Geophysical Research Abstracts,
Vol. 10, EGU2008-A-00706, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-00706
EGU General Assembly 2008

Interactions between natural hydrocarbon emissions, ozone and climate: towards a fully coupled dynamic earth system model

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The interactions between vegetation, climate, and trace gas concentrations in the troposphere are numerous and complex. Increasing levels of carbon dioxide mean that plant growth may be stimulated, as many are limited by carbon dioxide levels. However, the corresponding increase in temperatures mean that conditions may get too hot for some species, and soil moisture levels may fall, both of which act to reduce growth. Vegetation is known to emit a wide range of biogenic volatile organic compounds (BVOCs), of which the most important are isoprene and monoterpenes. These BVOCs are highly reactive, and play an important role in controlling the surface concentrations of ozone. Their emissions may increase in the future, owing to the warmer temperatures [1]. They are also an important source of aerosols, which in turn control cloud properties and the radiation budget at the surface. Increasing carbon dioxide levels act to reduce the size of stomata on the surface of leaves, which reduces the uptake of toxic gases such as ozone by vegetation. Ozone is know to damage vegetation [2], and rising ozone levels may reach dangerous levels in the future, reducing yields from crops, and the quality of the crop.

In order to understand how the different process listed above interact, the process-based isoprene emission scheme of Arneth et al. [3] will be implemented into the JULES land surface model, which forms part of the Met Office's Earth System model HadGEM2-ES. The ozone damage formulae of Sitch et al. [2] will also be included. The HadGEM2-ES model also contains a global chemistry module, and a comprehensive aerosol module. The interactions between vegetation, rising carbon dioxide levels, and ozone levels will be studied using this fully dynamic earth system model, allowing the key feedbacks between vegetation, atmospheric chemistry and climate to be identified and quantified.

As a first step, we have made offline simulations of isoprene emissions in order to test the sensitivity of the algorithm to uncertainties in e.g. the impact of seasonality, vegetation productivity, emission rates for given plant functional types. The results of these simulations and their implication for the coupled modelling will be discussed.

References

[1] M.G. Sanderson et al., 2003, Geophys. Res. Lett., 30, 1936

[2] S. Sitch et al., 2007, Nature., 448, 791-794

[3] A. Arneth et al., 2007, Atmos. Chem. Phys., 7, 31-53.