Adding Integrated Assessment to CESM: Progress and prospects

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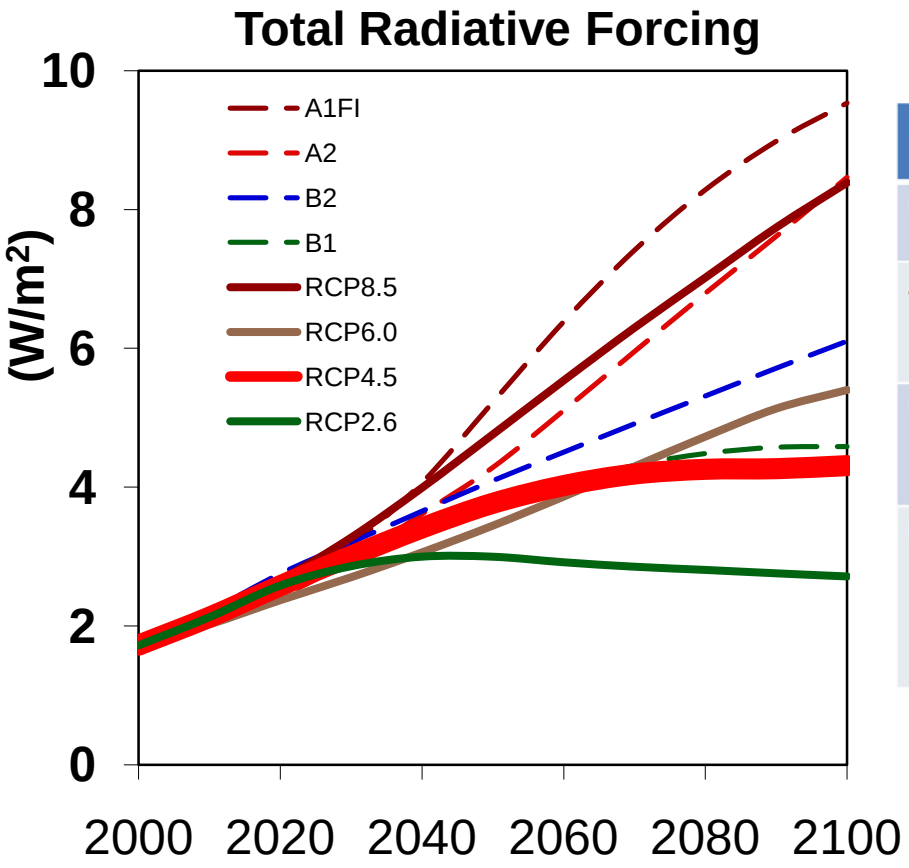
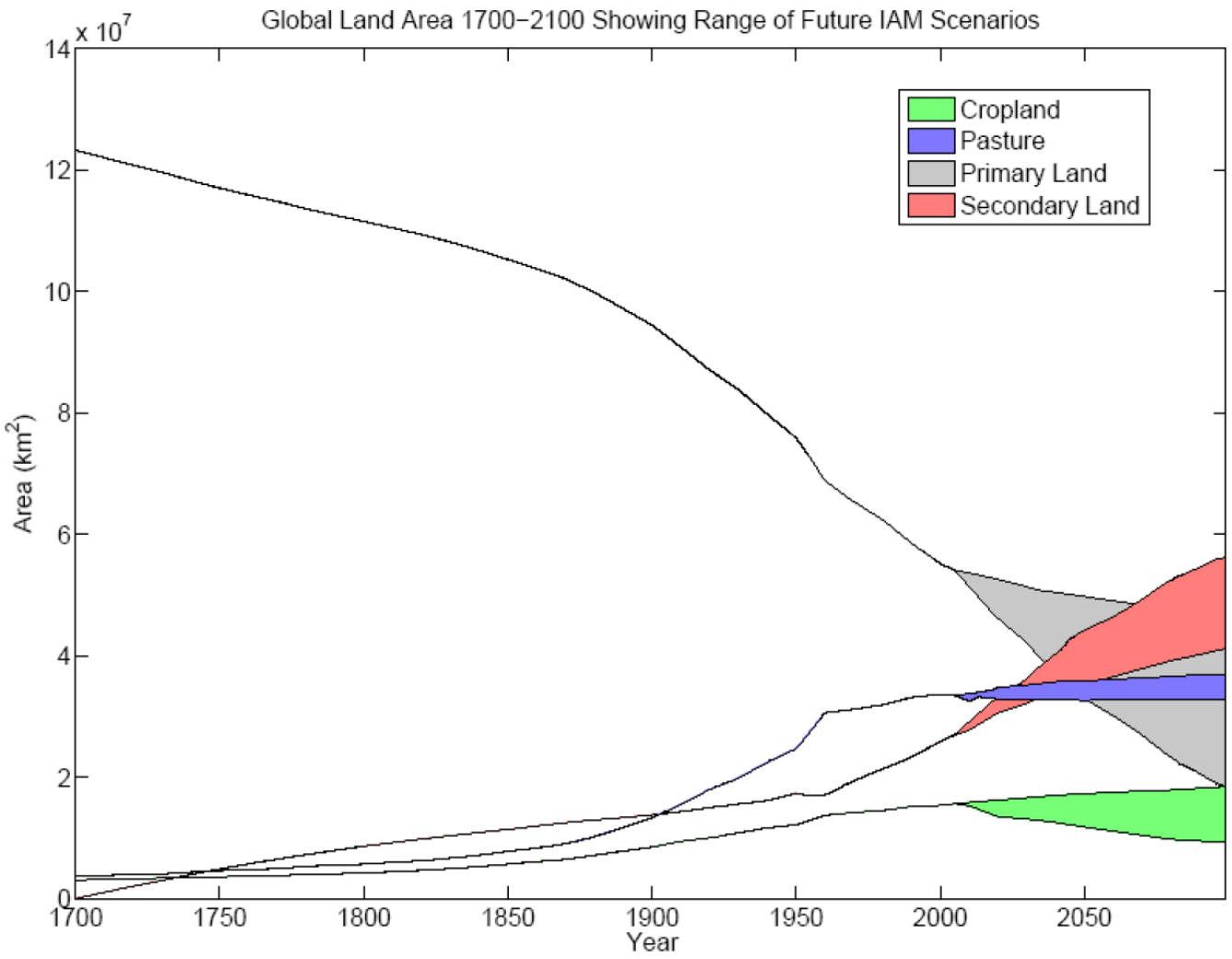
The Representative Concentration Pathways

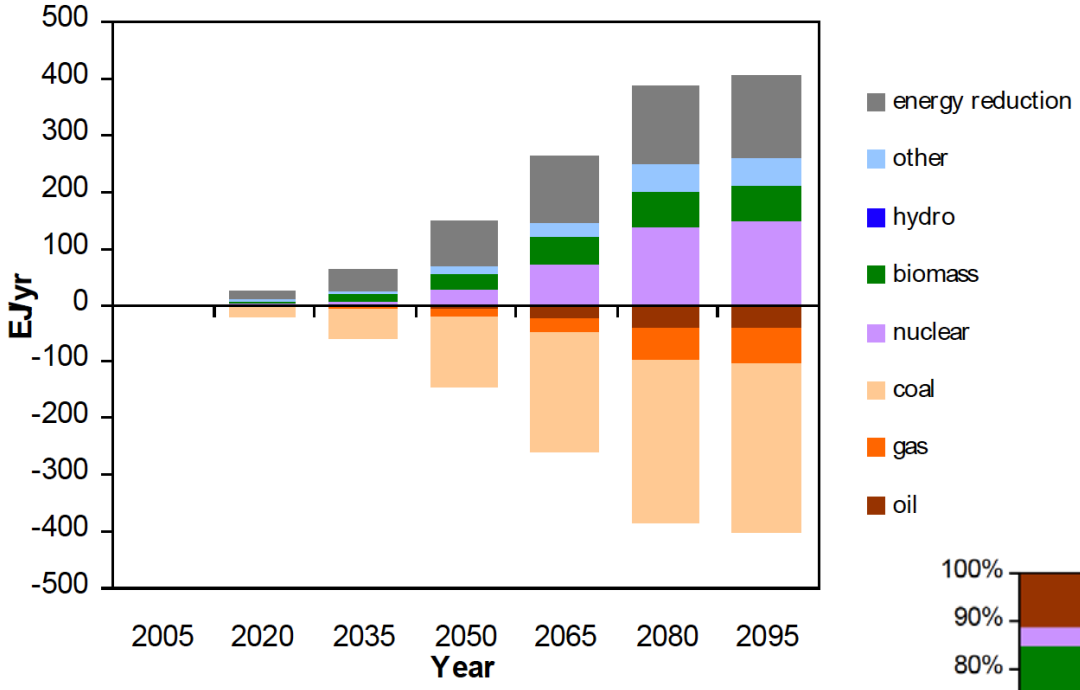


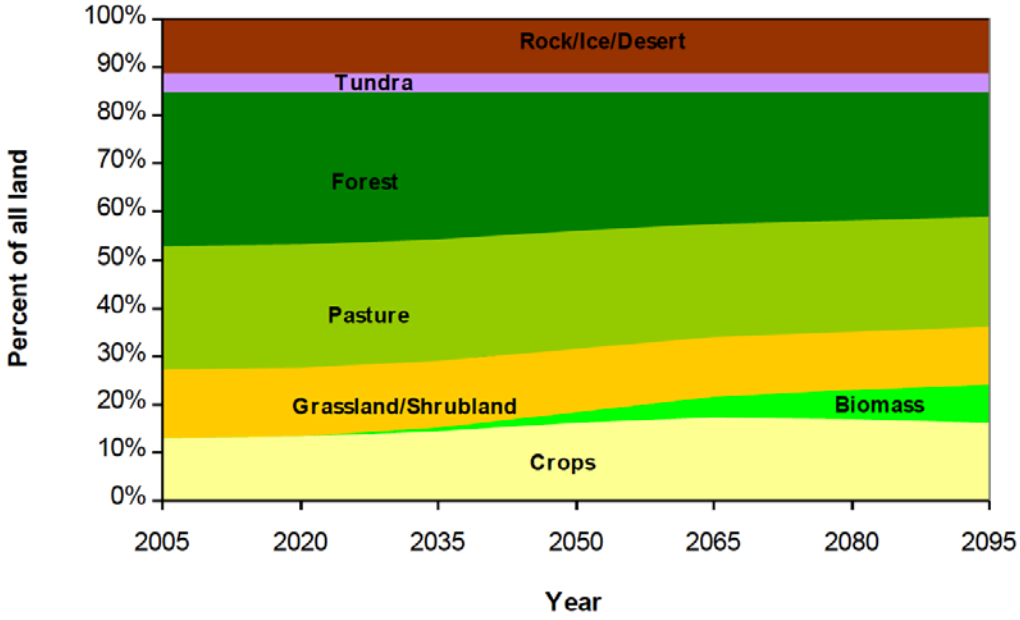
IAM	RCP	Radiative Forcing	Concentration	Pathway Shape
MESSAGE	8.5	>8.5 W/m² in 2100	> ~1370 CO_2-eq in 2100	Rising
AIM	6	~6 W/m² at stabilization after 2100	~850 CO_2-eq at stabilization after 2100	Stabilization without overshoot
MiniCAM	4.5	~4.5 W/m² at stabilization after 2100	~650 CO_2-eq at stabilization after 2100	Stabilization without overshoot
IMAGE	2.6	Peak at ~3 W/m² before 2100 and then declines to 2.6 W/m² by 2100	Peak at ~490 CO_2-eq before 2100 and then decline	Peak and decline

Implications for Land-use/Land-cover change



Deployment of biofuels in RCP 4.5





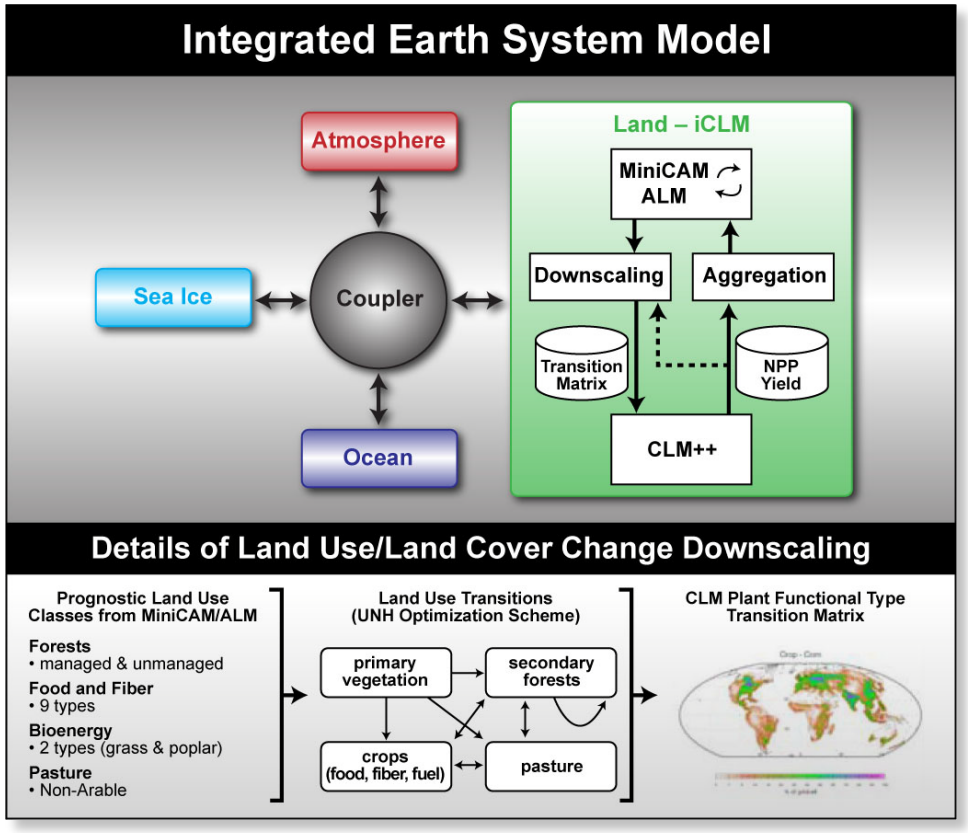
Science case beyond the RCPs

- ***In the present world emissions mitigation analysis is undertaken under the assumption that the climate is not changing.*** E.g. crop yields are unchanged, water resources are unchanged, and energy systems don't have to cope with a changing climate.

- ***Climate impacts analysis is undertaken with the assumption that no resources are being diverted to address climate change.*** E.g. no land is being used for reforestation, no land is being used to grow bioenergy, and energy prices are unchanged.

- The development of an iESM means that fully consistent analysis of potential future climate change, emissions mitigation options, and impacts and adaptation options will be possible.

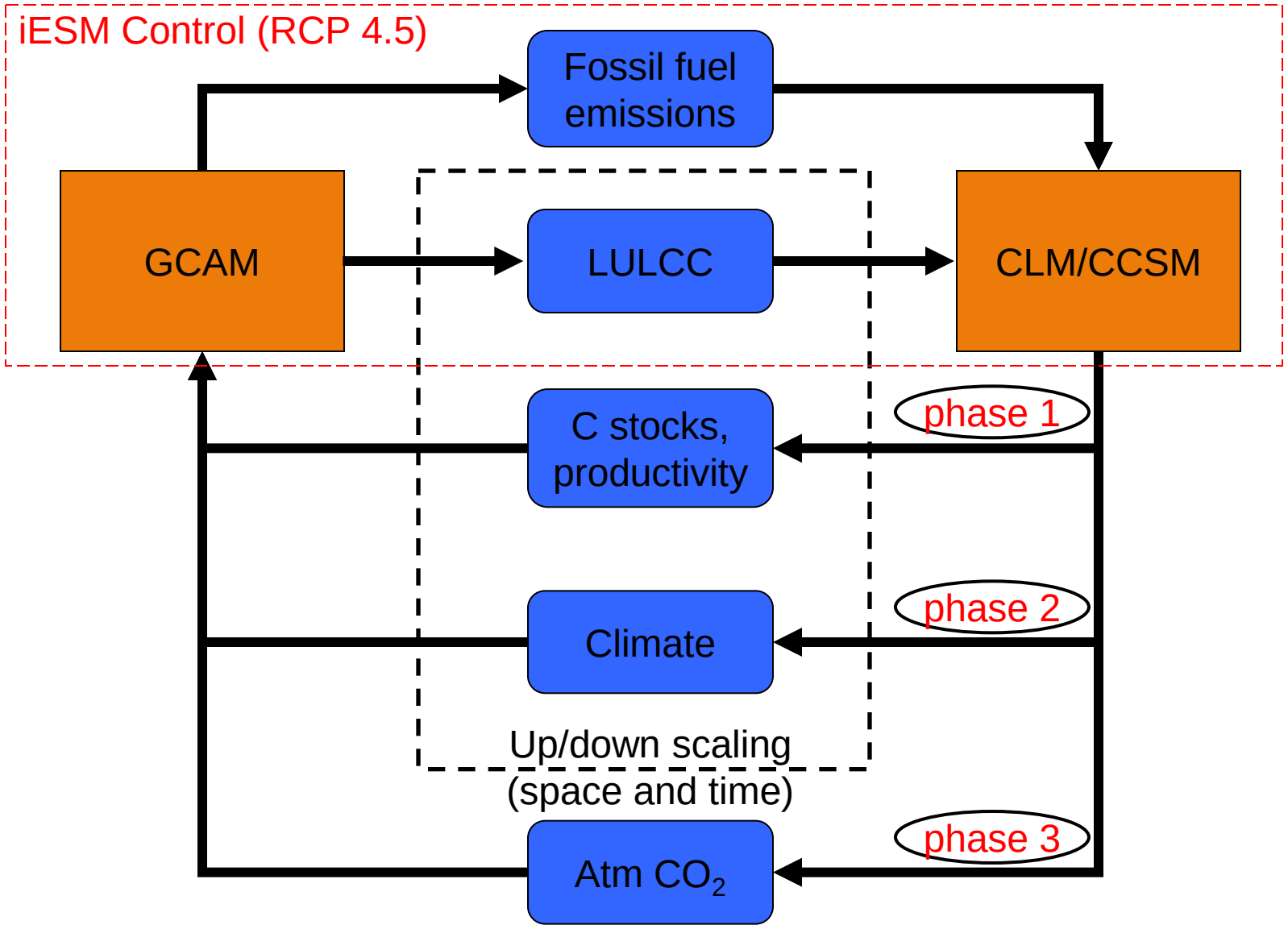
The integrated Earth System Model (iESM) Project



Three Primary Tasks

- **Create a first generation integrated Earth System Model (iESM)** with both the human components of an IAM and a physical ESM
- Further develop components and linkages within the iESM and **apply the model to improve our understanding of the coupled physical, ecological, and human system**
- **Add realistic hydrology** as well as representations of freshwater availability from surface water, ground water, and desalinization

Phases of iESM experiment and coupling strategy



Advantages of the GCAM IAM

- GCAM was one of four models chosen to create the representative concentration pathways for the IPCC's AR5
- GCAM was one of three models used to create scenarios for the CCSP's scenario analysis.
- GCAM has been a prominent tool for analysis in the Climate Change Technology Program.
- GCAM or one of its related models, e.g. MiniCAM, has participated in virtually every major climate/energy/economics assessment over the last 20 years:
  - Every EMF study on climate
  - Every IPCC assessment
- GCAM has been used for strategic planning by energy and other private companies.
- GCAM is now used by research institutions and governments internationally.

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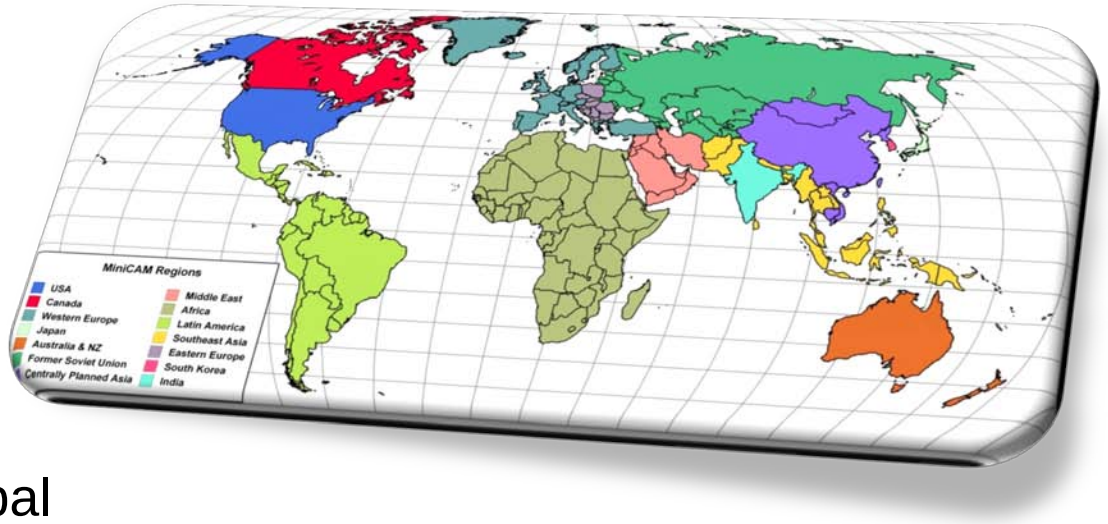
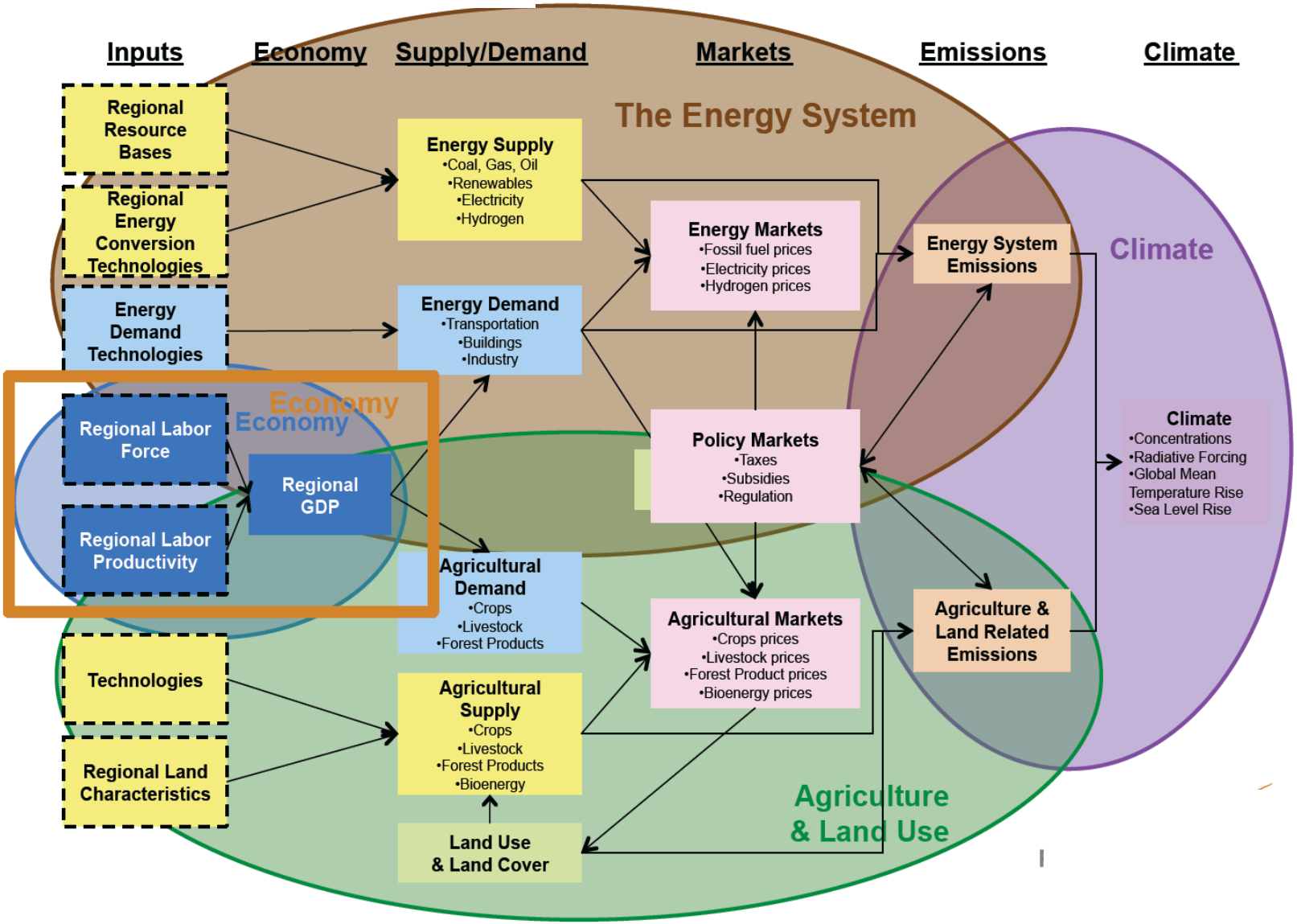
Current GCAM Characteristics

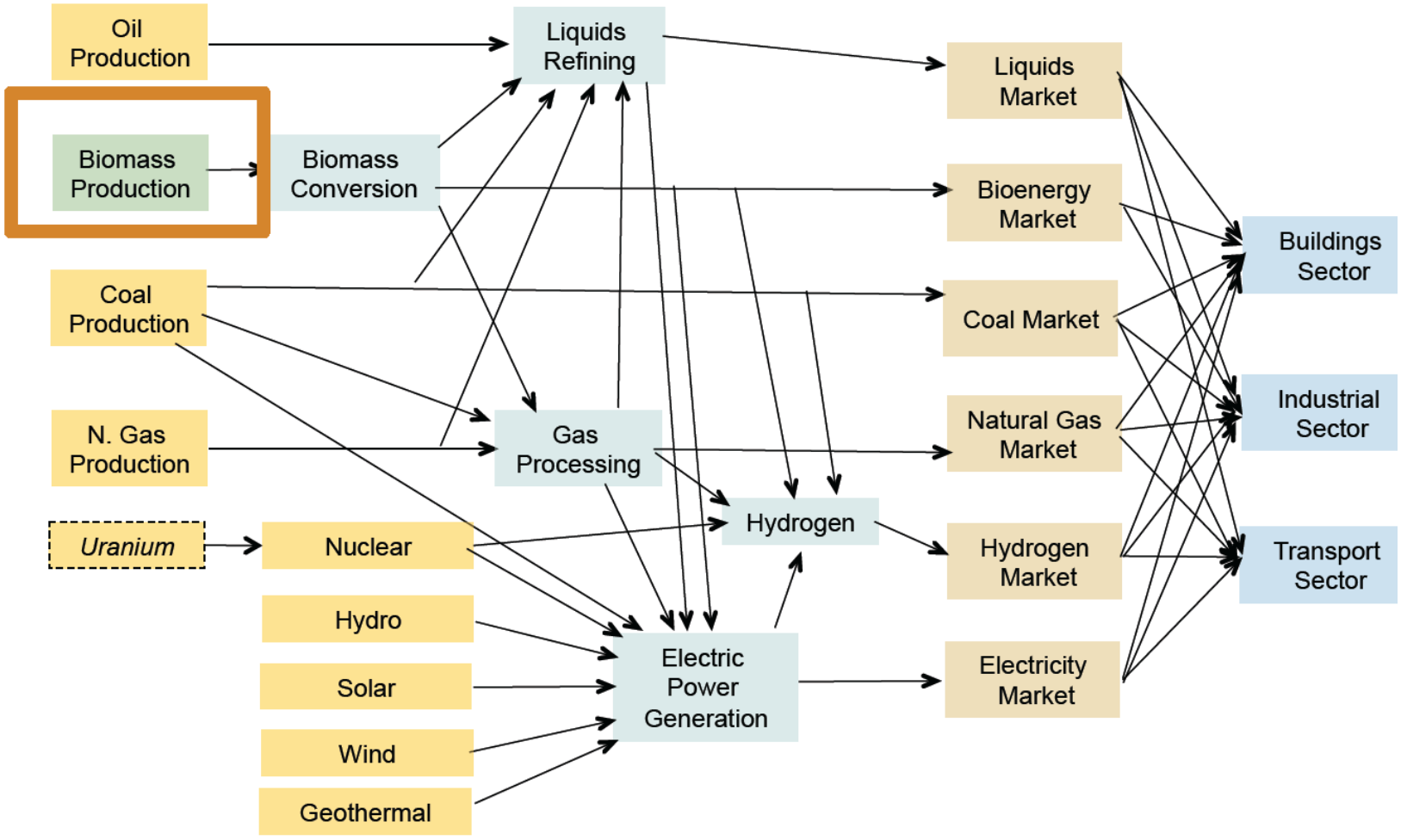


- **Regional Details:**
  - ***Regional Scope:*** Global
  - ***Number of Sub-Regions:*** 14
- **Time Step:** 15 years
- **Time Frame:** 1990 to 2095
- **Model Type:** Dynamic Recursive
- **Equilibrium Type:** Market Equilibrium
- **Underlying Computing Framework:** Object Oriented (C++)

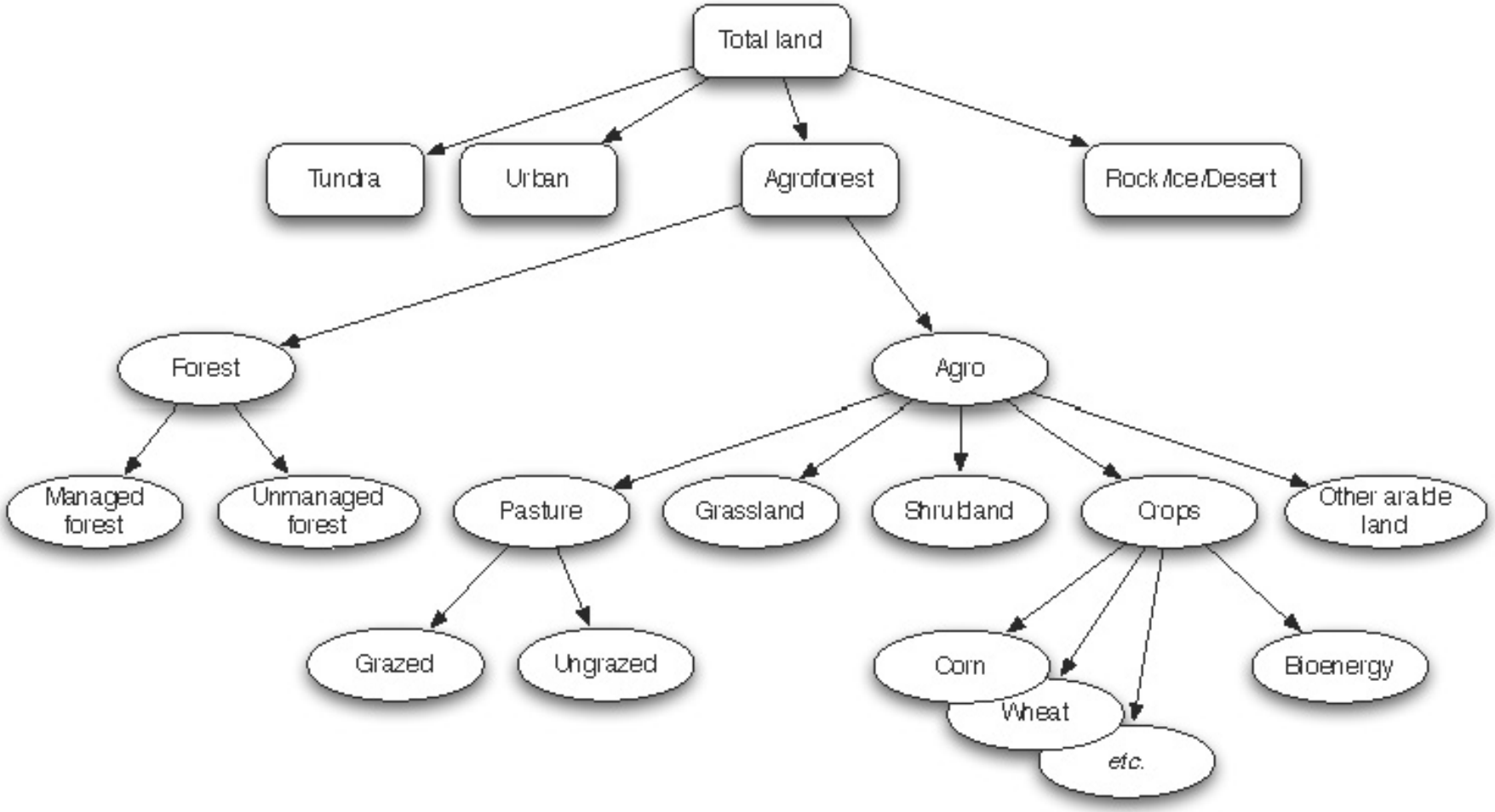
Schematic and data flow of GCAM



Role of biofuels in GCAM's energy markets



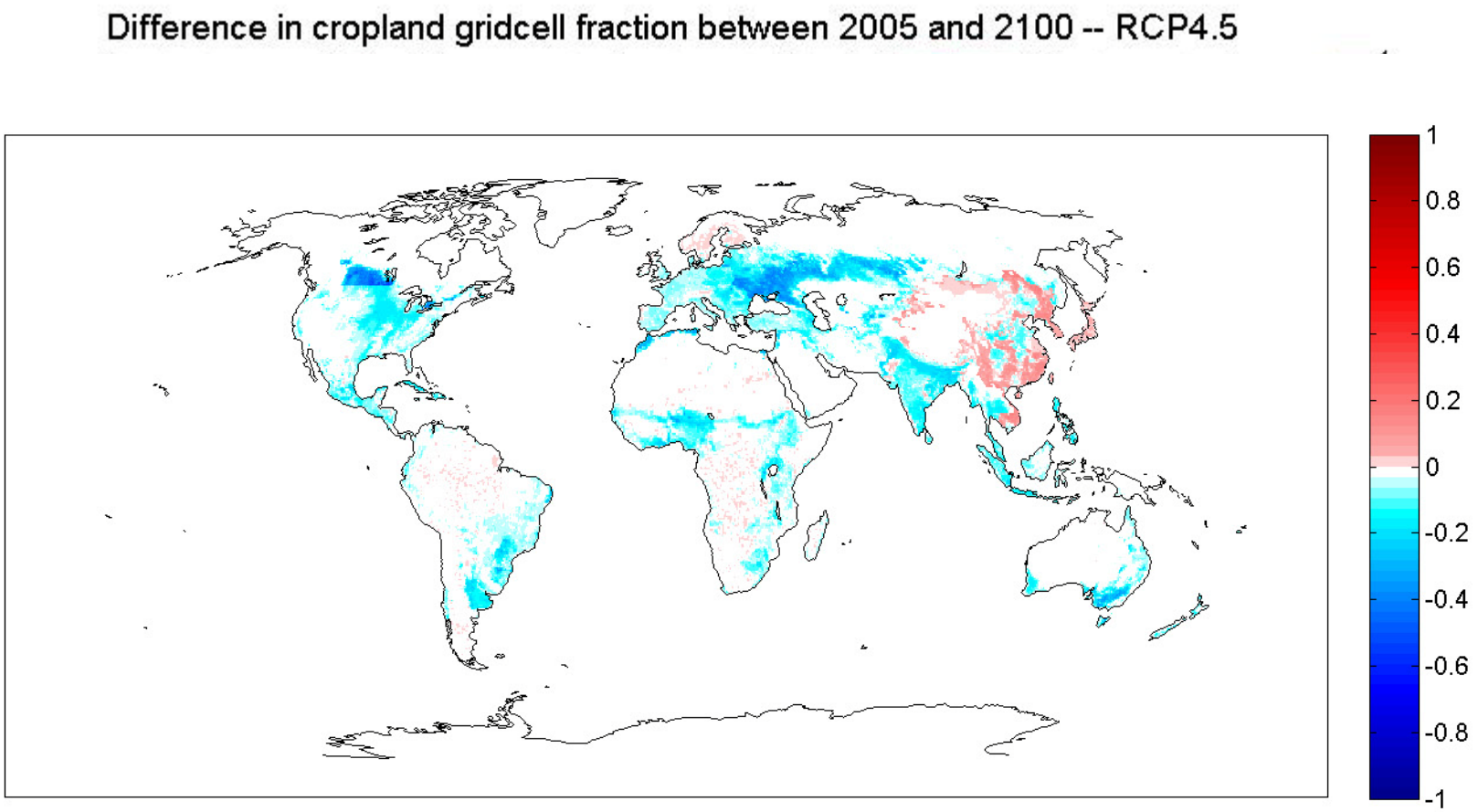
Action of the markets on LULCC



GCAM Land allocation based on profitability (representative structure shown here)

Down-scaling algorithms for land cover:

GCAM regions to CLM grid points



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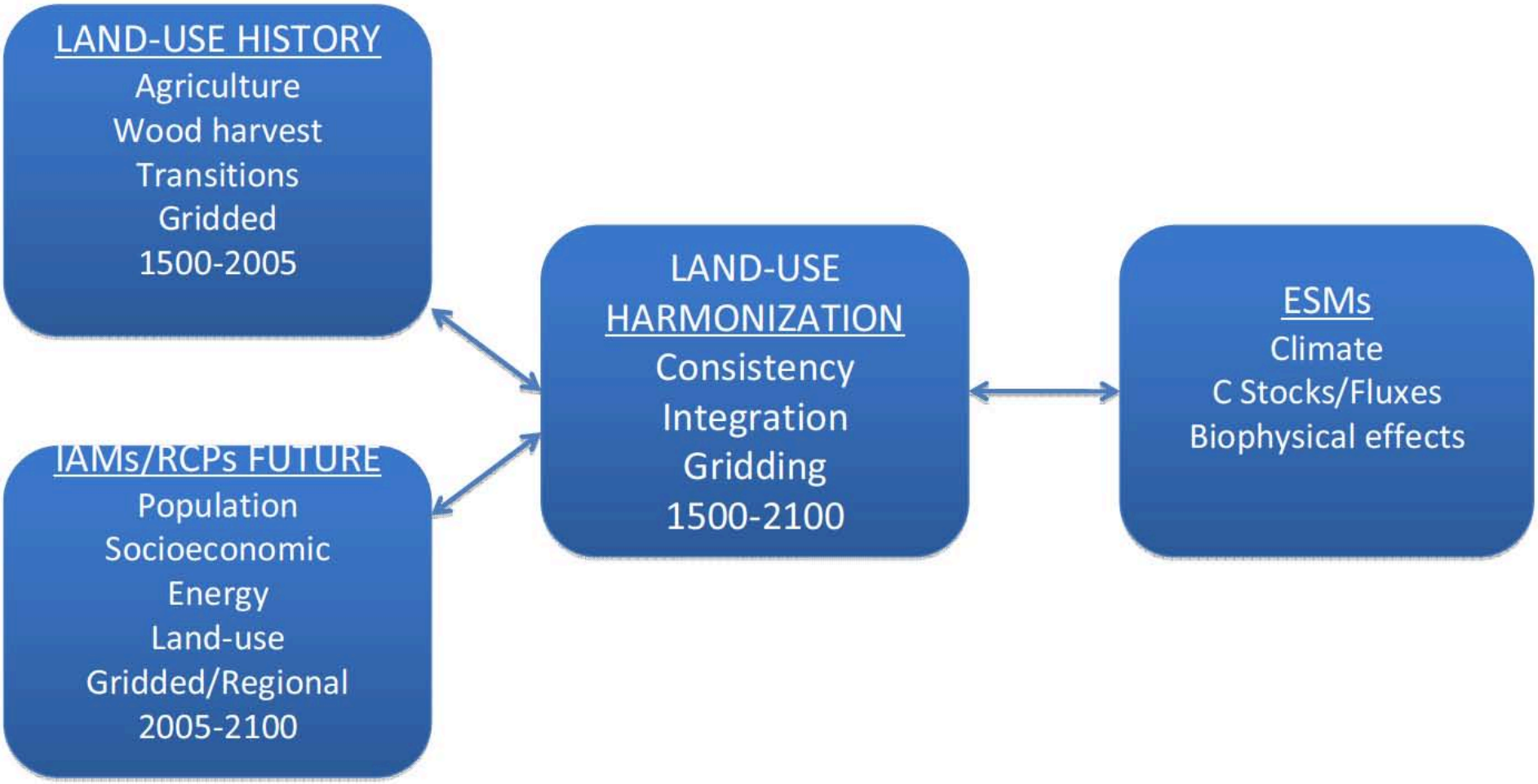
Downscaling via the Global Land Model



Spatial resolution of LULCC from the IAMs

IAM	RCP	Crop and Pasture Data	Wood Harvest Data	Includes Climate Feedbacks for Forest Re-growth?	Biofuel treatment
MESSAGE	8.5	Gridded	Gridded	No (only for allocation of crops)	Included in wood harvest
AIM	6	Gridded	Gridded	No	Included in cropland
MiniCAM	4.5	Regional	Regional	No	Included in cropland
IMAGE	2.6	Gridded	Regional	Yes	Included in cropland

Procedure for regional harmonization

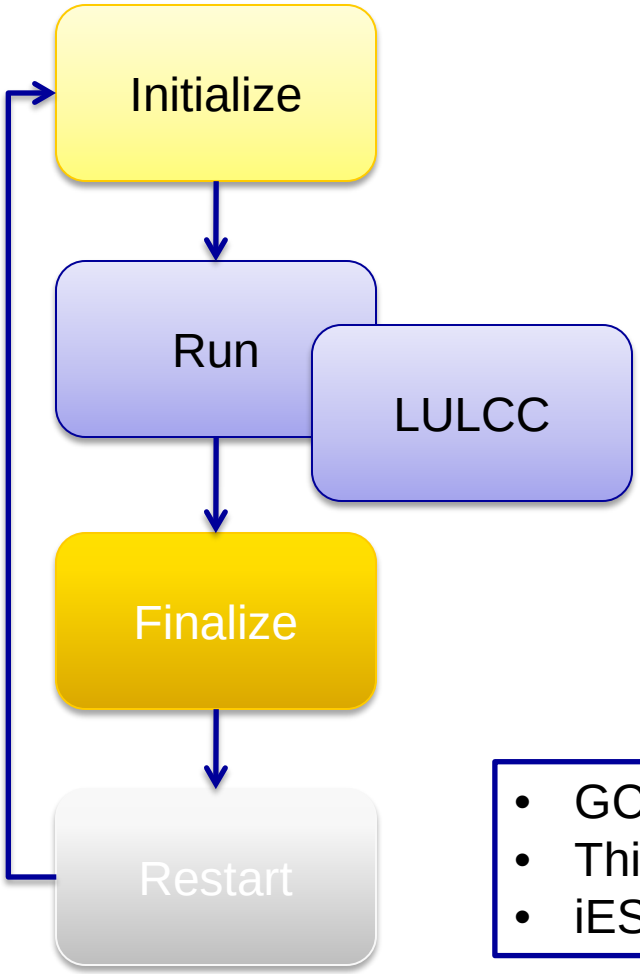
- Changes in the IAM **regional** crop and pasture data are computed between 2005 and 2010
- For regional crop or pasture *decreases*, the regional percentage decrease is applied to all half-degree HYDE gridcells with crop or pasture in 2005 to get half-degree crop and pasture maps for 2010.
- For regional crop or pasture *increases*, we apply this new crop or pasture demand to the HYDE half-degree gridcells that already have existing crop or pasture in 2005. Each gridcell receives a share of the regional crop or pasture demand that is weighted by the available land in the gridcell.
- If the crop or pasture increase cannot be met within the gridcells that have existing crop or pasture in 2005, we then search in neighboring cells, expanding our search radius until the increase can be met
- This method is then repeated for the next IAM interval (i.e. 2010 to 2020)
- Harmonized half-degree grids are linearly interpolated to annual grids

Transfer of GCAM code to iESM teams

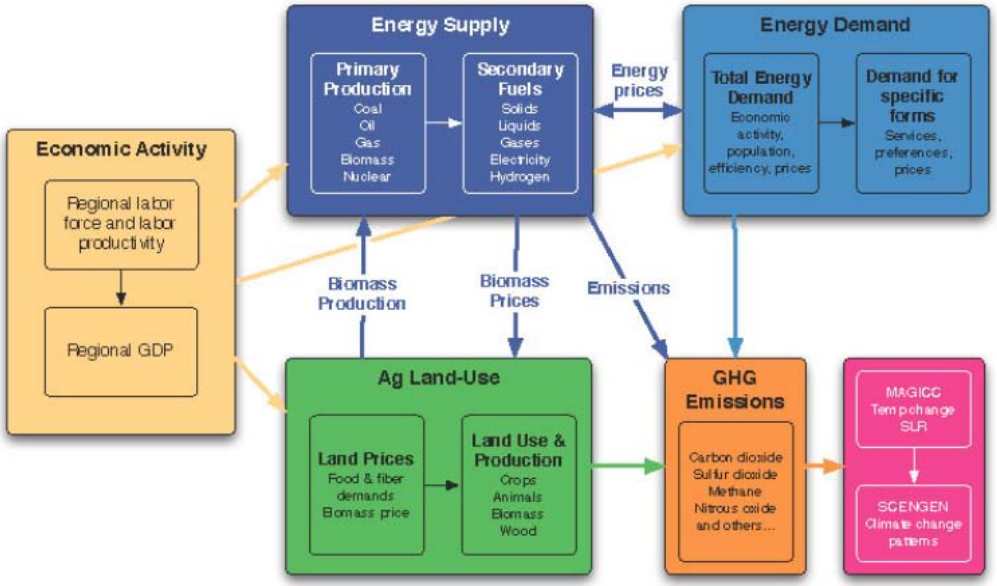
- GCAM code, data and documentation installed on iESM project repository.
- LBNL, ORNL and PNNL all have access to common iESM project repository.
- Benchmark GCAM runs for comparison identified and GCAM benchmark results installed on project repository.
- GCAM integration with CLM and CESM well underway:
  - GCAM has been converted to a CESM component.
  - GLM has been rewritten and converted to a CESM component.
  - Recoding of GLM->CLM PFT conversion is underway.

Integration of GCAM and CCSM

GCAM Interfaces for CCSM

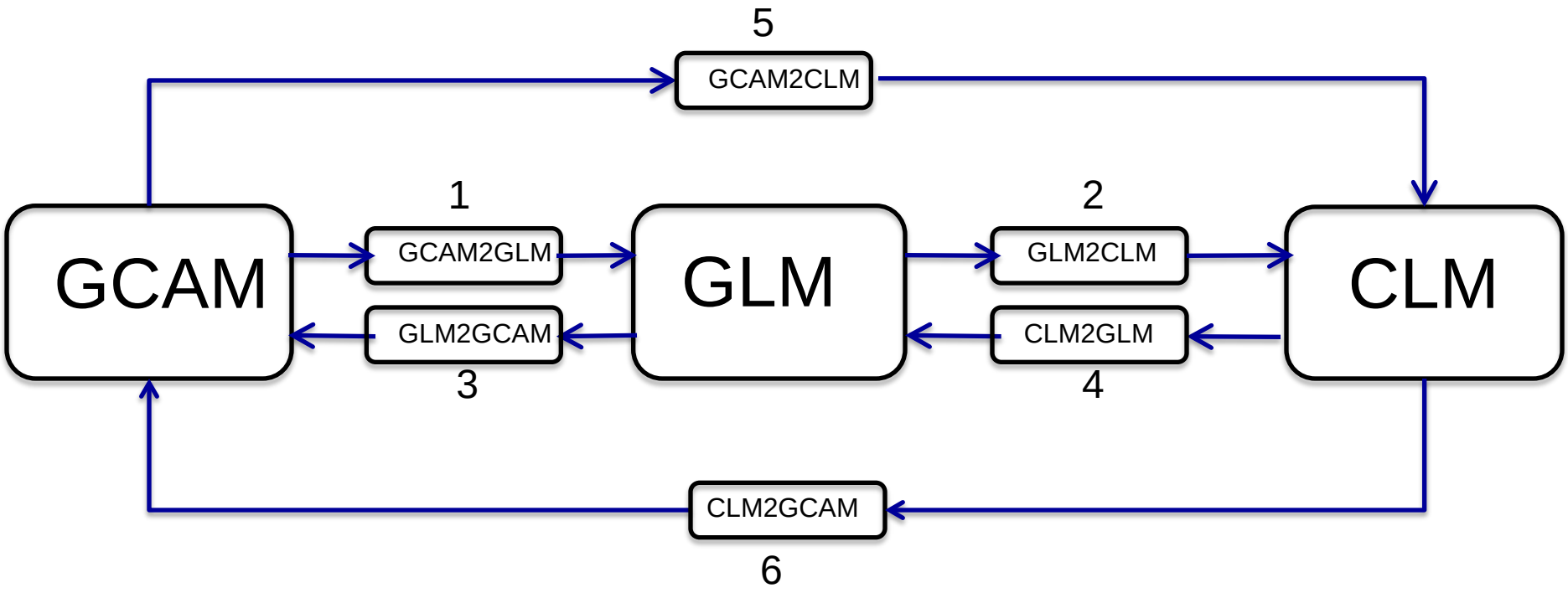


GCAM Structure



- GCAM and GLM can operate stand-alone or coupled.
- This flexibility is integrated with GCAM and GLM codes.
- iESM can track latest versions of GCAM and GLM.

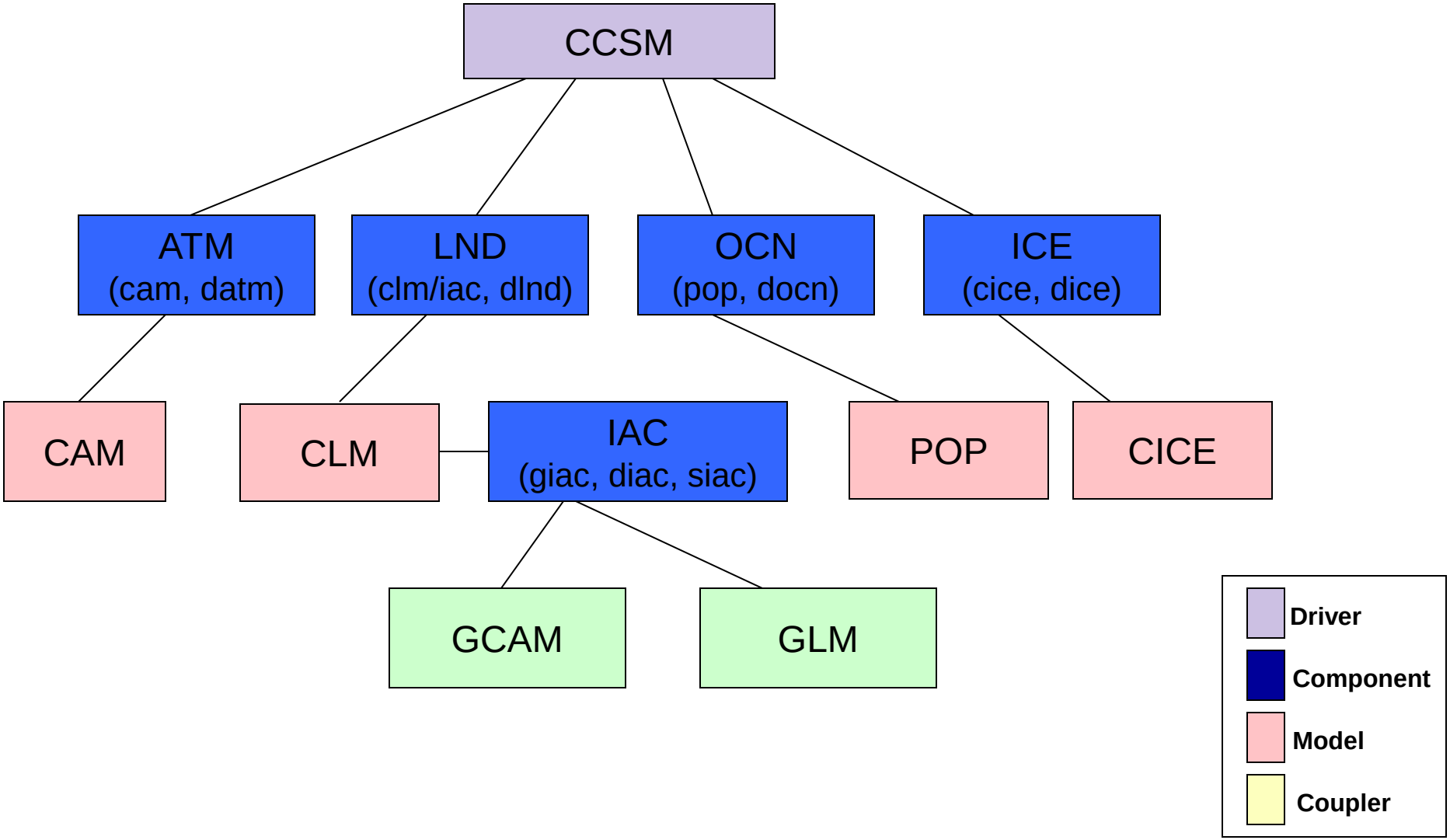
The iESM Coupling Diagram



Couplers:
1) GLM Matlab Code
2) PL + mksurfdat
3) Nothing (yet)
4) mapping (how?)
5) scalar coupling (?)
6) GCAM averaging tool

NOTE: Couplers may map spatially, time average, and/or derive new fields

Current iESM Coupling Implementation



Conclusions

- Technical goal is to integrate a leading IAM with CESM.
- We insure “dual use” of IAM components for maximum extensibility.
- Framework could be used for other IAMs.
- We will attempt first coupled experiments this spring.
- We will provide this system to the CESM community.

- Scientific goal is to understand the two-way interactions between mitigation measures and climate change.
- Starting point: introduce feedbacks into RCP 4.5 framework.
- “Sneaker net” experiment underway.

- *Other LBL talks on iESM: Andy Jones and Lisa Murphy*