Geophysical Research Abstracts
Vol. 19, EGU2017-8275, 2017
EGU General Assembly 2017

Spatial clustering and meteorological drivers of summer ozone in Europe

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We present a regionalization of summer near-surface ozone (O_3) in Europe. For this purpose we apply a K-means algorithm on a gridded MDA8 O_3 (maximum daily average 8-h ozone) dataset covering a European domain [15° W - 30° E, 35°-70° N] at 1° x 1° horizontal resolution for the 1998-2012 period. This dataset was compiled by merging observations from the European Monitoring and Evaluation Programme (EMEP) and the European Environment Agency's air quality database (AirBase). The K-means method allows identifying sets of different regions where the O_3 concentrations present coherent spatiotemporal patterns and are thus expected to be driven by similar meteorological factors. After some testing, 9 regions were selected: the British Isles, North-Central Europe, Northern Scandinavia, the Baltic countries, the Iberian Peninsula, Western Europe, South-Central Europe, Eastern Europe and the Balkans.

For each region we examine the synoptic situations associated with elevated ozone extremes (days exceeding the 95th percentile of the summer MDA8 O_3 distribution). Our analyses reveal that there are basically two different kinds of regions in Europe: (a) those in the centre and south of the continent where ozone extremes are associated with elevated temperature within the same region and (b) those in northern Europe where ozone extremes are driven by southerly advection of air masses from warmer, more polluted areas. Even when the observed patterns were initially identified only for days registering high O_3 extremes, all summer days can be projected on such patterns to identify the main modes of meteorological variability of O_3. We have found that such modes are partly responsible for the day-to-day variability in the O_3 concentrations and can explain a relatively large fraction (from 44 to 88 %, depending on the region) of the interannual variability of summer mean MDA8 O_3 during the period of analysis. On the other hand, some major teleconnection patterns have been tested but do not seem to exert a large impact on the variability of surface O_3 over most regions.

The identification of these independent regions where surface ozone presents a coherent behaviour and responds similarly to specific meteorological modes of variability has multiple applications. For instance, the performance of chemical transport models (CTMs) and chemistry-climate models (CCMs) can be separately assessed over such regions to identify areas where they present large biases that need to be corrected. Our results can also be used to test the models' sensitivity to the day-to-day changing meteorology and to climate change over specific regions.