CESM Societal Dimensions Working Group Meeting
4-5 March 2015
National Center for Atmospheric Research – Boulder, Colorado
Mesa Lab – Main Seminar Room
Abstracts

Wednesday, 4 March

JOINT LAND MODEL AND SOCIETAL DIMENSIONS WORKING GROUP MEETING

Peter Lawrence – Attribution of the biogeochemical and biogeophysical impacts of CMIP5 Land Cover Change in CESM

Peter Lawrence

As part of the Coupled Model Intercomparison Project phase 5 (CMIP5), land cover change and wood harvest were both prescribed as major climate forcings for both historical and future climate projections. While Lawrence et al. (2012) described how land cover change were prescribed in all of these simulations and how the climate system and carbon cycle responded to land cover change in concert to other transient forcing, the attribution of carbon cycle and climate changes due directly to land cover change where not possible due to the design of the experiments. To allow for the attribution of land cover change we ran ensembles of historical and RCP 4.5 and RCP 8.5 simulations with full transient forcing compared to the same simulations without land cover change. In this talk we present the differences in these experiments for both ecosystem carbon and climate.

Alan V. Di Vittorio – The effects of land unit boundaries on GCAM land use and cover

Alan V. Di Vittorio

Understanding the potential impacts of future climate change on human systems and decision making is complicated by differences in spatial scales among economic and biophysical models. Earth System Models (ESMs) operate on gridded representations of the globe while Integrated Assessment Models (IAMs) generally operate on coarser, geographically delineated land units. This study is a first step toward addressing the uncertainties associated with this mismatch in spatial scale by comparing the effects of different spatial initial conditions for the Global Change Assessment Model (GCAM) on land use/cover projections. Three initial conditions—agricultural production, harvested area, and land rent—have different global distributions when calculated for two different sets of land units: one based on 1961-1990 climate (151 land units) and one based on 2070-2099 climate (184 land units). These different initial conditions generate different land use/cover trajectories from 1990 to 2100. By 2100, 15 regions experience differences in harvested forest area greater than or equal 10%, 4 regions experience differences in cropland area greater than or equal 10%, and in some regions bioenergy crop area increases by over 100%. Including climate feedbacks on vegetation has the potential exacerbate these differences induced by different land unit sets. The current climate land units become more heterogeneous and the future climate land units become less heterogeneous as time progresses. Ongoing work in a coupled model framework will examine how these two sets of land units differentially affect climate and vegetation productivity estimates in the Community ESM (CESM) and the associated feedbacks to GCAM energy and land use projections. As different land use trajectorie can generate significant differences in global carbon cycling and climate, the presented results have broader implications for understanding policy scenarios and potential impacts and also for evaluating and comparing IAM and ESM simulations.

Candida Dewes – Exploring the climatic impacts of fulfilling the global biofuel potential

Candida Dewes, Peter Lawrence, Samuel Levis, Gordon Bonan, Deborah Lawrence

An increasing global demand for fossil fuel alternatives may prompt large-scale deforestation and land use conversion for the establishment of biofuel crops. In this study we use the Community Land Model (CLM) to investigate the biogeophysical and biogeochemical responses of the global land surface when a dramatic expansion of agricultural land takes place.

Using global suitability maps for five biofuel crops (maize, sugarcane, soy, rice and wheat), we created hypothetical land surfaces where each crop occupies the maximum area where it is suitable to grow. Current crop distribution is maintained as it is, with the assumption that existing food, fuel and fiber production remains unaltered, and new crop areas are designated to the biofuel crops.

We use a recent version of CLM (post-4.5), with active biogeochemistry and crop models with phenology arameterizations specific to each of the aforementioned crops. An idealized simulation, in which all crops were allowed to grow anywhere in the world if conditions were favorable, was carried out with a 1000 year spin-up to establish equilibrium of carbon and nitrogen pools. Outputs from this simulation were produced at the plant/crop functional type level, and from there reconstructed to the present-day and the hypothetical land surfaces. The spin-up period ran under transient atmospheric data representing 1850-1970, and our analysis focuses on the 40-year period leading up to present climate (1970-2009).

In our presentation we will be discussing changes in climatology and trends in radiative and non-radiative fluxes at monthly and seasonal time-scales, and their regional and global patterns. We expect to draw conclusions regarding the sensitivity of the uncoupled land surface model to different crop phenology and distribution patterns, and how these might affect regional and global climate.

Anthony W. King – Using landscape typologies to model socioecological systems

Anthony W. King, Sujithkumar Surendran Nair, Benjamin L Preston, Rui Mei

The complexity of socioecological systems (SES) has posed a persistent challenge to the development of methods for diagnostic and prognostic analyses. We have developed a high dimensional statistical framework to address this complexity and the very large number of variables characterizing these systems. Cluster analysis is used to characterize regional landscape typologies with the types of a typology represented by clusters of similarity in multivariate data space. The typologies are mapped back onto geographical space, and the types of the typologies are used as independent variables in regression modeling of SES outcomes (dependent variables) of interest. We have applied the framework to agroecosystems of the United States Gulf Coast to evaluate the determinants of geographical variability in crop yield. A regional biophysical typology (BPT; the integration of climate, soil, and topography typologies) and a socioecological typology (SET; the BPT combined with a socioeconomic typology) were developed. The SET model for long-term mean corn yields significantly out-performed the BPT model, with respective R2s of 0.89 and 0.72. Results were similar for soybean and cotton yield. Our typological approach is thus able to capture the influence of socioeconomic factors on the complex high dimensional system of agricultural productivity. We describe the extension of this framework to socioecological variables of interest, including vulnerability to climate hazards, and the use of projected future climate and socioecological scenarios (e.g., the Shared Socioeconomic Pathways) in predicting the future behavior of SES. We also discuss how the typological approach might be utilized within CESM.

Hong-Yi Li – Impacts of climate and human-induced changes on stream temperature in large river systems: An Earth system modeling perspective

Hong-Yi Li, L. Ruby Leung, Teklu Tesfa, Nathalie Voisin, Xiaofan Yang, Jenny Rice

Stream temperature plays an important role in closing the energy balance at local, regional and global scales, and exerts significant impacts on aquatic biodiversity, power plant operation and energy production. It is therefore a critical component for representing the energy-water nexus in earth system models. The stream temperature particularly in large river systems is very often regulated by human activities such as reservoir and power plant operations. This study is a first attempt to develop a physically based stream temperature model within the Community Earth System Model (CESM) framework. The Model for Scale Adaptive River Transport (MOSART) has been developed to represent riverine water dynamics and incorporated into CESM by coupling with the Community Land Model (CLM). Here we build upon CLM-MOSART to represent the riverine transport of heat along with water flux and the energy exchanges between river water and the atmosphere. More importantly, the impacts of reservoir operations are also explicitly parameterized within this new stream temperature model. This new stream temperature model will first be driven by historical forcing and validated against the observed stream temperature at a number of USGS gauges across the US. Then, driven by dynamically downscaled climate change scenarios, the relative contributions of climate change and reservoir operation on the projected spatiotemporal changes in stream temperature will be systematically analyzed. Lastly the current limitations and future directions will be discussed.

M. Hejazi – The effects of groundwater and return flow on future water deficits in the United States: A one-way coupling of GCAM and CLM

M. Hejazi, N. Voisin, L. Liu, R.L. Leung, T. Tesfa, H. Li, M. Huang

The integration of water management in integrated assessment and Earth system models at the regional scale is an important step toward improving our understanding of the interactions between human activities, terrestrial system and water cycle, and to evaluate how system interactions are affected by a changing climate at the regional scale. This integration is critical to investigate the implications of climate change impacts and adaptation and mitigation options on water resources (e.g., balances between water demand and supply) in the U.S., and how water constraints can feedback to influence other human decisions and physical processes.

The work has focused on several primary goals: 1) the development of a regional representation of water demands in the Global Climate Assessment Model (GCAM) and with a telescoping focus over the U.S. down to the state level, 2) the linkage of GCAM and the land surface component of Regional Earth System Model (RESM) – including the Community Land Model (CLM), the MOdel for Scale Adaptive River Transport (MOSART), and the Water Management (WM) components – to eventually propagate human decisions pertaining to water demand per sector and technology from the GCAM decision framework to RESM at the appropriate temporal and spatial scales, 3) improving the coupling of the integrated water system by passing additional variables (e.g., water withdrawals and return flows) from GCAM-USA to CLM-MOSART-WM, which is an important enhancement to deal to water recycling. This feature required the enabling of the WM module to account for both water withdrawals and consumptive use explicitly and to track the amounts of unconsumed water (i.e., return flow) in the system, where it is returned back, and its residence (lag) time, and 4) enabling the WM module to distinguish and track the portions of water demands from surface water and groundwater sources. Several experiments

were executed to understand the implications of different modeling assumptions for including return flows and groundwater in the overall framework. These goals required a careful effort in representing the interaction pathways in the integrated water cycle among GCAM and RESM (i.e., CLM-MOSART-WM) and in addressing any inconsistency in representing the integrated water cycle.

Thursday, 5 March

SDWG SCIENCE SESSION II – BRACE PROJECT

Ben Sanderson – A new ensemble of GCM simulations to assess avoided impacts in a climate mitigation scenario

Benjamin M. Sanderson , Brian O'Neill , Claudia Tebaldi , Keith W. Oleson , Warren G. Strand, Jennifer E. Kay, Clara Deser, Jean-Francois Lemarque

There is growing evidence that the influence of internal variability of future climate has been under-sampled in past assessments of model projections for the coming decades. In light of this, a 15 member ensemble has been produced to complement the existing 40 member "Large Ensemble" simulated with the Community Earth System Model (CESM). In contrast to the Large Ensemble, which explored the variability in the 'business as usual' RCP8.5 scenario, our new ensemble uses the moderate mitigation scenario outlined in RCP4.5. By comparing these two datasets, we assess at what point in the future the climates conditioned on these two scenarios will begin to significantly diverge. We find that although internal variability is a significant component of uncertainty for periods before 2050, the following decades from 2050-2080 show a rapid divergence in regional and global climate states. Hence, in the CESM's representation of the Earth System for the latter portion of the 21st century, the range of climatic states which might be expected in the RCP8.5 scenario is significantly and detectably further removed from today's climate state than the RCP4.5 scenario even in the presence of internal variability.

Brooke Anderson – Climate change and very dangerous heat waves: Projecting the frequency of high-mortality heat waves in 82 US communities in 2061--2080 under different climate, population, and adaptation scenarios

G. Brooke Anderson, Keith Oleson, Bryan Jones, Roger D. Peng

Certain rare heat waves can have devastating effects to a community's public health and well-being. Here, we built models to predict which heat waves are likely to be such "very dangerous" heat waves using present-day data from 82 large U.S. communities, 1987—2005. We built twenty potential classification models and used tools from machine learning (Monte Carlo cross-validations) to evaluate these models, identifying three models capable of predicting very dangerous heat waves. Using these three models, we predicted the frequency of very dangerous heat waves in these 82 communities in 2061—2080 under two scenarios of climate change (RCP4.5, RCP8.5), two scenarios of population change (SSP3, SSP5), and three scenarios of community adaptation to heat (none, lagged, on-pace). We found that the frequency of very dangerous heat waves was most strongly influenced by the pace at which communities are able to adapt to their changing climates. We found that the frequency also depended somewhat on the climate change scenario, while frequency was practically unchanged across different population scenarios. Our results suggest that it is critical to consider adaptation scenarios when projecting the health impacts of heat under climate change scenarios. Further, our findings suggest that community-level adaptation measures are likely to be a critical protection against future very dangerous heat waves.

Xiaolin Ren – Avoided economic impacts of climate change on agriculture

Xiaolin Ren, Matthias Weitzel, Brian O'Neill, Sam Levis, Prasanth Meiyappanha

Agricultural systems not only provide food but also are an important part of the economy for many countries. Crop and pasture yields are dependent on the level and variation of temperature, precipitation, CO2 concentration and extreme events, including heat waves, droughts, and storms, and are therefore vulnerable to the effects of climate change. We assess the impacts of climate change under two different climate projections (RCP8.5 and RCP4.5) and two different socioeconomic pathways (SSP3 and SSP5) in order to quantify the reduction in impacts on agricultural systems as climate change is reduced, and the dependence of this reduction on the socioeconomic development pathway that is assumed. Previous studies have investigated climate effects on crop yield as well as implications for agricultural markets, prices, land use, and food security. They show that climate change can have positive or negative impacts on different crop types at different locations and over time. Consequently, studies of effects on agricultural markets show that there can be agricultural winners and losers, especially over the next few decades, while over time if the degree of climate change worsens then impacts turn more uniformly negative. Recently, the Agricultural Model Intercomparison and Improvement Project (AgMIP) published a set of studies examining the effect of climate change relative to a no-climate-impact baseline. Fewer studies have evaluated the benefits of mitigation on agricultural system, i.e., avoided impacts. We employ the integrated Population-Economy-Technology-Science (iPETS) model, a global integrated assessment model for projecting future energy use, land use, and emissions, to assess the economic consequences of the climate impact on agricultural yields associated with RCPs 8.5 and 4.5. The iPETS scenarios are driven with the yield impacts of climate change estimated with the NCAR Community Land Model (CLM) and future cropland allocations are projected by downscaling iPETS demand for cropland at the regional level to the grid cell using a spatial allocation model for agricultural land (Meiyappan et al., 2014). Results are reported at the level of the nine iPETS world regions over the 21st century 2100. By comparing the outcomes from two alternative climate scenarios and two societal development pathways, we are able to evaluate the avoided agricultural impacts of climate change on food prices, consumption, and GDP, and their sensitivity to socio-economic scenario assumptions.

Meiyappan, P., Dalton, M., O'Neill, B.C., Jain, A.K. (2014) Spatial modeling of agricultural land use change at global scale, Ecological Modelling 291, 152–174.

James Done – Estimating avoided tropical cyclone impacts using an index of damage potential

James M. Done, Debasish PaiMazumder, Erin Towler, Chandra Kishtawal

An index of North Atlantic Tropical Cyclone (TC) damage potential is developed, using seasonal large-scale climate variables of relative sea surface temperature and large-scale steering flow as proxies for the key damaging TC parameters of intensity, size, and forward speed. This climate-based approach explains 48% of observed historical cyclone damage potential and has the advantage of sidestepping the need for data on individual TCs. Climate model simulations under Representative Concentration Pathways (RCPs) 4.5, 6.0, and 8.5 project a reduction in damage potential driven by a cooling relative SST. This assessment indicates that anthropogenic climate change provides benefits by reducing TC damage potential. However, the spread in damage potential reduction among the RCPs is less than that due to internal variability over the century assessed using a climate model large ensemble. Although the sign of the 21st future change is robust to RCP and internal variability, the magnitude of the reduction is dominated by unforced climate variability rather than anthropogenic forcing. The merit of the cyclone damage potential is its ability to make comparisons relative to past events or past periods. Stakeholders may translate

damage potential to actual damage using relationships between the damage potential index and their specific exposure and vulnerability characteristics. Stakeholders can use these results to help understand trends in their average annual loss and extreme loss.

SDWG SCIENCE SESSION II – CESM Applications

Anton Seimon – High-resolution CESM simulations of the Lake Tanganyika Watershed to Inform Conservation Planning

Anton Seimon, Peter Lawrence, Simon Nampindo

We describe an ongoing project being conducted in equatorial Africa to apply high spatial resolution CESM outputs to a range of real-world problems in conservation planning in the Lake Tanganyika watershed, one of Earth's foremost biodiversity hotspots also characterized by endemic poverty, rapid population increases and political instability. Our modeling approach is to generate specialized regional CESM simulations for a broad domain in Africa encompassing the watershed with varied RCP and land surface realizations. On the application side, we provide model outputs and translate information in dissemination workshops and through direct consultation to serve planning agendas of governmental and NGO partners active in the region. To date, we have performed three fully coupled earth system simulations for the project region at 10-11 km spatial resolution for the initial proof-of-concept work. These are: (1) an Historical run, covering the years 1980-2005, which provides a baseline of CESM variables that predictions can be contrasted against; (2 & 3) forecast simulations out to 2100 under RCP 4.5 and RCP 8.5, respectively. In this presentation we will report on both successes and challenges in this real-world test of direct application of CESM as a planning tool in a particularly problematic and data poor section of the global tropics.

Yangyang Xu – Model projections of 21 century heat extremes depend on scenarios of GHG and air pollution

Yangyang Xu, J.-F. Lamarque

Future changes of heat extremes under global warming conditions have been the subject of many recent modeling studies. A recent effort using multiple model ensembles (CESM Large Ensemble, with 30 members) projects a large increase in the frequency and intensity of heat extremes by the end of the 21st century, under Representative Pathway Concentration (RCP 8.5) scenario. In this business-as-usual scenario (RCP 8.5), CO2 concentration is drastically increasing, however, other manmade short-lived climate pollutants (SLCPs), especially particulate pollutants, are in decline following strengthened air quality policies. In order to assess the relative role of GHG increase and pollution decrease on future heat extremes statistics, we contrast the results the CESM Large Ensemble to two additional Medium Ensembles (15 members each). One of Medium Ensembles keeps SLCF emissions at 2005 level (but allowing GHGs to increase same as RCP 8.5) and the other uses RCP 4.5 scenarios with smaller GHG increases, but SLCPs approximately same as RCP 8.5.

We show that the end of 21st century climate (2060-2080) is cooler by 0.6 K if air quality policies in RCP 8.5 were not implemented. Over land, temperature is cooler by about 0.9 K and the heat wave frequency is also found to decrease significantly (6%). One the other hand, GHG mitigation in RCP 4.5 from higher RCP 8.5 causes 1.2 K of cooling. Spatially, the SLCF induced cooling are more located in NH and land areas, as opposed to GHG mitigation induced cooling. Moreover, the population-weighted occurrence of

heat wave suggested larger influence of SLCFs on human exposure to heat extremes. Normalized over global mean temperature change in these two cases, the frequency and intensity of heat wave events over NH extra-tropics are more controlled by SLCF forcing, and over the tropics, SLCF are more capable of changing heat extreme duration, which is linked with dynamical change of atmospheric circulation. These results highlight the importance to extreme heat impacts of scenario assumptions about air pollutant emissions.

Alan V. Di Vittorio – Climate change driven terrestrial feedbacks influence land use, crop price, emissions, and carbon projections

Alan Di Vittorio, Jae Edmonds, William Collins, Peter Thornton, Katherine Calvin, Andrew Jones, Louise Chini, Ben Bond-Lamberty, Jiafu Mao, Xiaoying Shi, John Truesdale, Allison Thomson, George Hurtt, Anthony Craig, Marcia Branstetter, Pralit Patel

The integrated Earth System Model (iESM) directly couples the Global Change Assessment Model (GCAM), the Global Land use Model (GLM), and the Community ESM (CESM) following the CMIP5 RCP coupling protocol. Additionally, the iESM includes terrestrial carbon feedbacks to GCAM and updated fossil fuel CO2 emissions and land use to CESM every 5 years. iESM RCP4.5 simulations show that feeding climate change induced increases in vegetation productivity back into GCAM projections at dramatically affects crop prices, CO2 emissions, and land use. These feedback induced changes in land use result in more vegetation carbon and less ocean and atmosphere carbon in CESM as compared with a no-feedback simulation. The changes in CO2 emissions will further affect the CESM carbon cycle and might impact climate, but we have yet to obtain these results as the required simulation is not yet complete. Our results also indicate that there are small feedback effects driven by land use change that are opposite to, and offset by, the climate change induced feedback effects. We conclude that policy scenario projections are sensitive to the evolution of the earth system, and that incorporating such feedbacks is important for understanding the potential effects of climate mitigation and adaptation strategies.