Understanding the Energy-Land-Use-Water-Climate System and Its Uncertainties

Jae Edmonds, Kate Calvin, Vaibhav Chaturvedi, Leon Clarke, Evan Davies, Mohamad Hejazi, Andy Jones, Sonny Kim, Page Kyle, Patrick Luckow, Pralit Patel, Marshall Wise

ENERGY MODELING FORUM

Workshop on Climate Change Impacts and Integrated Assessment (CCI/IA)

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Snowmass, CO

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A Few Thoughts on Energy, Land, and Water in the Context of Climate Change

- Energy, land, and water interactions with climate are extremely important and highly non-linear.
  - The are therefore extremely interesting from the perspective of research.
  - They are also relatively less well explored than for example energy emissions mitigation.

- It is therefore a major focus of our model development and research;
  - We have just finished developing a new GCAM agriculture-land-use-terrestrial carbon module.
  - We are developing modules of the supply of and demand for water, both withdrawals and consumption.

THE GLOBAL CHANGE ASSESSMENT MODEL (GCAM)

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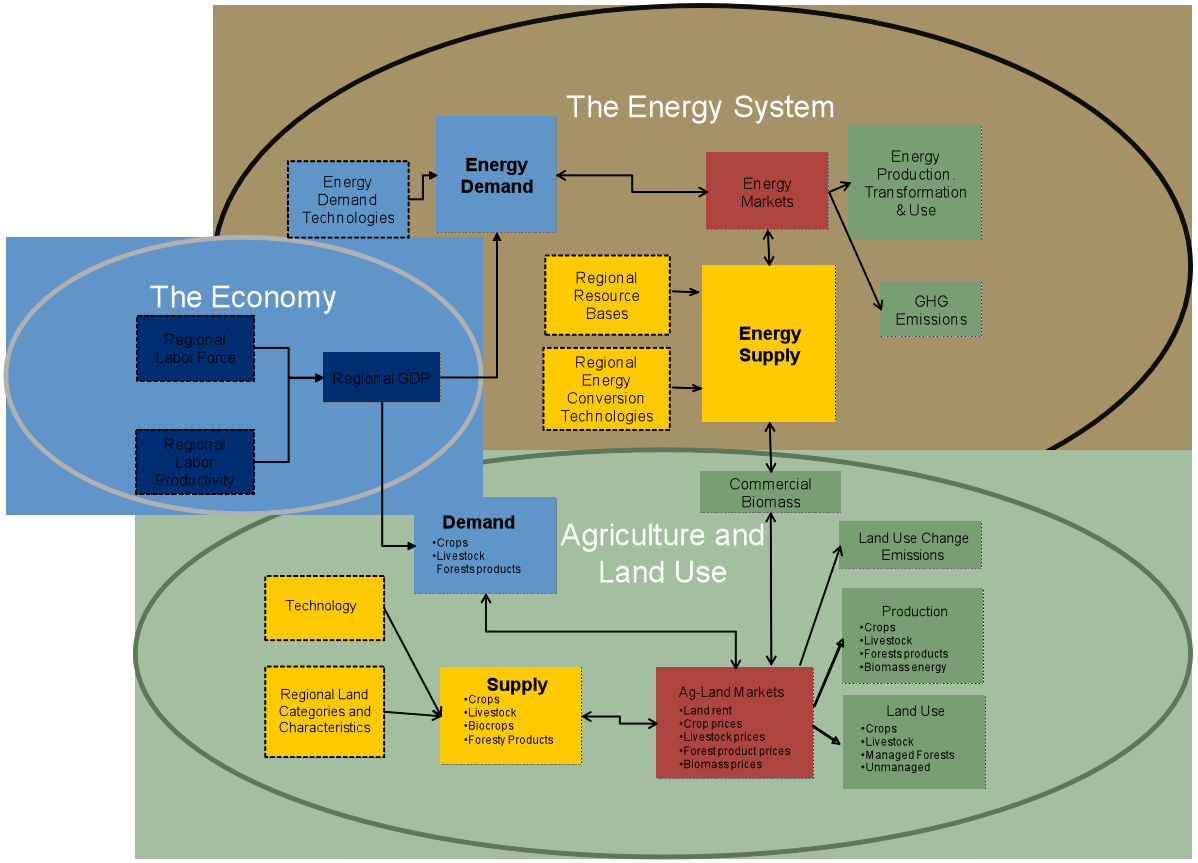
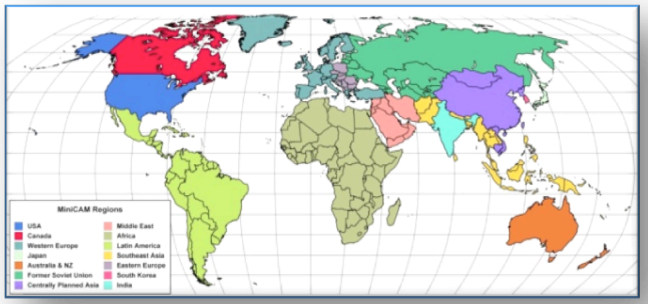
GCAM is an integrated assessment model

GCAM human Earth systems

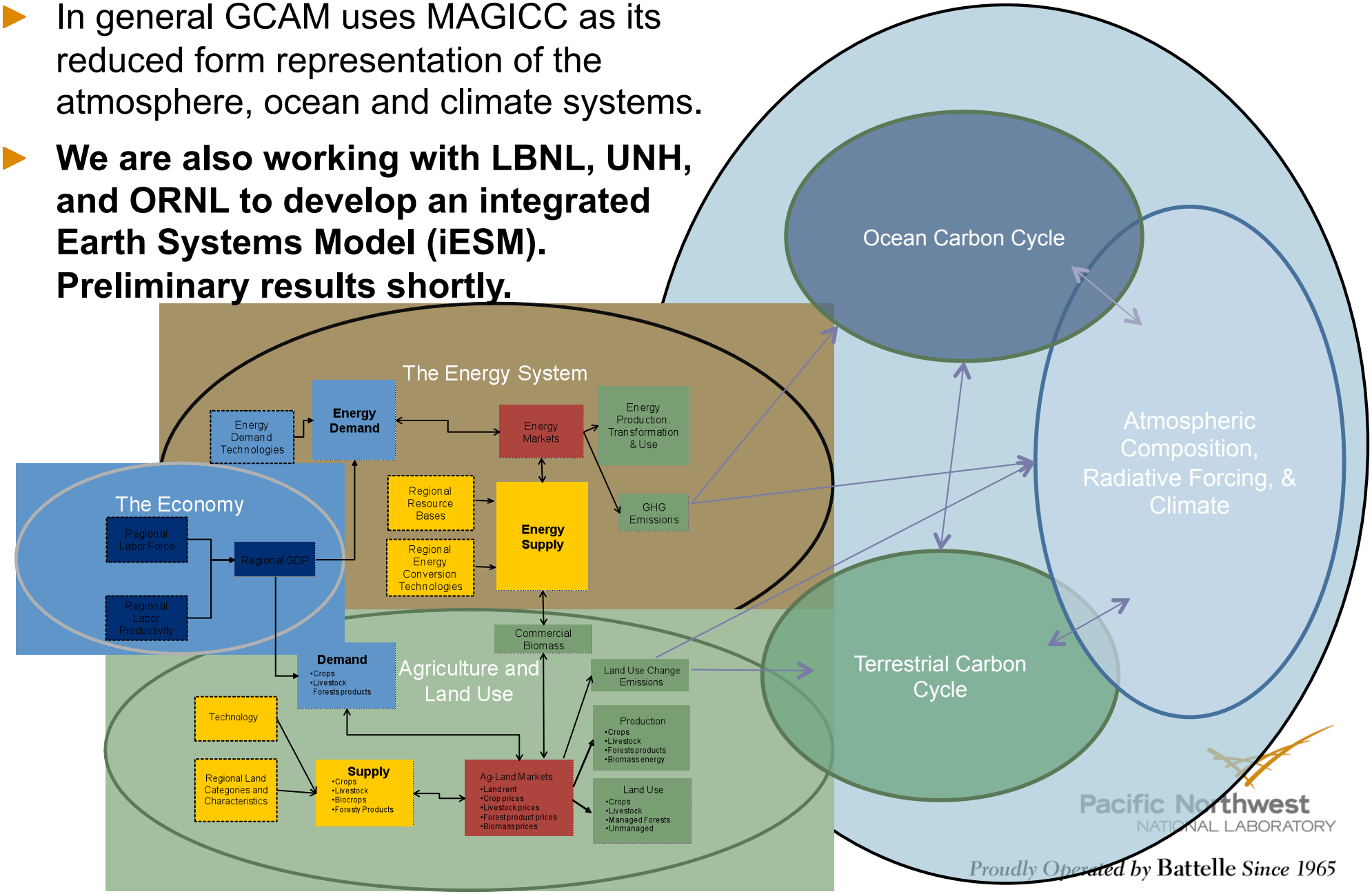




- **Open source model.**
- **Research model.**
- Dynamic-recursive model.
- **The GCAM human Earth systems model has Economic, Energy and Land-use systems.**
- Technologically detail.
- Emissions of 16 greenhouse gases and short-lived species: CO_2, CH_4, N_2O, halocarbons, carbonacious aerosols, reactive gases, sulfur dioxide.
- **Runs through 2095 in 5-year time-steps (time step is variable).**

GCAM Human and Natural Earth Systems

- In general GCAM uses MAGICC as its reduced form representation of the atmosphere, ocean and climate systems.
- **We are also working with LBNL, UNH, and ORNL to develop an integrated Earth Systems Model (iESM). Preliminary results shortly.**



Getting our feet wet in GCAM

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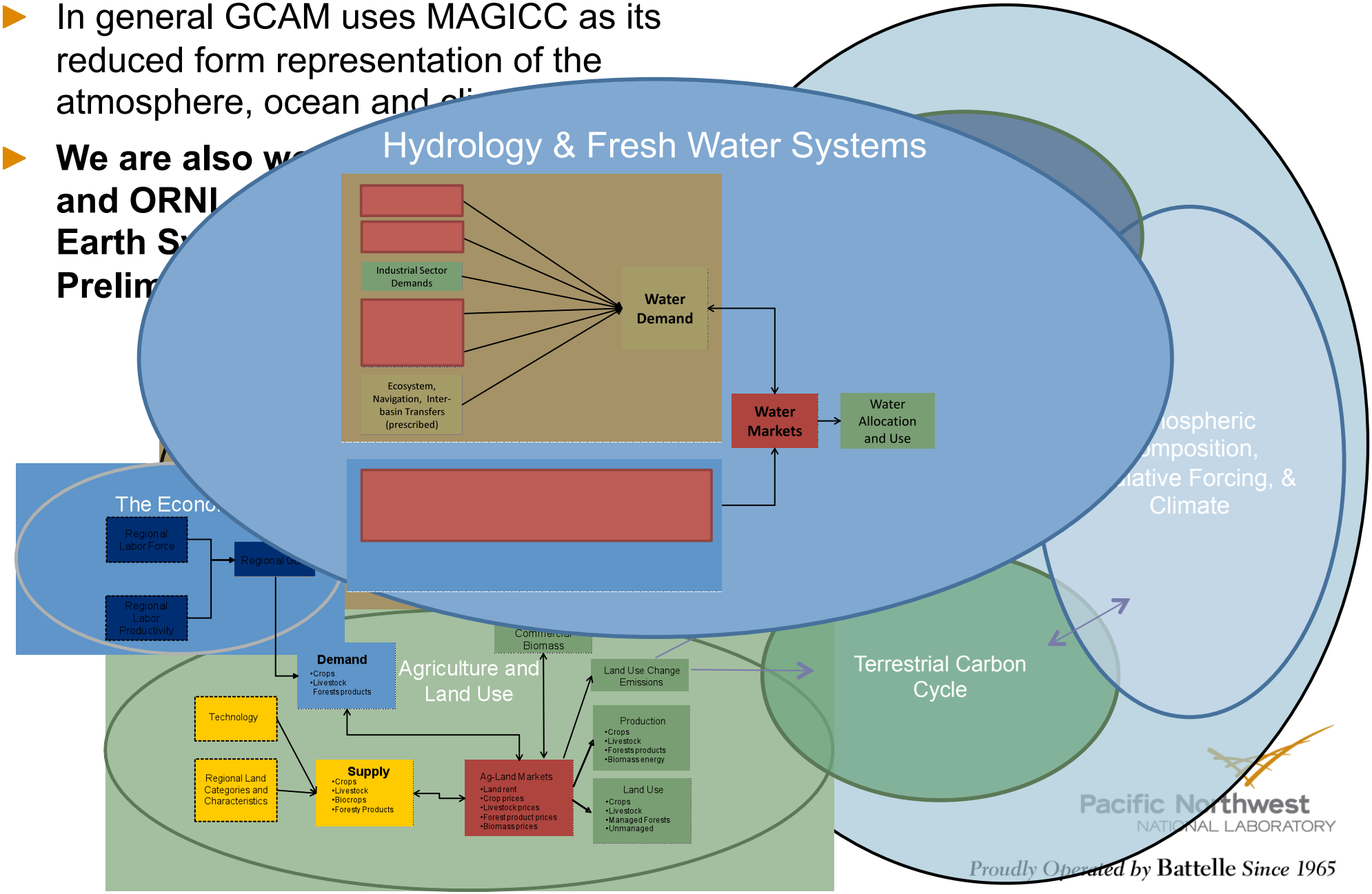
- **We are also w and ORNL Earth S Prelim**



CLIMATE FEEDBACKS

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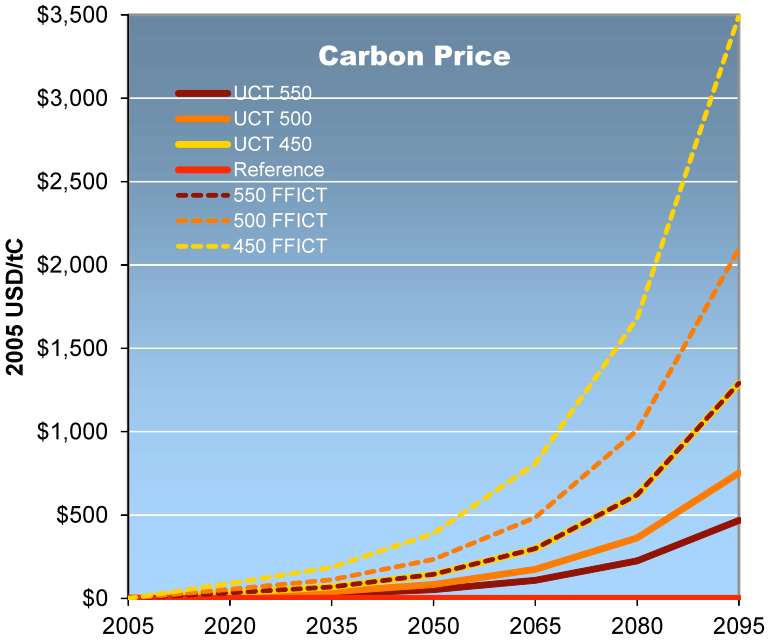
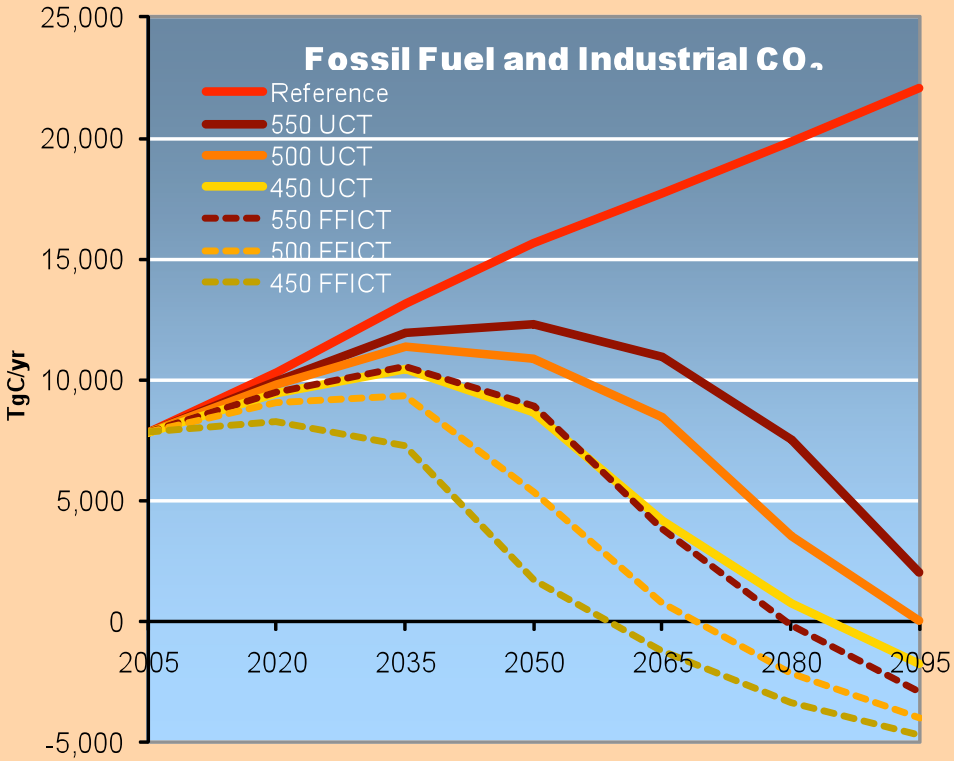
The Global Human and Natural Earth Systems Are Highly Integrated and Non-Linear

- To illustrate this we integrated four models into an integrated Earth System Model (iESM):
  - GCAM human systems,
  - The Global Land Model (GLM),
  - The Community Land Model (CLM),
  - The Community Earth System Model (CESM).
- We ran the Wise, et al. (2009) experiment
  - A common CO_2 concentration limit
  - Two alternative policy architectures
    - UCT = universal carbon tax—all carbon counts
    - FFICT = fossil fuel & indus. carbon tax—only FFI counts

Bioenergy with CCS and land use policy

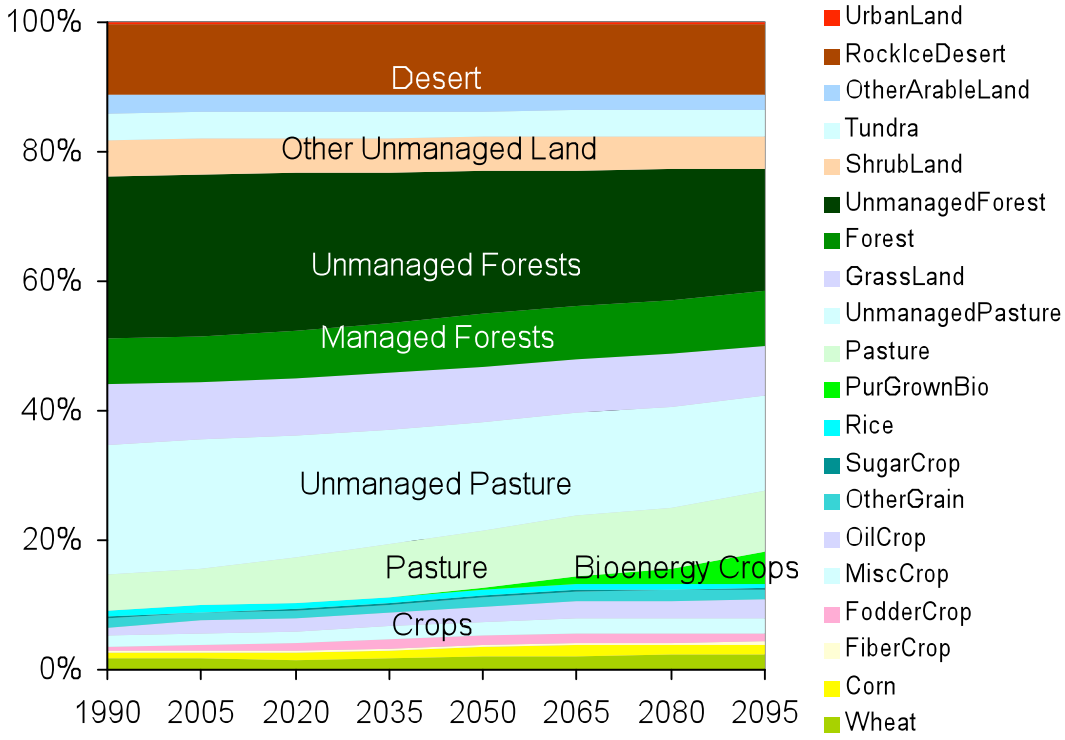
- Net carbon removal from the system can be large.



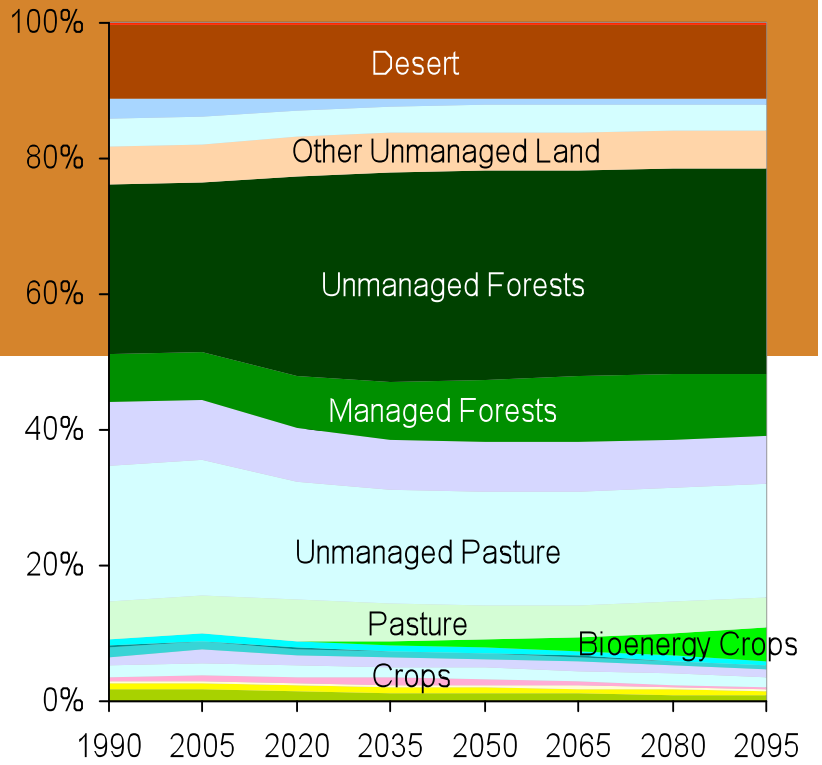


Lower FF emissions are needed in FFICT regime to offset land use change emissions

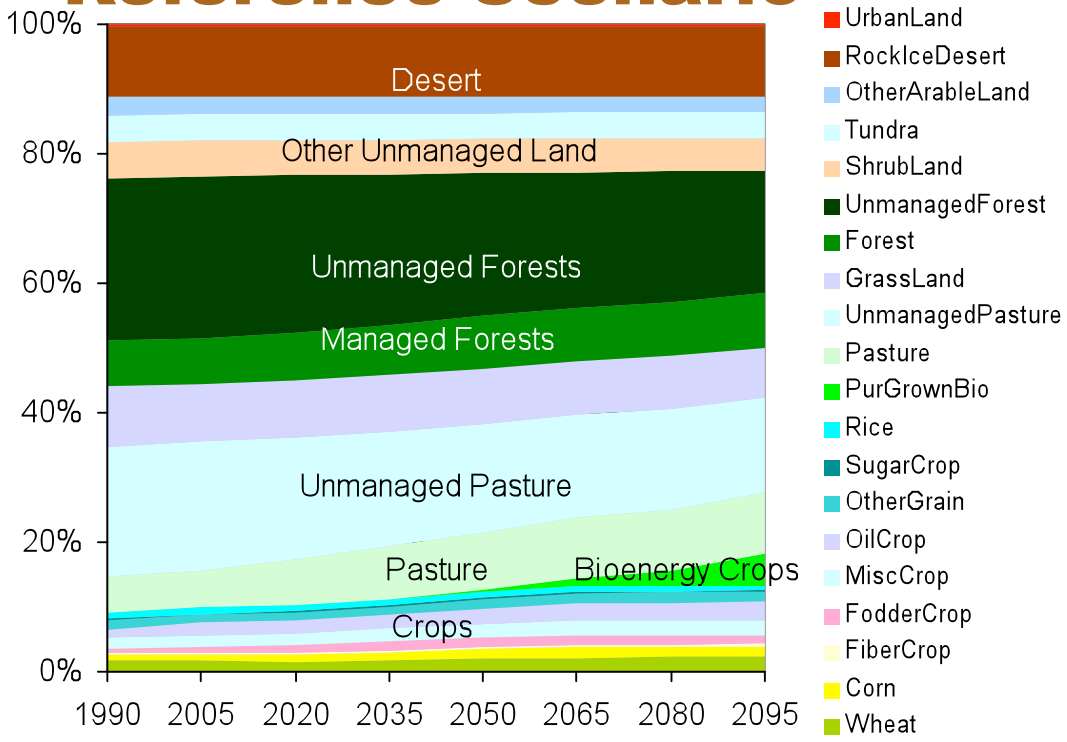
The Wise, et al. (2009) experiment

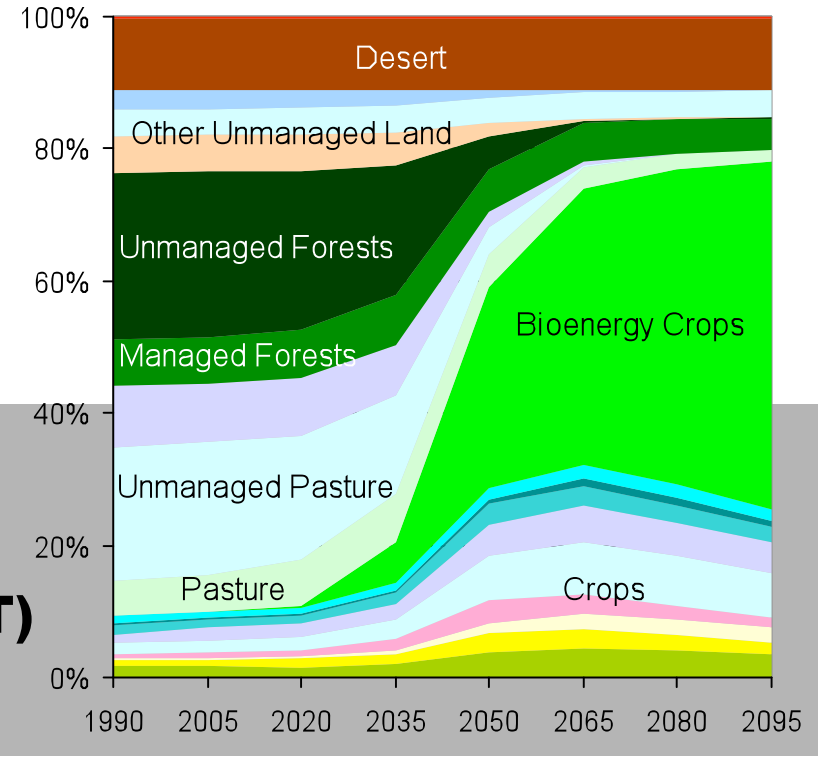


450 ppm Stabilization Scenario When ALL Carbon is Valued (UCT)



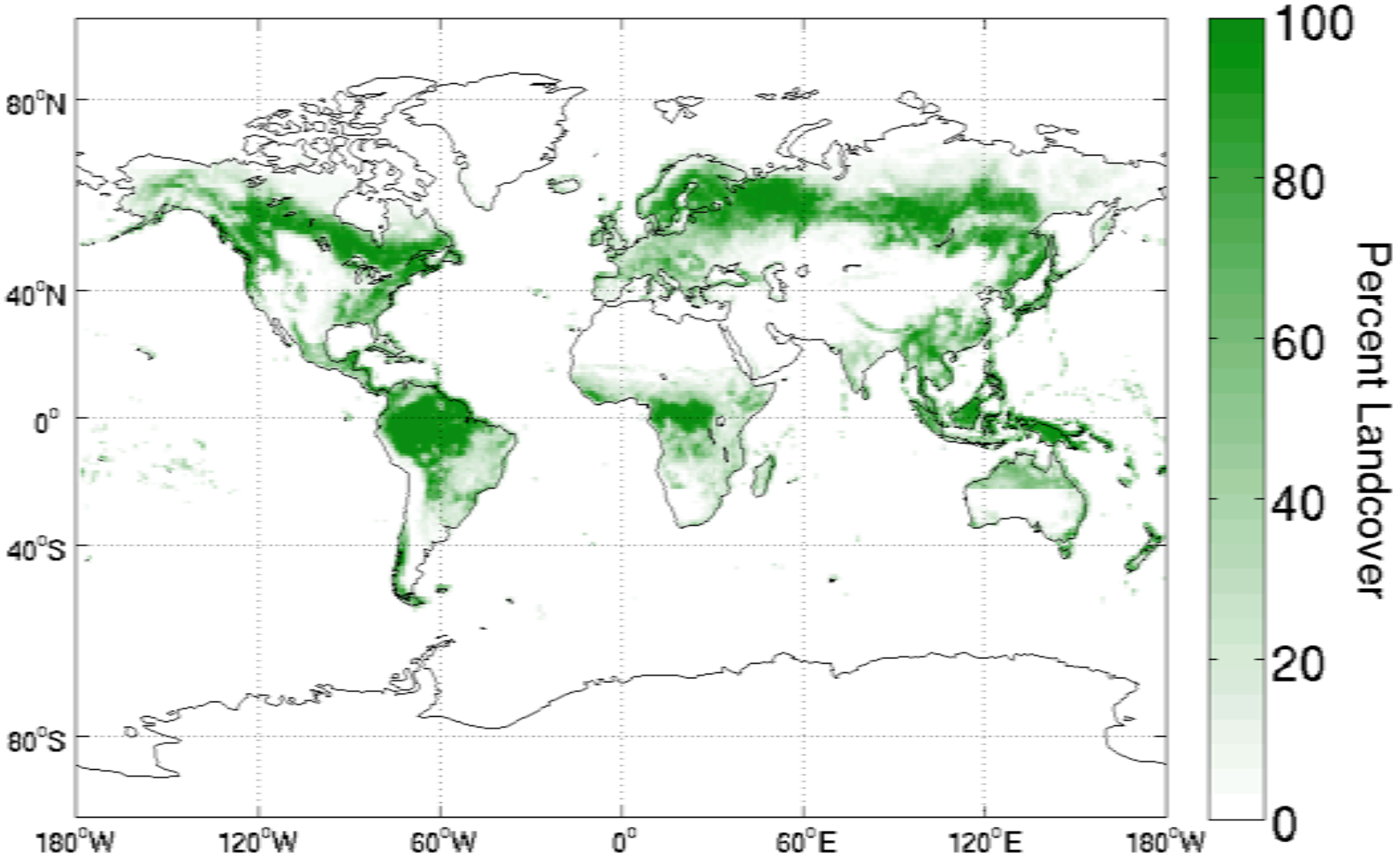
Reference Scenario





450 ppm Stabilization Scenario When Terrestrial Carbon is NOT Valued (FFICT)

Forest Cover 2005

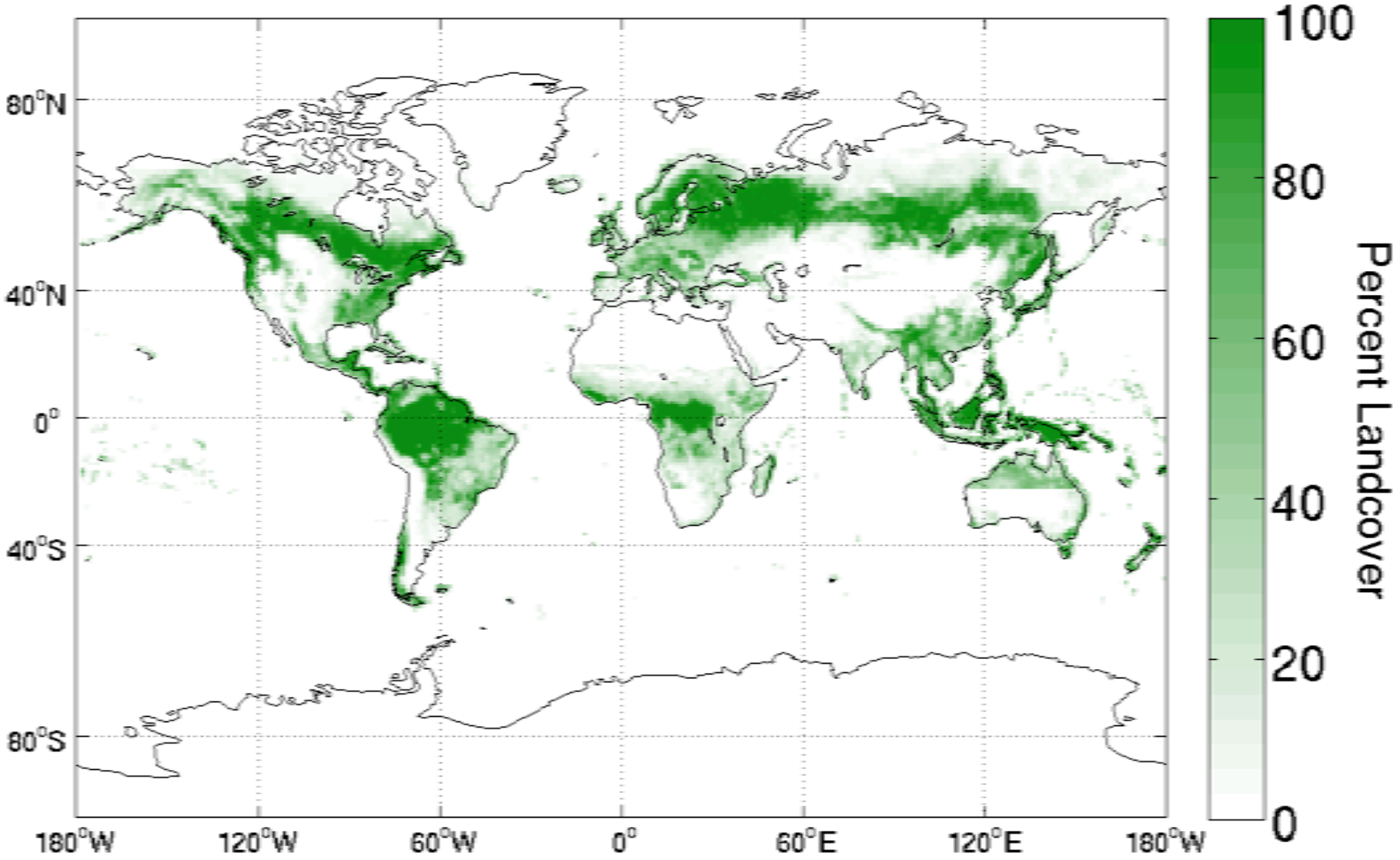


PRELIMINARY RESULTS

Andy Jones, LBNL

BERKELEY LAB

UCT 4.5Wm^{-2} RCP: Forest Cover in 2100

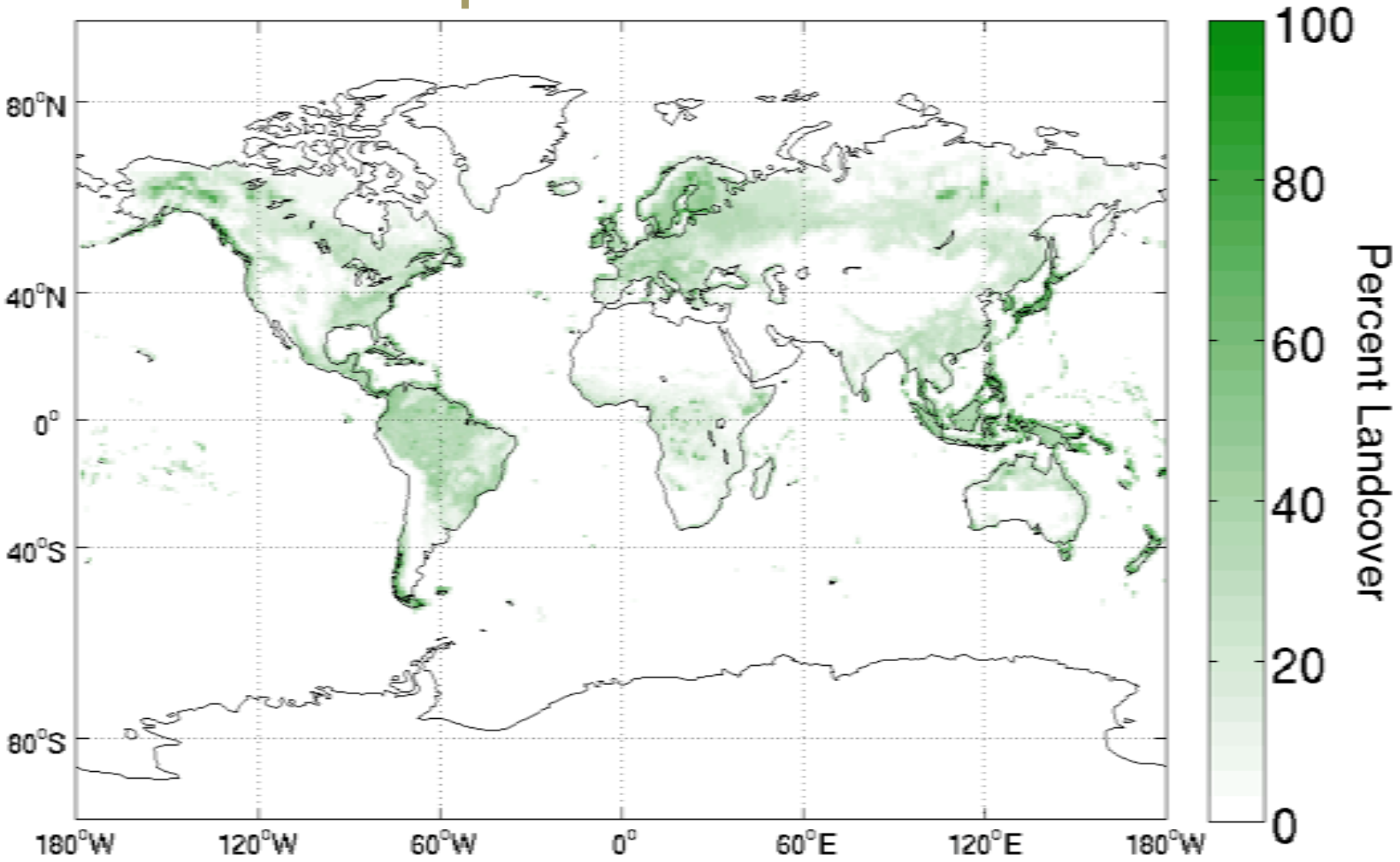


PRELIMINARY RESULTS

Andy Jones

BERKELEY LAB

FFICT 4.5 Wm^{-2} Replication: Forest Cover in 2100



PRELIMINARY RESULTS

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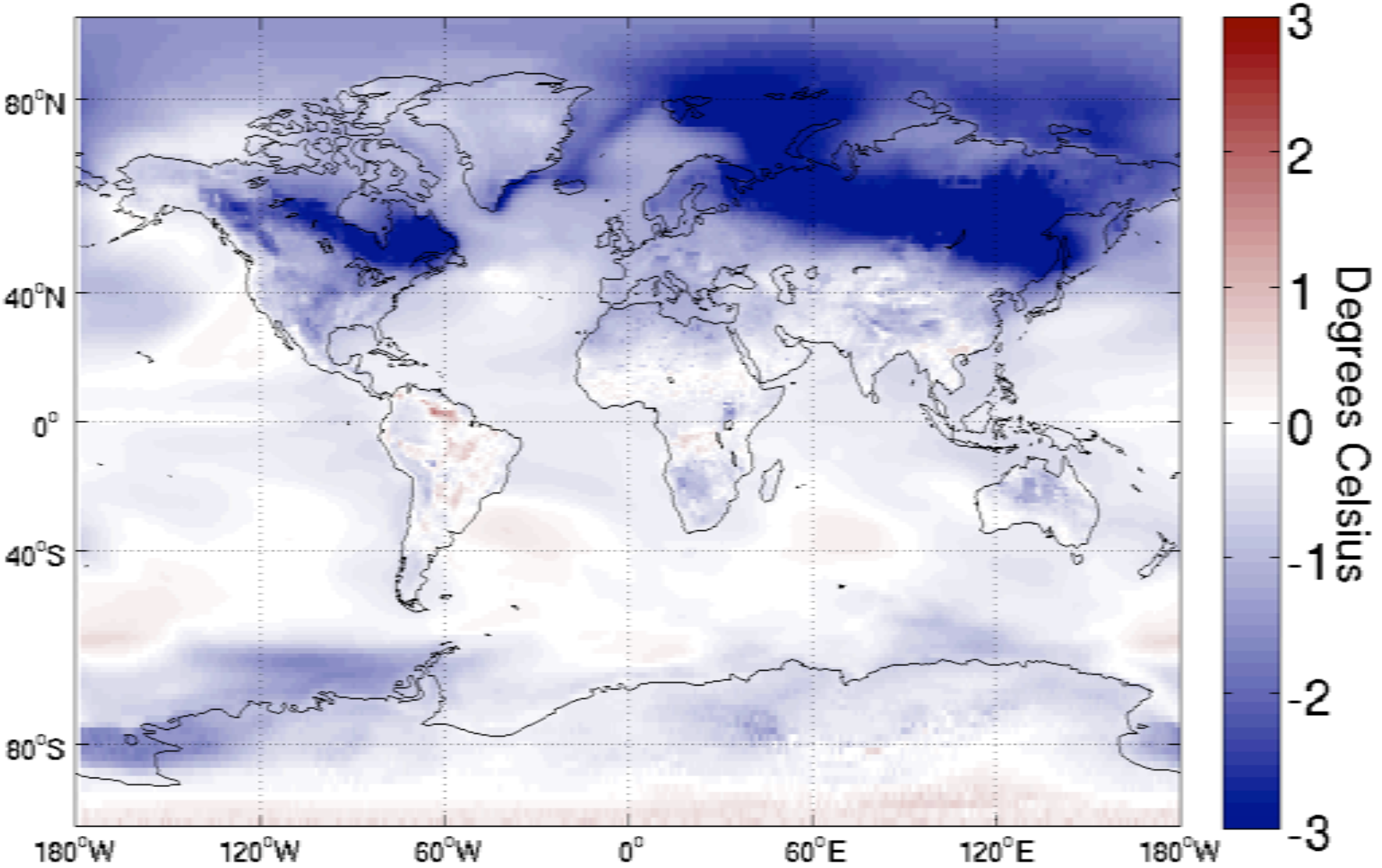
FFICT-UCT ($4.5Wm^{-2}$), Annual Average Temperature Difference: 2090-2100



PRELIMINARY RESULTS

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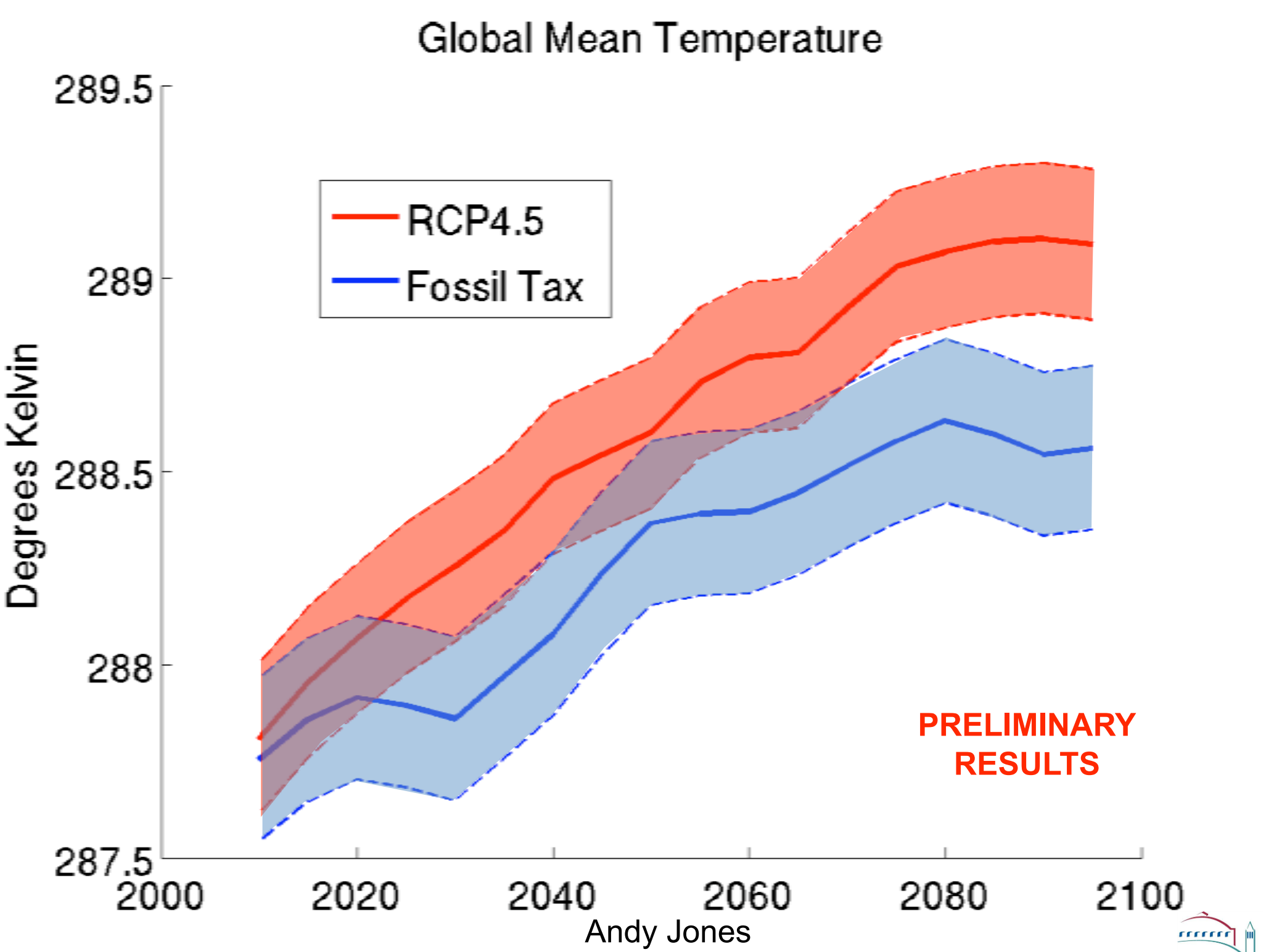
Global Mean Temperature
289.5
289
288.5
288
287.5
Degrees Kelvin
RCP4.5
Fossil Tax
PRELIMINARY
RESULTS
2000
2020
2040
2060
2080
2100
Andy Jones

WATER

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Water

- Water is not fully integrated into any of the present generation of IAMs, though most major IAM programs have some elements of water incorporated.
- Better representations of fresh water supply and use could yield important new results and improved understanding.
  - There can be some very large changes in land use and land cover as a consequence of changes in the number of humans, their income levels, and the activities that they pursue.
  - Terrestrial systems need fresh water
    - Precipitation (**Green water**)
    - Runoff (lakes and rivers) & ground water (**Blue water**)
  - Climate change can alter the amount, timing, and reliability of fresh water (both **Green** and **Blue**).

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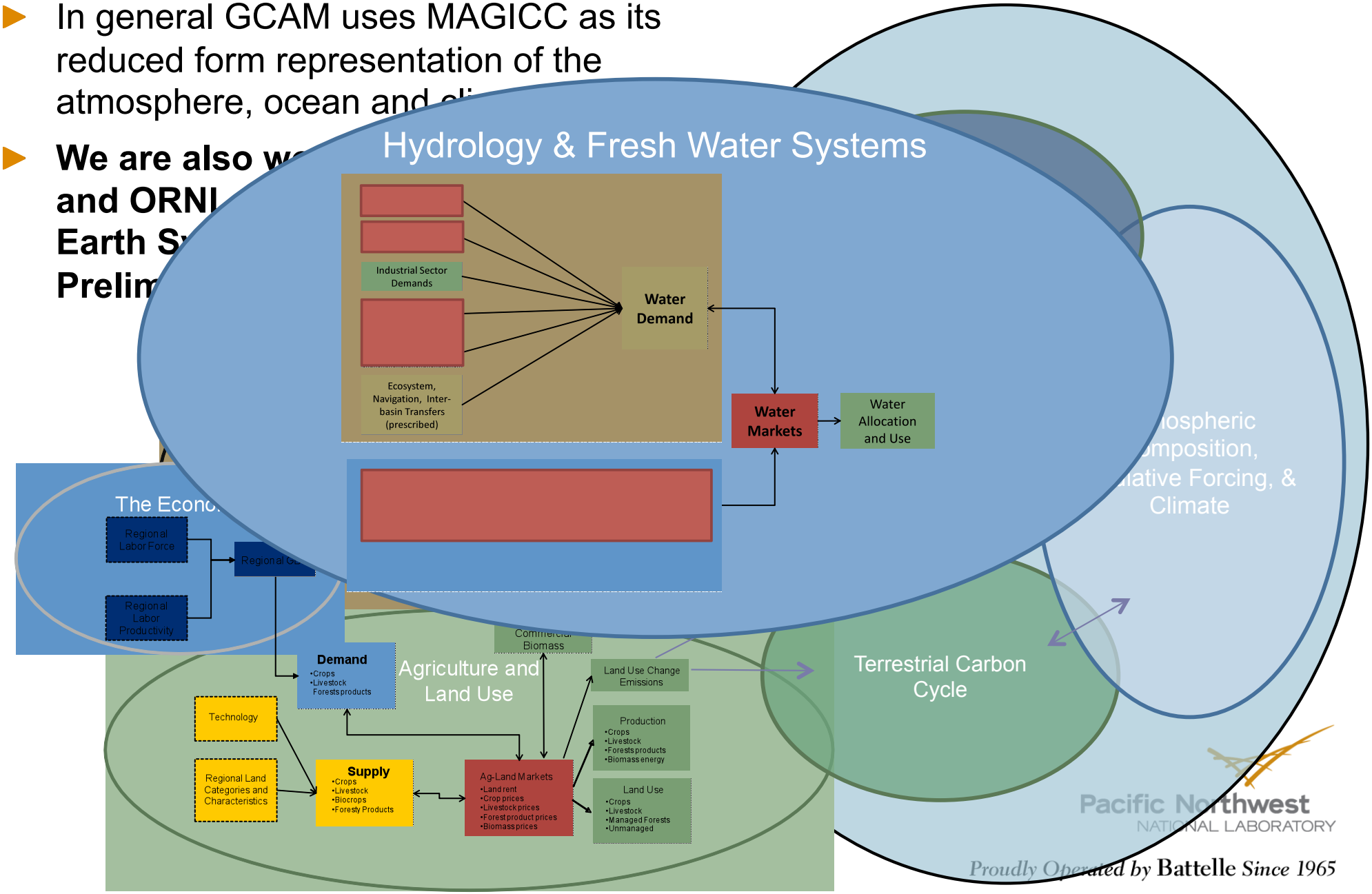
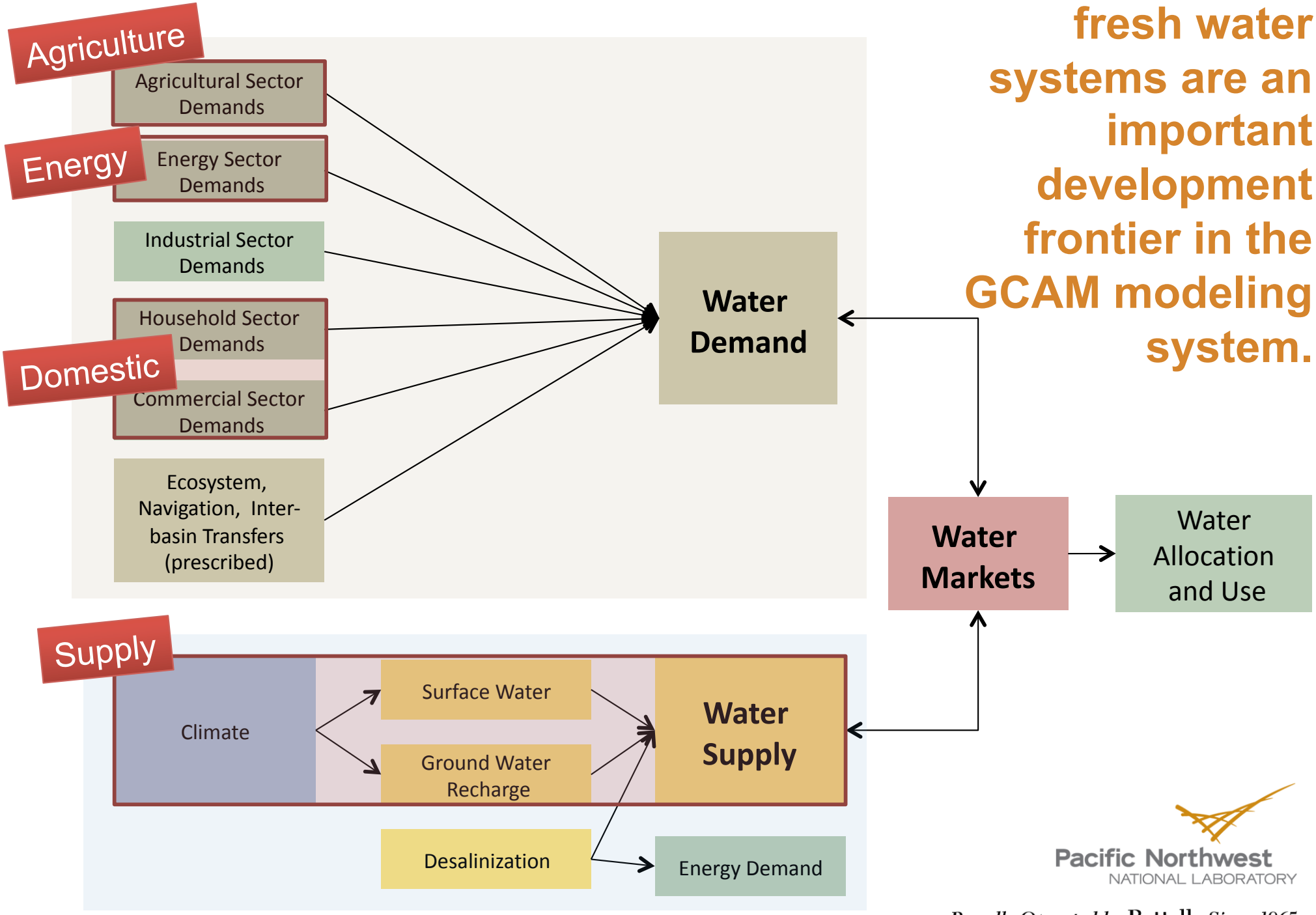


Hydrology and fresh water systems are an important development frontier in the GCAM modeling system.



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Some Preliminary Observations from GCAM Water Systems Research

- Agriculture is the largest user of water (70% withdrawals; 85% consumption).
- Developing countries demands for water can be expected to grow over time, particularly in the first half of the century.
- Energy systems need water—large source of withdrawals, much smaller consumer.
- Cooling water demands for power generation (the largest energy user of water) can be expected to grow in the future, particularly in the developing world.
- Emissions mitigation could increase water demands (relative to a no-mitigation scenario, particularly if CCS is available.
- New cooling technologies could dramatically reduce fresh water withdrawals, but increase fresh water consumption.

Where to from here?

- What are the high priority goals for model development?
- What are the high priority goals for analysis?

DISCUSSION