Six-way coupled COAMPS 48 h simulation of hurricane Frances (2004). Wave, atmosphere and ocean components are 2-way coupled using ESMF interfaces. The figure shows the 0.1 kg/kg isosurface plots of cloud (yellow), ice (white), rain (green), and graupel (purple) mixing ratio. The color shading is the sea surface temperature with darker shade of blue depicting the cooling beneath the hurricane. The white arrows represent the 10-m wind (m/s). The view is from the south east flank of the storm. Image and description courtesy of Sue Chen, NRL.
Table of Contents

Executive Summary ............................................................................................................ 3
1 Introduction .................................................................................................................. 5
2 Software framework description .................................................................................. 5
3 Timeline and strategic objectives ................................................................................ 5
4 Plans in brief for 2011 ................................................................................................. 6
5 Detailed accomplishments for FY2010 ................................................................. 7
  5.1 Develop software for grid representation and regridding .................................... 7
  5.2 Improve usability .................................................................................................. 8
  5.3 Provide ESMF training and support ..................................................................... 9
  5.4 Develop software utilities and links to science gateway services ...................... 10
  5.5 Framework optimization and porting ................................................................. 11
  5.6 Advance community adoption ........................................................................... 12
6 Project plan evaluation measures for FY2011 .......................................................... 13
  6.1 Complete a functionally mature, standardized version of ESMF ...................... 13
  6.2 Evolve prototype capabilities and add new features as required ....................... 13
  6.3 Develop conventions and software templates that will increase the level of  
    interoperability of ESMF components ........................................................................ 14
  6.4 Provide ESMF training and support .................................................................. 14
  6.5 Develop software utilities and science gateway services ................................... 14
  6.6 Framework optimization and porting ................................................................. 14
  6.7 Advance community adoption ........................................................................... 14
7 Impact of the ESMF project ...................................................................................... 15
8 Sponsors .................................................................................................................... 15
Appendix A: Table of Acronyms ...................................................................................... 16
Appendix B: Current and Pending Support, ESMF and Curator ...................................... 17
Executive Summary

During calendar year 2010, the Earth System Modeling Framework (ESMF) Core Team completed the major functional elements of the framework. The two most significant new capabilities added were high performance I/O and conservative remapping. In order to unify the code base, now at 500,000 lines of code, a final check for consistency was initiated across all public interfaces. At the conclusion of this standardization sweep, the ESMF project has committed to maintaining backward compatibility of interfaces for future releases. The release that will mark the beginning of backward compatibility, v5.2r, is currently scheduled for May 2011.

ESMF grid and grid interpolation libraries emerged in 2010 as software that could offer users a combination of features and performance not available in other packages. ESMF gridded data structures and methods are based on two flexible data representations that were constructed in previous years: an unstructured finite element mesh library and a general array class designed to support fields on logically rectangular grids. In the last year, options were added to these libraries for masking, pole options, regridding between regional and global grids, and support for handling unstructured and cubed sphere grids in the “off-line” interpolation weight generator. At this point, ESMF can produce bilinear, higher order, and conservative interpolation weights, in parallel or serial, 2D or 3D (for select cases), for grids that can be represented by triangles or quadrilaterals, during a model run or offline. ESMF continues to be regression tested on 20+ platforms daily.

In past years, ESMF component interfaces were implemented in some fashion in many of the prominent climate and weather codes in the U.S.: CCSM, WRF, NASA GEOS-5, EMC GFS/NEMS, NRL COAMPS and the GFDL MOM4 ocean (see Appendix A for a table of acronyms). Growth in ESMF use during 2010 occurred mainly through these codes extending their use of the framework, especially regridding functions.

Future development plans for ESMF center on new programs and projects in which the framework plays a role, funded by NOAA, DoD, NASA, and NSF. These include an effort to develop a layer of software templates and conventions that will increase the interoperability of ESMF components and promote a “common model architecture”; to enhance the ability to add new, externally developed I/O and grid interpolation functions; to create end-to-end, self-documenting workflows; and to increase the extent to which the framework is used in model applications.

In November 2009, the Core Team moved from NCAR to NOAA ESRL/CIRES, where the NOAA Environmental Software Infrastructure and Interoperability (NESII) group was formed to house ESMF and associated projects. The transition went smoothly but there was much work in its wake, in shifting funding streams and re-establishing project infrastructure. These migration-related efforts are wrapping up and at the end of 2010 the project was returning to normal routines.
Accomplishments in brief for 2010:

- Completed the transition of the ESMF project to its new home at NOAA ESRL/CIRES.
- Updated the ESMF Project Plan, which describes the ESMF multi-agency organization.\(^1\) A new “Content Standards Committee” was created in conjunction with the National Unified Operational Prediction Capability (NUOPC), a consortium of U.S. operational weather centers. The CSC Committee is developing usage and content conventions to increase component interoperability. (April 2010).
- Created a compliance checker that can be linked into a model at run-time. The layer of indirection between ESMF component interfaces and model code interfaces is utilized to check that metadata, model time handling, and other usage conventions are followed (ESMF 5.1.0, October 2010).
- Integrated a high performance parallel I/O library (PIO, developed by staff at NCAR and DOE laboratories) into ESMF (ESMF 5.1.0, October 2010).
- Delivered a Reference Manual for a minimal set of C interfaces in order to support the pWASH123-ADCIRC coupling project under the Battlespace Environments Institute (BEI) (ESMF v5.1.0, October 2010).
- Added standard metadata packages that enable model codes to write out comprehensive descriptions of a simulation following the Common Information Model (CIM) schema developed by the E.U. METAFORE project.\(^2\) The CIM, which targets the 5\(^{th}\) Coupled Model Intercomparison Project (CMIP5), can be ingested into the Earth System Grid data distribution portal for search and browse (ESMF 5.1.0, October 2010).
- Added the ability to handle unstructured and cubed sphere grids in the “offline” interpolation weight generation utility. This utility takes grid files in the netCDF format as input and produces a netCDF file of interpolation weights as output (ESMF 5.0.0, May 2010).
- Delivered a parallel conservative regridding method (ESMF v5.0.0, May 2010).
- ESMF interfaces were distributed with public releases of CCSM4 (April 2010) and CESM1 (June 2010).

---


\(^2\) [http://metaforclimate.eu/](http://metaforclimate.eu/)
1 Introduction

The Earth System Modeling Framework (ESMF) was motivated by the growing complexity of building and coupling Earth system models. ESMF provides a set of standard software interfaces and high-performance tools for common modeling functions, thereby promoting interoperable software systems and code reuse. It has transitioned from its initial NASA sponsorship to multi-agency support and management. It is the technical foundation for model coupling in the DoD Battlespace Environments Institute, the National Unified Operational Prediction Capability (NUOPC), the NASA Modeling Analysis and Prediction Program (MAP), and a host of smaller programs and projects. One of its offshoots is the Earth System Curator project, which has focused on creating end-to-end workflows involving high performance models and data distribution portals. More information about ESMF and its applications is available on the ESMF website, [http://www.earthsystemmodeling.org](http://www.earthsystemmodeling.org); Curator is at [http://www.earthsystemcurator.org](http://www.earthsystemcurator.org).

2 Software framework description

ESMF components are arranged in a hierarchical structure to form modeling applications. The current ESMF distribution contains:

- Tools for building scientific components and couplers, and a set of utilities for common modeling functions (e.g., calendar management, message logging, data communications).
- Scalability of core communication routines to tens of thousands of processors.
- Concurrent or sequential execution, single or multiple executable modes.
- Representation and interpolation of unstructured and logically rectangular grids, global or regional, in 2D or 3D, during a model run or offline, with bilinear, higher order, and conservative interpolation options.
- Support for configuring ensemble members sequentially or concurrently.
- Fortran interfaces and complete documentation, select C interfaces and documentation.
- A comprehensive test suite with thousands of tests, including unit tests, system tests, and examples. A suite of realistically sized “use test cases” is available for separate download.
- Support for 20+ platform/compiler combinations, including IBM, Cray XT, SGI, Linux, Mac, Windows, and other platforms. The complete list is available on the ESMF website. \(^3\)

3 Timeline and strategic objectives

ESMF strategic objectives are described in detail in the *ESMF Strategic Plan for 2008-2010*\(^4\). As outlined in the Plan, there were three main activity areas:

---

\(^3\) [http://www.earthsystemmodeling.org/download/platforms/](http://www.earthsystemmodeling.org/download/platforms/)

\(^4\) [http://www.earthsystemmodeling.org/plans/plan_0802_esmfstrat.doc](http://www.earthsystemmodeling.org/plans/plan_0802_esmfstrat.doc)
1. Completing the functional requirements of the framework and improving its ease of use
2. Developing capabilities and strategic partnerships that help to integrate the framework into end-to-end computational environments (science gateways)
3. Supporting users who are integrating ESMF into applications

ESMF’s second funding cycle, under NOAA, NASA, DoD, and NSF sponsors, was largely completed at the end of 2010. What still remains is the delivery of a public release for the last major release increment in this cycle: ESMF v5.2r, which will focus on consistency of interfaces and behavior across all the framework classes. ESMF interfaces after v5.2r will be backward compatible so that updating to new versions should not require user code changes.

The ESMF Core Team began work in 2010 with new funding from two major new programs, NUOPC and the Global Interoperability Program (GIP). These, and smaller awards initiated in 2010, will help to shape future strategic objectives. In the course of the year, the ESMF project also received a new award under the NASA Modeling, Analysis and Predictability (MAP) program, with funding starting in 2011. An updated version of the ESMF Strategic Plan covering 2011-2015 will be prepared in 2011.

All ESMF activities remain rooted in the project’s core values of community ownership, distributed development, and open access to information.

4 Plans in brief for 2011

In 2011, the ESMF Core Team will focus on:

- Completing the review of all ESMF public interfaces for consistency of form and behavior, and delivering the ESMF v5.2r release which will mark the beginning of backward compatibility.
- Completing, adding features, and testing elements of ESMF that are still in a new or prototype phase (exchange grids for merging fields, Fortran interfaces for the mesh library, I/O, metadata handling) and continuing to add features as required to mature elements.
- Developing capabilities and strategic partnerships that help to integrate the framework into end-to-end computational environments (science gateways)
- Supporting users who are integrating ESMF into applications and improving user training.
- Developing a layer of conventions and software templates that will increase the level of interoperability of ESMF components, in collaboration with the NUOPC consortium and other ESMF users.

The National Unified Operational Prediction Capability (NUOPC) is a DoD/NOAA-led collaboration that is developing a multi-model ensemble for operational NWP. In 2011, ESMF will be focusing on a pilot project to establish a set of conventions for atmosphere-ocean coupling, and to deliver a set of prototype codes that conform to these conventions, based on NOGAPS-HYCOM, COAMPS, and NOAA NEMS.
The NOAA Global Interoperability Program (GIP) addresses software infrastructure across a set of high-priority activities including CMIP5. GIP is supporting efforts to increase adoption and develop end-to-end, self-documenting workflows facilitated by the framework. ESMF will be working with the CESM group to implement metadata Attributes in that model and export the results to the Earth System Grid (ESG) in order to improve recording of data provenance. The ESMF team will also be collaborating with members of the Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI) to couple an atmospheric model using ESMF with a hydrologic model using OpenMI, a widely used framework in the water resources community. The connection is made by using an option in ESMF that enables components to be run as web services.

A new Modeling, Analysis and Predictability (MAP) program award from NASA will improve the ability for externally developed capabilities such as grid interpolation algorithms, grid representations, and I/O formats to be integrated into ESMF. Work will also include the merger, to the extent possible, of the MAP interoperability Layer (MAPL) with ESMF and the emerging NUOPC interoperability Layer. MAPL was developed at Goddard and used in the GEOS-5 model as an ESMF wrapper and stopgap for incomplete ESMF functions during the framework’s early development.

Under a TeraGrid award, the ESMF team will be continuing a collaboration with NCAR and Purdue University on a web-based interface and workflow system for CESM and potentially other climate models, based on the Purdue CCSM Portal. This effort also leverages GIP funding. It will enable CESM runs to be configured and submitted through a GUI, and to output both model output data and comprehensive simulation metadata to the Earth System Grid, where the metadata can be searched and browsed.

The Commodity Governance (CoG) project funded by NSF will enable the ESMF team to partner with GFDL, Earth System Grid, University of Michigan and the Community Surface Dynamics Modeling System (CSDMS) hydrology consortium to develop on-line governance functions for community modeling projects. For this project, ESMF serves as a facilitator for the construction of integrated modeling environments, and its distributed group dynamics are a subject of a social scientist study.

5 Detailed accomplishments for FY2010

5.1 Develop software for grid representation and regridding

Measures of success:
- Delivery of an ESMF release that includes the ability to represent and regrid multi-tile grids and exchange grids.
- Delivery of an ESMF release that offers integrated conservative regridding.
- Improved integration of ESMF with external regridding capabilities, including an updated version of SCRIP and libCF.

Actual performance, outputs and outcomes:
A research version of a conservative regridding strategy implemented in 2009 did not perform well and was completely re-implemented in 2010. The 2010 version has
proved to offer excellent accuracy and robustness. Numerous other features were added including support for masking, pole options, regional to global interpolation (and vice versa), and support for unstructured and cubed sphere grids in the “offline” interpolation weight generation application. (Note that global to global and regional to regional interpolation methods were already supported.) To keep track of the many regridding features and options, starting in 2010 a summary of regridding capabilities was provided with each release.5

Full implementation of multi-tile grids defined by connected logically rectangular regions, such as some cubed sphere grids, was deferred to 2011. The cubed sphere grids we worked with in 2010, from the HOMME project, were sufficiently irregular that representing them as unstructured meshes made more sense.

A prototype version of exchange grids was implemented for ESMF v5.1.0, in October 2010. Exchange grids were developed at GFDL to improve the accuracy of flux transfers between surface and atmosphere components. They are implemented as a collection of the intersected cells between atmosphere and surface, which can have irregular shapes. This initial delivery of exchange grids in ESMF only ran on one processor.

During summer 2010 a student intern (Andrew Scholbrock) working with the ESMF team through the NCAR-sponsored SIParCS program6 attempted to integrate the libCF regridding package with the ESMF regridding library. LibCF is being developed at Unidata in collaboration with GFDL and Tech-X. The project was partially successful: the libCF package only had a file-based interface, where files conform to the emerging “gridspec” schema being developed at GFDL. The student was able to write ESMF data structures out in the form of the GFDL schema, regrid them using libCF, and then use the weights. Although this is not a strategy that will be viable in the long run, the project helped to clarify steps required to connect the codes in the future.

5.2 Improve usability

Measures of success:
- Delivery of a release with highly consistent interfaces and behavior, ready to be frozen for backwards compatibility.
- Maintain or reduce the number of open bug reports and feature requests.

Actual performance, outputs, and outcomes:
ESMF began an in-depth review of interfaces for consistency of form and behavior,

5 http://www.earthsystemmodeling.org/esmf_releases/non_public/ESMF_5_2_0/esmf_5_2_0_regridding_status.html
6 http://www2.cisl.ucar.edu/
but did not have a release during calendar year 2010 (the beta release of this capability would happen in February 2011).

Figure 1 (a) shows that the number of open bug reports continued to grow through the end of the year. Since inconsistencies and gaps in documentation are classified as bugs, the in-depth interface review generated a steady stream of new items in this tracker. The number is expected to level off or shrink with release 5.2r. Figure 1 (b) shows that the number of open feature requests increased through 2010, then lessened as internal releases 5.0.0 and 5.1.0 delivered new capabilities.

![Figure 1. Bug and feature request metrics.](image)

5.3 Provide ESMF training and support

**Measures of success:**
- Deliver on-line training materials to accompany the ESMF v5 release.
- User comments, surveys, and/or evaluations show that ESMF customers are satisfied with support, training, and documentation.
• Produce one or more journal papers on ESMF.
• Develop an Outreach Plan for 2010-2015 to promote use of the framework.

**Actual performance, outputs, and outcomes:**
An on-line web tutorial was completed and delivered with ESMF v5.1.0. It currently leads a new user through one coupled flow demonstration program. This is a good start at a new web format, but at the end of 2010 the examples and system tests bundled with the software distribution were still the main avenue for user training. The web tutorial requires thorough user review, updates to the example used, and additional instruction units.
The ESMF Core Team hosted a Town Hall meeting at the Fall AGU conference in San Francisco. The Town Hall meeting covered many aspects of ESMF design and use and was well attended. Other venues in which members of the ESMF team made presentations are listed on the ESMF website.7

Although our information is anecdotal, it appears that users are satisfied with the ESMF software, documentation, and support, for example:

Dear Gerhard, Excellent explanation! I enjoy your teaching. Thank you very much.

The new build using gfortran appears working. The "gmake all_tests" has been going on for more than 10 minutes. It is a good sign. Thanks.

Sections for two book chapters were submitted in 2010, and are pending publication. A paper on community modeling was published in EOS. (Voinov, A., C. DeLuca, R. R. Hood, S. Peckham, C. R. Sherwood, and J. P. M. Syvitski. A Community Approach to Earth Systems Modeling, *EOS*, 91:13, March 20, 2010.)

The Outreach Plan was deferred to 2011 so it could be timed to coincide with later releases of ESMF v5.

5.4 **Develop software utilities and links to science gateway services**

**Measures of success:**
• Delivery of a public ESMF release that includes new features for existing utilities and an I/O library.
• Continued development of ESMF Attributes, including a more general and robust XML write capability.

**Actual performance, outputs, and outcomes:**
ESMF v5.1.0 included an integrated parallel I/O capability based on the Parallel I/O (PIO) package jointly developed by staff from NCAR and DOE laboratories. The

7 [http://www.earthsystemmodeling.org/presentations/](http://www.earthsystemmodeling.org/presentations/)
PIO library was wrapped so that users only see and write ESMF data objects. Minor features were added to logging, time management, and other utilities. These are detailed in release notes.8

The ESMF Attribute class, which is responsible for metadata handling, was made more robust through integration of the Xerces XML parsing tool. Attribute classes are now included for many kinds of metadata, based on a variety of standards. ESMF includes ISO packages, a Climate and Forecast (CF) package for fields, and Common Information Model (CIM) packages based on the schema developed by the E.U. METAFOR project for CMIP5. The packages can be aggregated to create complex schema, and written out from models in XML format.

5.5 Framework optimization and porting

Measures of success:

- Minimal performance burden for working code. (Target <5% overhead in component overhead and regridding methods.)

Actual performance, outputs, and outcomes:

Users and internal tests indicate that continued development has not degraded performance and ESMF still represents <5% overhead for most applications. Two performance reports were generated in 2010. The first analyzed the overhead of component constructs in CCSM4 and found them to be negligible (see Figure 2). The second compared the performance of the ESMF offline interpolation weight generation utility with the SCRIP package from Los Alamos. Since ESMF is a parallel utility, it can provide better performance than SCRIP for high resolution grids. Both reports are posted on the metrics page of the ESMF website.9

![Figure 2 Performance overhead of ESMF](http://www.earthsystemmodeling.org/download/releases.shtml)

Figure 2 Performance overhead of ESMF. This chart shows the timing of CCSM4 running with ESMF component interfaces (blue line) and without (red line). Times are within 3% and are representative of results from other model applications. The ESMF version does not introduce any changes to the internals of model components. (Platform: IBM Power 575, bluefire, at NCAR. Versions: CCSM_4_0_0_beta42 and ESMF_5_0_0_beta_snapshot_01)

---


5.6 Advance community adoption

Measures of success:

- Number of ESMF components available. A goal for 2010 will be successful completion of all the BEI coupled applications.
- Number of ESMF applications in routine use or operations. Goals for 2010 include having at least two more ESMF codes transition to production or operations.
- Define a technical and programmatic relationship between ESMF and other standard community interfaces, particularly OpenMI in the hydrology domain.

Actual performance, outputs, and outcomes:

Capabilities were delivered to support BEI coupled applications. There are now about 90 ESMF components that have been implemented. The following are now in operations or production, defined as in routine use or supported in a public release:

- The WRF code has had optional ESMF bindings in its distribution since December, 2006.
- The NASA GEOS-5 atmospheric general circulation model based on ESMF has been in production since 2005.
- The NCEP GFS with ESMF was put into operations in August, 2006.
- The coupled HYCOM and CICE model using ESMF is now in routine use at the Naval Research Laboratory.
- The COAMPS and NCOM application using ESMF components and coupling has been in use since 2007.
- The CCSM family of codes includes ESMF components in its distribution since April 2010.

MAP, BEI and NUOPC are the largest programs to date that have been based on ESMF.

A technical interface between ESMF applications and OpenMI applications was explored through a coupling project that involved the Community Atmospheric Model (CAM) and the Soil Water Analysis Testbed (SWAT), which predicts stream flow. The motivation is to introduce climate inputs into the SWAT model, feed information about local and regional surface processes, including lateral movement of water, back into the climate model, and ultimately provide more accurate information on water availability and other issues of societal importance. This is a "reach" effort because the scales of the climate model and hydrological model are currently so different. However, over the next five to ten years climate models are expected to increase in resolution and models like SWAT to cover increasingly large domains.

The atmospheric model is implemented as an ESMF component and is wrapped with an OpenMI interface, which facilitates the communication with the OpenMI-
compliant hydrological model. The hydrological model, driver, and the two OpenMI wrappers physically exist on a personal computer running Windows. The ESMF component itself exists on a multi-threaded Linux computer. An ESMF web services interface is used to bridge the two computer platforms. In 2010 a first prototype of the system was delivered under GIP seed funding. Figure 3 illustrates the arrangement.

Figure 3 Coupling of ESMF and OpenMI components for modeling a hydrological system. The driver and hydrological component are run on a personal computer, while the atmosphere is run on a high performance cluster.

6 Project plan evaluation measures for FY2011

6.1 Complete a functionally mature, standardized version of ESMF

Measures of success

- Complete the exhaustive review of ESMF interfaces and deliver the ESMF v5.2r release, which will mark the beginning of backward compatibility for major framework classes.

6.2 Evolve prototype capabilities and add new features as required

Measures of success

- Add features as needed to regridding libraries, which may include further testing of the 3D regrid option, direct support for hexagonal elements (currently these are represented as triangles) or introducing higher order conservative weights.
- Enable users to easily set up multi-tile grids.
- Continue development and testing of prototype Location Stream, Exchange Grid, Mesh, I/O and Attribute classes and initiate backward compatibility for their interfaces.
- Unify information handling across the framework by integrating the functionality of Attributes, I/O, and Config classes, and descriptors set through data structure argument lists.
• Enable the I/O capability to accept other packages besides PIO and other formats besides netCDF.
• Maintain or reduce the number of open bug reports and feature requests.

6.3 Develop conventions and software templates that will increase the level of interoperability of ESMF components

Measures of success
• In collaboration with NUOPC partners and the ESMF Joint Specification Team\textsuperscript{10}, deliver documents and software templates that define a common model architecture that will minimally work for atmosphere-ocean use cases, and is broadly applicable to coupling problems.
• In collaboration with NUOPC partners, deliver tracking documents that show how NOGAPS, COAMPS, and NEMS have adopted the proposed conventions, and deliver prototypes of these codes that demonstrate use of the new NUOPC Layer.

6.4 Provide ESMF training and support

Measures of success:
• Improve ESMF on-line web training and add additional instructional modules.
• Support users who are integrating ESMF into applications.
• Develop an Outreach Plan.

6.5 Develop software utilities and science gateway services

Measures of success:
• Deliver an ESMF release that includes the ability to run an ESMF component as a web service.
• In collaboration with a modeling group, demonstrate how ESMF Attributes can enable model code to be self-documenting, with metadata automatically archived to a portal.

6.6 Framework optimization and porting

Measures of success:
• Minimal performance burden for working code. (Target <5% overhead for ESMF component and regridding methods vs. native packages.)
• Continued demonstration of performance viability for petascale and other emerging computing architectures.
• Requested ports delivered.

6.7 Advance community adoption

Measures of success:
• Number of ESMF components available should reach 100 in 2011.

\textsuperscript{10} \url{http://www.earthsystemmodeling.org/management/jst.shtml}
• Number of ESMF applications in routine use or operations. Goals for 2011 include having at least one more ESMF code transition to production or operations.
• Demonstrate a coupling interface between ESMF and OpenMI in the hydrology domain.

7 Impact of the ESMF project

Widespread use of ESMF represents a paradigm shift in the way weather, climate, coastal, and related models are constructed. Through ESMF standard interfaces, community governance, and shared tools, large centers are more easily able to collaborate on infrastructure needs and exchange codes. The end result is an Earth science community better equipped to explore basic research issues and to answer questions about the changing environment.

8 Sponsors

Core ESMF development is sponsored by the NSF, NASA, NOAA, and the Department of Defense. In addition, a variety of ESMF-based application adoption projects have been sponsored by NASA, NOAA, the U.S. Geological Survey/Department of the Interior, and other agencies and institutions.
### Appendix A: Table of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADCIRC</td>
<td>Advanced Circulation Model for Coastal Ocean Hydrodynamics</td>
</tr>
<tr>
<td>AR5</td>
<td>IPCC 5th Assessment Report</td>
</tr>
<tr>
<td>BEI</td>
<td>Battlespace Environments Institute</td>
</tr>
<tr>
<td>CCSM</td>
<td>Community Climate System Model</td>
</tr>
<tr>
<td>CICE</td>
<td>Los Alamos sea ice model</td>
</tr>
<tr>
<td>CMIP5</td>
<td>5th Coupled Model Intercomparison Project</td>
</tr>
<tr>
<td>COAMPS</td>
<td>Coupled Ocean/Atmosphere Mesoscale Prediction System</td>
</tr>
<tr>
<td>CoG</td>
<td>Commodity Governance project</td>
</tr>
<tr>
<td>CSDMS</td>
<td>Community Surface Dynamics Modeling System</td>
</tr>
<tr>
<td>ESMF</td>
<td>Earth System Modeling Framework</td>
</tr>
<tr>
<td>FMS</td>
<td>Flexible Modeling System</td>
</tr>
<tr>
<td>GEOS-5</td>
<td>Goddard Earth Observing System Model</td>
</tr>
<tr>
<td>GFDL</td>
<td>Geophysical Fluid Dynamics Laboratory</td>
</tr>
<tr>
<td>GFS</td>
<td>Global Forecast System</td>
</tr>
<tr>
<td>GIP</td>
<td>Global Interoperability Program</td>
</tr>
<tr>
<td>GO-ESSP</td>
<td>Global Organization of Earth System Science Portals</td>
</tr>
<tr>
<td>HYCOM</td>
<td>Hybrid Coordinate Ocean Model</td>
</tr>
<tr>
<td>IMaGe</td>
<td>Institute for Mathematics in the Geosciences</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>MAP</td>
<td>Modeling Analysis and Prediction program</td>
</tr>
<tr>
<td>MAPL</td>
<td>Modeling Analysis and Prediction program Layer</td>
</tr>
<tr>
<td>METAFORE</td>
<td>common Metadata For climate modelling digital repositories</td>
</tr>
<tr>
<td>MOM4</td>
<td>Modular Ocean Model 4</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NCAR</td>
<td>National Center for Atmospheric Research</td>
</tr>
<tr>
<td>NEMS</td>
<td>NOAA Environmental Modeling System</td>
</tr>
<tr>
<td>NESII</td>
<td>NOAA Environmental Software Infrastructure and Interoperability group</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NRL</td>
<td>Naval Research Laboratory</td>
</tr>
<tr>
<td>NSF</td>
<td>National Science Foundation</td>
</tr>
<tr>
<td>NUOPC</td>
<td>National Unified Operational Prediction Capability</td>
</tr>
<tr>
<td>NWP</td>
<td>Numerical Weather Prediction</td>
</tr>
<tr>
<td>PCMDI</td>
<td>Program for Climate Model Diagnosis and Intercomparison</td>
</tr>
<tr>
<td>pWASH123</td>
<td>parallel WAterSHed 1-2-3D model</td>
</tr>
<tr>
<td>ROMS</td>
<td>Regional Ocean Modeling System</td>
</tr>
<tr>
<td>SCRIP</td>
<td>Spherical Coordinate Interpolation and Remapping Package</td>
</tr>
<tr>
<td>SWAN</td>
<td>Simulating WAves Nearshore model</td>
</tr>
<tr>
<td>SWAT</td>
<td>Soil Water Analysis Testbed</td>
</tr>
<tr>
<td>WRF</td>
<td>Weather Research and Forecast model</td>
</tr>
</tbody>
</table>
Appendix B: Current and Pending Support, ESMF and Curator

<table>
<thead>
<tr>
<th>Program</th>
<th>Sponsor</th>
<th>Period of Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battlespace Environments Institute Infrastructure Development</td>
<td>DoD</td>
<td>$1M/yr; end 12/10</td>
</tr>
<tr>
<td>Modeling Analysis and Prediction Program Infrastructure Development and Curator</td>
<td>NASA</td>
<td>$800K/yr; end 12/10</td>
</tr>
<tr>
<td>Modeling Analysis and Prediction Program ESMF Development</td>
<td>NASA</td>
<td>about $400K/yr, end 6/16</td>
</tr>
<tr>
<td>Science Gateway Development</td>
<td>NSF TeraGrid</td>
<td>$50K/yr; 8/09-8/11</td>
</tr>
<tr>
<td>Curator Portal Workspaces and Commodity Governance (CoG)</td>
<td>NSF CISE</td>
<td>$300K/yr; 2/10-2/13</td>
</tr>
<tr>
<td>NUOPC</td>
<td>NOAA/DoD</td>
<td>TBD; 3/10-March 3/15</td>
</tr>
<tr>
<td>Global Interoperability Program</td>
<td>NOAA</td>
<td>TBD; 6/09-TBD</td>
</tr>
</tbody>
</table>