Seasonality and geographical variability of tropospheric ozone (O_3), stratospheric influence and recent trends

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The relative importance of the stratosphere in determining tropospheric ozone (O_3), with respect to O_3 precursor emissions is still subject to much debate. However, recent improvements in diagnostic and modeling tools provide new evidence that the stratosphere can have a significant influence, even in explaining long term trends and determining extreme air pollution events. This study aims to characterise the seasonal and geographical distribution of tropospheric O_3, its variability and trends, and provide quantification of the stratospheric influence on these measures. To this end, we evaluate hindcast specified dynamics chemistry-climate model (CCM) simulations from the ECHAM/MESSy Atmospheric Chemistry (EMAC) model and the Canadian Middle Atmosphere Model (CMAM), as contributed to the IGAC/SPARC CCMI activity, together with satellite observations from the Ozone Monitoring Instrument (OMI) and ozonesonde profile measurements derived from the World Ozone and Ultraviolet Radiation Data Centre (WOUDC) database. Agreement of the CCM data with the observations is rigorously assessed on seasonal and inter-seasonal timescales. Noting the consistency of the CCMs, both O_3 volume mixing ratio (VMR) tracer and stratosphere-tagged O_3S VMR tracer simulations, resolved at fine scale vertical resolution, are then used to estimate the stratospheric influence on tropospheric O_3 on a seasonally averaged basis between 1980 and 2010. The influence of the model chemistry schemes and internal dynamics is discussed in relation to the inter-model differences shown. Finally, the long term trends in the CCM O_3 tracers are calculated for different seasons over this period. It will be shown that trends in tropospheric O_3 are positive and statistically significant across much of the world, but particularly in the Northern Hemisphere and in the middle to upper troposphere (typically > 2-3 ppbv dec^{-1}). Across many regions, a large percentage of this increase can be attributed to an increase in stratosphere-troposphere exchange (STE) of O_3. Although this contribution is less in the lower troposphere, the influence is estimated to be substantial across much of the mid-latitudes. These findings have significant implications for the radiative forcing, air quality and oxidation capacity of the troposphere.

Key words: Tropospheric ozone (O_3), stratosphere-troposphere exchange (STE), chemistry climate models (CCMs), ozone monitoring instrument (OMI), ozone variability and trends.