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Assessment of air pollution in Krasnoyarsk based on satellite data of different spatial resolution

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Abstract. Spectrometer MODIS, installed on TERRA and AQUA satellites, provides daily global coverage of the Earth. Based on its measurements, data on aerosol optical depth (AOD) with different spatial resolution are formed: 10, 3, 1 km. The classical algorithm with a coarse spatial resolution of 10 km is not suitable for studying the variability of aerosols at the city scale. Introduced in 2018, a new algorithm for multi-angle implementation of atmospheric correction (MAIAC) provides AOD data with spatial resolution of 1 km. This information can already be used to analyze the spatial distribution of aerosols in the city. The relationship between MAIAC AOD and PM2.5 concentrations of particulate matter was investigated, which is measured at automated posts of city environmental services. Our analysis showed that the data with a spatial resolution of 1 km allow us to see the areas of dust pollution inside the city. This information, together with measurements at the posts, can be used as an objective assessment of the environmental situation.

1. Introduction

Aerosols or airborne particulate matters (PM) of natural or anthropogenic origin have a significant impact on climate, environment and human health [1]. Numerous epidemiological studies have shown that there is a relationship between PM concentrations and various adverse health effects [2]. Therefore, air quality assessment, especially in terms of PM10 and PM2.5 (PM with diameters less than 10 and 2.5 μm respectively) is an urgent problem now. Ground-based observations from stationary observation posts (SOPs) show important spatial and temporal information on PM concentrations in the atmosphere.

PM monitoring is mainly based on ground-based measurements. Although station networks exist in large cities, point measurements do not provide information on the spatial characteristics and distribution of PM across urban areas of interest. The time coverage of on-site PM measurements also varies greatly depending on the period of operation of the instrument and its functionality. These reasons have led to ongoing efforts to evaluate PM using satellite remote sensing techniques.

Aerosol optical depth (AOD) is a parameter obtained from a satellite, which is most often used as a basis for PM estimation [3]. AOD-integrated atmospheric dispersion of radiation by aerosols in the vertical column of the atmosphere. This parameter is proportional to the number of particles in the air and depends on their mass concentration. AOD is usually used as a basis for PM evaluation. Several methods have been used to correlate the AOD based on remote sensing with the PM data measured on the ground. These include linear relations [4], statistical and chemical transport models [5], multiple regression analysis [6] and neural networks [7].

There are several factors limiting the correlation between AOD and PM2.5. This is the effect of the vertical aerosol profile, which is responsible for the difference between measurements in the atmospheric column (AOD) and near-surface (PM2.5); the effect of relative humidity; wind speed; particle size distribution; particle composition, etc. [7]. In [8] the correlation between measurements of the common AOD column and near-surface PM2.5 and these variables was investigated. These studies showed a wide range of correlations between AOD and PM2.5 values.

In this article, we use AOD data with a spatial resolution of 1 km and 10 km, obtained for the city of Krasnoyarsk. The task is to determine the degree of change in the correlation between the concentrations of PM25 measured on the ground and AOD values obtained based on satellite data with increasing the spatial resolution of AOD. This study assumed a linear relationship between the AOD and PM2.5 data.

2. Materials and methods

2.1. Ground-level PM2.5 data

In July 2018 PM2.5 air monitoring in Krasnoyarsk was performed on three SOPs of the regional ecological system. Figure 1 shows the location of the SOPs from which data were used in our study.

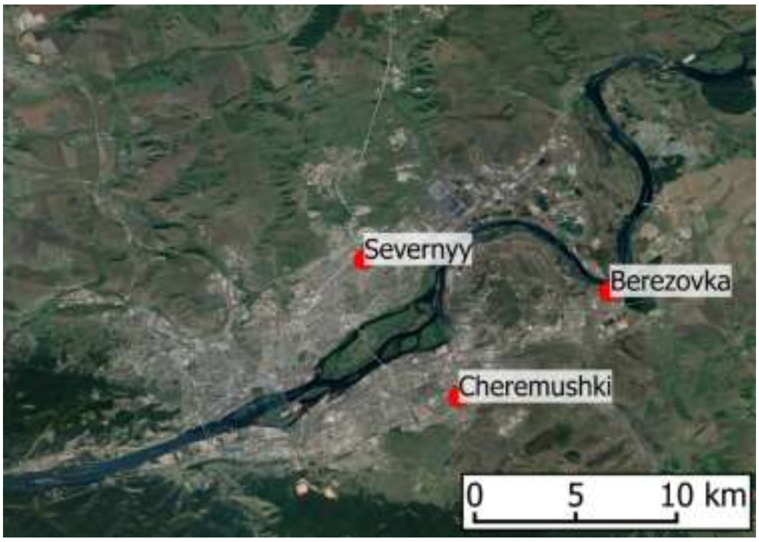

Figure 1. Location of monitoring posts in Krasnoyarsk used in the study.

To measure PM25 concentration on SOPs, radioisotope based operating principle is used, which is generally accepted all over the world. It is based on the absorption of β-radiation by particulate matters deposited on the filter belt. The isotope C14 is used as a source of β-radiation. Particulate matter is deposited on the filter belt as a result of pumping the air sample by the pump. Measurement of the radiation absorption value is carried out using the built-in Geiger-Muller detector-counter. To estimate the amount of air pollution, we used average daily concentrations.

2.2 Satellite data

The MAIAC algorithm [9] was developed for processing MODIS data. MAIAC retrieves aerosol parameters over land with a resolution of 1 km. The MCD19A2 (MAIAC) product contains MODIS spectrophotometer data installed on Terra and Aqua satellites. This product was published on May 30, 2018, and contains AOD data from February 1, 2000 [10]. Aerosol parameters include optical depth at wavelengths from 0.47 to 0.67 μm and aerosol type, including background, smoke and dust models [11]. In our study, we used AOD data at a wavelength of 0.47 μm.

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In [12] the correlation between ground measurements of PM2.5 and satellite measurements of AOD at different wavelengths was carried out. This study showed that the correlation between PM2.5 is greater for a wavelength of 0.47 μm.

The increased accuracy of MAIAC is the result of the explicit surface characterization method as opposed to the empirical approach to surface parameterization used in the MOD04 and MYD04 algorithms. Moreover, MAIAC incorporates a cloud mask algorithm, based on spatial-temporal analysis, which complements traditional methods for the detection of clouds at the pixel level [13]. MAIAC provides a uniform grid resolution of 1 km in the selected projection regardless of the scanning angle.

In addition to MAIAC data, we used daily aerosol data from MODIS Level 2, Collection 6.1 from Aqua and Terra satellites, which were obtained with a spatial resolution of 10×10 km^2 (in nadir). MYD04 and MOD04 aerosol products were obtained on the basis of spectral radiation measured by MODIS using seven spectral channels in the wavelength range from 470 to 2130 nm [14].

Additional wavelengths in other parts of the spectrum are used to identify and mask clouds, snow, and suspended river sediments [15].

2.3 Data preprocessing and integration

In our study, we used PM2.5 values measured at SOPs and satellite based AOD data for July 2018. We studied the relationship between AOD measurements and PM2.5 within the territory of Krasnoyarsk city area. The frequency of SOPs measurements is 1 measurement in 20 minutes. We used average values of PM2.5 per day. For city-level correlation between AOD and PM2 data, 10 days were available, a total of 30 pairs. The days were chosen taking into account the absence of clouds.

3. Results and discussion

Figure 2 shows the high resolution of MAIAC 1 km (left) and the low resolution of 10 km (right). High spatial resolution data show the spatial variability of AOD at both moderate and low pollution levels that lower spatial resolution data cannot provide.

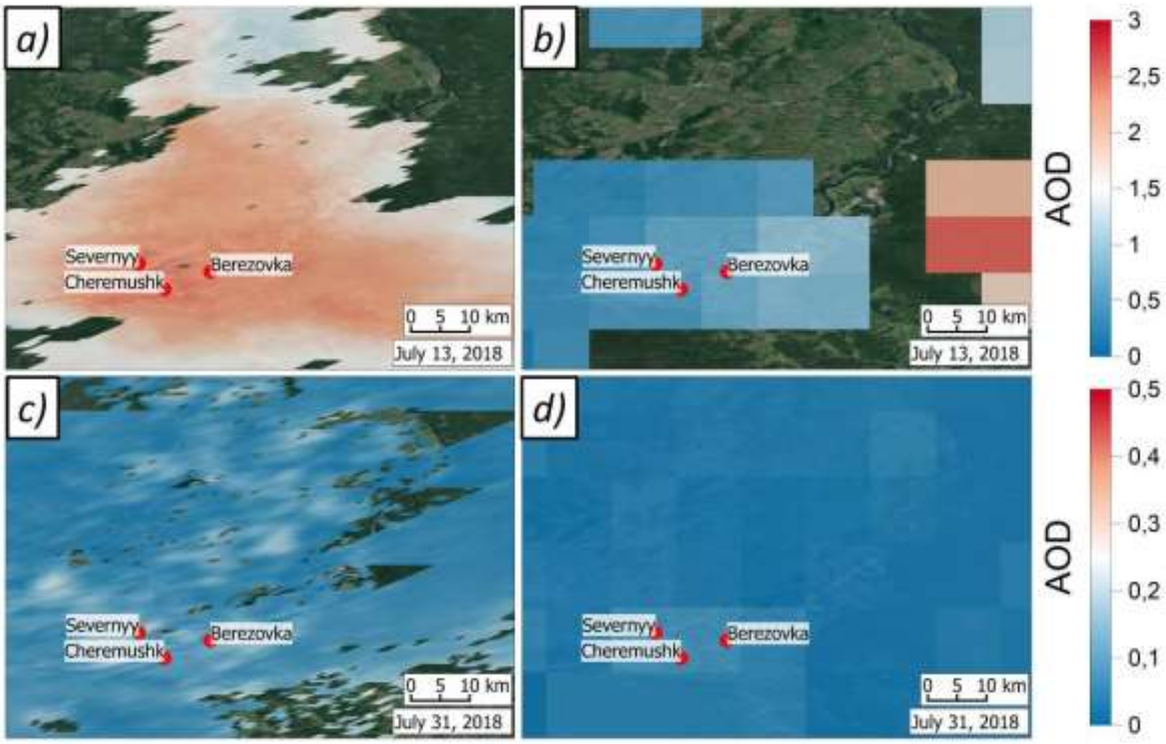

Figure 2. AOD map for the territory of Krasnoyarsk with its surroundings. Data calculated using algorithms with a spatial resolution of 1 km (a, c) and 10 km (b, d) were selected for two different days: with low (a, b) and high (c, d) air pollution.

Figure 3 shows the relationship between the results of the AOD determination on one of the days in July 2018 according to the MAIAC algorithm with a spatial resolution of 1 km and the average daily PM2.5 values measured at three SOPs in Krasnoyarsk. The coefficient of determination in this case is 0.53 (R^2=0.53). It should be noted that for different satellite images during the study period, the coefficient of determination varied in the range from 0.5 to 0.8, which indicates a good relationship with the ground measurements of PM2.5. The correlation values for the10 km resolution algorithm were comparable.

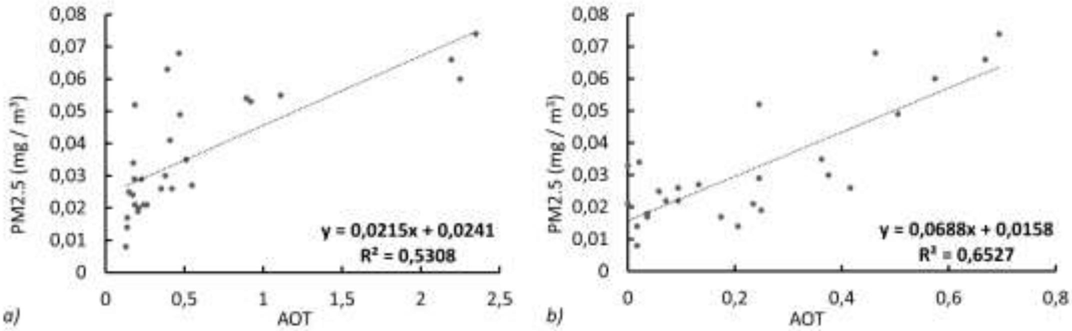

Figure 3. Correlation of AOD with ground measurements of PM2.5 for algorithms with a spatial resolution of 1 km (a) and 10 km (b).

4. Conclusions

In this paper, we used a new MAIAC algorithm to estimate AOD from MODIS data with a high spatial resolution of 1 km, compared it with a classical algorithm that has a coarser resolution of 10 km. Our analysis shows that the correlation between PM2.5 and AOD with a spatial resolution of 1 and 10 km is approximately similar. However, the use of higher spatial resolution makes it possible to identify areas of dust pollution in the city. This will make it possible to determine more qualitatively environmentally unfavorable areas of the city. The use of ground-based observation posts in combination with high spatial resolution satellite data from MAIAC can provide an information basis for a modern environmental monitoring system on a regional scale and contribute to the improvement of the environmental situation in the city.

An important disadvantage of the considered technique is the inability to obtain AOD data in winter and on days when clouds do not allow seeing Earth's surface from the satellite.

References

[1] Kaufman Y J, Tanré D and Boucher O A 2002 *Nature* **419** 215
[2] Schwartz J, Laden F and Zanobetti A 2002 *Envir. health. perspec.* **110** 1025-9
[3] Koelemeijer R B A, Homan C D and Matthijsen J 2006 *Atmos. Envir.* **40** 5304-15
[4] Yap X Q and Hashim M 2012 Atmos. Chem. & Physics Discus. **12**
[5] Kloog I, Nordio F, Coull B A and Schwartz J D 2012 *Environ. Sci. Technol.* **46** 11913-21
[6] Gupta P and Christopher S A 2009 *Geophys. Res.* **114** D14205
[7] Wang J. and Christopher S 2003 *Geophys. Res. Lett*. **30** 2095
[8] Hoff R and Christopher S 2009 *Air Waste Manage* **59** 645–75
[9] Lyapustin A, Wang Y, Korking S and Huahg D 2018 *Atmos. Measur. Techniq.* **11**
[10] Lyapustin A and Wang Y 2018. MCD19A2 MODIS/Terra+Aqua Land Aerosol Optical Depth Daily L2G Global 1km SIN Grid V006 [Data set] NASA EOSDIS Land Processes DAAC
[11] Lyapustin A, Korkin S, Wang Y, Quayle B, and Laszlo I 2012 *Atmos. Chem. Phys* **12** 9679–86
[12] Tian J and Chen D 2010 Canadian Journal of Remote Sensing **36** 119-28
[13] Lyapustin A, Wang Y, and Frey R 2008 *Geophys. Res* **113** D16207
[14] Remer L A et al. 2005 *Atmos. Sci* **62** 947–73
[15] Ackerman S, Strabala K, Menzel W, Frey R, Moeller C, and Gumley L 1998 *Geophys. Res* **103** 32141–157