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Assessing the influence of the North Atlantic Oscillation on the European atmospheric composition from a climatic perspective: a case study for polycyclic aromatic hydrocarbons

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The North Atlantic Oscillation (NAO) controls a large amount of the European climate variability with asymmetric impacts in both time and space. These NAO-related impacts on the atmospheric fields are bound to influence the atmospheric composition, through both local processes and large-scale transport of air pollutants. The studies devoted to explore such an influence from a climatic perspective (long-term modeling) are few, and even less disentangling between local and large-scale settings. Therefore, the contribution of the local NAO-controlled processes on the climatology of air pollution levels is still hardly established.

Hence, the objective of the present study is to assess the NAO fingerprint in terms of mean concentration of polycyclic aromatic hydrocarbons (PAHs, in this case benzo[a]pyrene, BaP) in a region covering the entire Mediterranean basin from the north of Africa to the north of Europe, focusing on the influence of the small scale processes. BaP is arguably the most studied PAH, and the reference for PAH air quality standards defined by the European Commission.

To achieve this goal, we use a numerical simulation of the atmospheric chemical composition that spans from 1989 to 2010 and fixing the anthropogenic emissions, thus allowing to isolate the climatic variations in BaP. The chemistry transport model selected was CHIMERE and the domain considered has a spatial resolution of 0.2 degrees in the horizontal, which is about 25 km at the European latitudes considered, and eight vertical levels unevenly spaced up to 550 hPa. This resolution is higher than the commonly applied in climate runs.

The simulation was designed to disregard the signals from the NAO impact on the long-range transport, using constant climatological boundary conditions for the pollutants concentrations. This allows the enhancement of our understanding regarding the role of the local underlying mechanisms as they are governed by the NAO.

The results show impacts with asymmetries in both time (i.e. between seasons) and space (i.e. between northern and southern areas). In winter, higher ground-levels of BaP are observed around the Mediterranean basin during the positive NAO phases, while these signals are northward shifted in the summer season. These differences involve variations up to and over 100% in the mean levels. Eventually, softer signals of opposite sign (i.e. NAO-enhancing the ground-level concentration of BaP) are observed in northern (southern) areas in winter (summer).

The causes for these NAO-related variations in the levels of aerosols have to be sought in a variety of climatic factors varying between positive and negative NAO phases, namely: (1) increased/reduced temperature (particularly in northern Europe), (2) different distribution of the precipitation patterns across Europe, (3) changes in the photolysis of primary and secondary pollutants due to changes in cloudiness, and (4) the cleaning effect of enhanced winds.