Earth System Modeling Framework (ESMF)

Summary, 1/21/2008

General

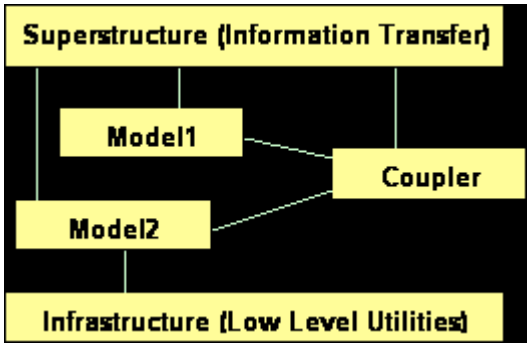
Domain: Geoscience Community
Project Funding: NASA, DoD 2002-2010, NCAR
Homepage: http://www.esmf.ucar.edu
Availablility: Public, open source

Purpose: Programmable integration framework for numerical models based on composite pattern
Goal: To increase software reuse, interoperability, ease of use and performance portability in climate, weather, and data assimilation applications.

Architecture:

Based on a common object-oriented multi-platform infrastructure, numerical models adapted as ESMF components are integrated via couplers in form of a hierarchy. A superstructure provides data distribution capabilities.

ESMF components (adapting numerical models) and couplers are written by modelers.



Technologies: Fortran, C++. Runs on most high performance parallel computing environments

See: http://www.nws.noaa.gov/ost/climate/STIP/esmf.htm

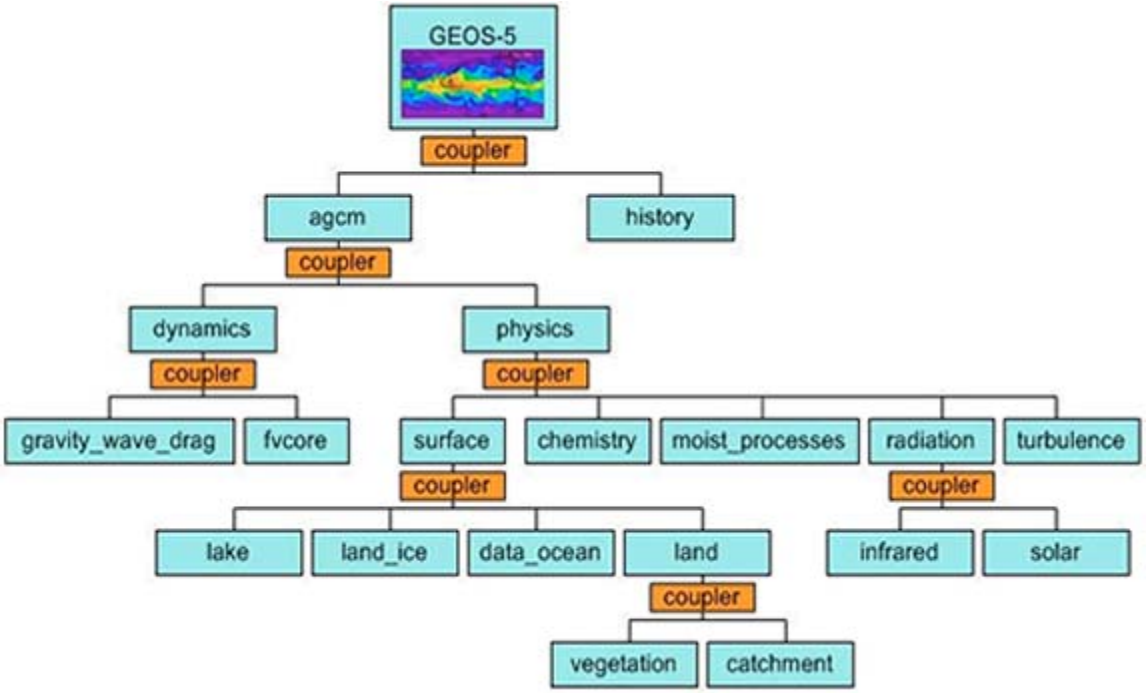
Material

The Earth System Modeling Framework (ESMF) collaboration is building high-performance, flexible software infrastructure to increase ease of use, performance portability, interoperability, and reuse in climate, numerical weather prediction, data assimilation, and other Earth science applications. The ESMF defines an architecture for composing complex, coupled modeling systems and includes data structures and utilities for developing individual models.

The basic idea behind ESMF is that complicated applications should be broken up into smaller pieces, or components. A component is a unit of software composition that has a coherent function, and a standard calling interface and behavior. Components can be assembled to create multiple applications, and different implementations of a component may be available. In ESMF, a component may be a physical domain, or a function such as a coupler or I/O system.

ESMF also includes toolkits for building components and applications, such as regridding software, calendar management, logging and error handling, and parallel communications.

The figure below shows ESMF components in practice. It is a diagram of the structure of the NASA GEOS-5 Atmospheric General Circulation Model, built from the ground up using ESMF. Each of the boxes is an ESMF component, including the couplers. The hierarchical tree of components can be "snipped" at different levels so that the whole physics package could be replaced, or a single parameterization. Each component is potentially "swappable."



[http://www.esmf.ucar.edu/about_us/]

Modeling Infrastructure for the Geoscience Community

An innovative modeling framework is helping smooth the way for simulations that run the gamut from weather and climate to emergency response and battlefield settings. The ESMF project is a national effort to build a software infrastructure that enables different weather, climate, and data-assimilation components to operate together on a variety of

platforms, from laptops to supercomputers. ESMF allows scientists to build models quickly, reuse existing software rather than reinventing it, and exchange modeling components in a systematic way. The goal is twofold: to increase scientific productivity and to promote new scientific opportunities.

ESMF was used to couple an atmosphere model and an ocean model that had not interacted before. This image shows the sea surface temperature after five iterations of the simulation. Credit: Shep Smithline, GFDL; Chris Hill, MIT.

ESMF software is component-based. It represents models as collections of smaller components that are coupled together. This makes it easier for researchers to assemble complex models. The framework includes tools for regridding, data decomposition, and communication on parallel computers and for common modeling functions such as time management and message logging. Researchers using ESMF have a standard way to add new capabilities and swap in different options. By helping scientists and engineers use common software to solve routine computational problems, ESMF will ultimately result in better research and accelerated progress in simulating the Earth's weather and climate systems.

Erik Kluzek, an NCAR software engineer, explains the appeal of the new modeling framework. “ESMF is all about taking the burden of designing software off the scientists and shifting it to software engineers, so scientists can concentrate on science,” says Kluzek. “For example, I work with the Community Climate System Model. In CCSM, we want to be able to ‘plug and play' different models into our system, to be able to easily switch in various land and atmosphere models. ESMF provides a software interface that makes it natural to do that.”

As proof of concept, Kluzek and colleagues used ESMF to connect the CCSM's atmosphere model (the Community Atmosphere Model or CAM) to two other systems for the first time: MIT's ocean model and the Spectral Statistical Interpolation analysis from THE NOAA Centers for Environmental Prediction.
Multiagency ESMF Initiatives

The NASA Modeling, Analysis and Prediction Program in collaboration with other NASA programs, DoD and participating universities, will develop an ESMF-based modeling and analysis environment to study climate variability and change.

The Department of Defense Battlespace Environments Institute is developing integrated Earth and space forecasting systems that use ESMF as a standard for component coupling.

Earth’s Atmosphere and Space Weather Initiatives at NASA, NOAA and participating universities are working with ESMF to couple together Earth and space software components. Sponsored by NSF.

NOAA GFDL, the Earth System Grid, PCMDI, and participating universities are working with the ESMF team and data specialists to create the Earth System Curator, an end-to-end knowledge environment that spans the gap between models and datasets.

A multiagency collaboration

ESMF is being developed and deployed by a multiagency collaboration that includes many of the major geophysical modeling and data assimilation efforts in the U.S. Support for ESMF development and application teams is provided by the NASA Earth Science Technology Office, the High-Performance Computing Modernization Program of the U.S. Department of Defense, and NSF. Staff from modeling centers at the U.S. Department of Energy, DOD, NASA, NOAA, NSF, and numerous universities have contributed requirements, feedback, and software to ESMF, and are now beginning to evaluate and adopt the framework.

“ESMF is an unprecedented community effort,” says Cecelia DeLuca, manager of the core implementation team, based in NCAR's Scientific Computing Division. The team is working with a change review board and a joint specification team, both with members from many other organizations, to implement ESMF on a day-to-day basis. “It's tremendously exciting to see. When we started, many of the groups we were working with had no regular contact with each other. ESMF has facilitated real cooperation that extends across agencies.”

“ESMF could become a central part of how climate models and data assimilation programs are structured, so there can be more reuse of codes than within a given shop,” notes Arlindo da Silva (NASA Goddard), who heads the ESMF data assimilation applications team. “It will open doors on a technical level and make collaboration easier if people want to collaborate. It's a very needed addition to the kind of modeling we do.”

Smaller institutions also stand to benefit from ESMF, says DeLuca. “This kind of community, open-source software really opens up modeling to a lot of university groups who might have not been able to address the kind of problems they now can address by using the infrastructure we're building. We're helping to lower the bar to get involved with modeling for many researchers with limited resources.”

Modelers can learn more about ESMF through training classes and documentation. See the ESMF Web site for tutorials and schedules.
[http://www.cisl.ucar.edu/research/2005/esmf.jsp]