

CESM Societal Dimensions Working Group Meeting
26 - 27 February 2014
National Center for Atmospheric Research – Boulder, Colorado
Mesa Lab – Main Seminar Room

Abstracts

WEDNESDAY, 26 February

JOINT LAND MODEL AND SOCIETAL DIMENSIONS WORKING GROUP MEETING

Peter Thornton – The influence of prognostic land use and land cover change representations in CESM simulations over the period 1850-2100

Alan DiVittorio – From land use to land cover: Restoring the afforestation signal in GCAM to CESM land coupling and the implications for CMIP5 RCP simulations

Alan V. Di Vittorio, Louise Parsons Chini, Ben Bond-Lamberty, Jiafu Mao, Xiaoying Shi, John Truesdale, Tony Craig, William D. Collins, Jae Edmonds, George C. Hurtt, Allison Thomson, Peter Thornton, Kate Calvin, Andrew Jones

Climate projections depend on scenarios of fossil fuel emissions and land use change, and the parallel process of IPCC AR5 assumes that the climate scenarios simulated by IAMs match the climate scenarios simulated by ESMs. To facilitate this, CMIP5 used a novel land use harmonization to provide a consistent set of 1500-2100 land use trajectories--generated from historical data and four Integrated Assessment Models--for several Climate and Earth System Models. However, a direct coupling of GCAM to CESM using CMIP5 methods revealed that only 18% of GCAM's RCP4.5 global afforestation signal, and none of the pasture loss, were being seen by CESM from 2005 to 2040. We modified GLM and the CESM land use translator to obtain 66% of GCAM's afforestation by 2040, which allowed CESM to implement losses in shrubland and grassland equivalent to 97% of GCAM's pasture loss over the same period. This additional afforestation increases vegetation carbon gain by 19 PgC and decreases atmospheric CO₂ gain by 8 ppmv from 2005 to 2040. We also show that the CMIP5 CESM afforestation is only 22% of the RCP4.5 afforestation by 2100. As land use change emissions are a significant component of radiative forcing, it is likely that the MiniCAM and CESM RCP4.5 climate scenarios are not the same. To varying degrees, similar inconsistencies exist in other CMIP5 model results because the land use harmonization did not provide specific land cover information, and in the case of RCP4.5 the afforestation might exceed the potentially viable

forest area of the ESMs. We conclude that land cover information is required in addition to land use information to provide reliable land coupling between IAMs and ESMs.

Ruby Leung – Representing human influence in CESM: Global testing of a river routing and water management model coupled to CLM

L. Ruby Leung, Hongyi Li, Nathalie Voisin, Maoyi Huang, and Mohamad Hejazi

Human systems have significantly perturbed the water cycle through water management and water use. As part of the Community Earth System Model (CESM), the Community Land Model (CLM) includes sophisticated representations of biophysics, soil hydrology, and biogeochemistry, but human systems of water are largely ignored. As a step towards modeling the fully integrated water cycle, a water management model has been developed for coupling with CLM and a river routing model. The water management model uses generic operating rules for multi-purpose reservoirs. The river routing model adopts a physically based framework to represent river routing from hillslopes to the main channels and through the channel network. The models have been evaluated over large river basins in the US and coupled one-way with an integrated assessment. With the goal of representing water management in a global earth system model, both the river routing and water management models have been implemented globally at 0.5-degree resolution. This presentation will discuss the global implementation and evaluation of the models and the sources of uncertainties and their impacts on the simulations.

Mark Rounsevell – Towards decision-based global land use models for improved understanding of the Earth system

Mark Rounsevell and Almut Arneth et al.

A primary goal of Earth system modelling is to improve understanding of the interactions and feedbacks between human decision making and biophysical processes. The nexus of land use and land cover change (LULCC) and the climate system is an important example. LULCC contributes to global and regional climate change, while climate affects the functioning of terrestrial ecosystems and LULCC. However, at present, LULCC is poorly represented in Global Circulation Models (GCMs). LULCC models that are explicit about human behaviour and decision making processes have been developed at local to regional scales, but the principles of these approaches have not yet been applied to the global scale level in ways that deal adequately with both direct and indirect feedbacks from the climate system. In this presentation, we explore current knowledge about LULCC modelling and the interactions between LULCC, GCMs and Dynamic Global Vegetation Models (DGVMs). In doing so, we propose new ways forward for improving LULCC representations in Earth System Models. We conclude that LULCC models need to better conceptualise the alternatives for up-scaling from the local to global. This involves

better representation of human agency, including processes such as learning, adaptation and agent evolution, formalising the role and emergence of governance structures, institutional arrangements and policy as endogenous processes and better theorising about the role of teleconnections and connectivity across global networks. Our analysis underlines the importance of observational data in global scale assessments and the need for coordination in synthesising and assimilating available data.

Almut Arneth – The EU project LUC4C: Land-use change: Assessing the net climate forcing, and options for climate change mitigation and adaptation

Almut Arneth (on behalf of the LUC4C consortium)

It is evident that the LUC-climate change interplay poses important challenges for societies and land-use policies that aim to foster efficient climate mitigation and adaptation options and to optimise trade-offs with other sectors or localities. The climate, environmental and socio-economic research communities are challenged to jointly provide the required understanding of the fundamental processes that operate in this complex system, and the many interactions across local, regional, and global scales. New research is required to account for both the direct and indirect effects of LUC on past and future climate change, and additionally the impacts on ecosystem services and socio-economic sectors.

LUC4C is a project funded through the European Commission addressing the land-use change - climate change interactions. Its overarching objective is to advance the fundamental knowledge of the interactions between climate change and land-use change, and in doing so develop a framework for the synthesis of complex earth system science into guidelines that are of practical use for policy and societal stakeholders.

LUC4C brings together natural and socio-economic knowledge of complex systems that is essential in understanding the many facets of the interactions between climate change and land use change. The project is framed by the following research questions:

(1) Where and how do human decisions, such as land-based mitigation policies and societal adaptations in Europe and internationally, affect land-use and land-cover change directly and indirectly? How does the response of the climate system to LUC and land-based mitigation options affect the supply and societal demand of ecosystem services related to food, energy and water?

(2) How does LULCC alter biophysical and biogeochemical land surface properties that affect the climate, and how does this vary between regions and over time? How can we best quantify the performance and uncertainties of LUC modelling in Earth system models, and communicate what these uncertainties mean to relevant stakeholders?

(3) How can understanding of complex Earth system science best be synthesised to aid the design and implementation of land-based mitigation policies, as well as the monitoring, reporting and verification of policy effects?

Jerry Nelson – Critical challenges for integrated modeling of climate change and agriculture: Addressing the lamppost problem

One of the recommendations will be that we need to move our modeling of food security and climate change phenomena into the 21st century. This include crop, hydrology, economic, climate, and integrated assessment modeling. We need to have standard data protocols, open source code, and modularization of model elements so it is possible to do some kind of plug and play and close cooperation with data collection efforts to improve the parameterization of the models, whether it is of radiation use efficiency in plants or demand elasticities for rice in China. I'd like to ask if we could put discussion about this on your working group meeting agenda.

THURSDAY, 27 February

SDWG SCIENCE SESSION I

Chris Anderson – Object-oriented evaluation of downscaled Midwest warm-season rainfall

One of the most robust signals in climate change projections for the Midwest is an increase in spring rainfall. Its implications are wide-reaching having importance, for example, in flood mitigation planning, bridge and reservoir design, wildlife habitat management, and infrastructure for agriculture. However, seasonal rainfall projections are insufficient for use in vulnerability analysis and evaluation for planning. Instead, it is important to evaluate the sequence and frequency of individual heavy rainfall events that collectively create damaging inundation events.

In support of bridge vulnerability analysis for Iowa Department of Transportation, object-oriented evaluation of asynchronous regional regression model and NARCCAP downscaled data has been achieved with the MODE software of the Meteorological Evaluation Toolkit. This initial evaluation demonstrates

- (1) the ability to compare statistics of objects within observed and downscaled data sets, such as the object frequency, trend, sequencing, and contribution to seasonal rainfall,
- (2) the ability to identify in observations the physical processes associated with rainfall objects, and
- (3) the EaSM fields that are needed to develop automated algorithms to objectively link within EaSMs the rainfall objects with EaSM physical processes in order to advance understanding of the efficacy of EaSM rainfall objects.

This evaluation framework, though developed with rainfall, is not limited to rainfall fields. It may be applied to any meteorological field that can be decomposed into an event with clear boundaries in space or time or both.

Mohamad Hejazi – The representation of water systems in GCAM: A perspective of the human dimension in CESM

Mohamad Hejazi, Kate Calvin, Leon Clarke, Jae Edmonds, Maoyi Huang, Sonny Kim, Page Kyle, Ruby Leung, Hongyi Li, Lu Liu, Pralit Patel, Teklu Tesfa, Nathalie Voisin, Marshall Wise

Water systems are well-suited to analysis within an integrated assessment (IA) framework. IA models are designed to examine large-scale interactions between human and Earth systems, and can provide important insights from the linking of human and natural Earth systems. IA models have traditionally focused on energy, agriculture, land use, and climate. Yet, hydrologic systems are central to understanding all other human and natural Earth systems. With rapid shifts expected in socioeconomic human systems in the future, especially in the developing world, as well as the possibility of large-scale but varying impacts of climate change on global and regional hydrological cycles, modeling global water systems within an IA framework can provide rich insights about alternative future global water demand and supply scenarios. In fact, these feedbacks are crucial for characterizing the implications of the human systems and their effects on modeling hydrologic systems. This talk will discuss the current representation of the water system in the global change assessment model (GCAM) and some recent modeling advancements that facilitated the linkage of GCAM to the community Earth system model (CESM) – including the Community Land Model (CLM), the MOdel for Scale Adaptive River Transport (MOSART), and the Water Management (WM) components. The ability to propagate human decisions pertaining to water demand per sector and technology from the GCAM decision framework to CESM at the appropriate temporal and spatial scales marks an important milestone toward improving our understanding of the interactions between human activities, terrestrial system and water cycle. Both, recent results and planned tasks will be discussed.

Bill Collins – The Climate Readiness Institute initiative on adaptation and mitigation in the SF Bay Area

We will present a new initiative we have launched among Berkeley Lab, UC Berkeley, UC Davis, and Stanford focused on adaptation and mitigation in the Bay Area. Climate projections will be a major component of information exchange from the climate scientists in CRI with public utilities, businesses, NGOs, and governments in the region.

Kenichi Wada – The Water-Food-Economy-Climate nexus of ALPS scenario

Kenichi Wada, Keigo Akimoto, Ayami Hayashi, Fuminori Sano and Takashi Homma, RITE

The ALPS (ALternative Pathways toward Sustainable development and climate stabilization) project explores policy implications for mitigation in the context of sustainable

development, assessing the nexus of climate, water, food, land use, energy and economy in a consistent manner. Climate policy is one of the multifaceted sustainable development goals, so mitigation options need to be implemented not only from the climate perspective but also from the well-balanced perspectives among other global challenges with deep understanding of their trade-offs and synergies.

The ALPS scenarios consist of three different axis; 1) socio-economic scenarios, 2) climate change policy scenarios, and 3) emissions scenarios consistent with Representative Concentration Pathways (RCPs). Combination of these scenarios with RITE's integrated assessment framework, including DNE21+ model for energy-related CO₂, land use model, non-energy CO₂ emission scenario, and non-CO₂ GHG assessment model, allows us to perform comprehensive modeling assessment for sustainable development challenges.

Land use model is used to evaluate potentially available land area for energy crop production and afforestation, which is one of the input data of DNE21+ model. The water-stressed population are assessed based on the water demand for agriculture, industry and household and on the annual water availability for river basins based on annual runoff. One of our findings suggest that the size of the water-stressed population is affected by the change of population significantly, and is expected to increase, implying that the water-stressed population is affected more by socio-economic trends such as population and economy than by the level of emissions reduction.

Historically, high economic growth entailed lower population growth. Under the stringent CO₂ emission reduction targets of 2-2.5 degrees Celsius above pre-industrial levels, higher economic growth can lead to cheaper mitigation solution consequently because relatively smaller population, which involves smaller food demand, gives room for afforestation, because higher technological progress is expected and because higher electrification rate makes it easy to reduce CO₂ emissions significantly.

SDWG-RELATED PROJECTS HIGHLIGHT SESSION

James McFarland – An overview of the CIRA Project: Multi-model framework to achieve consistent evaluation of climate change impacts in the United States

The Climate Change Impacts and Risk Analysis (CIRA) project develops a new multi-model framework to systematically assess the physical impacts, economic damages, and risks from climate change in the United States. The primary goal of this framework is to estimate the degree to which climate change impacts and damages in the United States are avoided or reduced under multiple greenhouse gas (GHG) emissions mitigation scenarios. The CIRA exercise is designed to quantify the changes in risk and explore key uncertainties. It uses two integrated assessment models and 15 sectoral models encompassing six broad impacts sectors: water resources, electric power, infrastructure, human health, ecosystems, and forests. Three consistent socioeconomic and climate scenarios are used to analyze the benefits of global GHG

mitigation targets: a reference scenario and two policy scenarios with total radiative forcing targets in 2100 of 4.5 W/m² and 3.7 W/m². A range of climate sensitivities, climate model outputs, natural variability measures, and model structures are examined to explore the implications of key uncertainties. This presentation describes the motivations, goals, design, and academic contribution of the CIRA modeling exercise and briefly summarizes key results. The results across impact sectors show that: GHG mitigation provides benefits to the United States that increase over time, adaptation can reduce net damages, and impacts exhibit spatial and temporal patterns that are informative to mitigation and adaptation policy formation.

Eric Gilleland – Advanced climate and regional model validation for societal applications

Earth System Models (EaSM) comprehensively encapsulate the complex interactions between physical, geo-chemical and biological subsystems, but their standard products are not directly useful for most planning and decision-making processes that are confronted with the need to account for climate change. One important necessity for more useful information includes an evaluation of EaSM performance. Such evaluations inherently need to address specific concerns depending on the system of interest so that evaluation tools must be tailored to inform about these specific issues. Generally, the spatial and temporal scales necessary for most such users are relatively fine, requiring more sophisticated tools than those often used currently, such as comparisons of zonal or other large spatial and temporal domain averages. Tools from weather forecast verification, which typically occur at much finer scales, should be very useful. Here, we employ some of these methods to climate model evaluation with the further aim of considering the specific needs of water management systems.

Brian O’Neill – Project on Benefits of Reduced Anthropogenic Climate change (BRACE)

The Climate & Global Dynamics division (CGD) at NCAR has established a new cross-cutting program called the Climate and Human Systems Project (<http://chsp.ucar.edu/>). One of the first activities of this project is to carry out a coordinated investigation of avoided impacts. Avoided impacts refers to the reduction in climate change impacts that would occur as a consequence of limiting climate change through mitigation or geoengineering. This activity on the Benefits of Reduced Anthropogenic Climate change (BRACE) will focus on differences in impacts resulting from climate change driven by the RCP-8.5 forcing scenario versus the RCP-4.5 scenario. It will involve more than a dozen individual analyses addressing differences in physical climate outcomes between these two RCPs, statistical methods for measuring such differences, and consequent differences for societal impacts. The study will draw on CMIP5 simulations for both RCPs, a large ensemble of RCP8.5 simulations being carried out with CESM, and a “medium ensemble” to be produced with CESM for RCP4.5.

Kate Calvin – Climate change impacts in Latin America: A multi-model analysis

The Latin American Modeling Project aims to better articulate the role of Latin America in addressing climate change and to better understand the implications of climate change for Latin America. This exercise brings together global with regional modelers and experts with Latin American-specific knowledge, understanding, data, and analysis. This project builds on the experience gained in the Asia Modeling Exercise. However, we have shifted the region of focus and expanded the analysis to include an assessment of impacts in addition to mitigation.

Latin America is heavily dependent on hydropower and a large producer of agricultural products today, and in most future projections. As such, the region is particularly vulnerable to changes in climate, particularly changes in temperature and precipitation. In the LAMP project, we have begun to quantify the effect of climate change, focusing on agriculture, hydropower, and building energy demand.

Crop yields are expected to increase as a result of CO₂ fertilization, and could either increase or decrease with changes in temperature and precipitation. The precise change in yield varies across crop, region, emissions scenario, climate model, and crop model. Our preliminary assessment of climate change impacts on agriculture in Latin America focuses on a single emissions scenario (RCP8.5), climate model (Hadley Center), and crop model (EPIC). Using this scenario, we assess the effect of climate change on agricultural production, agricultural trade, land cover, and agricultural prices in Latin America across several agricultural economic and integrated assessment models.

Changes in climate, particularly changes in precipitation, have implications for runoff and streamflow in the future. These factors, in turn, affect the hydropower potential in the future. The precise change in precipitation, and thus, hydropower potential, varies significantly across emissions scenario and climate model. Like our assessment of agriculture, we begin by focusing on a single emissions scenario and climate model. Using this scenario, we assess the effect of climate change on hydropower potential, including looking at changes in electricity production from other fuel sources, energy demand, energy prices, and energy-related emissions across several energy-economic and integrated assessment models.

Increases in future temperature will have an effect on the demand for energy in buildings, particularly for space heating and space cooling. Like our assessment of agriculture, we begin by focusing on a single emissions scenario and climate model. Using this scenario, we assess the effect of climate change on the demand for heating and cooling, including the resulting changes in energy supply, energy prices, and energy-related emissions across several energy economic and integrated assessment models.

We conclude with a discussion of future directions, including efforts to address uncertainty, improve our methodology, and expand to other sectors.

SDWG SCIENCE SESSION II

Chas Fant, Adam Schlosser – IGSM-CLM-WRS framework to undertake a large-ensemble scenario exercise to study Southeast Asia

We have used the IGSM-CLM-WRS framework to undertake a large-ensemble scenario exercise to study Southeast Asia - and the impacts of combined socio-economic pathways with regional climate outcomes on managed water stress. We have just completed 500+ member simulation looking at unconstrained growth/emissions and will also explore a stabilization scenario. We have been able to assess the combined and individual influence between the socio-economic and climate changes on risks to managed water-stress.

Martyn Clark – ACE / BOR hydrology project

Erwan Monier – Greenhouse gas emissions and climate impacts of a large-scale biofuels expansion

A global biofuels program will potentially lead to intense pressures on land supply and cause widespread transformations in land use. These transformations can alter the Earth climate system by increasing greenhouse gas (GHG) emissions from land-use changes and by changing the reflective and energy exchange characteristics of land ecosystems. Using an integrated assessment model that links an economic model with climate, terrestrial biogeochemistry, and biogeophysics models, we examine direct and indirect effects of possible land-use changes from an expanded global cellulosic bioenergy program on greenhouse gas emissions over the 21st century, along with the biogeochemical and biogeophysical impacts on surface temperatures over the first half of the 21st century. Our integrated assessment model shows that land clearing, especially forest clearing, has two concurrent effects— increased GHG emissions, resulting in surface air warming; and large changes in the land’s reflective and energy exchange characteristics, resulting in surface air warming in the tropics but cooling in temperate and polar regions. Overall, these biogeochemical and biogeophysical effects will only have a small impact on global mean surface temperature. However, the model projects regional patterns of enhanced surface air warming in the Amazon Basin and the eastern part of the Congo Basin. Therefore, global land use strategies that protect tropical forests could dramatically reduce air warming projected in these regions.

Caspar Ammann – Enhancing use of CESM output through an efficient downscaling capability with feedback to model development

Many societal applications require climate model output that is both different in nature (e.g. specific climate characteristics, indices) as well as higher in spatial/temporal resolution (~10km

or higher in space, and daily if not sub-daily in time) than standard CESM output. Although there are known limitations with any approach to generate high-resolution transformation of GCM output, it might be necessary for the SDWG to consider a toolbox of downscaling methods that are well known and efficient enough to immediately get applied against selected new CESM simulations -- not only production runs, but potentially including development. Additionally, a flexible way might also allow members of the group to apply this toolset by themselves for their own purposes, given that the necessary information is stored. The purpose would be (a) to make CESM data more immediately useful for the users in the SDWG, and (b) to provide the baseline for diagnostics/evaluations/validations for the modelers to monitor performance of the simulations through the metrics of applications. This "presentation" is to launch the discussion about how to more directly engage users while at the same time improve feedback to developers of the CESM. A short overview would be followed by a discussion around a few key objectives leading to the formation of a proposal for execution that could be presented to CESM by the summer workshop time frame. This proposal could be seen as one of the requests from the SDWG towards CESM as suggested next development needs.