CEST 2019

16th International Conference on Environmental Science and Technology

Rhodes, Greece, 4 to 7 September 2019

Statistical modeling of meteorological conditions and air pollution over Athens, Greece

Deligiorgi D.[1], Philippopoulos K.[1], Diamanti A.[1]

[1]Section of Environmental Physics and Meteorology, Department of Physics, National and Kapodistrian University of Athens, Athens, Greece

*corresponding author: Deligiorgi Despina: e-mail: despo@phys.uoa.gr

Abstract

The importance of meteorological parameters and topography in determining the air pollution levels in a specific area is well established. The aim of this study is to model the association between air pollution levels and meteorological parameters for a single site in Athens, Greece. The statistical analysis is based on the Multiple Linear Regression (MLR) models for simulating the relationship amongst primary and secondary pollutants (CO, NO, NO_2, O_3 and SO_2) and air temperature, wind speed, relative humidity and atmospheric boundary layer (ABL) depth. The meteorological variables are used as explanatory variables for training different statistical models for each pollutant. The analysis is performed for a twenty-year period (1990-2009) at 00Z and 12Z. Special emphasis is given to the most accurate representation of the ABL depth by using three different methods (i.e. Holzworth, virtual Richardson number and potential temperature gradient). The modeling results indicate the superior performance in the case where the ABL depth was calculated by the virtual Richardson number method. The results indicate the importance of meteorology in air quality along with the significance of other factors that increase air pollution variability in urban environments.

Keywords: air pollution, meteorology, multiple linear regression

1. Introduction

Air pollution concentrations such as NO_2, NO, O_3, CO and SO_2 in urban areas are indicative of the quality of the atmospheric air and related to the quality of life. The main factor of increased air pollution levels is attributed to the human activity and are influenced by the prevailing meteorological conditions (Jayamurugan et al. 2013, Mavrakou et al., 2014). The negative consequences of urban air pollution require statistical methods to address the relationship of ambient air quality and local meteorology. The present analysis besides the surface meteorological conditions, accounts for the ABL depth.

2. Methods, area of study and data

The area of study is the urban suburb of Nea Smyrni in Athens Greece. Air pollution concentrations are obtained from the air monitoring network of the Ministry of Environment and Energy, while the meteorological data are provided from the nearby Hellinikon meteorological station from 1990 to 2009 at 00Z and 12Z (20-year period).

Multiple linear regression analysis (MLR) was used to model the relationship between CO, NO, NO_2, O_3 and SO_2 concentrations and air temperature (T), wind speed (WS), relative humidity (RH) and atmospheric boundary layer (ABL) depth (MH). In the current study the depended variables are the air pollution concentrations while the meteorological parameters are used as explanatory variables. In more detail, regarding the ABL depth, three different methods were used:

- Holzworth method (*Hz*), where the ABL depth is defined as the height where the potential temperature profile intersects the dry adiabatic starting from the surface temperature.
- virtual Richardson number (*vRi*), where the ABL depth is defined as the height where the Richardson number is between 0.2-1, considering also the humidity by using the virtual temperature.
- potential temperature gradient (*gradT*), where the ABL depth is the height where the potential temperature gradient has its maximum value.

The analysis is performed for the entire period and on a seasonal basis. Furthermore, besides the linear expressions the MLR method was also employed, using the logarithmic values. The predictive performance of the models is examined using the correlation coefficient R between the observed and the predicted concentrations.

3. Results and conclusions

A general remark regarding the MLR equations for the entire period of study is that the best results are obtained for O_3, followed by NO_2 concentrations. In Figure 1 the scatter diagrams are presented for the pollutants under study at 12Z. The seasonal analysis reveals that the higher correlation coefficients are obtained for O_3 during spring, autumn and summer at 12Z, where temperature is the most critical predictor variable. In all other cases, the relative magnitude of the wind speed regression coefficients in the resulting MLR equations reveals the importance of wind speed in urban air pollution levels. In Table 1 the MLR models are presented for all pollutants, while in Table 2 the results of the seasonal analysis are presented for O_3 at 12Z and NO_2 at 00Z.

The use of the MLR models with logarithmic transformations of the air pollutant concentrations and meteorological parameters didn't exhibit significant improvement in the resulting correlation coefficients. Focusing on the effect of *MH* as a predictor variable, in most cases the best results are obtained using the vRi method (68.33% of the total cases), followed by the *Hz* (23.33%) and the *gradT* methods (8.33%). The results of the study exhibit the effect of meteorology in urban air pollution and the significance of additional factors that determine local air pollution variability along with the requirement of using advanced non-linear predictive models.

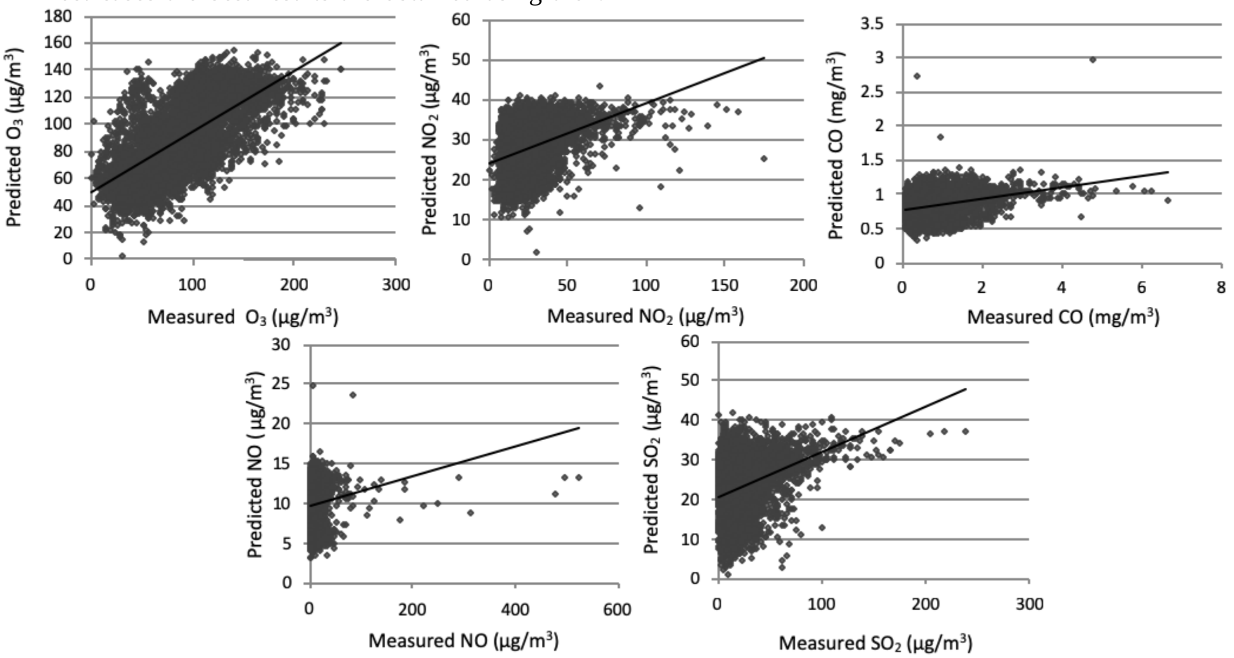

Figure 1: Comparison of the predicted and observed concentrations for the entire period for O_3, NO_2, CO, NO and SO_2 at 12Z.

Table 1: MLR models for the entire period at 00Z and 12Z

00Z	12Z
CO=0.920-0.008*T+0.003*RH-0.025*WS-0.0002*vRi	CO=0.827-0.009*T+0.004*RH+0.038*WS-0.0001* vRi
NO=10,906+0.109*T-0.023*RH-0.510*WS-0.002*vRi	NO=15.630-0.169*T+0.014*RH+0.101*WS-0.002*vRi
NO_2=49.705-0.227*T-0.019*RH-2.084*WS-0.013*vRi	NO_2=44.014-0.396*T+0.038*RH-0.189*WS-0.005*vRi
O_3=69.843+0.924*T-0.563*RH+1.559*WS+0.009*vRi	O_3=1.322-0.015*T-0.0001*RH+0.015*WS-0.0001*vRi
SO_2=37.818-0.727*T-0.185*RH-0.281*WS-0.001* vRi	SO_2=53.602-0.712*T-0.099*RH-0.052*WS-0.006*vRi

Table 2: Seasonal MLR models for O_3 at 12Z and NO_2 at 00Z (the first row corresponds to the winter period, the second for spring, the third for summer and the forth for autumn)

O_3 at 12Z	NO_2 at 00Z
O_3=17.837+1.483*T-0.026*RH-0.313*WS+0.014*vRi	NO_2=51.752-0.197*T +0.068*RH-2.190*WS-0.011*vRi
O_3=26.644+3.006*T+0.089*RH-0.050*WS+0.005*vRi	NO_2=37.665-0.133*T+0.139*RH-2.061*WS-0.013*vRi
O_3=21.559+3.308*T+0.417*RH-1.635*WS-0.004*vRi	NO_2=37.665-0.134*T+0.139*RH-2.062*WS-0.013*vRi
O_3=4.919+3.399*T-0.154*RH-0.859*WS+0.006*vRi	NO_2=69.592+0.108*T-0.311*RH-1.996*WS-0.021*vRi

References

Jayamurugan R., Kumaravel B. Palanivelraja S. and P. Chockalingam M. (2013). Influence of Temperature, Relative Humidity and Seasonal Variability on Ambient Air Quality in a Coastal Urban Area. International Journal of Atmospheric Sciences. **2013**, 264046

Mavrakou T., Philippopoulos K. and Deligiorgi D. (2012). The impact of sea breeze under different synoptic patterns on air pollution within Athens basin. Science of the Total Environment. **433**, 31-43.