TRACKING THE GODZILLA DUST PLUME USING GOOGLE EARTH ENGINE PLATFORM

A. B. Asare-Ansah[1]*, Y. A. Twumasi[1], Z. H. Ning[1], P. B. Ansah[2], D. B. Frimpong[1], F. Owusu[1], C. Y. Apraku[1], M. Anokye[1], P. M. Loh[1], R. N. D. Armah[1], J. Oppong[1]

[1] Urban Forestry and Natural Resources, Southern University and A & M College, Baton Rouge, Louisiana, USA – abena.ansah@sus.edu
[2] CSIR – Forestry Research Institute of Ghana

KEYWORDS: Godzilla, dust plume, aerosol, air quality, Sentinel-5P, Google Earth Engine, Sahara Desert, Africa

ABSTRACT

As part of Earth's nutrient cycle, a layer of air travels every summer from Africa across the Atlantic Ocean. In June 2020, the thickest and densest dust plume traveled over 5000 miles along with the Saharan Air Layer (SAL) from Africa towards the USA and the Caribbean. Due to its gravity and impact, it was nicknamed "Godzilla". While the cause of this event remains unclear, the advantage of using remote sensing applications to monitor aerosol concentrations and movement provides future opportunities to leverage machine learning technologies to build predictive models with the goal of early forecasting and public health interventions. The Sentinel-5P satellite instrument measures the air quality, ozone, and Ultraviolet (UV) radiation, and can be used for climate monitoring, and forecasting. Available on this platform is the UV Aerosol Index (AI) product, a qualitative index that indicates the presence of elevated layers of aerosols in the atmosphere. In this paper, we used Google Earth Engine to monitor the transatlantic movement of this historic dust plume across the Sahara Desert and estimate the aerosol concentrations throughout June 2020. The flexibility of the platform enabled us to generate time series maps to visualize the movement of the Godzilla dust storm from the Sahara Desert across the ocean. The results obtained are relevant for effective planning and interventions to ameliorate the health threats associated with the movement of the dust plume. The outcome is useful for defining the relationship between aerosol concentrations, human health, and aquatic life.

1.0 INTRODUCTION

Aerosols are very minute particles or liquid droplets suspended in the atmosphere and can cause major health concerns if inhaled. They may include particles of dust, volcanic ash plumes, microorganisms, airborne allergens, and other toxic pollutants produced by anthropogenic activities (Boucher, 2015; Nieder et al., 2018; Tobías et al., 2020). Desert dust which is an example of an aerosol is a mixture of particulate matter (PM) emitted from the surface of arid and semi-arid regions (Querol et al., 2019). Large deserts such as the Sahara in North Africa and the Gobi and Taklamakan deserts in Asia are the primary sources of annual mobilized dust in the atmosphere (Prospero, 1999; Sun et al., 2001). According to Rushingabigwi et al., (2020), the Sahara Desert is the biggest source of global dust and the major transporter of aerosol, especially during summer (Prospero, 1999). As part of the Earth's natural phenomenon, dust particles from the Sahara Desert travel every summer across the Atlantic Ocean to the Southeastern USA and the Caribbean (Griffin et al., 2001; Kellogg et al., 2004). On average, trade winds carry around 180 million tons of dust from North Africa across the tropical North Atlantic Ocean each year and this dust settles in various locations across the Americas and the Caribbean Basin (Yu et al., 2015a). This dust storm involves high-velocity winds capable of carrying tiny dry particles from the desert to the Atlantic Ocean (Goudie et al., 2006). According to Ginoux, (2012), 75% of atmospheric particles are made up of desert dust and this can impose a gigantic impact both positive and negative across space and time.

The transatlantic movement of dust has the potential of increasing the population of phytoplankton. These living organisms are an essential component of the food chain in the ocean (Zaigham et al., 2021). In addition to that, the desert dust can supply the gigantic Amazon Forest with nutrients including iron and phosphorus (Rizzolo et al., 2017; Swap et al., 1992). However, Africa's dust storm is known as an exposure pathway for various fungal diseases including coccidioidomycosis (Querol et al., 2019). The World Health Organization also confirms that Africa's aerosol load exceeds the clean air standard of 10μg/m3 of $PM_{2.5}$ (Bauer et al., 2019). Dust can also reduce the quality of the air we breathe and pose great health challenges. The Godzilla dust cloud resulted in a record-breaking PM_{10} concentration of 453 μgm−3 in Puerto Rico and higher $PM_{2.5}$ levels in the southern United States, which exceeded the EPA's air quality regulations (Yu et al., 2021). This $PM_{2.5}$ can trigger respiratory tract diseases such as pneumonia as well as other diseases that can affect the nervous system and cardiovascular system (Rushingabigwi et al., 2020, Christopher and Jones, 2010). Various studies (Dockery et al., 2003; McCreanor et al., 2007; Al Frayh et al., 2001) also confirm that air pollution is associated with respiratory or cardiovascular morbidity and mortality, and that desert dust may increase the incidences and severity of asthma. Another cause of the possible health impacts of dust is the biological and microbiological load of dust. According to Watanabe, 2011, Japanese cedar and cypress pollen found in Asian dust storms, which is another form of a dust storm in spring has been associated with the worsening of respiratory and skin symptoms in adult asthma patients. Also, these pollens or spores from plants can be transported and introduced through the atmospheric pathway into a new environment as an invasive species. This will compete with native species in the new area for resources and eventually disturb the peaceful ecosystem (Isard et al., 2005).

In June 2020, Earth experienced the thickest and densest dust plume that traveled over five thousand (5000) miles along with the Saharan Air Layer (SAL) from Africa towards the USA and the Caribbean. The dust plume had a greater wind velocity compared to the previous 20-year experience (Borunda, 2020). Because of its gravity and impact, it was nicknamed "Godzilla" (Yu et al., 2015a). Information from the National Oceanic and Atmospheric Administration (NOAA) asserted that the Godzilla plume was about 60 % to 70 % larger than the average plume travel in the past (Zhongming et al., 2020). Currently, the background cause of this event remains unclear, with possible hypotheses of, whether it is a meteorological anomaly or effects of extra earth warming degenerating into extreme convectional currents. However, the warmth, dryness, and strong winds associated with the dust plume have been shown to suppress the formation and intensification of tropical cyclones (Sun et al., 2009; Luo et al., 2021). This study uses Google Earth Engine to monitor the movement of this historic dust plume across the Sahara Desert and estimate the Absorbing Aerosol Index (AAI) throughout June 2020. The flexibility of the platform will enable us to generate a time series animation to visualize the movement of the Godzilla dust across the desert from June 1st to 30th 2020. The results obtained would be relevant for effective planning and interventions to ameliorate the health threats associated with the movement of the dust plume.

2.0 METHODS

2.1 Study Area

Situated on the African continent, the Saharan desert is the world's largest desert which covers an area of about 9,200,000 square kilometers and extends from 12°N to 34°N. The desert is bordered by the Atlantic Ocean to the West, the Atlas Mountain, the Mediterranean Sea to the North, the Red Sea on the east, and the Sahel zone on the South (Tucker et al., 1999). According to Laity (2009), the Sahara Desert is made up of barren, rocky plateaus and salt flats, dunes, mountains, dry valleys, and sand. Approximately 25% of the Sahara's surface is covered with sand sheets and dunes (Gritzner, 2019). The Sahara has been a major source of fine particles, blown offshore to the other side of the Atlantic Ocean (Prospero, 1996).

Fig. 1. Study Area Map. Source: National Geographic Style Map, ESRI base maps

2.2 Data Description

In this research, we explored Sentinel-5P, launched by the European Space Agency on 13th October 2017. This satellite captures data on air pollutants including aerosol, ozone, methane, nitrogen oxide, and sulfur dioxide (Safarianzengir et al., 2020). It is relevant for monitoring air pollution, climate monitoring, and forecasting as well as UV and ozone radiation. Specifically, we used the offline Absorbing Aerosol Index (AAI), also known as the Ultraviolet (UV) Aerosol Index available on the Google Earth Engine platform. Google Earth Engine (GEE) is a cloud-based platform that stores a variety of satellite images useful for trend analysis, detecting changes in the landscape, and estimating differences in the earth's surface (Gorelick et al., 2017). AAI is an index that qualitatively shows elevated aerosol layers in the atmosphere with notable absorption (De Graaf et al., 2005). The product was calculated based on a pair of measurements at the 354 nm and 388 nm wavelengths (Kooreman et al., 2020). The AAI band measures particulate matter such as desert dust, biomass burning, and volcanic ash plumes and has a spatial resolution of 1113.2 meters and daily global coverage.

2.3 Image Collection Preparation and Analysis

The area of interest was imported into GEE as a shapefile and the Offline UV Aerosol Index was added as an image collection. A date filter was applied, and the spatial extent was set to the study area. Composites were created every three days in June 2020 using the mean reducer. This reduced the number of observations in June and improved the pixel quality. In all, ten (10) composites for the Sahara Desert were generated. An appropriate color palette was assigned to visualize the absorbing aerosol index and the images were used to create time series maps showing the Godzilla movement.

3.0 RESULTS AND DISCUSSION

This study revealed noticeable changes during the Godzilla dust storm. The brown to cream colors on the map confirms the Sahara Desert's location in Africa. A positive absorbing aerosol index indicates the presence of aerosols which includes dust and values close to zero (0) represent non-absorbing aerosols (Althaf et al., 2022). High positive values indicate the presence of high levels of desert dust (Jethva et al., 2005). From the legend, the purple color indicates the absence of aerosol in the atmosphere whilst the cyan to cream color shows the presence of aerosol in high concentrations.

Fig. 2 shows the mean composite of the aerosol index acquired from Google Earth Engine for June 2020. The 1st mean composite for June 2020 gives an idea of the extent of the dust storm with more dust particles present in countries such as Mali, Niger, and Chad.

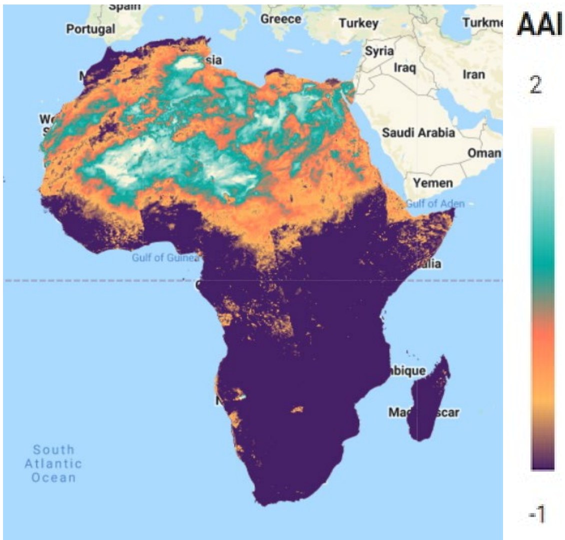

Fig. 2. Aerosol movement from 1st – 3rd June of 2020

Between the 4th and 6th of June 2020, the dust plume expanded horizontally and covered a wider range.

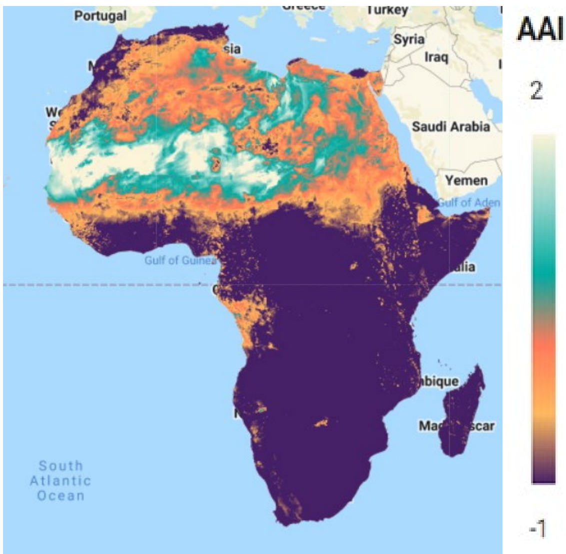

Fig. 3. Aerosol movement from 4th – 6th June of 2020

By the 7th to 9th of June, the dust extended to Western Sahara, Mali, Niger, Mauritania, Southern Algeria, and Chad mostly with an AAI of 2.

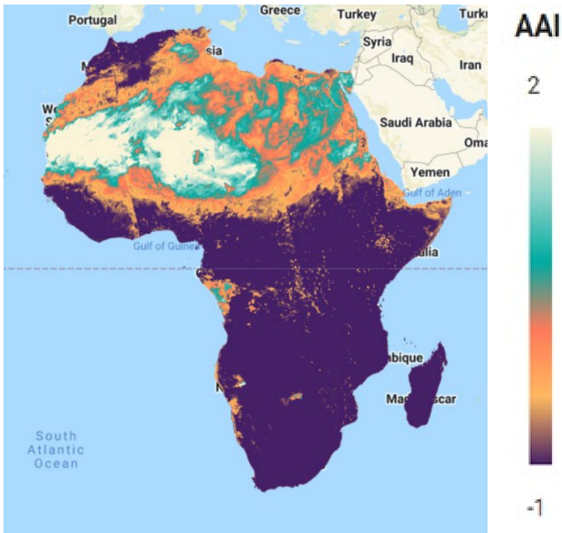

Fig. 4. Aerosol movement from 4th – 6th June of 2020

Furthermore, the dust plume extended to eastern countries such as Sudan and Northwards toward Libya as shown in Fig. 5.

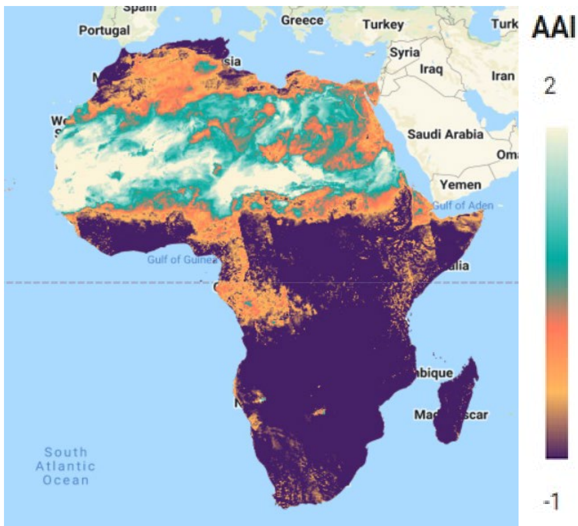

Fig. 5. Aerosol movement from the 10th – 12th of June 2020

The western part of Africa with countries such as Western Sahara, Mauritania, and Mali were not left out on the impact of the Godzilla dust plume. As seen in Fig 6, the west shows a higher absorbing aerosol index of 2. Confirming a study made by Warren (2020), the first traces of the dust reached the Caribbean by 20th June.

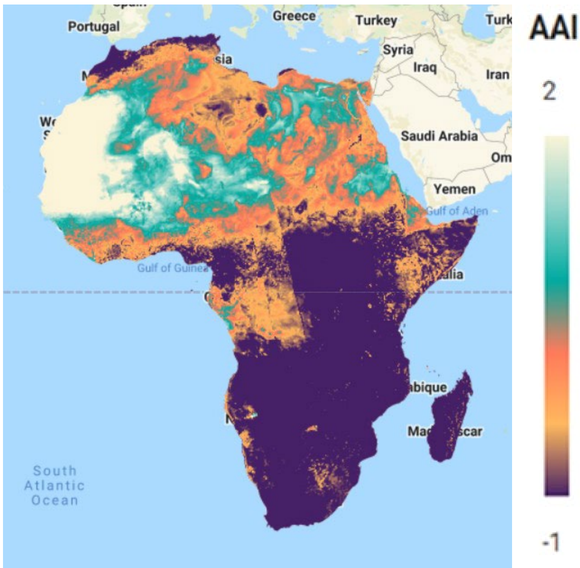

Fig. 6. Aerosol movement from the 16th – 18th of June 2020

However, from the 10th composite (Fig 7), there was a significant decrease in the size of the dust plume as it moved into the Atlantic Ocean This serves as a rich source of phosphorus and iron to phytoplankton, and other plant species in the ocean (Zaigham et al., 2021).

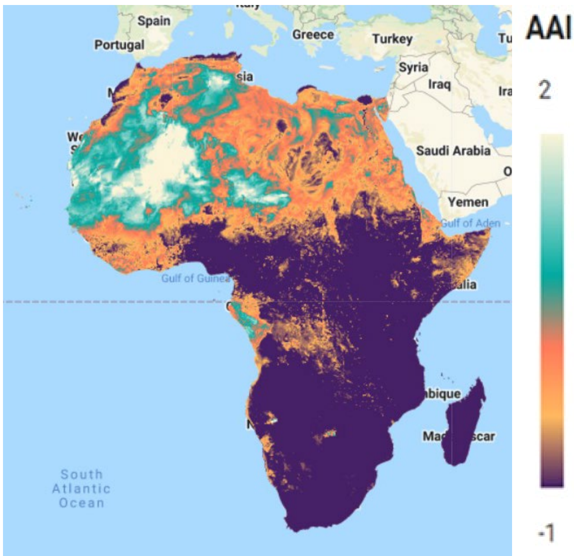

Fig. 7. Aerosol movement from the 28th – 30th of June 2020

4.0 CONCLUSIONS

Various works of literature confirm that although the trans-Atlantic movement of dust supports plant and aquatic life, it also poses serious health issues to humans. The extreme dust movements reduce visibility and so affects the rate at which people travel from one point to another thereby affecting various economies. This study has proven that aerosols in the form of desert dust can be monitored using Earth observation techniques. In the future, leveraging machine learning and AI could be a useful tool for building predictive models for early forecasting to support rapid response preparedness. Further studies could also be carried out to identify the relationship between the health impact of the desert dust across countries in the Sahara and how desert dust suppresses the formation and intensification of tropical cyclones. This could benefit Southern states in the US and Caribbean that frequently experience these events.

ACKNOWLEDGEMENT

We would like to acknowledge the American Society for Photogrammetry and Remote Sensing for granting us a scholarship to present at the 2022 ASPRS Annual conference and the United States Department of Agriculture (USDA) National Institute of Food and Agriculture McIntire Stennis Project NI21MSCFRXXXG003 for their support.

REFERENCES

Althaf, P., Shaeb, K. H. B., & Kumar, K. R. (2022). Hotspot analysis and long-term trends of absorbing aerosol index from dust emissions were measured by the Ozone Monitoring Instrument at different urban locations in India from to 2005–2018. Atmospheric Environment, 118933.

Al Frayh AR, Shakoor Z, Gad El Rab MO, Hasnain SM (2001): Increased prevalence of asthma in Saudi Arabia. Ann Allergy Asthma Immunol; 86:292-6. https://doi.org/10.1016/S1081-1206(10)63301-7

Bauer, S. E., Im, U., Mezuman, K., & Gao, C. Y. (2019). Desert dust, industrialization, and agricultural fires: Health impacts of outdoor air pollution in Africa. *Journal of Geophysical Research: Atmospheres*, *124*(7), 4104-4120.

Boucher, O. (2015). Atmospheric aerosols. In Atmospheric Aerosols (pp. 9-24). Springer, Dordrecht.

Borunda, A. (2020). *Saharan dust is bad for health. But it's also crucial to Earth's biology and climate*. Retrieved from National Geographic: https://www.nationalgeographic.com/science/article/concerned-saharan-dust-plume-crucial-to-ecosystem?loggedin=true

Christopher, S. A., & Jones, T. A. (2010). Satellite and surface-based remote sensing of Saharan dust aerosols. Remote Sensing of Environment, 114(5), 1002-1007.

De Graaf, M., Stammes, P., Torres, O., & Koelemeijer, R. B. A. (2005). Absorbing Aerosol Index: Sensitivity analysis, application to GOME, and comparison with TOMS. Journal of Geophysical Research: Atmospheres, 110(D1).

Dockery DW, Pope CA 3rd, Xu X et al (2003): An association between air pollution and mortality in six U.S. cities. N Engl J Med 329:1753-9. https://doi.org/10.1056/NEJM199312093292401

Ginoux, P., Prospero, J. M., Gill, T. E., Hsu, N. C., & Zhao, M. (2012). Global-scale attribution of anthropogenic and natural dust sources and their emission rates based on MODIS Deep Blue aerosol products. Reviews of Geophysics, 50(3). https://doi.org/10.1029/2012RG000388

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote sensing of Environment, 202, 18-27.

Goudie, A. S., & Middleton, N. J. (2006). Dust entrainment, transport, and deposition. Desert Dust in the Global System, 13-31.

Griffin, D. W., Kellogg, C. A., & Shinn, E. A. (2001). Dust in the wind: long-range transport of dust in the atmosphere and its implications for global public and ecosystem health. Global Change and Human Health, 2(1), 20-33.

Gritzner, J. Allman and Peel, Ronald Francis (2019, November 26). Sahara. Encyclopedia Britannica. https://www.britannica.com/place/Sahara-desert-Africa
Isard, S. A., Gage, S. H., Comtois, P., & Russo, J. M. (2005). Principles of the atmospheric pathway for invasive species applied to soybean rust. Bioscience, 55(10), 851-861.

Jethva, H., Satheesh, S. K., & Srinivasan, J. (2005). Seasonal variability of aerosols over the Indo-Gangetic basin. Journal of Geophysical Research: Atmospheres, 110(D21).

Kellogg, C. A., Griffin, D. W., Garrison, V. H., Peak, K. K., Royall, N., Smith, R. R., & Shinn, E. A. (2004). Characterization of aerosolized bacteria and fungi from desert dust events in Mali, West Africa. Aerobiologia, 20(2), 99-110.

Kooreman, M. L., Stammes, P., Trees, V., Sneep, M., Tilstra, L. G., de Graaf, M., ... & Veefkind, J. P. (2020). Effects of clouds on the UV Absorbing Aerosol Index from TROPOMI. Atmospheric Measurement Techniques, 13(12), 6407-6426.

Laity, J. J. (2009). Deserts and desert environments (Vol. 3). John Wiley & Sons.

Luo, H., & Han, Y. (2021). Impacts of the Saharan air layer on the physical properties of the Atlantic tropical cyclone cloud systems: 2003–2019. Atmospheric Chemistry and Physics, 21(19), 15171-15184.

McCreanor J, Cullinan P, Nieuwenhuijsen MJ et al (2007): Respiratory effects of exposure to diesel traffic in persons with asthma. N Engl J Med; 357:2348-58. https://doi.org/10.1056/NEJMoa071535

Nieder, R., Benbi, D. K., & Reichl, F. X. (2018). Soil-borne particles and their impact on environment and human health. In Soil components and human health (pp. 99-177). Springer, Dordrecht.

Prospero, J. M. (1999): Long-term measurements of the transport of African mineral dust to the southeastern United States: Implications for regional air quality. Journal of Geophysical Research: Atmospheres, 104(D13), 15917–15927. https://doi.org/10.1029/199jd900072.

Prospero, J. M. (1996). Saharan dust transport over the North Atlantic Ocean and Mediterranean: An overview. The impact of desert dust across the Mediterranean, 133-151.

Querol, X., Tobías, A., Pérez, N., Karanasiou, A., Amato, F., Stafoggia, M., ... & Alastuey, A. (2019): Monitoring the impact of desert dust outbreaks for air quality for health studies. Environment international, 130, 104867. https://doi.org/10.1016/j.envint.2019.05.061

This contribution has been peer-reviewed.
https://doi.org/10.5194/isprs-archives-XLVI-M-2-2022-33-2022 | © Author(s) 2022. CC BY 4.0 License.

Rizzolo, J. A., Barbosa, C. G., Borillo, G. C., Godoi, A. F., Souza, R. A., Andreoli, R. V., ... & Godoi, R. H. (2017). Soluble iron nutrients in Saharan dust over the central Amazon rainforest. Atmospheric Chemistry and Physics, 17(4), 2673-2687.

Rushingabigwi, G., Nsengiyumva, P., Sibomana, L., Twizere, C., & Kalisa, W. (2020). Analysis of the atmospheric dust in Africa: The breathable dust's fine particulate matter PM2. 5 in correlation with carbon monoxide. Atmospheric Environment, 224, 117319.

Safarianzengir, V., Sobhani, B., Yazdani, M. H., & Kianian, M. (2020). Monitoring, analysis, and spatial and temporal zoning of air pollution (carbon monoxide) using Sentinel-5 satellite data for health management in Iran, located in the Middle East. Air Quality, Atmosphere & Health, 13(6), 709-719.

Swap, R., Garstang, M., Greco, S., Talbot, R., & Kållberg, P. (1992). Saharan dust in the Amazon Basin. Tellus B, 44(2), 133-149.

Sun, D., Lau, W. K. M., Kafatos, M., Boybeyi, Z., Leptoukh, G., Yang, C., & Yang, R. (2009). Numerical simulations of the impacts of the Saharan air layer on Atlantic tropical cyclone development. Journal of Climate, 22(23), 6230-6250.

Sun, J., Zhang, M., & Liu, T. (2001): Spatial and temporal characteristics of dust storms in China and its surrounding regions, 1960–1999: Relations to source area and climate. Journal of Geophysical Research: Atmospheres, 106(D10), 10325–10333. https://doi.org/10.1029/2000jd900665

Tobías, A., & Stafoggia, M. (2020). Modeling desert dust exposures in epidemiologic short-term health effects studies. Epidemiology (Cambridge, Mass.), 31(6), 788.

Tucker, C. J., & Nicholson, S. E. (1999). Variations in the size of the Sahara Desert from 1980 to 1997. Ambio, 587-591.

Watanabe, M., Igishi, T., Burioka, N., Yamasaki, A., Kurai, J., Takeuchi, H., ... & Shimizu, E. (2011): Pollen augments the influence of desert dust on symptoms of adult asthma patients. Allergology International, 60(4), 517-524. https://doi.org/10.2332/allergolint.10-OA-0298

Warren, C. (2020). *Godzilla' dust storm traced to shaky northern jet stream*. Retrieved April 2022, from Science: https://www.science.org/content/article/godzilla-dust-storm-traced-shaky-northern-jet-stream

Yu, H., Chin, M., Yuan, T. L., Bian, H., Remer, L. A., Prospero, J. M., Omar, A., et al. (2015a.): The fertilizing role of African dust in the Amazon rainforest: A first multiyear assessment based on CALIPSO lidar observations. Geophys. Res. Lett., 42,1984-1991 https://doi.org/10.1002/2015GL063040

Yu, H., Tan, Q., Zhou, L., Zhou, Y., Bian, H., Chin, M., ... & Holben, B. N. (2021): Observation and modeling of the historic "Godzilla" African dust intrusion into the Caribbean Basin and the southern US in June 2020. Atmospheric Chemistry and Physics, 21(16), 12359-12383. https://doi.org/10.5194/acp-21-12359-2021

Zaigham, N. A., Alam, T., Mahar, G. A., & Nayyar, Z. A. (2021). Dust storms add in blooming of phytoplankton, tiny wanderer plants as food-chain, over Arabian sea: a research study based on temporal satellite images. Pak. J. Bot, 53(4), 1449-1457.

Zhongming, Z., Linong, L., Xiaona, Y., Wangqiang, Z., & Wei, L. (2020). Satellites track unusual Saharan dust plume.