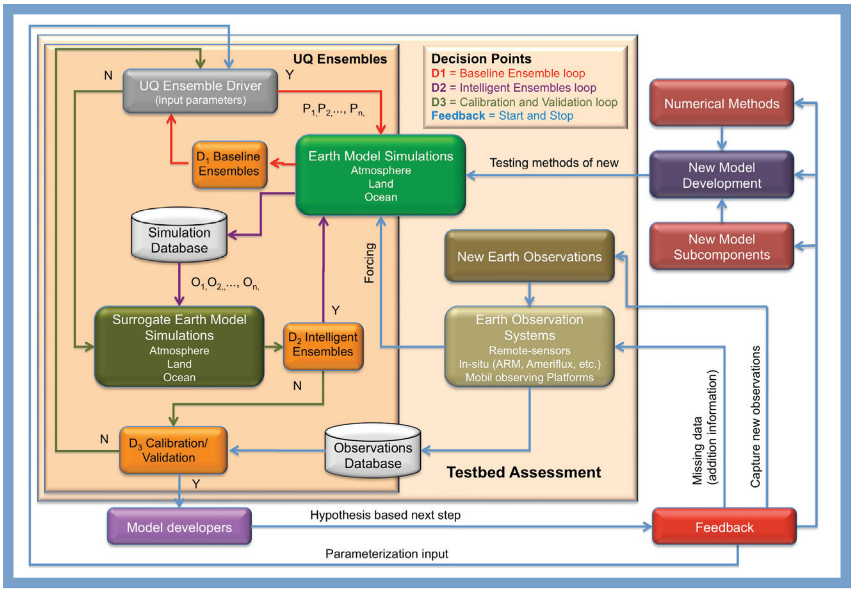
U.S. DEPARTMENT OF ENERGY | Office of Science

CLIMATE SCIENCE FOR A SUSTAINABLE ENERGY FUTURE (CSSEF)

In 2010, the U.S. Department of Energy Office of Science asked its national laboratory system to collectively develop the Climate Science for a Sustainable Energy Future (CSSEF) project to bring together their tremendous scientific assets to meet ongoing and long-term challenges in advancing climate prediction. CSSEF addresses these objectives through an unprecedented collaboration among eight national laboratories* and the National Center for Atmospheric Research.



The CSSEF testbed and development system was designed by the crosscutting Data Infrastructure and Testbed team based on requirements set by CSSEF modelers and observational scientists.

CRITICAL OBJECTIVES

- Accelerate the incorporation of new knowledge, including small-scale process data and observations, into climate models.
- Develop new methods for the rapid validation of improved models including quantifying their uncertainty.
- Develop novel approaches to exploit computing at the level of many tens of petaflops in climate models.

MAJOR RESEARCH THEMES

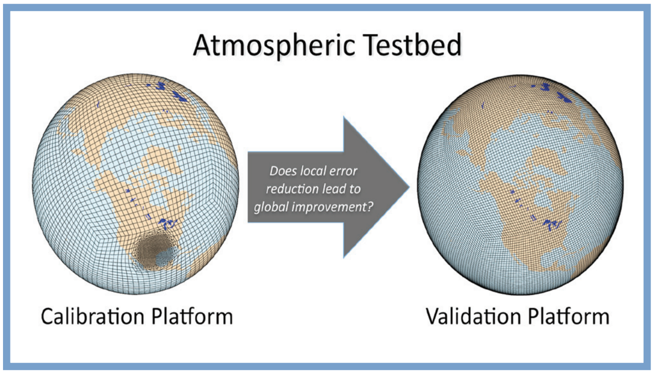
- Accurate simulation of the full hydrological cycle across all scales.
- Development and implementation of variable resolution component models for the global atmosphere and ocean general circulation.
- Quantification and reduction of uncertainty in simulating the terrestrial carbon and other biogeochemical cycles.

Central to CSSEF is the ability to thoroughly test and understand the uncertainties in the overall model and its components as they are being developed. CSSEF exploits DOE laboratory expertise in computational science and information technologies to construct advanced testbeds that allow the automated and rapid ingest of observational data together with computer simulation to evaluate model components.

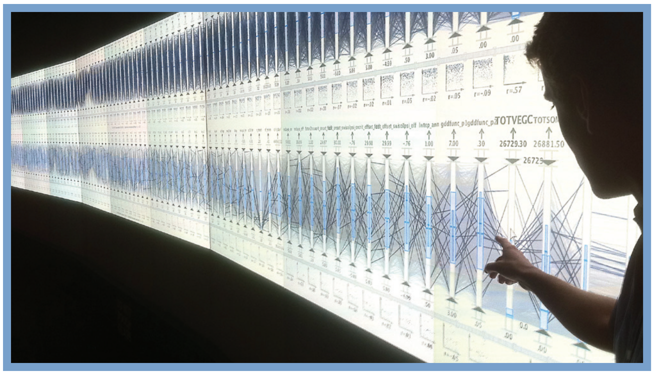
CSSEF AND THE "NEXT +1" GENERATION EARTH SYSTEM MODEL

CSSEF will have a major impact on Earth System Modeling through integration with the core long-term development of the Community Earth System Model (CESM) project. The CESM community collaboration has produced four generations of state-of-the-science global climate models, including the most recent, CESM1. Because aspects of development require 10 to 15 years, the CSSEF project focuses on the long-term development of CESM3, which will complement the

*Argonne, Brookhaven, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, Pacific Northwest and Sandia National Laboratories



The atmospheric component testbed employs two different versions of the global Community Atmosphere Model (CAM). Calibration of model parameters is performed with a variable and very highly refined grid over the Atmospheric Radiation Measurement Climate Research Facility observational site in the Southern Great Plains. The parameters are validated in a global, uniform resolution model version.



Uncertainty quantification is built-in: A power wall visualization of a Monte Carlo sensitivity study involving 1000 single-point model simulations of the Community Land Model with carbon-nitrogen biogeochemistry (CLM-CN) at the Niwot Ridge flux tower in Colorado is demonstrated.

community effort now dedicated to application of CESM1 and the development of CESM2 (the next generation model), scheduled to be released in the next 4-5 years.

INTERACTIVE TESTBEDS–THE HEART OF CSSEF

CSSEF research is centered on interactive testbeds that enable researchers to rapidly propose, test, and implement improvements to the major CESM components, the Community Land Model, Community Atmosphere Model (CAM), Community Ice Code Sea-Ice Model (CICE) and Model for Prediction Across Scales-Ocean (MPAS-O). The testbeds integrate multiple and diverse observational data sets and model simulations within an interactive environment that utilizes the latest capabilities in information and computer sciences.

Using multiple instrument observational data streams, scientists employ model simulations and data analytics coupled with uncertainty quantification tools to develop and improve model parameterizations of processes, such as cloud formation and precipitation, ocean mixing, and carbon uptake by plants.

FUTURE DIRECTIONS

- Adaptive Grids – CSSEF is developing a dynamically adaptive mesh version of CAM that includes full atmospheric physics and is extending the MPAS formulation to the CICE sea-ice model.
- Full Earth System Model – A “Next+1” generation component coupler for CESM3 is being designed and will be tested so that CESM3 will run efficiently on hybrid computer systems of the type proposed for the DOE Leadership Computing Facilities.
- Uncertainty Quantification – To generate the very large ensembles of simulations needed to thoroughly quantify model uncertainty, computationally efficient surrogate models will be developed for the component codes.

CONTACTS

Dorothy Koch, Ph.D.
DOE Program Manager
Earth System Modeling
dorothy.koch@science.doe.gov

David C. Bader, Ph.D.
CSSEF Science Team Leader
Lawrence Livermore National Laboratory
bader2@llnl.gov

Project Website:
http://climatemodeling.science.energy.gov/projects/cssef-climate-science-sustainable-energy-future