A new look at Tropospheric Chemistry

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Tropospheric science

The troposphere is the lowest part of the atmosphere from the ground up to what's known as the 'tropopause' - a narrow region at roughly 10km altitude across which there is a significant change in atmospheric properties. The chemistry in the troposphere is very complex. Computer models of tropospheric chemistry need to consider emissions from natural (e.g. lightning) and anthropogenic (e.g. industry, transport) sources, gas phase reactions that take place on both short and long timescales as well as heterogeneous gas reactions such as aqueous reactions in clouds. At the Centre for Atmospheric Science, University of Cambridge, scientists are using a range of computer models to study various aspects of tropospheric chemistry and in particular the role of ozone.

Although only a trace gas, ozone plays an important role in the troposphere, both radiatively and chemically. Ozone is an effective greenhouse gas and research suggests that, on recent timescales, it could be at least as important a greenhouse gas as methane. Chemically, ozone is the precursor for the main tropospheric oxidising agents, and hence has a strong influence on the ability of the troposphere to remove atmospheric pollutants. Furthermore, ozone near the Earth's surface is itself a pollutant and is detrimental to people with respiratory problems and to ecosystems. However, there is a still a large uncertainty in the factors controlling ozone in the troposphere.

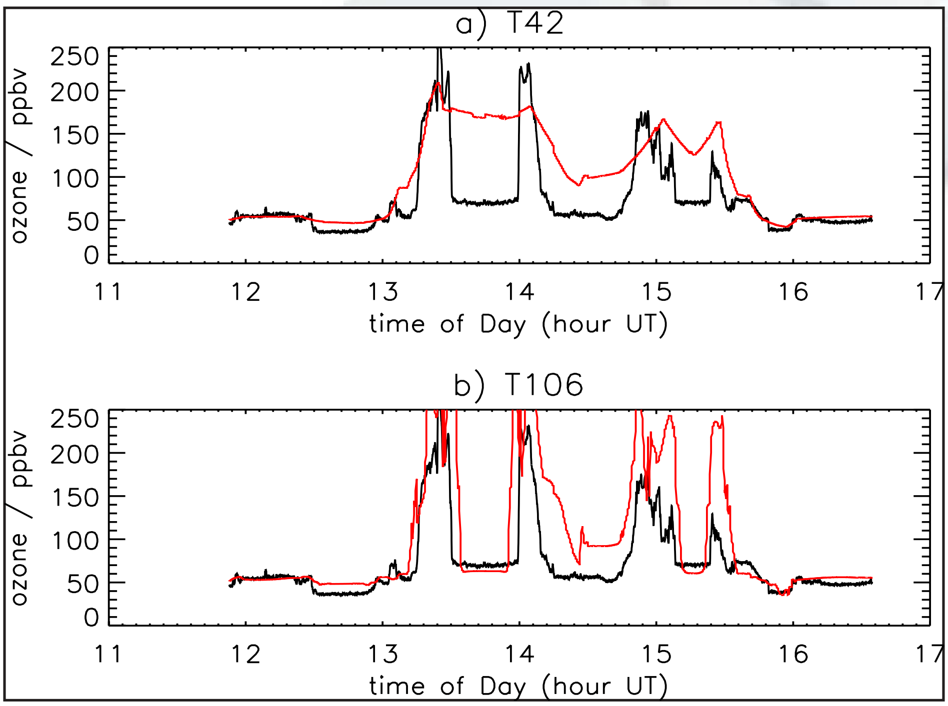

Figure 1: Comparison between modelled (red) and measured (black) ozone concentrations along a flight track from two TOMCAT integrations a) on the 3x3 degree model grid (normal resolution) and b) on the 1x1 degree model grid, made possible by the new model. The flight track is an example of a flight involving the UK Meteorological Office C-130 aircraft during the ACTO (Atmospheric Chemistry and Transport of Ozone) campaign in May 2000, funded by NERC's UTLS (Upper Troposphere/Lower Stratosphere) thematic programme.

Tropospheric chemistry modelling research

One of the main models used is the 'TOMCAT' 3D model of tropospheric chemistry. This is what is known as a 'transport model' in that it uses meteorological analyses, winds and temperatures, to transport modelled chemical species accurately on a 3D model grid representation of the troposphere. Until recently, this model was run on the Fujitsu vector computer at Manchester but the closure of that service prompted the development of a new version of TOMCAT based on MPI. The new version offers substantially improved performance, enabling much faster runtimes than before and new research topics to be tackled. Assistance in porting the model was provided by CSAR.

The TOMCAT model is an ideal tool for carrying out studies of the role of ozone in the troposphere. For example, recent work for the Intergovernmental Panel on Climate Change has examined the impact of increased surface emissions on air quality in the coming century and found that air quality standards, in relation to ozone, will be strongly violated. TOMCAT has also been used to study the impact of subsonic aircraft on ozone. It was found that aircraft emissions result in enhancements to tropospheric ozone and hence contribute to the greenhouse effect. In addition, tropospheric ozone is strongly influenced by transport from the ozone layer above the tropopause. Current research aims to quantify the impact of this transport and the impacts from individual sources such as lightning, aircraft as well as surface emissions from Europe and the other continents. However, such emissions are very localised and the chemical processes acting on those emissions are non-linear. As a result, a crucial aspect in studying the impact of emissions on ozone levels in the current and future atmospheres is the issue of the importance of spatial scales from local, to regional, to continental and global. The new TOMCAT model will, for the first time, allow integrations at high horizontal and vertical resolution to be carried out. The new model offers the opportunity for a major advance in our understanding of the complex scientific problem, a problem of direct relevance to society.

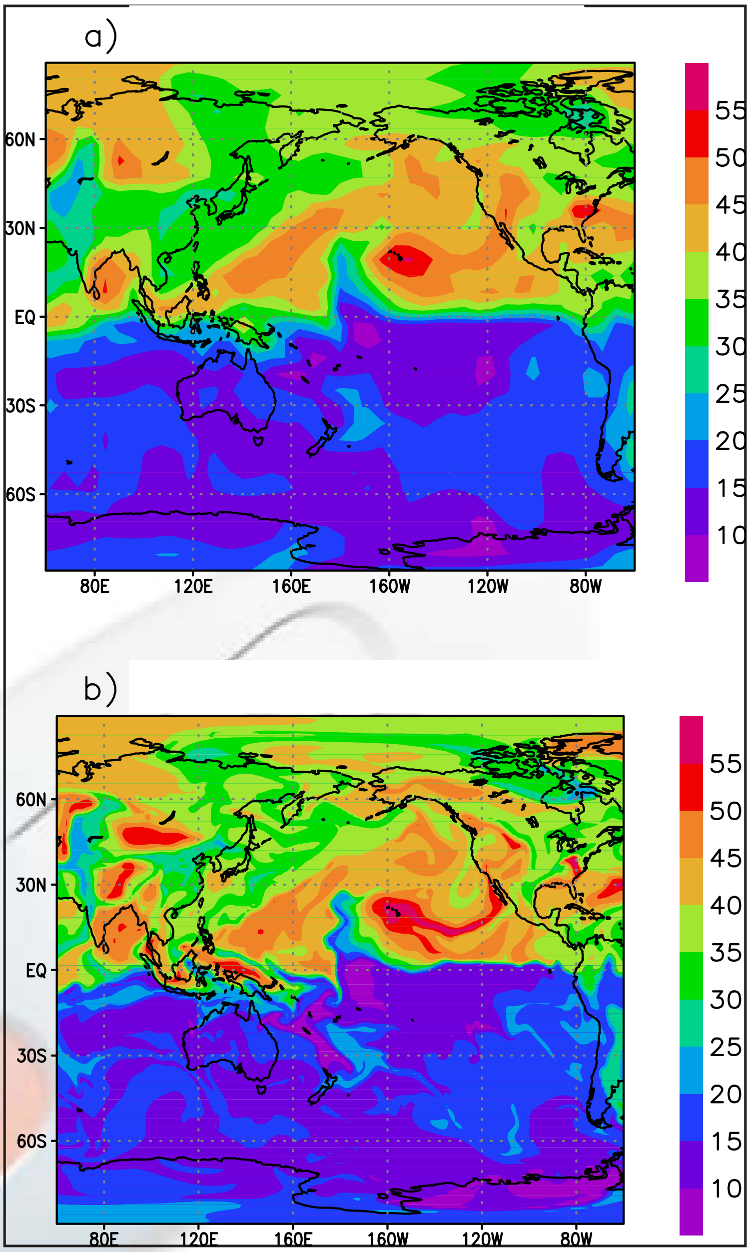

Figure 2: Modelled ozone concentrations at the surface for the Pacific region from TOMCAT a) on the 3x3 degree model grid and b) on the 1x1 degree model grid. Of particular interest is the ability of TOMCAT at high horizontal resolution to maintain features of small spatial scales and to conserve very sharp gradients e.g. near the equator.

Acknowledgements

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