THE WEBAIR -2 PROJECT': WEB AND 3G MOBILE PHONE BASED AIR QUALITY MANAGEMENT: PARTICULATES, PUBLIC HEALTH, CO-BENEFITS

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ABSTRACT

This paper presents an overview of the general methodology followed in the 'WebAir-2' project (Eureka Project). WEBAIR-2 will follow-up on E!3266 WEBAIR, extending scope and IT technologies employed to (1) particulates (PM10/2.5) emission modelling and public health, (2) CO2/GHG emissions, energy efficiency and the co-benefits between Kyoto targets and air pollution, and (3) use of 3G mobile phone technology. In detail specific particulates PM10 and PM2.5 will be modelled based on remote sensing data and techniques for large-scale synoptic observations. Due to inadequate spatial-temporal coverage of air pollution from existing air pollution stations, MODIS (Moderate Resolution Imaging Spectroradiometer) products will assist to this task both spatial and temporal. The statistical AOD (Aerosol Optical Depth) model will be cross-validated during satellite overpass based on handheld sun-photometers and daily CIMEL sun-photometer (NASA/AERONET network) measurements. Moreover ground LIDAR measurements for vertical distribution of the aerosols will be carried out. The results will be validated with ground data from air quality stations.

1. INTRODUCTION

Aerosols have an impact on the climate which is not yet well understood and quantified (Intergovernmental Panel on Climate Change, 2007). Aerosols also affect human health (Brunekreef and Holgate, 2002) and the range of activities through alteration of visibility (Wang et al., 2009). Aerosol monitoring requires data with high spatial resolution. Networks of ground-based measurements such as air-quality stations or Sun photometers (Holben et al., 1998) provide accurate information (aerosol mass and optical depth/properties, respectively) at specific sites with high temporal resolution but they lack a needed continuous spatial coverage. The determination of the aerosol spatial and temporal distribution remains challenging from the modeling point of view (Cuvelier et al., 2007), because of relatively short lifetimes of aerosols, high variability of species, sources, sinks and physical-chemical transformations. A rapid development of satellite sensors in the last decades allowed quantification of aerosol properties within the spatial and temporal coverage specific to polar orbiting (Yu et al., 2006) and geostationary platforms (e.g Prados et al., 2007). The MODIS onboard the polar orbiting TERRA and AQUA satellites provide a global daily coverage at the equator per instrument and a higher coverage toward the poles. Both these products, which have a spatial resolution of 10 km, are intended for continental/ global applications. In order to measure the air pollution a Lidar and a sun-photometer system were established at the Cyprus University of Technology, which is located at the city of Lemesos in Cyprus. With the aid of satellite images and ground measurements, the Remote Sensing Laboratory of the Cyprus University of Technology is monitoring pollution at a citywide level (Retalis et al. 2009). Satellite remote sensing is a valuable tool for assessing and mapping air pollution due to its major benefit of providing complete and synoptic views of large areas in one snap-shot image, on a systematic basis due to the sufficient temporal resolution of various satellite sensors and thus, can be used to assist in air quality monitoring.

2. METHODOLOGY

The methodology adopted in WEBAIR-2 project (Eureka Project) will follow-up on E!3266 WEBAIR for urban and industrial air quality management. It will be include: Particulates (PM10/2.5) emission modelling and public health, with emphasis on the political controversial concepts of local traffic reductions by various regulatory and economic instruments; CO2/GHG emissions, energy efficiency and the co-benefits between Kyoto targets and finally an alert system based on 3G mobile phone technology for personalized health related information, warnings and exposure reports.

One of the major scopes of the WEBAIR-2 is the determination of contribution of the local versus long range transport aerosols. For this purpose combined monitoring data analysis supported by long-range transport modelling and remote sensing for large-scale synoptic observations will be used. The dataset that will be used in this study are given in the following.

2.1 Satellite data

In this study the daily level-2 AOD data Collection 5 (C005) Level 2 from the Terra and Aqua MODIS aerosol products (MOD04 L2, MYD04 L2) have been used through the MODIS webpage (http://ladsweb.nascom.nasa.gov/data/search.html). The Aerosol Optical Depth (AOD) values are retrieved by MODIS at 550 nm for both ocean (best) and land (corrected) as described by the MODIS sensor website (http://modis-atmos. gsfc.nasa.gov/products.html). Over land, the collection 005 eliminates loadings and underestimation for high loadings (e.g. Mi et al., 2007), which existed in previous collections. Collection 005 also expands MODIS AOD coverage to bright desert surfaces by using the deep-blue retrieval algorithm (Hsu et al., 2006). Over oceans, the MODIS AOD is systematically higher than that from the GACP aerosol product (Geogdzhayev et al., 2004). The three aerosol products to be employed in the WEBAIR-2 are: 1) the AOD at 550 nm, 2) the aerosol Ångström exponent (derived from AOD data at 440 and 670 nm) and 3) the aerosol integrated mass concentration (in μg/cm3). The uncertainties in determining these three aerosol parameters are different for each algorithm and are mainly attributed to the non sphericity of the aerosol particles, the different algorithms used over land and ocean and the sub-pixel water contamination. These uncertainties usually lead to overestimation of the AOD (Chin et al., 2004).
The MODIS aerosol retrieval is calculated on a 10x10 km resolution (known as Level 2 data), and is directly retrieved from the radiance data observed by MODIS (Level 1B data). Since the radiance/reflectance data are observed at 500 m (for most channels), this means that the 500-m data are aggregated into these 10-km boxes (i.e., a 20x20 box of radiance data). Clouds are screened within the 20x20 km box (Levy et al., 2007) and the aerosol retrievals are performed if there are sufficient numbers (approximately 10% remaining) of non-cloudy (or otherwise not masked) pixels. Therefore, the 10-km (Level 2) products may be valid even when the considered box is 90% cloudy.

2.2 Sun-photometer

Additionally, data from CIMEL sun photometer operated by CUT (Cyprus University of Technology) will be used in the present study. CIMEL sun photometer is an automatic sun-tracking and sky-scanning radiometer which makes direct sun measurements with a 1.2^{o} field-of-view, in the spectral bands of 440, 500, 675, 870, 940 and 1020 nm. Taking into account all the information about the instrument precision, calibration precision and data accuracy (Holben et al., 1998), the accuracy of the aerosol optical depth (AOD) measurements is estimated to be of the order of ±0.02 regarding the level 2 (cloud-screened and quality-assured) data (http://aeronet.gsfc.nasa.gov/) and of the order of ±0.03 regarding the level 1.5 (cloud-screened) data. Taking the ratio between the AOD at wavelength λ_1=440 nm and λ_2=870 nm, one can derive the Ångström exponent (AE), which provides the spectral dependence of the AOD in the visible domain. The Ångström exponent value depends mostly on the aerosol size distribution.

2.3 Lidar System

Within WEBAIR project ground based lidar measurements will be used. The Raymetrics Backscattered Lidar, located in the Lemesos area will be used for this purpose. The Lidar emits a collimated laser beam with a repetition rate of 20 Hz, in the atmosphere and then detects the backscattered laser light from atmospheric aerosols and molecules. The CUT lidar system is an elastically backscattered lidar operating at 532 and 1064 nm, equipped with a depolarization channel at 532 nm that provides high-resolution vertical profiles of aerosols and clouds from 170m up to free troposphere.

3. RESULTS AND DISCUSSION

Lemesos is an Eastern Mediterranean seaside city located in Southern coast of Cyprus. Under favourable meteorological conditions (sea breeze and calms) and due to the trans-boundary pollution (forest/biomass burning fires, dust from Saharan region, etc.), the concentration of air pollutants may exceed the air quality standards of the European Union and the World Health Organization (WHO). Thus, the
Satellite remote sensing is certainly a valuable tool for assessing and mapping air pollution due to their major benefit of providing complete and synoptic views of large areas due to the good temporal resolution of various satellite sensors. AOD is considered as the main parameter that is used to assess air pollution. MODIS on board the Earth Observing System (EOS) Terra and Aqua satellites is a sensor with the ability to

measure the total solar radiance scattered by the atmosphere as well as the sunlight reflected by the Earth's surface and attenuated by atmospheric transmission.

The C005 Level 2 MODIS aerosol products concerning Lemesos, Cyprus (34. 67°N, 33.04°E) have been used in our syudy. Validation of satellite aerosol retrieval is commonly performed by means of direct comparison with a reference AOD retrieved by AERONET Sun photometers. In this study, the quality assurance of the MODIS optical parameters was established from a ground based continuously operating scientific instrument. Under the aegis of the CUT, the ground based Remote Sensing Station is operating continuously to monitor atmospheric pollution levels over the city of Lemesos in Cyprus. This station is equipped with a CIMEL sunphotometer (fully operating since April 2010), which is part of the global network AERONET (hhttp://aeronet.gsfc.nasa.gov). The availability of AERONET Level 1.5 AOD data in the years 2010 and 2011 is about 250 days of observations for each year, with the exclusion of one season due to the calibration of the instrument. The AERONET data are available between morning and afternoon observations. The mean daily Level 1.5 AOD values obtained from the CIMEL used in this study. For the validation approach, we considered all pixels from satellite data within 25km from the Sun photometer location.

The correlation coefficient between the CIMEL (500nm) and MODIS AOD (550nm) data over the city of Lemesos is presented in Figure 1, which demonstrates a sufficiently good agreement between the values obtained by two instruments. The MODIS data on board in Aqua satellite shows a better agreement than Terra data for the 2 years period.

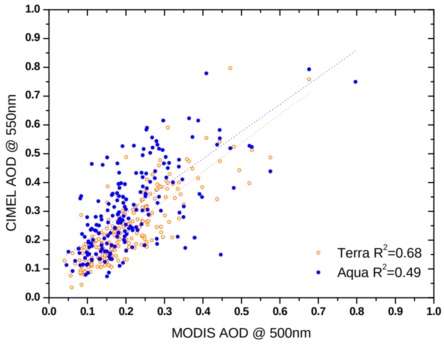

Figure 1: Correlation coefficient between AOD values obtained by MODIS (550 nm) and CIMEL (500 nm).

In Figure 2 we present the temporal variability of AOD at UV, Vis and IR as well as the Ångström exponent at 380/500nm over Lemesos, retrieved from AERONET data. The seasonal variability of the aerosol optical properties is strongly related to the seasonal characteristics of aerosol production and transportation processes, over specific regions. As can be seen from Figure 2, the AOD reach maximum values during spring (0.30 at 500nm) and summer (0.5 at 500nm), and more specifically during the months June and July. Lower AOD values appeared during winter months mostly because of the aerosol washout by rain, but also due to the absence of Saharan dust transport events, forest fires or polluted air mass transportation coming from anthropogenic sources from Asian Continent.

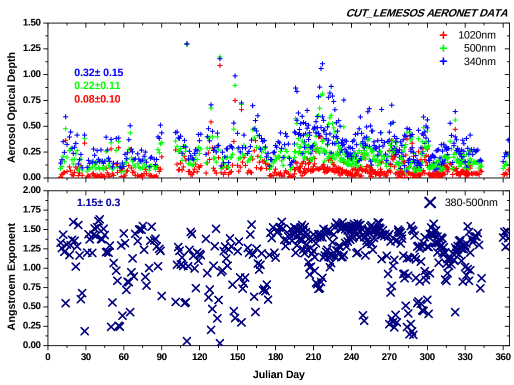

Figure 2: Temporal variability of AOD at 30, 500 and 1020nm and Ångström exponent at 380/500nm, as retrieved by CIMEL data.

The strong variability of the AOD over Lemesos is also demonstrated by the aerosol integrated mass concentration variability from MODIS data (not shown here). In addition, the Ångström exponent which had a mean value of 1.15, varied from 0.2 up to 1.7. This large variability is directly related to the aerosol size (big up to small particles), during the studied period. Low values of Ångström exponent (accompanied with high AOD value) is linked with coarse particles suspended in the atmosphere, usually dust particles from Saharan desert. On the other hand, the high Ångström values are linked with fine particles, mainly of anthropogenic origin. The higher AOD values measured during spring and summer months are due to Saharan dust events over the greater Mediterranean region; very high AOD values measured in some specific days of extreme dust events could then affect the mean AOD monthly value, as well (Papayannis et al., 2005). At this point we would like to comment on the great importance of the geolocation of Cyprus, which is on the crossroad of three continents, thus it is affected from air masses coming from Europe, Asia, as well as from dust particles coming from Saharan region.

4. CONCLUSION

WEBAIR-2 expands the basic air quality modelling technology (web-based client server) developed in E!3266 WEBAIR in several ways. The Particulates PM_{10} and $PM_{2.5}$, dynamic modelling of particulates emissions will be studied concerning: (a) Natural surfaces (dust) dynamic entrainment with high-resolution temporal meteorological data; (b) Traffic, as a function of road surface vehicle fleet composition and speeds, estimating both combustion (especially from diesel engines) and mechanical (abrasion) contributions; (c) Construction activities with emphasis on temporal patterns (activity planning using distributed access and editing possibilities) and surface mining; (d) Large scale synoptic validation including long-range transport at a European scale (EMEP) combining three level nesting of simulation with remote sensing data (AOT);(e) Public health effects (dynamic non-linear exposure, in-door pollution). The Kyoto targets will be considering in case of CO_2/GHG emissions. As final product, a 3G mobile communication will be used to provide information and alerts for air quality conditions to the users.

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