CASE STUDY

Saharan Dust Impacts and Climate Change

BY JOSEPH M. PROSPERO

AFRICAN DUST

Huge quantities of mineral dust are carried from sources in North Africa to the western Atlantic Ocean every year. Satellite images often show immense dust clouds emerging from the coast of West Africa (Figure 1). These dust-laden air masses are carried across the Atlantic Ocean by the Trade Winds and reach the Caribbean about a week later. Measurements of wind-borne dust on Barbados, West Indies (13° 10′ N, 59° 32′ W), show the presence of high concentrations of dust much of the year (Figure 2), starting in the spring and extending through the fall. During this period, substantial concentrations of dust, tens of micrograms per cubic meter of air, are measured almost every day. During intense dust events, dense hazes cover the region, and dust concentrations can exceed 100 μg m^{-3}.

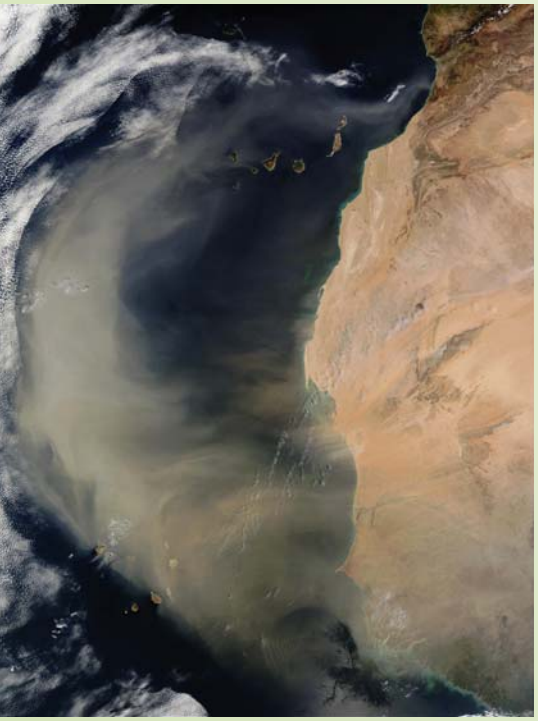

Figure 1. MODIS satellite image, March 2, 2003. Image shows a dust arc extending along the entire west coast of North Africa. The Canary Islands are in the top center of the image and the Cape Verde Islands in the lower left. This dust outbreak reached Barbados on March 8 and yielded a daily average dust peak of 65 μg m^{-3}. Human health may be negatively impacted because these tiny dust particles can be deposited in the lungs. (For more information visit: http://visibleearth.nasa.gov/view_rec.php?id=5078).

DUST AND HEALTH

The presence of such high concentrations of mineral dust for such long periods of time raises concerns about the impact on human health. About half the mass consists of particles less than 2.5 μm diameter (Prospero, 1999); because of their small size, they can readily penetrate the respiratory system and be deposited in our lungs. For this reason, particles under 2.5 μm diameter are defined by the U.S. Environmental Protection Agency (EPA) as "respirable." Epidemiological studies, mostly in the United States and Europe, have shown that high concentrations of respirable particles are associated with increased death rates and respiratory-related hospital admissions (e.g., aggravated asthma, severe respiratory symptoms, and chronic bronchitis) (Pope, 2000).

Based on this evidence, the EPA established a standard for respirable particles that sets a limit at 15 μg m^{-3} for the annual mean and 65 μg m^{-3} for the 24-hour mean. During some years, the dust concentrations at Barbados, and, by extension over large areas of the Caribbean, can approach or exceed the EPA standards. Such high concentrations of dust could conceivably pose a health threat, but to date there have been no studies of actual impacts. Mineral-dust studies generally focus on agricultural dusts (Schenker, 2000), which are expected to have distinctly different characteristics from those of African dust.

The potential for health impacts is not restricted to the Caribbean. During the summer months, African dust is carried into the higher latitudes, covering large areas of the Gulf of Mexico and the southern United States (Prospero, 1999; Prospero et al., 2001) and the eastern seaboard (Perry et al., 1997). Although the concentrations are lower than those over the Caribbean, there are sporadic dust events when dust loads are quite large (Prospero, 1999; Prospero et al., 2001). The presence of large amounts of dust in the presence of pollutants further complicates the assessment of health effects (Utell and Samet, 1996).

Some research is focused on the mechanisms by which these particles impact our health, but most research is focused on the role of pollutant species associated with particles. No clear picture has emerged (Utell and Samet, 1996; Pope, 2000). African dust is a special case in that it is comprised almost entirely of inorganic materials—only a few percent of the mass is organic—and the concentration of pollutant species is relatively low. Thus, the assessment of dust-related health effects will require a special focus. Although this case study has focused on dust effects in the Caribbean and eastern United States, the question of health impacts has a much broader context. About a third of Earth's surface is arid, and dust concentrations are often very high over large regions, much higher than those measured on Barbados. Thus, a large fraction of the world's population could be affected by dust-health issues.

DUST AND CLIMATE

If dust has an impact on health, then we might expect the impact to vary with climate because of the great sensitivity of dust emissions to weather and climate conditions in the source areas. Studies on Barbados show very large year-to-year changes in dust transport that are linked to rainfall and associated meteorological conditions in the Sahel region of North Africa (Prospero and Lamb, 2003). It is also notable that some of the dustiest years in Barbados were associated with El Niño Southern Oscillation (ENSO) events (Figure 2). It is not clear how global warming will affect dust emissions in Africa; some models predict a wetter North Africa and some a drier. It is conceivable that the currently active sources will weaken and others, now dormant, will become active.

This case study has thus far focused on the respiratory impact of African dust. There are many other ways that dust can affect our health and wellbeing. A major area of research focuses on the role of dust-borne iron (Fe) on the ocean carbon cycle (and, hence, on atmospheric CO_2). Iron is an essential micro-nutrient for many marine microorganisms. (For reviews, see Jickells et al., 2005; Mahowald et al., 2005.) Thus, large changes in dust transport to the ocean could have major consequences that transcend the direct impact on marine organisms.

For example, recent research suggests that African dust-Fe plays an essential role in triggering red tides along the west coast of Florida (Lenes et al., 2001; Walsh and Steidinger, 2001). Microorganisms could also be playing a more dust-related role. Recent research on Barbados shows that substantial concentrations of viable (culture-forming) bacteria and fungi are found in association with African dust (Prospero et al., 2005). Although none of the identified species is known to be pathogenic, it is nonetheless conceivable that pathogenic species could be transported by the same mechanisms. It would be expected that changes in climate would affect the amounts and the types of microorganisms associated with dust.

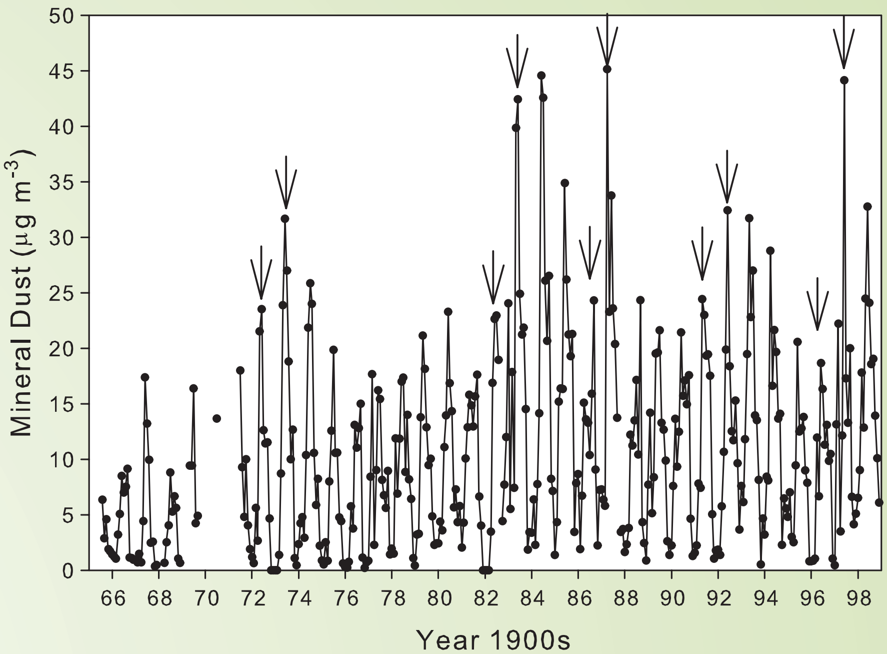

Figure 2. Monthly mean African dust concentrations measured in the Trade Winds at Barbados, 1965–1998. The arrows indicate years when major El Niño events occurred. These were often associated with severe drought in the Sahel. The most intense drought occurred in the 1980s, years when Barbados experienced extended periods of unusually high dust concentrations. Modified from Prospero and Lamb (2003).

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