

Sensing Systems For Environmental Measurements: Influence of Wind on Particulate Matters and Ozone

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Abstract— Particulate matters and ozone are often neglected as pollutant elements when people deal with widespread pollution. Particulate matters PM₁₀, PM_{2.5}, are produced by human activities namely industries and car traffic but also by natural activities like blowing wind from desert, volcanoes, etc... Ozone, instead, has a double consideration: it is beneficial as ozone layer in the upper atmosphere because it serves as natural filter to reduce UV rays that arrive at earth surface. But at ground level, high amounts of ozone, in terms of concentration are harmful for human health. The research presents the effect of wind in a transitional and seasonal period on particulate matters and ozone. The paper also illustrates the application of retarded differential functional equations or delayed differential functional equations for studying the effect of wind in pollution distribution.

Index Terms - Sensing system, environmental measurements, Particulate matters, Ozone, delayed differential functional equations.

I. INTRODUCTION

Atmospheric conditions such as wind speed (WS), wind direction (WD), relative humidity (RH), and air temperature (TC) gradients interact with the physical features of the landscape to determine movement and dispersal of air pollutants. Regarding to the U.S EPA, this organization has identified six criteria for air pollutants that are pervasive in urban environments and for which state and national health-based ambient air quality standards have been established. EPA calls these pollutants criteria for air pollutants because the agency has regulated them by developing specific public health- and welfare-based criteria as the basis for setting permissible levels. Short-term exposure to ozone can irritate the eyes and cause constriction of the airways. Besides causing shortness of breath, ozone can aggravate existing respiratory diseases such as asthma, bronchitis, and emphysema. Ozone is not emitted directly into the atmosphere [1], but is a secondary air pollutant produced in the atmosphere through a complex series of photochemical reactions involving reactive organic gases (ROGs) and nitrogen oxides (NO_x). ROGs and NO_x are known as precursor compounds for ozone. Significant ozone production generally requires ozone precursors to be present in

a stable atmosphere with strong sunlight for approximately three hours. Ozone is a regional air pollutant because it is not emitted directly by sources, but is formed downwind of sources of ROGs and NO_x under the influence of wind and sunlight. Ozone concentrations tend to be higher in the late spring, summer, and fall, when the long sunny days combine with regional subsidence inversions to create conducive conditions to the formation and accumulation of secondary photochemical compounds, like ozone [2]. When ozone is the only pollutant affecting air quality, the risks to people's health can be described from both short-term exposure to ozone (based on 1-hr averaged concentrations) and longer-term exposure to ozone (based on 8-hr average concentrations). Table 1 EPA scale that relates shorter and longer-term exposure to the ambient ozone concentrations, in parts per billion (ppb), to health risk.

Table 1 Air quality index for ozone

Index values(Conc. Range)	Air Quality	Caution for Ozone
0-50(0-59ppb) 51-100(60-75ppb)	Good Moderate	No health impacts Unusually sensitive people should consider limiting prolonged outdoor exertion
101 - 150 (76-95 ppb)	Unhealthy for Sensitive Groups	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion
151 - 200 (96-115 ppb)	Unhealthy	Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children should limit prolonged outdoor exertion.
201 - 300 (116-374 ppb)	Very Unhealthy	Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.

When ozone is the only pollutant affecting air quality, the risks to people's health can be described from both short-term exposure to ozone (based on 1-hr averaged concentrations) and longer-term exposure to ozone (based on 8-hr average concentrations). But ozone is produced through a complex set of chemical reactions in the atmosphere. It needs the starting ingredients of nitrogen dioxide and hydrocarbons to make the reactions happen and these gases are hugely emitted from

urban areas. Usually higher ozone can be found in a downwind direction from the urban area, since it takes a few hours for the chemical reactions to occur and form higher ozone concentrations. A given amount of pollutant gases emitted within urban areas may cause higher ozone to form a few hours downwind, but if the winds are calm, the ozone-forming reactions will occur closer to the urban source areas and cause ozone buildup in the urban cores. A lot of pollutants, including fine particles, are also released in the urban areas, and under conditions of light winds and stagnation, ozone too can build up within the urban cores. PM_{10} and $PM_{2.5}$ consist of particulate matter that is 10 microns or less in diameter and 2.5 microns or less in diameter, respectively. PM_{10} and $PM_{2.5}$ represent fractions of particulate matter that can be inhaled into the air passages and the lungs and can cause adverse health effects. Some sources of particulate matter, such as wood burning in fireplaces, demolition, and construction activities, are more local in nature, while others, such as vehicular traffic, have a more regional effect. Very small particles of certain substances such as sulfates and nitrates can cause lung damage directly, or can contain adsorbed gases (e.g., chlorides or ammonium) that may be injurious to health. Particulates also can damage materials and reduce visibility. Large dust particles settle out rapidly and are easily filtered by human breathing passages. This large dust [3] is of more concern as a soiling nuisance rather than a health hazard. The remaining fraction, PM_{10} and $PM_{2.5}$, are a health concern particularly at levels above the federal and state ambient air quality standards. $PM_{2.5}$ (including diesel exhaust particles) is thought to have greater effects on health, because these particles are so small and thus, are able to penetrate to the deepest parts of the lungs. Scientific studies have suggested links between fine particulate matter and numerous health problems including asthma, bronchitis, acute and chronic respiratory symptoms such as shortness of breath and painful breathing. Recent studies have shown an association between morbidity and mortality and daily concentrations of particulate matter in the air [4] [5]. The effects of wind on the distribution of air pollutants in the atmosphere is mainly related to the air motion, wind direction and wind speed. Wind speed determines the travel time of a pollutant from its source to a receptor and accounts for the amount of pollutant diffusion in the windward direction. The frequency distribution of wind direction indicates the areas toward pollutants are most frequently transported.

II. MATERIALS AND METHODS

ISAC-CNR manages a Mobile Laboratory for environmental surveys, developed in collaboration with the Environment Office of the Province of Lecce, for analysis of the dispersion of pollutants and air quality applications. The Mobile Laboratory is fully equipped to take measurements of meteorological/micrometeorological (wind velocity and wind direction, temperature, relative humidity, rain, heat fluxes and fluxes of $PM_{2.5}$ or ultrafine particles). It is also equipped with samplers of atmospheric particles of different size (PM_{10} ,

$PM_{2.5}$ and $PM_{1.0}$) and gas detectors (NO_2 , NO , NO_x , O_3 , Benzene, Toluene and Xylene). For specific applications, it is possible to increase the available instrumentation with an optical photometer (Mie PDR-1200) for measuring real-time concentration of $PM_{2.5}$ and a counter CPC Grimm 5.403 for ultrafine particle measurements. Fig. 1a to c show materials of the mobile laboratory environmental surveys [6].



Fig.1a. Mobile laboratory for environmental surveys



Fig.1b. Mobile laboratory for environmental surveys



Fig.1c. Mobile laboratory for environmental surveys

A special high-capacity server stores some data obtained at the

experimental field of ISAC-CNR and at others sites obtained using the Mobile Laboratory for environmental surveys. It is also connected permanently to the sodar system PC-MTSodar and continuously upgrades a web database that could be polled from the interactive web portal. In addition, the system creates an archive of “raw” data in duplicate.

III. RESULTS

In this research we take into account data measurements from the meteorological/micrometeorological Servers Center of the ISAC-CNR in Italy (wind velocity and wind direction, temperature, relative humidity, rain, Ozone, heat fluxes and fluxes of $PM_{2.5}$ or ultrafine particles) collected within a transitional and seasonal period of three months (from March to May). Figg.2a to c show the evolution of 4 meteorological parameters (wind speed, temperature, relative humidity, and rain) during every last week of the three selected months with respect to the transitional and seasonal period.

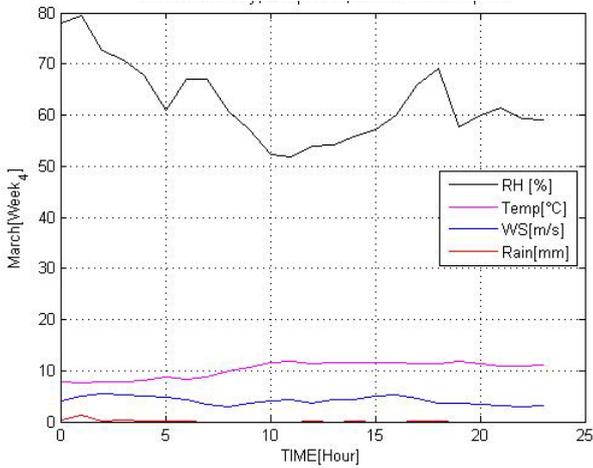


Fig.2a. Evolution of 4 meteorological parameters during March

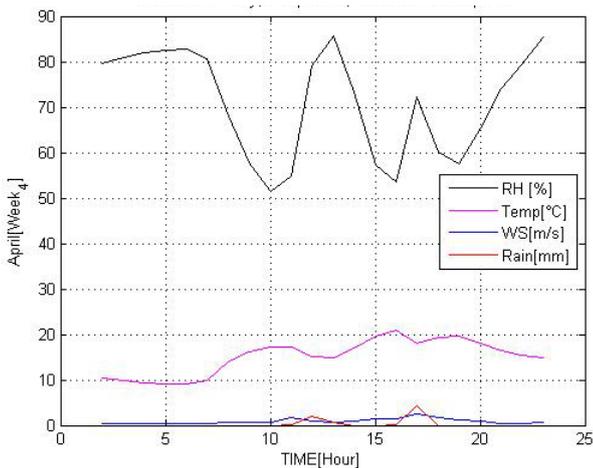


Fig.2b. Evolution of 4 meteorological parameters during April

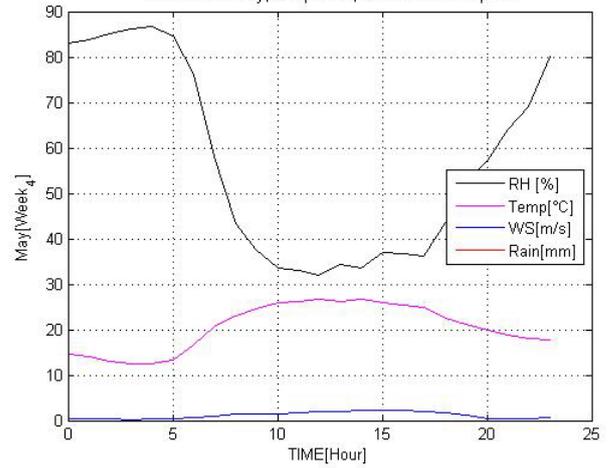


Fig.2c. Evolution of 4 meteorological parameters during May

Fig 3a to c present the trend of ozone within the transitional and seasonal period of March to May.

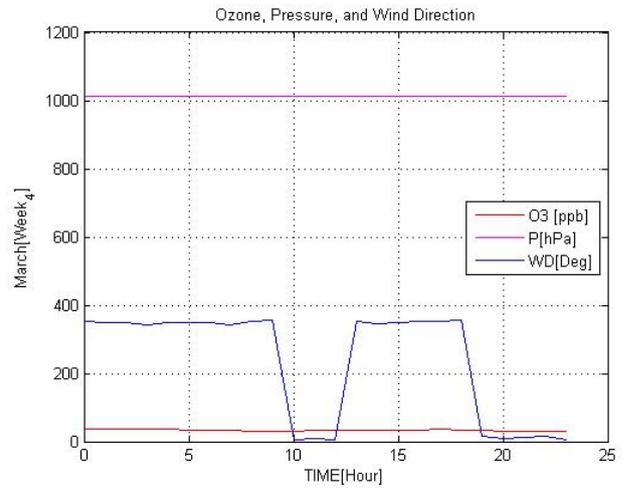


Fig.3a. Evolution of 4 meteorological parameters during May

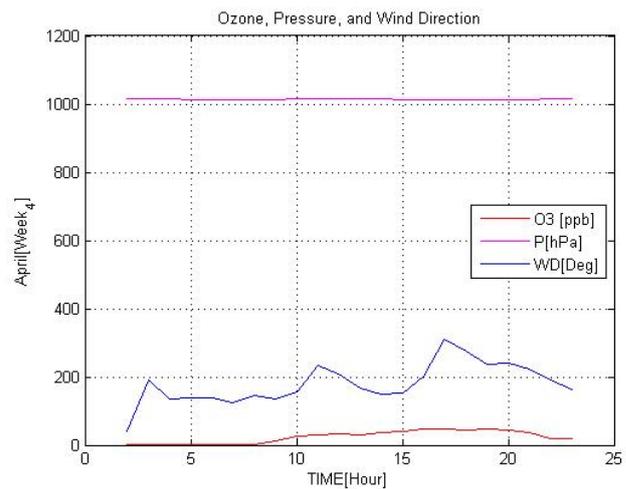


Fig.3b. Evolution of 4 meteorological parameters during May

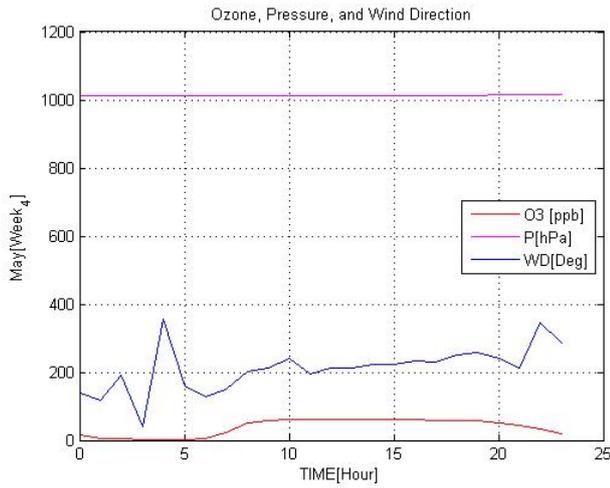


Fig.3c. Evolution of 4 meteorological parameters during May

It is shown that the concentration of ozone is steady in march and fluctuating in april and may with respect to wind direction and speed. We illustrate the application of retarded differential functional equations or delayed differential functional equations [7] for studying the effect of wind in pollution distribution. The techniques introduced here are based on Delayed Differential Equations (DDEs). DDEs are a generalization of ordinary differential equations (ODEs) with time delays. DDEs have to be used to describe the underlying dynamics in particular physical and biological processes [8]. Such processes are typically characterized by a delayed reaction. Delay differential equations (DDEs) are a type of differential equation in which the derivative of the unknown function at a certain time is given in terms of the values of the function at previous times. A general form of the time-delay differential equation for $x(t) \in \mathbb{R}^n$ is presented as follows:

$$\frac{d}{dt} x(t) = f(t, x(t), x_t) \quad (1)$$

Where, $x_t = \{x(\tau) : \tau \leq t\}$ represents the trajectory of the solution in the past and f a functional operator from $\mathbb{R} \times \mathbb{R}^n \times C^1(\mathbb{R}, \mathbb{R}^n)$ to \mathbb{R}^n . Delayed differential equations (DDEs) differ from ODEs in that the derivative at any time depends on the solution at prior times (and in the case of neutral equations on the derivative at prior times). DDEs often arise when traditional pointwise modeling assumptions are replaced by more realistic distributed assumptions. With constant or state-dependent 'point' delays $\tau_i(y(t))$ as expressed in (2):

$$\frac{d}{dt} y(t) = f(y(t), y(t - \tau_1), y(t - \tau_2), \dots, y(t - \tau_m)) \quad (2)$$

In this paper we use this simplest linear DDE as model $y'(t) = y(t - 1)$ on the interval $[0, 5]$ with history for $t \leq 0$, The history has jump discontinuities prior to $t = 0$. With a delay of 1, thus only jumps that occur at $t \geq -1$ can have

an effect in $[0, 5]$. Fig.4 shows an application of the DDE for studying the effect of wind in O_3 distribution within the last week of may.

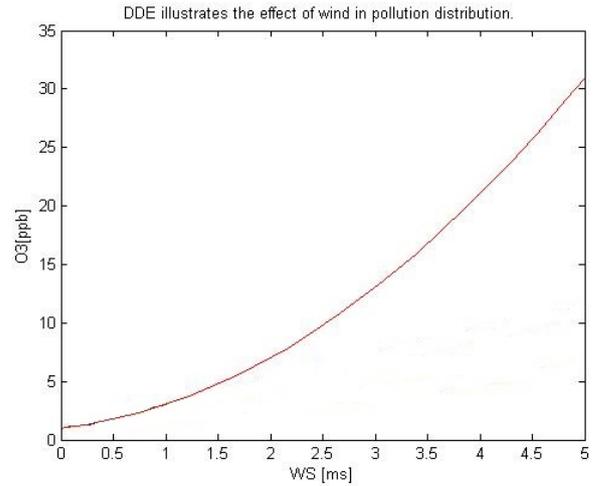


Fig.4. Illustration of DDE for studying the effect of wind in pollution distribution.

We illustrated the straightforward solution of a simplest linear DDE model for computing and plotting the wind effect in O_3 pollution distribution.

IV. CONCLUSIONS

Air quality plays a key role in city governance according to environmental viewpoint. Macro and micropollutants must be put under control and monitored [9] [10] [11]. In this work, we illustrate the application of retarded differential functional equations or delayed differential functional equations for studying the effect of wind in pollution distribution. The techniques introduced here are based on Delay Differential Equations (DDEs). The research also presents the effect of wind in a transitional and seasonal period on particulate matters and ozone.

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