An Overview of Advances in Integrated Assessment at the Joint Global Change Research Institute

The Joint Global Change Research Team

May 26, 2010
Joint Global Change Research Institute
Overview of Discussion

- [5] Introduction (include things we’re not going to talk about – RCPs, load segments, downscaling)
- [10 + 10] AgLU (Kate/Marshall)
- [5 + 5] Variable time steps (Sonny)
- [5 + 5] Enhanced Climate Modeling – MAGICC (Ben/Bill, maybe Jae/Leon for some strategic context)
- [8 + 7] Subregional U.S. + California (Page/Leon/Sonny and Steve)
- [5 + 10] Community Modeling (Leon)
- [5 + 5] New Computing Capability (Bill/Ben)
- [5 + 10] iESM (Allison/Sonny/Jae)
- [5 + 10] Water (Evan/Allison/Jae)
- [5 + 5] Macro-economy in GCAM (Kate)
- [5 + 5] SGM in GAMS (Leon/Kate/Marshall)
Introduction
Current GCAM Characteristics

- **Regional Details:**
  - *Regional Scope:* Global
  - *Number of Sub-Regions:* 14

- **Time Step:** 15 years

- **Time Frame:** 1990 to 2095

- **Model Type:** Dynamic Recursive

- **Equilibrium Type:** Market Equilibrium

- **Underlying Computing Framework:** Object Oriented (C++)
We are doing quite a bit of work to enhance our integrated assessment capabilities. Today we will run through the following areas of model development and interaction with community.

- Enhanced agriculture and land use model
- Variable temporal resolution
- Enhanced climate modeling
- Subregional capability in GCAM – Multi-region U.S. model.
- GCAM as a community model
- New computing resources at JGCRI
- The iESM project
- Incorporating water into GCAM
- Incorporating a macro-economy into GCAM
- Building a version of SGM in GAMS
Agriculture and Land Use Modeling

Marshall Wise, Kate Calvin
(20 Minutes)
Current Ag/Land Use Development Goals and Strategies

► Goal – represent more physically-defined characteristics in our economic modeling of land

► Strategy – model economic decisions on smaller units of land where uniform characteristics could be defined and assumed to be uniform for that land
  ■ E.g. Physical characteristics such as crop yield for a given technology, carbon densities of each use of land.
  ■ Economic characteristics such as value or price of land

► Approach – Model economic land use in up to 18 AEZs in each of our GCAM regions
  ■ Data, calibration, land use modeling at the regional AEZ level
  ■ Markets remain at regional or global levels
Regional Disaggregation: Agro-ecological zone approach
Example land Allocation Structure (occurs in each Regional AEZ): Allocation based on profitability
Global Forest Area

![Graph showing the trend of global forest area from 2005 to 2095. The graph includes two lines: Science Paper and Updated AgLU. The forest area decreases over time, with the line for Science Paper showing a slight decrease compared to the Updated AgLU line. The x-axis represents years from 2005 to 2095, and the y-axis represents the forest area in billion hectares.]
Variable Temporal Resolution

Sonny Kim
(10 minutes)
Shorter and Variable Time Steps in GCAM

**Goals**
- Increased frequency of information exchange with integrated assessment models (GCAM) and earth systems models (agricultural & land models, GCM’s)
- Extend GCAM beyond 2095
- More accurate representation of stocks and flows in GCAM
  - Resource availability, cumulative and annual production
  - Capital stock vintages: new investments, retirements & retrofits
  - Annual flows of goods and services
- Greater precision in targeting technology and climate change policies
  - “When” flexibility and accuracy of policy implementation
  - Better representation of technology availability

**Challenges**
- Availability of vintaged datasets (annual capital and physical stocks)
- Accurate representation of delayed investments, retirements and retrofits
- Revisions to current datasets for utilizing shorter time step capability

**Status**
- GCAM code is ready
- Established default behaviors for those periods with unspecified socio-economic and technology representations and other required modeling parameters
- Continuing to collect more detailed global datasets by region and time
- In the process of verifying shorter time step behavior and results
Shorter Time Step Advantages

**Better characterization of technology deployment**

**Better characterization of near-term policies**
Enhanced Climate Modeling

Ben Bond-Lamberty, Bill Emanuel

(10 minutes)
GCAM currently relies on MAGICC. What is MAGICC?

- A gas-cycle, carbon, climate and ice-melt model used in IPCC assessments.
- Treats various GHGs and halocarbons.
- When coupled to GCAM, is primarily used to provide estimates of atmospheric GHG levels under a particular policy case.
Enhancements to Climate Modeling in GCAM (1)

1. Enable climate feedbacks
   - Feedback of CO₂ and global mean temperature provides a first-order mechanism for, e.g., increase of carbon density with changing climate
   - **Status:** Complete (experimental only)

2. Translate MAGICC to language of GCAM, C++
   - Will provide better integration, debugging, use of modern profiling tools, and easier distribution of GCAM package
   - **Status:** 95% complete (debugging)
Enhancements to Climate Modeling in GCAM (2)

3. Algorithm diagnosis and mapping
   - MAGICC is implemented in Fortran 77 without a modular structure
   - Many components do not reflect current science
   - **Status:** 33% done

4. Building a new model with similar scope and applicability
   - Open-source, object oriented
   - Designed for easy GCAM coupling as well as stand-alone capability
   - Simplified, designed for community development
   - **Status:** in planning
Subregional U.S. + California

(Page Kyle, Steve Smith)
(15 minutes)
Subregionalization Capability in GCAM

- We will be incorporating a subregional capability within the GCAM.
- The first application will be development of a 10-15 subregion U.S. model.
- Concurrently, we have been developing a research version of a California subregion that can be run within the GCAM.
Subregions of the US: Example EPRI Disaggregation

- Pacific
- Mountain
- New England
- Atlantic-N
- Atlantic-S
- Central-NW
- Central-NE
- Central-SW
- Central-SE
- Florida
- Central
- SW
- Texas
- California
US Residential Energy

Total by Service and Fuel

Total by Subregion and Fuel

Heating by Subregion and Fuel

Proudly Operated by Battelle Since 1965
Subregional Focus in GCAM: Example for A California GCAM

- A California region within the GCAM model would allow:
  - The ability to place California-specific policies within a national and global context.
  - Using the same representation as the rest of the United States and, in many, cases other world regions, allowing consistent assumptions and comparisons.
  - Future projections of the California energy system will consistent with the economic and energy impacts of national and global climate and energy policies with endogenous prices for all energy goods.

- Needs for an effective California region:
  - Shorter (5-year) time steps.
  - End-uses representation by service --> technology representation
  - California-specific electricity generation sector
  - Delivered energy prices specific to California
GCAM as a Community Model

Leon Clarke
(15 minutes)
GCAM as a Community Model

There are no state-of-the-art, open, community models presently in the integrated assessment modeling community. This project will use a state-of-the-art IAM, the GCAM, to create an open model for the IAM research community. We are proceeding in three stages:

- **Stage 1.** Create and facilitate open access to an executable version of the GCAM model.
- **Stage 2.** Facilitate open access to the underlying GCAM source code and create a publically accessible modeling data archive.
- **Stage 3.** Open GCAM core model development to external proposals from the full IAM user community.
Progress?

- We plan to hold a workshop to kick off the GCAM community modeling process.
- We are already working on many of the community modeling issues through the iESM project, because of the interface with CLM/CCSM.
- We are completing first versions of “user packages” for Stage 1 and Stage 2.

- A number of research institutions are already using GCAM for global and regional research and there are existing requests for the executable and the code.
New Computing Capability

Bill Emanuel
(10 minutes)
Evergreen

High-End Computational System for Climate Change Integrated Assessment Research

- 224 node computing cluster; nodes:
  - 2 quad-core Intel Nehalem 2.8Ghz processors
  - 48 GBytes 1,333 MHz DDR3 memory
- 1.1 PByte mass-storage system.
- Hosted by the University of Maryland, College Park.
- Available to users October 1, 2010.

The Evergreen system will provide a computational resource to the integrated assessment research community, enabling

- More realistic representations of energy-economic and Earth system processes in models;
- Increased spatial and temporal detail in integrated assessments of climate change;
- More advanced uncertainty analyses and inter-model comparisons; and
- Development of open-source, community models and data.
iESM

Jae Edmonds
(15 minutes)
Three Primary Tasks

- Create a first generation integrated Earth System Model with the human components of an IAM and the physical components of an ESM
- Apply this iESM to improve our understanding of the coupled physical, ecological, and human system
- Add realistic hydrology, including freshwater demand, allocations, and demands to hold stocks of water as well as representations of freshwater availability from surface water, ground water, and desalinization
Research with GCAM for the iESM

- Transfer of GCAM code – LBNL partners have now made GCAM an active component of CCSM.
- Develop down-scaling algorithms for land cover.
- Incorporate water in GCAM.
- Create a variable time-step versions of GCAM.
- Greater spatial resolution of agriculture and land-use modeling using Agro-ecological Zones (AEZ)
  - Incorporate climate feedbacks
  - Representation of multiple crop management technologies
- Global buildings representation with climate feedback
Develop down-scaling algorithms for land cover

Thomson et al., 2010 (In Revision)
iESM ver0: Multi-phase Coupling Strategy

Fossil fuel emissions

GCAM

LULCC

CLM/CCSM

C stocks, productivity

Climate

Atm CO₂

Up/down scaling (space and time)

phase 1

phase 2

phase 3

iESM Control (RCP 4.5)
Water

Allison Thomson, Jae Edmonds
(10 minutes)
Approach for Modeling Water in GCAM

Water Sources
- Surface Water
- Ground Water (graded depletions/rechargeable resource)
- Desalination

Water Allocation

Water Demands
- Energy System
- Households
- Commercial
- Industrial
- Agricultural
Status of water modeling: current activities

- Water withdrawals and consumption for energy technologies and energy extraction are in the model
- Water withdrawals and consumption for agriculture in the new AEZ version of AgLU are under development
- Evaluating options for water supply modules through collaborations
- Scoping methods for water markets in GCAM
Development of water use accounting for the energy sector

Water consumption by energy generation technologies

GCAM Reference
Water Consumption (km³/year)

GCAM Stabilization
Water Consumption (km³/year)
Macro-economy in GCAM

Kate Calvin
(10 minutes)
Macro-Economy in GCAM

Goals:
- A better representation of GDP
- Explicit modeling of investment
- Inclusion of welfare measures

Means:
- We will nest a simple CGE model at the top of the existing GCAM
- We will track capital stock, savings, and investment
- We will include a utility function
SGM in GAMS

Leon Clarke
(10 minutes)
Moving SGM to GAMS

- In 2009, JGCRI staff successfully ported SGM from Fortran to the ObjECTS framework in C++.
  - SGM was used in the EMF 22 international scenarios.
- We are now working to create a GAMS version of SGM working in collaboration with
  - Ian Sue Wing: Boston University
  - Karen Fisher Vanden: Penn State University
- We hope to make this version of SGM more comprehensively available to the community.
## Comparing SGM & GCAM

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<th>GCAM</th>
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<td><strong>Structure</strong></td>
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<td>- General Equilibrium</td>
<td>- Partial Equilibrium</td>
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<tr>
<td>- Aggregate technology representation</td>
<td>- Detailed technology representation</td>
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<tr>
<td>- Detailed electricity sector</td>
<td>- Detailed electricity sector</td>
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<tr>
<td>- Multiple industrial sectors</td>
<td>- Aggregate industrial sector</td>
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<tr>
<td>- Bilateral trade in all goods and services</td>
<td>- International trade in energy and agricultural products</td>
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<td>- Integrated agriculture and land-use component</td>
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# Comparing SGM & GCAM

## SGM

- **Uses**
  - Calculating the cost of limiting carbon emissions
  - Examining the impact of a carbon tax on energy consumption
  - Comparing different international regimes
  - Studying leakage in industrial production
  - Assessing the impacts of border taxes on consumption and trade

## GCAM

- **Uses**
  - Calculating the cost of limiting carbon emissions
  - Examining the impact of a carbon tax on energy consumption
  - Comparing different international regimes
  - Studying leakage in agricultural production
  - Analyzing the impact of different technologies on the cost of a carbon policy
  - Exploring terrestrial carbon policies