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CLIMATE CHANGE IMPACTS IN EUROPE - THE ROLE OF EXTREME TEMPERATURE EVENTS

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1. INTRODUCTION

The majority of previous climate change impact studies, summarised most recently in the IPCC Third Assessment Report (McCarthy et al. 2001), have based their assumptions about the impacts of future climate on long-term changes in mean meteorological variables. Results suggest a gradual increase in stress being placed upon many of the world's ecosystems and societies leading to, for example, falls in regional agricultural potential, reductions in ecosystem biodiversity and productivity, and a reduction in the level of human comfort and population health. These studies, however, may be understating the problem. The use of long-term means masks the potentially greater threat of an increase in extreme events, which could be far more likely to cause significant disruption to the natural and human environment. This is especially the case if the rate of increase is too rapid to allow for adaptation to take place.

2. RESEARCH PLAN

This new study has two main aims:

a) To evaluate the ability of several state-of-the-art global climate models (GCMs) to replicate current daily temperature extremes, and to understand how the occurrence of these extremes may change in the future under elevated levels of atmospheric greenhouse gases.

b) To couple indices of daily temperature extremes derived from the climate models with impact models in order to explore the potential implications of changes in extreme occurrence for energy demand and supply and human health.

To achieve the first aim, a suite of statistical analyses, including Kolmogorov-Smirnov tests and generalised extreme value (GEV) analyses, have been undertaken. Direct comparisons have been made between model data and several spatially-averaged composite observed series, such as the Central England Temperature (CET) series (Parker et al. 1992). These tests evaluate the performance of the GCMs at the individual gridbox scale across a European window (71.25°N - 33.75°N, 13.125°W - 43.125°E). In addition, analyses have also been conducted comparing daily temperature data from HadCM3 with output from the NCEP/NCAR reanalysis model (Kalnay et al. 1996), both for individual gridboxes and across the entire European window.

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To fulfil the second aim two new impact models are being developed to assess the potential impact of future changes in temperature extremes on energy consumption, with particular reference to domestic energy used for space heating and cooling, and human health in Europe. These models link daily temperature statistics to national-level energy and health data for 18 European countries. At this stage the two models are completely separate but it is hoped that in the future the models can be coupled together to allow adaptive capacity analyses to be undertaken.

3. PRELIMINARY RESULTS

Work so far has focussed on the evaluation of climate model performance. Preliminary results, based on the analysis of HadCM3 (Gordon et al. 1999) data, suggest that temperature extremes from the latest global climate models agree poorly with observations, especially in the European continental interior.

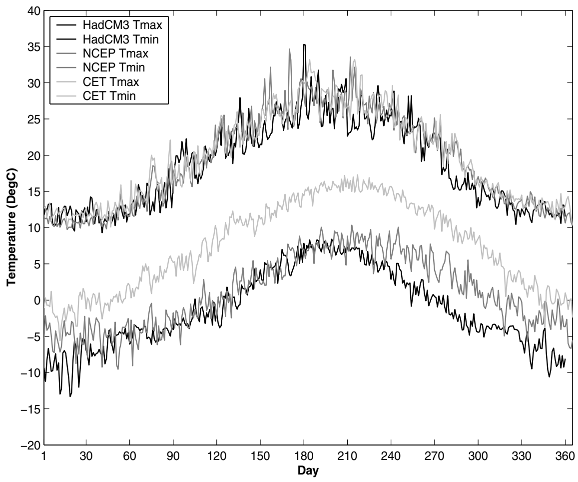

FIG. 1. Comparison of 30-year-high maximum and 30-year-low minimum near-surface daily temperatures over the UK (for the period 1961-90) as simulated by the HadCM3 AOGCM, the NCEP/NCAR reanalysis model and recorded in the Central England Temperature series.

Fig. 1 shows a comparison of highest maximum temperatures (upper three lines) and lowest minimum temperatures (lower three lines) on any one day over a 30-year period (1961-90) for a single HadCM3 gridbox over the UK. The behaviour of the extreme maximum temperatures appears in good agreement across the two models and the observed CET series. However, examination of the minima is less encouraging. The two models, HadCM3 and the reanalysis, are in good agreement for the first 190 days of the year but then diverge rapidly so that by day 240 the HadCM3 lowest minima are more than 5°C colder than forecast by the NCEP/NCAR reanalysis model. This discrepancy, however, is overshadowed when the model outputs are compared to the observed CET data - both models exhibit a significant cold bias of as much as 10°C. This difference is most likely due to parameterisation of cloud cover in the models, so that at night too much energy is allowed to escape from the Earth's surface (Jones 2001, personal communication).

The model behaviour depicted in Fig.1 is to some extent present irrespective of the location and regional climate characteristics. Fig. 2 illustrates similar model behaviour occurring over the Iberian Peninsula. Extreme maximum temperatures are well modelled, except in summer (day 170 - 250). This can be at least partially explained by a shortage of soil moisture leading to elevated near-surface air temperatures. Extreme minimum temperatures are once again too cold in both the GCM and reanalysis models when compared to station records for the region.

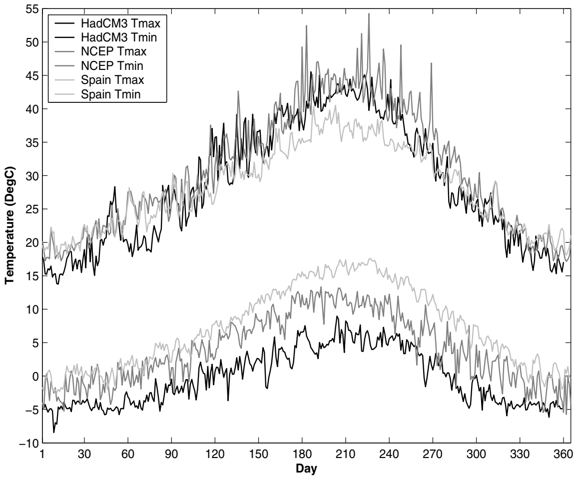

FIG. 2. Comparison of 30-year-high maximum and 30-year-low minimum near-surface daily temperatures over Southern Spain (for the period 1961-90) as simulated by the HadCM3 AOGCM, the NCEP/NCAR reanalysis model and extracted from a composite series constructed from the records of 21 meteorological stations found within one HadCM3 gridbox.

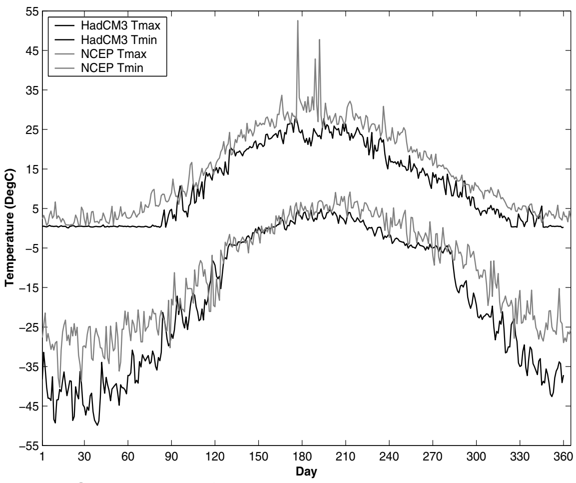

FIG. 3. Comparison of 30-year-high maximum and 30-year-low minimum near-surface daily temperatures over Southern Finland (for the period 1961-90) as simulated by the HadCM3 AOGCM and the NCEP/NCAR reanalysis model.

The largest differences occur in regions of Europe where the climate is less subject to maritime influences. Fig. 3 is a plot of the highest and lowest daily maxima and minima in the period 1961-90, as experienced over southern Finland. It clearly shows maximum and minimum temperatures in the GCM being truncated at ~0°C. Similar behaviour has been noted in other climate models, where it was suggested that this phenomenon might be the result of interpolation of GCM near-surface temperatures between the prognostically-derived ground temperature and the lowest model-layer temperature. The ground temperature will not rise above 0°C in the spring until the snow cover has gone and the soil has thawed. Similarly, temperatures will not fall below 0°C in the autumn until the ground freezes (Palutikof et al. 1997).

4. FUTURE WORK

The second aim of this study is to try to couple daily data from several climate models directly to a suite of simple impact models so that future potential impacts from changes in the behaviour of extremes can be analysed. However, the above analyses show that the use of the HadCM3 GCM data would cause problems in the light of the differences which exist between observed and simulated minimum temperatures and also the presence of a 0°C threshold in temperatures calculated for locations in the European interior. Hence, the next step will be the analysis of the Hadley Centre's latest regional climate model (HadRM3) to establish if the temperature output agrees more closely with screen temperature observations.

Work is also to continue on the impact models. A primary enhancement for the energy consumption model will be the ability to produce sub-national estimates of potential impacts. Meanwhile, the human health model will be modified and recalibrated for specific causes of death rather than the existing, all-cause deaths model.

5. REFERENCES

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