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Decadal variability of aerosol optical depth in Europe and its relationship to the temporal shift of the NAO in the realm of dimming and brightening

Marc Chiacchio (1), Tracy Ewen (3), Martin Wild (1), Mian Chin (2), and Thomas Diehl (2)

(1) ETH, Institute for Atmospheric and Climate Science, Zurich, Switzerland (marc.chiacchio@env.ethz.ch), (2) NASA Goddard Space Flight Center, Greenbelt, Maryland, USA, (3) Department of Geography, University of Zurich, Zurich, Switzerland

Long-term aerosol optical depth (AOD) over Europe was analysed from the Goddard Chemistry Aerosol Radiation and Transport (GOCART) model from 1979-2007. In particular, we studied the decadal sulfate AOD variability caused by large sulfur emissions from anthropogenic sources in Europe with a peak in 1988-1989. Simulated annual means from 1985-2007 over the continent showed statistically significant declines of 69% and a maximum of 75% in Eastern Europe. Seasonally, greatest variations occurred during winter and spring followed by summer and autumn. The decrease in AOD agrees with the increase in the annual, spring, and summer mean solar radiation in Europe after the mid-1980s as well as surface-based AOD measurements. However, the long-term AOD variability does not explain the trends found in solar radiation during winter and autumn, which may be due to the contribution from the North Atlantic Oscillation (NAO) and associated cloud cover. We also investigated a possible link between sulfate AOD and NAO and found a statistically significant correlation of -0.77 in winter for Europe. Wavelet coherence analysis revealed a strong and significant anti-phase relationship around 1-year that was most pronounced in the late 1980s. Cross-correlation analysis showed a seasonal dependence of sulfate AOD and NAO with negative correlation during winter and positive during summer. This analysis may help explain the seasonal decadal variability of surface solar radiation and whether sulfate aerosols have contributed to the large positive trend of the NAO during the 1980s. However, the cause and effect relationship between sulfate aerosols and NAO remains unclear.