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A study of trends for Mexico City ozone extremes: 2001-2014

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RESUMEN

Se analiza la tendencia de altos valores de ozono troposférico sobre la Ciudad de México basados en observaciones para los años 2001-2014. Los datos consisten en máximos de ozono mensuales basados en 29 estaciones de monitoreo. Dada la gran cantidad de valores faltantes, se consideran los máximos mensuales sobre cinco zonas geográficas de la ciudad. Se evalúan las tendencias de ozono en el tiempo mediante un modelo estadístico que asume que las observaciones siguen una distribución generalizada de valores extremos, la cual nos permite estimar un parámetro de tendencia para cada zona y un parámetro de tendencia global. Se comparan los resultados de este modelo con un modelo que asume que las observaciones siguen una distribución normal. Nuestros estudios muestran alguna evidencia de que estos máximos mensuales de ozono han disminuido durante el periodo de estudio.

ABSTRACT

We analyze trends of high values of tropospheric ozone over Mexico City based on data corresponding to the years 2001-2014. The data consists of monthly maxima ozone concentrations based on 29 monitoring stations. Due to the large presence of missing data, we consider the monthly maxima based on five well identified geographical zones. We assess time trends based on a statistical model that assumes that these observations follow an extreme value distribution, where the location parameter changes in time accordingly to a regression model. In addition, we use Bayesian methods to estimate simultaneously a zonal and an overall time-trend parameter along with the shape and scale parameters of the Generalized Extreme Value distribution. We compare our results to a model that is based on a normal distribution. Our analyses show some evidence of decaying ozone levels for the monthly maxima during the period of study.

Keywords: Trend analysis, GEV distribution, Mexico City ozone levels, Bayesian methods.

1. Introduction

For many decades environmental pollution has been a problem that affects major cities. In particular for Mexico City, with more than 21 million inhabitants in its metropolitan area, air-pollution has been historically a major concern. According to Lezama (2000), since the beginning of the 1940s, which corresponds to the start of an explosive growth in industry and population in Mexico, air pollution increments were estimated to a 3% annual rate. In addition, air visibility diminished during the 1940s and 1950s, which became a strong reason for authorities, scientists and citizens in general, to learn more about the health risks associated with exposure to atmospheric pollutants. After various years, these concerns led to the creation of Mexico City's environmental atmospheric monitoring system known as Sistema de Monitoreo Atmosférico (SIMAT).

Currently SIMAT is formed by the Red Manual de Monitoreo Atmosférico (Manual Atmospheric Monitoring Network, REDMA), the Red de Depósito Atmosférico (Atmospheric Deposit Network, REDDA), the Red de Meteorología y Radiación Solar (Meteorology and Solar Radiation Network, REDMET) and the Red Automática de Monitoreo Atmosférico (Automated Atmospheric Monitoring Network, RAMA) which continuously measures levels of ozone (O_3), sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), particles less than 10 µm (PM_{10}), and particles less than 2.5 µm ($PM_{2.5}$). Nowadays, RAMA consists of various monitoring stations across Mexico City's metropolitan area.

Table I presents information about the 29 RAMA stations that monitor O_3 concentrations over Mexico City. The name of each station followed by its acronym is included along with the geographical area to which each station belongs. We report the number of observed monthly maxima that is available for each station and for the years 2001-2014. For these years, there is a total of 168 possible monthly maxima ($T = 168$). It is worth noting that in several cases, there is a limited number of observations available due to shutdowns or recent opening of stations.

The presence of hydroxyl radicals and organic volatile compounds (OVC) in the atmosphere from natural or anthropogenic sources, produce changes in chemical equilibrium towards higher ozone concentrations. The anthropogenic sources that are more relevant as tropospheric ozone precursors are gases generated from vehicle emissions, industrial emissions and chemical sources. As described on SIMAT (2014) and SSA (2014), it is typically the case that these precursors originate in high-density urban areas and are carried by winds for various kilometers producing increments in ozone concentrations in areas that are less densely populated. High tropospheric levels of O_3 are a major cause of respiratory issues when long term exposures are predominant. Epidemiological studies have found associations between high levels of O_3 and mortality, hospital admissions and total number of emergency hospital admissions. In consequence, the Mexican official norm NOM-020-SSA1-1993 established a permissible maximum limit of O_3 of 0.11 ppm. According to Peñalosa (2014), this norm has been recently updated and a monitoring site satisfies the one-hour limit when each of its hourly concentrations is less or equal to 0.095 ppm.

Table I. Information about 29 RAMA monitoring stations.

Zone	Station	Abbreviation	Data
Northwest	Atizapán	ATI	23
	Cuautitlán	CUT	24
	FES Acatlán	FAC	168
	Tlalnepantla	TLA	168
	Tultitlán	TLI	42
Northeast	Acolman	ACO	87
	La Presa	LPR	36
	Los Laureles	LLA	39
	Montecillo	MON	166
	San Agustín	SAG	165
	Xalostoc	XAL	168
	Villa Flores	VIF	42
Center	Camarones	CAM	42
	Hospital General de México	HGM	34
	Iztacalco	IZT	90
	Merced	MER	168
	San Juan de Aragón	SJA	42
Southwest	Centro de Ciencias de la Atmósfera	CCA	5
	Coyoacán	COY	115
	Cuajimalpa	CUA	161
	Pedregal	PED	168
	Santa Fe	SFE	35
	Santa Ursula	SUR	165
	Tlalpan	TPN	138
Southeast	Chalco	CHO	87
	Nezahualcóyotl	NEZ	42
	Tláhuac	TAH	167
	UAM-Iztapalapa	UIZ	167
	UAM-Xochimilco	UAX	35

There have been several studies based on physics, chemistry and statistics dealing with how ozone concentrations in Mexico City arise from other pollutants, among them Bravo *et al.* (1992) and Cortina-Januchs *et al.* (2009). In particular, the importance of