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RODRIGES ZALIPYNIS R.A.
(UKRAINE, DONETSK)

THE PLACE OF UKRAINE IN EUROPE ACCORDING TO THE LEVEL OF AIR POLLUTION USING EARTH REMOTE SENSING DATA

Problem statement. Nitrogen dioxide (NO_2) is a very toxic gas and is one of the major air pollutants in Europe [1]. Aerosols and, especially particulate matter ($PM_{2.5}$, PM_{10}), are considered to be the primary causes of lung diseases [2]. Carbon monoxide (CO) reduces oxygen delivery to the heart and brain [3] while carbon dioxide (CO_2) is one of the main greenhouse gases. It is important for a country to comply with international agreements restricting pollutant emissions, for example, Kyoto protocol [4]. The locations of air pollution hot-spots largely influence budget allocation decisions.

Today, air pollution data come mainly from irregularly spaced network of ground-based stations [5]. Many EU countries as well as Ukraine have large areas without air quality control stations [6]. It is impossible to obtain a complete picture of typical air pollution pattern over the whole Europe using only these data. Satellite Earth remote sensing delivers consistent measurements of atmospheric pollutant concentrations for the whole Europe with high spatial and temporal resolution. Satellite data and new technologies [7] provide a unique chance to consistently compare Ukraine with EU countries.

Task formulation. The research goal is to estimate the relative level of air pollution in Ukraine to other EU countries and identify regions in Europe having highest levels of air pollution. To reach the goal, maps of air pollution risks are built using the method presented below. Maps possess inherent ability to clearly compare regions while new risk assessment method considers a temporal component.

Satellite Earth remote sensing data. Daily values in air column were taken from several radiometers of Terra, Aura and Aqua satellites on regular latitude-longitude grids (table 1, approximate spatial resolution in kilometers is given for 48º latitude). AOT is unitless between -0.05..5, NO_2 and CO are in DU (Dobson Units, 1 DU = 2.69×10^{16} molecules/cm^2), CO_2 is in ppm.

Table 1. Satellite Earth remote sensing data.

Pollutant	Radiometer	Resolution	Time interval
Nitrogen dioxide (NO_2)	OMI	0,25°×0,25° 27,5×18 km	01.10.2004 20.06.2012
Aerosol optical thickness, AOT	MODIS	1,0°×1,0° 110×72 km	02.03.2000 04.10.2012
Carbon monoxide (CO)	MOPITT	1,0°×1,0° 110×72 km	03.03.2000 31.10.2012
Carbon dioxide (CO_2)	AIRS	2,0°×2,5° 220×144 km	01.01.2004 29.02.2012

Air pollution risk assessment method. In this paper, the air pollution risk is defined as the probability of observing a pollutant concentration in a given interval over the territory under investigation. The risk is calculated for each grid cell as $R(a, b)=S(a, b) / T$, where $S(a, b)$ is the number of observations with a pollutant concentration between $a..b$ while T is the total number of days for which pollutant measurements are not missing due to clouds or other reasons. Both $S(a, b)$ and T are calculated using the whole available time interval (table 1).

Pollution categories were experimentally selected. For NO_2 the interval between 0.0..0.2 DU is considered to be low pollution level, 0.2..0.4 DU – moderate (fig. 1), 0.4..0.6 DU – high, 0.6..0.8 DU – very high, over 0.8 DU – catastrophic. For AOT: 0.0..0.2 – very low, 0.2..0.4 – low, 0.4..0.6 – moderate (fig. 2a), 0.6..0.8 – high, 0.8..1.0 – very high, 1.0..5.0 – catastrophic. For CO: less 100 DU – low, 100..150 DU – moderate (fig. 2b), over 150 DU – high.

Results. The highest levels of air pollution by nitrogen dioxide in Europe are observed over Germany, Belgium, Netherlands and southern part of the North Sea as well as over large cities. The highest levels of air pollution by aerosols in Europe are observed over the north of Italy (cut from the map to prevent dimming of its remaining part). The stripe is identified over which the highest risk levels of air pollution by aerosols are found over the rest of Europe.

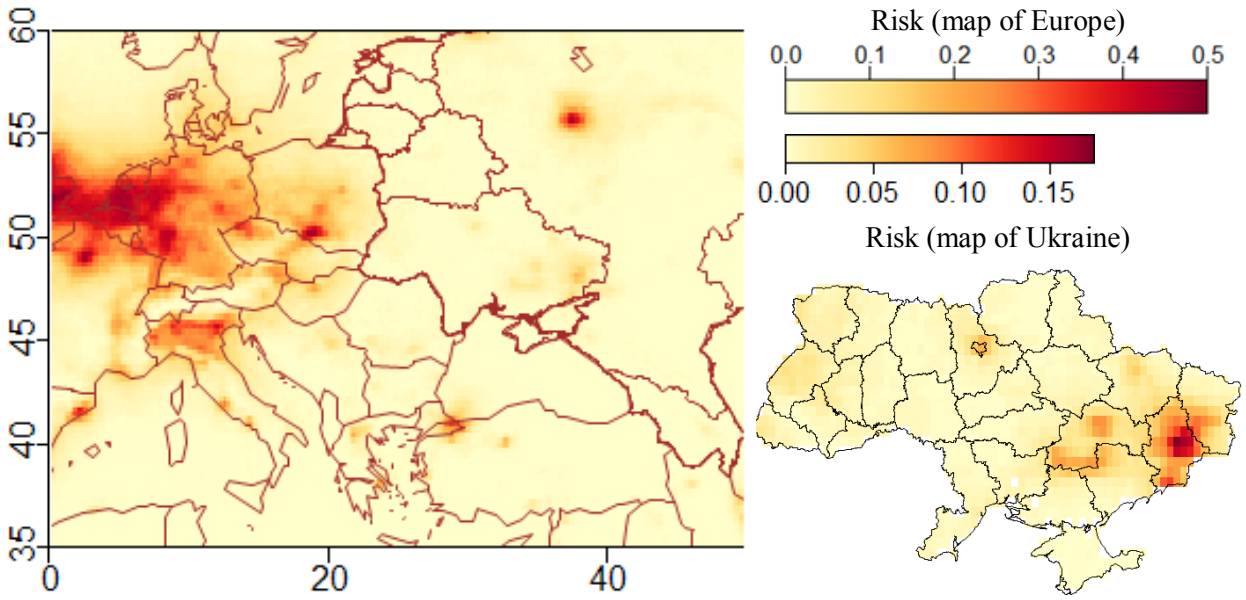

Fig. 1. Risk of moderate level of air pollution by nitrogen dioxide (NO_2)

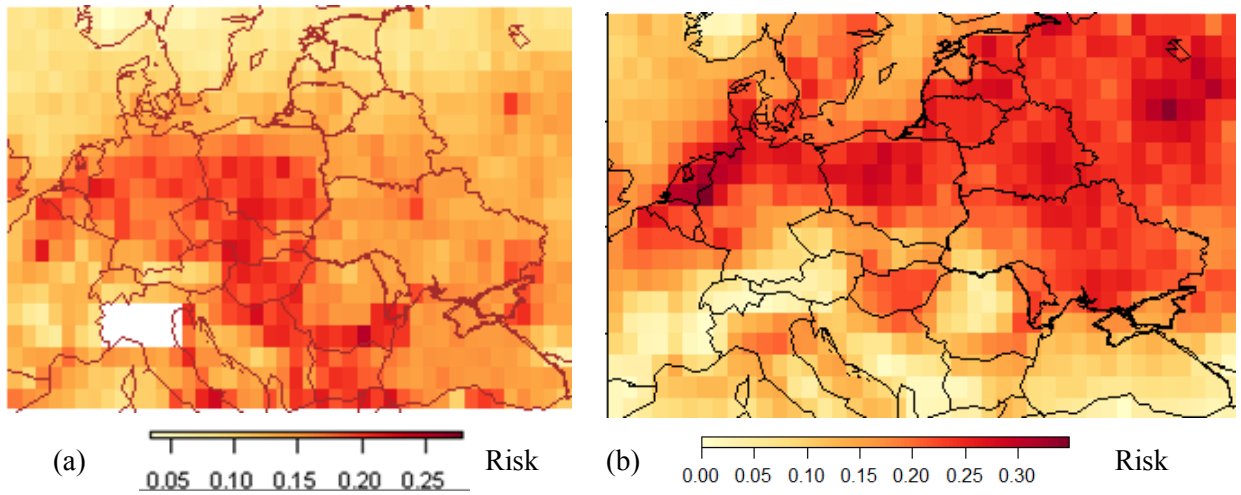

Fig. 2. Risk of moderate level of air pollution by (a) aerosols and (b) carbon monoxide (CO)

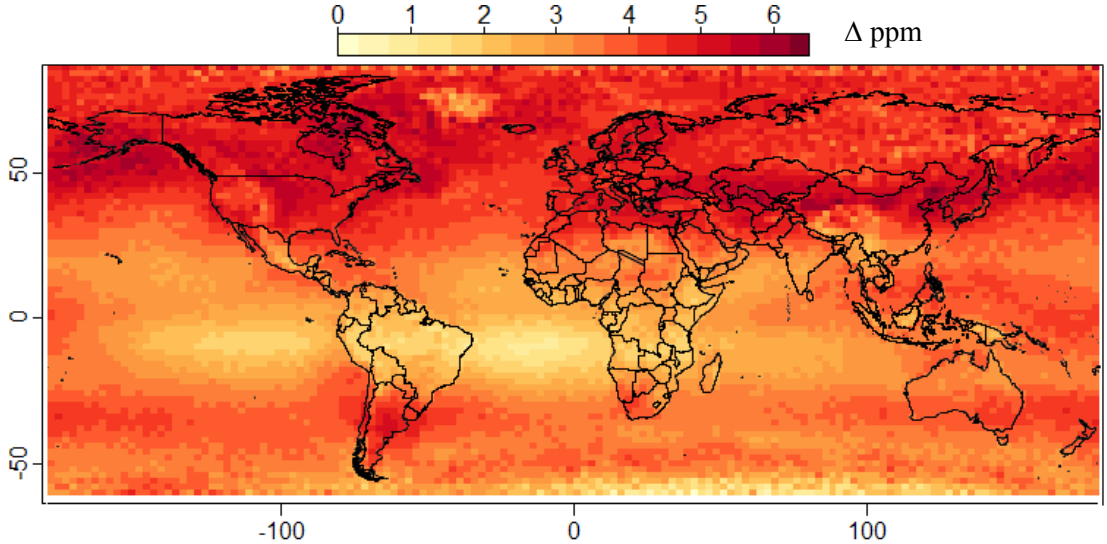

Fig. 3. The map of mean differences of CO_2 trends

For each cell of global regular latitude-longitude grid 2,0°×2,5° time series of CO_2 concentrations are built [7]. From monthly mean values for each time series trends were extracted using STL method [8]

and mean difference Δppm was calculated as follows. Let $v = \langle v_1, v_2, \ldots, v_{98} \rangle$ and $w = \langle w_1, w_2, \ldots, w_{98} \rangle$ – extracted trends from arbitrary and fixed cell correspondingly during the computation. The 98 is the number of months since January, 2004 till February, 2012. Mean difference Δppm for trend v equals $\sum(v_i - w_i)/98$, where $i = 1, 2, \ldots, 98$. By adding to Δppm the minimum among all obtained mean differences, the map on fig. 3 is obtained. Only 16 colors were used to increase the contrast.

Conclusions. The presented risk calculation technique is simple yet delivers extensive understanding of air pollution character. Due to good mixing, monthly mean concentration of CO_2 over Ukraine, US, China, Western Europe and North Pole can be considered the same. Electronic copy of this paper with colored maps is also freely available at http://wikience.donntu.edu.ua/rodriges.

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Родрігес Заліпиніс Рамон Антоніо, к.т.н, асистент кафедри комп'ютерних систем моніторингу Донецького національного технічного університету, +380 99 241 678 2, rodriges@csm.donntu.edu.ua, Skype: antonio.rrz

Rodriges Zalipynis R.A. **The place of Ukraine in Europe according to the level of air pollution using Earth remote sensing data.** For the first time maps of air pollution risks by NO_2, CO and aerosols over the territory of Europe with spatial resolution of up to 27.5×18 km were created. The global distribution of CO_2 was estimated for the last 7 years.

Keywords: remote sensing, geopolitics, risk, air pollution, NO_2, CO, aerosol, CO_2
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***Родригес Залепинос Р.А.*.** **Место Украины в Европе по уровню загрязнения атмосферного воздуха по данным дистанционного зондирования Земли.** Впервые построены карты рисков загрязнения атмосферного воздуха NO_2, CO и аэрозолем над территорией Европы с пространственным разрешением до 27,5×18 км. Оценено глобальное распределение CO_2 за последние 7 лет.

Ключевые слова: дистанционное зондирование, геополитика, риск, загрязнение атмосферного воздуха, NO_2, CO, аэрозоль, CO_2
УДК 504.064.36:37

***Родрігес Заліпиніс Р.А.*.** **Місце України у Європі за рівнем забруднення атмосферного повітря згідно даних дистанційного зондування Землі.** Вперше побудовано карти ризиків забруднення атмосферного повітря NO_2, CO та аерозолем над територією Європи із просторовою роздільною здатністю до 27,5×18 км. Оцінено глобальне розподілення CO_2 за останні 7 років.

Ключові слова: дистанційне зондування, геополітика, ризик, забруднення атмосферного повітря, NO_2, CO, аерозоль, CO_2
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