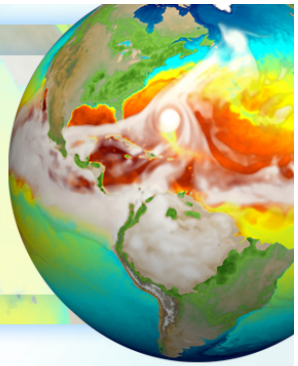
Energy Exascale Earth System Model Project



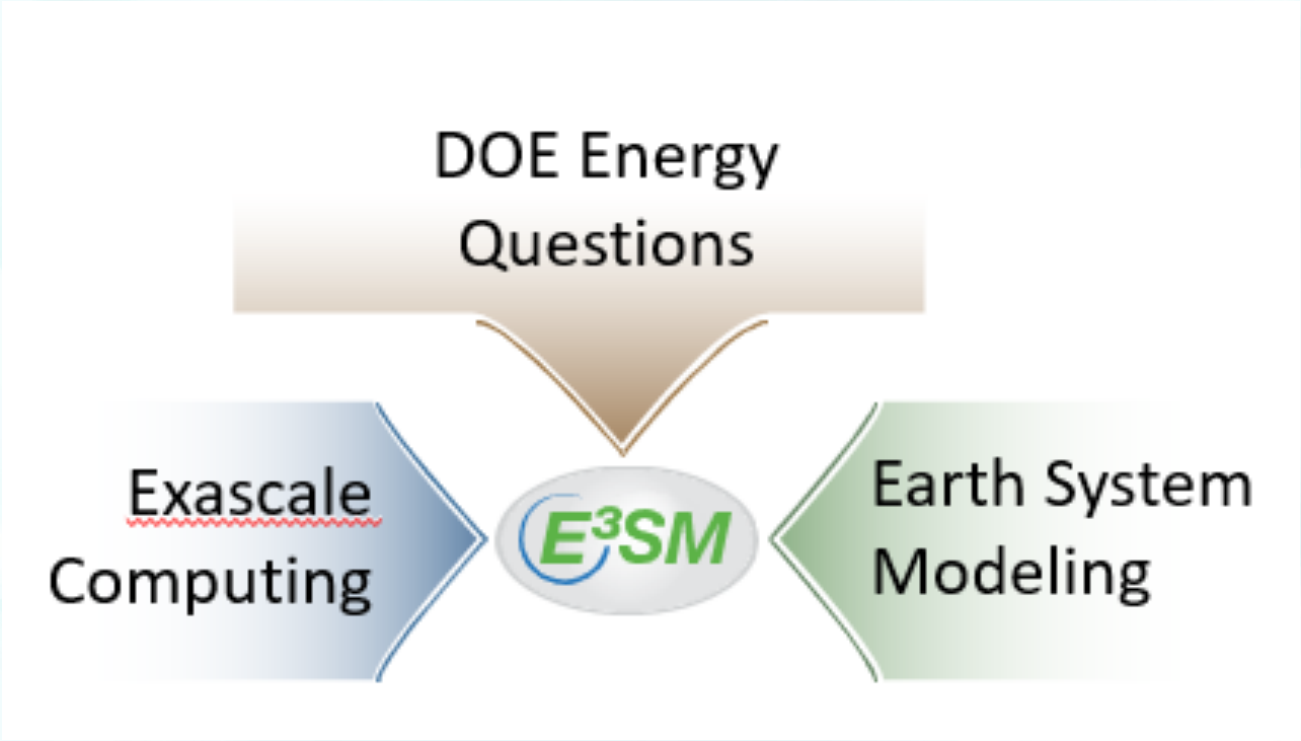
Dave Bader, E3SM Council Chair, Presenter

Ruby Leung, Renata McCoy, Mark Taylor, Chris Golaz, Luke Van Roekel, Steve Price, Mark Petersen, Wuyin Lin, Kate Calvin, Susannah Burrows, Rob Jacob, Jill Zhang, Phil Jones, Sarat Sreepathi, Peter Caldwell, Ben Bond-Lamberty, Shaocheng Xie, Andy Salinger and the E3SM Team from Eight DOE Laboratories and Many Universities

Regional and Global Model Analysis Principal Investigators (PI) Virtual Meeting

October 14, 2020

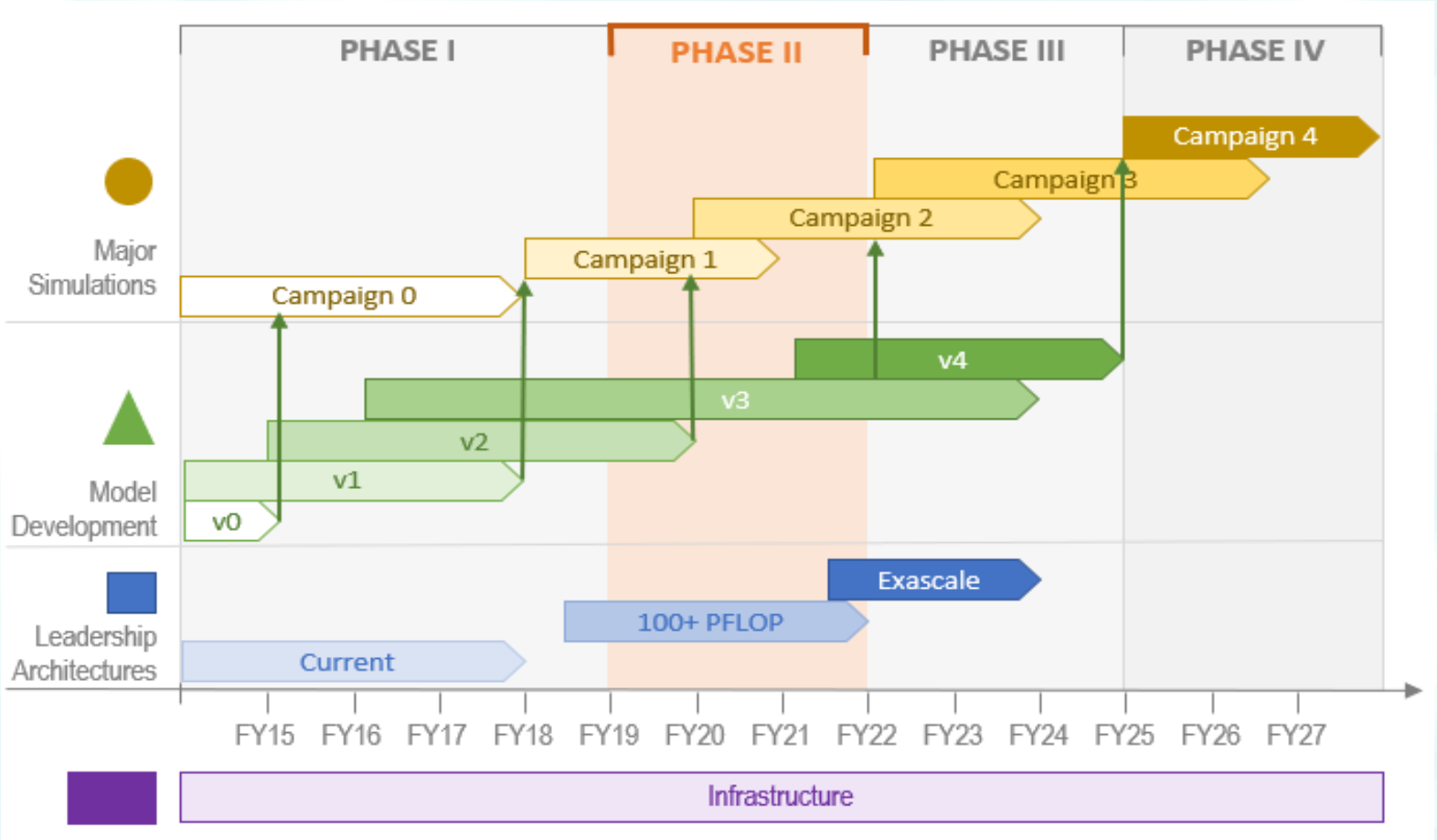
"A DOE Model for the DOE Mission on DOE Computers"



Science and mission drives development and experimentation

- ***Resolution*** – weather-scale to convective scale-atmosphere and eddy-resolving ocean for simulation of multi-scale phenomena
- Utilize ***next-generation disruptive computing*** to enable high-throughput, high resolution simulations
- Extensive use of ***ensembles*** to quantify and bound uncertainty for ***actionable predictions.*** Even small reductions in uncertainty are useful in risk analysis.
- Coordinated efforts to ***reduce biases*** and ***address mission questions***

Overlapping Development Cycle Paradigm Adopted from NWP Centers



E3SM Model Versions

E3SMv1

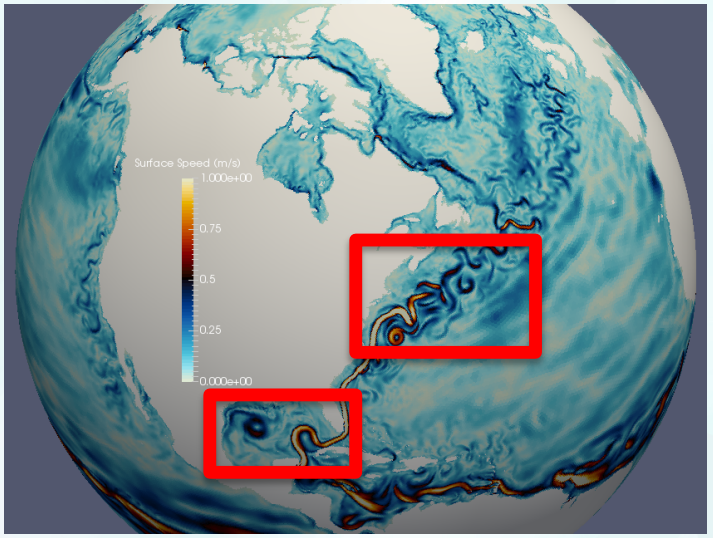
- **Jan 2018** Simulation campaign starts.
- **April 2019** Low-resolution paper accepted (Golaz et al. 2019).
- **Oct 2019** High-resolution paper accepted (Caldwell et al. 2019).

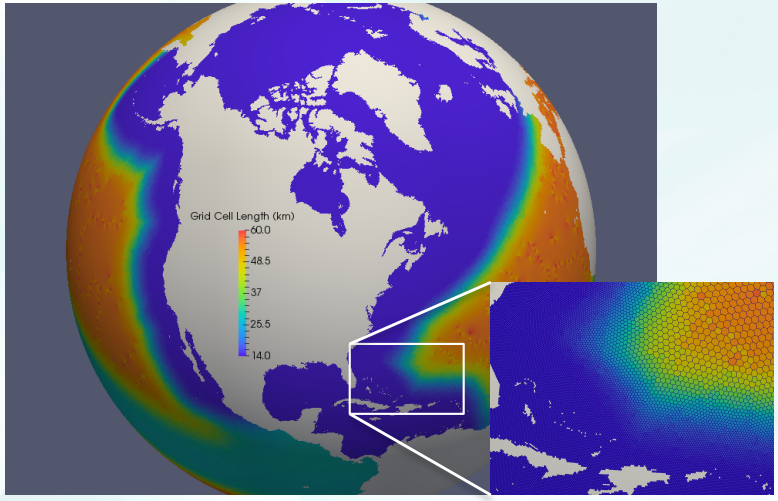
E3SMv2

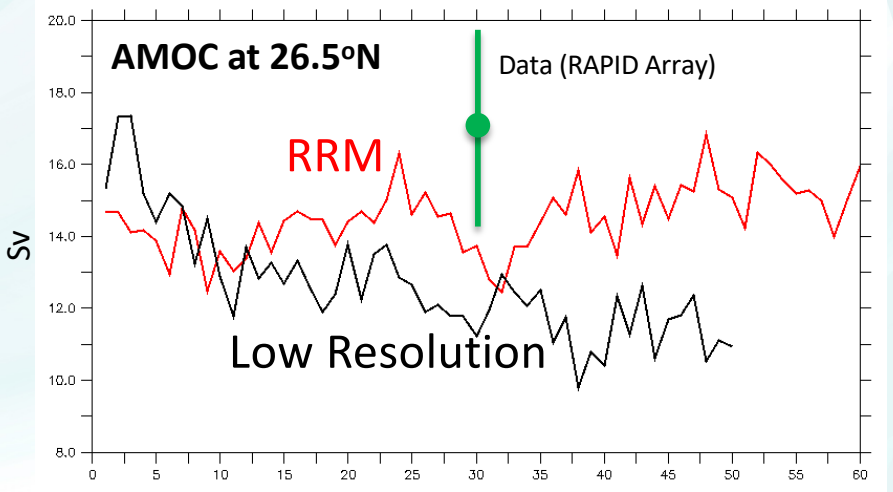
- Evolution from v1, but with many new features.
- Planning to freeze and start simulation campaign in **Fall 2020**.
- Compared to v1: "**faster and better**".

Regionally Refined Ocean

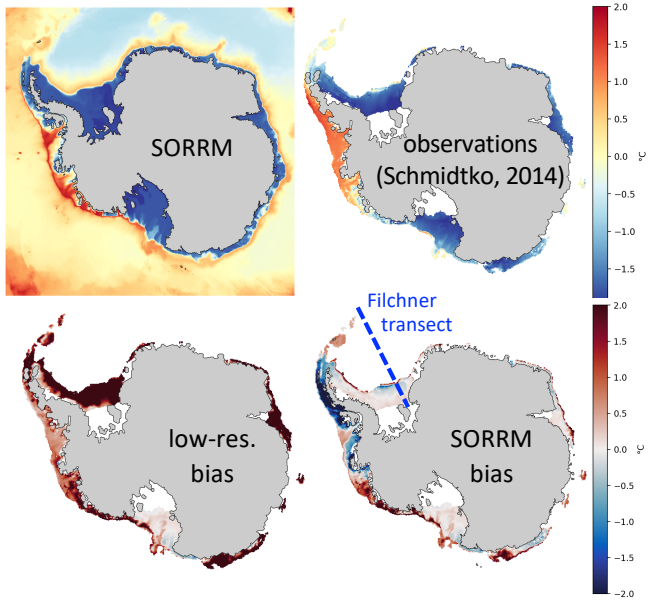
- Key feature of v2 is a regionally refined capability
- For Water Cycle (Below):
  - Base is standard low resolution mesh from v1
  - Resolution increased to 14 km in N. Atlantic and Arctic and near N. American Coast
- In forced ocean sea-ice cases, results are encouraging
  - Gulf stream: Strength, separation, variability
  - AMOC (~4Sv improvement)

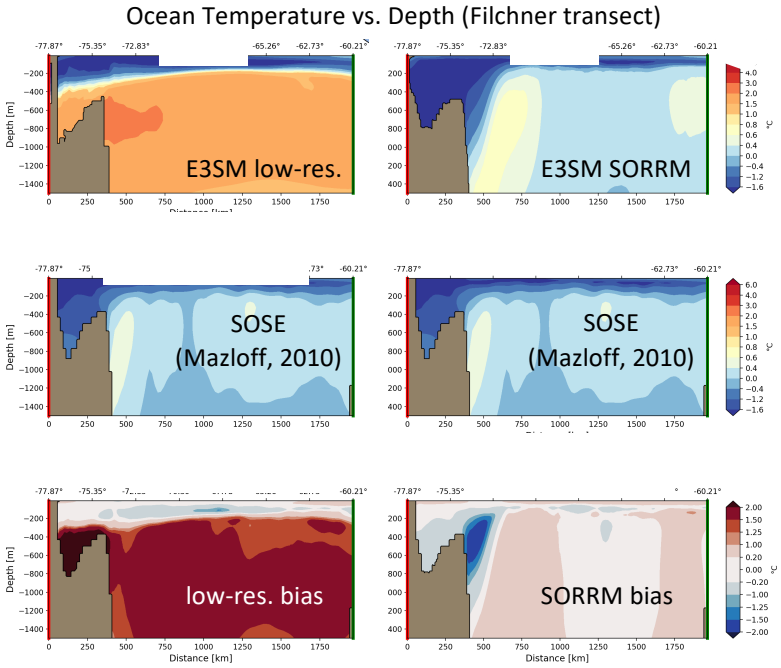


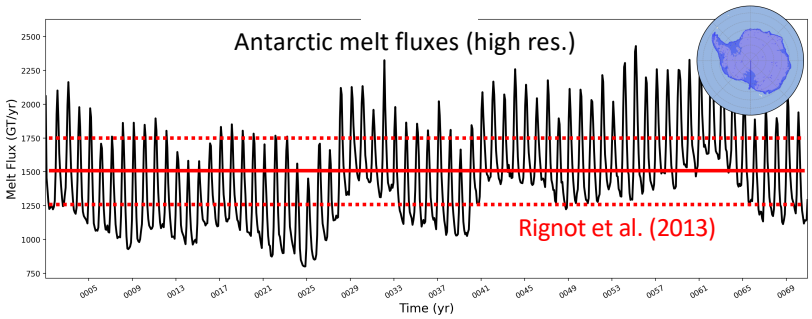




V2 Results: variable resolution configuration

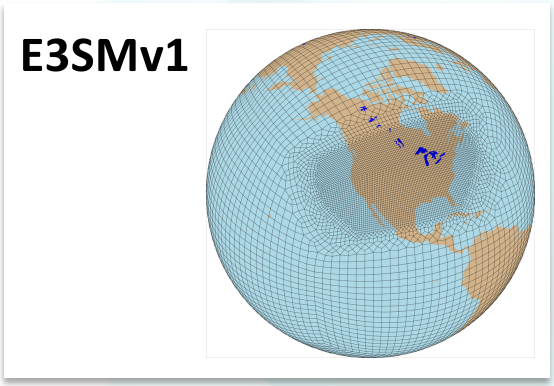


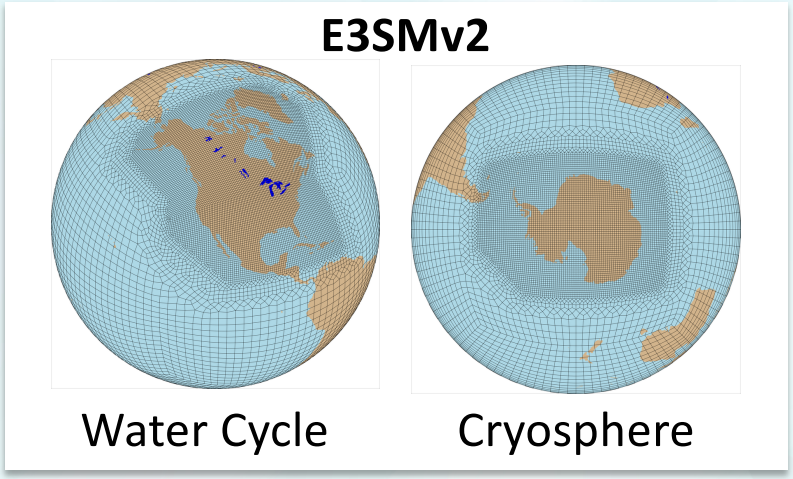




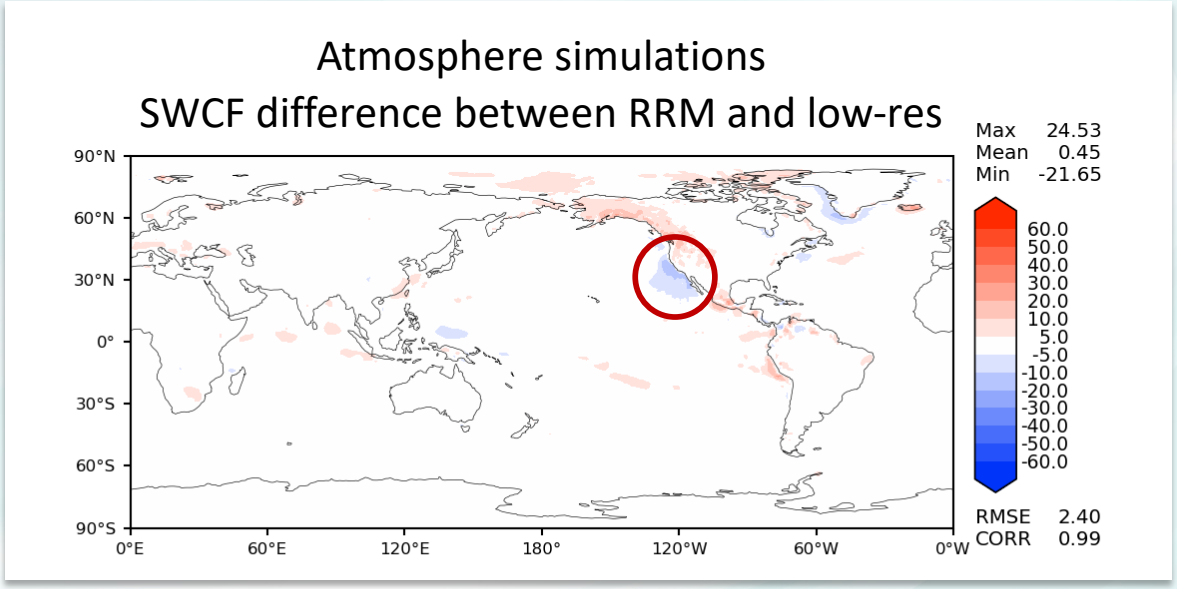
Higher ocean / ice res. around Antarctica improves on low-res. biases in regions with no GM closure

Regionally Refined Meshes Atmosphere

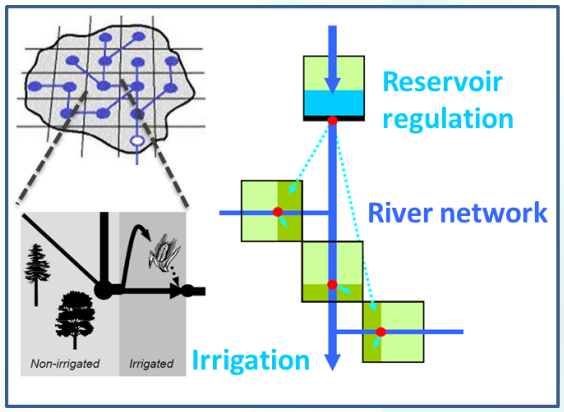




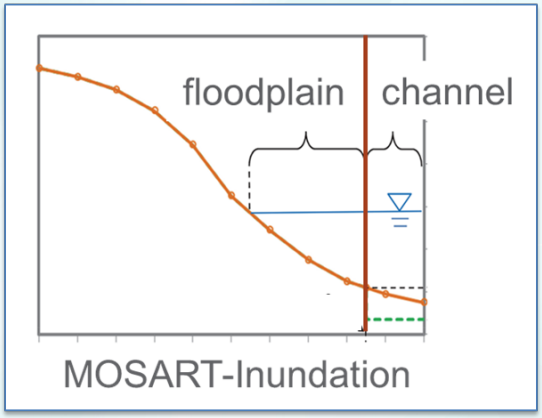
- With hybrid time step, no (or minimum) retuning is required for RRM compared to low-res atmosphere.
- RRM reduces shortwave cloud forcing bias over **stratocumulus** region



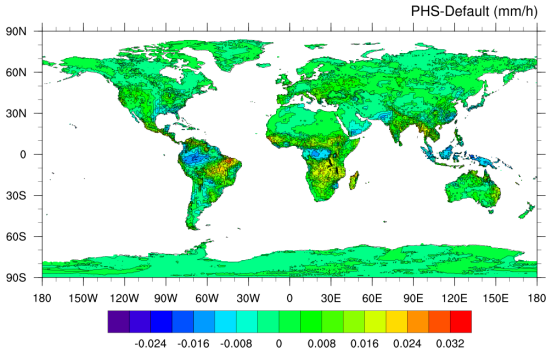
New land and river features



- **Land** and **river** models now on a **common grid** (1/2 or 1/8°), separate from atmosphere ("tri-grid").
- **Water management** and two-way coupled **irrigation** schemes.
- Flood **inundation** scheme.
- New **plant hydraulics** (PHS).
- **Sub-grid topographic units** with downscaling of atmospheric forcing.

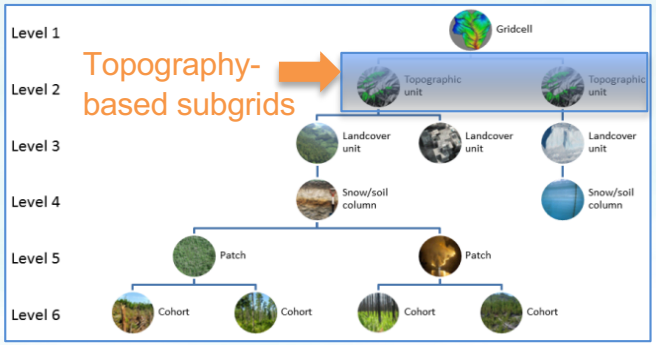


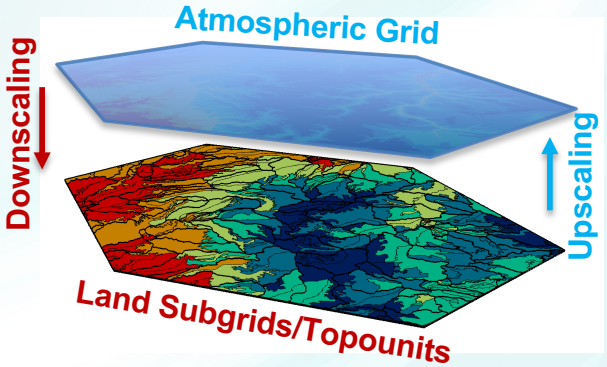
Annual average ΔET (mm/h)



ET increases in the deciduous forest of tropical regions with PHS

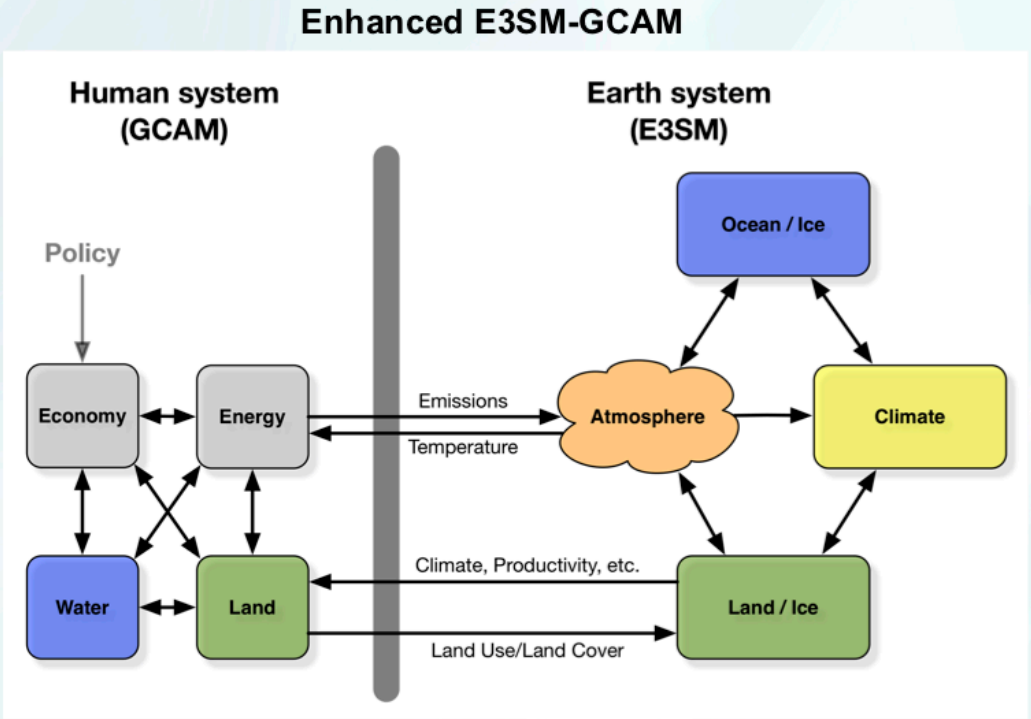
Hierarchical sub-grid structure in E3SM





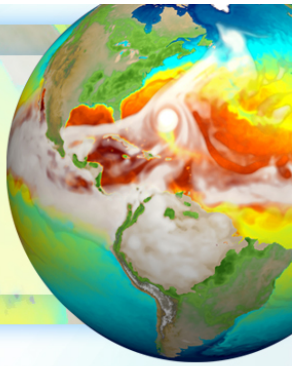
Energy Developments for v2

- Couple the Global Change Analysis Model (GCAM) with the E3SM
  - GCAM to E3SM: LULCC, CO_2 emissions, Non-CO_2 emissions/concentrations
  - E3SM to GCAM: changes in land productivity



= Complete, = In Progress

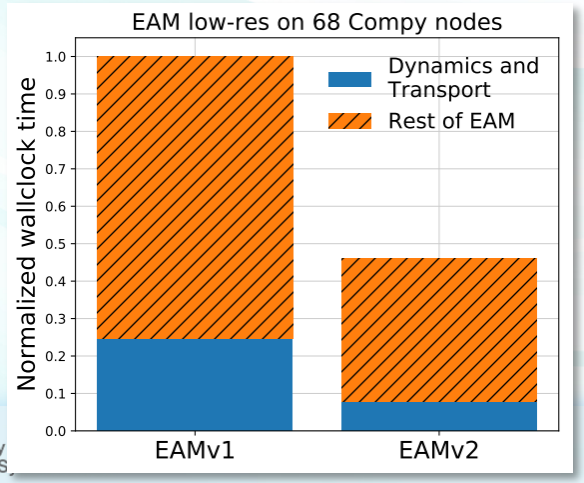
New computational improvements

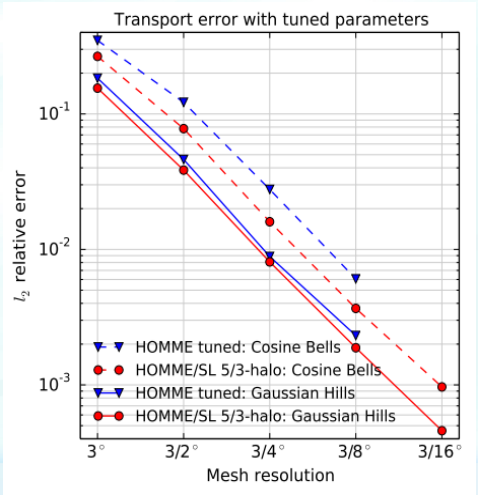


- New dynamical core (theta)
- Semi-Lagrangian (SL) tracer transport
- Physics grid (pg2)

✓ ~3-5x faster tracer transport
✓ ~2x faster atmosphere

v2 tracer transport is faster than v1, with no loss of accuracy





E3SM Energy Earth S

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Summary

- Despite limited time for development, E3SMv2
  - is **faster** than E3SMv1 (~2x at standard-resolution)
  - has **better** climate (precipitation, SST, sea-ice, …)
- New **regionally refined** capabilities for **coupled simulations**.

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- Simulation campaign to start before the end of the year.

Collaborations with RGMA Scientists

- E3SM Large Ensemble Project – Assisting with Data Management and Computer Time.
- RUBISCO – Provided space and assistance to publish additional RUBISCO-led C4MIP Experiments with E3SM to CMIP6 Database on LLNL's ESGF node
- Cloud Feedbacks - Provided space and assistance to publish CFMIP Experiments with E3SM to CMIP6 Database on LLNL's ESGF node

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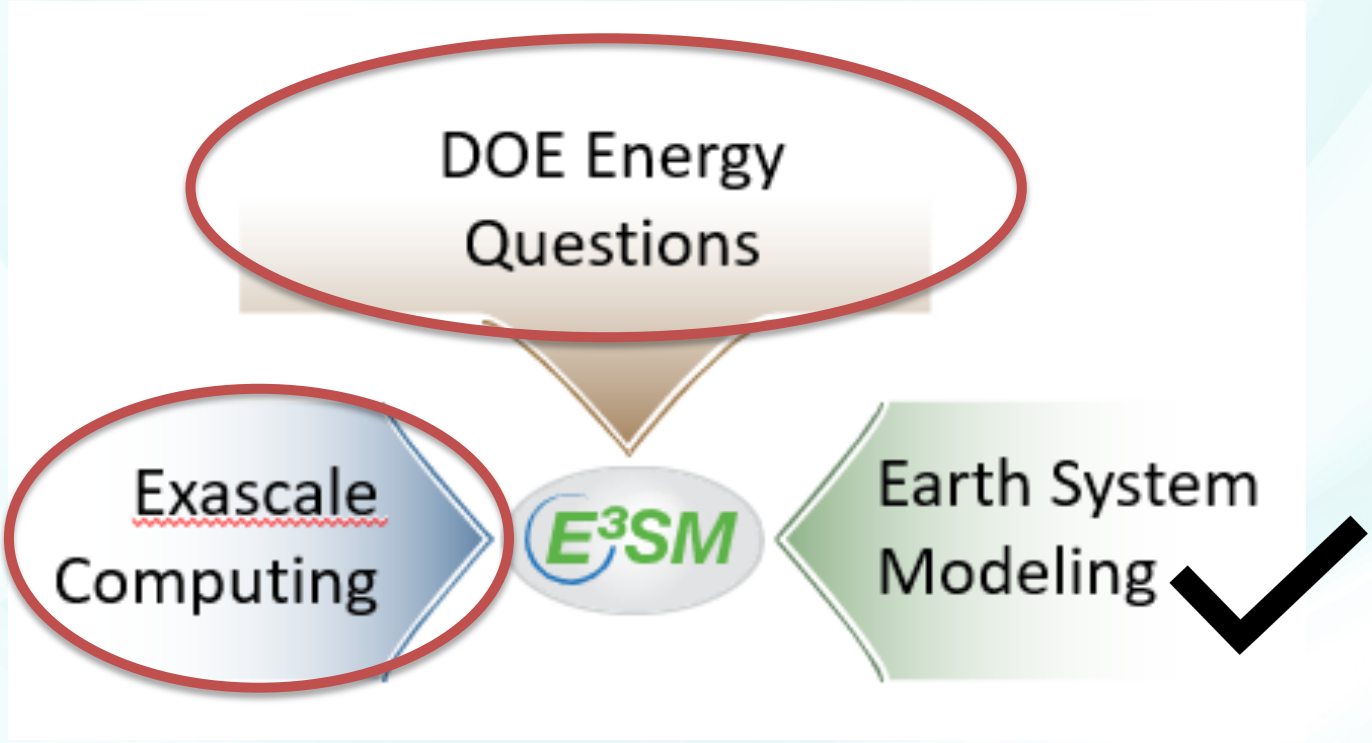
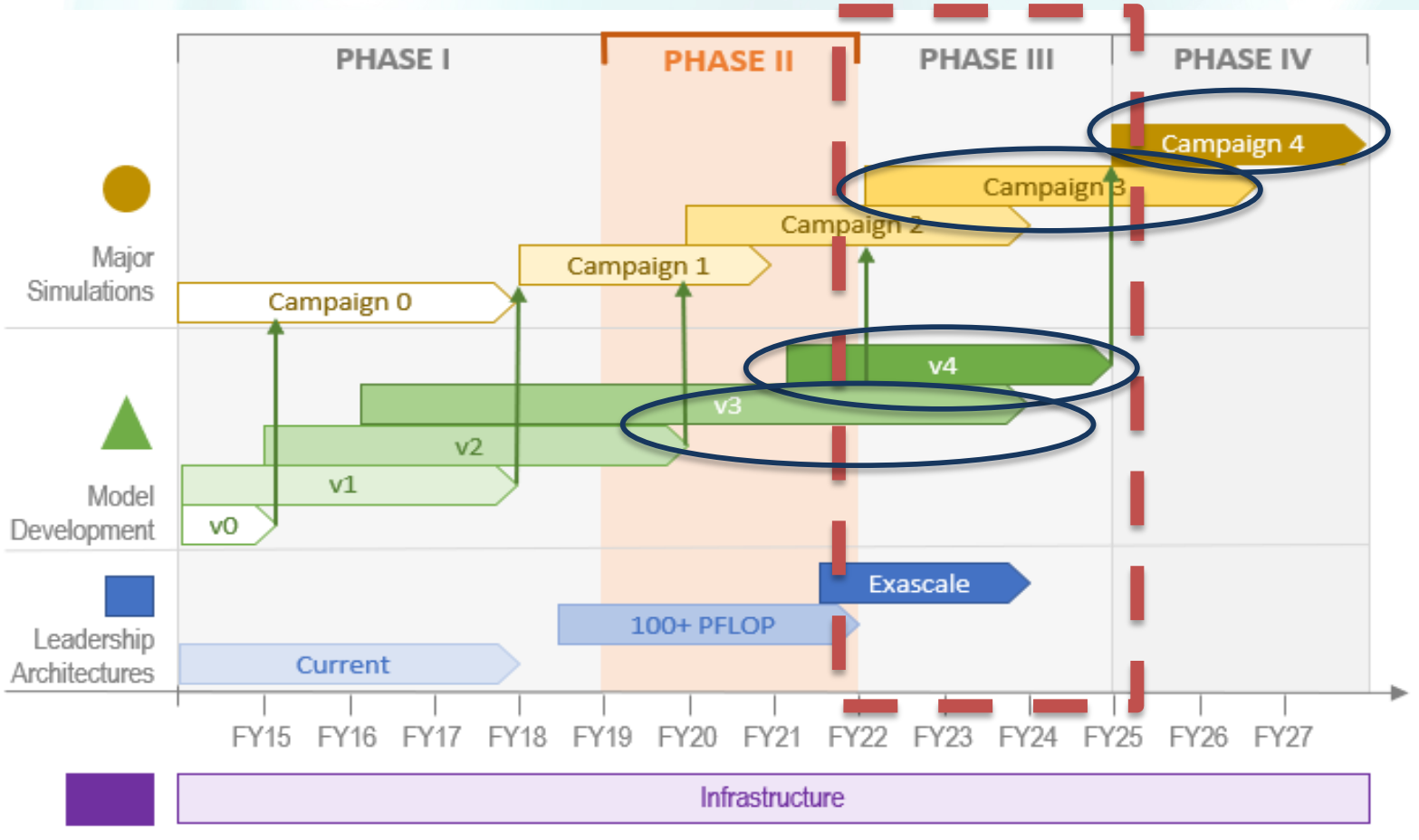


Overlapping Development Cycle Paradigm Adopted from NWP Centers



Project Direction - commence parallel, but coordinated, development of v3 and v4

- v3 release date is 6/30/23; the v4 release date is 6/30/26
- Model Science Developments are assigned priorities based on science question needs
- Model Technology Developments are assigned priorities based on needs to run on DOE LCF systems
- Single code base for v3 for all science drivers. Starting point is v2 + NGD Land and NGD Atmosphere. Other developments, e.g. some ocean NGD improvements or outside contributions are possible.
- Single code base for v4 for all science drivers. Starting point is C++ atmosphere (SCREAM codebase). v4 will need to coordinate with v3 developments to include them.