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Have aerosols affected precipitation variations in Europe?

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According to cloud physics, an increase in sulphate aerosol concentrations may reduce cloud droplet sizes and thus inhibit precipitation, while decreasing aerosol concentrations may have the opposite effect. Here, we investigate whether the large variations in anthropogenic sulphate emissions over the last decades have had a notable effect on precipitation in Europe. We use point observations as well as gridded data sets of precipitation to study changes in the heavily industrialized region on the borders of Poland, the Czech Republic and Germany, formerly known as the "Black Triangle" (BT). High concentrations of sulphuric gases in this area caused severe forest dieback in the 1970s and -80s, after which the air quality has improved significantly. Changes in the BT area are compared to changes in a clean region at the western coast of Europe, where trends in pollution have been minor.

We find that the horizontal visibility at stations in the BT area increased dramatically over the past three decades, whereas in clean coastal areas the visibility only changed slightly. The high correlation between trends in sulphate concentrations and visibility demonstrates that the substantial emission reductions have impacted the radiation budget and conceivably the hydrological cycle. Indeed, the period of strongest decrease in pollution (1983-1995) is associated with a large increase in precipitation in the BT area and with a weaker increase in the clean coastal region. However, an earlier period with increasing pollution levels (1947-1970) was also associated with increasing precipitation, and there was no discernable difference between urban and rural areas when analyzing the geographic distribution of the trends. Light and heavy precipitation were studied separately, but neither showed any sign of aerosol influence. Finally, stratification of the data with respect to weather types, e.g. wind direction or NAO index, was performed to elucidate the potential aerosol signal, which would be much larger in the BT than in the clean region. But instead of seeing a larger difference between the two regions, this only made the precipitation trends more similar.

Altogether, we find no decisive verification that changes in sulphate concentrations have caused measurable changes in precipitation over Europe, despite the large changes in visibility that we found. Further studies will simulate precipitation changes using a global climate model.