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Linking meteorology and air quality under a changing climate: future European air pollution under several IPCC scenarios

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The analysis of the influence of future climatic variations on air quality needs of methods that give a space-time display of large atmospheric data related to air pollution. Here a new approach in order to assess the impacts of climate change on the patterns of variation of air pollution over Europe is presented. The most widely used method of analysis (selected time-slices, future-minus-present method) is very sensitive to the chosen control and future periods because of the internal variability of the climate system.

In order to overcome this limitation, full transient simulations for the period 1991-2050 have been carried out using the regional modelling system MM5 (regional climate model version)-CHIMERE for Europe with a horizontal resolution of 25 km, and a vertical resolution of 23 layers in the troposphere. The IPCC SRES A2 and B2 scenarios are analysed by the Empirical Orthogonal Functions (EOFs) methodology in order minimise the uncertainty associated to the internal variability due to the longer time series obtained.

The first EOF (EOF1) is defined as that accounting for the maximum amount of variance in the data set, and much of the variance modes of pollutants and meteorological fields can be represented only with the EOF1 (which also leads the changing trend for future variations), making this methodology a useful data reduction technique applied to air quality data and modelling results. Projection of the pollutants concentration or the meteorological fields onto the EOFs defined the principal components (PCs); these time series describe the temporal variation in the contribution of the associated EOF to the total variance in the original data. Hence, here we analyse the correlations of EOF1s between the different gaseous pollutants-particulate matter components and the meteorological parameters, which is an index of the similarity between the spatial patterns of variation, and also the correlation of PC1s, depicting the temporal evolution associated to the spatial pattern of change.

The results indicate that the EOF1 accounts for around 30-50% of the total variance for different gas-phase and aerosol pollutants and points out a general increase of its trend over the entire domain ($p < 0.005$), except in the case of nitrate, whose change signal is not significant ($p > 0.1$). The correlation between pollutants and meteorological parameters indicates that the trends and patterns of variation of aerosols are related to the higher temperature projected for the future climate. It favours the formation of secondary gas-phase pollutants and aerosols, such as sulphates and ammonium (increasing the concentrations of atmospheric oxidants) and the decomposition of volatile species such as ammonium nitrate, remaining in the gas phase. Further, the decreases in precipitation have a strong effect on the frequency of the washout and therefore in the levels of aerosols. The concentrations of aerosols decrease with increasing precipitation as wet deposition provides the main aerosol sink. The trend from a decreasing mixing height found in several areas of Europe is frequently related to a decrease in precipitation, representing an adding effect for the enhanced future pollutant concentrations.