Earth & Environmental Systems Modeling

J. Strengthening EESM Integrated Modeling Framework – Towards a Digital Earth

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What are the grand challenges in advancing the research on this topic?

Digital Earth:

- How is a 'Digital Earth' different than what we are doing now? (a) Better use of observations for initialization, evaluation, OSSEs, and data driven modeling (b) integration with human systems and stakeholder needs, (c) flexibility and repeatability
- Digital Earth is a framework that likely will be configured uniquely (flexibly) for a specific purpose. Should pick a few examples to start with (Urban, Coastal Flooding, Energy sector) to build out the concept.

High-Resolution Integrated Modeling:

- How do we balance computational efficiency with model fidelity?
- Need better observations at the right scales to evaluate and understand extremes
- Data assimilation can improve processes, understand uncertainty, not just for prediction
- Model parameterizations need to respond appropriately across scales.
- Incorporate instrument simulators to compare to data, guide future campaigns
- Documentation fuels AI to enable some automation of model setup and running.

What are the gaps in research / infrastructure / coordination that prevent advances?

- Human-side of a Digital Earth: We need advances in methods for effectively coupling multisector models with climate system models. More two-way coupling on human-system relevant timescales
- Data volumes and required variables: CMIP model of run once and save everything does NOT scale at high resolution or across human sectors.
- Fit for purpose simulations will require flexible configuration for specific applications. Flexible but robust tools for coupling (loose or strong) of diverse models of the human system across scales, (e.g. ESMs and watershed models) or across sectors (e.g. water system models, energy grid models). Can we build infrastructure that ENABLES coupling (not do it for everyone).

What opportunities exist to overcome each of those gaps?

Digital Earth:

- Very few Digital Earth applications require a global solution: Focusing on regional and sector-specific results with appropriate complexity is a good way forward.
- Identify a few early test cases that we could utilize to test candidate frameworks for a Digital Earth (e.g., testing in specific urban environments with use cases informed by stakeholder engagement from the Urban IFLs).
- Expanded investment in hardened, robust, and reusable software infrastructures. These tools accelerate the science and reduce the need for technical experts.

High-Resolution Integrated Modeling:

- Going to higher resolution allows us to develop and test new physics parameterizations such as those that would be needed to simulation wildfire dynamics.
- Develop unified ways to compare models to observations in areas where existing instrument simulators no longer work (Emulation can assist simulator and process model development)
- Take advantage of hierarchy of models (e.g., emulators to process models to model hazards and impacts in GCAM & E3SM at the right scales)