Linking Models of Human Behavior and Climate Alters Projected Climate Change

Brian Beckage[1], Louis J. Gross[2], Katherine Lacasse[3], Eric Carr[2], Sara S. Metcalf[4], Jonathan M. Winter[5], Peter D. Howe[6], Nina Fefferman[2], Travis Franck[7], Asim Zia[1], Ann Kinzig[8], and Forrest M. Hoffman[9]

[1]Univesity of Vermont Burlington, [2]University of Tennessee Knoxville, [3]Rhode Island College, [4]State University of New York Buffalo, [5]Dartmouth College, [6]Utah State University, [7]Climate Interactive, [8]Arizona State University, and [9]Oak Ridge National Laboratory

June 20, 2018

OAK RIDGE National Laboratory

SESYNC National Socio-Environmental Synthesis Center

NIMBioS National Institute for Mathematical and Biological Synthesis

SESYNC/NIMBioS Working Group

Integrating Human Risk Perception of Global Climate Change into Dynamic Earth System Models

Brian Beckage, Eric Carr, Nina Fefferman, Louis Gross, Travis Franck, Forrest Hoffman, Peter Howe, Ann Kinzig, Katherine Lacasse, Sara Metcalf, Jonathan Winter, Asim Zia

Meeting at SESYNC (May 2018)

Human Risk Perception and Climate Change

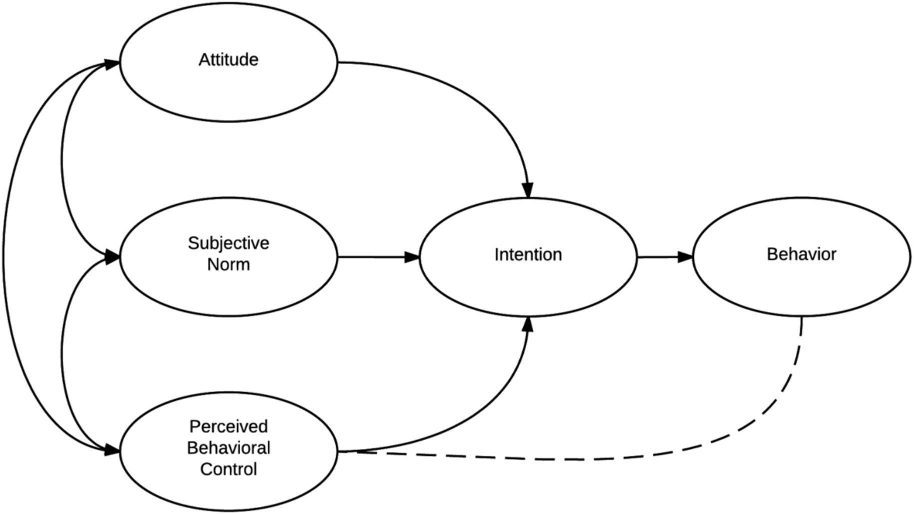
- Human activities are interconnected with Earth systems and projections of future climate.
- Our objective is to consider how human risk perception and behaviors it induces might impact and interact with climate change.
- In particular, our study addresses whether the potential feedbacks from human systems are sufficient to significantly, by some appropriate metric, push the Earth system response to a different state.
  - That is, are there circumstances in which risk perception shifts, perhaps in response to changes in extreme events, in a manner that causes behavioral changes and policy responses that could measurably impact future climate?
- Earth system models (ESMs) do not account for feedbacks from human social system changes, and integrated assessment models (IAMs) assume a fixed scenario/trajectory for human activities. **These models do not capture social system dynamics.**

Theory of Planned Behavior

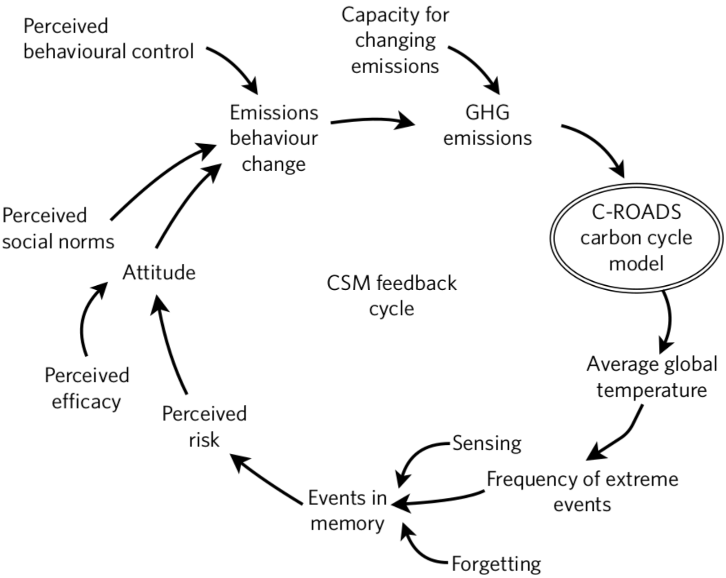
The Theory of Planned Behavior considers how attitudes, perceived social norms (PSN), and perceived behavioral control (PBC) interact to influence human behaviors.

- *Attitudes* are people's positive or negative evaluation of behaviors and policies related to climate change mitigation, comprised of both
  1. *risk perception* of the adverse effects of climate change and
  2. *perceived efficacy*, defined by the extent to which people believe a behavior will influence GHG emissions.
- *Perceived social norm (PSN)* is the perception of how much a behavior is performed or approved of by other people, and influences the likelihood that people will undertake or support particular behaviors.
- *Perceived behavioral control (PBC)* refers to people's perception of how much influence they have on policy makers or on their ability to undertake mitigation behaviors.

Theory of Planned Behavior



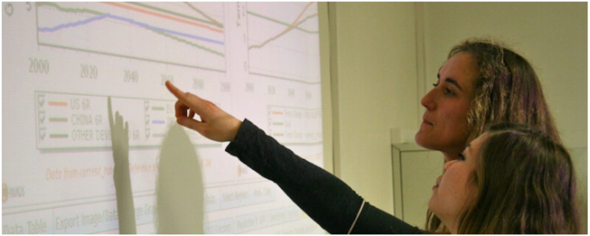
Climate Social Model (CSM)



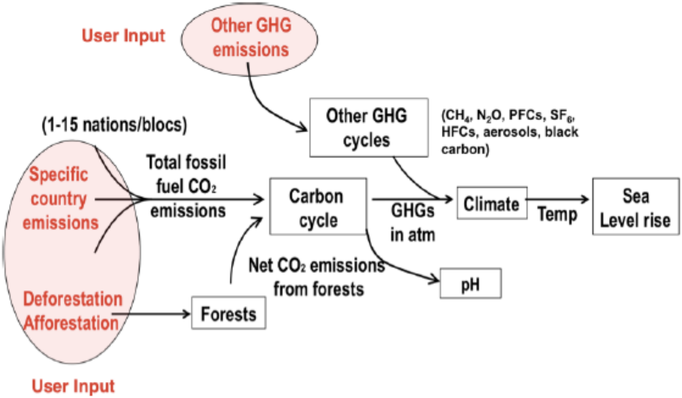
Climate Rapid Overview and Decision Support Simulator

C-ROADS

Climate change policy simulator



C-ROADS Overall Structure



C-ROADS is an IAM that includes a system-dynamics model for each of the components and utilizes outputs from detailed GCMs or ESMs.

Key CSM Assumptions

1. Human behaviors feed back to climate through a modification (increase or decrease) in GHG emissions;
2. Human behavioral responses arise from perceptions of risk established through experiencing and then remembering the progression of extreme events;
3. The annual number of extreme events are characterized from temperature conditions, with the number of extreme events occurring per time step being stochastic, but increasing with mean temperature;
4. Modification of emissions due to behavior feedbacks are maintained in a pool representing cumulative changes that reflect cumulative infrastructural changes that continue to impact future emissions even without additional behavioral responses;
5. There is a minimum level of GHG emissions that no behavioral changes can modify and a maximum change per time step in emissions that can arise from behaviors.

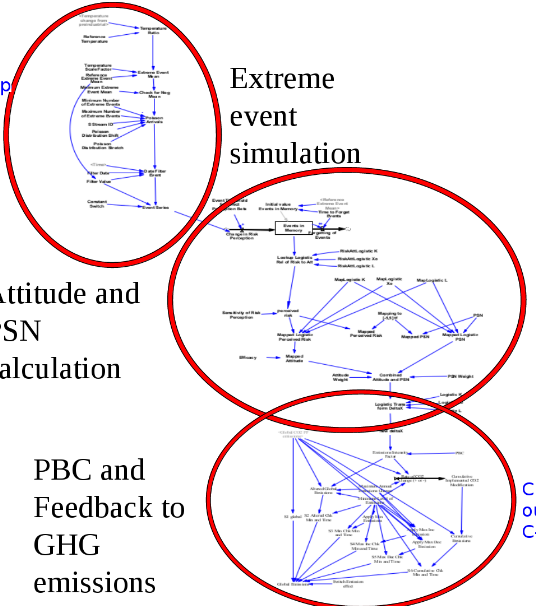
CSM Workflow Structure

Global temp input from C-ROADS

Extreme event simulation

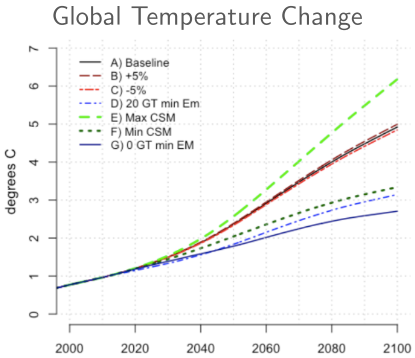
Attitude and PSN calculation

PBC and Feedback to GHG emissions



C emissions output to C-ROADS

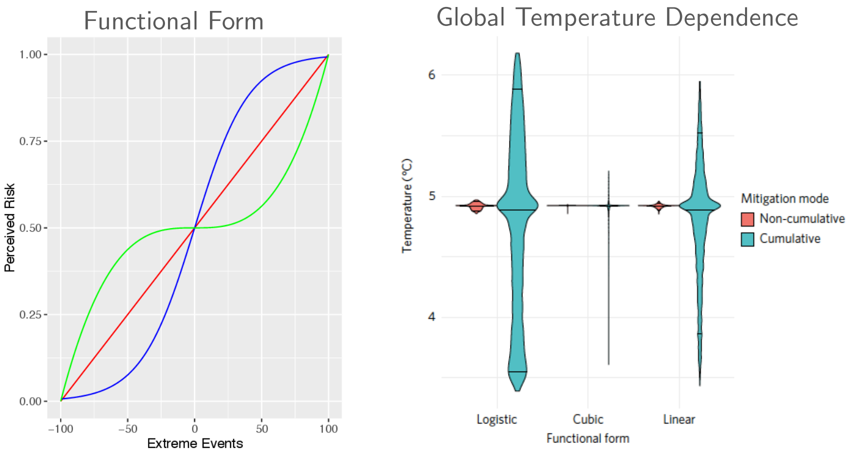
Dynamics of Global Temperature and Carbon Emissions



A) Baseline C-ROADS model, B) 5% increase or C) 5% decrease in annual C emissions (non-cumulative), D) 20 Gt/yr min C emissions, E) max temperature change of CSM with 20 Gt/yr min C emissions, F) min temperature change of CSM with 20 Gt/yr min C emissions, G) case F but with 0 Gt/yr min C emissions. Cases A–D used C-ROADS only; E–F included CSM.

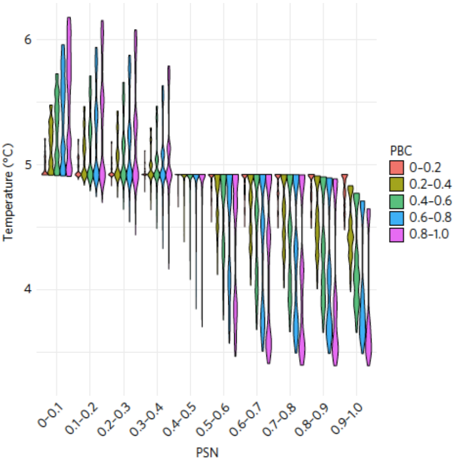
E (max): PBC=1, PSN=0, perceived efficacy=0, TTF=0.5 yr, sensing=1 yr rolling window.
F&G (min): PBC=1, PSN=1, perceived efficacy=1, TTF=120 yr, sensing=30 yr rolling window.

Effect of Modeled Functional Form on Temperature



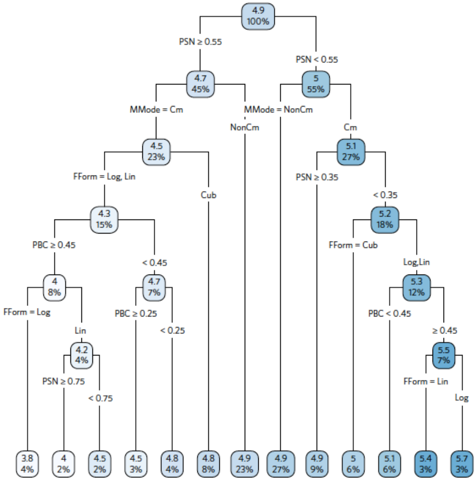
Effect of modeled functional form (**logistic**, **cubic**, and **linear**) on mean global temperature change from pre-industrial in 2100

Effect of Interactions of PSN and PBC on Temperature



Effect of interactions of perceived social norm and perceived behavioral control on temperature change from pre-industrial in 2100 for cumulative mitigation mode

Regression Tree Partitioning of Variation in Temperature



Regression tree partitioning of variation in mean global temperature in 2100 across 766,656 model simulations varying functional form and parameters

CSM–C-ROADS Integration Conclusions (1/2)

- Dynamic interactions between human behavioral and climate system models resulted in a global temperature change ranging from 3.4–6.2°C by 2100 compared with 4.9°C for the C-ROADS model alone.
- Cumulative infrastructural change significantly curbed future climate change. Non-cumulative, short-term behaviors (e.g., adjusting thermostats, limiting mileage driven) had much smaller impacts on the future temperature trajectory compared to longer-term infrastructural change.
- The magnitude of behavioral uncertainty in model results for mean global temperature in 2100 (2.8°C) was of a similar magnitude to physical uncertainty (3.5°C).

CSM–C-ROADS Integration Conclusions (2/2)

- Model components with the largest influence on temperature were the functional form of response to extreme events, interactions of perceived behavioral control with perceived social norms, and behaviors leading to sustained emissions reductions.
- Our results suggest that policies emphasizing the appropriate attribution of extreme events to climate change and infrastructural mitigation may reduce climate change the most.

Future Directions

- Regional version of CSM
- Different population distributions, scenarios (CMIP6?), geoengineering
- Different models of human behavior and social networks

Reference

Beckage, Brian, Louis J. Gross, Katherine Lacasse, Eric Carr, Sara S. Metcalf, Jonathan M. Winter, Peter D. Howe, Nina Fefferman, Travis Franck, Asim Zia, Ann Kinzig, and Forrest M. Hoffman (2018), Linking Models of Human Behaviour and Climate Alters Projected Climate Change, *Nature Clim. Change*, 8(1):79–84, doi:10.1038/s41558-017-0031-7.

Acknowledgments

This work resulted from a working group jointly supported by both the National Institute for Mathematical Biological Synthesis (NIMBioS)—a synthesis center sponsored by the National Science Foundation through award DBI-1300426 with additional support from The University of Tennessee, Knoxville—and the National Socio-Environmental Synthesis Center, sponsored by the National Science Foundation through award DBI-1052875. B.B., J.M.W., and A.Z. additionally acknowledge support from the National Science Foundation through Vermont Established Program to Stimulate Competitive Research grant numbers EPS-1101317 and OIA-1556770. F.M.H. additionally acknowledges support from the Reducing Uncertainties in Biogeochemical Interactions through Synthesis and Computation (RUBISCO) Scientific Focus Area, which is sponsored by the Regional and Global Climate Modeling (RGCM) Program in the Climate and Environmental Sciences Division (CESD) of the Office of Biological and Environmental Research (BER) in the U.S. Department of Energy Office of Science. Oak Ridge National Laboratory (ORNL) is managed by UT-Battelle, LLC, for the U.S. Department of Energy under Contract No. DE-AC05-00OR22725.