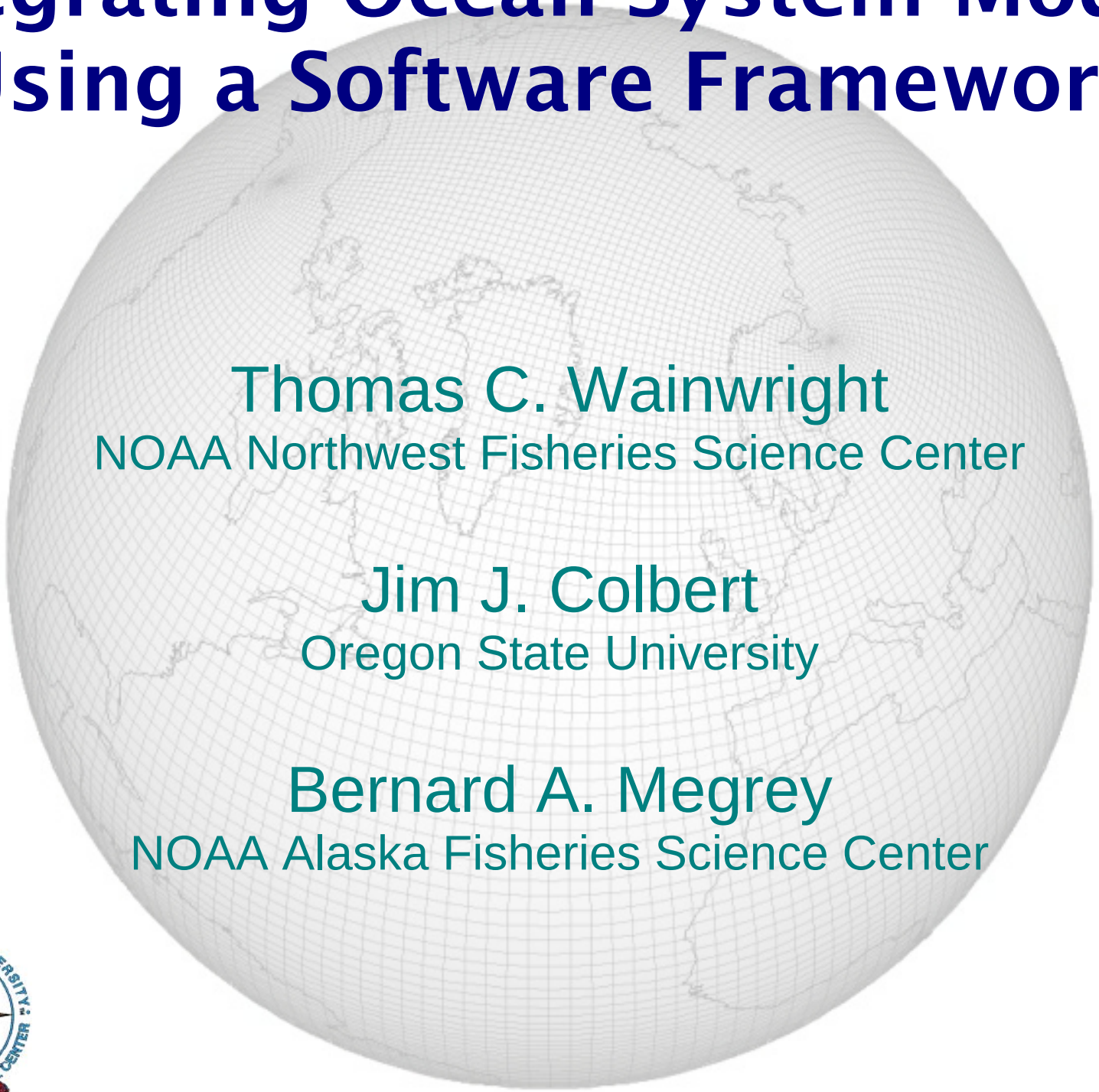
Integrating Ocean System Models Using a Software Framework



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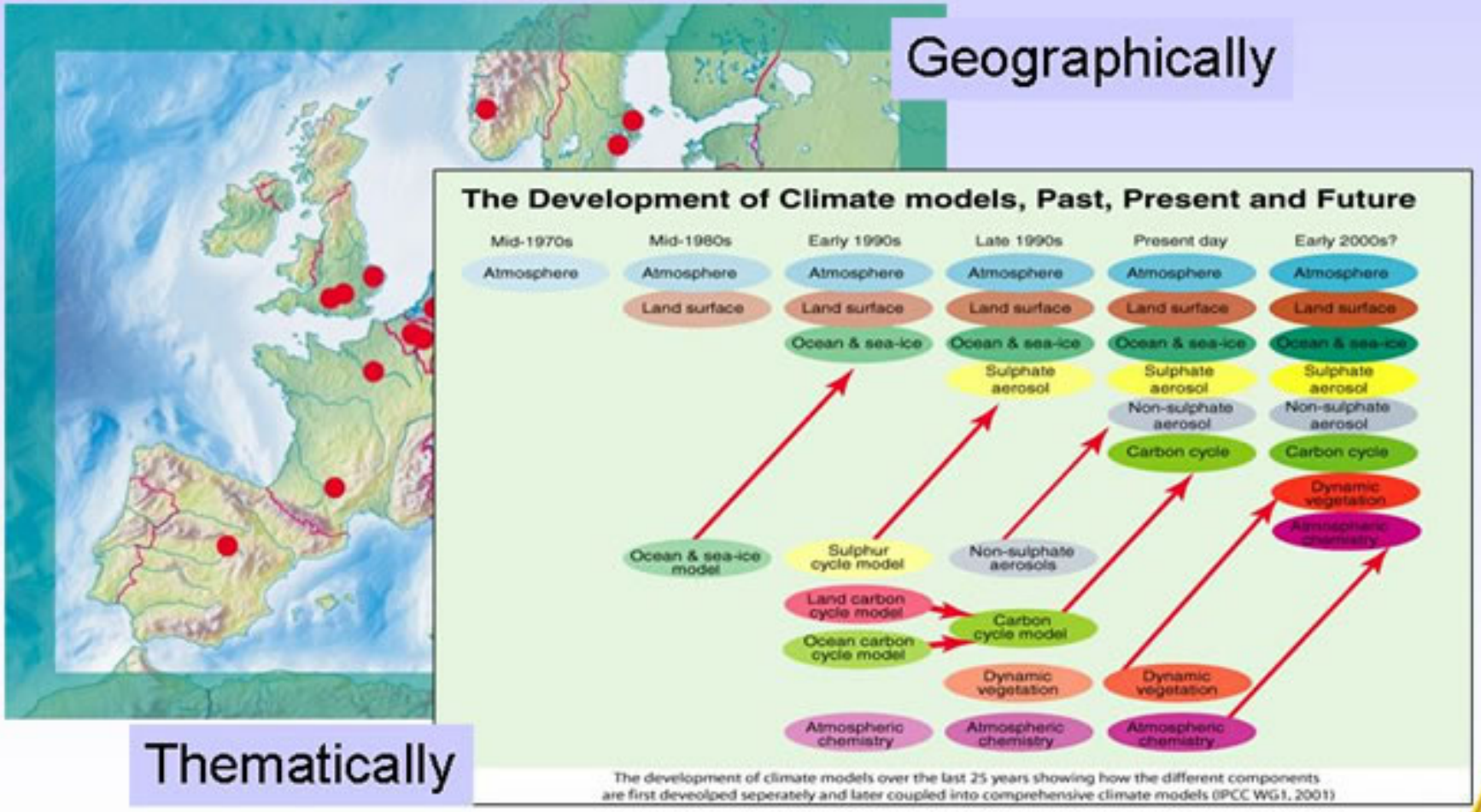
Motivation

- 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

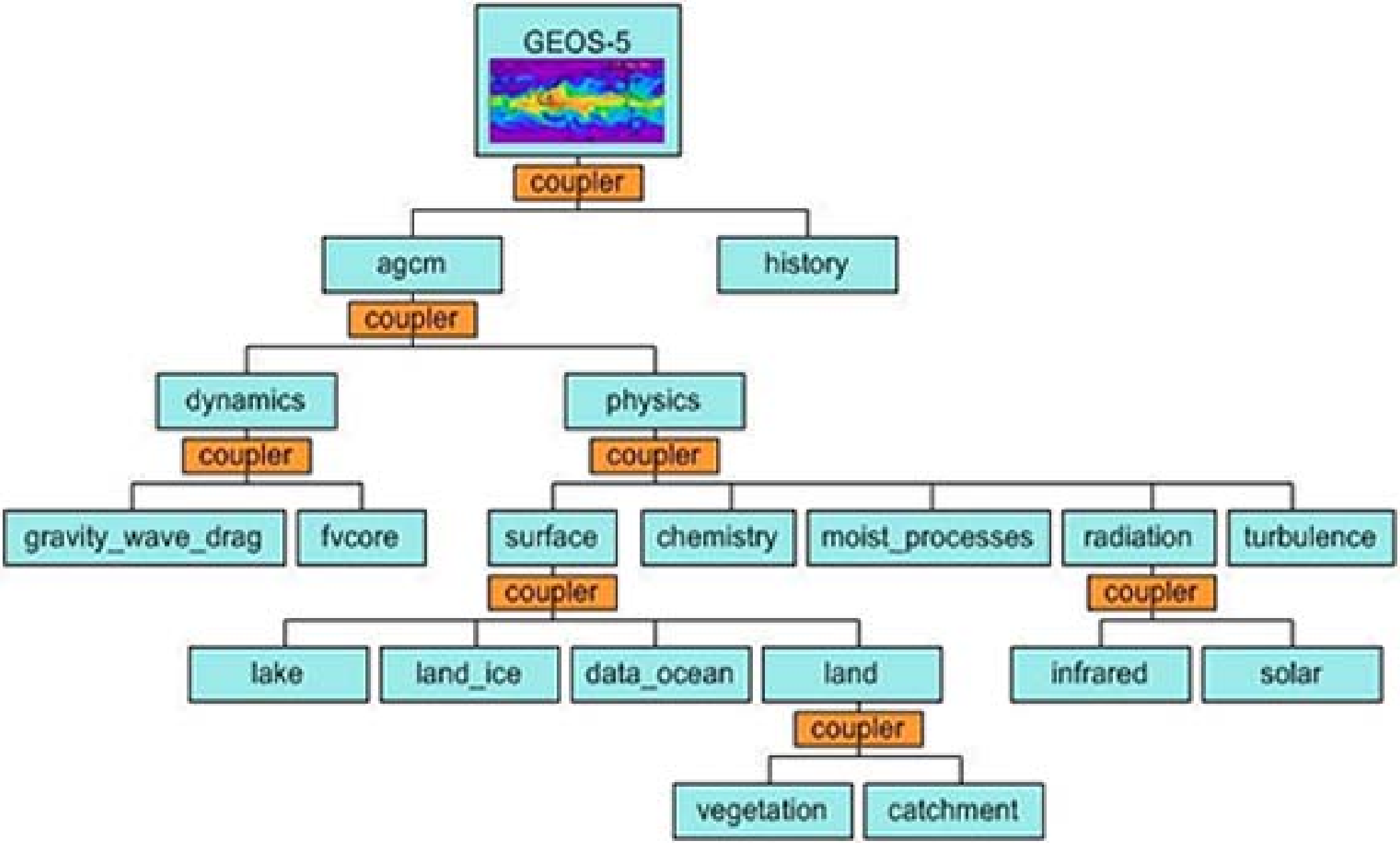


Courtesy of PRISM (http://www.prism.enes.org)

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

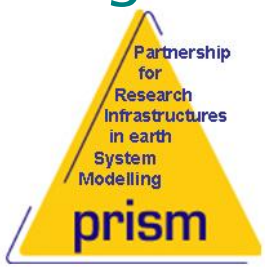
NASA GEOS-5



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

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”

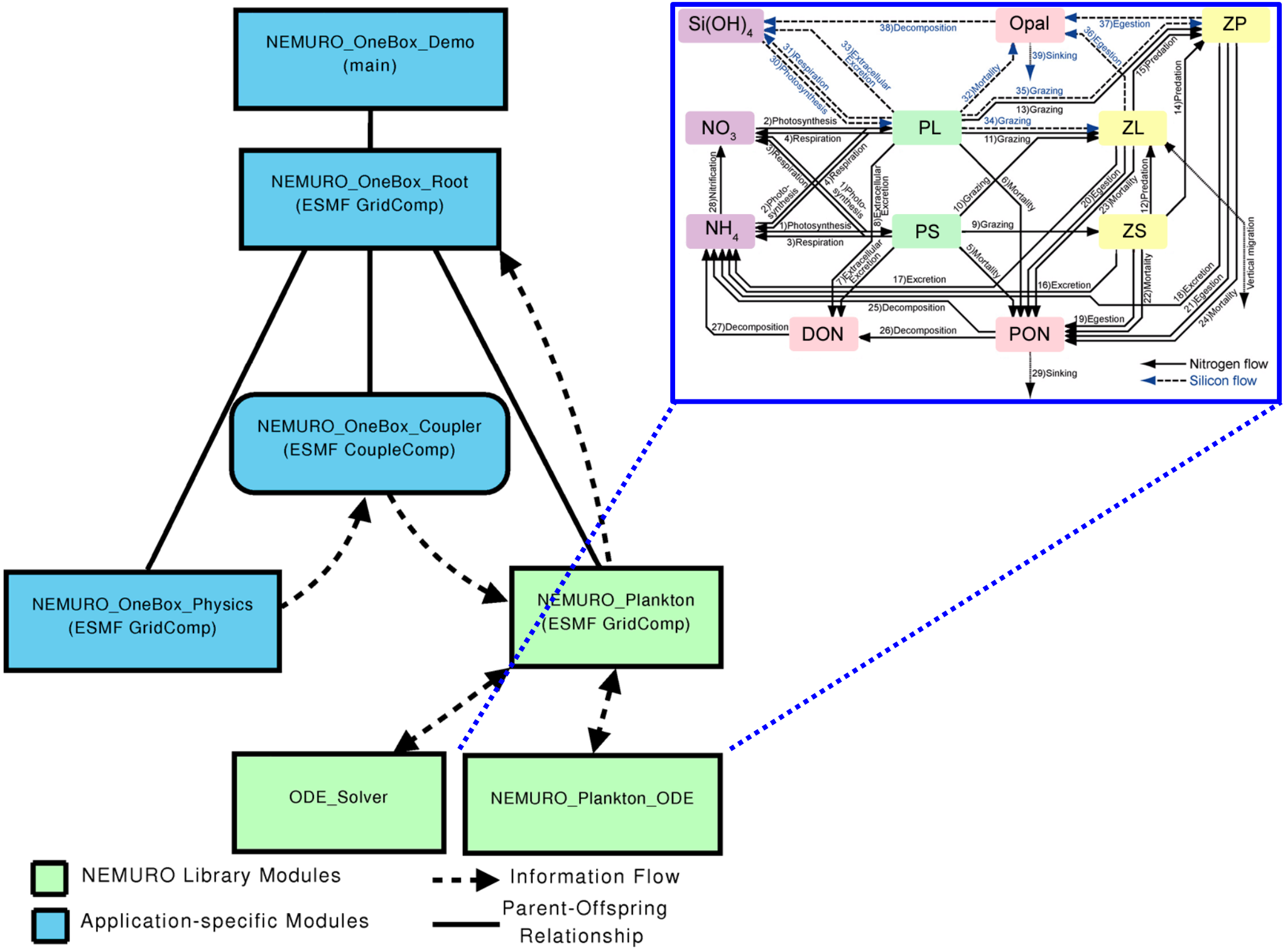


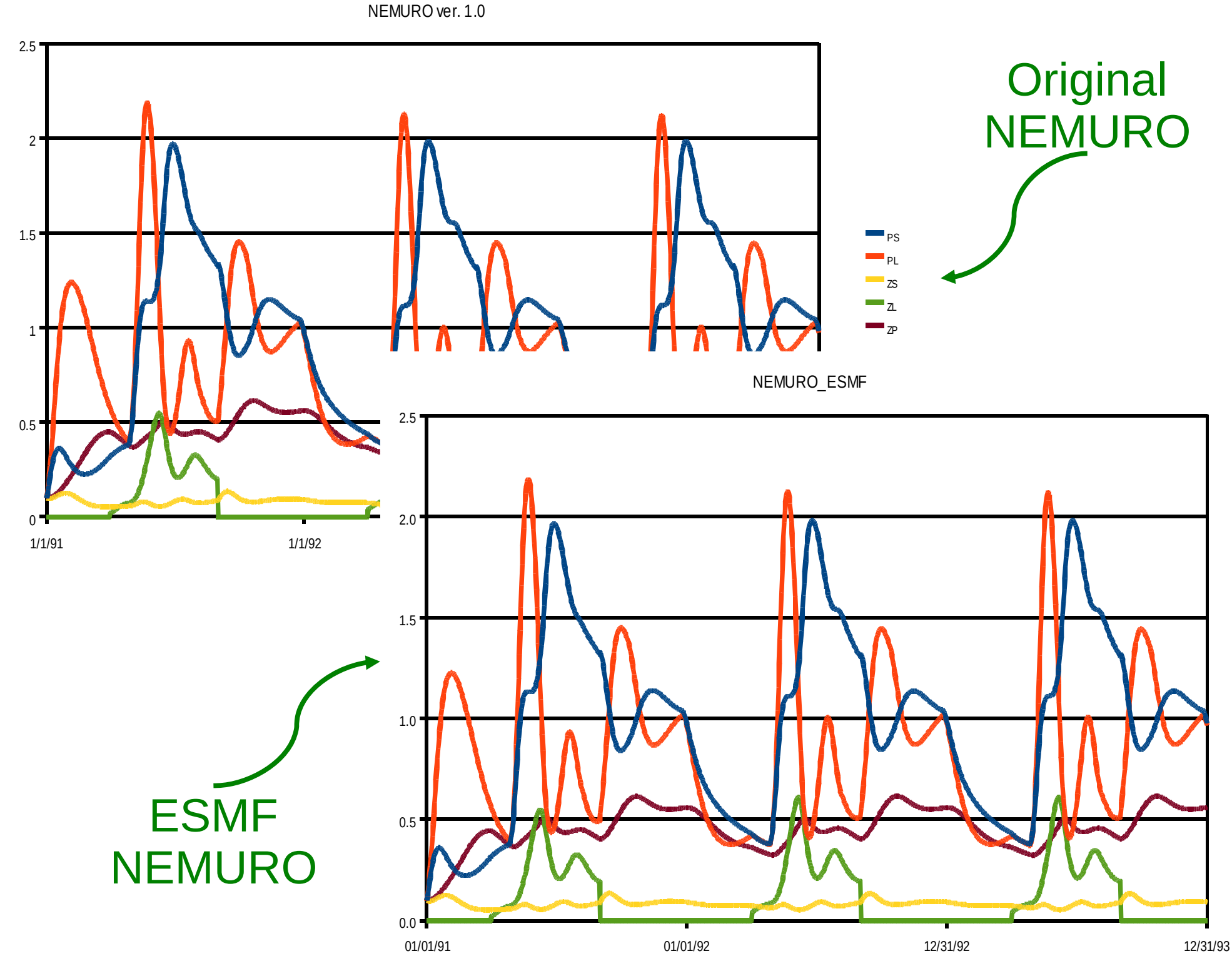
Why ESMF?

- 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


NEMURO_OneBox_Demo
(main)
NEMURO_OneBox_Root
(ESMF GridComp)
NEMURO_OneBox_Coupler
(ESMF CoupleComp)
NEMURO_OneBox_Physics
(ESMF GridComp)
NEMURO_Plankton
(ESMF GridComp)
ODE_Solver
NEMURO_Plankton_ODE
Si(OH)4
Opal
ZP
NO3
PL
ZL
NH4
PS
ZS
DON
PON
38)Decomposition
37)Egestion
39)Sinking
35)Grazing
13)Grazing
34)Grazing
11)Grazing
2)Photosynthesis
4)Respiration
1)Photosynthesis
3)Respiration
9)Grazing
17)Excretion
16)Excretion
25)Decomposition
26)Decomposition
27)Decomposition
19)Egestion
29)Sinking
Nitrogen flow
Silicon flow
NEMURO Library Modules
Application-specific Modules
Information Flow
Parent-Offspring Relationship


NEMURO ver. 1.0
2.5
2
1.5
1
0.5
0
1/1/91
1/1/92
PS
PL
ZS
ZL
ZP
Original
NEMURO
NEMURO_ESMF
2.5
2.0
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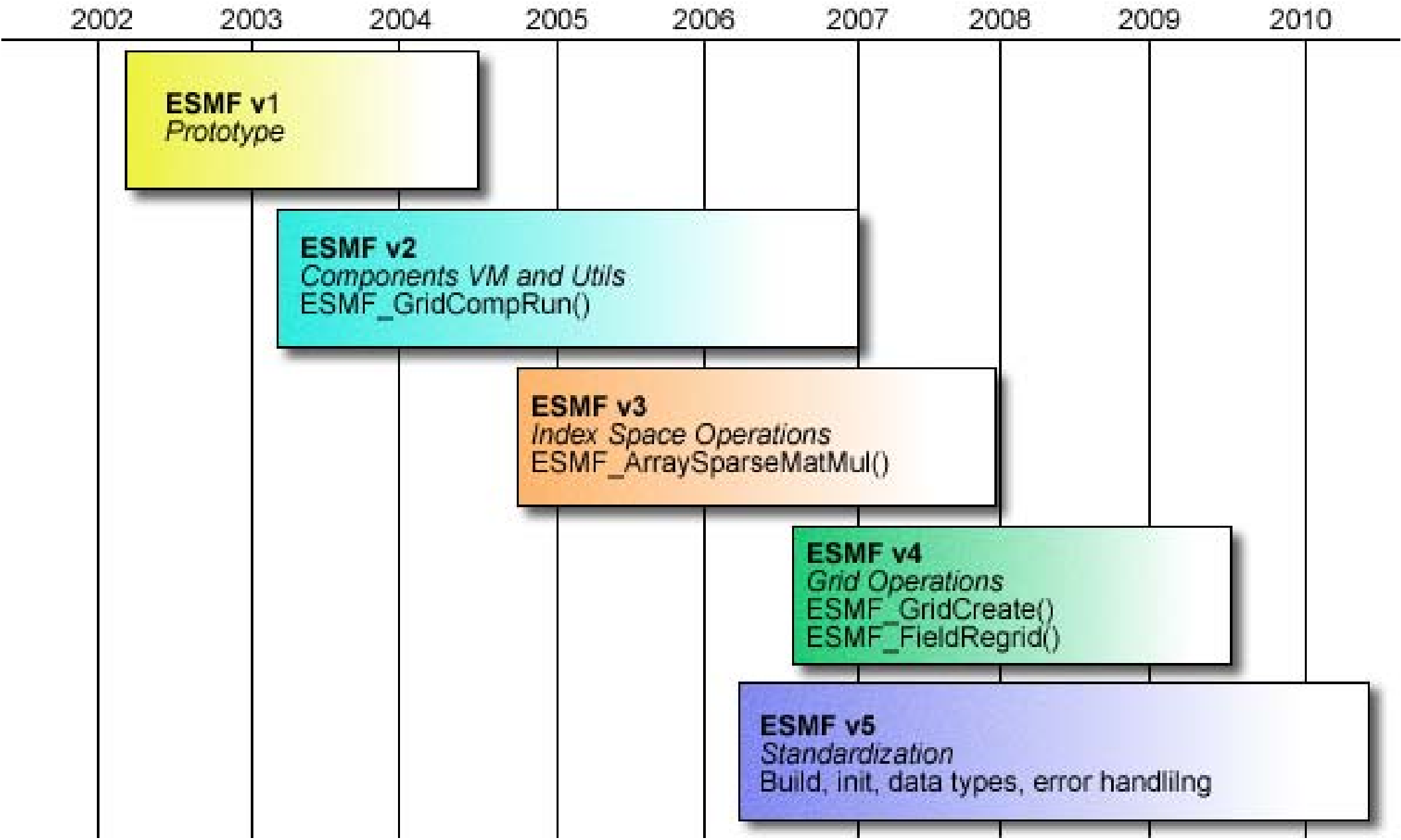
01/01/92
12/31/92
12/31/93
ESMF
NEMURO

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

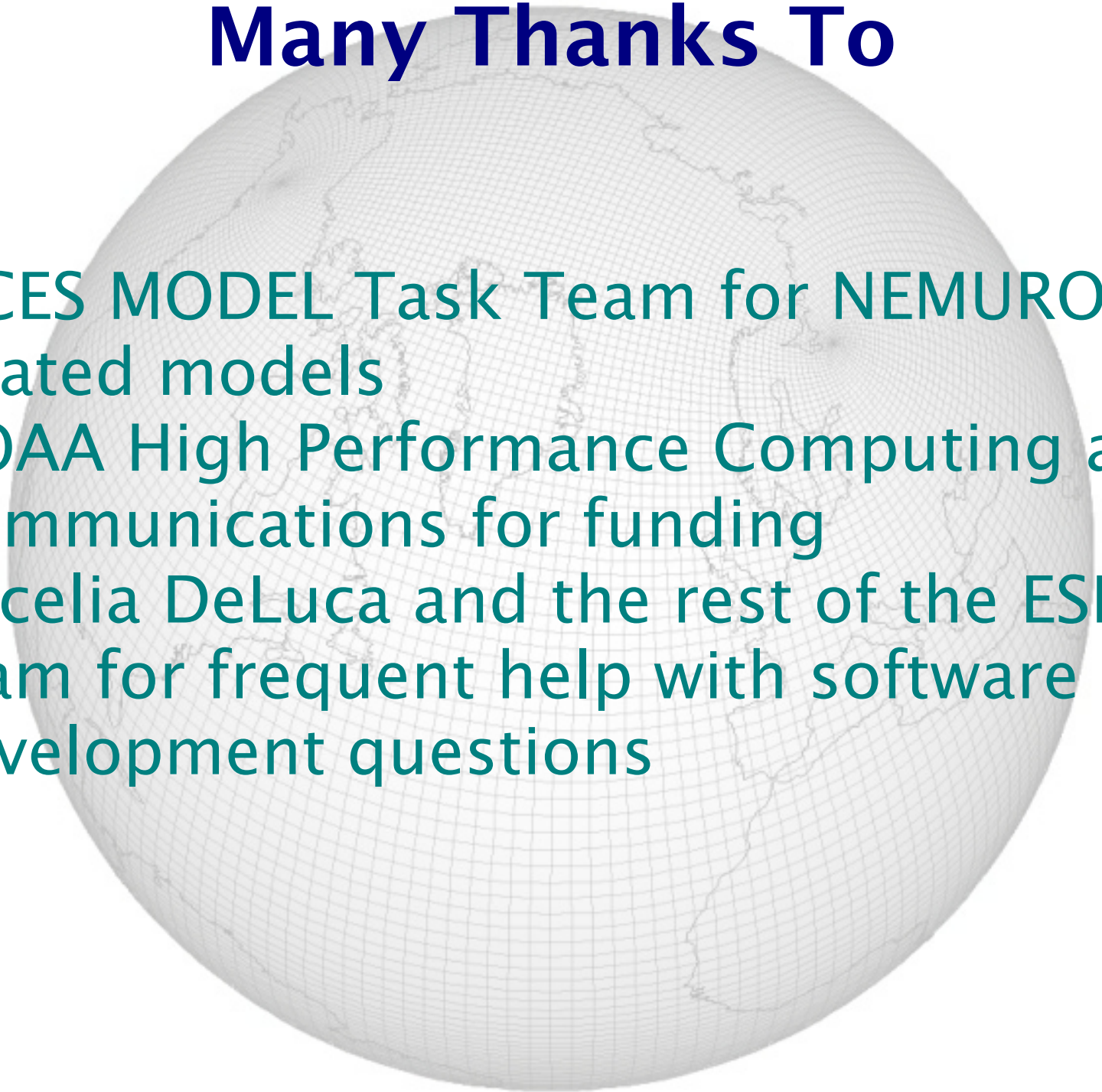


Courtesy of ESMF (http://www.esmf.ucar.edu)

Next Steps

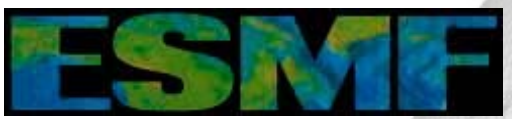
- Put prototype code on PICES MODEL web site
- Finish coupling with ROMS-ESMF
  - Full 3D gridded physics
  - Based on ROMS “BioToy” configuration
    - Provides standard benchmark example
- Run Benchmarks
  - NEMURO-ESMF coupled to ROMS vs. native ROMS implementation of NEMURO
    - Check correctness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

Many Thanks To



- PICES MODEL Task Team for NEMURO and related models
- NOAA High Performance Computing and Communications for funding
- Cecelia DeLuca and the rest of the ESMF team for frequent help with software development questions

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