

Eighth International Conference on Flood Management (ICFM8):

“Lowering Risk by Increasing Resilience”

The University of Iowa, Iowa City, Iowa, USA

August 9 – 11, 2021



THE IMPORTANCE OF SOCIAL-ECONOMIC-CLIMATIC FEEDBACKS FOR WATER RESOURCES MANAGEMENT

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ABSTRACT: The standard climate change modelling approach focuses on the climate system and neglects important feedback-effects from socio-economic systems. This failure to represent the whole system is problematic, since natural and socio-economic systems exhibit complex, nonlinear behaviour, and each certainly affects the other. Simple models offer an alternative approach, based on explicit modelling of the feedbacks within and between components of the social-economic-climatic system. The system dynamics simulation methodology used here facilitates representation of feedback processes, time delays, and nonlinearities, and encourages an understanding of the interconnections within a system that fundamentally determine its behaviour. As a working example of the system dynamics approach, our paper describes a simple climate-carbon cycle-water cycle-population-land use closed-loop model. Three experiments compare a “business-as-usual” case with model modifications, including exogenous technology change, and endogenous equation and parameter changes. Analysis of the experimental results demonstrates model sensitivities and shortcomings: exponential growth patterns may indicate the necessity for additional model sectors and feedbacks, and sensitive relationships suggest the need for further study. Future work will improve the representation of water cycle and socio-economic sectors of the model.

Key Words: feedback, climate change, system dynamics, simulation

1. INTRODUCTION

Increasing awareness that the global climate has changed demonstrably since pre-industrial times, and that human activity is at least partially responsible, has led to an international dialogue that aims to clarify the science behind climate change and its effects, and to provide policy-relevant information for governments (IPCC, 2001a). *Climate change modelling* plays an essential role in these efforts by encouraging researchers to 1) test and improve their understanding of processes that operate within individual system components (Hartmann, 1999); 2) identify and include the feedbacks, both within and between components, that influence systemic behaviour; and 3) predict future changes in both physical and socio-economic systems at regional to global scales. Since better understanding encourages better decision-making, modelling can also help policy-makers to enact effective policies and programs to address and to adapt to climate change.

Climate change modelling typically involves the use of *climate models* with *driving scenarios*, such as the SRES scenarios used by the IPCC (IPCC, 2000). These climate models come in at least three different forms: *General Circulation Models* (GCM), *Earth-System Models of Intermediate Complexity* (EMIC), and *simple models* (Harvey *et al.*, 1997). Increasingly, models of the global carbon cycle are combined with climate models for climate change modelling purposes, and, like climate models, these carbon cycle models range in scale from regional to global. Dynamic Global Vegetation Models, or DGVMs, have the highest resolution at a grid size of 0.5° x 0.5°, and are often designed for incorporation into complex climate models (Cramer *et al.*, 2001).....

2. OUR APPROACH

This section describes the general *GCM-driving scenario* approach to modelling the social-economic-climatic system and explains its limitations. It then provides another option, using the system dynamics methodology, that focuses on the full system.

2.1 The problem

In the real world, natural and socio-economic systems do not exist in isolation from one another. After all, it is the interaction between *anthropogenic* greenhouse gas (GHG) emissions and *natural* feedbacks that drives climate change (Stott *et al.*, 2000) and that will likely result in a global temperature increase of roughly 1.5°C to 4.5°C (IPCC, 2001a). However, despite the importance of socio-economic feedbacks with the climate, the conventional *GCM-driving scenario* modelling approach requires the application of projected trends (or scenarios), outputs from another model, or reanalysis data as input to either a climate model or to a coupled climate-carbon cycle model. Data from the driving scenarios then influences the behaviour of the climate model over time, forcing it to adapt to higher levels of carbon dioxide (CO₂) in the atmosphere, for example. It therefore includes socio-economic influences on the climate system as a set of *external drivers*.

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- Bullet 2.

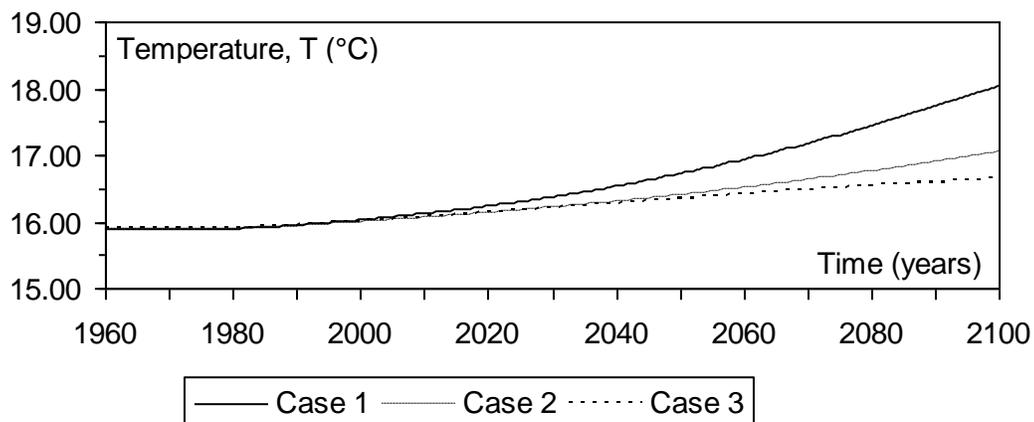


Figure 1: Effect of Emission Controls on Surface Temperature

2.2 Feedback between Model Sectors

Because this paper focuses on the importance of feedbacks, or *causal connections*, between the five model sectors, we describe the connections between model parts in **Error! Reference source not found.**, rather than listing all the equations in each individual sector.

The link between the carbon cycle and the global climate takes this form:

$$[1] F_r = 0.006079 \times C_a - 4$$

where F_r [$W\ m^{-2}$] is the net radiative forcing that results from increasing atmospheric CO_2 concentrations, and C_a [Gt C] is the current atmospheric CO_2 concentration. The constants are the slope of the *linear* relation between current atmospheric CO_2 concentrations and pre-industrial levels, and the assumed forcing of $4\ W\ m^{-2}$ for a doubling of CO_2 concentrations. Although the equation is simple, the net forcing values used are consistent with IPCC (2001a), and changes to the form of the relationship – to a logarithmically-slowing increase in forcing beyond a $4\ W\ m^{-2}$ level for CO_2 -doubling, for example – can be made easily.....

3. REFERENCES

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