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Thematic focus: Harmful substances and hazardous waste, ecosystem management

Forecasting and early warning of dust storms

Why is this issue important?

Soon after a massive dust storm engulfed Sydney, Australia in September 2009, the worst the city had experienced since 1940 (Leys et al., 2011), a call was made for the development of more early warning systems to be able to predict these devastating events in the future (UN, 2009). The city was covered in dust for nine hours and suffered disruption to communications, daily activities, car and air traffic, and reduced visibility to 0.4 km (Leys et al., 2011). Impacts such as these can be quite common during a dust event and can result in great costs. Other impacts can include the deposition of foreign sediments causing cropland to suffer; compromised air quality and human health when dust particles remain suspended in the atmosphere; and reduced efficiency of renewable energy sources when dust interferes with their mechanics. Suspended dust particles can alter the atmospheric radiation balance and contribute to climatic variations (Du et al., 2002) such as alteration of regional monsoon patterns or the acceleration of glacial melt (Gautam et al., 2010). Dust storms can have high interannual, as well as annual and decadal, variability, thus it is important that more research is conducted over longer periods of time to analyze trends and associated storm severity (Ganor et al., 2010; Goudie, 2009). With increased information about long term trends, more accurate forecasts of dust storm movements can be developed, the appropriate efforts to mitigate damage can be put into place and effective early warning can be communicated.

What are the findings?

What causes a dust storm?

When high winds at a threshold speed (Table 1) blow over areas with minimal vegetation cover, soils that lack snow and/or soil moisture content (NRL, 2009), or soils that are vulnerable to surface disturbance (Wilcox, 2012) a dust storm has the potential to occur. Other types of areas that can also be vulnerable to a dust storms when threshold winds are present are areas in which soils have dried out and displaced after a flash flooding event (UCAR/COMET, 2010) or areas with dried out lakebed sediments.

Wind speed thresholds for different desert environments	
Environment	**Threshold wind speed**
Fine to medium sand in areas with sand dunes	16 to 24.1 kmph
Sandy areas with poorly developed desert pavement	32.2 kmph
Fine material in desert flats	32.3 to 40.2 kmph
Dry lake beds and/or crusted salt flats	48.3 to 56.3 kmph
Well-developed desert pavement	64.4 kmph

Table 1. Wind speed thresholds for different desert environments. Wind speed threshold refers to the minimum wind speed required to lift suspended sediment in a certain environment (UCAR/COMET, 2010).

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Desert soils are naturally resistant to wind erosion because they form a thin cohesive surface crust that helps to keep the soils intact. The crust is most prevalent in areas between plants because they help to stabilize and protect soil from wind and can trap suspended soil particles (Urban et al., 2009; Steenburgh et al., 2012; Wilcox, 2012). When the crust is disturbed or there is a reduction in vegetation cover, the risk of a dust storm occurrence is increased as the loosened sediments are free to be picked up by high winds. Land degrading events such as overgrazing of livestock and clearing of land for agricultural or infrastructure development are common sources of soil disturbance. Dust and sand from storm events can also bury crops blocking sunlight and damaging plant tissue, thus inhibiting future growth (Sivakumar, 2005). If crops do not recover from such an event, then the resulting barren field becomes fuel for the next dust storm. A brief life cycle of a dust storm, and how one can fuel itself, is described in Figure 1.

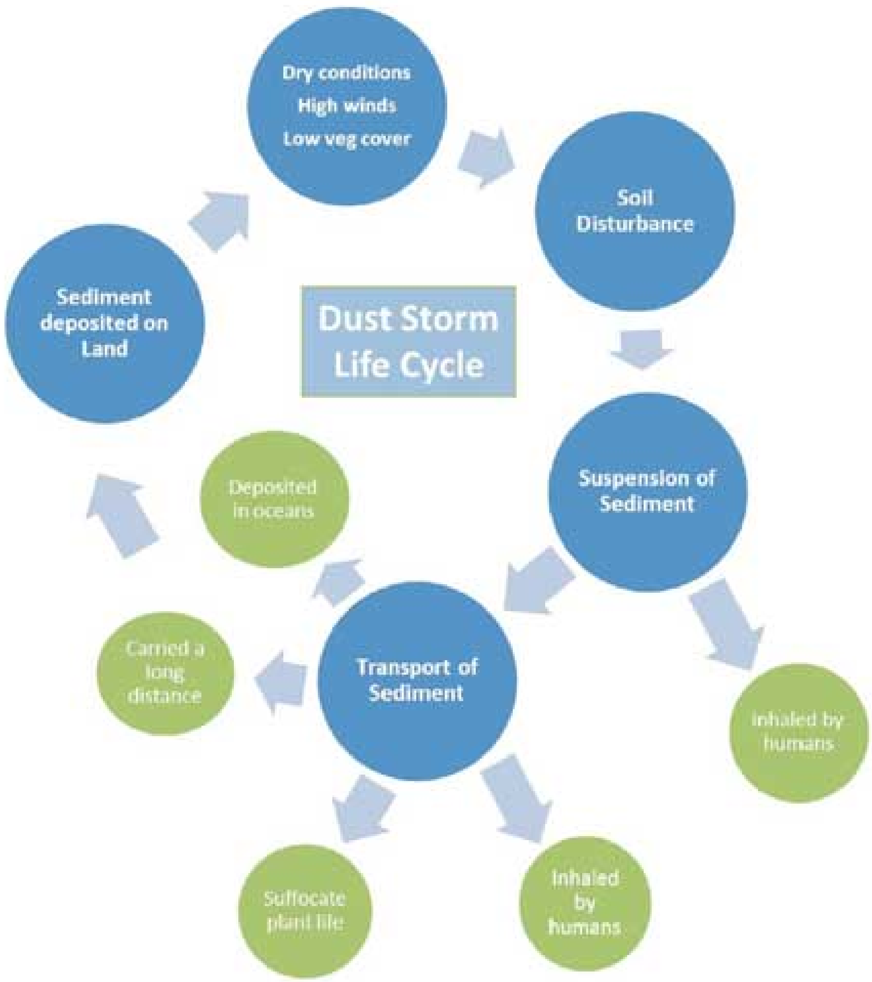

Figure 1. Dust Storm Life Cycle. This simplified diagram of the life cycle of a dust storm and its impacts illustrate how a dust storm can fuel itself.

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Where and when do dust storms occur?

The primary dust producing regions on earth are classified as some type of a desert with minimal saturation as indicated by a high erodible fraction value (Figure 2). These regions are the Sahara Desert, the Middle East (Figure 3), the Taklamakan Desert in northwest China, southwest Asia, central Australia, the Etosha and Makgadikgadi basins of southern Africa, the Salar de Uyuni (Bolivia) and the Great Basin (USA) (NRL, 2009; Washington et al., 2003). Topographically, most of these regions encompass a large basin with an internal drainage system and are prone to high winds that facilitate dust mobilisation (Washington et al., 2003). Dust storms can occur on less than 40 days a year such as in the United States (NCDC/NOAA, 2012) or on more than 100 days a year such as in parts of Mongolia (Dagvadorj et al., 2009). Dust storms from around the world emit an estimated 1000 to 3000 teragrams per year (Tg/year) of dust into the atmosphere; the Sahara Desert region is the single largest contributing region with estimated dust emissions of 500 to 1000 Tg/yr (Goudie, 2009).

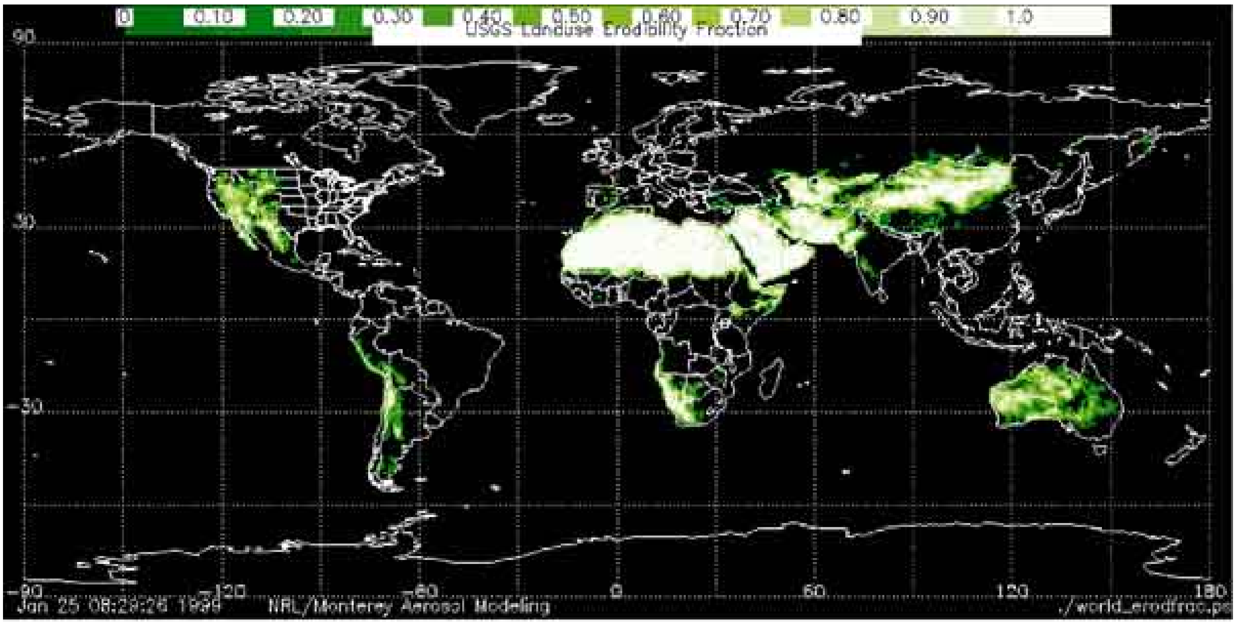

Figure 2. Historically regarded global dust producing regions (NRL 2009). Highlighted areas represent regions with a higher erodible fraction, a value that considers land cover type and the associated wetness value of the area.

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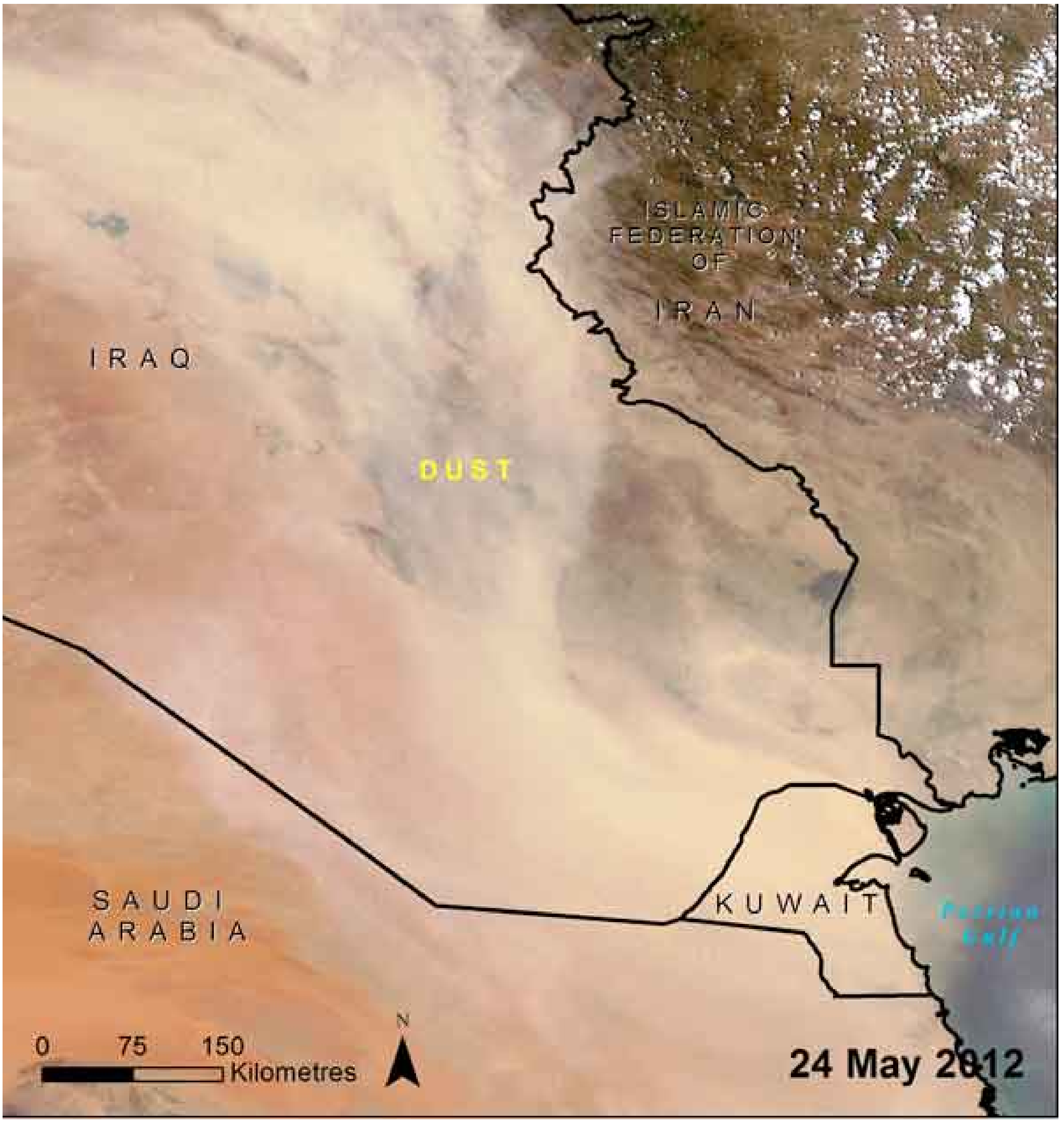

Figure 3. Dust blowing south from Syria over Iraq, Kuwait, and slightly clouding the Persian Gulf. Image acquired on 24 May 2012 by the Moderate Resolution Imaging Spectrometer (MODIS) on NASA'a Aqua satellite (image courtesy Jeff Schmaltz in Scott, 2012; visualisation by UNEP/GRID-Sioux Falls).

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Some regions are continual dust producers year round, but dust intensity in other regions can be influenced by seasonal changes. Large scale seasonal weather systems such as El Niño or La Niña or smaller regional patterns such as an influx of rainfall or excessive snowmelt can influence the severity of dust events. One way of identifying seasonal fluctuations in dust concentration is by looking at the global aerosol index (Figure 4). The aerosol index (AI) is a measurement of absorbing aerosol particles such as dust and smoke and is commonly used to identify dust source areas (NRL, 2009; Washington et al., 2003). The AI is obtained using NASA's Ozone Monitoring Instrument (OMI) on NASA's Earth Observing Satellite Aura (NASA, n.d). For example, the image from 1 April 2012 shows evidence that the aerosol index is much higher in India and East Asia during its spring season than in any other season. Intensity over India decreases by July, which coincides with its monsoon season that brings air-clearing rains (Gautam et al., 2010).

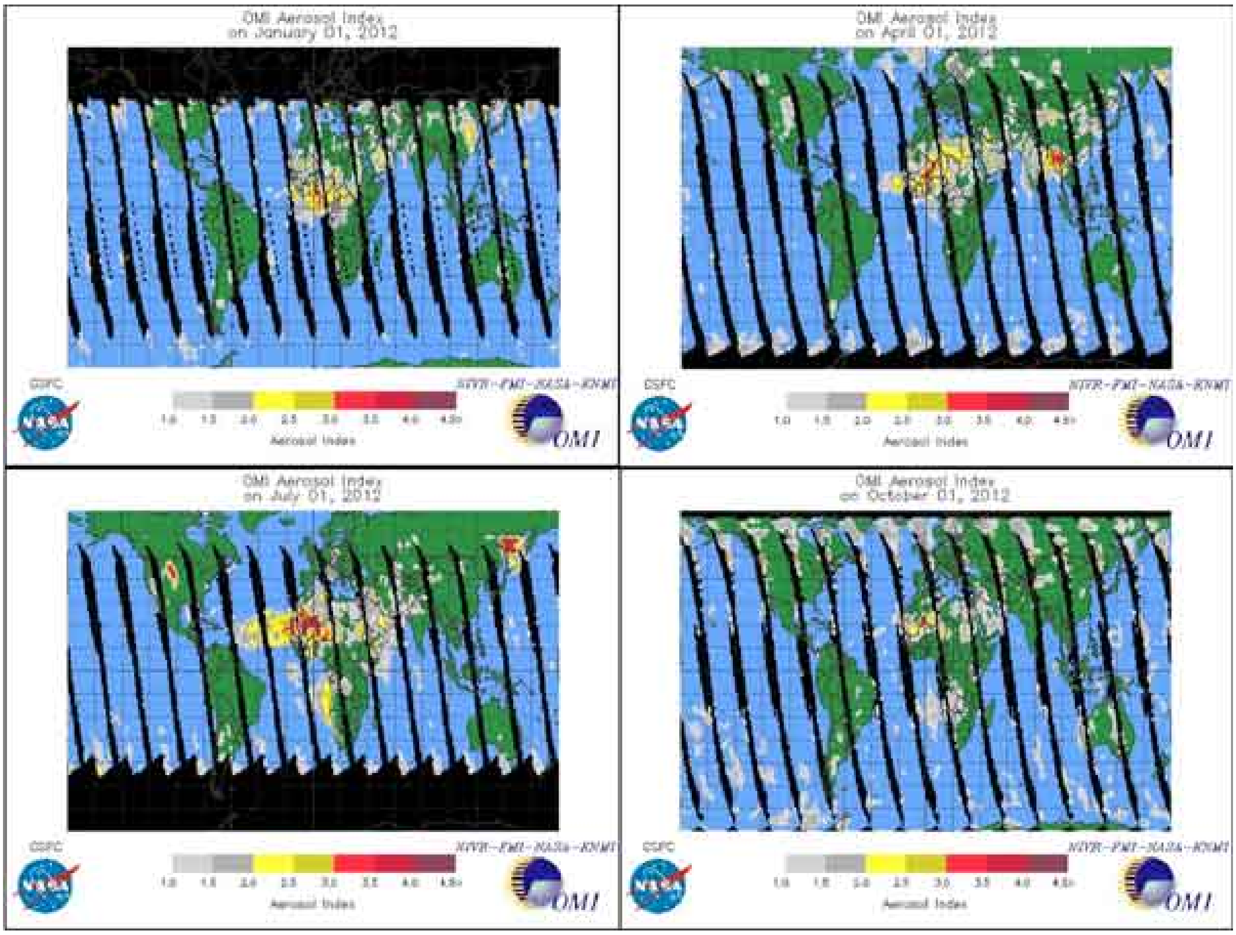

Figure 4. Global OMI Aerosol Index images from 1 January 2012, 1 April 2012, 1 July 2012 and 1 October 2012 (NASA, 2012b).

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What are the implications for policy?

Travelling dust: a transboundary issue

A dust storm can not only impact the area surrounding its origin, but can also impact land and people a great distance away where the dust finally settles. Trade winds can carry dust originating in the Sahara Desert north to Spain and the United Kingdom as well as across the Atlantic Ocean to the east coast of the United States of America (USA), Central America, and South America. Several countries surrounding the Arabian Gulf transport dust across the Gulf at various times of the year (Figure 5). Dust originating in inner and southern Mongolia and northern China can be carried to Japan, the Democratic People's Republic of Korea (DPRK), the Republic of Korea and the Taiwan Province of China causing yellow sands and muddy rains (Lee and Liu, 2004; Kimura, 2012a; Kimura, 2012b). Dust storms originating in eastern Australian have been known to settle across the Tasman Sea in New Zealand (Marx et al., 2009). Therefore, many countries or entire regions may be affected and this can cause difficulty when creating policies pertaining to dust storm mitigation (i.e. vegetation restoration efforts) or early warning communication. These transboundary movements can pose challenges when formulating policies pertaining to dust storm mitigation (i.e. vegetation restoration efforts) or early warning communication.

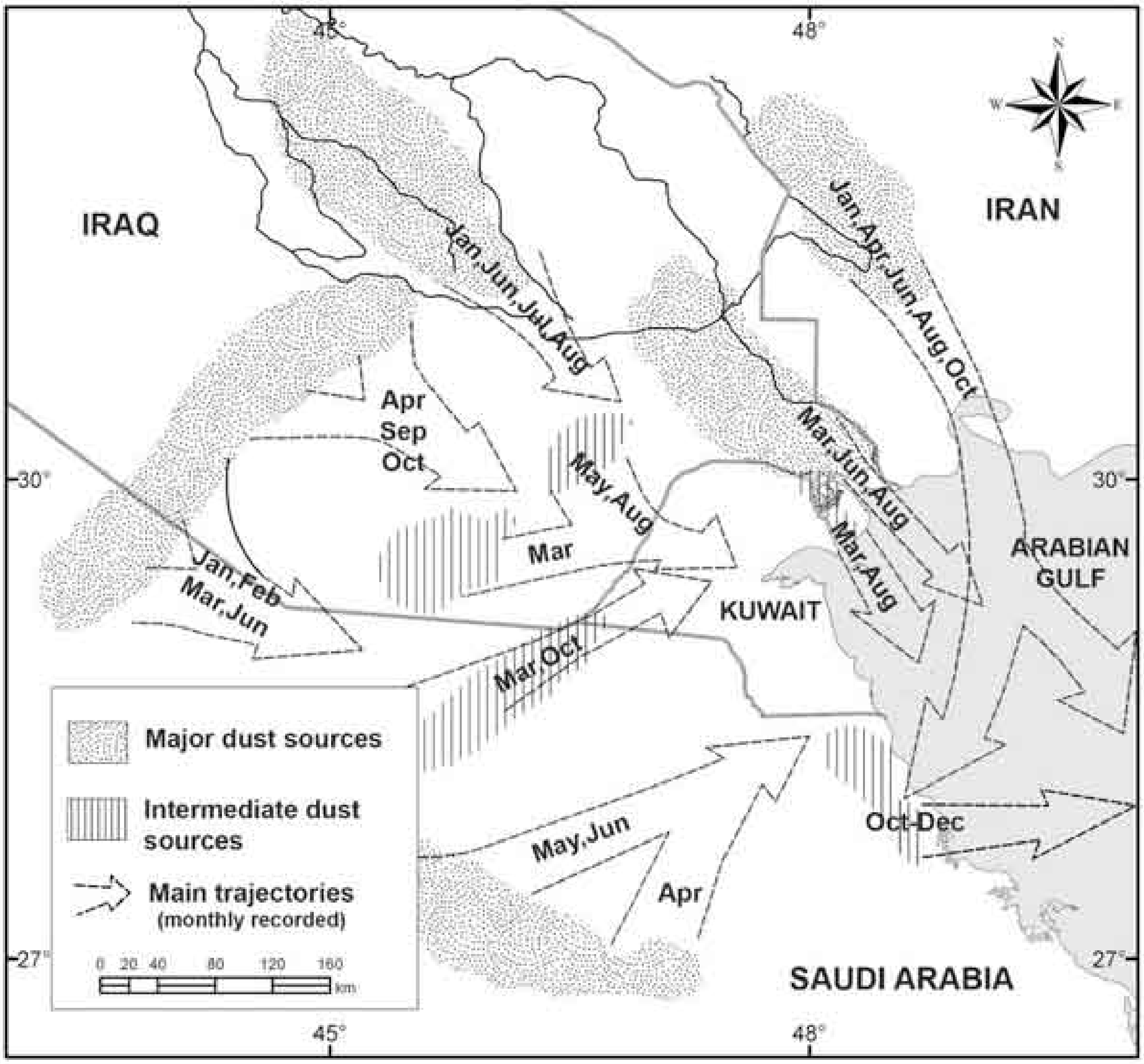

Figure 5. Approximate locations of major and intermediate sources of dust and their corresponding trajectories over areas northwest of the Persian Gulf (Al-Dousari and Al-Awadhi, 2012; visualisation by UNEP/GRID-Sioux Falls)

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Long distance travel of dust from the Sahara Desert

A dust storm originating in the Sahara Desert blew over the Canary Islands and the Atlantic Ocean on 25 June 2012 (Figure 6). This dust storm persisted for several days and reportedly travelled as far north as the United Kingdom by 28 June where it covered cars and other surfaces with a thin layer of dust (Met Office, 2012). The corresponding global aerosol index image for 25 June 2012 (Figure 7) provides insight as to how much of a wider region may also have been affected by dust in the atmosphere.

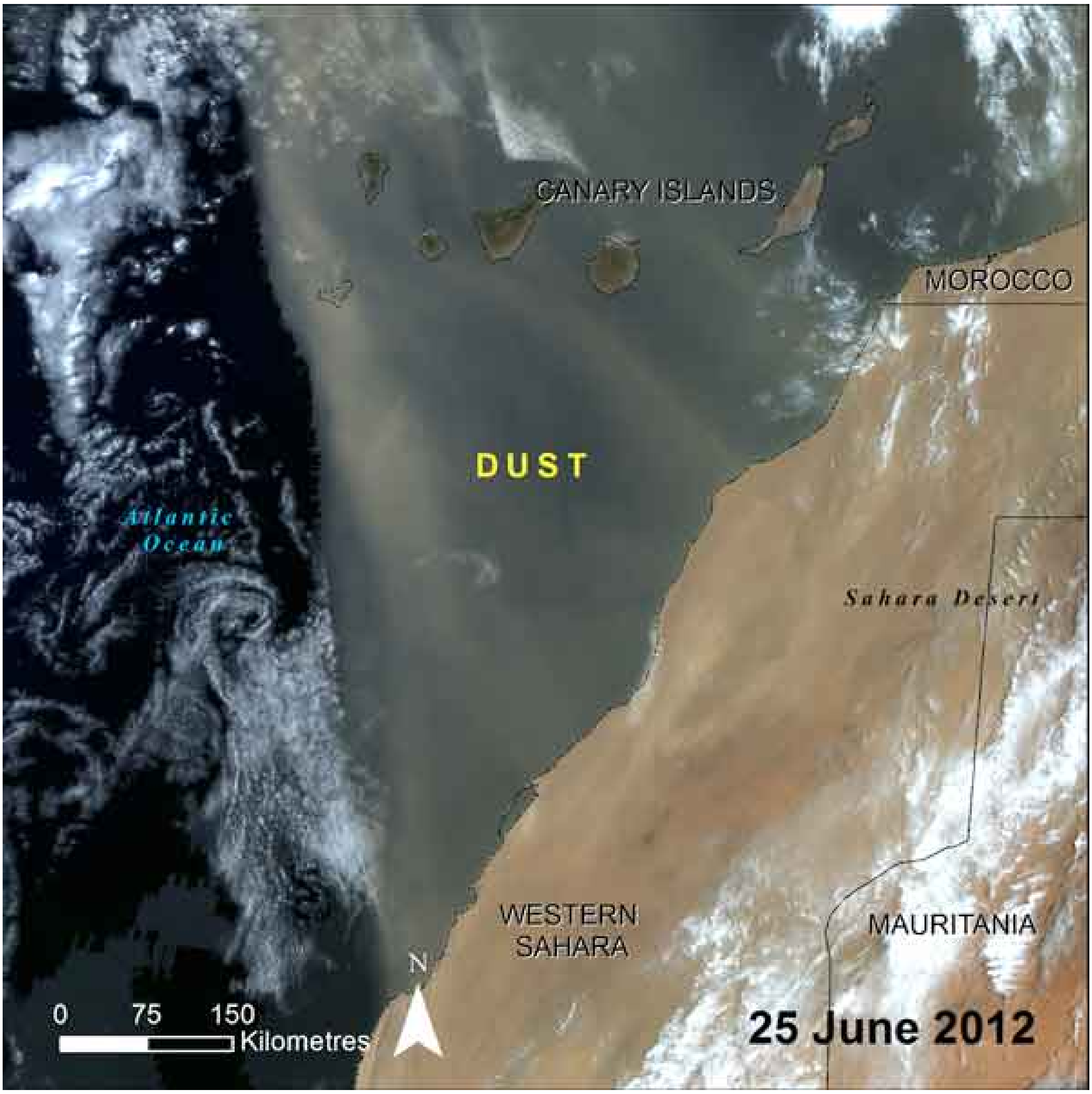

Figure 6. Dust from the Sahara Desert blowing over the Atlantic Ocean and the Canary Islands. Image acquired on 25 June 2012 by MODIS on NASA's Terra satellite (NASA image; visualisation by UNEP/GRID-Sioux Falls).

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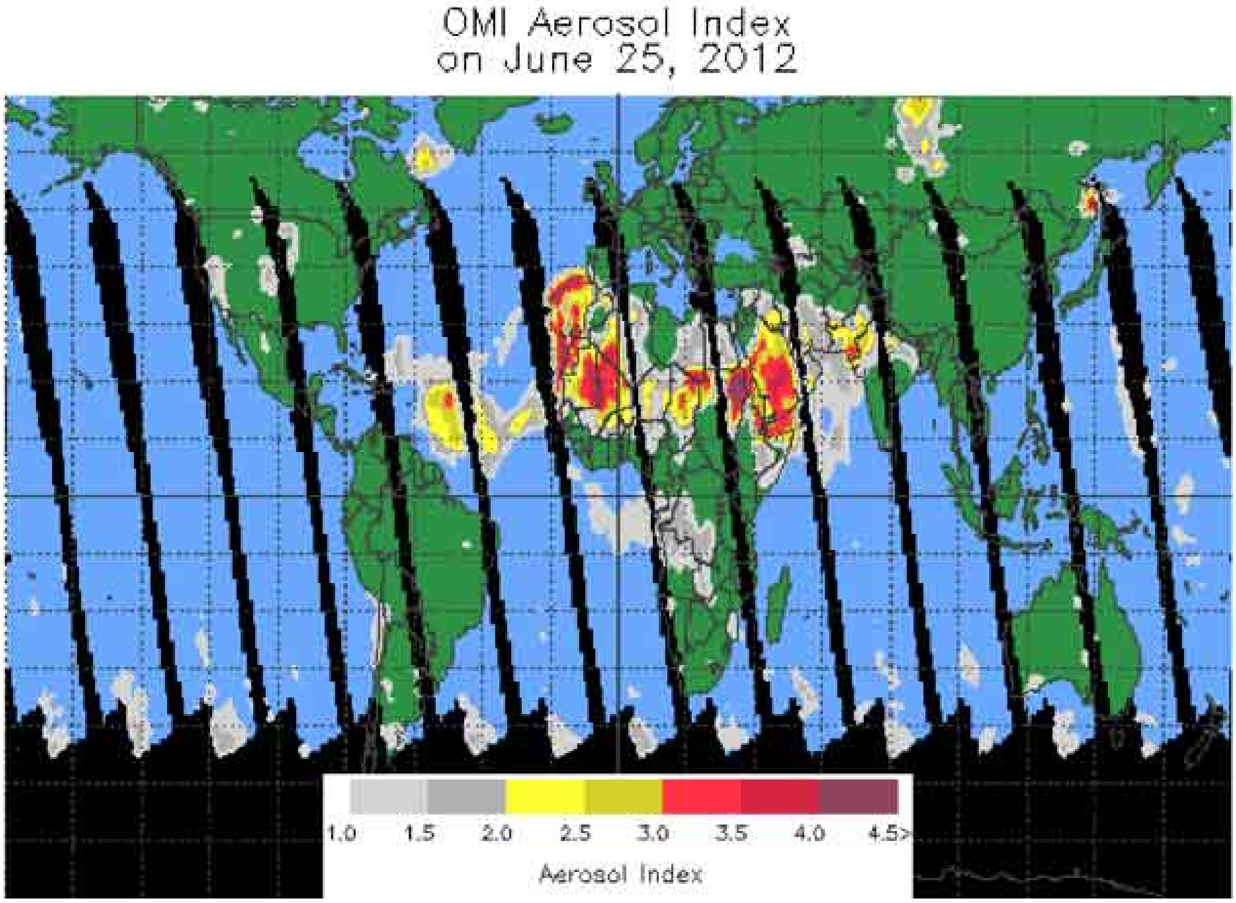

Figure 7. Global OMI Aerosol Index Image from 25 June 2012 (NASA, 2012b).

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Yellow Sands in Japan

Each spring Japan is plagued with "yellow sands" as a result of dust storms that originate in northeast Asia, notably the Taklamakan Desert and Loess Plateau in China and the Gobi Desert in southern Mongolia, and Inner Mongolia (Lee and Liu, 2004; NASA, 2012a; Kimura, 2012b; Onishi et al., 2012). Evidence of dust being carried over the Sea of Japan is presented in Figure 8. Yellow sand dust storms create an array of problems for Japan such as decreased visibility, presence of soil-derived and anthropogenic metals when transported with dust (Onishi et al., 2012), and decreased agricultural activity conducted in glass houses since dust prevents adequate UV light from reaching crops and plants (Taylor, 2002; Kimura, 2012b). These storms have also been reportedly responsible for worsened symptoms in asthmatics, heightened cases of respiratory