Chemistry and Climate Studies with the Met Office Unified Model

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Introduction

A number of studies of the impact of natural and anthropogenic emissions and interannual variability on atmospheric composition and climate are being performed with the Met Office Unified General Circulation Model (UM).

Modelling the atmospheric impact of the 1783-1784 Laki eruption

A chemistry-transport model (STOCHEM) coupled to the UM has been used to simulate the atmospheric impact of the 1783-1784 Laki volcanic eruption from Iceland [*Stevenson et al*., 2003]. This effusive eruption added about 60 Tg(S) to the troposphere and lower stratosphere over an 8 month period, starting in June. By comparison, present-day anthropogenic emissions total about 70 Tg(S)/yr, and the 1991 explosive eruption of Mt. Pinatubo added about 20 Tg(S) to the mid-stratosphere. Figure 1 shows zonal, JJA mean sulphate concentrations simulated by the model, for the present-day, the pre-industrial, and for two Laki simulations with differing height profiles of emissions (Lo: evenly distributed 0-9 km; Hi: 25% (0-3 km), 75% (9-13 km)). The sulphate has a mean atmospheric lifetime of 6-9 days, although the local lifetime is of order a few months in the lower stratosphere. When added to a climate model, the aerosol generates a Northern Hemisphere mean top of the atmosphere radiative forcing of up to –6 Wm^{-2} for a few months, before decaying fairly rapidly as the eruption ceases [*Highwood and Stevenson*, 2003]. The Hi scenario produces a climate cooling in the Northern Hemisphere of order –0.2 K for the year 1783, in good agreement with the limited data for the time. This modelling study has many areas of uncertainty, but represents the first attempt to apply detailed atmospheric models to the climate impact of large-scale effusive volcanic eruptions.

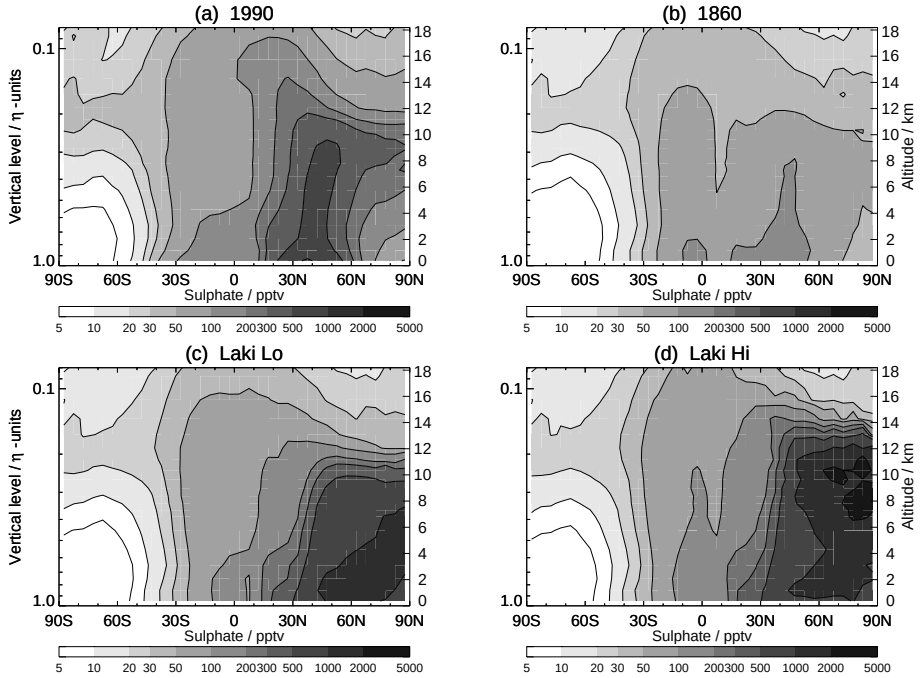

Figure 1: Sulphate concentrations from different model simulations—see text for details.

The influence of ENSO on tropospheric ozone variability

Results from a modelling experiment using the HadCM3 UM coupled to the STOCHEM chemistry model are being examined to investigate the role of interannual variability in climate on tropospheric ozone. The IPCC SRES A2 future high growth emissions scenario is used to provide the climate forcing for 1990-2100 and also the (annual smoothly growing) anthropogenic emissions input to the chemistry model. Natural emissions are annually invariant, hence the modelled ozone variability arises solely from interactions between climate and chemistry.

ENSO is the dominant mode of variability in the tropics on interannual timescales. Correlation maps using the Niño3 index show the patterns of surface temperature and precipitation associated with ENSO for the last 30 years of

the experiment(Figure 2). Tropospheric column ozone analysed from this experiment, also shown, exhibits ENSO-like spatial patterns, with positive coefficients suggesting enhanced ozone over Indonesia, and negative coefficients suggesting suppressed ozone over the central and western Pacific, under El Niño like conditions. Over Indonesia, lower temperatures and humidities during El Niño give rise to lower OH and ozone destruction rates and higher net chemical production of ozone. In addition to reduced humidities, dynamical changes in convection during El Niño may also be contributing to the simulated ozone pattern. The converse situation occurs over the central and western equatorial Pacific. Variations in biomass burning and lightning emissions are not included, but are likely to be major contributors in the real atmosphere.

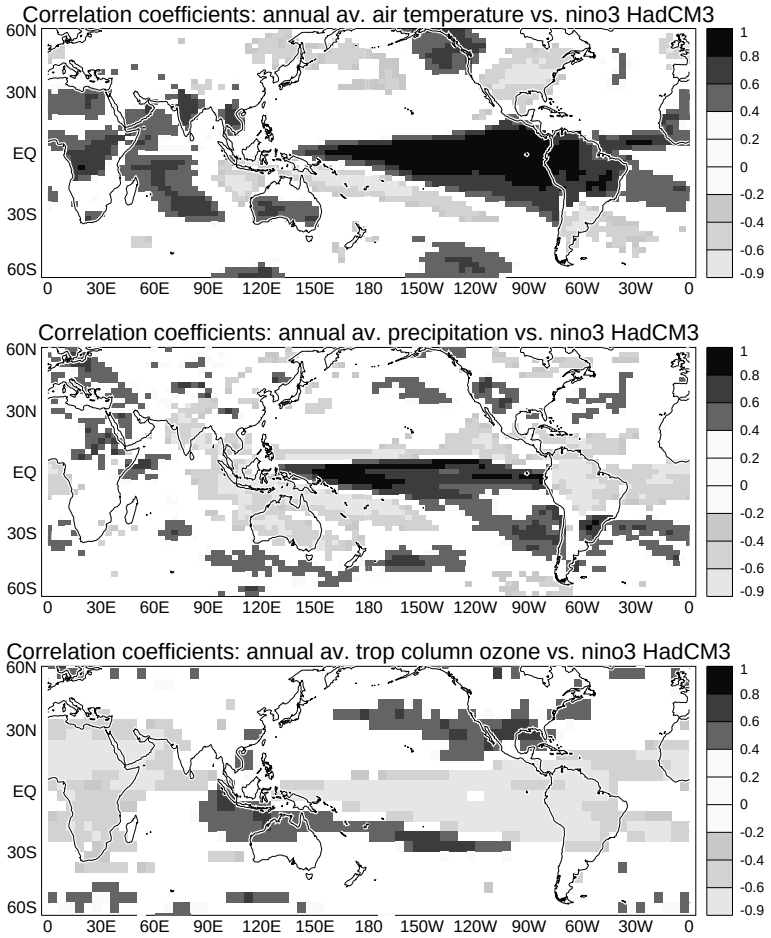

Figure 2: Correlation coefficients between the Niño3 ENSO index and surface temperature, precipitation and tropospheric ozone column for 30 years of a UM simulation (only values significant above the 95% level are plotted).

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

A recently-completed study with the UM suggests that under the IPCC SRES B2 emission scenario, the H_2O increase stemming from stratospheric oxidation of increased atmospheric CH_4 contributes approximately 10% of the total middle-atmospheric cooling occurring between 1995 and 2060 [*Mackenzie and Harwood*, 2003]. The $\sim$25% fraction of the increase in polar stratospheric clouds in 2060 compared with 1995 which is attributable to the extra H_2O (the remainder being due to the reduced temperatures) makes the 2060 Arctic ozone loss $\sim$15% greater than it would otherwise be. (Albeit, the loss is still much less than in 1995 owing to the reduced chlorine loading.)

References

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