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Impact of stratospheric volcanic aerosols on the daily temperature range (DTR) in Europe over the past 200 years: observations vs. model simulations

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Explosive tropical volcanic eruptions can affect climate and weather on many timescales and over large areas and are one of the major causes of natural climate variability. The dominant and best understood mechanism through which volcanic eruptions influence climate is the direct radiative perturbation through secondary sulfate aerosols in the stratosphere, enhancing the reflectance of solar radiation and as a consequence leading to a loss of energy at the Earth's surface. The decrease of shortwave radiation on the ground affects the energy balance during daytime only. During the night (and also during the day), even a slight increase in surface net radiation is expected due to the increase in downwelling longwave radiation. Overall, these changes in the energy balance may lead to an overall reduction of the daily temperature range (DTR). Hence, the DTR can be utilized as a quantitative measure of the radiative forcing impact through stratospheric volcanic aerosols.

We analyze this impact over Europe using long-term daily and sub-daily station records. Eight stratospheric volcanic eruptions from the instrumental period (ca. 200 years) are investigated. Seasonal all-sky DTR anomalies after volcanic eruptions are compared to contemporary (ca. 20 year) reference periods. We further use clear-sky DTR anomalies to eliminate cloud effects and better estimate the signal from the direct radiative forcing of the volcanic aerosols. We find a stronger negative signal in the clear-sky DTR anomalies compared to the all-sky case. Although the all-sky and clear-sky anomalies for different stations, volcanic eruptions, and seasons show heterogenic signals in terms of magnitude and sign, the significantly negative DTR anomalies (e.g., for Tambora) are qualitatively consistent with other studies. We quantify the impact on clear-sky DTR through stratospheric volcanic forcing, by applying a weighted linear regression model to clear-sky DTR anomalies and radiative forcing. Our estimate points to a DTR change in the order of magnitude of previously published studies for the 'global dimming' period, however being at the lower end.

This comprehensive observation based analysis quantifies, for the first time, the impact of stratospheric volcanic eruptions on clear-sky DTR over Europe, providing valuable information for geo-engineering purposes. Furthermore, we compare our results from the observations to a modeling framework, repeating the same methodology for a 30-member ensemble of ECHAM5.4 general circulation model simulations.