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Diagnosing changes in European tropospheric ozone: A model study of past and future changes

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In recent decades, the negative impacts of tropospheric ozone on human and ecosystem health have led to policy changes aimed at reducing emissions of ozone precursor gases such as nitrogen oxides (NO_x) and carbon monoxide (CO). Although emissions of these species have significantly decreased in Europe and North America since the early 1990s, observational data indicate that free tropospheric ozone over Europe has not decreased as expected. Uncertainty remains as to how much of a role the transport of stratospheric ozone or tropospheric ozone from remote source regions has played in recent trends, as well as to how this will evolve in a changing climate.

The global chemistry-climate model SOCOL (SOlar Chemistry Ozone Links) is used to investigate tropospheric ozone over Europe from 1960 to 2100. To fully disentangle the effects of both long-range transport and input from the stratosphere, simulations are run with ozone tracers from 21 different atmospheric regions. In addition to a standard reference run, several sensitivity simulations are run: one with emissions of NO_x and CO held constant at 1960 levels, one with methane (CH4) held at constant 1960 levels (in addition to the NO_x and CO), and a third with NO_x and CO emissions from Asia fixed at 1960 levels. Results suggest that the largest contributions to European tropospheric ozone originate from the tropical and northern mid-latitude boundary layer and free troposphere. Contributions from these regions increase over the historical period (1960-2010), indicating that changes in source gas emissions have affected ozone concentrations in the European free troposphere most strongly. Contributions from these regions then decrease from 2010-2100, but remain considerably larger than input from the stratosphere, which is relatively small in all simulations throughout the entire simulated period (1960-2100). The stratospheric contribution does, however, increase slightly over the 21st century, in tandem with ozone recovery and a simulated strengthening of the Brewer Dobson circulation.