



Homeland Defense & Security
Information Analysis Center



HDIAC TECHNICAL INQUIRY (TI) RESPONSE REPORT

Global Atmospheric Dust Research Efforts

Report Number:

HDIAC-BCO-2024-616

Completed November 2024

HDIAC is a U.S. Department of Defense
Information Analysis Center

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE (DD-MM-YYYY) 18-11-2024		2. REPORT TYPE Technical Research Report		3. DATES COVERED (From – To)	
4. TITLE AND SUBTITLE Global Atmospheric Dust Research Efforts				5a. CONTRACT NUMBER FA8075-21-D-0001	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Daniel Fleming				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Homeland Defense & Security Information Analysis Center (HDIAC) SURVICE Engineering Company 4695 Millennium Drive Belcamp, MD 21017-1505				8. PERFORMING ORGANIZATION REPORT NUMBER HDIAC-BCO-2024-616	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Defense Technical Information Center (DTIC) 8725 John J. Kingman Road Fort Belvoir, VA 22060-6218				10. SPONSOR/MONITOR'S ACRONYM(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Distribution Statement A. Approved for public release: distribution is unlimited.				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
				13. SUPPLEMENTARY NOTES	
14. ABSTRACT The Homeland Defense and Security Information Analysis Center was asked to provide information on quantifiable impacts or even potential impacts that atmospheric dust particulates have on climate. The primary focus is on atmospheric dust that centers around the northern Africa region and the regions of the Atlantic Ocean in close proximity, but any global information is also of interest. This report contains findings for which organizations have detection and cataloging capabilities for atmospheric dust particulates, as well as which organizations have been performing climate-related research as it relates to trends in the presence of atmospheric dust over time.					
15. subject terms (provided by author) atmospheric dust, dust deposition, climate change, environmental impacts, atmospheric models					
16. SECURITY CLASSIFICATION OF: U			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 12	19a. NAME OF RESPONSIBLE PERSON Ted Welsh, HDIAC Director
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U			19b. TELEPHONE NUMBER (include area code) 443-360-4600

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

About

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TI Research

A chief service of the DoDIAC is free technical inquiry (TI) research limited to four research hours per inquiry. This TI response report summarizes the research findings of one such inquiry. Given the limited duration of the research effort, this report is not intended to be a deep, comprehensive analysis but rather a curated compilation of relevant information to give the reader/inquirer a "head start" or direction for continued research.

Abstract

The Homeland Defense and Security Information Analysis Center was asked to provide information on quantifiable impacts or even potential impacts that atmospheric dust particulates have on climate. The primary focus is on atmospheric dust that centers around the northern Africa region and the regions of the Atlantic Ocean in close proximity, but any global information is also of interest. This report contains findings for which organizations have detection and cataloging capabilities for atmospheric dust particulates, as well as which organizations have been performing climate-related research as it relates to trends in the presence of atmospheric dust over time.

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1.0 TI Request

1.1 Inquiry

Can an annotated bibliography be provided on atmospheric dust globally or emanating from and/or affecting Africa?

1.2 Description

The Homeland Defense and Security Information Analysis Center (HDIAC) was asked to provide information on research to date for trends in atmospheric dust and its relation to climate-related trends. Of particular interest is information centered around the northern Africa region and the regions of the Atlantic Ocean in close proximity, but any information on these topics globally is also of interest.

2.0 TI Response

A literature search was performed on the Defense Technical Information Center's Research and Engineering Gateway and on open-source platforms. Additionally, a call for information was sent out to HDIAC's member network to seek contributions on this topic. This research is important to the U.S. Department of Defense (DoD), as ensuring a strong military posture and the protection of critical infrastructure are impacted by military sensing capabilities, which exceed thresholds in atmospheric particulates and might impact some sensing capabilities. Additionally, climate-related considerations are a key factor in many regional decisions for U.S. forces and allies.

2.1 National Aeronautics and Space Administration (NASA)

NASA coordinated with HDIAC to provide information on the Observations of Aerosols Above Clouds and Their Interactions (ORACLES) investigation [1], as well as the Global Reference Atmospheric Model (GRAM) platform [2] and the Global Positioning System Occultation Analysis System (GOAS) [3]. Additionally, NASA's Jet Propulsion Laboratory developed the Earth Surface Mineral Dust Source Investigation (EMIT) tool, which is "an imaging spectrometer that records a full spectrum of solar-reflected light at each pixel in an image" [4].

2.1.1 ORACLES

The ORACLES investigation is a 5-yr research effort that is designed to study key processes that determine climate impacts of African biomass burning (BB) aerosols [1]. With its focus on

the Africa region, this investigation is used to study the “aerosol-cloud interactions in the southeast Atlantic,” with the goals of determining the impact that BB has on the region and better understanding various radiation interactions that BB could have on a global scale [1].

2.1.2 GRAM

The GRAM platform is an “engineering-oriented atmospheric model that estimates mean values and statistical variations of atmospheric properties for planetary destinations” [2]. Key parameters that GRAM can generate include: atmospheric density, temperature, pressure, winds, and chemical composition [2].

2.1.3 GOAS

The GOAS “processes atmospheric and ionospheric occultation data obtained from low-Earth-orbiting Global Positioning System transmission receivers” [3], which can be used to provide information on atmospheric density, temperatures, pressures, refractivity, and bending angles of signals vs. altitude up to 30 km from the Earth’s surface [5].

2.1.4 EMIT

The EMIT tool is an imaging spectrometer developed at NASA’s Jet Propulsion Laboratory, which was launched to the International Space Station on 14 July 2022. This spectrometer records a full spectrum of solar-reflected light to map mineral-dust-forming regions at a global level to better inform research on dust composition and related radiative-forcing effects in the presence of these mineral-dust regions [4].

2.2 DoD

The DoD has performed atmospheric-dust-related research across various components. Information on the research to date is detailed in Sections 2.2.1 and 2.2.2.

2.2.1 U.S. Army

The Army has performed research in atmospheric dust tracking and compared the generated data with climate-related phenomena over time. The U.S. Army Engineer Research and Development Center (ERDC) published its findings pertaining to four dust-related events in the Africa region from 2017 to 2021 [6]. ERDC suggested that further research in this field be completed, as “a recent study found that the Godzilla dust event of June 2020 could have contributed to an increase in tropical cyclone activity in the Atlantic Basin due to a net warming

of sea surface and air temperatures over the Atlantic Ocean” [6]. Similarly, dust and atmospheric analysis reports are being conducted for additional regions [7].

2.2.2 U.S. Navy

The Navy has been committed to studying the operational impacts of aerosolized particulates to DoD operations for multiple decades [8]. Navy agencies, such as the Naval Research Laboratory and the Office of Naval Research, have partnered with the Johns Hopkins University Applied Physics Laboratory team “for end-to-end prediction of dust impacts on DoD operations, with a focus on visibility; [intelligence, surveillance, and reconnaissance] ISR; and directed-energy electro-optical systems.” To achieve this end-to-end capability, the Navy developed:

- The U.S Navy Aerosol Analysis and Prediction System Reanalysis tool
- International Cooperative for Aerosol Prediction Multi-Model Ensemble
- Multi-satellite sensor and observation holdings
- Extensive field campaign dataset holdings
- A diverse network of subject matter experts in the scientific community

2.3 Other Agencies

Many additional agencies have been researching the presence or origin of dust particulates in the atmosphere, or the impact that those particulates have on climate. The information in this section is not a fully inclusive list of information available on the topic but instead reflects what can be published in this report. For additional information, please follow up with the HDIAC team.

2.3.1 University of Georgia

The University of Georgia has partnered with the National Science Foundation, Texas A&M University-Corpus Christi, and additional partners to perform research to further understand the effects that atmospheric particulate deposition into marine environments has on regional climates [9]. This research focuses on the impacts that the deposition from dusts originating in the Saharan region has on microbes found within the Atlantic Ocean by relating the trends of dust present in the atmosphere with temporal trends of measurable concentrations in biogeochemical and microbial responses in the subtropical Atlantic.

2.3.2 Institute for Defense Analyses (IDA)

IDA has assembled a team of researchers who utilize established databases and tools to assist in the realm of atmospheric research [10]. It has experience with reanalysis tools and projected climate datasets to generate K-means, unsupervised, machine learning tools to generate aerosol optical depth data, weather information, and land-type information for trend analysis.

Key reanalysis tools and datasets include:

- Reanalysis
 - The European Centre for Medium-Range Weather Forecasts Reanalysis Tool v5 (known as ERA5): a fifth-generation atmospheric reanalysis capability maintained by the European Centre for Medium-Range Weather Forecasts for global climate. This tool focuses on atmospheric, land, and oceanic climate variables, with hourly updates [11].
 - National Centers for Environmental Prediction and National Center for Atmospheric Research Reanalysis 2 Tool: a tool that provides daily and monthly atmospheric modeling records from 1948 to the present [12]. This tool is updated several times a day to provide information on air temperature, convective precipitation rates, divergence data, downward longwave radiation flux, downward solar radiation flux, geopotential height, ground heat flux, ice concentrations, land-sea masks, latent heat net flux data, sea level data, orography, atmospheric pressure data, cloud data, solar data, and more.
- Projected Climate Datasets
 - Community Earth System Model Large Ensemble Community Project (known as CESM LENS): a climate variability and climate change simulation model [13]. Its simulations are available publicly to review.
 - Hadley Centre Global Environment Model Family (known as HadGEM3): a family of models that can provide details on both atmospheric data and Earth surface-level information, such as dynamic vegetation, ocean biology, and atmospheric chemistry [14].

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Biography

Daniel Fleming is a research inquiry analyst for the Homeland Defense and Security Information Analysis Center. He has 6 yr of military experience and 4 yr of experience in a clinical pharmaceutical setting. As a Marine Corps combat engineer, he used his skillsets both domestically and internationally. During his time in the pharmaceutical industry, he served as a lead analytical technician, executing established methods; assisting in developing site-specific methods and programs; performing registration, storage, and testing; and ensuring accurate reporting of tests on thousands of drug and vehicle suspensions. Mr. Fleming also executed on-site training plans at several stages to ensure modern compliance with federal regulations.