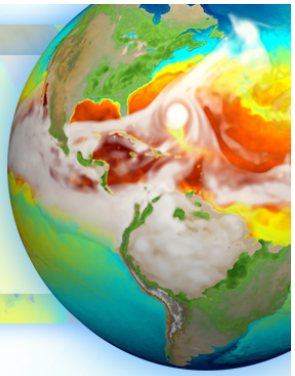


E3SM Next Generation Development (NGD): Land and Energy

Ben Bond-Lamberty

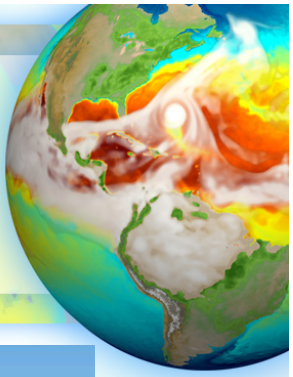
(on behalf of many)

E3SM Project Review – November 9-10, 2020

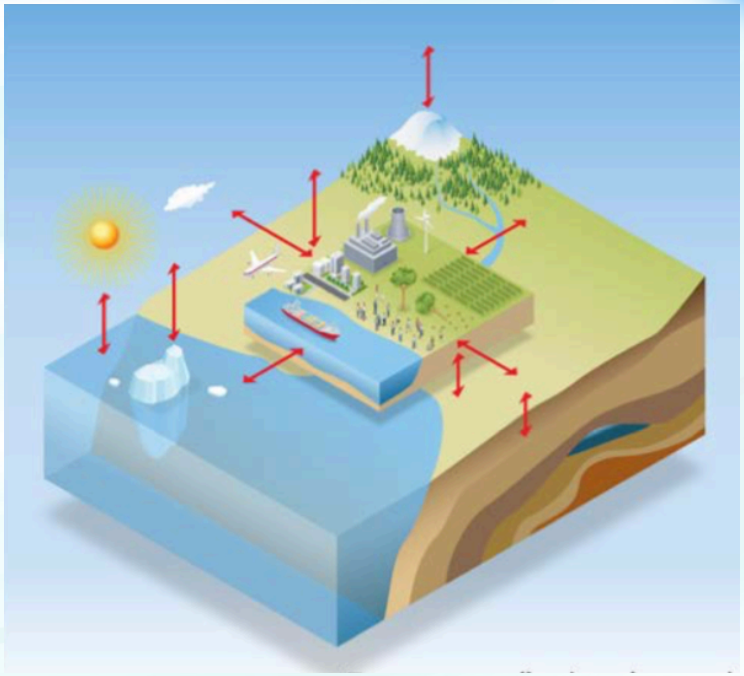
E3SM Energy Exascale Earth System Model

U.S. DEPARTMENT OF ENERGY

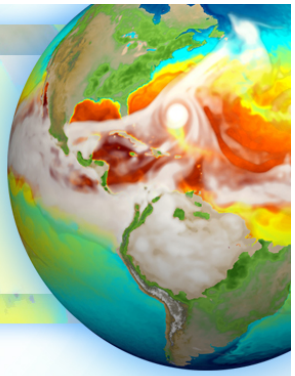
v3/v4 science questions

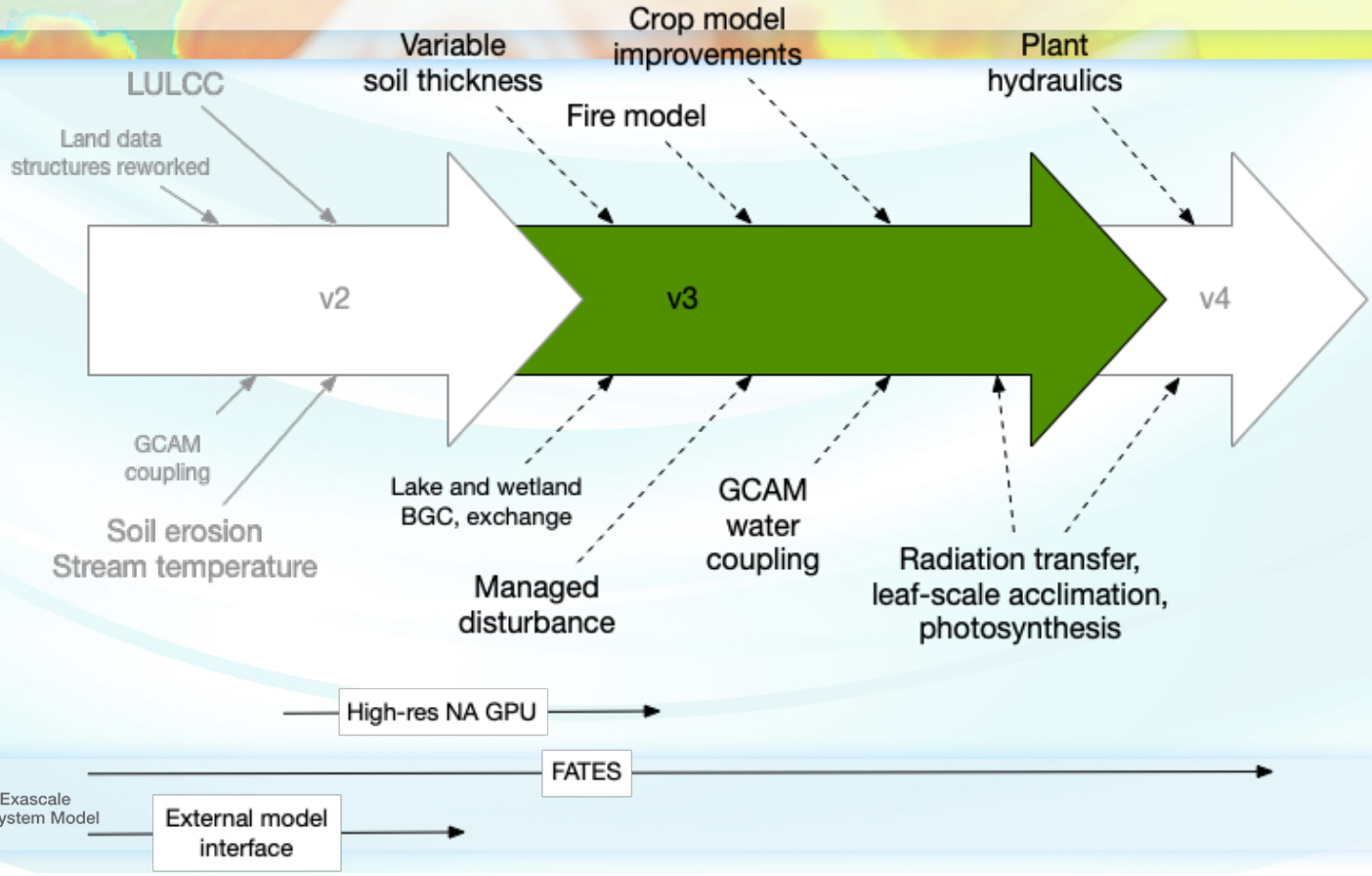


- **Water cycle**: How will the moisture sources and precipitation over land change?
- **Biogeochemistry**: What are the impacts of different energy and land use on land biogeochemistry and terrestrial-aquatic processes?
- **Cryosphere**: What are the implications of sea level rise and extreme storms for coastal inundation?



Land-Energy NGD overview





E3SM Energy Exascale Earth System Model

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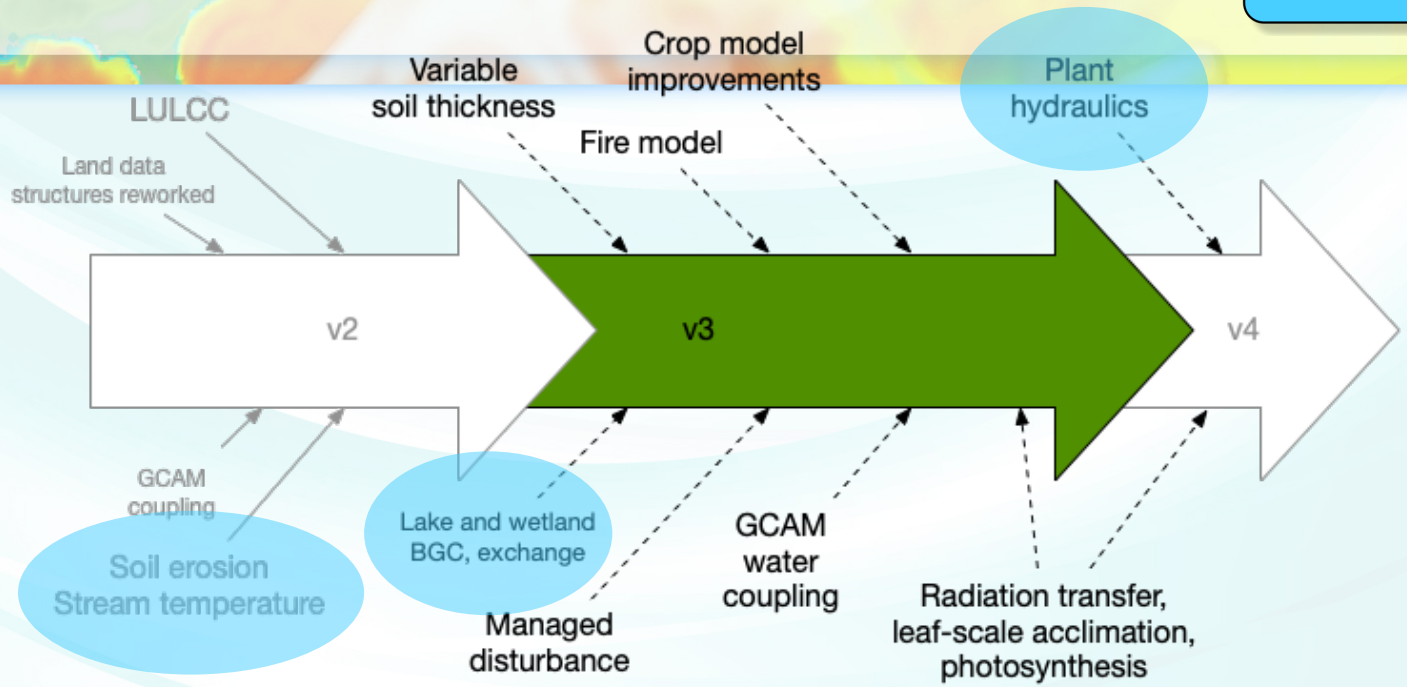
Land-Energy NGD overview

Hydrology and plant hydraulics
Water cycle
Cryosphere



High-res NA GPU

FATES

External model interface

E3SM Energy Exascale Earth System Model

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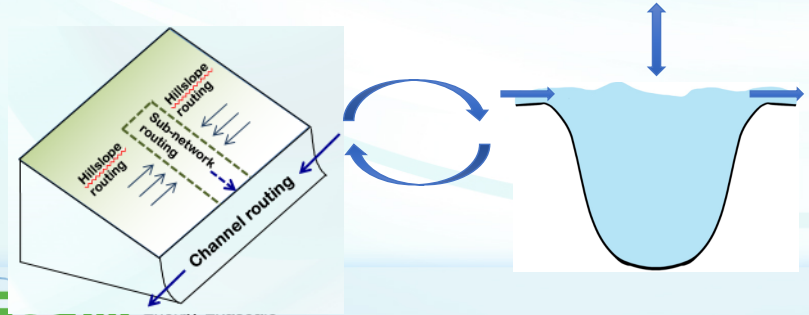
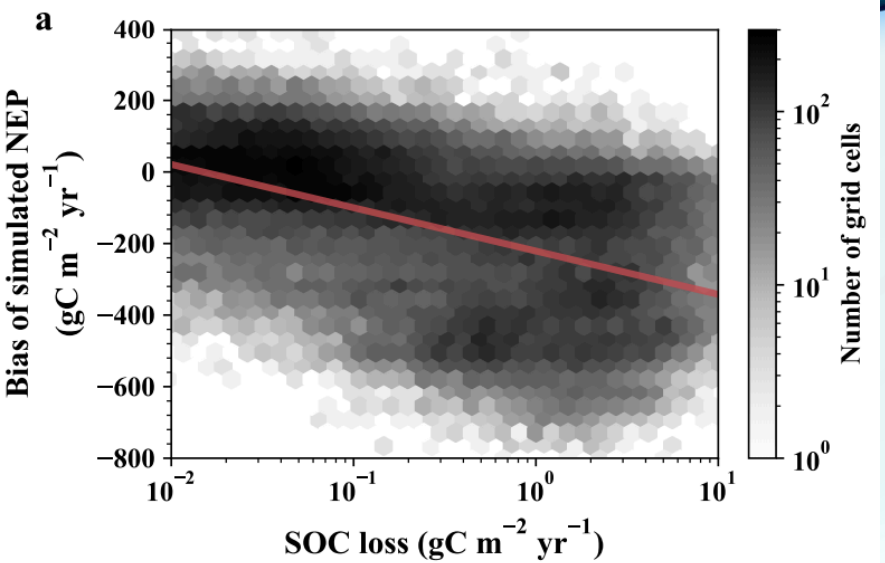
Progress - MOSART

Hydrology and plant hydraulics
Water cycle
Cryosphere

- MOSART-carbon, MOSART-lake, MOSART-wm etc. progressing on multiple fronts
- Papers on erosion, sediment transport, links with heterotrophic respiration in model



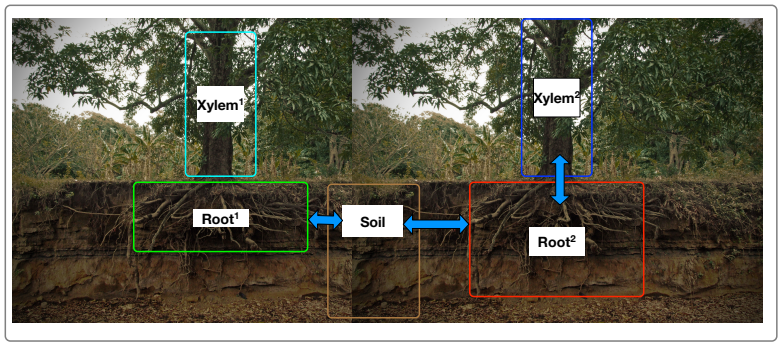


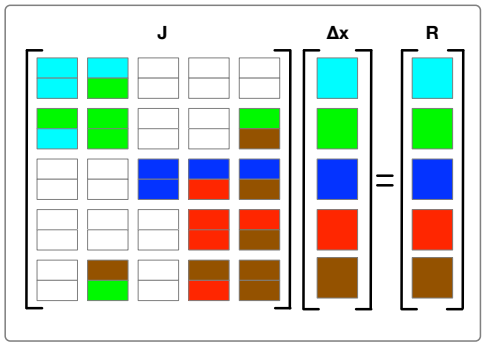
Tan et al. 2020 *Global Change Biology*

Development of a tree-level hydrodynamic model for ELM

Hydrology and plant hydraulics
Water cycle
Cryosphere

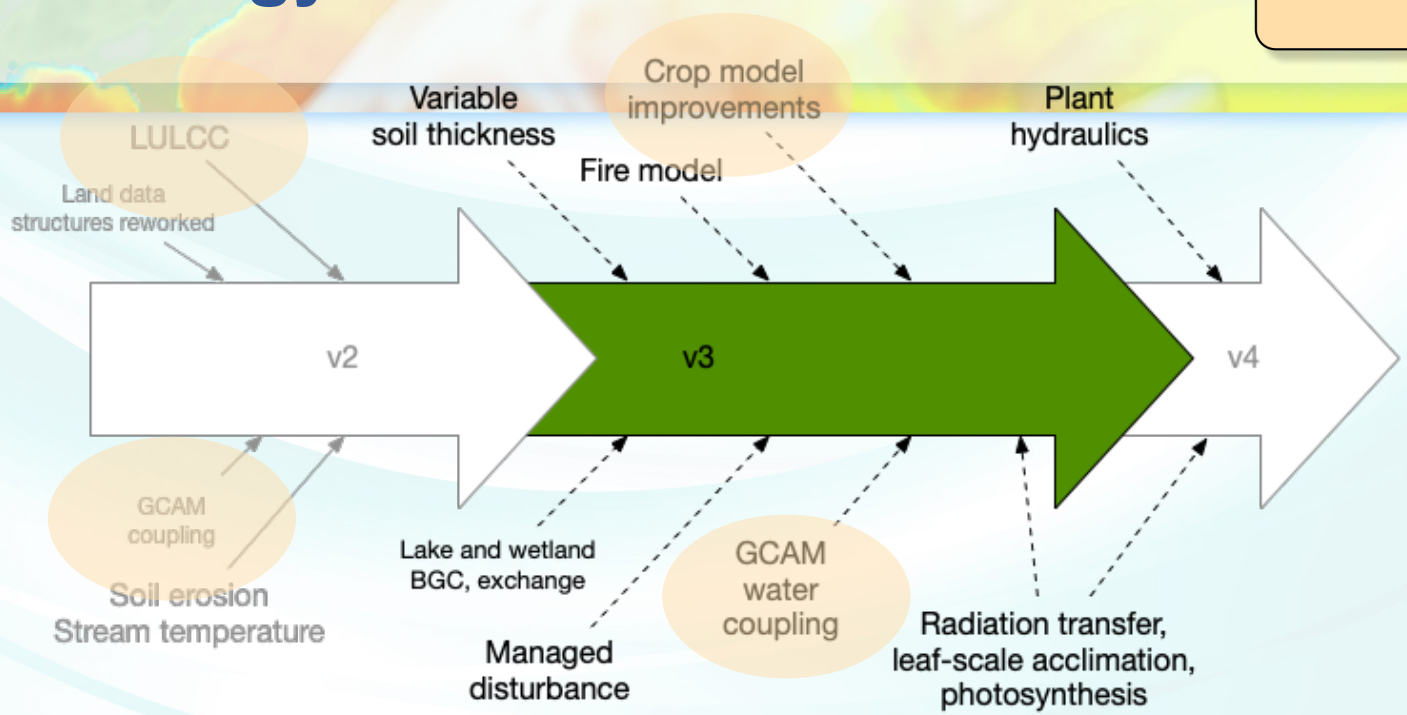
- Increasing vegetation mortality due to drought and temperature
- ELM-v1.0 excludes transport of water through vegetation structure and excludes competition for water
- Developed a tree-level hydrodynamic model that exploits PETSc's *DMComposite* to flexibly solve tightly coupled multi-physics problems





Land-Energy NGD overview

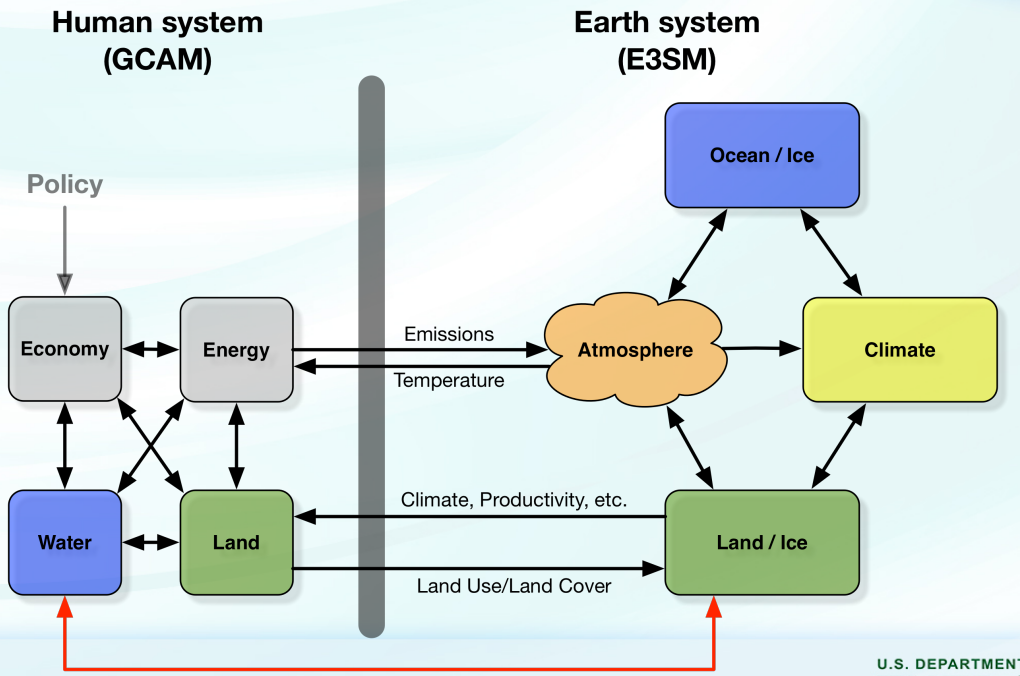
Land/energy
Water cycle
Biogeochemistry



E3SM-GCAM coupling

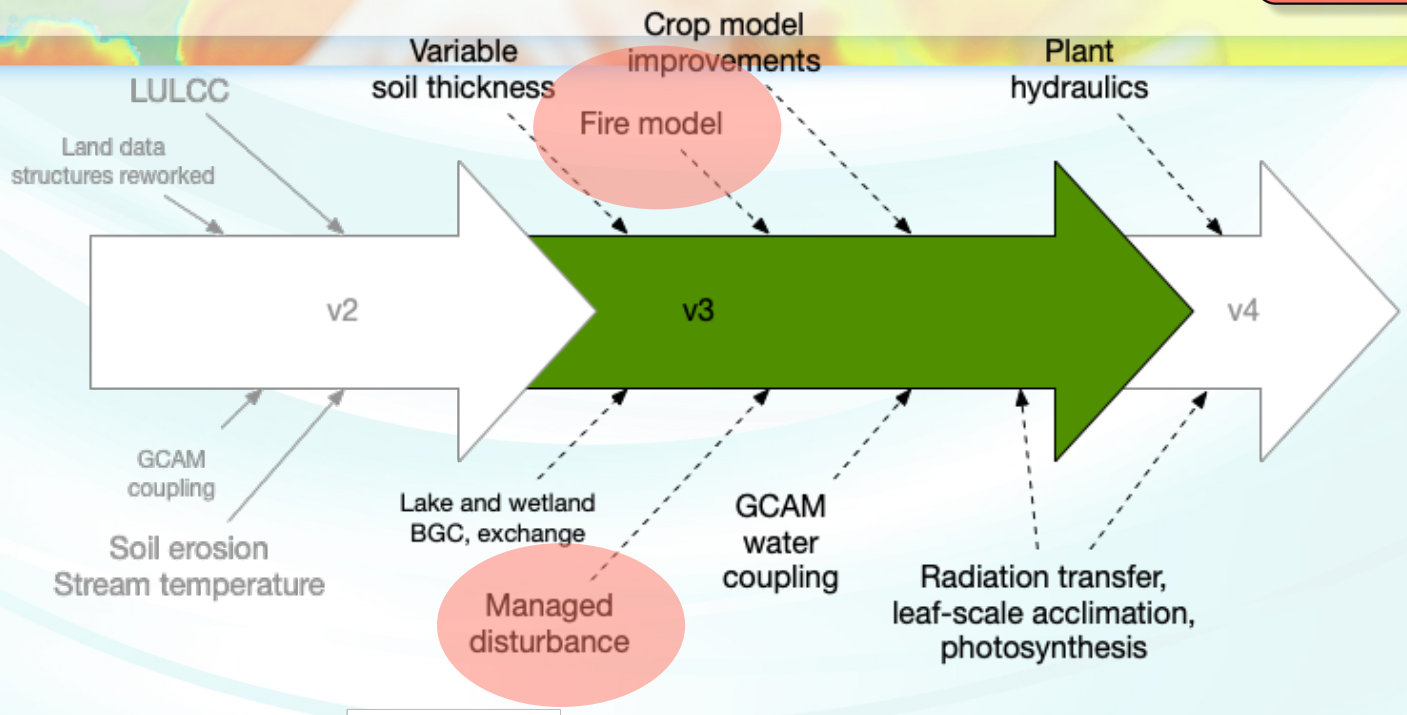
Land/energy
Water cycle
Biogeochemistry

- v2 (emissions) coupling finishing now
- For v3 (water) will want to step back and re-think approach and tools



Land-Energy NGD overview

Disturbances
Water cycle
Biogeochemistry



E3SM Energy Exascale Earth System Model

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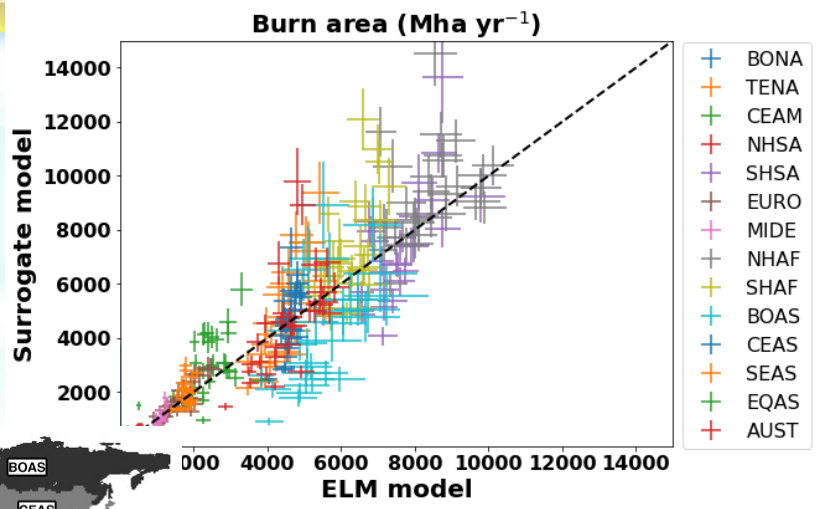
Improving and simplifying the ELM fire model

Disturbances
Water cycle
Biogeochemistry

- Improve realism, and simplify structure, of the fire model
- First manuscript: fire emission effects
- Second phase
  - improving the fire model with GFED observations
  - ML fire model

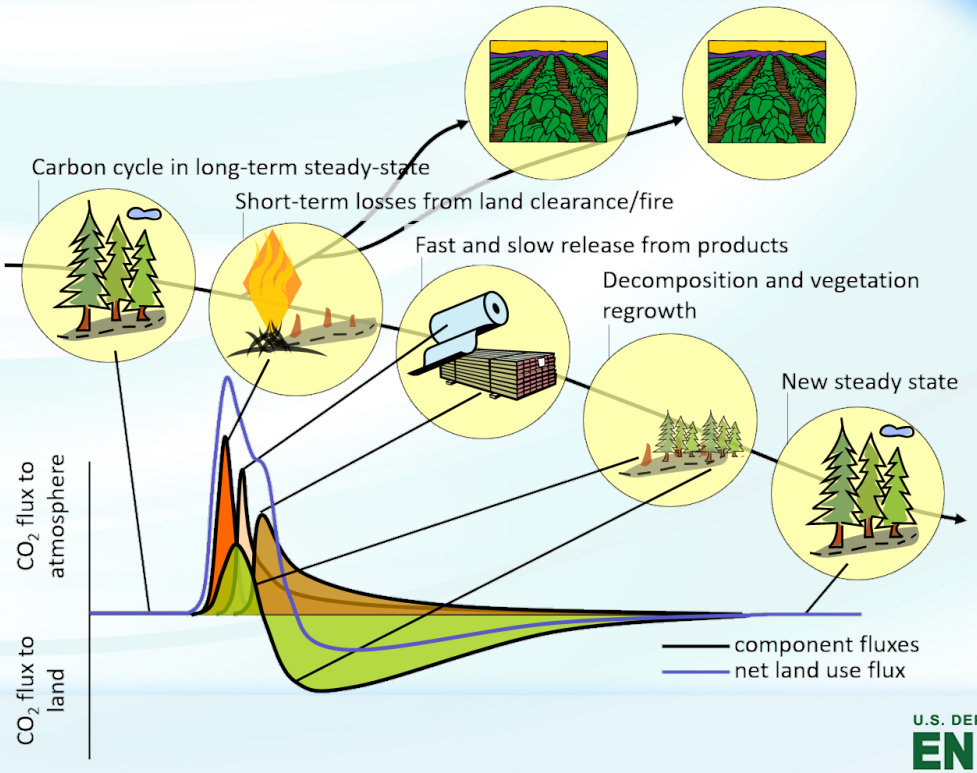


BONA	Boreal North America	NHAF	Northern Hemisphere Africa
TENA	Temperate North America	SHAF	Southern Hemisphere Africa
CEAM	Central America	BOAS	Boreal Asia
NHSA	Northern Hemisphere South America	CEAS	Central Asia
SHSA	Southern Hemisphere South America	SEAS	Southeast Asia
EURO	Europe	EQAS	Equatorial Asia
MIDE	Middle East	AUST	Australia and New Zealand

Managed disturbances

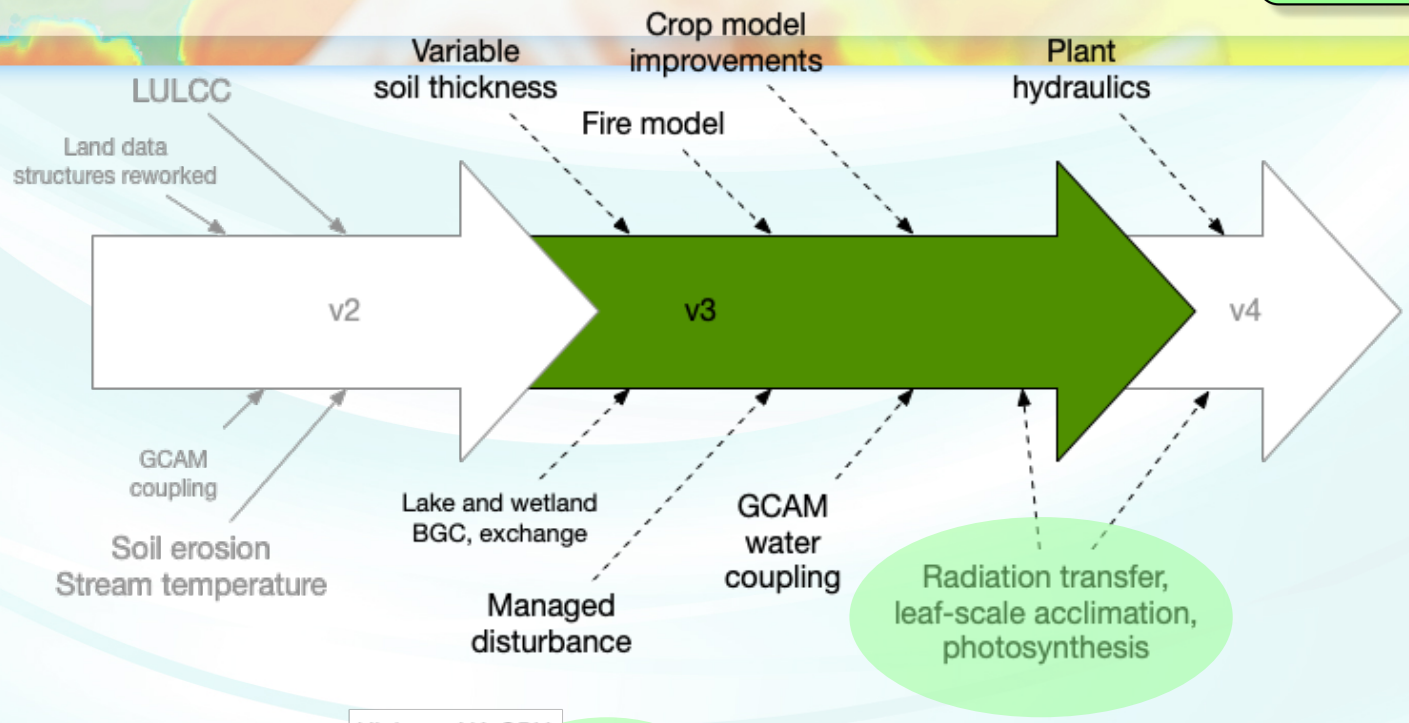
Disturbances
Water cycle
Biogeochemistry

- ORNL coordinating with ANL on the use of LUH2 classes at the landunit level, including crop classes



Land-Energy NGD overview

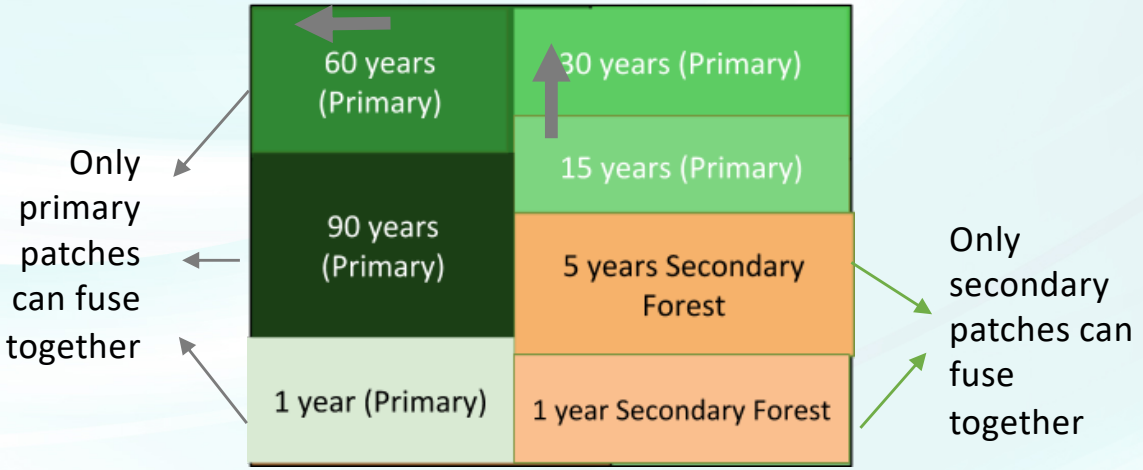
Vegetation dynamics
Biogeochemistry



First LULCC capabilities in ELM-FATES

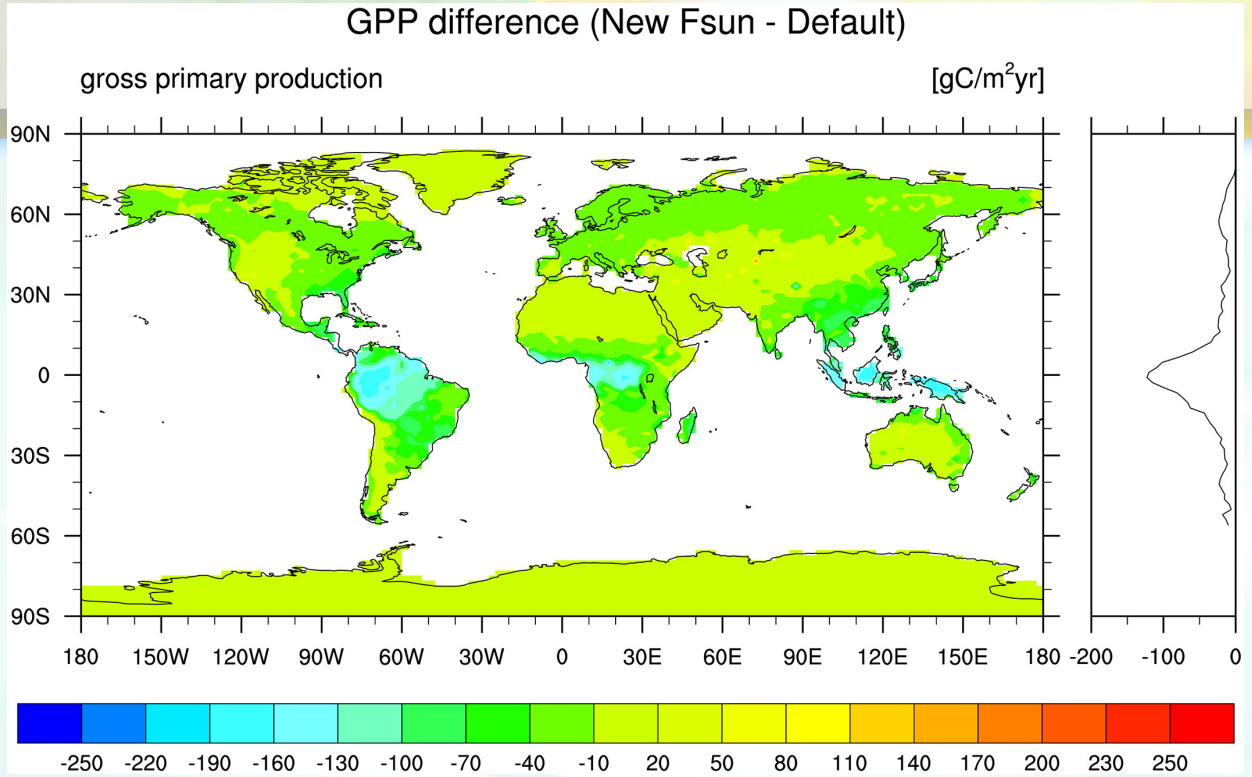
Vegetation dynamics
Biogeochemistry

- Working on getting harvest into FATES; one benchmark run completed and a global one in progress
- Testing global run on Cori: CN-Harvest works the same as before (FATES not active, just ran for a couple of years)
  - Currently regrowing forest for testing FATES harvest

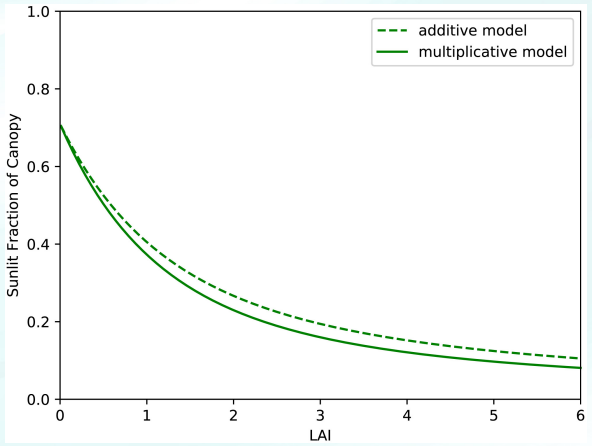


Canopy light and nitrogen scaling fix

Vegetation dynamics
Biogeochemistry

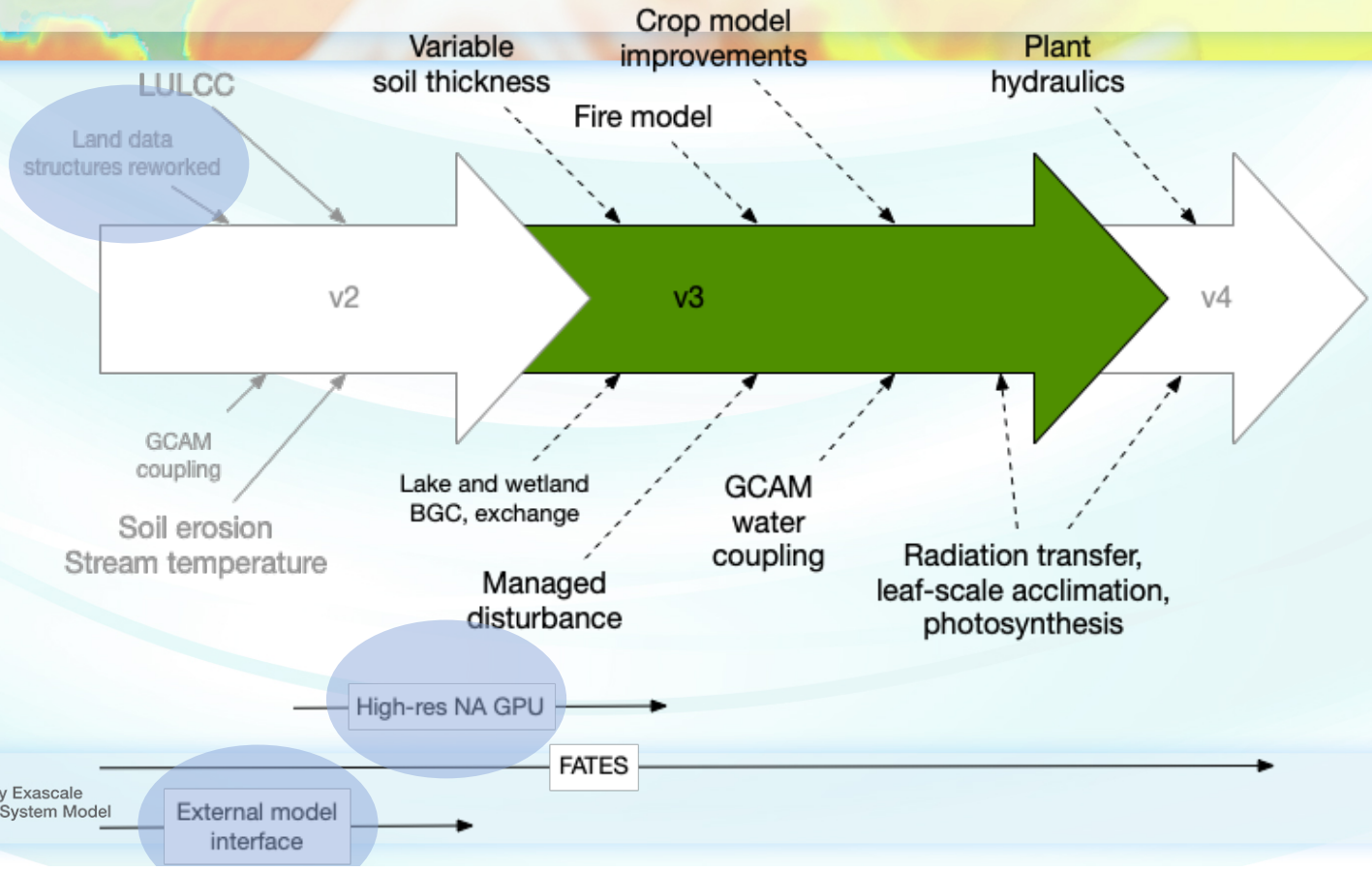


$$NSCALE_a^{Sun} = \frac{\int_0^{LAI} n_a f_{leaf}^{Sun} dl}{F_{Sun} LAI} = \frac{1 - e^{-(k_n + k_b)LAI}}{(k_n + k_b) LAI_{Sun}}.$$



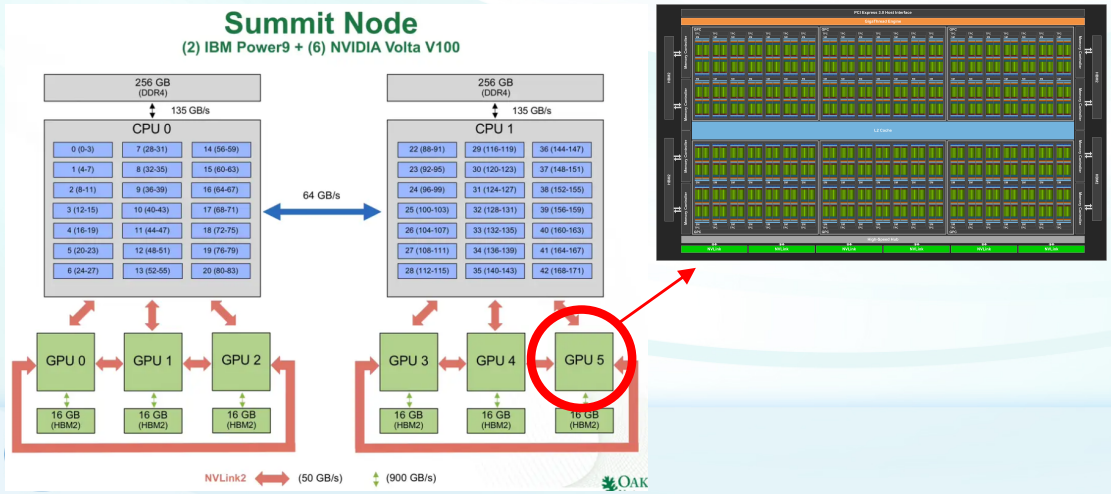
From Butler et al. (2020)

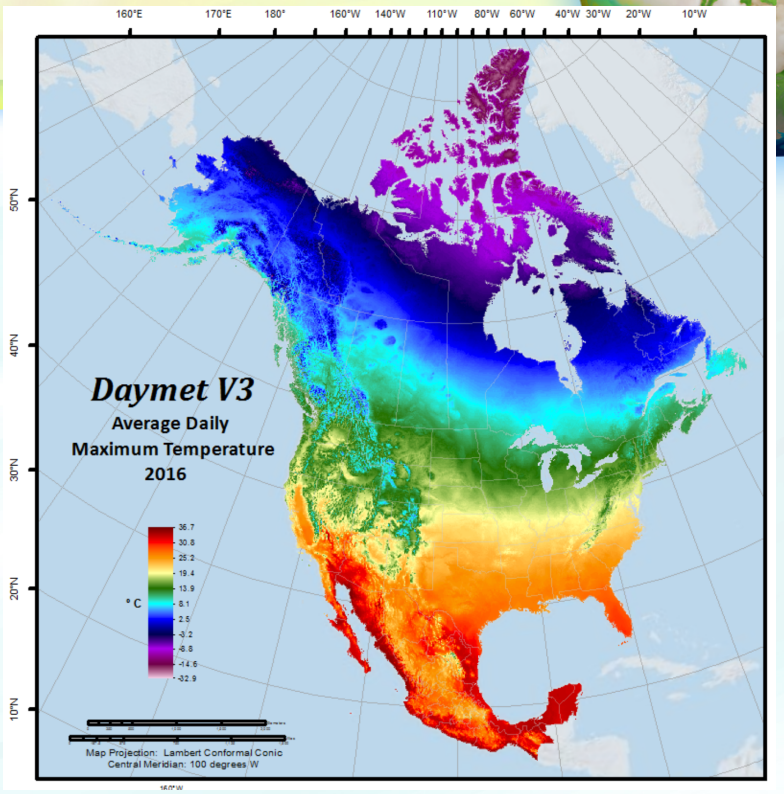
Land-Energy NGD overview



Target: 1 km^2 grid resolution over N. America

- Massively parallel ELM runs on Summit
- Refactoring, GPU performance optimization





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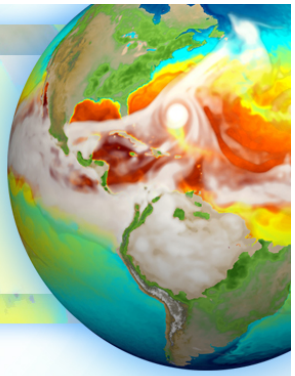
Summary



- Developments linked to v3/v4 science questions, targeting needed capabilities
  - Hydrology and plant hydraulics
  - Land/energy
  - Disturbances
  - Vegetation dynamics
- Leveraging machine learning
- Data structure and interface changes enabling new capabilities
- Exploring high-resolution NA run using Summit GPUs