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Combining environment and health information systems for the assessment of atmospheric pollution on human health

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HIGHLIGHTS

- Air-quality data has been combined with population maps in order to assess estimated health effects.
- We used of in-situ micro sensors for measuring air pollution for 5 regulated gases.
- We examine concentration in comparison to data from conventional monitoring instruments.
- Explained how these sensors can be used by citizens in existing networks.
- Explained possible associations between satellite and in-situ observations.
- We have outlined new areas of regulatory application with merging sensing technologies with real-time temporal verifications.

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ABSTRACT

The use of emerging technologies for environmental monitoring with satellite and in-situ sensors have become essential instruments for assessing the impact of environmental pollution on human health, especially in areas that require high spatial and temporal resolution. This was until recently a rather difficult problem. Regrettably, with classical approaches the spatial resolution is frequently inadequate in reporting environmental causes and health effects in the same time scale. This work examines with new tools different levels of air-quality with sensor monitoring with the aim to associate those with severe health effects.

The process established here facilitates the precise representation of human exposure with the population attributed in a fine spatial grid and taking into account environmental stressors of human exposure. These stressors can be monitored with innovative sensor units with a temporal resolution that accurately describes chronic and acute environmental burdens.

The current understanding of the situation in densely populated areas can be properly analyzed, before commitments are made for reductions in total emissions as well as for assessing the effects of reduced trans-boundary fluxes. In addition, the data processed here with in-situ sensors can assist in establishing more effective regulatory policies for the protection of vulnerable population groups and the satellite monitoring instruments permit abatement strategies that are close to real-time over large geographical areas.

1. Introduction

For determining the status of air pollutants such as CO, NO_2, NO, O_3, C_6H_6 and PM_x, monitoring stations are usually placed at the centre and periphery of urban areas as well as in surrounding rural areas. The procedure of positioning these stations is different from country to country and the measuring instruments employed vary for different pollutants. In addition, for generalization purposes it is essential to demonstrate the geographical representation of measurements. It is well known that this depends greatly on the complexity of topography and the existence of nearby emission sources (either from the industry, power stations or even the transportation infrastructure). For several European metropolitan areas, these complexities prevent the establishment of representative urban monitoring stations in most domains. Furthermore, the annual availability of these data is not usually 100%, mainly due to frequent calibration needs or due to simple malfunctions (reasons that are taken into account in air-quality regulatory directives). For these reasons since the late nineties, we have been

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developing devices that could be utilized on real-time, ideally have low cost, be mobile and simple to operate so that could be used in existing network by ordinary citizens.

At the same time we have been looking into sensors that could be deployed in satellites and can characterize the local level of atmospheric pollution with the same instrument over large geographical areas. The aim of such sensors was to have available data with instruments that can provide details in high spatial resolution and at the same time characterize the air pollutants at different heights in the vertical column along the trajectory of the satellite pass.

Modern mobile telecommunication needs have financed the deployment of a dense network of ground and satellite based telematic stations that can relay an enormous number of data and internet sharing among users. These infrastructures are capable of handling more citizen activities. In particular, they can describe accurately the randomness of human behavior. For example if there is real danger from anthropogenic emissions we need to know why a certain number of cars need to utilize a certain piece of road at a specific time of a day. Certainly we need also to know where this pollution is dispersed. Efforts therefore are being made to set up information systems, which link health effects to environmental causes through a set of monitoring parameters, which are generally referred to as indicators. Unfortunately, these are usually inadequate to identify concretely the health and environment effects. Nor, it was possible to characterize with such indicators peak health events that occur at specific locations (hot spots) during specific episodes. Hence, large area averaging and reporting over the whole year are not sufficient and result in doubtful conclusions or even to incorrect abatement approaches.

Impact assessment has also to consider that both human and environmental populations consist of individuals – every one of whom reacts in a unique way to a challenge or stressor. The key concept is high spatial resolution monitoring of populations susceptible to specific environmental hazards. Existing ground and remote telecommunication infrastructures can change drastically the monitoring of ambient (outdoor and indoor) air pollution and enhance the use of low cost innovative applications for the abatement of environmental pollution. The potential benefits from the deployment of a network of sensors are already realized (Skouloudis, 2010) and knowledge of population exposure, with the use of existing tools, can lead to the accurate characterization of health effects. Such sensor networks can be coupled with a wider use of earth observation that can assist in facilitating the monitoring and reporting requirements in high resolution and promote the development of new applications for Environment and Health protection strategies. These observations also harmonize reporting and provide a systematic warning of legislative violations.

2. In-situ sensors for atmospheric pollution

A pilot unit has been installed for a testing period of nine months and stayed operational for more than three years. This unit is equipped with five sensors for the measurement of CO, NOx, NO2, O3 and C6H6. Contrary to conventional monitoring devices, this unit is a system capable of recording values with a frequency of a few seconds and storing the values locally for transmission to a remote based data storage system. Hence, hourly values can be real temporal average of 120 measurements made every 30 s instead of instantaneous values obtained every 60 minutes. Such high frequencies have the advantage that can verify precisely peak concentrations and represent the time series far better than the existing air-quality regulations. It might have the disadvantage of costly data transmission but is this resolved by intelligent devices that can store data for later transmission during off-peak hours. Hence costly remote interrogations can be also avoided.

Such devices (Fig. 1) have been tested for several years at full-scale monitoring and there are several referred publications (Kappler et al., 2001; Capone et al., 2001; Reichel et al., 2003; Sberveglieri, 2006; Barsan et al., 2007; Rickerby and Skouloudis, 2014), with intercomparisons carried out with conventional monitoring in difficult sites next to ports (Fig. 2) or industrial installation or in locations near to heavy traffic and street canyons (Fig. 3). The inter-comparison at such sites we used for demonstrating the capabilities at various ranges of concentrations, at different climatic conditions and difficult environments where other types of monitoring could not be implemented.

Prior to full scale deployment a pilot unit has been utilized as a plug and play monitoring device over several months. The purpose of such deployments is not to inter-compare with conventional tools, nor the reporting for this single system for air-quality standards, but a demonstration of the capabilities of these systems to measure concentrations at a rate that other systems cannot do. Such comparison examples are shown for two of the five gases (CO and C_6H_6) at Fig. 4.

The monitoring was carried out during the spring of 2009 then the unit of the sensors was moved to another location. A similar graph for the same gases is shown at Fig. 5 for the summer of the same year. The comparison reveals that such units with the multi-gas sensors are capable to reproduce the concentrations from the conventional measuring instruments. Are also capable for the real-time temporal characterization of peaks because the sensors have a higher frequently of measuring than conventional stations. These units can be also utilized for attributing human exposure to specific residential areas without the need to refer to exposure boxes. It should be also taken into consideration that the sensor units do not have need for repetitive calibration

a b

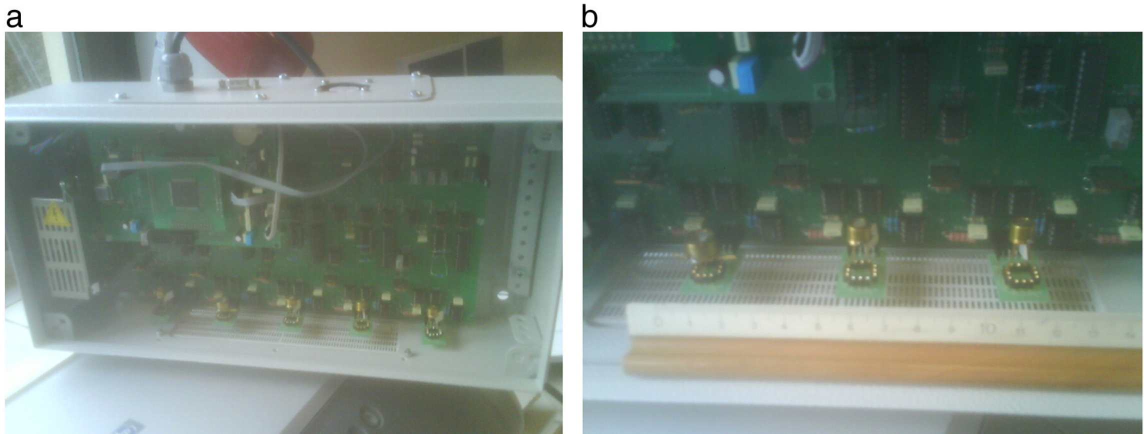

Fig. 1. A depict of the sensor unit (a) including the communication device and the sensors for CO, NO_x, NO_2, O_3 and C_6H_6. Close up of three sensors (b) next to the monitoring inlet.

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