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

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

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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?

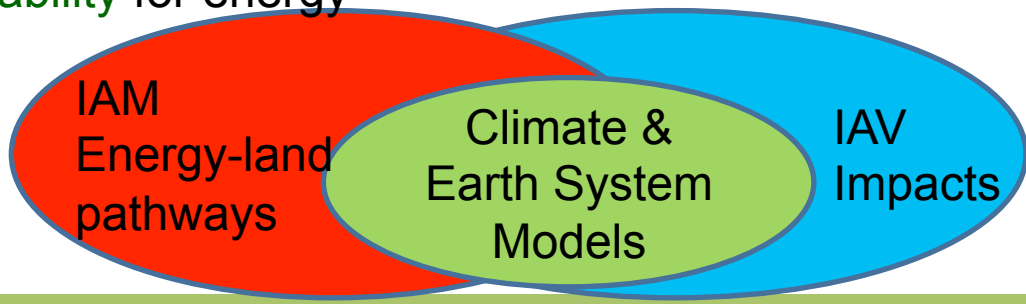
Mainly IAM -> ESM

- **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

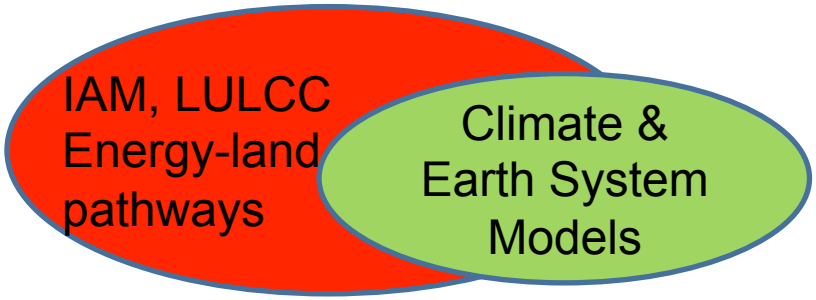


IAMs, LULC and ESMs

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?

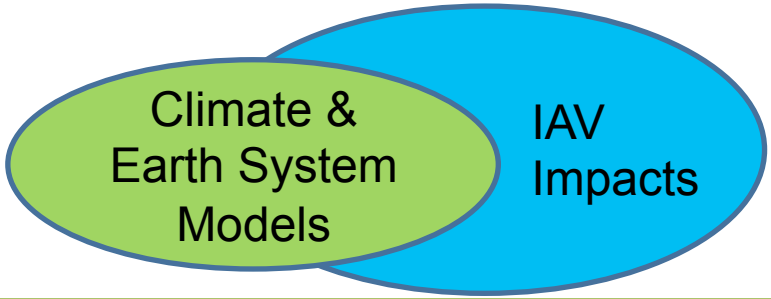
- Extremes effects on infrastructure
- Sea-level/storm effects on coasts
- Water availability for energy
- Changes to wind, solar for energy

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?

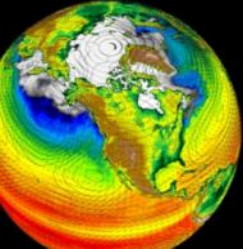
Should we be deliberately co-developing IAM, ESM, IAV?
E.g.:
- Same crops, agricultural practice
- Same land-types

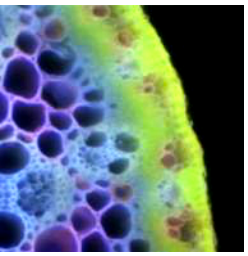
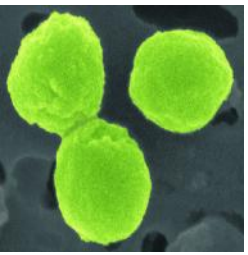
Design specific diagnostics in the ESM for IAV or IAM e.g.:
- Energy use based on temperature
- Reservoir levels

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

Other ideas?

Begin with the questions to be addressed…



Thank you!

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