Bulgarian Academy of Sciences. Space Research and Technology Institute.
Aerospace Research in Bulgaria. 37, 2025, Sofia

USING AAI FORM GOME 2 INSTRUMENT, ONBOARD METOP A, B, AND C SATELLITES FOR INVESTIGATION OF DUST POLLUTION OVER BULGARIA

Maria Dimitrova, Yordanka Pregyova

Space Research and Technology Institute – Bulgarian Academy of Sciences
e-mail: maria@space.bas.bg

Keywords: *AAI, Dust pollution, Remote sensing*

Abstract
In the paper, we use the Absorption Aerosol Index (AAI) from the GOME 2 instrument onboard the three satellite platforms MetOp A, B, and C for the period from the beginning of year2007 till the end of 2023 to investigate tendencies in dust pollution over Bulgaria. We use monthly averaged values with a spatial resolution of 1 degree and observe temporal, spatial, and seasonal trends of AAI. A comparison was made between the data results of the same type of instruments for the three satellites and an analysis of the possibility of their joint use.

Introduction

Knowledge of the air quality is very important for human health as well as for agriculture, animal husbandry, and natural environment preservation.

Dust pollution is one of the most common natural pollution events that directly impact the human respiratory system [1, 2].

Dust pollution can be studied by automatic measuring stations (AIS), which provide point measurements, or satellite data, which shows a global picture.

The problem is that from space, we can't measure dust amount even in a total column as for the other pollutants – NO2, SO2, CO, CO2, and others. We observe dust pollution using values such as Aerosol Optical Depth (AOD), Aerosol Index (AI), or Absorption Aerosol Index (AAI). These values are measureless, and AAI may have positive and negative values.

Such satellite data is difficult to use for any measurement of dust presence but can be used to show a global picture and for registration of significant dust events such as desert dust from the Sahara.

The proposed study aims to use AAI from MetOp satellites to investigate the global dust picture over Bulgaria from 2007–2023.

Data and Methods

Absorbing Aerosol index (AAI) indicates the presence of elevated absorbing aerosols in the troposphere, like desert dust, smoke, and volcanic ash. AAI separates the spectral contrast at two ultraviolet (UV) wavelengths caused by absorbing aerosols from other effects, including molecular Rayleigh scattering, surface reflection, gaseous absorption, and aerosol and cloud scattering. AAI is a unitless quantity, positive values of AAI indicating the presence of absorbing aerosols in the atmosphere. It should be noted, however, that AAI values depend on several factors, e.g., the amounts of absorbing aerosols and aerosol layer height. This should be considered when comparing, e.g., different episodes [3].

The aerosol types that are mostly seen in the AAI are desert dust, biomass burning, and volcano ash aerosols. The AAIs are derived from the reflectances measured by GOME-2 at 340 and 380 nm, where absorbing aerosols are present.

AAI is provided as Offline Level 2 data from GOME-2 observations, disseminated via the Finnish Meteorological Institute data service. There are two types of products available, "AAI" and "AAI from PMDs", that differ by their spatial resolution. The Spatial resolution of "AAI" is equal to the spatial resolution of the GOME-2 instruments: 40 km x 40 km for MetOp-A and 80 km x 40 km for MetOp-B and C. The spatial resolution of AAI from the Polarisation Measurement Detectors (PMDs) is equal to the spatial resolution of the small field-of-view PMD detectors: 5 km x 40 km for MetOp-A and 10 km x 40 km for MetOp-B and C.

Here, we use level 3 data for AAI from Tropospheric Emission Monitoring Internet Service (TEMIS) [4, 5]

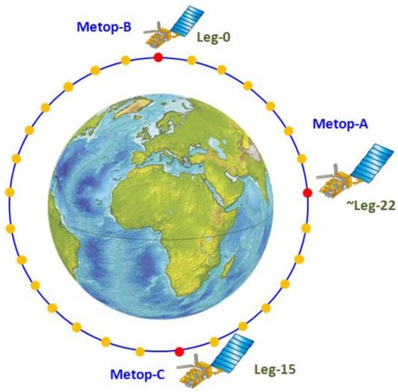

Fig. 1. Relative position between MetOp A, B, and C satellites

Three MetOp satellites (MetOp-A (launched 2006), MetOp-B (launched 2012), and MetOp-C (launched 2018)) fly in a sun-synchronous polar orbit at an altitude of about 840 km, circling the planet 14-15 times each day and crossing the equator at 09:30 local (sun) time on each descending (south-bound) orbit.

Successive orbits are displaced westward due to the Earth's own rotation, giving global coverage of most parameters at least twice each day, once in daylight and once at night (depending on the position of the satellites in the orbital plane) [5].

MetOp A, B, and C satellite relative positions are shown in Fig. 1 [6].

With a spatial resolution of 1 degree, we have 17 areas, covering all of Bulgaria region, as it is shown in Fig. 2

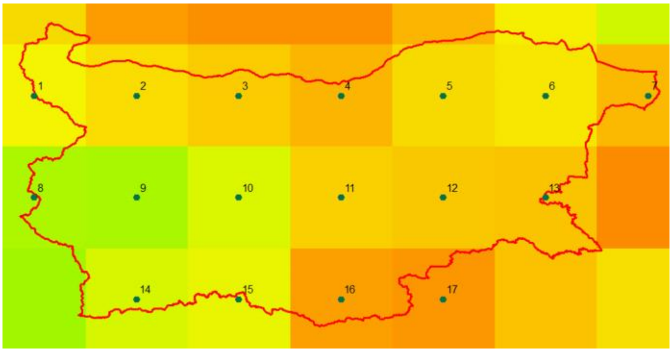

Fig. 2. Areas of provided monthly AAI from MetOp A, B, and C satellites

For each month and each one of the areas, we take AAI value and build seasonal behavior for each year of the observed period. We made this for each of the three satellites, respectively

- From 2007 to 2020 MetOp A
- From 2013 to 2023 MetOp B
- From 2019 to 2023 MetOp C

Then, we calculate the averaged seasonal curves for each one of the satellites.

Averaging monthly values for each year, we obtained the first spatial dust distribution for each one of the areas and then averaged the temporal behavior for the whole Bulgarian region.

It is not clear what kind of events represent negative AAI. The used monthly values and obtained average values are mostly negative. However, they are averaged, and we hope that we can use them not for any measure of dust quantity but to show global spatial, temporal, and seasonal dust pollution tendencies.

Results and analyses

In Figs. 3, 4, and 5, we show the averaged seasonal AAI behavior from each of the MetOp satellites.

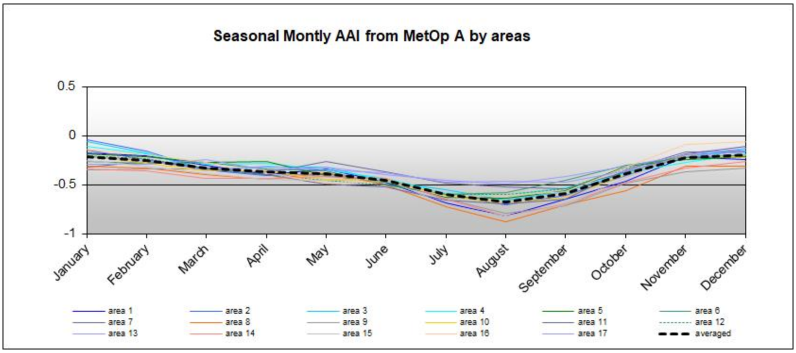

Fig. 3. Seasonal AAI MetOp A behavior

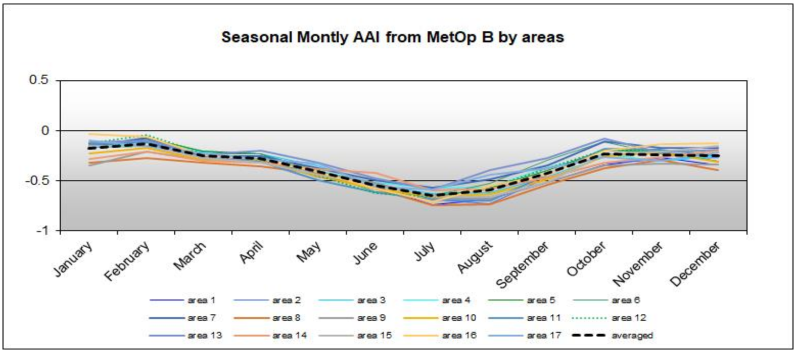

Fig. 4. Seasonal AAI MetOp B behavior

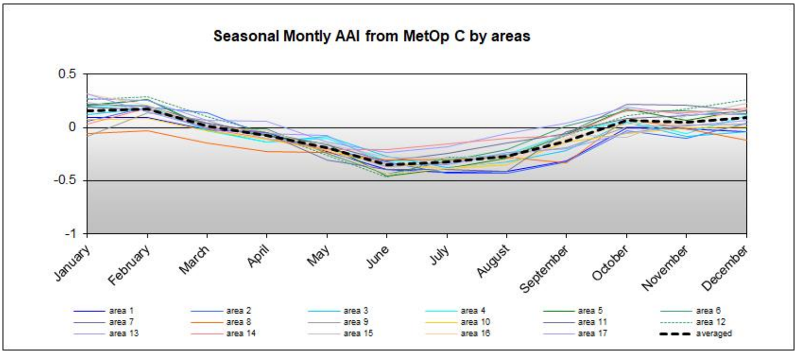

Fig. 5. Seasonal AAI MetOp C behavior

In Fig. 6, we show the comparative and averaged seasonal behavior of AAI data from all three satellites.

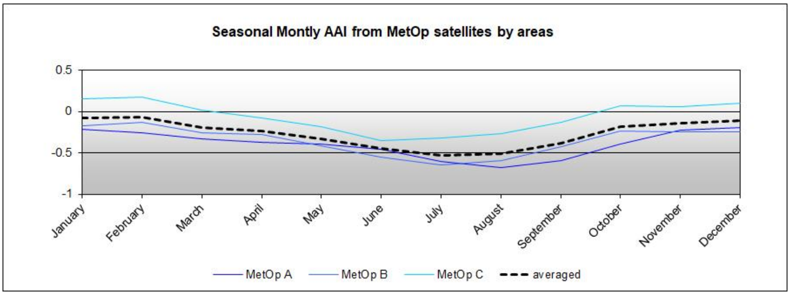

Fig. 6. Comparative seasonal AAI behavior.

In Fig. 7, 8, and 9, we show the regional distribution of AAI data from all three satellites, respectively.

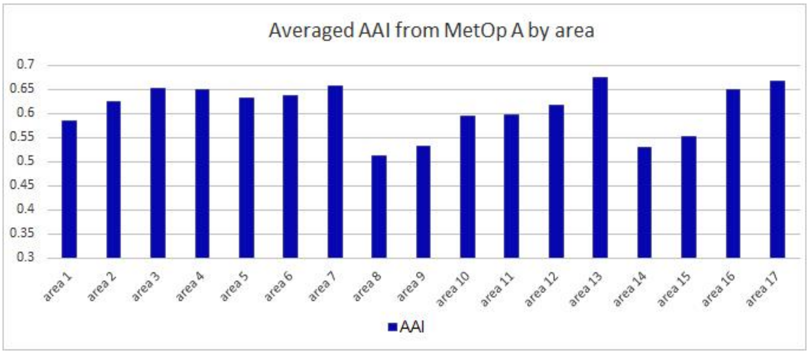

Fig. 7. Spatial distribution of AAI from MetOp A

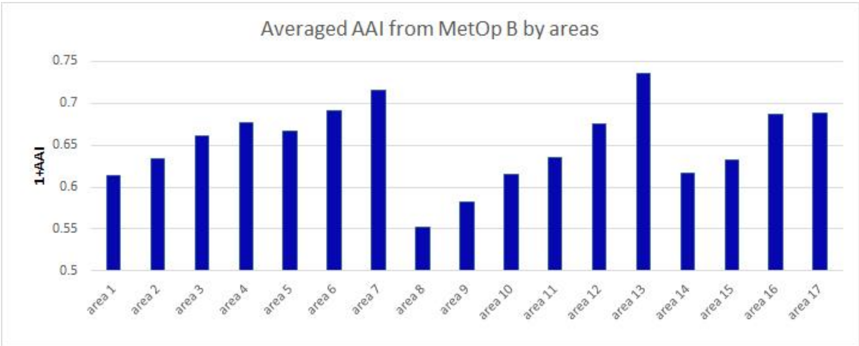

Fig. 8. Spatial distribution of AAI from MetOp B

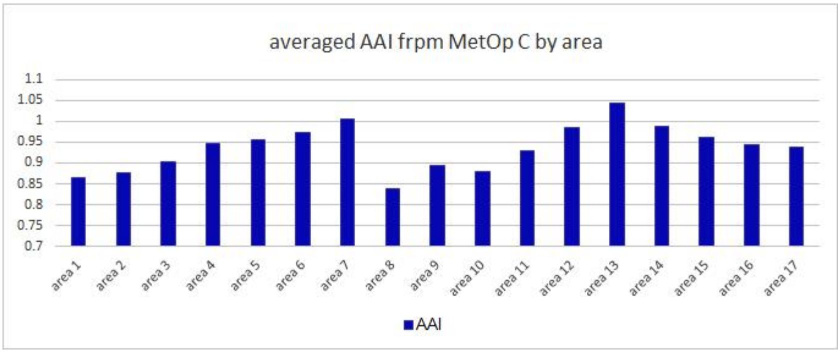

Fig. 9. Spatial distribution of AAI from MetOp A

As we can see from Fig. 7, 8, and 9, spatial distribution obtained from different satellite data is quite different. The only common results are that minimal AAI values are these for area 8, West part of the country. Maximal AAI values have the East part of Bulgaria, areas 7 and 13.

Such differences may be caused by different time periods of satellite data from three MetOp satellites.

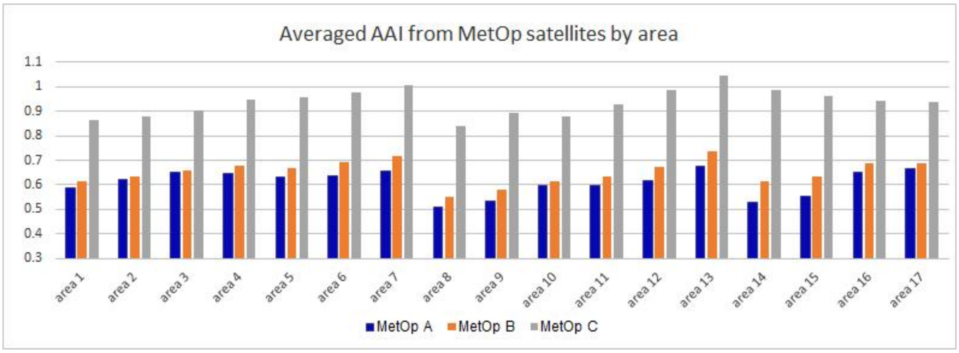

Fig. 10. Comparative spatial AAI distribution

In Fig. 10, we show the comparative spatial distribution and average seasonal behavior of AAI data from all three satellites.

In Fig. 11, 12, and 13, we show the temporal distribution of AAI data from all three satellites, respectively.

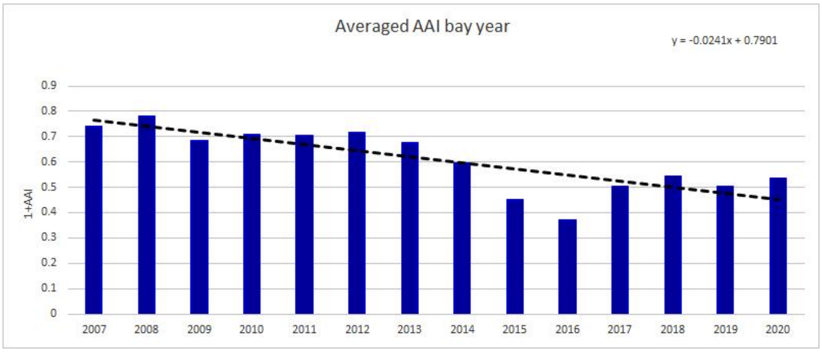

Fig. 11. Temporal AAI MetOp A behavior

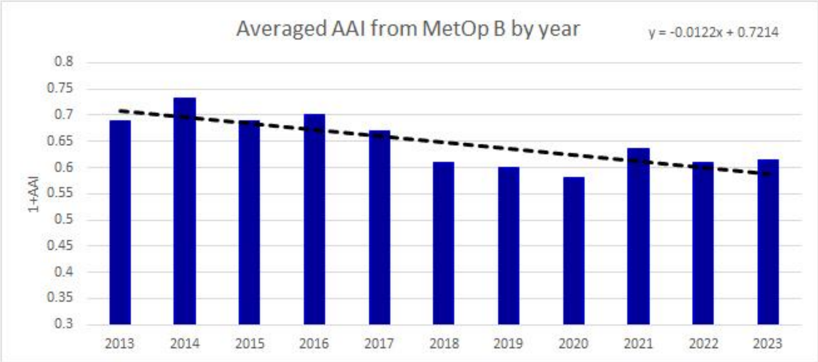

Fig. 12. Temporal AAI MetOp b behavior

As we see from Fig. 12 and 13, AAI shows a decreased tendency.

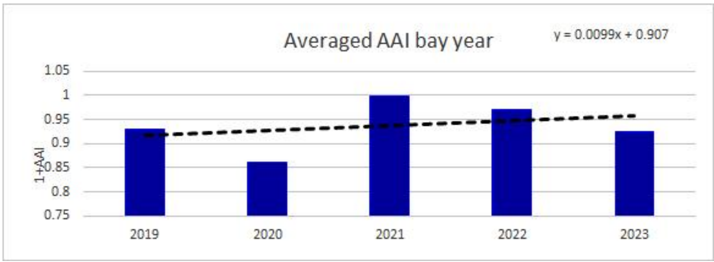

Fig. 13. Temporal AAI MetOp C behavior

As we see from Figs 11 and 12, the temporal trend of AAI, shown from MetOp A and B data, is almost the same. There is a low tendency to decrease. AAI data from MetOp C are available only for a short time period, four years, and show only the expected minimum in 2020, with no decreasing trend.

In Fig. 14, we show the comparative spatial distribution and average seasonal behavior of AAI data from all three satellites.

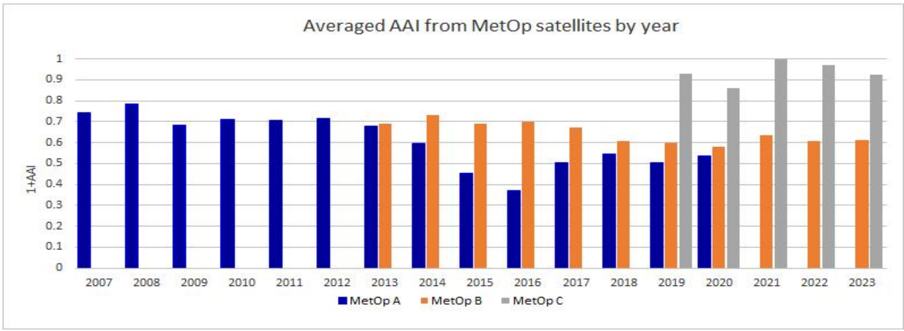

Fig. 14. Comparative temporal AAI distribution

Conclusion

Comparative temporal and spatial distributions from Fig. 10 and 14 can be used for several conclusions:

- AAI values from MetOp C satellite are significantly higher than those from MetOp A and B satellites.
- AAI data from MetOp A satellite shows an unexpected decrease during the period of 2014 – 2017.
- AAI data from all three satellites show that dust pollution is higher in the East part of the country, areas 7 and 13, and minimal in area 8, West part.
- We can’t use AAI data even from MetOp A and B satellites. AAI data from the MetOp C satellite shows completely different temporal and spatial distribution.

References

1. Nazari S, Kermani M, Fazlzadeh M, Matboo S, Yari A. THE ORIGINS AND SOURCES OF DUST PARTICLES, THEIR EFFECTS ON ENVIRONMENT AND HEALTH, AND CONTROL STRATEGIES: A REVIEW. JAPH. 2016;1(2):137-152.
2. Kameswaran, S., Y. Gunavathi, and P. Gopi Krishna. "Dust pollution and its influence on vegetation-a critical analysis." Research journal of Life sciences, Bioinformatics, Pharmaceutical and Chemical sciences 5.1 (2019): 341-363.
3. EUMETSAT - https://classroom.eumetsat.int/mod/page/view.php?id=13065
4. Tropospheric Emission Monitoring Internet Service (TEMIS) - https://www.temis.nl/index.php

5. Eumetsat – product user manual for the NRT, Offline and Data Record Absorbing Aerosol Index Products - https://acsaf.org/docs/pum/Product_User_Manual_NAR_NAP_ARS_ARP_Apr_2020.pdf3. Larson, R., (2013), Elementary Linear Algebra, 7th edition, ch. 10-2, p. 578, Brooks / Cole, CENGAGE Learning, MA
6. Righetti PL, de Juana Gamo JM, Sancho F. Metop-C deployment and start of three-satellite operations. The Aeronautical Journal. 2020;124(1276):902-916. doi:10.1017/aer.2020.10

ИЗПОЛЗВАНЕ НА ААI ОТ ИНСТРУМЕНТА GOME 2 НА БОРДА НА СПЪТНИЦИТЕ МЕТОР А, В И С ЗА ИЗСЛЕДВАНЕ НА ПРАХОВОТО ЗАМЪРСЯВАНЕ НАД БЪЛГАРИЯ

М. Димитрова, Й. Прегьова

Резюме

В статията използваме абсорбциония аерозолен индекс (AAI) от инструмента GOME 2 на борда на трите спътника MetOp A, B и C за периода от началото на 2007 г. до края на 2023 г., за да изследваме тенденциите в праховото замърсяване над България. Използваме усреднени месечни стойности с пространствена разделителна способност от 1 градус и наблюдаваме времеви, пространствени и сезонни тенденции на AAI. Направено е сравнение между резултатите от данните на еднотипните инструменти за трите спътника и анализ на възможността за съвместното им използване.