Free Tropospheric Aerosols Measured at Mauna Loa: Sources and Trends

Do you know where your sulfate's been?

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Introduction

As industrial development continues to increase in Eastern Asia, the pollution produced by this development has begun to concern other countries. Previous studies (Heald et al., 2006) have confirmed the transport of air parcels from East Asian sources, such as China, to the western United States. It is important to know how this contribution changes with changing amounts of Asian pollution.

A 20-year set of daily aerosol data collected at Mauna Loa, in Hawaii, presents the opportunity to look at long-term trends in sulfate (SO_4^{2-}) aerosols and compare them to changes in sulfur dioxide (SO_2) emissions over the same period.

Data

The data were collected at Mauna Loa Observatory (3.4 km asl) by the University of Hawaii on a daily basis. In order to sample air from the free troposphere, samples were taken at night. Downslope mountain winds that occur at night bring that air down to the observatory. The samples were analyzed for quality in order to exclude samples that had local contamination. They were then analyzed by ion chromatography for major ions, including SO_4^{2-}, Ca^{2+}, Na^+, and NO_3^-, among others.

Methods

- ❖ Screening the data for quality
  For my analyses of the UH data alone, I used only the data which had passed the quality control criteria for all but 1 hour or less of the sampling period.
- ❖ Computing trends
  In order to compute the trend lines, I computed the Theil slope, which is the median of the slopes between all possible pairs of points in the data. The y-intercepts were calculated by using the Theil slope and the median x and y values. Percent change per year was simply the Theil slope divided by the median y value. The significance of these trend lines differing from no trend was calculated by computing Kendall's tau statistic.

Conclusions

❖ During the spring, Asian anthropogenic SO_4^{2-} is transported to Mauna Loa.

❖ Increasing SO_2 emissions may be causing increased levels of SO_4^{2-} aerosols at Mauna Loa.

References

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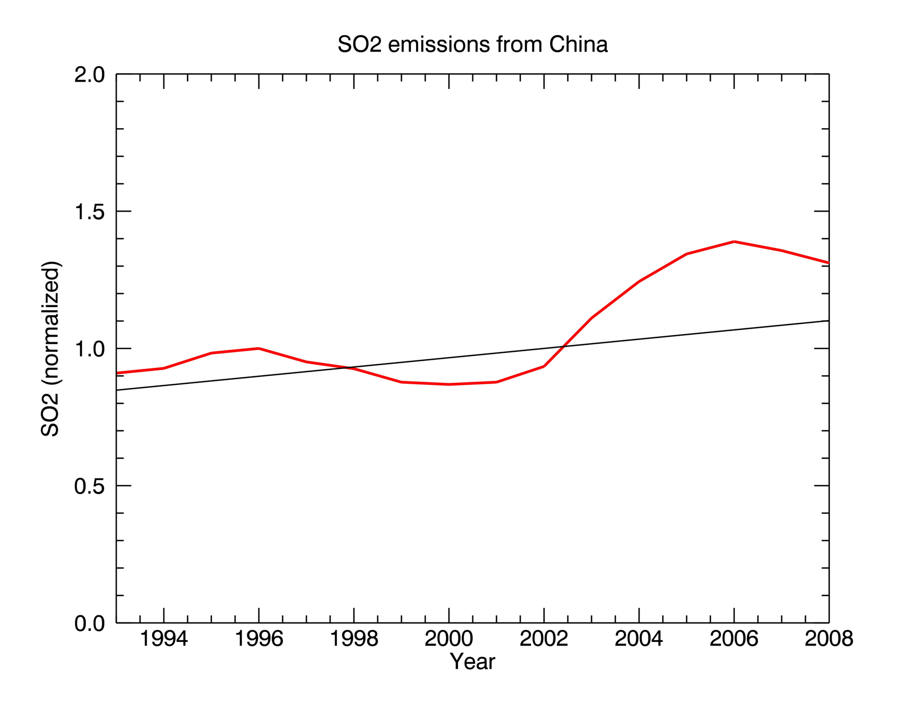

Figure 1: Normalized SO_2 emissions from China (Lu et al., 2010; Lu and Streets, 2011) from 1993 to 2008. Trend line: +1.72%/year, p = 0.013

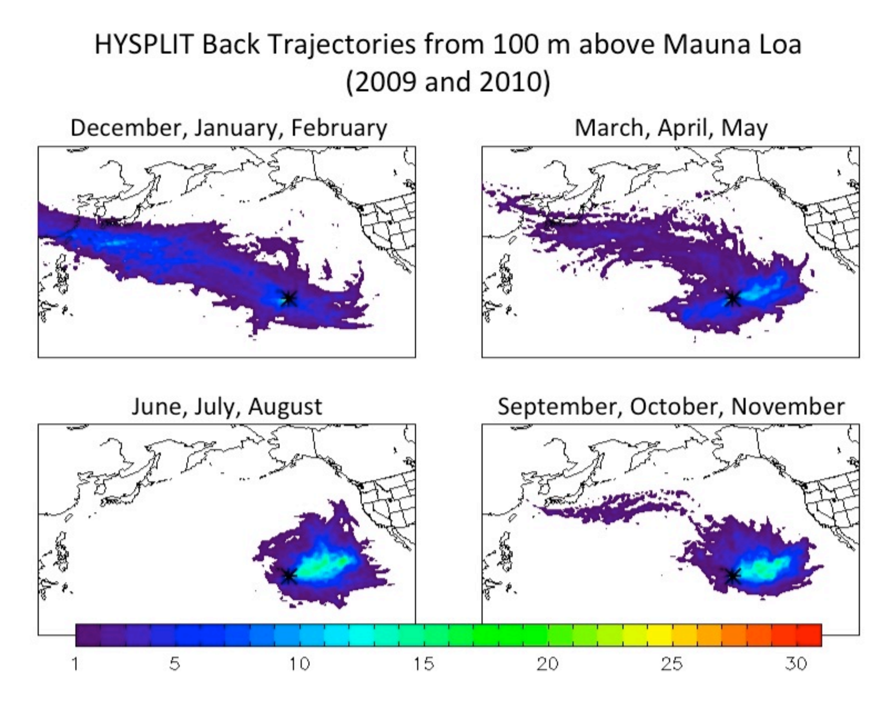

Figure 2: Back trajectories from 100 meters above Mauna Loa calculated in HYSPLIT for the years 2009 and 2010.

Dust

Large dust storms that occur during the spring over the Gobi and Taklamakan Deserts coupled with long-range eastward transport during the same season make dust a good potential tracer of Asian air parcels.

When spring SO_4^{2-} is compared with dust, the correlation between the two is still fairly low (Figure 3: $r^2 = 0.027$). However, the correlation between the two seems to improve at higher levels of dust.

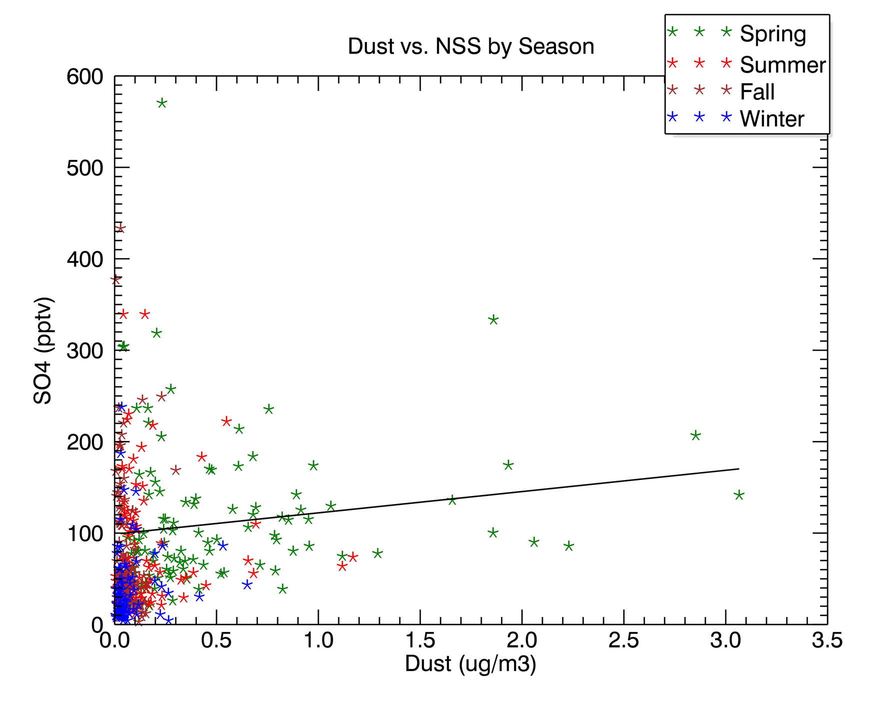

Figure 3: Comparison of dust with non-sea salt SO_4^{2-} by season.
Spring trend line: SO4 = 98.858 + 23.279*Dust ($r^2 = 0.027$)

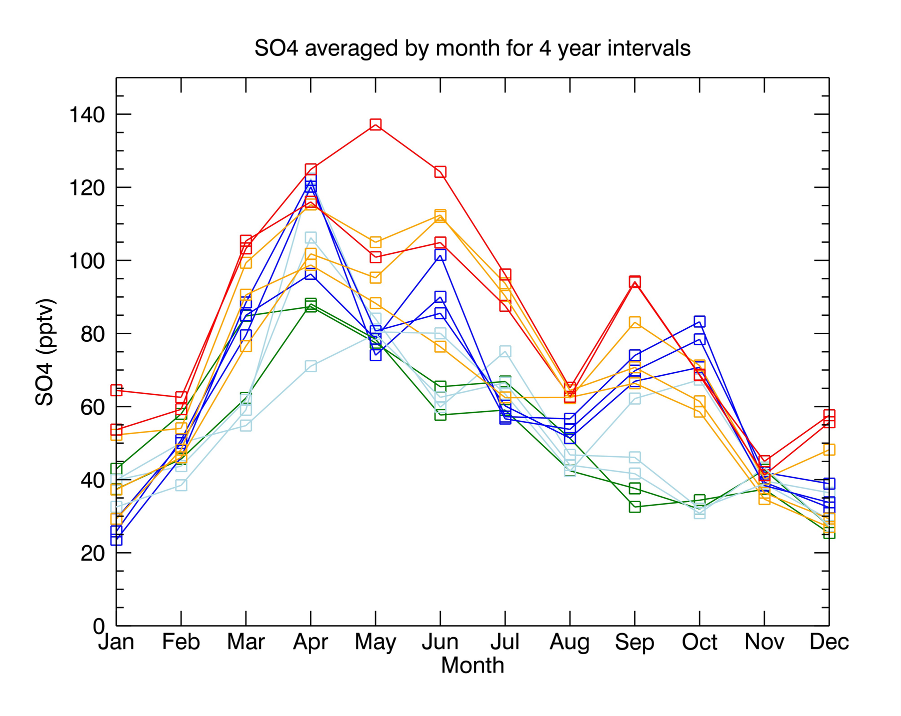

Figure 4: Monthly SO_4^{2-} averages over 4 year intervals (e.g. 1993-1996, 2005-2008) for the period 1993 to 2008. In chronological order: green, light blue, blue, orange, red.

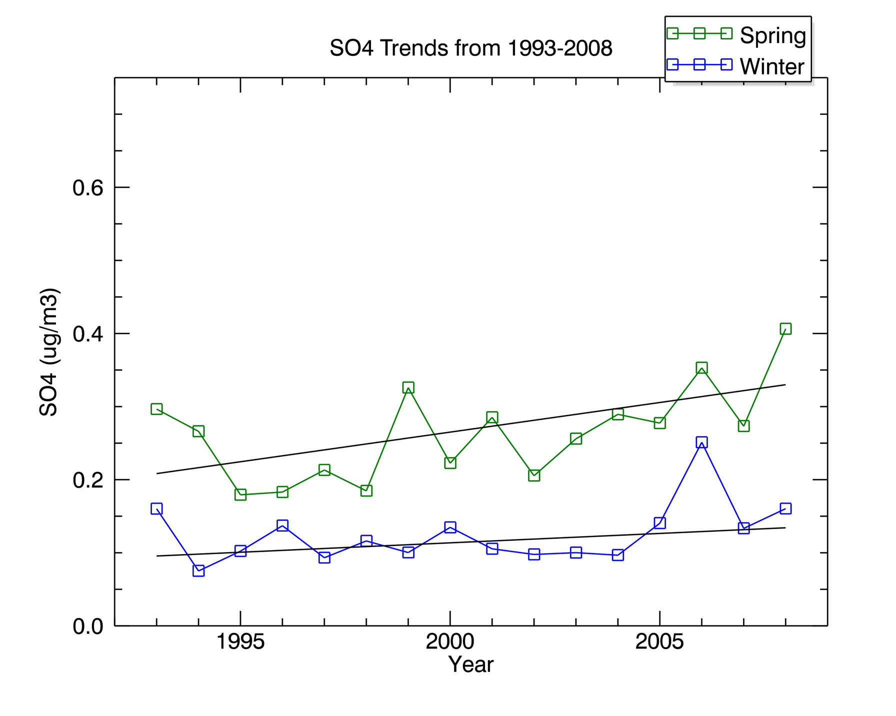

Figure 6: Seasonal average SO_4^{2-} values for the years 1993 to 2008. Spring trend: +6.06%/year, p = 0.038; Winter trend: +1.92%/year, p = 0.28.

SO_2 Emissions from China

SO_2 emissions in China have increased since 1993 at a rate of ~1.7%/year (See Figure 1; p = 0.013). If the SO_4^{2-} produced by these emissions is reaching Hawaii, a concomitant increase in SO_4^{2-} aerosols at Mauna Loa should be observed over the same time period.

As can be seen in Figure 2, transport to Mauna Loa from East Asia, and China in particular, occurs primarily from December to May. The transport period from December to February has been largely ignored by previous studies of this phenomenon, possibly because these months see the transport of air from farther south. There is also a smaller amount of dust transported during these months.

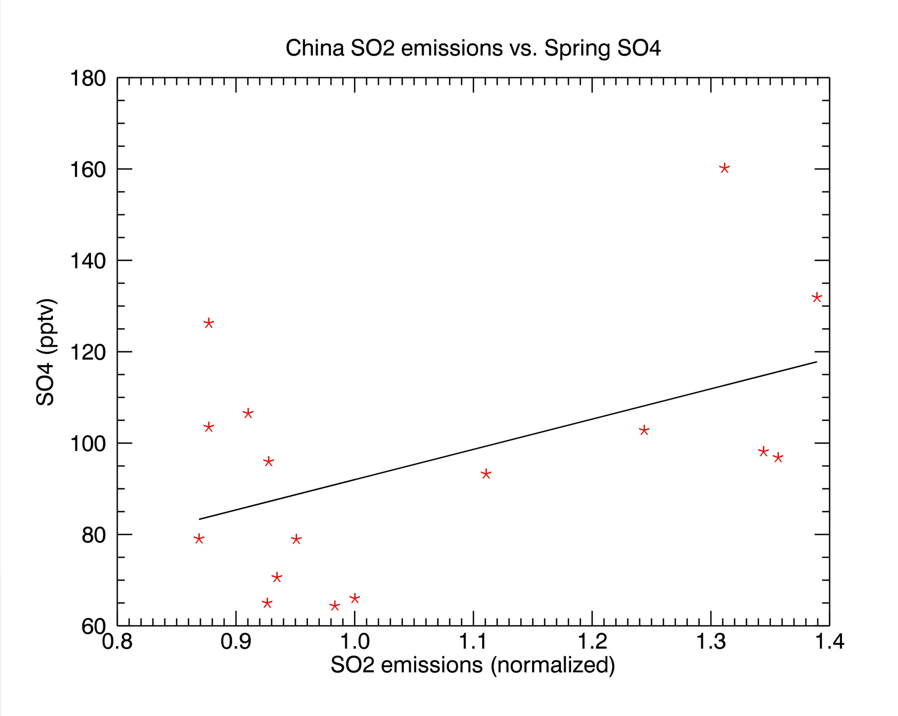

Figure 6: Comparison of SO_2 emissions from China (Lu et al., 2010; Lu and Streets, 2011; normalized to the year 1996) and SO_4^{2-} values.
Trend: SO4 = 25.74 + 66.26*SO2 ($r^2 = 0.23$)

SO_4^{2-} Aerosols at Mauna Loa

The level of SO_4^{2-} aerosols found at Mauna Loa shows a distinct seasonal pattern, as can be seen in Figure 4. The main peak in SO_4^{2-} occurs during the spring, when there is transport from Asia. There is also a second peak around September that may be the result of transport from Central America.

The spring SO_4^{2-} is also increasing over time. This can be seen in both Figures 4 and 5. However, although winter is also a time for transport from Asia, there is no significant increase in winter SO_4^{2-} over the time period examined (Figure 5).

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