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African Dust Carries Microbes Across the Ocean: Are They Affecting Human and Ecosystem Health?

Atmospheric transport of dust from northwest Africa to the western Atlantic Ocean region may be responsible for a number of environmental hazards, including the demise of Caribbean corals; red tides; amphibian diseases; increased occurrence of asthma in humans; and oxygen depletion (eutrophication) in estuaries. Studies of satellite images suggest that hundreds of millions of tons of dust are transported annually at relatively low altitudes across the Atlantic Ocean to the Caribbean Sea and southeastern United States. The dust emanates from the expanding Sahara/Sahel desert region in Africa and carries a wide variety of bacteria and fungi.

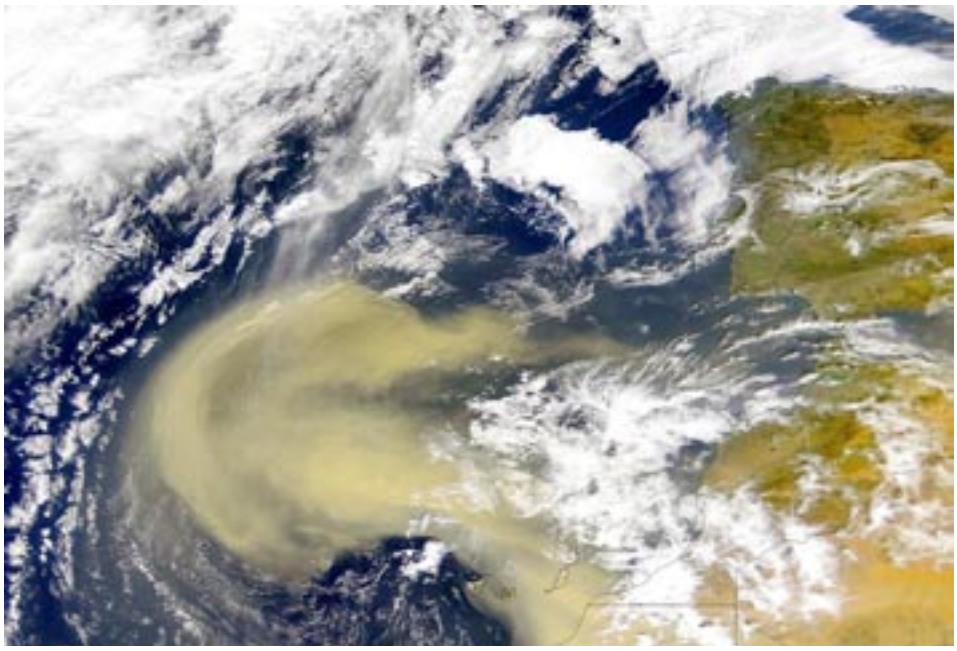

Figure 1. The satellite image, acquired by NASA/Goddard Spaceflight Center's SeaWiFS Project and ORBIMAGE on February 26, 2000, shows one of the largest Saharan dust storms ever observed by SeaWiFS as it moves out over the eastern Atlantic Ocean. Spain and Portugal are at the upper right; Morocco is at the lower right.

The U.S. Geological Survey, in collaboration with the NASA/Goddard Spaceflight Center, is conducting a study to identify microbes—bacteria, fungi, viruses—transported across the Atlantic in African soil dust. Each year, millions of tons of desert dust blow off the west African coast and ride the trade winds across the ocean, affecting the entire Caribbean basin, as well as the southeastern United States. Of the dust reaching the U.S., Florida receives about 50 percent, while the rest may range as far north as Maine or as far west as Colorado. The dust storms can be tracked by satellite and take about one week to cross the Atlantic.

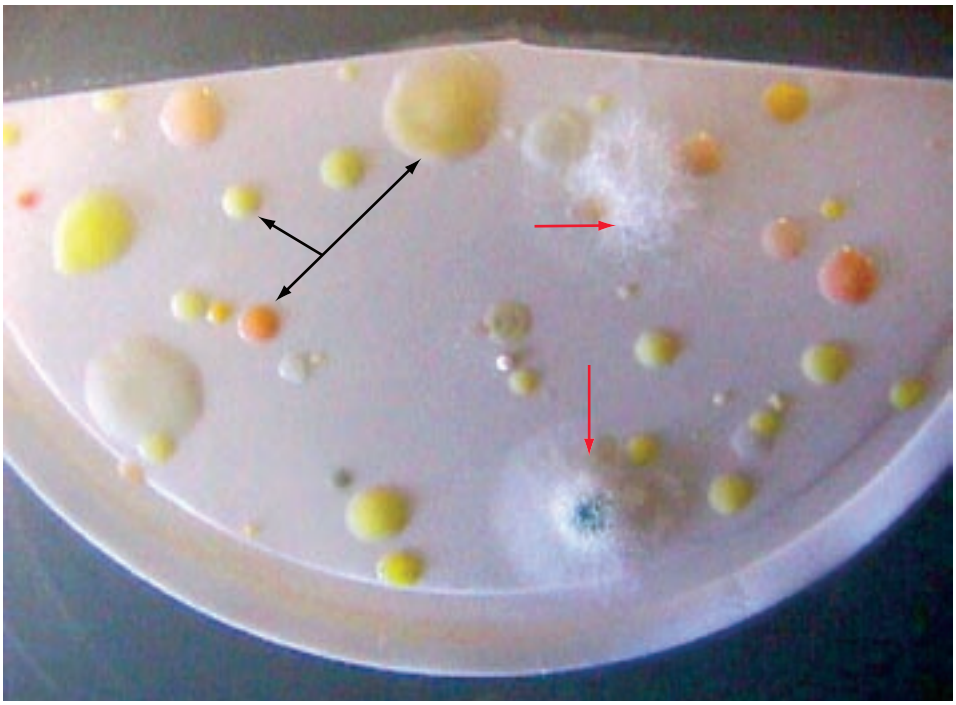

Figure 2. This half of an air filter represents 40 liters of air (roughly the amount it would take to fill a 10 gallon aquarium) sampled during a dust storm in Mali, Africa. The filter is placed on nutrient media for 48 hours so the viable microbes can grow. The shiny, colorful circles (indicated by the black arrows) are bacterial colonies. The fuzzy patches (indicated by the red arrows) are fungi. These colonies range in size from about 1 to 5 millimeters.

How many microbes can a dust event carry? There are not enough data at this point to answer that question. However, a conservative estimate of 10,000 microbes per gram of soil, suggests that in 1 million tons of dust (airborne soil) there would be 10 quadrillion (10^{16}) microbes! Conventional wisdom says ultraviolet radiation from the sun would kill most microbes during the 5- to 7-day trip

Figure 3. The eight brightly colored bacteria streaked on this petri dish of agar were isolated from a dust event in Africa. While many bacteria are colorless or off-white in appearance, the intense colors and opaque appearance of these streaks are examples of how deeply pigmented many of the dust bacteria are. Having lots of pigment is thought to help shield the microbes from harmful solar radiation, sort of like wearing sunscreen.

across the Atlantic. Our studies thus far indicate that of the microbes that become airborne, hundreds are surviving the aerial journey in each gram of dust, apparently sheltered within the particles, shrouded by protective pigments, or shielded by overlying dust layers. Air samples taken in the Virgin Islands show an increase of 3 to 10 times as many microbes during dust events than during clear conditions. Air samples taken in the country of Mali, west Africa, can contain as many as 15 viable bacteria per liter of air (approximately one breath).

What types of microbes are in the dust? Bacteria, fungi, and viruses—some of them pathogenic (capable of causing diseases) and some of them common to many environments. Roughly 30 percent of the bacteria isolated from airborne soil dust are known pathogens, able to affect plants, animals, or humans.

What are the possible impacts of these microbial travelers on downwind ecosystems? USGS scientists have monitored coral reef vitality for nearly 40 years and have observed that the Caribbean and Florida coral reefs have been in a state of decline since the late 1970s. Moreover, a number of other marine species, including the grazing sea urchin, *Diadema*, and sea fans, have experienced a widespread and sudden demise, roughly coincident with the deaths of the stony coral populations and increased pulses of African dust. Recent studies at the University of South Carolina Aiken have identified several species of soil fungi, *Aspergillus*, in African dust samples collected from the Caribbean atmosphere. One of these, *Aspergillus sydowii*, has been shown to be the causative agent of a disease in sea fans (now known as aspergillosis). Many coral diseases are not well characterized and could possibly be caused by microbes that may have rained down from passing dust clouds.

It is also possible that microbes in the African dust could be linked to some of the well-known outbreaks of infectious diseases in endangered marine species, such as manatees, dolphins, and turtles. Loggerhead sea turtles in the Canary Islands (off the west coast of Africa) have been dying from a bacterial infection caused by *Staphylococcus xylosus*, which has been found in a dust sample taken in Mali.

The soil dust contains a number of plant and animal pathogens that could affect agriculture and livestock in downwind areas. Fungal diseases, affecting commercial crops like sugarcane and bananas, have appeared in the Caribbean within a few days after an outbreak in Africa, suggesting the spores could have traveled in a dust storm. Our research has identified bacterial pathogens of rice and beans in the Caribbean air samples, as well as those that cause disease in fruit and a variety of trees, from African air samples. It has been speculated that African dust may carry the virus responsible for Foot and Mouth Disease (which is endemic to sub-Saharan Africa) because tentative links have been made between dust storms that passed over Great Britain and subsequent outbreaks of the disease at multiple points. We will be testing future air samples for evidence of this and other viruses. The dust has

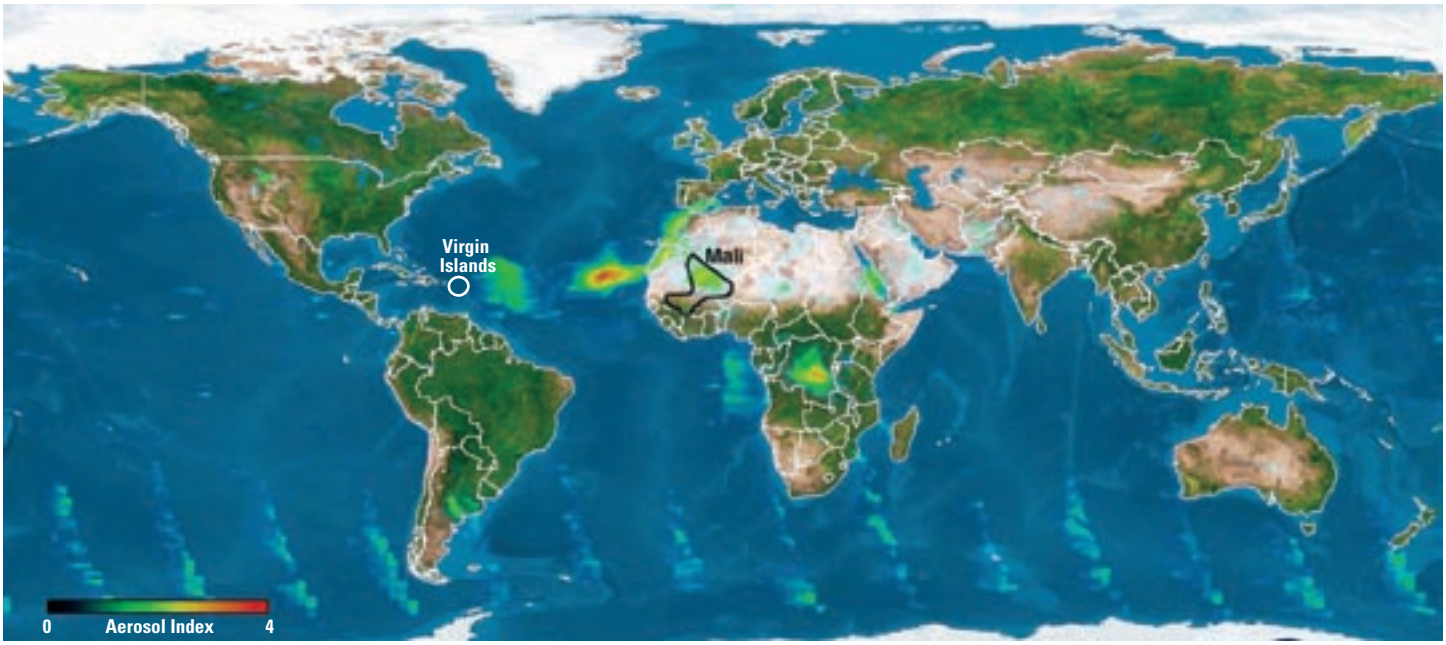

Figure 4. This image, acquired by NASA's Earth Probe TOMS (Total Ozone Mapping Spectrometer) satellite, shows pulses of African dust moving across the Atlantic Ocean. Our study sites, the Virgin Islands and Mali, have been outlined for clarity.

been found to contain bacteria that cause infections in birds, pigs, and cattle.

The African dust events also have a direct effect on human health. During a dust event, airborne particulate concentrations in Mali exceed international health standards tenfold. African dust clouds arriving in the Caribbean are still thick enough to obscure visibility and coat windshields. Several investigators are currently studying a possible link between high rates of asthma in the Caribbean and African dust events. For example, there has been a 17-fold increase in the incidence of asthma on the island of Barbados since 1973. Whether this is due to tiny mineral particles irritating the lungs, bacterial and fungal spores, pollen, or some combination of these and other factors remains to be determined. In addition to allergic or asthmatic responses, there is the separate issue of microbes that are able to cause infections. Although we have detected bacteria and fungi in the dust that are capable of causing infection in people with weakened immune systems, there have been no cases of infectious illness in the Caribbean or U.S. that have been directly linked to intercontinental dust events.

In addition to hosting microbes, the African dust is carrying other unpleasant passengers. Dust from the extraordinary dust event of February 26, 2000 (shown on the first page), was collected by researchers at the University of the Azores. The smallest particles (one micrometer) were found to contain 2 parts per million of the element mercury, which is many times greater than the amounts normally found in air. The mercury may have originated from open-pit mercury mines in Algeria and from the rock formations from which the mercury is mined.

Figure 6. The dark purple coloring surrounding dead tissue on this sea fan is indicative of the disease aspergillosis. The fungus (*Aspergillus sydowii*), now known to cause this disease in the tropical western Atlantic, was identified by Garriet Smith's laboratory at the University of South Carolina Aiken. The fungus was isolated in its active pathogenic form from air samples taken during dust events in the Virgin Islands and in Mali.

Figure 5. The hallmark brick red color of the African dust can be seen on the street as well as in the air in this photo taken in the city of Bamako, Mali. Dust concentrations in Mali (west Africa) range from 26 -13,735 $\mu g/m^3$, sometimes greatly exceeding international health standards. Easily inhaled, the small particles become trapped in human lungs and are difficult to expel.

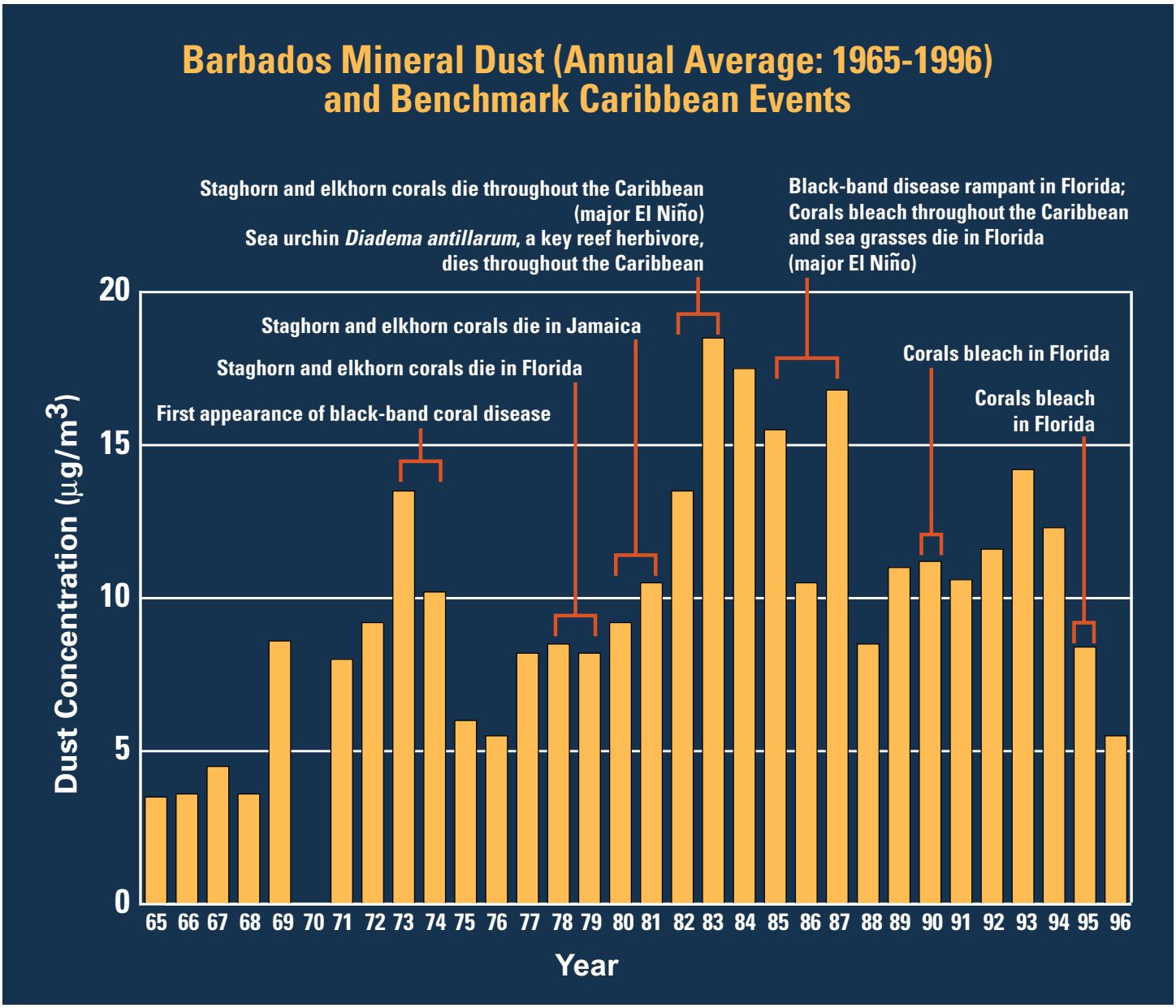

Figure 7. This graph shows the overall increase in African dust reaching the Caribbean island of Barbados since 1965. Notice that the peak years for dust deposition were 1983 and 1987. These were also the years of extensive environmental change on Caribbean coral reefs. (Data courtesy of Joe Prospero, University of Miami.)

At the first sign of locusts, the countries of north Africa in the Sahel region apply large amounts of pesticides, including those banned in the U.S., to fight the pests. These pesticides and other chemicals, such as byproducts of burned plastic garbage, may also be present in the dust reaching the Caribbean and southern U.S.

The dust itself is composed of chemical elements such as iron, phosphorus, and sulfates that have been shown to stimulate phytoplankton growth in tropical waters. Collaborators at the University of South Florida have shown a correlation between dust events and algal blooms, like the red tides that occur in Florida's coastal waters.

Results of research on the composition of dust at many locations indicate a long history of influx of African dust across the Atlantic Ocean and suggest many new questions to be addressed. Scientists of the USGS, in cooperation with scientists at the University of Miami, Duke University, University of South Carolina Aiken, Florida International University, and the University of South Florida, are conducting this work.

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http://coastal.er.usgs.gov/african_dust/