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Influence of future cropland expansion on regional and global tropospheric ozone

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With the global population set to rise over the next 100 years, the fraction of land used for crop cultivation is likely to increase, the trend being most pronounced in developing regions such as Brazil and South East Asia. In these regions currently there stands natural rainforest, a high emitter of isoprene. As many staple crops, such as soy bean, are low emitters of isoprene, increasing the crop fraction in these regions will decrease isoprene emissions. Ozone over ∼35 ppb has been shown to be damaging to plants, and as ground level ozone is sensitive to isoprene concentrations, altering isoprene emissions could increase ground level ozone, potentially resulting in crop damage. This mechanism was investigated by comparing two configurations of an atmospheric chemistry-climate model (UM-UKCA) under a 2100 climate following an IPCC scenario of moderate climate change. The first run had a present day crop distribution but isoprene emissions concurrent with 2100 temperatures and climatic conditions. The second run had isoprene emissions representative of both a 2100 climate and a 2100 crop distribution in accordance with the IMAGE model. By comparing these runs it was established that ozone increased by up to 8 ppb (∼30%) due to crop land expansion. Over the Amazon (the most affected region) it was found that crops were exposed to a daily maximum 8-hour (DM8H) ozone above the 35 ppb threshold for up to 65 days more per year than in the base case. These conclusions suggest that increasing the crop fraction in current areas of natural rainforest could increase regional ground level ozone, having a significant effect on crop yield and air quality. The sensitivity of such conclusions to isoprene chemistry was examined by varying the isoprene chemistry scheme within the model. The CheT isoprene scheme used here (50 reactions) was compared with the AQUM (23 reactions) and CESM Superfast (2 reactions) isoprene schemes, all of which are currently used in Earth-system models. It was found that the effect of transplanting these isoprene schemes into the base CheT chemistry scheme lead, in both cases, to higher ozone over isoprene rich regions by up to ∼40 ppb. Furthermore, upon repeating the land use change experiment with these other isoprene schemes, it was found that the AQUM scheme produced more ozone (up to ∼20 ppb more) in isoprene rich regions due to crop expansion than CheT. However the CESM Superfast scheme showed the opposite effect, producing less ozone than the CheT scheme in isoprene-rich regions. These varied responses highlight the sensitivity of future trends in surface ozone to isoprene chemistry within the range of some currently used chemical schemes, and suggest that further research is needed in order to most effectively parameterise this complex chemistry.