Urban PM$_{10}$ Air Quality Indicator Sensitivity ($\star$)

Analisi di sensitività di un indicatore della qualità dell’aria per il PM$_{10}$

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1. Introduction

An Air Quality Index (AQI) is a standardized indicator of the air quality in a given location. Air Quality Strategy for Italy, fixed by the D.M.A. 02/04/2002 and related “daughter” directives, sets limits and quality objectives to protect health for the main air pollutants: Particulate Matter (PM$_{10}$), Nitrogen dioxide (NO$_2$), Sulphur dioxide (SO$_2$), Carbon monoxide (CO) and Ozone (O$_3$). Data used to compute AQIs refer to these air pollutants and are collected according to three dimensions: time, space and pollutant. In this work we’ll refer only to PM$_{10}$, particulate matter with an aerodynamic diameter less than 10 $\mu m$, and we’ll develop our analysis considering a two-dimensional synthesis, time and space, remanding the third-dimensional synthesis to a future work. There are many functions used to aggregate data on time and space. The most used in this framework are mean, median and maximum functions. The aim of this paper is to assess the sensitivity of urban PM$_{10}$ Air Quality Index to the presence/absence of each site in a monitoring network. The approach on a factorial analysis of variance will be based. Mean and median aggregating functions will be used and compared (the same function will be used to aggregate as regard both time and space). All possible combinations among monitoring sites that can be included in the AQI’s computation will be considered and results will be compared according to the impact that every site, or every combination of sites, has on the final AQI.

2. Data, method and some preliminary results

Several statistical studies have been carried out in the past to synthesize the status of air quality. They have been based on the main objective to detect an appropriate air quality index with a synthesis to time, space and pollutants. In all these works authors have tried to detect an appropriate function that, applied to elementary data, could be useful to aggregate them referring to their three dimensions: time, space and type of pollutant (Bruno and Cocchi (2002) and Murena (2004)). Bruno and Cocchi (2002) use a hierarchical aggregation process that eliminates the three dimensions and obtains the final value. Their aggregation is based on order statistics, median in particular, or maximum. Murena (2004) assumes that each station is representative of a situation of air pollution in the urban area; for this reason, a weight could be attributed to each station corresponding to the percentage of the urban area surface represented by that

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station. By the use of the mean or maximum function to aggregate data on space, a single value of AQI is obtained. But, how important is a single monitoring site value to determine the AQI value? Sensitivity analysis consists in determining the amount and kind of change produced in the model predictions by a change in a model parameter. Among methods used in literature to study sensitivity a factorial analysis of variance method has been chosen. Therefore, in order to evaluate sensitivity of mean/median-based AQI to the presence or absence of a site, or a combination of them, a matrix of dummy variables has been considered, accounting for all possible combinations among sites included for AQI computation. PM$_{10}$ data analyzed in this paper in 10 minutes step measurements are provided. They are bi-hourly aggregated and measured in 8 urban traffic sites, in the urban area of Palermo, Sicily, since 2003 to 2005. For every year, starting from PM$_{10}$ daily values, mean or median function has been used to aggregate data on space, first, and then on time (to get a yearly value). We worked on six different data sets, two data sets per year per different aggregation function used. The design matrix consists of $2^8 - 1$ rows and 8 columns. Each row represents one possible combination of presence/absence of sites, where 1 means that a site is included and 0 means that a site is non included in the AQI computation. The response column is the mean/median-based AQI computed over the running (according to the design matrix) monitoring sites. For each aggregating function and each year, the factorial analysis of variance model is:

$$Y_i = \sum_{s=1}^{S} \beta_s X_s + \sum_{s\neq t=1}^{S} \beta_{st} X_s X_t + \sum_{s\neq t\neq k=1}^{S} \beta_{stk} X_s X_t X_k + \varepsilon_i \quad (i = 1, \ldots, 255; \ S = 1, \ldots, 8),$$

where $Y_i$ denotes yearly AQI and $X_s$ dummy variables denoting presence/absence of the site. For every year, a final model has been obtained and compared to the others accounting for significant interaction terms, factors that mostly contribute to the output variability and explained model variability. Results show and highlight that AQI mean-based and AQI median-based are in the same way sensitive to presence or absence of a site, or a combination of them. All single sites are significant and decisive for urban PM$_{10}$ AQI computation. Two way interactions are not significant for couple of sites showing comparable, but with different sign, coefficients: this means that the contemporaneous presence/absence of both site data does not change the AQI value significantly. Analogous results we obtain for three way interactions. Concluding, AQI values, being influenced by the running of each monitoring site in the network, should be considered together with (or corrected by) information about a possible malfunction of one or more monitoring sites.

References


D.M.A. 02/04/2002 Valori limite di qualita’ dell’aria ambiente per il biossido di zolfo, il biossido di azoto, gli ossidi di azoto, le particelle, il piombo, il benzene ed il monossido di carbonio, *Suppl. n.77 alla G.U. n.87, 13/04/2002*.