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MAGICC and SCENGEN: Integrated models for estimating regional climate change in response to anthropogenic emissions

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EXTENDED ABSTRACT

MAGICC and SCENGEN are a suite of models that determine the regional details of future climatic change for specified emissions scenarios, together with estimates of their uncertainties. These models follow through and compare the consequences of a "policy" emissions scenario and a "reference" scenario. MAGICC (Model for the Assessment of Greenhouse-gas Induced Climate Change) converts emissions to concentrations, to radiative forcing, to global-mean temperature and sea-level change. SCENGEN uses this temperature change output together with information from General Circulation Models (GCMs) to develop regional scenarios for climate change.

Input emissions data (from an editable "library") are required for CO_2 (fossil and land-use emissions separately), CH_4, CO, NO_x, NMHCs, halocarbons and fossil SO_2. CO_2 concentration changes are calculated using the carbon cycle model of Wigley (1993), which uses CO_2 fertilization to give a contemporary carbon budget consistent with observations. CH_4 concentrations are determined using the variable-lifetime model of Osborn and Wigley (1994). For both CO_2 and CH_4, user, best-guess, low and high projections are given to allow an assessment of uncertainty. N_2O and halocarbon concentrations are computed using simple constant-lifetime mass-balance models. For the halocarbons, input is required only for four key species, CFC11, CFC12, HCFC22 and HFC134a. A scaling method calibrated against a range of more comprehensive analyses is used to account for other halocarbons. The effect of halocarbon-induced stratospheric ozone depletion is included using a modification of the chlorine-loading method of Wigley and Raper (1992). Fossil-based SO_2 emissions are used to determine both the direct and indirect radiative forcing effects of sulfate aerosols, following the method of Wigley and Raper (1992). Tropospheric ozone and carbonaceous aerosol effects are also accounted for, albeit in a relatively simple way. For the gas-cycle and radiative forcing models, all parameters are consistent with the latest (1994 and 1995) recommendations of Working Group 1 of the Intergovernmental Panel on Climate Change (IPCC).

Radiative forcing values are transformed to global-mean temperature changes and oceanic thermal expansion using the upwelling diffusion energy-balance climate model of Wigley and Raper (1992). The temperature change values are used to drive ice-melt models for Greenland, Antarctica, and small glaciers and ice caps in order to obtain total sea level rise. The models currently

used are those of Wigley and Raper (1993), but these are in the process of being updated as a part of the 1995 IPCC exercise. Uncertainty ranges for global-mean temperature and sea level change are also calculated. The temperature and sea level results from MAGICC are being used by IPCC for their 1995 assessment of climate change—in this sense, the models used represent the current state of the art.

MAGICC temperature output is used to drive the SCENGEN climate scenario generator. Regional patterns of climate change, $\underline{\Delta C}(t)$ (the underlining here indicates a two-dimensional pattern), are calculated using $\underline{\Delta C}(t)=\Delta T(t)\underline{\Delta C}^*$ where $\Delta T(t)$ is the global-mean temperature change and $\underline{\Delta C}^*$ is the normalized pattern of climate change. $\underline{\Delta C}(t)$ may be temperature, precipitation, humidity, cloudiness, etc. on monthly, seasonal and annual time scales. $\underline{\Delta C}^*$ (based on more than 10 GCMs) may be either for single models or averages of a number of models. $\underline{\Delta C}^*$ values are obtained by dividing the results from individual GCMs by the corresponding global-mean temperature change values. This scenario generation method allows time-dependent patterns of climate change to be developed from either equilibrium GCM or transient coupled A/OGCM results (or both), under the assumption of a time-invariant "signal" pattern (which can be justified by analysis of coupled A/OGCM results). It also allows results from models with widely different climate sensitivities to be combined.

For the globe, SCENGEN gives output at the 5° latitude by 5° longitude level. For Europe and the USA, output is available at 1° by 1° or better. To obtain the higher resolution, the 5° by 5° data are smoothly interpolated to 1° by 1° and added to high-resolution, high-quality baseline climatologies. Uncertainties are quantified at two levels, either by driving SCENGEN with low, mid or high global temperature changes from MAGICC, and/or by using the 90% confidence bands for $\underline{\Delta C}^*$ obtained from an analysis of inter-model differences. The whole system is embedded in a user-friendly shell, and is designed to run rapidly on a high-level (e.g. 80486-based) microcomputer. A full simulation can be completed in a few minutes.

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