SEASONAL CHANGES OF SAHARA DESERT DUST TRANSPORT OVER BALKANS

Maria Dimitrova

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

Keywords: Remote Sensing, Air Pollution, Dust Pollution, Ecology

Abstract
This article presents an investigation of seasonal behavior of Sahara desert dust transport over the Balkans. The data used is satellite measurements of monthly averaged AAI value. The researched period is from June 1995th till the end of 2019th. The data used is from four different space instruments onboard five satellites. The area of interest is a rectangle with corners 23 E 43 N and 245 E 35 N. The data from different sources is compared and discussed.

Introduction
Mineral dust is the second largest source of natural aerosols. North African deserts emit most of the dust particles released to the atmosphere worldwide.

The smallest dust particles affect strongly human health (mainly the respiratory system).

The physics, chemistry and biology of the marine atmosphere and the biogeochemical cycles in seawater are strongly influenced by the atmospheric transport and deposition of mineral aerosol particles which are massively exported from the desert areas. Sahara and the peripheral regions are the main source of soil-derived aerosols over the Atlantic and the Mediterranean.

Desert dust transports minerals, bacteria and other small pollutants. Cristal aerosols influence the atmospheric radiative balance through scattering and absorption, and by acting as cloud condensation nuclei when sulfation and nitration occur.

It is now well known that satellite observations of the sunlight reflected by the Earth-atmosphere system enable a relatively accurate retrieval of the vertically integrated dust aerosol content over the ocean in terms of optical thickness [1, 2]. Remote sensing by operational meteorological onboard sensors is suitable for the monitoring of large desert dust plumes which exhibit high temporal and spatial variability.
These dust plumes are spread over thousands of kilometers, and can persist for many days. They have extremely deleterious effects on the air quality near the African continent but are also important on a global scale.

Some authors during the last decades investigate dust transport over Mediterranean [1–6], more often in direction toward Italy and Spain [7] and even more scientists paid attention on dust transport over the Atlantic [8–11]. Results indicate that during “African dust-events,” the numbers of cultivatable airborne microorganisms can be 2 to 3 times more than these found during “clear atmospheric conditions” [12, 13]. There are no exhaustive investigations done on the influence of Sahara dust over the Balkans.

In this paper we use monthly averaged satellite data of AAI (Absorption Aerosol Index), which has close to linear dependence with optical depth from five satellites for the period of 1995 till the end of 2019 to investigate seasonal behavior over the Balkans in nine areas in direction North – South.

**Area of interest, satellite data and investigation method**

In this work we research seasonal behavior (and its variations) of dust atmospheric pollution from Africa in North – South direction over the Balkans. Invested area is rectangle with corners respectively 23 E 43 N and 245 E 35 N.

We choose nine areas (cells of 1 x 1 degrees). Points indicates the center of each one of the areas (Fig. 1).

Fig. 1. Area of interest. On the left – optical image from MODIS with points. On the right – combined image AAI from GOME-2 over the same optical picture and points.
We use satellite data from four space instruments onboard five satellites with similar space and temporal resolution as follows:

- GOME onboard ERS-2 – from 6.1995 till 6.2003 (40x40 km)
- SCIAMACHY onboard ENVISAT – from 9.2002 till 4.2012 (30x60 km)
- OMI onboard AURA – from 9.2004 till now (40x40 km)
- GOME-2 onboard MetOp A – from 1.2007 till now (40x40 km)
- GOME-2 onboard MetOp B – from 12.2012 till now (40x80 km)

On fig. 2 the working duration of each one of these instruments is shown. On the figure we show GOME-2 instrument onboard MetOp C satellite. We don’t include data from them later on because data is available only for one year.

**Fig. 2. The working duration of chosen space instruments**

We choose to use monthly averaged data for AAI in “.nc” format (Longitude: 360 bins centered on 179.5 W to 179.5 E (1 degree steps), Latitude: 180 bins centered on 89.5 S to 89.5 N (1 degree steps) from ESA - TEMIS (Tropospheric Emission Monitoring Internet Service) [14]. There is free data for almost every day during the work time of each one of the chosen instruments.

The Absorbing Aerosol Index (AAI) indicates the presence of elevated absorbing aerosols in the Earth's atmosphere. The aerosol types that are mostly seen in the AAI are desert dust and biomass burning aerosols. The AAI provided here are derived from the reflectance measured by GOME-1, SCIAMACHY and GOME-2 at 340 and 380 nm, and from the reflectance measured by OMI at 354 and 388 nm.

**Results**

For every one of instruments and each year it’s working we built graphics of dependence AAI - month of year. Then we obtained averaged value of AAI for each area and month.
We don’t show results for the 5th and the 8th areas, because these areas are fully over sea regions. Our interest is focused on spatial dust transport distribution over land areas. Results we show on Figures 3 – 7.

Fig. 3. Seasonal behavior of averaged AAI by points from GOME instrument

Fig. 4. Seasonal behavior of averaged AAI by points from SCIAMACHY instrument

Fig. 5. Seasonal behavior of averaged AAI by points from OMI instrument
As it is seen from the above figures, seasonal AAI behavior is quite different for different areas. Areas from 1\textsuperscript{st} to 4\textsuperscript{th} show increase of AAI for winter months, while areas 6\textsuperscript{th}, 7\textsuperscript{th} and 9\textsuperscript{th} show significant increases in AAI during summer. Moreover – AAI increase with point number increasing. As our previous investigations show [15], sand storms from Africa during last 15 years are mainly in winter months (from February till June). Results from the older instruments (GOME and SCIAMACHY) show longer period with increase – till October.

As the area number increases with decrease of Latitude, it shows increasing of desert dust with Latitude decrease. For the illustration of above conclusion and comparison of data from different instruments, on fig. 8 we show averaged AAI value for each area.
As it is seen from the last above graphic - averaged AAI for last area has highest value. AAI differences in areas are similar for GOME-2 and SCIAMACHY instruments. Data from GOME shows similar behavior but lower values.

It seems that the combination of data from OMI with data from other mentioned instruments is not correct. The reason for it may be longer and non stable work of the satellite as well as the different spectral diapason of AAI measurement of this instrument.

Conclusions

As a result of the present research we can conclude that satellite data for AAI shows expected increase in south direction. It means that the dust transport affect the southern Balkan areas (here Crete) stronger then the northern Bulgarian regions. The seasonal behavior shows change during last 15 years. While earlier sand transport continues from February till October, during last decade it shows increase only from March till July with outstanding maximum around May.

References

1. Moulin, C. and F. Guillard, Long-term daily monitoring of Saharan dust load over ocean using Meteosat ISCCP-B2 data 1. Methodology and preliminary results for 1983-1994 in the Mediterranean, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 102, NO. D14, PAGES 16,947-16,958, JULY 27, 1997
2. Moulin, C., C. E. Lambert, U. Dayan, TM V. Masson, M. Ramonet, P. Bousquet, M. Legrand, Y. J. Balkanski, W. Guelle, B. Marticorena, G. Bergametti, and F. Dula, Satellite climatology of African dust transport in the Mediterranean atmosphere, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 103, NO. D11, PAGES 13,137-13,144, JUNE 20, 1998
3. Nilgun Kubilay, Slobodan Nickovic, Cyril Moulin, Franc7ois Dulac, An illustration of the transport and deposition of mineral dust onto the eastern Mediterranean, Atmospheric Environment 34 (2000) 1293}1303
4. Querol, X., J. Peya, M. Pandolfi, A. Alastuey, M. Cusack, N. Per rez, T. Moreno, M. Viana, N. Mihalopoulous, G. Kallos, S. Kleanthous, African dust contributions to mean ambient PM10 mass-levels across the Mediterranean Basin, Atmospheric Environment 43 (2009) 4266–4277

5. Pey, J., X. Querol, A. Alastuey, F. Forastiere, and M. Stafoggia, African dust outbreaks over the Mediterranean Basin during 2001–2011: PM10 concentrations, phenomenology and trends, and its relation with synoptic and mesoscale meteorology, Atmos. Chem. Phys., 13, 1395–1410, 2013

6. Salvador, P., S. Alonso-Pérez, J. Pey, B. Artiñano, J. J. de Bustos, A. Alastuey, and X. Querol, African dust outbreaks over the western Mediterranean Basin: 11-year characterization of atmospheric circulation patterns and dust source areas, Atmos. Chem. Phys., 14, 6759–6775, 2014

7. Blanc, F. De Tomasi, E. Filippo, D. Manno, M. R. Perrone, A. Serra, A. M. Tafuro, and A. Tepore, Characterization of African dust over southern Italy, Atmos. Chem. Phys., 3, 2147–2159, 2003

8. Kevin, D. Perry, Thomas A. Cahill, Robert A. Eldred, and Dabrina D. Dutcher, Long-range transport of North African dust to the eastern United States, Journal of Geophysical Research, vol. 102, NO. D10, pages 11,225-11,238, MAY 27, 1997

9. Joseph, M. Prospero, Long-term measurements of the transport of African mineral dust to the southeastern United States: Implications for regional air quality, Journal of Geophysical Research, vol. 104, NO. D13, pages 15,917-15,927, JULY 20, 1999

10. Sebastian Engelstaedter, Ina Tegen, Richard Washington, North African dust emissions and transport, Earth-Science Reviews 79 (2006) 73–100

11. Y. Ben-Ami, I. Koren, and O. Altaratz, Patterns of North African dust transport over the Atlantic: winter vs. summer, based on CALIPSO first year data, Atmos. Chem. Phys., 9, 7867–7875, 2009

12. Dale, W. Griffin, Virginia H. Garrison, Jay R. Herman & Eugene A. Shinn, African desert dust in the Caribbean atmosphere: Microbiology and public health, Aerobiologia 17: 203–213, 2001

13. Dale, W. Griffin, Douglas L. Westphal, Michael A. Gray, Airborne microorganisms in the African desert dust corridor over the mid-Atlantic ridge, Ocean Drilling Program, Leg 209, Aerobiologia (2006) 22:211–226

14. ESA – TEMIS - http://www.temis.nl/index.php

15. Dimitrova, M., P. Trenchev, E. Georgieva, N. Neykova, R. Neykova, R. Nedkov, D. Gochev, D. Syrakov, B. Veleva, D. Atanassov, T. Spassova, Seasonal changes of aerosol pollutants over Bulgaria, Proceedings of the Fifteenth International Scientific Conference Space, Ecology, Safety, SES 2019, (Print ISSN 2603-3313; Online ISSN 2603-3321), 2019, 241–252
СЕЗОННО ИЗМЕНЕНИЕ НА РАЗПРОСТРАНЕНИЕТО НА ПУСТИНЕН ПЯСЪК ОТ САХАРА НАД БАЛКАНИТЕ

М. Димитрова

Резюме

Статията представя едно изследване на сезонното поведение на пустинен пясък от Сахара, който се разпространява над Балканите. Използвани са спътникови данни за месечните стойности на AAI. Данните са от четири инструмента на борда на пет спътника за периода от „ни 1995-та до края на 2019-та. Изследване е правоъгълна област с ъгли съответно 23 E 43 N and 245 E 35 N. Данните от различните инструменти са сравнени и дискутирани.