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Coupling a Climate Model and an Integrated Assessment Model using Dimensionally Reduced Emulation: Feedbacks between Climate and Energy Demands

P.B. Holden (1), N.R Edwards (1), P.H. Garthwaite (1), M Labriet (2), A Kanudia (2), R Loulou (2), K Fraedrich (3), F Lunkeit (3), and E Kirk (3)

(1) Open University, Earth and Environmental Sciences, Milton Keynes, United Kingdom (p.b.holden@open.ac.uk), (2) ENERIS Environmental Energy Consultants, Madrid, Spain, (3) Meteorological Institute, University of Hamburg, Germany

Changes in energy demands due to changing heating and cooling (H/C) requirements in a warming world may impact greenhouse gas emissions, generating a feedback loop between the climate and energy systems. Estimating the magnitude of this effect requires an evaluation of the interaction between local temperature, energy and technology options.

To address this problem, we apply the global TIAM-WORLD Integrated Assessment Model [1] and the PLASIM-ENTS climate model [2,3]. In view of the computational demands of PLASIM-ENTS, a direct coupling of the models themselves is not feasible. Instead we build a dimensionally-reduced spatio-temporal emulator of PLASIM-ENTS from a large ensemble of future simulations, building on [4]. The main focus of the presentation will be a description and evaluation of this technique.

The spatio-temporal emulator outputs are used to derive population-weighted seasonal Heating and Cooling Degree Days, aggregated for input to the 16 regions of TIAM-WORLD. TIAM-WORLD computes the consequent impacts on energy system and outputs greenhouse gas concentration profiles which are returned to the climate emulator, completing the feedback loop. The coupled system is iterated until convergence with a targeted constraint on global temperature rise.

Preliminary results show small climate feedbacks induced by the changes in H/C at the global level: the impacts of additional cooling demands in some regions are compensated by the decrease of heating demands at other times or in other regions. However, the impacts of climate change on H/C are significant at the regional level and so are important for the evaluation of energy decisions. Cooling results in electricity consumption while the reduction of heating requirements is found to have greater impacts on bioenergy, coal and gas than on electricity consumption. These dynamics lead to an increased electricity price, mainly in summer.

Future work will examine the feedbacks between precipitation and hydroelectricity and between temperature and the thermal efficiency of the fossil and nuclear power, using a similar framework based on the spatio-yemporal emulator of PLASIM-ENTS.

[1] www.kanors.com or Loulou, R. and Labriet, M., 2008. ETSAP-TIAM: the TIMES integrated assessment model. Part I: Model Structure. Computational Management Science, Special issue "Managing Energy and the Environment", Vol. 5, Issue 1, pp.7-40. [2] Fraedrich K et al, 2005, “The Planet Simulator: Towards a user friendly model”, Meteorologische Zeitschrift, 14, 299-304 [3] Williamson MS et al, 2006, “An efficient numerical terrestrial scheme (ENTS) for Earth system modelling”, Ecological Modelling, 198, 362-374 [4] Holden PB and Edwards NR, 2010, “Dimensionally reduced emulation of an AOGCM for application to integrated assessment modelling”, Geophysical Research Letters, L21707 doi:10.1029/2010