1 The Nature and Importance of Dust Storms

1.1 Introduction

This book is about dust storms, atmospheric events that are typically associated with deserts. The study of desert dust, its entrainment, transport and deposition is an area of growing importance in investigations of global environmental change because dust storms have great significance for the physical environment and the world's human inhabitants (Table 1.1). Most dust events are generated by the erosion of surface materials in the world's drylands. Dry, unprotected sediments in any environment can be blown into the atmosphere, but the main sources of soil-derived mineral dust are located in desert regions. However, the impacts of wind-blown desert dust are global in their extent, making their study an area of major concern in Earth System Science.

Among the reasons why dust storms are important is that dust loadings in the atmosphere are significant for climate (Park et al. 2005). They affect air temperatures through the absorption and scattering of solar radiation (Haywood et al. 2003). In addition, dust may affect climate through its influence on marine primary productivity (Jickells et al. 1998); and there is some evidence that it may cause ocean cooling (Schollaert and Merrill 1998). Changes in atmospheric temperatures and in concentrations of potential condensation nuclei may affect convectional activity and cloud formation, thereby modifying rainfall (Bryson and Barreis 1967; Maley 1982) and possibly intensifying drought conditions.

Dust loadings may also change substantially in response to climatic changes, such as the North Atlantic Oscillation (Ginoux et al. 2004; Chiapello et al. 2005) or the Pacific Decadal Oscillation (Leslie and Speer 2005), to drought phases (Middleton 1985a; Littmann 1991a; Moulin et al. 1997; McTainsh et al. 2005) and in response to land-cover alterations (Tegen and Fung 1995). In these situations, the monitoring of dust storms can be indicative of environmental change.

Dust deposition provides considerable quantities of nutrients to ocean surface waters and the sea bed (Talbot et al. 1986; Swap et al. 1996). Aeolian dust contains appreciable quantities of iron (Zhu et al. 1997), the addition of which to ocean waters may increase plankton productivity (Gruber and Sarmineto 1997; Sarthou et al. 2003). Dust aerosols derived from the Sahara influence the nutrient dynamics and biogeochemical cycling of both terrestrial and oceanic

Table 1.1. Some environmental consequences and hazards to human population caused by dust storms

Consequence	Example
Environmental	
Algal blooms	Lenes et al. (2001a, b)
Butterfly transport	Davey (2004)
Calcrete development	Coudé-Gaussen and Rognon (1988)
Case hardening of rock	Conca and Rossman (1982)
Climatic change	Maley (1982)
Clouds	Sassen et al. (2003)
Coral reef deterioration	Shinn et al. (2000)
Desert varnish formation	Dorn (1986), Thiagarajan and Lee (2004)
Easterly wave intensification	Jones et al. (2003)
Glacier mass budget alteration	Davitaya (1969)
Loess formation	Liu et al. (1981)
Mercury translocation	Cannon et al. (2003)
Ocean productivity	Sañudo-Wilhelmy (2003), Jickells et al. (2005)
Ocean sedimentation	Rea and Leinen (1988)
Plant nutrient gain	Das (1988), Kaufman et al. (2005)
Playa (pan) formation and relief inversion	Khalaf et al. (1982)
Radiative forcing	Coakley and Cess (1985), Miller et al. (2004a)
Rainfall acidity/alkalinity	Stensland and Semorin (1982), Rogora et al. (2004)
Rock polish	Lancaster (1984)
Salt deposition and ground water salinization	Logan (1974)
Sediment input to streams	Goudie (1978)
Silcrete development	Summerfield (1983)
Soil erosion	Kalma et al. (1988)
Soil nutrient gain	Syers et al. (1969)
Stone pavement formation	McFadden et al. (1987)
Terra rossa formation	Delgado et al. (2003)
Tropospheric ozone	Bonasoni et al. (2004)
Ventifact sculpture	Whitney and Dietrich (1973)
Human-related	
Air pollution	Hagen and Woodruff (1973)
Animal madness	Saint-Amand et al. (1986)
Animal suffocation	Choun (1936)

Table 1.1. Some environmental consequences and hazards to human population caused by dust storms—cont'd

Consequence	Example
Asthma incidence	Gyan et al. (2005)
Car-ignition failure	Clements et al. (1963)
Closing of business	Gillette (1981)
DDT transport	Riseborough et al. (1968)
Disease transmission (human)	Leathers (1981)
Disease transmission (plants)	Clafin et al. (1973)
Drinking-water contamination	Clements et al. (1963)
Electrical-insulator failure	Kes (1983)
Machinery problems	Hilling (1969)
Microwave propagation	Ghobrial (2003)
Radio communication problems	Martin (1937)
Radio-active dust transport	Becker (1986)
Rainfall acid neutralization	Löye-Pilot et al. (1986)
Reduction of property values	Gillette (1981)
Reduction of solar power potential	Goossens and Van Kerschaever (1999)
Respiratory problems and eye infections	Kar and Takeuchi (2004), Chen et al. (2004)
Transport disruption	Houseman (1961), Brazel (1991)
Warfare	Agence France Press (1985)

ecosystems. Moreover, because of the thousands of kilometres over which the dust is transported, its influence extends as far a field as Northern Europe (Franzen et al. 1994), Amazonia (Swap et al. 1992) and the coral reefs of the Caribbean. Saharan dust has been suggested by Shinn et al. (2000) to be an efficient medium for transporting disease-spreading spores, which on occasion can cause epidemics that diminish coral reef vitality, a good match having been found between times of coral-reef die-off and peak dust deposition (Fig. 1.1). Atmospheric dust also influences sulphur dioxide levels in the atmosphere, either by physical adsorption or by heterogeneous reactions (Adams et al. 2005).

On land surfaces, additions of dust may affect soil formation. This has been proposed, inter alia, in the context of calcretes, salt horizons, *terrae rossae*, stone pavements and desert varnish (Thiagarajan and Lee 2004).

Dust additions play a major role in the delivery of sediments to the oceans (Fig. 1.2). For example, Guerzoni et al. (1999, p. 147) have suggested that: "Both the magnitude and the mineralogical composition of atmospheric dust inputs indicate that eolian deposition is an important (50%) or even dominant (>80%) contribution to sediments in the offshore waters of the entire Mediterranean

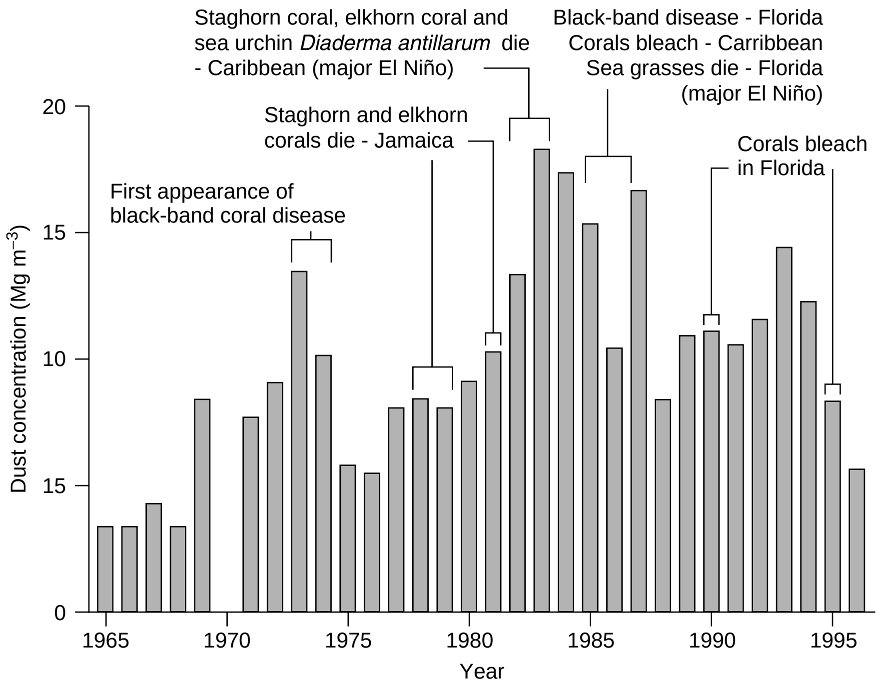

Fig. 1.1. The overall increase in dust reaching Barbados since 1965. Peak years for dust were 1983 and 1987. These were also the years of extensive damage to Caribbean coral reefs. Modified after Shinn et al. (2000)

basin". The role of dust sedimentation in the eastern Atlantic off the Sahara is also extremely important (Holz et al. 2004), and its significance in the Arctic Ocean has been discussed (Mullen et al. 1972; Darby et al. 1974).

Dust storms help to create various geomorphological phenomena by evacuating material from desert surfaces and then depositing it elsewhere. Desert depressions, wind-fluted bedforms (*yardangs*) and stone pavements are among such features. Above all, however, dust storms play a general role in the denudation of desert surfaces.

Dust storms also have many direct implications for humans. They can, for example, transport allergens and pathogens and disrupt communications. They may be a manifestation of desertification and of accelerated soil erosion. As 'Big Hugh' Bennett, father of the soil conservation movement in the United States, wrote at the end of the Dust Bowl: "To an alarming extent . . . the fertile parts of the soil are blowing away; to an equally alarming extent, menacing, drifting sand is left behind." (Bennett 1938b, p. 382)

Standard World Meteorological Organization (WMO) definitions for dust events that involve dust entrainment in the atmosphere are given by McTainsh and Pitblado (1987): (a) *Dust storms* are the result of turbulent winds raising large quantities of dust into the air and reducing visibility to less than 1000 m.

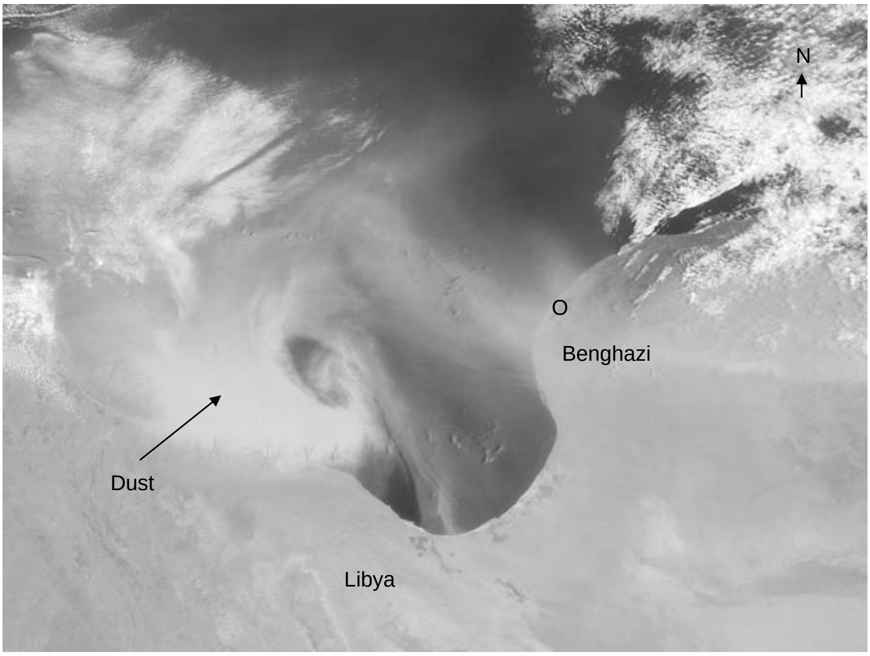

Fig. 1.2. Dust over northern Libya and the Gulf of Sirte, 26 May 2004 (MODIS)

(b) *Blowing dust* is raised by winds to moderate heights above the ground reducing visibility at eye level (1.8 m) but not to less than 1000 m. (c) *Dust haze* is produced by dust particles in suspended transport which have been raised from the ground by a dust storm prior to the time of observation. (d) *Dust whirls* (or *dust devils*) are whirling columns of dust moving with the wind and are usually less than 30 m high (but may extend to 300 m or more) and of narrow dimensions. There is some confusion in the literature between 'sand storms' and 'dust storms'. The former tend to be low altitude phenomena of limited areal extent, composed of predominantly sand-sized materials. Dust storms reach higher altitudes, travel longer distances and are mainly composed of silt and clay. In this work, the term *dust storm* refers to an atmospheric phenomenon in meteorology, where the horizontal visibility at eye level is reduced to less than 1000 m by atmospheric mineral dust.

While airborne particles in the world's atmosphere may be derived from a number of different sources – including cosmic dust, sea salt, volcanic dust and smoke particles from fire – in this book we concentrate very largely on the dust emitted from desert surfaces in low latitudes, though we recognize that dust may be emitted from glacial outwash material in polar regions and from disturbed agricultural land on susceptible soils in more humid parts of the world (Table 1.2).

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