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Management flight simulators to support climate negotiations☆

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ABSTRACT

Under the United Nations Framework Convention on Climate Change (UNFCCC) the nations of the world have pledged to limit warming to no more than 2 °C above preindustrial levels. However, negotiators and policymakers lack the capability to assess the impact of greenhouse gas (GHG) emissions reduction proposals offered by the parties on warming and the climate. The climate is a complex dynamical system driven by multiple feedback processes, accumulations, time delays and nonlinearities, but research shows poor understanding of these processes is widespread, even among highly educated people with strong technical backgrounds. Existing climate models are opaque to policymakers and too slow to be effective either in the fast-paced context of policy making or as learning environments to help improve people's understanding of climate dynamics. Here we describe C-ROADS (Climate Rapid Overview And Decision Support), a transparent, intuitive policy simulation model that provides policymakers, negotiators, educators, businesses, the media, and the public with the ability to explore, for themselves, the likely consequences of GHG emissions policies. The model runs on an ordinary laptop in seconds, offers an intuitive interface and has been carefully grounded in the best available science. We describe the need for such tools, the structure of the model, and calibration to climate data and state of the art general circulation models. We also describe how C-ROADS is being used by officials and policymakers in key UNFCCC parties, including the United States, China and the United Nations.

Software availability

Name of software: C-ROADS
Developers: Climate Interactive, MIT Sloan School of Management, Ventana Systems
First available year: 2009
Software requirements: Runs under Windows® XP, 2003, Vista, 7; requires Excel
Program language: Stand-alone application; developed in Vensim, Sable
Availability and cost: Free from climateinteractive.org
Primary contact: Stephanie McCauley
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1. Introduction

In 1992 the nations of the world created the United Nations Framework Convention on Climate Change (UNFCCC), committing themselves to limiting greenhouse gas (GHG) emissions to prevent "dangerous anthropogenic interference in the climate system,"[1] which is generally accepted to mean limiting the increase in mean global surface temperature to no more than 1.5–2 °C above preindustrial levels.[2] In 2007 the Intergovernmental Panel on Climate Change (IPCC) concluded, in its Fourth Assessment Report (AR4), that "Warming of the climate system is unequivocal" and "Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG concentrations" (IPCC, 2007; AR4

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[1] unfccc.int/essential_background/convention/background/items/1349.php.
[2] The 2 °C target was articulated in the Bali Declaration (www.climate.unsw.edu.au/news/2007/Bali.html). More recent statements by the UNFCCC Secretariat argue for no more than 1.5 °C (unfccc.int/files/press/press_releases_advisories/application/pdf/pr20110606sbs.pdf).

Summary for Policymakers, pp. 2, 5; emphasis in the original). Yet even as the scientific consensus has grown stronger, the prospects for action grow dimmer. The UNFCCC has, thus far, failed to produce an agreement sufficient to meet the 2 °C goal (UNEP, 2010, 2011) and, under the 2009 Copenhagen Accord, reaffirmed at the 2011 Durban meeting, now seeks voluntary pledges from individual nations rather than a binding international treaty. However, the prospects for passage of policies to reduce emissions in key nations, including the United States, are poor.

To fulfill their mission negotiators and policymakers must be able to understand the dynamics of the climate and the relationship between emissions proposals and expected warming and other impacts. Historically, policymakers have had to rely on the results of the complex climate simulation models such as those used by the IPCC. Such models are essential in developing reliable scientific knowledge of climate change and its impacts, and are used to quantify the impact of and uncertainties in different scenarios for global GHG emissions (IPCC, 2007; Edwards, 2010). These models include advanced atmosphere-ocean general circulation models (AOGCMs) that include feedbacks among the biosphere, atmosphere and oceans.

However, although these models capture the best available scientific understanding of the climate, they are opaque and expensive. The cycle time for creating and running scenarios is too long to be useful in the fast-paced environment of the UNFCCC negotiation process, government and executive briefings, and even for some purposes of the scientific community such as uncertainty analysis (IPCC, 2007; WG1 Ch. 8-8). Consequently, the IPCC and others use Earth-system Models of Intermediate Complexity (EMICs) and Simple Climate Models (SCMs) as complements to the state-of-the-art AOGCMs. However, while EMICs and SCMs run quickly relative to the AOGCMs, they too are opaque and many still run far too slowly to be useful in the negotiation process. Most importantly, existing models are generally neither available to nor usable by key constituencies including policymakers and negotiators, members of the media, educators, businesses, civil society and the general public.

Consequently, negotiators and other parties are forced to rely on their intuition to assess the likely impacts of proposals. However, intuition, even among experts, is highly unreliable when applied to understanding how proposals for emissions reductions affect likely future atmospheric GHG concentrations, temperatures, sea level, and other climate impacts.

First, the proposals offered by different nations in climate negotiations make different assumptions about future population and economic growth and are framed in incompatible terms, for example, changes in emissions relative to a base year or relative to a business-as-usual scenario; changes in emissions or in the emissions intensity of the economy or in emissions per capita. At a 2009 UNFCCC meeting in Bonn,

> "…delegates complained that their heads were spinning as they were trying to understand the science and assumptions underlying the increasing number of proposals tabled for Annex I countries' emission reduction ranges. "They all seem to use different base years and assumptions: how can we make any sense of them?" commented one negotiator." (Earth Negotiations Bulletin, 9 April 2009, http://www.iisd.ca/vol12/enb12403e.html.

Second, decision makers should consider the impact of uncertainty, requiring multiple simulations of climate models under different assumptions, while decades of research show widespread errors and biases in people's intuitive ability to assess uncertainty (e.g., Kahneman et al., 1982; Kahneman and Tversky, 2000; Gilovic et al., 2002).

Third, and perhaps most important, our mental models lead to pervasive, systematic and consequential errors in our assessments of likely climate dynamics (Sterman, 2008, 2011; Sterman and Booth Sweeney, 2002, 2007; Moxnes and Saysel, 2009). These errors are caused neither by poor training in science nor by the complexity of the climate: even highly educated people with significant training in Science, Technology, Engineering or Mathematics (STEM) consistently err in understanding much simpler and more familiar systems such as bathtubs, bank accounts and compound interest (Booth Sweeney and Sterman, 2000, 2007; Cronin et al., 2009; Brunstein et al., 2010). The research documents widespread, robust difficulties in understanding processes of accumulation (stocks and flows), feedback, time delays and nonlinearities (Sterman, 1994), all of which are important in understanding the dynamics of the climate-economy system. Common errors include violations of mass balance, use of correlational reasoning, use of open-loop mental models that omit basic feedbacks, and linear projections of exponential processes. Because these errors are not the consequence of unfamiliarity with climate science they cannot be corrected simply by presenting people with more information on climate change, nor with graphs and tables showing the results of models. Interactive learning, through which people can use simulation models as "management flight simulators" to discover, for themselves, how complex systems behave is required to improve people's mental models (Corell et al., 2009; Sterman, 2000, 2011; Morecroft and Sterman, 1994).

Poor understanding of the relationship between GHG emissions and their likely climate impacts not only afflicts the public, but the negotiators themselves. In 2008, Christiana Figueres, then lead negotiator for Costa Rica, and named executive secretary of the UNFCCC in 2010, commented

> "Currently, in the UNFCCC negotiation process, the concrete environmental consequences of the various positions are not clear to all of us…. There is a dangerous void of understanding of the short and long term impacts of the espoused… unwillingness to act on behalf of the Parties" (personal communication, Sept. 2008).

The C-ROADS (Climate Rapid Overview And Decision Support) model is designed to address these issues. The purpose of C-ROADS is to build shared understanding of climate dynamics and the risks of climate change, in a way that is solidly grounded in the best available science and rigorously nonpartisan, but that is simultaneously accessible to, understandable by, and useful to policymakers, negotiators, business leaders, educators, and the public at large. Without such a capability, the most technically advanced models and analysis have little impact.

The C-ROADS model provides a capability to assess proposals for emissions abatement at the level of individual nations or regional blocs. The model provides estimates of the likely impacts of these policies consistent with the best available science. The choice of policy is entirely up to the user. Users are free to create any emissions scenarios they wish for their own nation and those of others, based on their assessment of the risks of climate change, the costs of abatement, geopolitical strategy, and equity across nations and generations.

C-ROADS has several attributes that make it useful for a scientifically objective and commonly shared climate policy design and assessment platform. C-ROADS:

- Is based on the best available peer-reviewed science and calibrated to state-of-the-art large scale climate models;
- Tracks the Kyoto greenhouse gases, including CO_2, CH_4, N_2O, SF_6, halocarbons, aerosols and black carbon;
- Distinguishes emissions from fossil fuels from deforestation/afforestation (REDD+) impacts;