Motivation

- **Ensemble Modeling**
  Benefits of ensemble analyses using multiple alternative model formulations

- **Complexity of Modeling Systems**
  Increasing complexity in climate modeling systems
  Difficulty of linking together disparate models

- **Software Reliability**
  Modular software isolates bugs, eases maintenance
  Re-usable components reduce introduction of errors while porting models to new systems
Why a common software framework?

- Earth system modelling expertise widely distributed

Geographically

Thematically

PRISM overview

Courtesy of PRISM (http://www.prism.enes.org)
Earth Systems Modeling Frameworks

- **Component-based System for Linking Gridded Models**
  - Each component has a standard calling interface and behavior
  - Designed for multi-processor communications

- **Superstructure for Linking Components**
  - Gridded Components and Couplers
  - Data communications and regridding

- **Infrastructure for Developing Components**
  - Time Management
  - Data structures: arrays, fields, etc.
  - Message logging and data I/O
Earth Systems Modeling Frameworks

- ESM Software Frameworks Can Reduce Costs:
  - Shared development costs
  - Component re-use
- Enhance Science:
  - Scientists focus on science, not software
  - Software available to smaller, lower budget teams
  - Allow comparison of diverse models
- Two main ESM Frameworks
  - **PRISM**
    - EU “Partnership for Research Infrastructures in earth System Modelling”
  - **ESMF**
    - US “Earth Systems Modeling Framework”
Why ESMF?

- Wide adoption, at least in U.S.
  - 4 Agency Sponsors
  - Numerous components already in use
    - Atmosphere: 19, Ocean: 9, Land: 7, Other: 3
    - Many others under development
    - Atmosphere: 19, Ocean: 7, Land: 3, Other: 9

- Consistent modular design
- High Portability
- Free and Open Source
- Community Supported
ESMF NEMURO

A Prototype Ocean Ecosystem
ESMF Component
ESMF Evaluation

Advantages
- Strongly modular design
- Highly portable
- Flexible data structures
- Growing user base

Disadvantages
- Complex API
- Difficult to learn
- Shifting interfaces
- Some computation overhead

Barriers to Adoption
- Little known outside U.S.
- Lacks critical mass of applications

Conclusion
- A useful tool, but not yet fully ready
ESMF v1
Prototype

ESMF v2
Components VM and Utils
ESMF_GridCompRun()

ESMF v3
Index Space Operations
ESMF_ArraySparseMatMul()

ESMF v4
Grid Operations
ESMF_GridCreate()
ESMF_FieldRegrid()

ESMF v5
Standardization
Build, init, data types, error handling

Courtesy of ESMF (http://www.esmf.ucar.edu)
Next Steps

■ Put prototype code on PICES MODEL website
■ Finish coupling with ROMS-ESMF
  Full 3D gridded physics
  Based on ROMS “BioToy” configuration
  ► Provides standard benchmark example
■ Run Benchmarks
  NEMURO-ESMF coupled to ROMS vs. native
  ROMS implementation of NEMURO
  ► Check correctness of native ROMS NEMURO
  ► Benchmark overhead cost of ESMF coupling
  Optimize NEMURO ESMF code
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For More Information:

http://www.esmf.ucar.edu

http://www.prism.enes.org

NEMURO ESMF -- Coming soon to:

http://www.pices.int/members/task_teams/MODEL.aspx