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MAPPING OF URBAN ATMOSPHERIC POLLUTION IN THE NORTHERN PART OF ALGERIA WITH NITROGEN DIOXIDE USING SATELLITE AND GROUND-TRUTH DATA

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ABSTRACT: Atmospheric pollution is a major concern in many countries. The case of Algeria’s megacities which have known recently rapid urbanization and remarkable development in various sectors, demonstrates the air quality degradation. Moreover, the intensive industrial activities, inadequate waste disposal, mining, energy production and transport have introduced excessive amounts of pollutants into the ambient air. These factors are contributing to the increase in the number of potential sources of air contamination. The aim of the present study is to estimate the air pollution with nitrogen dioxide in the northern part of Algeria using the satellite and ground-base data. Assessment of atmospheric pollution with NO_2 is carried out using to the data of satellite spectrometer EOS / OMI, information products Level 3 from Goddard Earth Sciences Data, (GES DISC) NASA for 2006-2009. According to the results study, the concentration of NO_2 in the air of the metropolis of Algiers exceeds twice the value of the maximum allowable concentration. However, slightly lower content of NO_2 in the air near the cities recorded Mascara, Skikda, Oran and Annaba. Based on the results of the present study, it was found an increased risk of accumulation of NO_2 on the above urban agglomerations. The findings in this study will help to create awareness of air pollution to Algeria’s policymakers in the mitigation of atmospheric pollution, and serve as a stepping stone towards air pollution monitoring, risk assessment of acid rains local and regional negative impact.
Keywords: air pollution, remote sensing, NO_2**,** Samasafia**,** northern Algeria**.**

INTRODUCTION:

Air pollution generated by rapid urbanization, population growth and industrialization has taken alarming dimensions. To prevent further decline of air quality, scientific planning of analysis methods and pollution control are required. Within this framework it is necessary to (i) analyze and specify all pollution sources and their contributions to air quality; (ii) study the different factors which cause the pollution; and (iii) develop tools to reduce pollution by introducing control measures and alternatives to existing practices (Kolehmainen, 2004). Air pollution concentrations are a combination of pollutant emissions, chemical and physical processes in the atmosphere, earth surface properties and geometry. The pollutant chemical reactions depend on ambient air conditions and are generally influenced by short-wave radiation, air temperature, wind speed, wind direction and relative humidity (Elminir, 2005). It is extremely important to consider the effect of meteorological conditions on air pollution, because they directly influence the dispersion effect of the atmosphere. Severe pollution episodes in the urban environment are not usually attributed to sudden increases in the emission of pollutants, but to certain meteorological conditions which decrease the capacity of the atmosphere of dispersing pollutants (Ziomas *et al.*, 1995).

It is known that the degree of atmospheric pollution from anthropogenic sources depends on the particular combination of meteorological factors. At constant parameters of the level of atmospheric pollution emission direction is determined, the type and dispersion contaminants in the air, the intensity of solar radiation, which results photochemical reactions of toxic substances, the appearance of secondary pollution products, increase the amount and duration rainfall patterns facilitating "washing out" of impurities from the atmosphere. Diffusing ability of the atmosphere depends on the vertical distributions of temperature and wind speed conditions, the intensity of turbulent exchange of air layers (Crutzen, 1979). As a result, in one case, some substances will spread over long distances from the pollution source and in the other – to concentrate in the vicinity of their release. In the last decade, due to the resumption of the pace of industrialization and urbanization, air pollution has become a major environmental problem in the industrial in the northern cities of Algeria (Benouar, 2006).

The constant excess of maximum permissible concentration (MPC) in terms of technogenic dust, nitrogen dioxide, carbon monoxide and some other pollutants in the atmosphere of urban agglomerations leads to the formation of acid rain, photochemical smog, increased health problems among the local population and, in particular, children (Benaissa *et al.*,2014). The danger of acid rain is that they may fall at a distance of many hundreds or thousands of kilometers from the source of the primary release of substances. Nitrogen dioxide formed by the oxidation of air nitrogen at high temperatures, as well as

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decomposition and oxidation of the nitrogen compounds present in the fuel.

In the atmosphere nitrogen dioxide is supplied as a warm emission from large industrial plants and power plants as well as “low” cold emissions of transport. Houses, high industrial buildings in the city form an uneven surface which becomes an obstacle to the free movement of large air masses and thus alters the structure of air. Taking into account that the surface of the city and developed a more intersected than the same equal to the area of rural location, where there is a formation of the phenomenon called “heat island” (Stankevich *et al.*,2013). These differences lead to greater absorption of solar energy in the city during the day and store it in a long period of time at night. As a result, powerful streams of warm air masses in the center of the city rise into the upper atmosphere, taking with itself a share of pollutants. This stream is then diverges in all directions, and is cooled down on the outskirts of the city, where in the ground layer moves back to the center. Therefore, air circulation is formed, which is itself maintains and may be broken only powerful air stream. In this regard, the calm days under the dome smoky urban pollutant concentrations are increased.

The aim of our study was to analyze the time series by comparing the stationary surface and satellite observations of atmospheric pollution with NO_2 in the northern part of Algeria.

SATELLITE REMOTE SENSING SYSTEMS OF ATMOSPHERE

The basic principle of remote sensing of the atmosphere is to measure the spectral intensity of electromagnetic radiation in certain spectral bands to determine the physical medium parameters. This is possible due to the presence of spectral absorption lines and its own infrared or microwave radiation according to Kirchhoff's law. Hence, the spectral intensity of radiation passing through the atmosphere it is a function of gas composition and temperature (Maini *et al.*, 2011).

To measure the parameters of the Earth’s atmosphere, specialized optical or microwave sensors are used on satellite remote sensing systems. From functioning is currently satellite-based remote sensing of the atmosphere the most known European Envisat (GOMOS, MIPAS and SCIAMACHY spectrometers) and MetOp (IASI, GOME-2 and HIRS/4 spectrometers), as well as American EOS (MOPITT, AIRS, OMI, TES infrared spectrometers, HIRDLS and MLS microwave radiometers) and NPOESS (OMPS ultraviolet / visible spectrometer) (Kokhanovsky *et al.*,2013). The main technical specifications of the onboard equipment for measuring the Earth’s atmosphere in operating satellite systems are given in Table 1.

Table 1.
Technical specifications of equipment for measuring atmospheric parameters of existing satellite systems

Satellite system	Equipment	Spectral bands, μm	Spectral resolution, μm	Swath,km	Spatial resolution, km	Atmospheric products
Envisat	GOMOS	0,25 – 0,95	0,17 – 0,20	120	15 – 40	O_3, NO_2, NO_3, O_2, H_2O, aerosols
	MIPAS	4,15 – 14,6	1,6 – 2,0	150	3 × 30	O_3, NO, NO_2, HNO_3, N_2O_5, $ClONO_2$, CH_4CH_4
	SCIAMACHY	0,24 – 2,40	(0,2 – 0,5) $\cdot 10^{-3}$	960	32 × 215	O_3, NO_2, BrO, SO_2, HCHO, H_2O, CH_4, CO, CO_2, aerosols
MetOp	IASI	3,62 – 15,5	$1,4\cdot 10^{-3}$	1066	12 – 18	O_3, aerosols
	GOME-2	0,24 – 0,79	$0,135\cdot 10^{-3}$	960	80 × 40	O_3, NO_2, BrO, SO_2, HCHO
	HIRS/4	3,8 – 15,0	0,5 – 0,7	2160	10 – 16	CO_2, O_3, N_2O
EOS	MOPITT	2,2 – 4,7	0,22 – 0,55	650	22	CO, CH_4
	AIRS	3,74 – 15,4	$4,9\cdot 10^{-3}$	1650	13,5 – 19,5	CO_2, CO, CH_4, O_3, SO_2, aerosols
	OMI	0,27 – 0,5	(0,45 – 1,0)$\cdot 10^{-3}$	2600	13 × 24	O_3, NO_2, SO_2, HCHO, BrO, OClO, аэрозоли
	TES	3,2 – 15,4	(29 – 85) $\cdot 10^{-3}$	5,3 × 8,5	0,53 × 5,3	H_2O, O_3, CH_4, CO, HNO_3
	HIRDLS	6 – 18 мм	(0,4 – 0,8) $\cdot 10^{-3}$	500	10 × 300	O_3, HNO_3, NO_2, N_2O_5, $CHClF_2$, CCl_2F_2
	MLS	118 – 2250 GHz	400 – 510 MHz	300	1,5 × 3	H_2O, HNO_3, HCN, ClO, N_2O, O_3, SO_2, CH_3CN, CO, HCl, HOCl, BrO, CH_3CN
NPOESS	OMPS	0,25 – 0,38	10^{-3}	2800	50 – 250	O_3, BrO, HCHO, NO_2, OClO, SO_2
GOSAT	TANSO	5,5 – 14,3	(0,6 – 0,8) $\cdot 10^{-3}$	790	1,5 – 10,5	CO_2, CH_4, aerosols, clouds

MATERIALS AND METHODS: GROUND-BASED AIR QUALITY MONITORING

The main major industrial centers of the north Algeria are represented cities: Algiers, Mascara, Skikda, Oran and Annaba. It is necessary to monitor the air quality to assess the actual degree of urban and industrial pollution and implement a policy to protect citizens' health. Since 2002 public authorities' implemented installations of air quality monitoring networks baptized SAMASAFIA (Samasafia. Tech.rep. 2006, 2007). They are located in four major cities of Algeria namely: Algiers, Annaba, Oran and Skikda as following:

- Algiers: Network consists of 04 stations connected to a central station
- Annaba: Network consists of 04 stations are connected to a central station.
- Oran: Network of stations 03 connected to a central station.
- Skikda: Network of stations 03 connected to a central station.

These networks have the role of measurement, operation and information for the public and to the authorities concerned for monitor the level of pollution due to the different indicators relating to road traffic pollution (NO_x, NO, CO, CO_2, O_3, SO_x, suspended particulate matter PM-10 and heavy metals).

- Detect pollution peaks and periods when limited thresholds are exceeded;
- Establish the air quality forecasts using simulation models;
- Alert authorities during critical situations of pollution;
- Inform people of the measures to be taken to reduce the health impacts.

The air quality monitoring networks consist of automatic measuring stations working continuously (24h / 24, 7 days/7). Due to their high acquisition and maintenance costs severely limit the number of networks in each city. As a result, they cannot provide a good spatial distribution of the air pollutant readings over an area.

DATA PROCESSING:

Satellite observations can serve a high spatial distribution of air pollution. The assessment of atmospheric pollution in northern Algeria with nitrogen dioxide measurements carried out according to the data of satellite spectrometer EOS / OMI with certification on surface data. The initial data used information products Level 3 Goddard Earth Sciences Data and Information Services Center (GES DISC) NASA for 2006-2009: tropospheric NO_2 molecules per cm^2 (http://disc.sci.gsfc.nasa.gov/Aura/ data-holdings/OMI/omno2e_v003.shtml), available through the Mirador search subsystem (http://mirador.gsfc.nasa.gov/). Territorial segments subsetting, selection of the layers of data and monthly average values were made using the Giovanni processing web-service (http://disc.sci.gsfc.nasa.gov/giovanni/). The result was obtained by measuring 36 segments on a regular grid (Figure 1) for each information product EOS / OMI.

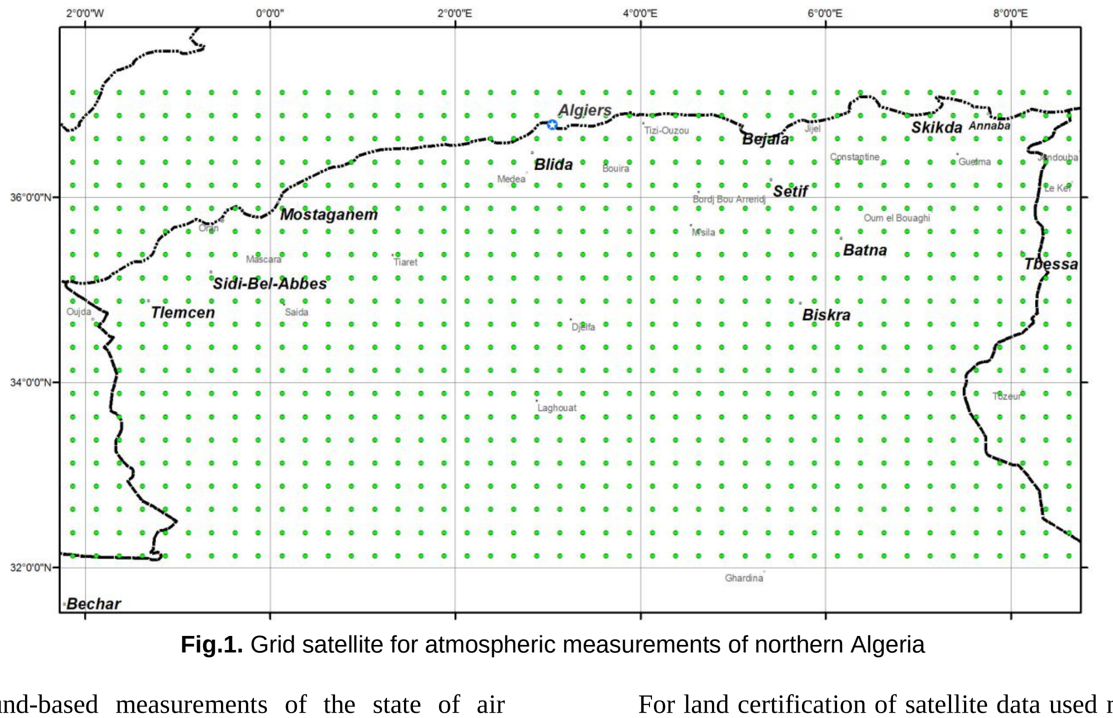
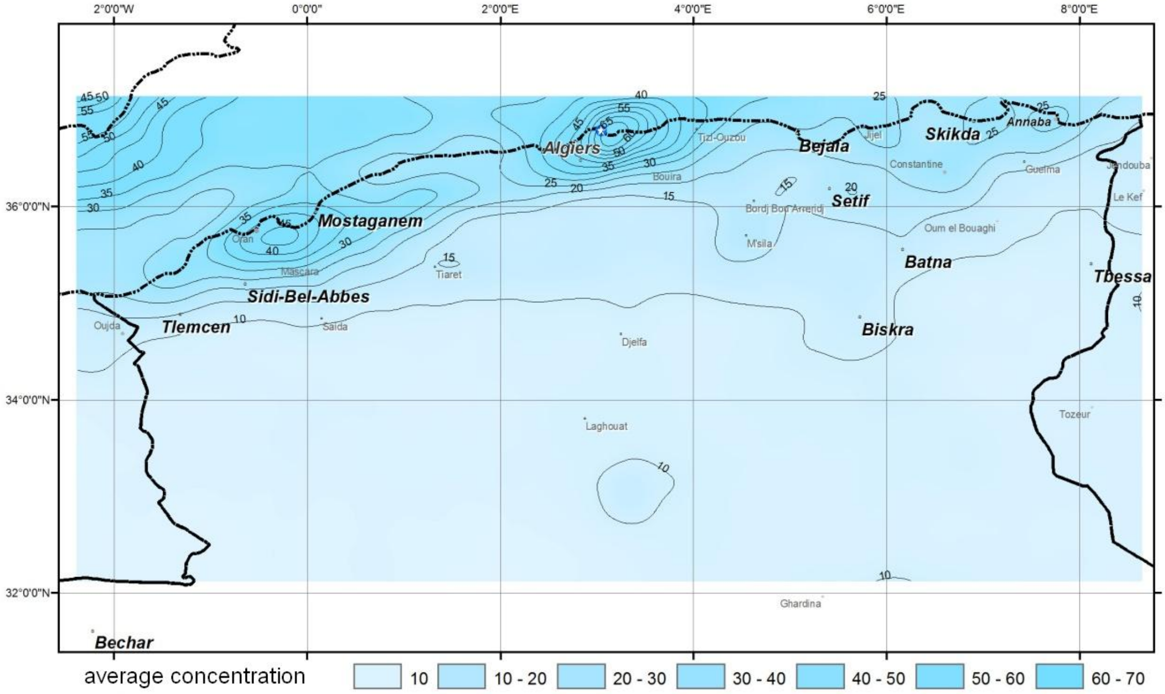


Fig.1. Grid satellite for atmospheric measurements of northern Algeria

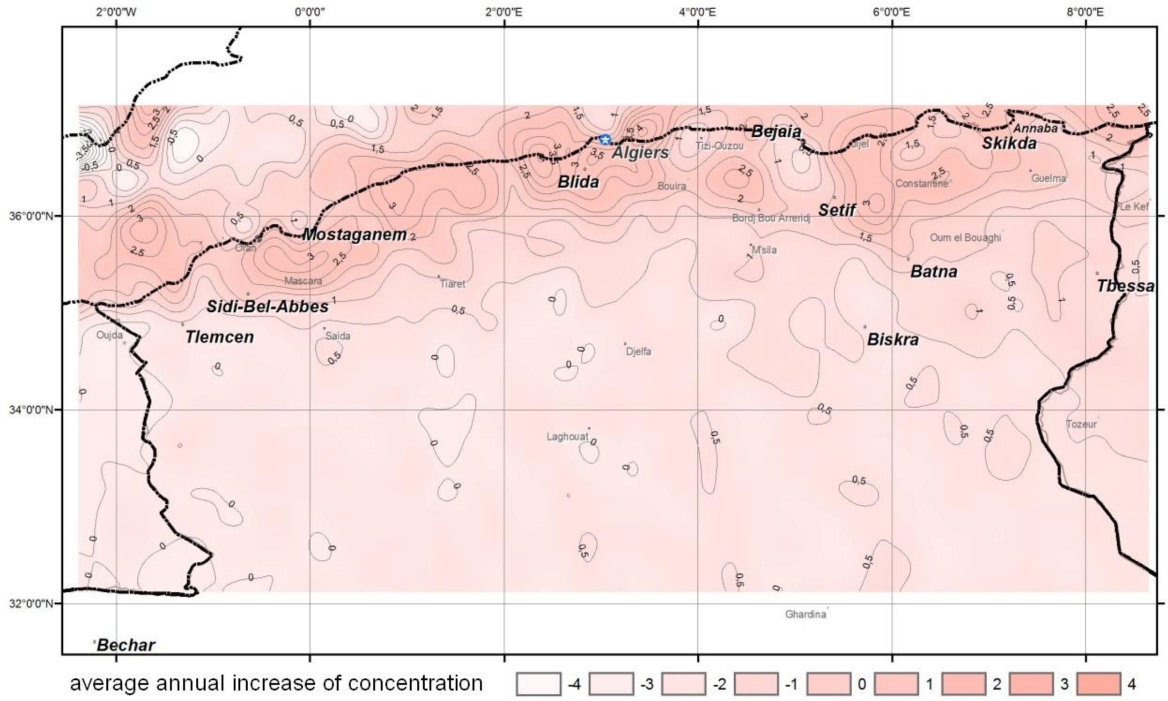
Ground-based measurements of the state of air near-ground layer were carried out using the obtained daily, monthly and annual average data of the stationary networks SMASAFIA. The obtained data of background monitoring of investigated substances in the air are compared with (MPC).

For land certification of satellite data used monthly averages of NO_2 concentration in mg/m^3 for 2006-2009. The satellite measurements values on a regular grid interpolated by the inverse-distance weighting (IDW) algorithm were estimated in terms of ground measurements using a linear regression. Average rating for regression confidence on 36 measurements at each point using Fisher's F-statistics was 0.62 (George *et al.*, 2003). Further satellite measurements on a regular grid were recalculated by the previously obtained regression equations for the entire study area. Formed by this way map of average monthly NO_2 concentrations enables the time-series analysis of whole observations.

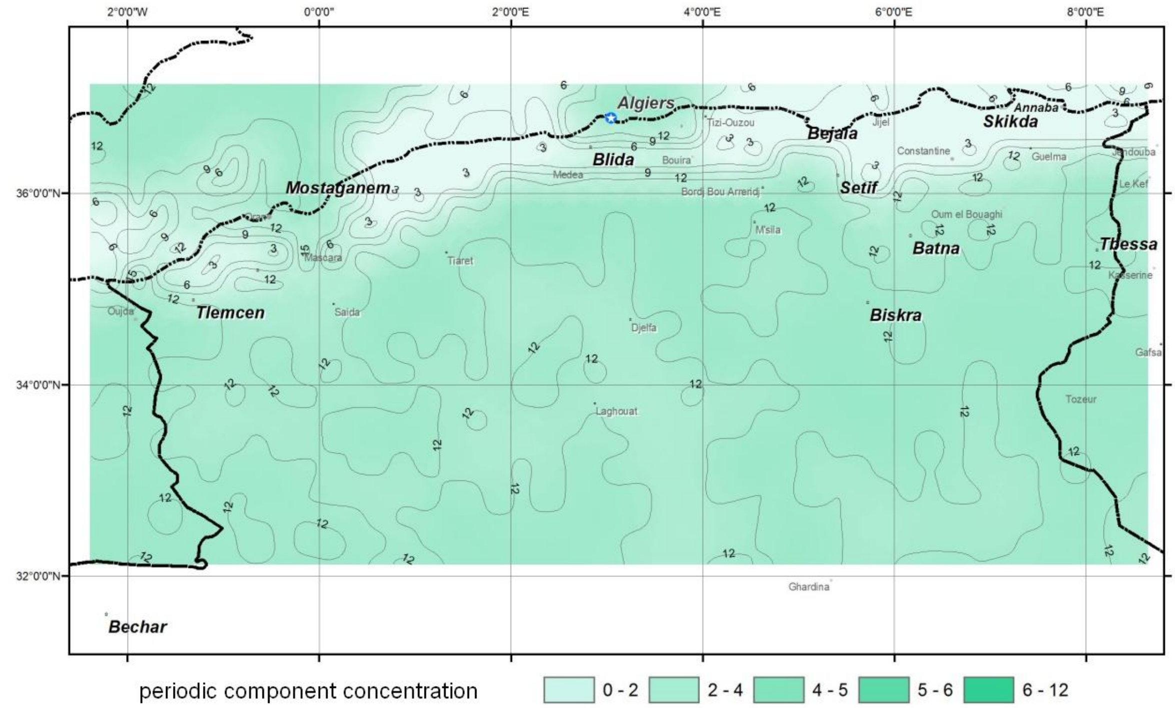
As a result, the average value during the observation period, the average annual growth and 12-months periodic component were mapped. The resulting maps of the distribution of these variables are shown in Figure 2.



a)



b)



c)

Fig.2. Spatial distributions of the NO_2 dynamics in the northern Algeria's atmosphere in 2006 – 2009: **a** – average concentration (mg/m^3), **b** – an average annual increment of concentration (%), **c** – annual periodic component concentration (‰).

RESULTS AND DISCUSSION:

Analysis of distribution maps of the concentrations of nitrogen dioxide in the atmosphere of the northern cities of Algeria indicates the formation of certain aerosol flow patterns. Obviously, their formation depends on the power sources. There is no doubt that the nature of the spread of flames through the region associated with the photochemical properties of toxicants, features megarelefa areas, including rivers.

Based on the data obtained and presented in map (2a), the concentration of nitrogen dioxide in the air of the metropolis as Algeria exceeds twice the value of the maximum allowable concentration (Loghin ,2010). Slightly lower content of NO_2 in the air near the cities recorded Mascara, Skikda, Oran and Annaba. Comparison of the data analysis of time series associated with the assessment of the average annual increase NO_2 concentrations in the atmosphere at the map (2b) also shows an increased risk of accumulation of nitrogen dioxide on the above urban agglomerations. Spatial distribution of annual periodic components of atmospheric pollutants anti-correlated with the location of industrial centers that can be attributed to the influence of remaining natural vegetation ecosystems affected by the seasonal cycle of atmospheric absorption activity.

CONCLUSION:

As can be seen from the analysis of distribution maps of torches NO_2 revealed some differences in the dispersion of toxicants. It is obvious that the formation of certain aerosol flow patterns associated with nitrogen dioxide photochemical properties of toxicants, the climate and terrain relief. The presented resultsts can be important for specialists and can be taken into account in the short-term forecasts of acid rain in the countryside; there is a risk of damage to agricultural crops. Using maps of average annual growth of concentration of toxicants is promising for quantitative and qualitative evaluation of photochemical smog formation, growth in the number of diseases among the population of industrial cities. Overlay maps for two studied parameters can help to develop preventive measures to reduce the risk of the combined effect associated with the formation of highly toxic intermediates.

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