Climate

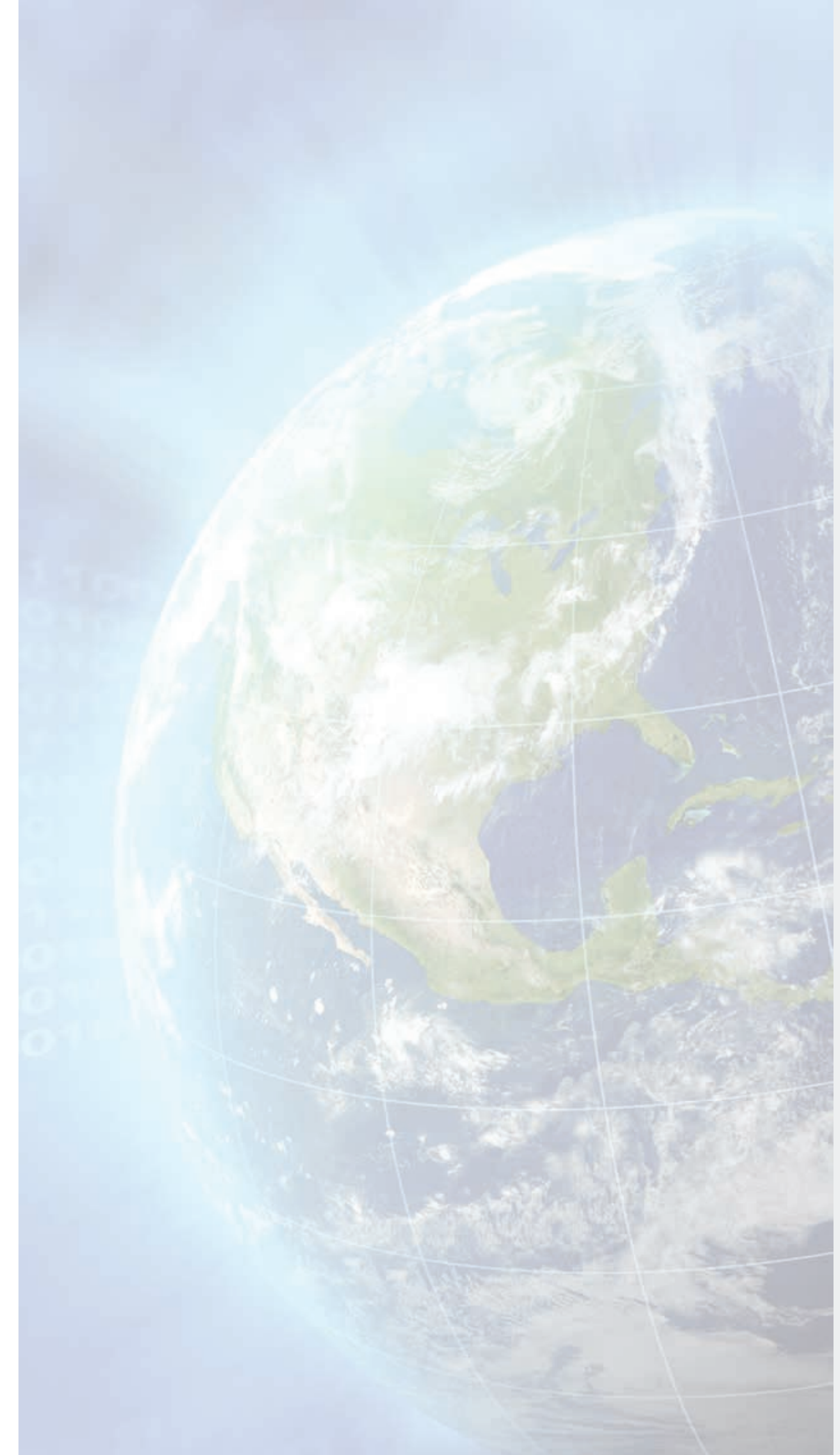
E3SM-MMF: Cloud-Resolving Climate Modeling of Earth's Water Cycle

The impact of climate change on the global and regional water cycles is one of the highest priorities and most difficult challenges in climate change prediction. Current earth system models possess limited ability to model the complex interactions between the large-scale, mostly 2D baroclinic atmospheric motions and the smaller-scale 3D convective motions found in clouds and individual storms. Because full-resolution climate simulation requires zetascale computation, E3SM is employing a superparameterized model to accurately incorporate cloud physics at a resolution previously unobtainable at petascale computing levels. This next-generation model will improve the scientific community's ability to assess regional impacts of climate change on the water cycle that directly affect multiple sectors of the US and global economies.

The goal of the E3SM-MMF project is to develop a cloud-resolving earth system model with throughput necessary for multidecade, coupled high-resolution climate simulations. This next-generation model has the potential to substantially reduce major systematic errors in precipitation found in current models because of its more realistic and explicit treatment of convective storms. These motions and their interactions, to first order, determine the spatial distributions and characteristics of regional precipitation. Complexities include the microscale chemistry and physics of cloud formation and the impacts of anthropogenic climate change on cloud formation. Properly resolving the key processes involved in cloud formation requires resolution (i.e., grid spacing) on the order of 1 km in the atmosphere. Today's petascale computing systems are capable of such resolution but only at great expense and for very short times (i.e., several simulated days). Running conventional climate models at this resolution, for 100 year simulations, requires a 5000× increase in computing resources.

The project will examine a multiscale modeling framework (MMF) approach to cloud resolution modeling. Often referred to as superparameterization, it offers significant opportunities for unprecedented improvement for a model that has yet to be fully explored due to limited computing resources. This project will integrate a cloud-resolving convective parameterization (i.e., superparameterization) into the DOE E3SM Earth System model using MMF and explore its full potential to scientifically and computationally advance climate simulation and prediction. The superparameterization will be designed to make full use of GPU-accelerated systems and will involve refactoring and porting other key components of the E3SM model for GPU systems. The acronym E3SM-MMF is used to refer to the superparameterized version of the E3SM model being developed under this ECP effort.

The challenge problem has several aspects: (1) achieving cloud-resolving resolution in the atmosphere with superparameterization, defined as at least 1 km grid spacing in both horizontal and vertical directions; (2) achieving weather-resolving resolution in the global atmosphere model, defined as 50–25 km average grid spacing in the horizontal directions with ~1 km grid spacing in the vertical directions (i.e., the resolution of today's global operational forecast models); (3) achieving an eddy-resolving ocean/ice model, defined as a minimum 18 km resolution in equatorial regions, decreasing to 6 km in polar regions; and (4) achieving model throughput necessary to perform the simulation campaign for the challenge problem in the course of one calendar year on the Frontier supercomputer.



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Progress to date

- Completed an initial port of superparameterization subcomponent to GPUs.
- Completed an initial port of E3SM-MMF atmosphere/land "F" compsets to Summit.
- Completed (in FY19) the first port of the atmosphere model to Summit, running at 0.6 simulation years per day and achieving a speedup of 31× relative to Titan.

The enhancements to E3SM enabled through the ECP will improve the scientific community's ability to predict, assess, and respond to the challenges imposed by local variations in the water cycle caused by global climate change.