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# The Earth System Modeling Framework

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**CLIMATE**

**DATA ASSIMILATION**

**WEATHER**

**HDF and HDF-EOS Workshop VII  
Silver Spring, MD  
23-25 September 2003**

*Arlindo da Silva, NASA/GSFC/GMAO*

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# Project Overview

# ESMF

**GOAL:** To increase software reuse, interoperability, ease of use and performance portability in climate, weather, and data assimilation applications

## PRODUCTS:

- Coupling superstructure and utility infrastructure software
- Synthetic code suite for validation and demonstration
- Set of 15 ESMF-compliant applications (including CCSM, WRF, GFDL models, MIT, NCEP and NASA data assimilation systems)
- Set of 8 interoperability experiments

**RESOURCES:** \$10M over 3 years

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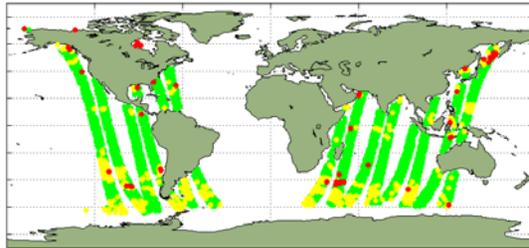
# The ESMF Team

<b>Teams and PIs:</b>	<p>Part I: Core ESMF Development (Killeen, NCAR)</p> <p>Part II: Modeling Applications (Marshall, MIT)</p> <p>Part III: Data Assimilation Applications (da Silva, NASA DAO)</p>
<b>Core Technical Leads:</b>	V. Balaji/GFDL, Cecelia DeLuca/NCAR, Chris Hill/MIT
<b>Co-Investigators:</b>	NASA/GSFC-DAO, NASA/GSFC-NSIPP, DOE/LANL, DOE/ANL, University of Michigan, MIT, NSF/NCAR-SCD, NSF/NCAR-CGD, NSF/NCAR-MMM, NOAA/NCEP, NOAA/GFDL
<b>Term:</b>	3 years, starting February 2002



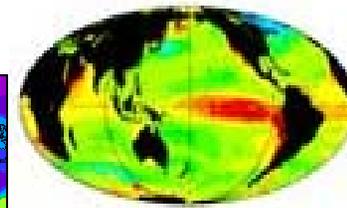
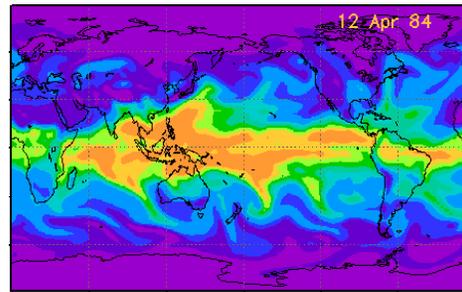
# ESMF

## Deployment Activities

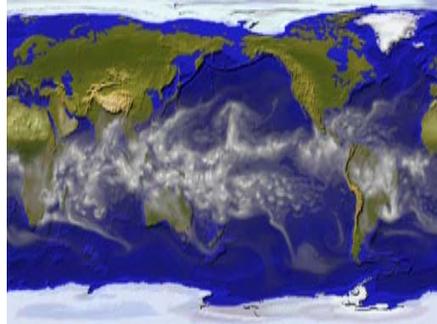


NASA GSFC PSAS

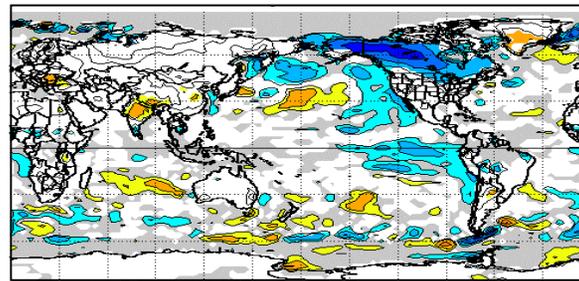
GFDL FMS Suite



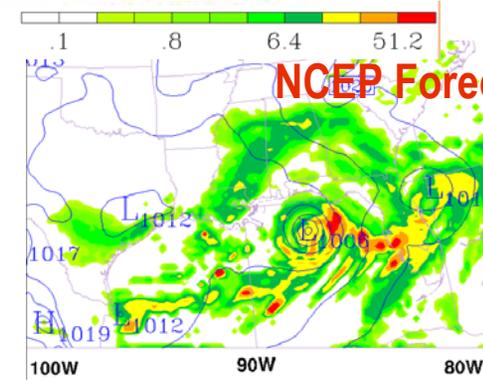
MITgcm



NCAR/LANL CCSM



-5 -4 -3 -2 -1 -.5 .5 1 2 3 4 5 °C



NCEP Forecast

NSIPP Seasonal Forecast



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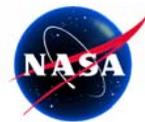
# ESMF Interoperability Demonstrations

# ESMF

COUPLED CONFIGURATION	NEW SCIENCE ENABLED
GFDL B-grid atm / MITgcm ocn	Global biogeochemistry (CO <sub>2</sub> , O <sub>2</sub> ), SI timescales.
GFDL MOM4 / NCEP forecast	NCEP seasonal forecasting system.
NSIPP ocean / LANL CICE	Sea ice model for extension of SI system to centennial time scales.
NSIPP atm / DAO analysis	Assimilated initial state for SI.
DAO analysis / NCEP model	Intercomparison of systems for NASA/NOAA joint center for satellite data assimilation.
DAO CAM-fv / NCEP analysis	Intercomparison of systems for NASA/NOAA joint center for satellite data assimilation.
NCAR CAM Eul / MITgcm ocn	Improved climate predictive capability: climate sensitivity to large component interchange, optimized initial conditions.
NCEP WRF / GFDL MOM4	Development of hurricane prediction capability.

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# Architecture

# ESMF

**ESMF SUPERSTRUCTURE**  
coupling services

gridded components,  
coupling components,  
custom components

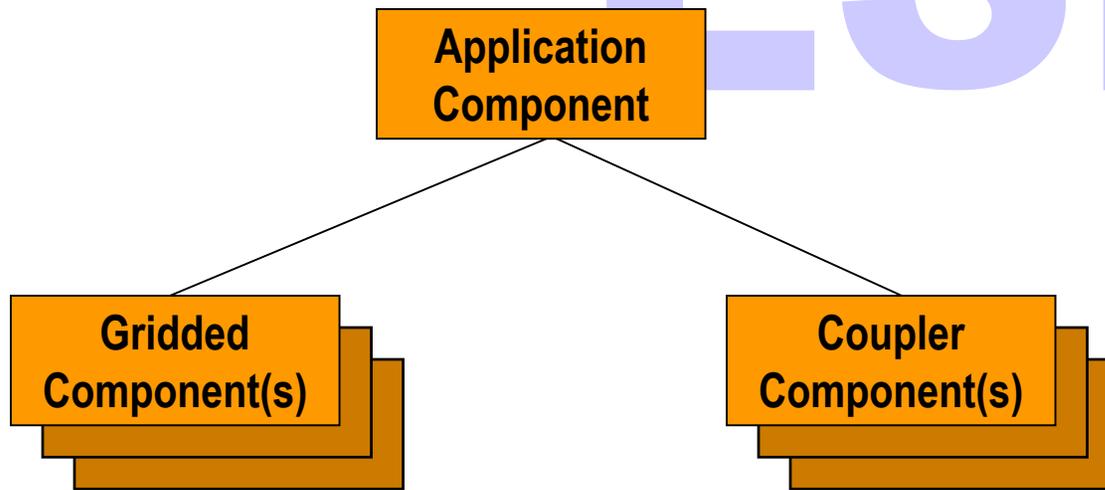
user-created model components

**ESMF INFRASTRUCTURE**  
integrated system utilities

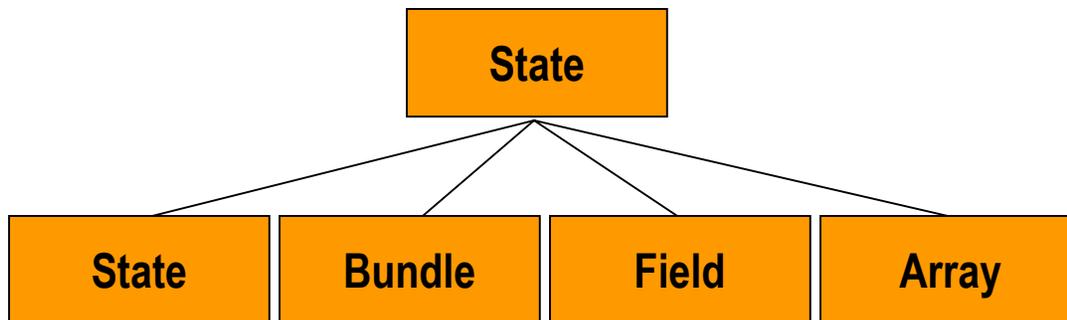
grids, transforms,  
communication kernel,  
timekeeping, ...

# Superstructure Classes

# ESMF



*Computation*



*Data*



# Infrastructure: Utilities

# ESMF

- Base
- **I/O**
- Attributes
- Machine Model
- PE List
- Layout
- Basic Communications
- Time Manager
- Registry
- Error Handling
- Logging
- Performance Profiling
- Configuration Attributes



# Infrastructure: ESMF I/O

- Requirement analysis has been completed, design is in progress
- The ESMF I/O layer must support:
  - Structured gridded data
  - Unstructured gridded data
  - Observational data on location stream
- ESMF I/O must support multiple data formats:
  - NetCDF, HDF 4, HDF 5, HDF-EOS
  - GRIB, BUFR
  - IEEE binary, GrADS compatible binary



# ESMF I/O: Metadata Convention

- The ESMF, along with the European PRISM framework, have adopted the Climate-Forecast (CF) conventions
- The CF conventions, now described in XML and independent of NetCDF, specify standard dimensions, and specify standard units for these dimensions and other quantities
- The ESMF team will work together with CF community to extend the CF conventions to support the variety of gridded/ungridded data we require.
- Other conventions such as HDF-EOS will co-exist with CF (as in current GMAO data products).



# ESMF I/O: Parallel Support

- **Two major drivers for I/O performance:**
  - **Enhancement in model resolution**
  - **Increase in I/O frequency**
- **Modes of Parallel I/O:**
  - **Single-threaded I/O**
  - **Multi-threaded, multi-fileset I/O**
  - **Multi-threaded, single fileset I/O (2)**
- **Synchronous and asynchronous I/O (2)**



# Summary

# ESMF

## **ESMF eliminates software barriers to collaboration among organizations**

- Easy exchange of model components accelerates progress in NWP and climate modeling
- Independently developed models and data assimilation methods can be combined and tested
- Coupled model development becomes truly distributed process
- Advances from smaller academic groups easily adopted by large modeling centers

## **ESMF facilitates development of new interdisciplinary collaborations**

- Simplifies extension of climate models to upper atmosphere
- Accelerates inclusion of advanced biogeochemical components into climate models
- Develops clear path for many other communities to use, improve, and extend climate models
- Many new model components gain easy access to the power of data assimilation

