Capabilities and gaps in integrated human-earth system modeling at the energy-water-land nexus

Scientific Drivers, Needs, and Trends
From DOE-ESM perspective

Dorothy Koch
Earth System Modeling
Climate and Environmental Sciences Division
Office of Biological and Environmental Research

July 25, 2016
Interests for DOE & Climate/Earth System Modeling

First goal is to improve climate model fidelity and projection capability. How does human activity (E-W-L) affect climate?
Mainly IAM -> ESM

- **Energy:** greenhouse gases and short-lived (aerosol-ozone) precursors affect radiative balance, temperature, precipitation, clouds, snow-albedo, ecosystems
- **Land:** land-use and land-cover affect albedo, carbon and energy fluxes
- **Water:** water use (withdrawals, irrigation) affects hydrology, energy-fluxes, albedo

Second goal is to “predict” how climate will influence energy (and related societal activities)
Mainly ESM -> IAV

- Changes to extremes (floods, droughts, storms, heat waves) impacts on infrastructure
- Sea-level change and storm surge – impacts to coastal infrastructure
- Shifts in water, wind, solar availability for energy
IAMs, LULC and ESMs

Standard approach is 1-way, with IAM providing emissions and LULC providing surface-types to ESMs.

Concerns and considerations:
- Are the assumptions in the IAM and the ESM consistent, do they need to be?
- Multiple IAMs: For specific source attribution, care in IAM assumptions and consistency is needed. For example, effects of coal-power-plants for RCP8.5 and RCP2.6?
- When and how are feedbacks from ESM to IAM important? E.g.:
  - Limitations on water availability influence energy pathway
  - Drought/fire/migration affect Land-use, land-cover, energy projections
iESM, the integrated Earth System Model project

iESM project 2009-2013, Edmonds, Collins, Thornton
iESM code to be released soon!
iESM hard-coupled GCAM and CESM
- What is coupled: 2-way feedbacks between land-use
- Challenges: land configuration differences among GCAM-land, GLM and CLM made coupling difficult (treatment of crops, forests, etc)
- What was found: climate feedback (CO2 fertilization particularly) increased land productivity, so e.g. biofuel productivity is more efficient for higher-RCP

What is not yet coupled in iESM but could be:
- Carbon cycle
- Atmospheric species – feedbacks in chemistry-climate affect emissions (Lamarque)
- Water

Questions:
- Is it meaningful to link a single climate model to a single IAM, given the uncertainties in each?
- Are the errors that result from off-line approach large enough to warrant hard-coupling, given all the other uncertainties in the IAM and the ESM?
  
  Careful sensitivity analysis should first justify the effort of coupling
- How to couple short-term ESM events (e.g. extremes) back to the IAM?
Earth System Model and IAV

For which impacts problems do we need full Earth System Model?
• Extremes effects on infrastructure
• Sea-level/storm effects on coasts
• Water availability for energy
• Changes to wind, solar for energy

Is there ever a reason for 2-way coupling, rather than just saving ESM output?
• What ESM output is needed, are models saving the correct diagnostics?

How good does the ESM need to be?
• Is statistical tendency sufficient, or must the models attain “forecast-mode”? 
New directions for ESM development?

Are there new ways to develop ESM’s to make them easier to couple with IAMs or IAV models?

Should we be deliberately co-developing IAM, ESM, IAV?
E.g.:
- Same crops, agricultural practice
- Same land-types

Design specific diagnostics in the ESM for IAV or IAM e.g.:
- Energy use based on temperature
- Reservoir levels

Design of scenarios to address questions, with ESMs, IAMs, IAV all in mind?

Other ideas?

Begin with the questions to be addressed…
Thank you!

Dorothy Koch, Program Manager
Earth System Modeling, BER
Dorothy.Koch@science.doe.gov
http://www.climatemodeling.science.energy.gov/