APPENDIX D. GLOBAL AEROSOL TRANSPORT

This appendix describes some of the key features of the global aerosol pattern. The most prominent aerosol plume is seen over the Atlantic, originating from West Africa and crossing the tropical Atlantic (Figure D.1). It clearly reaches the Caribbean Sea and Amazon delta, 6,000 km away. Measurements indicate that the plume is dominated by crustal material (soil or dust). The dust plume is most intense during the warm season (March-August) as shown in Figure D.1. In the winter, the West African dust plume is shifted south toward the Gulf of Guinea by the prevailing winds. Airborne sampling of cross-sections of the Atlantic aerosol plumes has provided clear evidence that a significant amount of aerosol is transported above and well separated from the boundary layer.

Particulate levels over Asia show extreme variations between the pristine clean air over the Tibet Plateau and the hazy low-lying valleys of the Indian subcontinent, Indochina and China, and the dusty regions of the Arabian Peninsula. The specific sources of the aerosol on the fringes of India, Indochina, and China are not known, but the hazy region is adjacent to the highest regional population density in the world. Continental Eastern Asia is known for its springtime dust sources, sulfur and other emissions from industrial sources, and for significant biomass burning.

Deforestation and agricultural burning produce thick layers of haze in the interior of South America. The PM levels are most pronounced over western Brazil and Bolivia, during the dry August, September, and October season when the biomass burning is most significant. Other aerosols of continental origin are evident off the coasts of Central America, from Mexico to Venezuela. They are most significant during the spring and summer and virtually disappear during fall and winter. These areas are also known for strong seasonal biomass burning.

A diffuse aerosol plume extends across the North Atlantic from eastern North America during the spring and summer seasons (Figure D.1). Measurements indicate the presence of small particles associated with the known SO$_4$-OC haze from urban industrial sources (e.g., Banic et al., 1996; Daum et al., 1996). Compared to other continents, North America and Europe show relatively low levels of aerosol optical thickness near their shores. Satellite imagery of the North African plume indicates transport reaching Central America and the U.S. Gulf Coast states, with the time of maximum impact occurring in July (Figure D.2). Measurements at surface sites along the transport path (e.g., Canary Islands, Bermuda) reveal that the dominant component of the North African PM plume is crustal material, also known as soil or dust. Surface-monitoring data from the IMPROVE network also show seasonal maximum dust concentrations in July (Figure D.3) and the plume is evident in daily PM$_{10}$ concentrations, whose 90th percentile values in the southeastern United States occur during July.

The transported component may be more significant to the daily-average concentrations during summer episodes, possibly representing about 5 to 10 µg/m$^3$ on some days and up to 20 µg/m$^3$ at some locations (Figure D.3). For example, analyses by the Texas Natural Resource Conservation Commission indicate that the North African plume contributed as much as 15 to 20 µg/m$^3$ at sites in the Houston area on two days in June and August, 1997 (Price et al., 1998).

The transport of dust from Asia to North America also has been documented (e.g., Jaffe et al., 1999). For example, during April 1998, satellite data provide evidence of an aerosol plume reaching into North America (Figure D.4). Over the Pacific Ocean, the dust cloud followed the path of the springtime East-Asian aerosol plume shown by the optical thickness data. The PM$_{2.5}$ dust concentration data from the IMPROVE speciated aerosol network showed virtually no dust on April 25th, suggesting that the dust cloud had not reached the surface (Figure D.5). Higher PM$_{2.5}$ values then occurred over the West Coast on April 29 and further inland on May 2 (Figure D.5). Presently available data suggest that this event had an unusually strong effect on surface PM

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* Material in this Appendix was contributed by R. Husar.
Figure D.1. Global distribution of aerosols and their likely source regions during June and December. (Source: R. Husar, pers. comm.)
concentrations. For example, over the period 1988-98, the average PM$_{2.5}$ dust concentrations at three northern IMPROVE monitoring sites (Mt. Rainier in WA, Crater Lake in OR, and Boundary Waters in MN) were well below 1 µg/m$^3$, with occasional peaks of 1 to 3 µg/m$^3$. On April 29, 1998, these sites showed a simultaneous sharp rise to 3 to 11 µg/m$^3$. Evidently, the April 1998 Asian dust event caused dust concentrations 2 to 3 times higher than any other event during 1988-1998. Transport episodes of the magnitude of the April 1998 event therefore appear to occur less frequently than once per year and perhaps no more often than once per ten years.

In April and May of 1998, satellite data showed the presence of large numbers of fires in Central America and prominent aerosol clouds (Figure D.6). Such fires represent a significant source of internationally transported fine PM affecting considerable portions of Mexico. Typically, these aerosol clouds move northward along the coastal areas, with the central mountain regions less affected (Figure D.6). During the PM episodes of April and May 1998, PM$_{10}$ concentrations at locations in Texas and the southeastern United States all increased (Figure D.7), indicating the presence of a regional aerosol affecting sites across a broad area. Speciated PM measurements from the IMPROVE site at Big Bend, Texas, indicated that about half the PM mass consisted of OC. On average days, OC may be one-fourth to one-third of PM mass.

As each of these examples of long-range transport indicates, the combined use of satellite and surface measurements provides evidence linking changes in surface PM concentrations to transported aerosol plumes. Further characterization of the frequency and magnitude of long-range aerosol transport requires systematic analysis of long-term databases of both satellite and surface measurements.
Figure D.3. Seasonal pattern of fine particulate soil (dust) concentration at IMPROVE monitoring sites in the southeastern United States. Top: Average of all sites versus date. Bottom: Monthly averages for six sites. (Source: R. Husar, pers. comm.).
Figure D.4. Aerosol optical thickness and illustration of the positions of a dust plume during April 1998. (Source: R. Husar, pers. comm.).

Figure D.5. PM$_{2.5}$ dust concentrations at IMPROVE monitoring sites on three dates during April and May of 1998. (Source: R. Husar, pers. comm.).
Figure D.6. Satellite imagery indicating the locations of major fires during April and July 1998 (top) and aerosol optical thickness during April and May 1998 (bottom). (Source: R. Husar, pers. comm.).
REFERENCES


