Ozone prediction model in Portugal: urban and rural case studies

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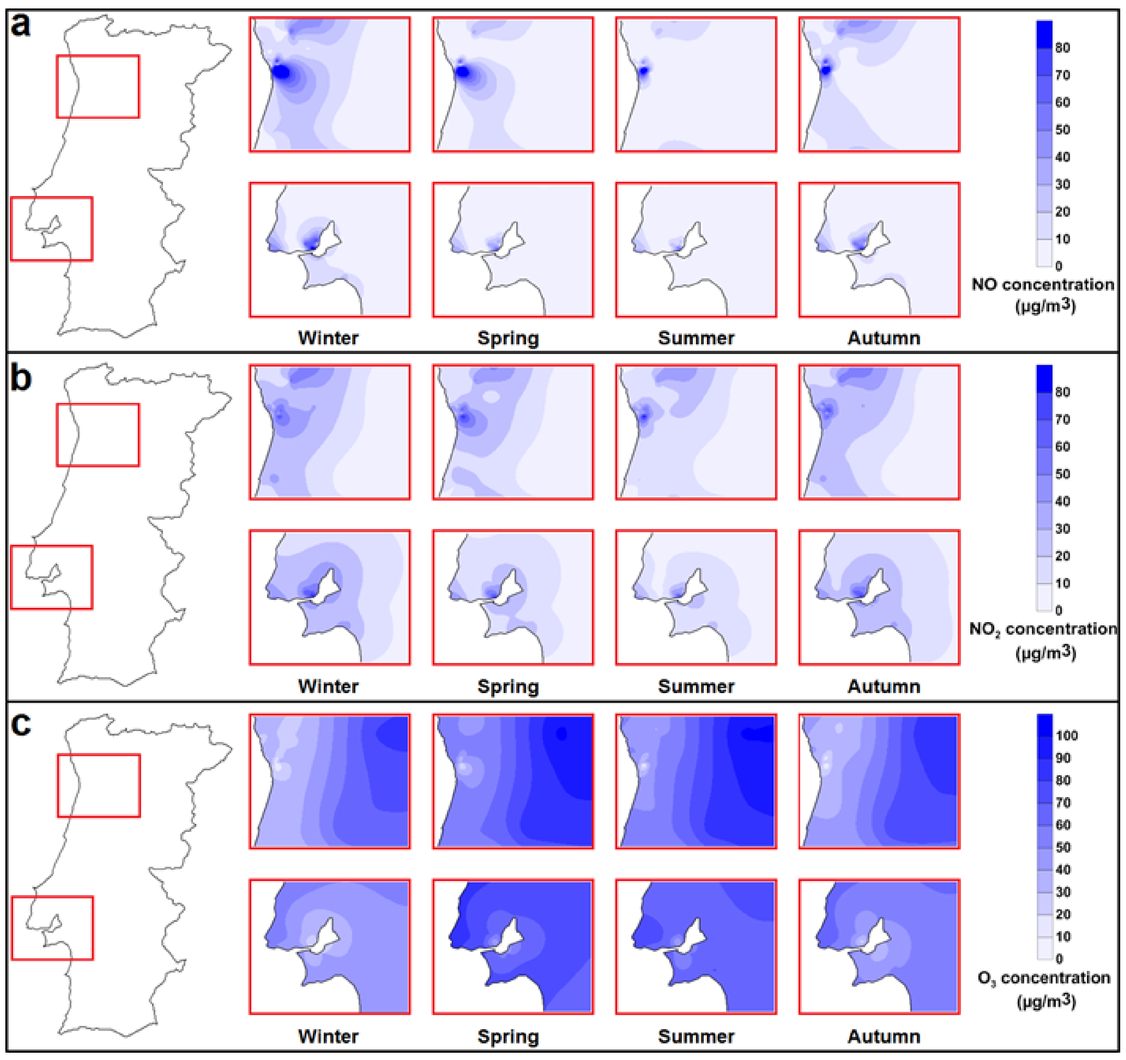
INTRODUCTION

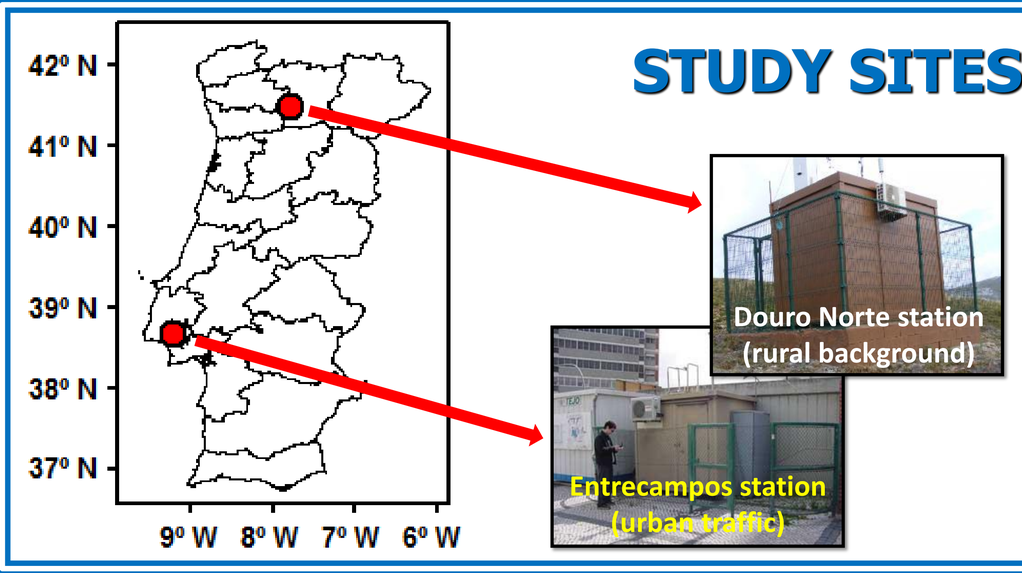
Assessment of ozone levels is essential especially in urban-industrialized areas (Melkonyan and Kuttler, 2012). For this purpose, an ozone prediction model was developed using data from the period 2004-2010 for a Lisbon urban site and a rural site of northeast Portugal (which present a completely different behaviour in terms of ozone production), based on a generalized linear model (GLM) with a log-link function. The independent variables used for studying its contribution to ozone levels were NO, NO_2, NO_X, NO/NO_2, NO_2/NO_X, SO_2, PM_{10}, temperature range (T), pressure (P), relative humidity (RH), wind speed (WS), wind direction (*sin*WD and *cos*WD), solar radiation (SR), dew point temperature (Dew) and precipitation (Precip).

Spatial distribution and seasonal patterns



Seasonally averaged (2004-2010) concentration maps of NO (a), NO2 (b) and O3 (c) for the most industrialized and urbanized regions of Portugal.

STUDY SITES



Predictor variables

Average concentration of pollutants and average values of meteorological variables recorded throughout the study period 2004-2010 for Entrecampos and Douro Norte monitoring stations.

Monitoring station	O_3 (µg/m^3)	NO (µg/m^3)	NO_2 (µg/m^3)	NO_X (µg/m^3)	NO/NO_2 ratio	NO_2/NO_X ratio
Entrecampos	42.69	28.58	48.49	92.31	0.49	0.62
Douro Norte	94.41	0.60	3.05	3.93	0.39	0.77
Monitoring station	PM_{10} (µg/m^3)	SO_2 (µg/m^3)	T (ºK)	T_{range} (ºK)	SR (Wh/m^2)	RH (%)
Entrecampos	37.14	2.84	291.24	7.93	4945.22	57.03
Douro Norte	20.03	2.04	286.74	10.43	4723.70	54.51
Monitoring station	P (hPa)	WS (m/s)	WD (º from N)	Dew (ºK)	Precip (l/m^2)	
Entrecampos	1013.67	4.79	333.90	284.26	1.79	
Douro Norte	948.07	3.42	323.70	280.27	2.47	

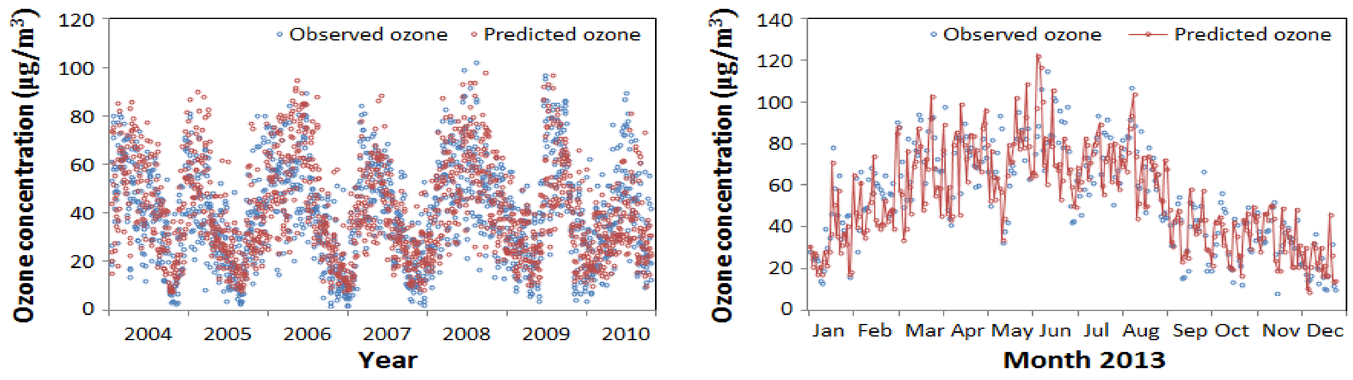
Stepwise regression model for the purpose of select the appropriate variables to predict ozone concentration in Entrecampos and Douro Norte stations.

Entrecampos	NO_2/NO_X	SR	WS	RH	sin WD	cos WD	Precip	PM_{10}	T_{range}
Adjusted R^2	0.595	0.649	0.679	0.689	0.694	0.701	0.704	0.706	0.707
F change	3150.245	327.728	202.221	69.288	38.047	51.390	22.557	16.388	5.287
Sig. F change	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.022
Douro Norte	RH	sin WD	cos WD	PM_{10}	NO_2/NO_X	SR	T_{range}	Precip	
Adjusted R^2	0.342	0.383	0.417	0.441	0.460	0.482	0.489	0.492	
F change	924.171	116.114	106.704	74.730	66.078	76.157	24.694	10.639	
Sig. F change	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	

OZONE PREDICTION MODEL

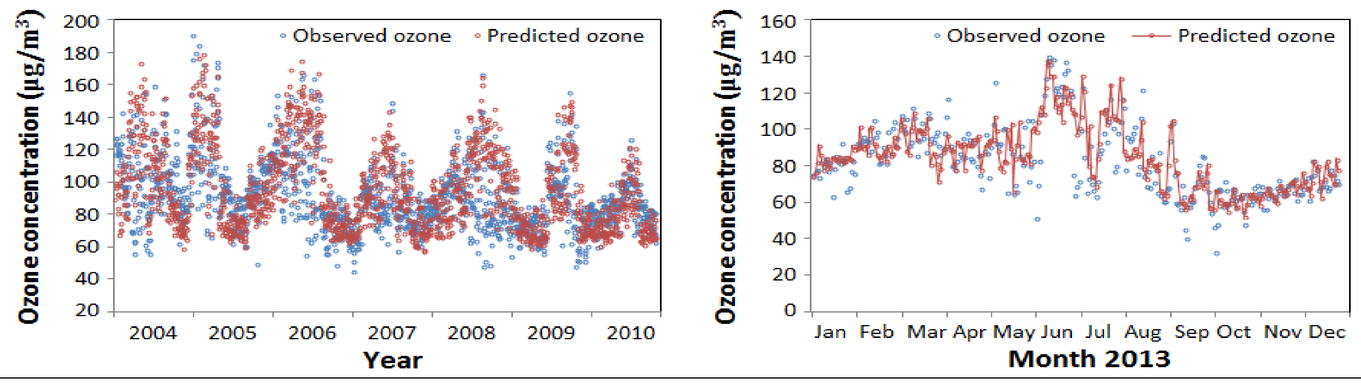
a

$[O_3] = EXP[2.509+2.079(NO_2/NO_X)+6.348\cdot10^{-5}SR+0.068WS-0.013RH-0.205WD_{sin}-0.119WD_{cos}+0.008Precip-0.002PM_{10}+0.002T]$



b

$[O_3] = EXP[4.597-0.01RH-0.034WD_{sin}-0.062WD_{cos}+0.002PM_{10}+0.219(NO_2/NO_X)+ 6.228\cdot10^{-5}SR+0.001T+0.003Precip]$



Observed and predicted values of ozone concentration provided by the GLM prediction equation for the study period 2004-2010 and for year 2013 in the urban site (a) and in the rural site (b).

The ozone concentration values obtained by the prediction equation in the urban station fit satisfactorily with the concentrations measured in the year 2013. The proposed model appears to be able to predict the most ozone extreme events in this monitoring station, as well as the ozone minimum values. The average absolute error of the prediction for the year 2013 was 9.00 µg/m^3 and 83.64 % of the absolute errors were less than 10 µg/m^3.

The fit of the ozone predicted concentrations registered in the year 2013 in the rural background monitoring station is not as high as in the case of the urban site due to the less variance in ozone concentration explained by the independent variables. Even so, the seasonal variation of ozone concentration was captured successfully by the model and the predicted ozone extreme events are seen to agree quite closely with the observed concentrations, but ozone minimum values seem to be a little overpredicted. The average absolute error of the prediction for this station was 10.24 µg/m^3 for the year 2013, whereas 78.37 % of the absolute errors were less than 10 µg/m^3.

CONCLUSIONS

For the rural site of northeast Portugal, the percentage of variance in ozone concentration explained by other pollutants is relatively low, being the meteorological variables such as wind direction, the factors that explain most of the variance. At urban traffic sites, most of the variance is explained by the NO_2/NO_X ratio. The concentration values obtained by the ozone prediction model in the urban traffic station fit perfectly with those registered on the last available validated data. In the northern rural areas, ozone minimum values seem to be a little overpredicted, but the predicted ozone extreme events are seen to agree quite closely with the observed concentrations.

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