Preliminary Conceptual Model - Causes of Haze in Boundary Waters Canoe Area Wilderness Area (BOWA1)

Sulfate transported from south of the site, and local and regional nitrate in the winter are the major causes of haze at the Boundary Waters Canoe Area.

The Boundary Waters Canoe Area Wilderness Area IMPROVE site is located on an exposed hilltop near a lookout (Fernberg Lookout Tower). Site elevation is ~ 524 m (1,718 ft) msl, which is 60 to 70 m (~200 ft) above surrounding lower terrain. The site thus has good exposure to regional scale transport winds. In Boundary Waters Canoe Area, the average $PM_{2.5}$ mass concentration during the years of 1997 to 2002 is 4.8 $\mu g/m^3$. The average total light extinction coefficient (B_{ext}) is 40.4 Mm^{-1} (Visual Range ~ 96 Km; Deciview ~ 14.0). The average contributions of the major aerosol components to Boundary Waters Canoe Area haze are particulate sulfate 37.4%, nitrate 13.2%, organic matter (OMC) 14.9%, elemental carbon (light absorbing carbon, LAC) 4.5%, fine soil 0.9% and coarse mass (CM) 4.4%. During the 20% worst haze days, sulfate is the largest contributor to aerosol light extinction, with an average contribution of 47%. Nitrate also contributes about 25% in the 20% worst days. Figure 2 suggests that the highest occurrence of the 20% worst days happened in January, July, August and November, in which ~30% of the sampling days are the 20% haziest days at Boundary Waters Canoe Area. During the winter season, nitrate particle is the largest contributor to haze, and contributes ~45% to haze in January and December, respectively as shown in Figure 3. While, in the summer, sulfate dominates the light extinction and contributes more than 50% to haze during the 20% worst days. Organics from fire emissions may have a significant contribution to haze during the summer fire episodes.

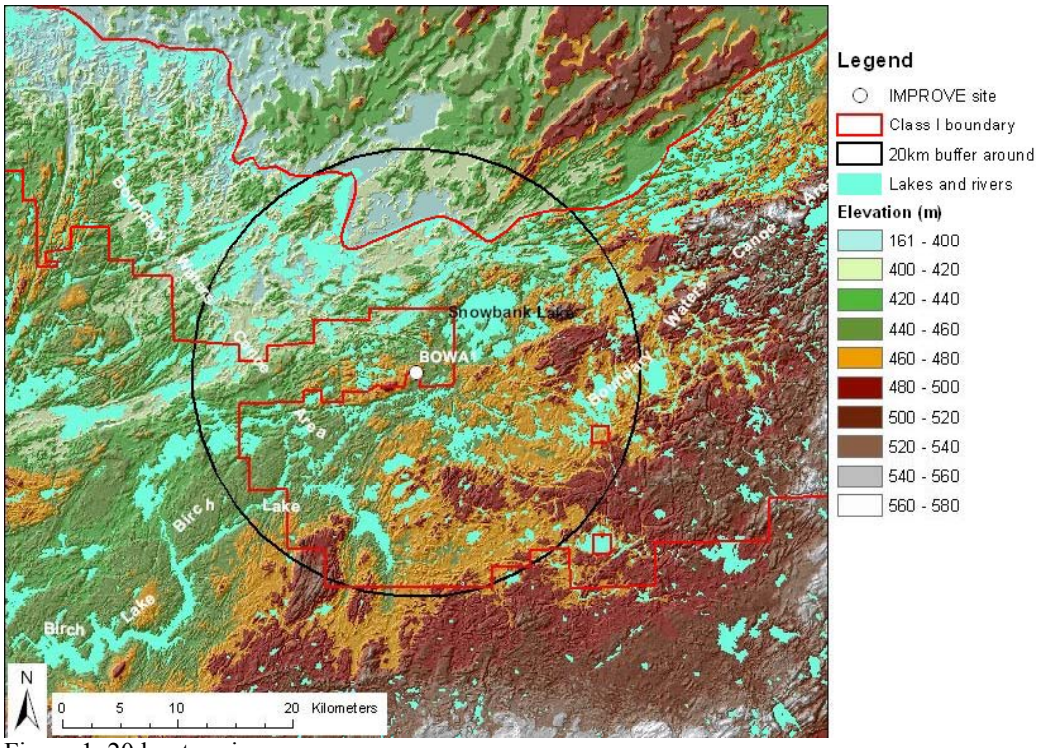

Figure 1. 20 km terrain map

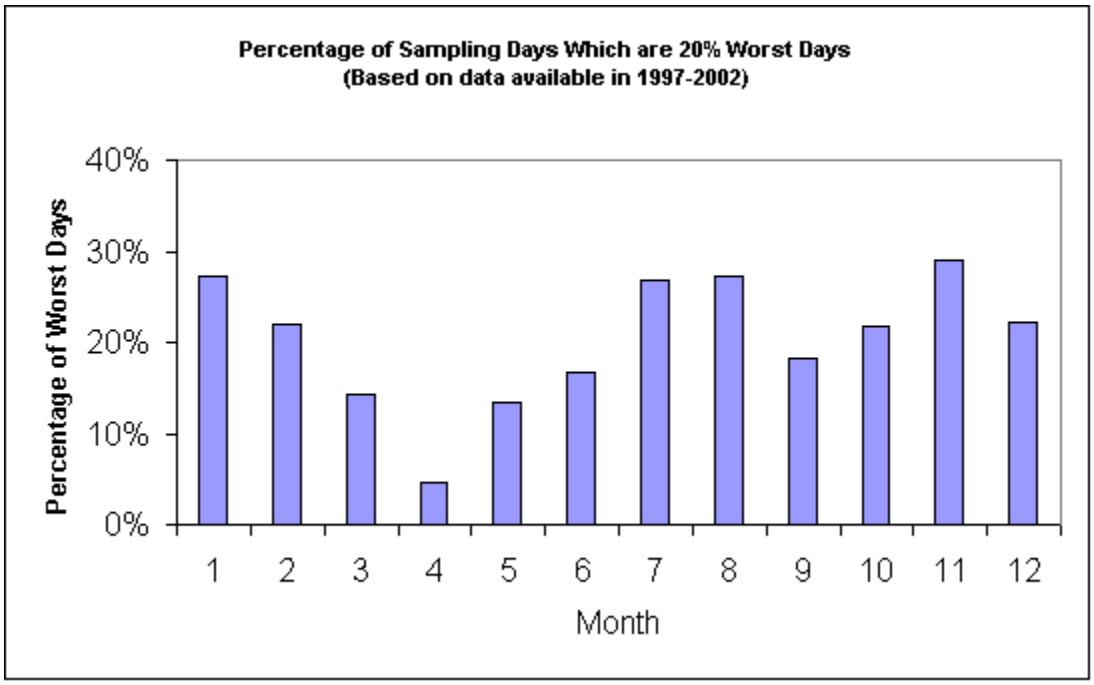

Figure 2. Percentage of sampling days that are 20% worst days in each month (Based on data available from 1997-2002)

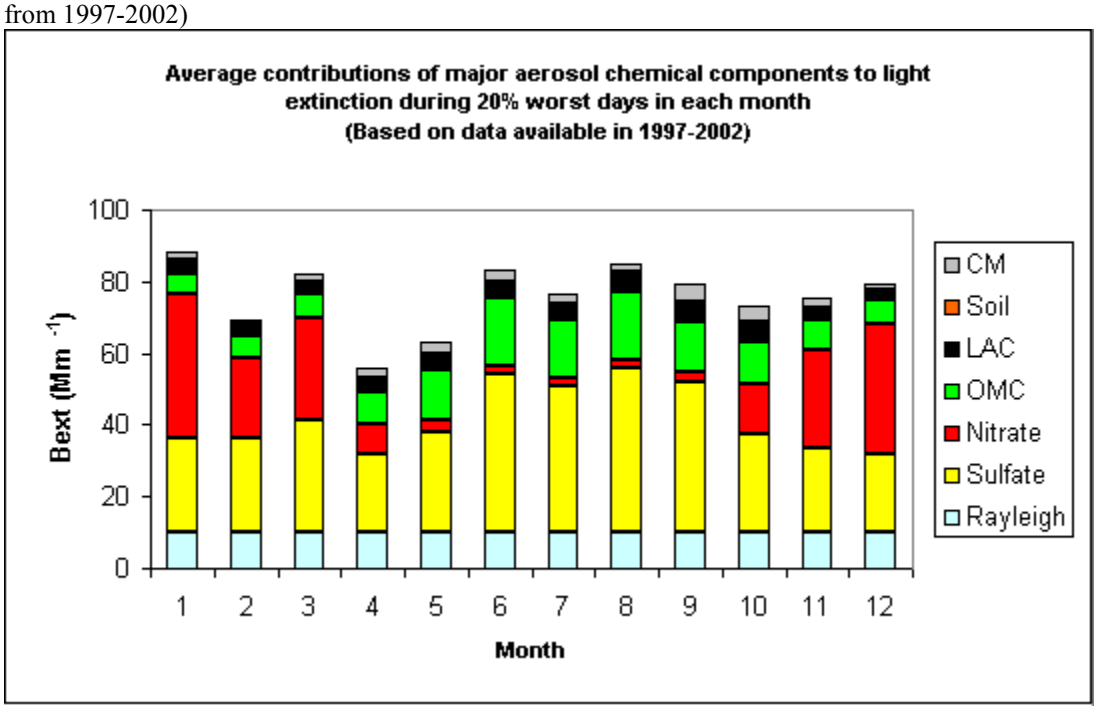

Figure 3. Average contributions of major aerosol chemical components to light extinction during 20% worst days in each month (Based on data available from 1997-2002)

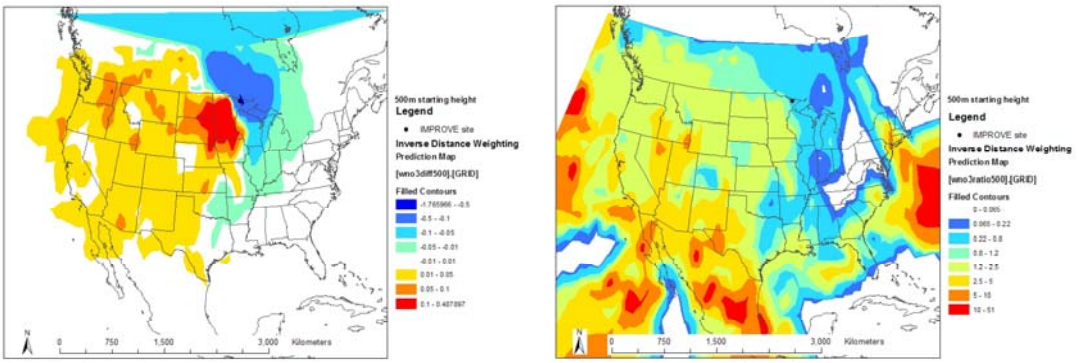

Figure 4. Difference (left) and ratio (right) of normalized residence time in 20% worst nitrate days and all days during 2000-2002 (Reddish means that more than 20% of the time when air passed through the area, the site was in 20% worst nitrate days)

Figure 4 indicates that NO_3 generally comes from local and regional sources in Minnesota as shown in Figure 5. The emissions of NOx from the local and regional sources (need specific source type information…), together with cold temperatures, which favors the partition of nitric acid to the particle phase, and the frequently occurring temperature inversion in the winter season are most likely to be the major causes of haze at the Boundary Waters Canoe Area Wilderness Area in the Winter.

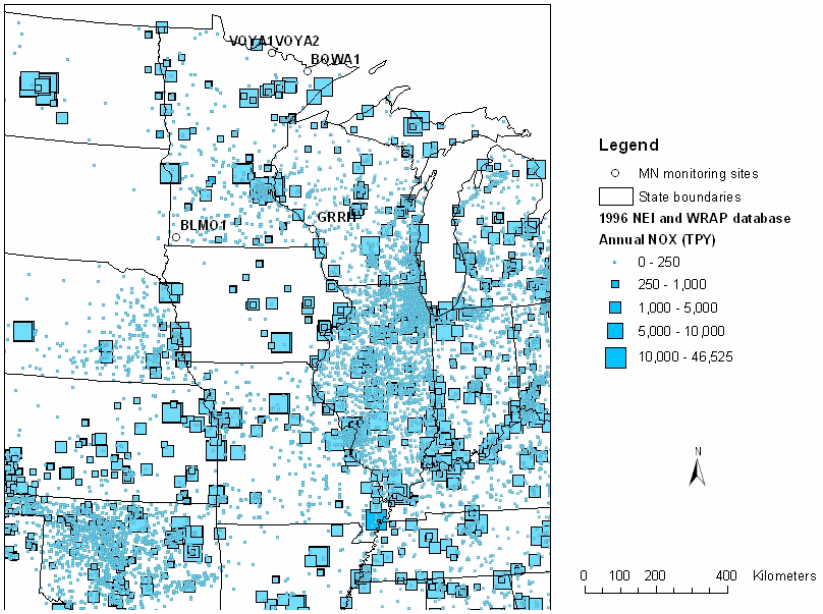

Figure 5. NOx sources based on 1996 NEI and WRAP database

During the summer, there is a higher frequency of southerly flow, which passes through southern Minnesota, eastern Nebraska and Kansas, Iowa, Missouri and western Illinois to the site, and result in high sulfate days. Subsidence inversions associated with buildup and stagnation of synoptic high pressure ridges are most likely to occur during the summer. They tend to cover a large area and are regional in nature, and may persist for periods of days, which helps to build up sulfate and results in worst haze days.

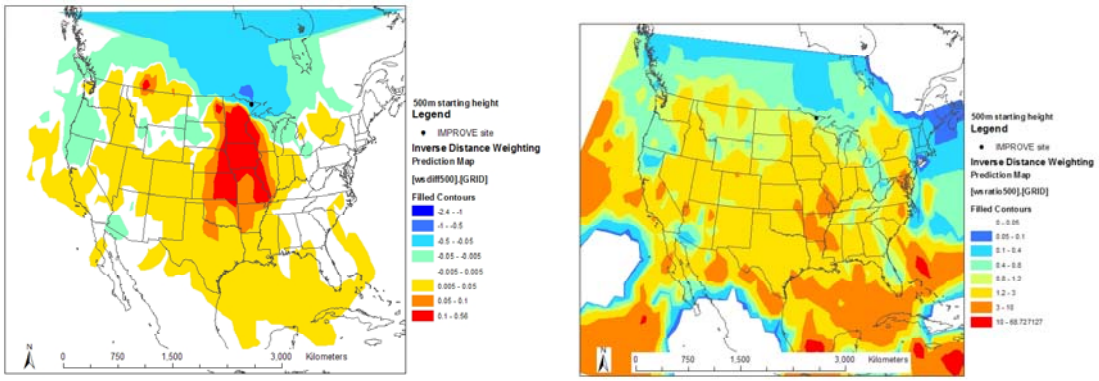

Figure 6. Difference (left) and ratio (right) of normalized residence time in 20% worst sulfate days and all days during 2000-2002 (Reddish means that more than 20% of the time when air passed through the area, the site was in 20% worst sulfate days)

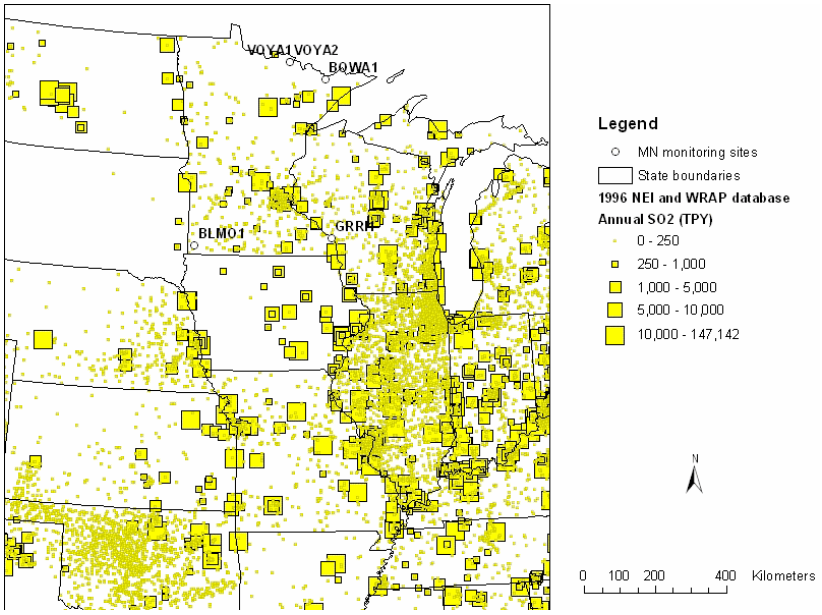

Figure 7. SO_2 sources based on 1996 NEI and WRAP database