicate that temperature and mixing height most strongly influence ozone conditions, while moisture levels (particularly relative humidity) are the strongest predictors of PM concentrations in all five cities examined. Meteorological variability typically accounts for 40–70% of ozone variability and 20–50% of PM variability. Long-term ozone trends are highly variable, but records from most stations indicate increasing concentrations over the last decade. Long-term trends in PM concentrations were relatively flat in all five cities analyzed but contained coincident extremes unrelated to meteorology.

Keywords: Air pollution; Kolmogorov–Zurbenko filter; Particulate matter; PM_{10}; Tropospheric ozone; Climate; KZ filter; US Southwest; Weather

1. Introduction

1.1. Overview

This study examines ozone and particulate matter (PM) in the Southwest. Ozone and PM are two of the most pervasive and potentially harmful air pollutants in the United States (United States Environmental Protection Agency [USEPA], 2003). Ozone is an extremely reactive chemical that has been shown to reduce visibility and have harmful effects on human health, commercial crops, and natural areas (Keyes et al., 2001). High levels of PM are significantly associated with adverse health effects, ecosystem damage, and degraded visibility (Goswami et al., 2002).

*Corresponding author. Tel.: +1 520 621 1652; fax: +1 520 621 2889.
E-mail address: ekwise@email.arizona.edu (E.K. Wise).

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In order to gage the effectiveness of air quality control regulations and improve air quality management efforts, long-term air quality trends must be detected and then linked to specific sources (Porter et al., 2001). Air quality in the Southwest is influenced by a wide variety of factors, both anthropogenic and biogenic. Anthropogenic sources of pollutants include emissions from automobiles, power plants, industry, and wood-burning stoves and fireplaces (Davis and Gay, 1993a). Wildfires, airborne dust and soil particles, and hydrocarbons emitted by vegetation are examples of biogenic influences (Davis and Gay, 1993a; Diem, 2000; Diem and Comrie, 2000). Meteorological conditions, however, appear to have the greatest impact on daily variations in air quality (Comrie, 1996; Davis and Gay, 1993b; Wise and Comrie, 2005). The strong linkage between weather conditions and pollutant levels can obscure the effects of changing emission levels over time. Thus, the meteorological signal must be removed in order to examine emissions-influenced trends.

The Rao–Zurbenko approach is a time-series filtering method utilizing the KZ filter, a low-pass filter produced through repeated iterations of a moving average. This method has been successfully applied to ozone time-series, primarily in the Eastern United States. However, the Southwest operates under different synoptic weather controls than other parts of the country. Research in other regions has indicated that ozone is strongly positively correlated with high temperatures and solar radiation, as these enhance the conditions needed for the photochemical process that creates ozone (Comrie, 1996; Diem and Comrie, 2001; Sillman, 1999). The influence of other meteorological variables is uncertain, particularly in the Southwest. Vukovich and Sherwell (2003) found that high temperatures, large concentrations of water vapor, high solar radiation, and stagnant conditions were the conditions correlated with high ozone concentrations in the Eastern United States. Milanchus et al. (1998) found that solar radiation, specific humidity, temperature, and dew point depression were the variables most highly correlated with ozone concentrations in several cities across the United States; however, none of these cities were in the Southwest.

Wind speed, mixing height (MH), and relative humidity (RH) are the meteorological variables believed to exert the most influence on PM concentrations (Gebhart et al., 2001). Stagnant conditions (usually associated with atmospheric inversions) are thought to correlate with high PM concentrations, as they allow particulates to accumulate near the earth's surface (Chow and Watson, 2001; Davis and Gay, 1993b; Triantafyllou et al., 2002). While high wind speeds can increase ventilation, they are normally correlated with high PM concentrations because they allow the resuspension of particles from the ground, as well as long-range transport of particulates between regions (Brazel and Nickling, 1986; Chow and Watson, 2001; Davis and Gay, 1993b; Gebhart et al., 2001; Holcombe et al., 1997; Smith et al., 2001; Triantafyllou et al., 2002). High PM concentrations are normally associated with dry conditions due to increased potential for suspension of dust, soil, and other particles.

1.2. Purpose of study

Ozone and PM are both pervasive air pollutants that have been shown to have harmful effects on human health and the environment. The recently revised and strengthened federal standards for these pollutants emphasize the growing acknowledgement of their detrimental effects and compel cities to look for improved management strategies. The detection of meteorological variables controlling ozone and PM and the demarcation of emissions-controlled pollutant trends will provide greater insight into the effects of past air quality management decisions and allow for more effective and proactive decisions to ameliorate future air pollution. Developing information on the risks associated with high ozone and PM concentrations has led to a proliferation of studies that examine these pollutants, particularly in the Eastern United States. However, air quality research carried out elsewhere does not necessarily apply to the Southwest due to its unique climatic and demographic conditions. This study aims to: (1) investigate how trends and controls in the Southwest differ from those in the Eastern United States; (2) examine differences and similarities in trends between Southwest cities; and (3) provide local air quality agencies with information on underlying emissions trends in their cities.

1.3. Study area

The Southwest can be defined in several different ways depending on the topic of interest (Liverman and Merideth, 2002). For instance, the region could be delimited based on climatology, hydrology, ecology, or political boundaries. Following the protocol established by the Climate Assessment for the Southwest project (Liverman and Merideth, 2002), this study focuses on the lower Colorado River basin, considering the states of Arizona and New Mexico as the core region, but including adjacent areas of California, Colorado, Nevada, Utah, and Texas. This study examines the major metropolitan areas in the Southwest: Albuquerque, NM; El Paso, TX; Las Vegas, NV; Phoenix, AZ; and Tucson, AZ.

A semi-permanent high-pressure ridge over the Southwest results in a distinctive climate with low annual precipitation, clear skies, and warm temperatures year-round. The climatic feature which most distinguishes the