Chemistry and Climate Studies with the Met. Office Unified Model

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Overview

A variety of studies of the transport, chemistry and radiative effects of trace gases in the troposphere and middle atmosphere are being carried out with the UK Met. Office's Unified General Circulation Model (UM). The studies will contribute to understanding of the impact on climate and air quality of projected trends in anthropogenic emissions.

Inter-continental transport of ozone pollution

A global modelling study is being carried out to investigate how future changes in regional trace gas (NO_x, CO, VOC) emissions may affect tropospheric ozone. In the Intergovernmental Panel on Climate Change SRES A2 scenario used here, emissions from Southeast Asia are projected to grow much faster than the global average, whereas regions with strict controls (e.g., Europe), or faltering economies (e.g., Russia) show modest growth, or even decline. Simulations with fixed meteorology were performed for 1990 and 2030 emissions, along with additional 2030 runs with regional (Europe, North America, Southeast Asia) emissions reverting to 1990 levels. Increases in Asian emissions (see Figure 1) generate extra ozone in the upper troposphere over Asia and downwind, extending over the Pacific and North America. Subsequent downwards transport and mixing allows Asian emissions to influence ozone throughout the troposphere in northern middle latitudes. The most widespread effects are seen in late spring, a trade-off between the longer ozone lifetimes during winter and the higher ozone production efficiency during summer. Lesser impacts are seen from the more northerly European and North American emissions, partly explained by the smaller magnitude increases, but also due to less convective lofting of emissions to the upper troposphere. Clearly the location of ozone precursor emissions has a major influence on their ozone production efficiency.

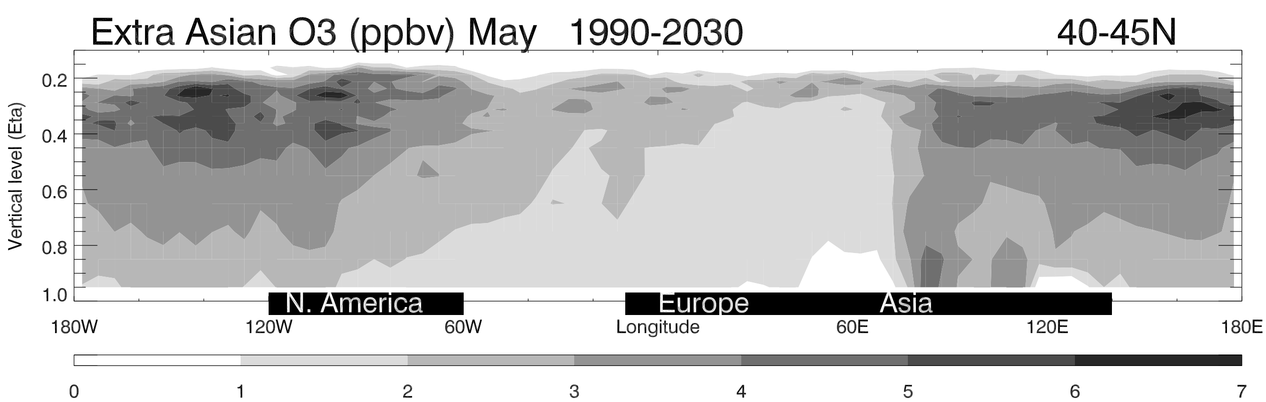

Figure 1: Simulated increase in tropospheric ozone between 1990 and 2030 due to anthropogenic trace gas emissions from Asia.

Impact of methane-derived water vapour on future middle-atmospheric climate

The UM with parameterized and interactive $CH_4/H_2O/H_2$ and O_3 chemistry is being used to examine the response of the middle atmosphere to an increase in its humidity caused by a possible future increase in CH_4. The chemical parameterization allows the middle-atmospheric H_2O change to evolve naturally from an imposed change in tropospheric CH_4. First, a control simulation of the present-day atmosphere is compared with a simulation of the year 2060 using postulated (IPCC SRES B2) concentrations of all the important long-lived, radiatively-active gases. Then, the particular contribution of the CH_4, and hence H_2O, change to the observed difference is isolated by comparing simulations of 2060 including and excluding the projected CH_4 change. The CH_4 and H_2O profiles from the different simulations are shown in Figure 2.

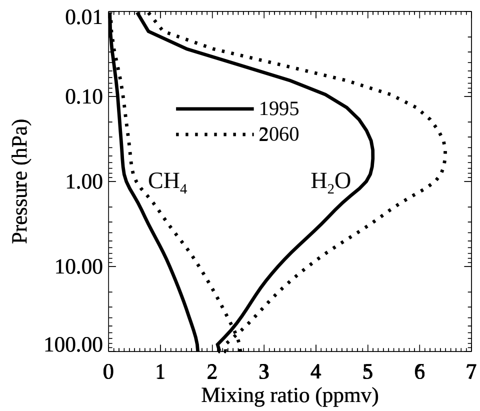

Figure 2: Annual, tropical mean profiles of CH_4 and H_2O from the 1995 and 2060 simulations.

Figure 3a shows the annual-mean temperature difference between 2060 and 1995 due to the combined influence of the change in all the radiatively-active gases. There is a general cooling of the 2060 middle atmosphere which peaks at around 5 K throughout the upper stratosphere and mesosphere. This nett cooling is due mainly to the increased CO_2 in 2060; the contribution of the increased H_2O to the temperature difference is indicated by Figure 3b. Over most of the middle atmosphere, the H_2O is responsible for a cooling of between 0.4 and 0.6 K or around 10% of the total temperature change between 1995 and 2060.

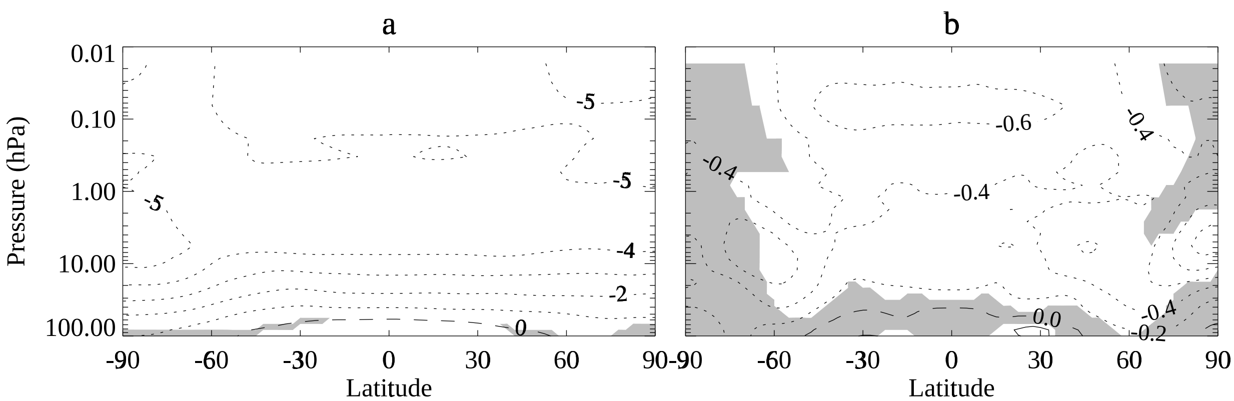

Figure 3: (a) Annual, zonal-mean temperature change (K) between 1995 and 2060 when all radiatively-active gases are adjusted in line with IPCC scenario SRES B2; (b) Individual contribution of the CH_4/H_2O adjustment to the total difference seen in (a). The shading indicates where the temperature difference is not statistically significant.