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URBAN AREAS IN CLIMATE SIMULATIONS

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1. INTRODUCTION

Urbanisation can significantly modify the physical properties of the landscape, and this is known to exert important influences on local meteorology. However, the potential interactions between urban meteorology and greenhouse gas-induced climate change have so far received little attention. Urban and non-urban areas are likely to exhibit different sensitivities to greenhouse forcing, but this is generally not accounted for in climate change impacts studies. Increased urbanisation may itself provide an additional climate forcing, but the influence of this on past and future climate change outside the urban areas themselves has not yet been examined.

2. NUMERICAL MODEL

A new parametrization of urban areas (Best 1998) has been implemented in the Hadley Centre General Circulation Model (GCM), to allow investigation of urban land surface processes in simulations of climate change and its impacts. The scheme is embedded within the MOSES2 land surface scheme (Essery *et. al.* 2001), which calculates separate energy balances for individual land surface types within each GCM gridsquare. It is therefore possible to diagnose the temperatures of urban and non-urban land separately. As an initial sensitivity study, climate simulations were performed with (i) current urban areas and (ii) with all urban areas replaced by non-urban land. The differences between the climates simulated with and without urban areas will be discussed.

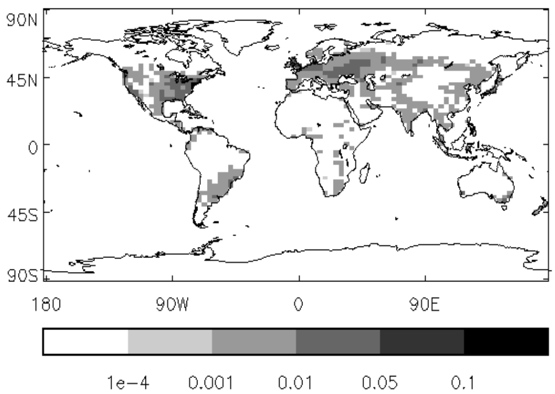

Figure 1: Fraction of gridbox containing urban areas.

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There are only small fractions of urban areas within any gridbox at the resolution of the climate model (2.5^o x 3.75^o). Figure 1 shows the fractions used in the climate integration. The gridbox containing New York, U.S.A., has the highest urban fraction of 12.5% with the gridbox containing London, U.K., having the second highest urban fraction at 8.7%. The relatively small fraction of urban making up each gridbox means that the influence of urban areas on the evolution of the atmosphere is likely to be smaller than in reality. This means that any signal from the climate simulations is likely to underestimate the true signal.

3. RESULTS

To assess the impact of urban areas on the climate, 20-year model integrations were made with both current-day atmospheric CO_2 levels and with double current-day levels. For the climate simulations without urban areas, the surface energy balance of the urban landuse was still calculated, but did not feed back into the atmosphere. This means that we can look at the impact on urban areas from of a climate simulation which does not have an urban influence.

The urban heat island from the climate simulations is calculated by taking the temperature difference between the urban landuse and the grass landuse. Figure 2 shows how the distribution of daily minimum heat island, from this definition, changes with doubling the atmospheric CO_2 levels.

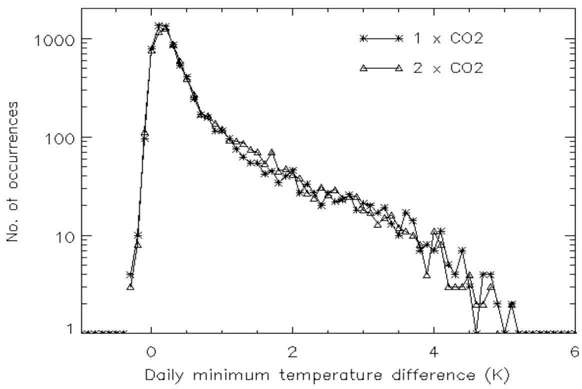

Figure 2: Heat island distribution for London, U.K..

This figure shows that there is a change in the distribution of the heat island between the current-day CO_2 levels and the doubling of the CO_2. With the higher atmospheric CO_2 there are less occurrences of neutral heat islands of between 0^oC and 0.5^oC and more occurrences of heat island between 1°C and 2°C. This implies that taking the current-day heat island distribution and applying it to a climate change simulation would result in an underestimation of the impact within urban areas.

Similar plot results are obtained when comparing the urban heat island from 2 x CO_2 simulations with the urban areas and without the urban areas (but calculating the urban surface energy balance diagnostically). The simulation with the urban areas has less occurrences of the neutral heat island and more occurrences within the range of 1°C and 2°C. This shows that the change in distribution from the current-day CO_2 levels to the doubling of CO_2 results mainly from the interaction between the atmosphere and the urban areas.

Figure 3 shows the distribution of daily maximum and daily minimum temperatures for the gridbox containing London, U.K., for both current-day CO_2 levels and double CO_2 levels. It is clear from this figure that the impact of increased CO_2 levels is to shift the temperature distributions to warmer values. Although the general shape of the distributions are similar there are some differences, for instance the number of occurrences of colder temperatures in the minimum has a more rapid tail off in the current-day CO_2 levels than for the double CO_2 levels.

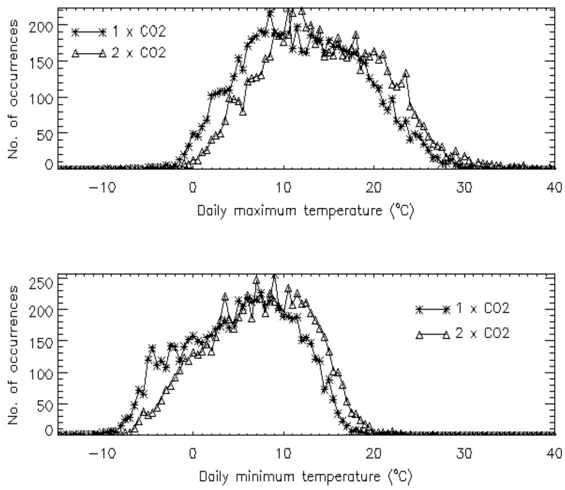

Figure 3: Urban temperature distribution for London.

The number of occurrences of temperatures below 0°C are almost halved with the increase in atmospheric CO_2. This has financial implications for road winter maintenance programs as well as the potential car accident rates. In addition, less frequent frozen conditions could lead to a reduction in the number of hospital admissions due to problems such as hip fractures.

There is also an established link between thermal stress on humans and cardiovascular problems (Martens 1998). The decrease in the number of cold minimum temperatures could lead to a reduction in the cardiovascular mortality rate. However, these reductions may be offset by the increase due to warmer maximum temperatures.

Warmer daily maximum temperatures will also impact on the building industry and city planners. Maximum temperature may reach the point where air conditioning units are required for all buildings. The heat generated by the air conditioning units will be a positive feedback into the atmosphere increasing the climate change signal, and temperatures, within the cities.

4. CONCLUSIONS

Urban areas could have a significant impact on climate change. To study the impact of this climate change on the cities, interactive urban landuse must be included in the simulations so that the correct heat island behaviour can be captured. Using current-day heat island distributions along with climate simulations which have not taken account of the urban landuse, will not be able to take account of the changes to the heat island distribution.

The impacts of climate change on the built environment could have important logistical and financial implications. It could also affect admission rates into hospitals and even mortality rates. All of these impacts need to be studied in detail so that plans can be made and preventative action taken.

The simulations presented in this study are likely to be underestimates of the true impact of climate change on cities, due to the course resolution of climate models and hence the small fractions of urban landuse within the gridboxes. Furthermore, the simulations presented here have neglected anthropogenic heat sources, which are likely to increase the climate change signal still further. This means that additional work is required to understand the full impact of urban areas, with anthropogenic influences, on the likely future climates for the places where the majority of the World's population live.

5. REFERENCES

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