Grid-Enabled Earth System Models

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Outline

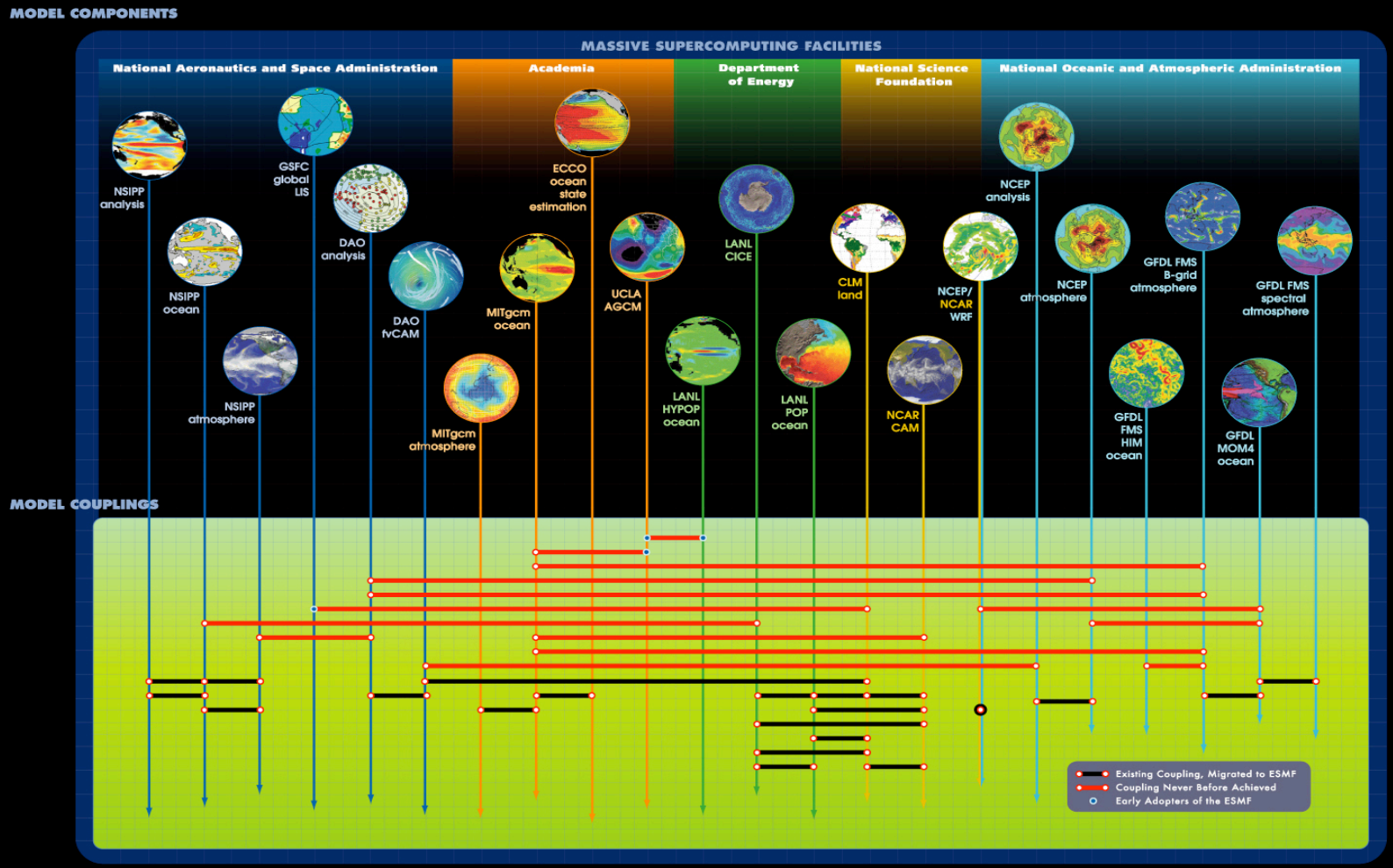
- Background
  - Earth System Model Framework (ESMF)
  - Common Component Architecture (CCA)
  - Grid Computing (OGSI/OGSA)
  - Lambda Networks
- Grid-enabled Earth system models
  - ESMF-CCA Prototype
  - Couple climate models via Grid
  - Grid-enabled ESMF model components
  - Next Step
- Summary

Earth System Models

- Typical Earth system models (e.g., climate, weather, data assimilation) consist of several complex components coupled together through exchange of a sizable amount of data.
- There is a growing need for coupling model components from different institutions
  - Discover new science
  - Validate predictions

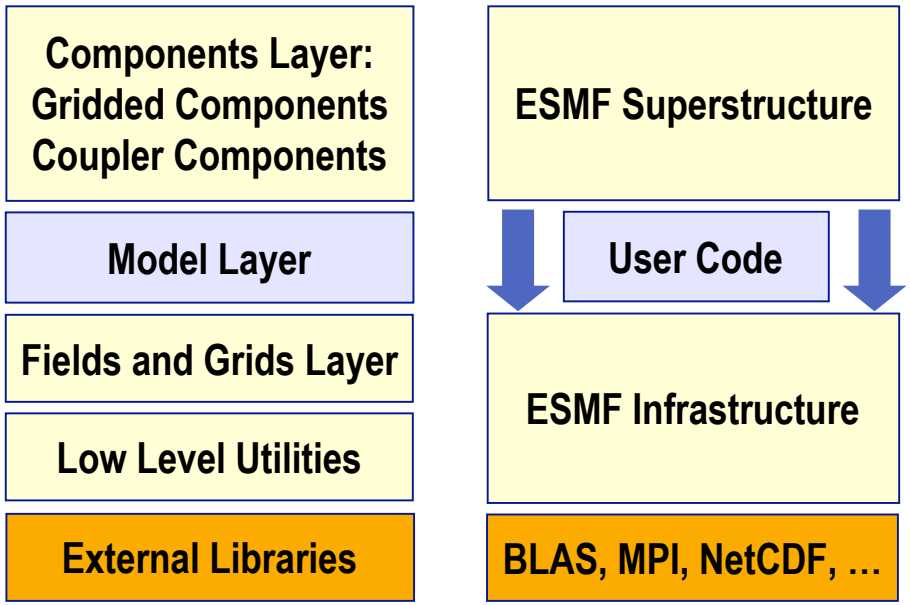
ESMF

EARTH SYSTEM MODELING FRAMEWORK



ESMF Architecture

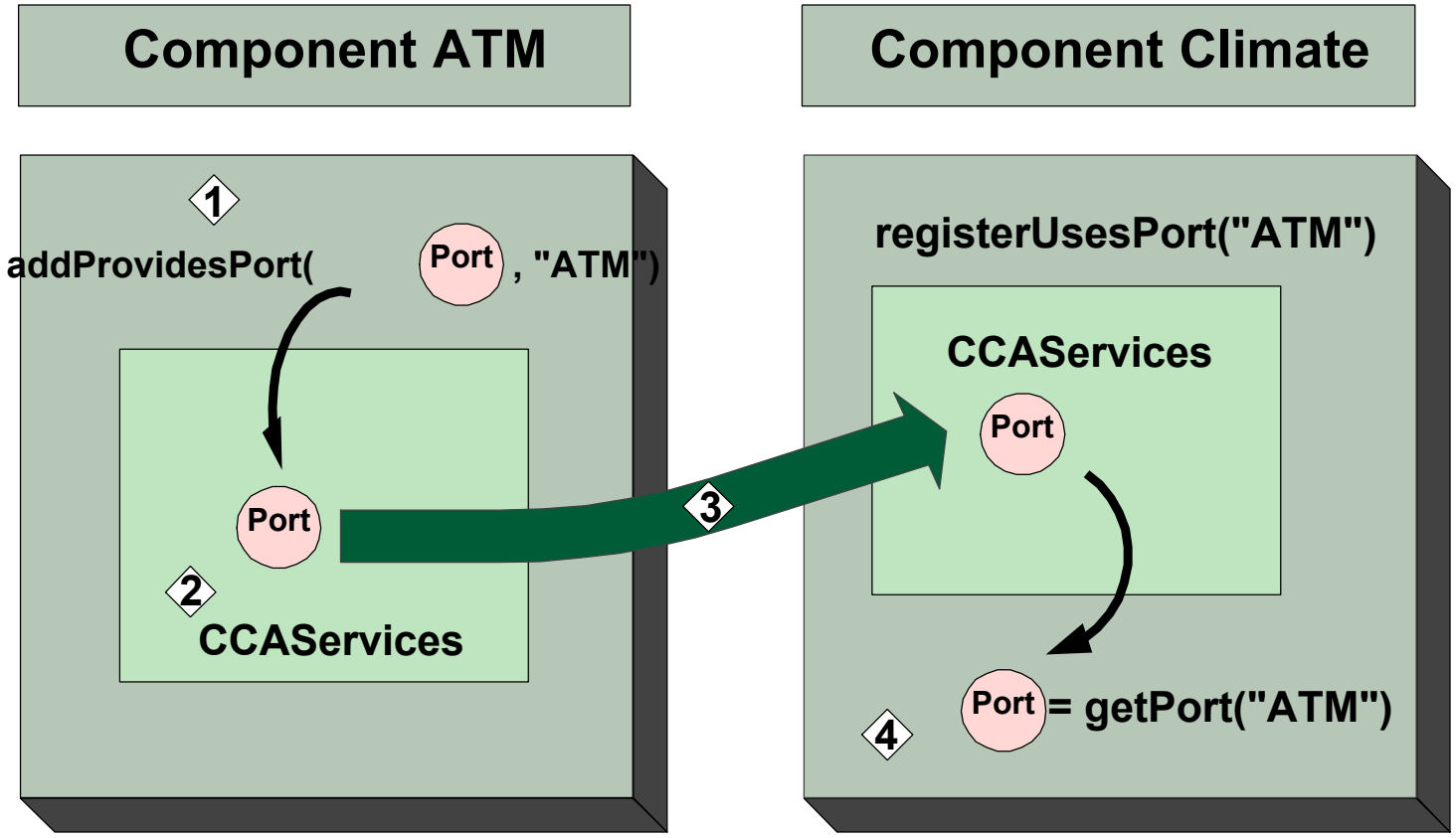
1. ESMF provides an environment for assembling geophysical components into applications.
2. ESMF provides a toolkit that components use to
   i. increase interoperability
   ii. improve performance portability
   iii. abstract common services



Common Component Architecture (CCA) Funded by DOE

- Goal: Interoperability between components developed by various groups/organizations.
- Define specifications for high-performance scientific components & framework.
- Provide frameworks such as Ccaffeine and XCAT to support CCA-compliant components.

CCA Ports and the Provides/Uses Design Pattern for Coupling Components is Simple and Flexible



Grid Computing (OGSI/OGSA)

- Effort to standardize Grid functionality
- Proposes a programming model for the Grid
- Defines standard interfaces and behaviors of a Grid service
- Uses the Web Services model for the Grid

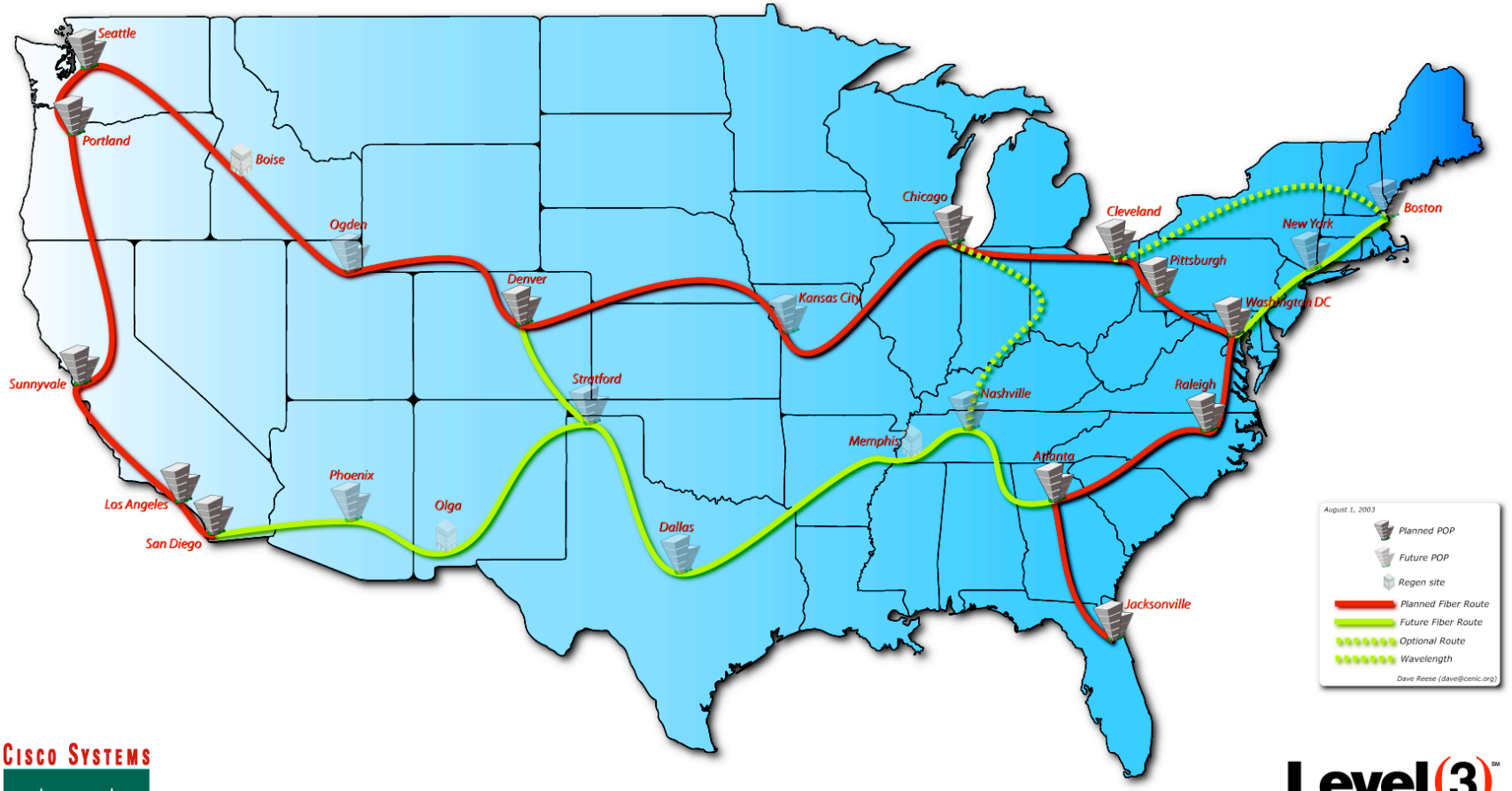
CCA/XCAT

- Merging CCA and OGSI
  a) Component model
     - ✓ Compliant with CCA specification
  b) Grid services
     - ✓ Each XCAT component is also a collection of Grid services
     - ✓ XCAT Provides Ports are implemented as OGSI web service
     - ✓ XCAT Use Ports can also accept any OGSI compliant web service
- XCAT: provides a component based Grid services model for Grid computing
     - ✓ Component Assembly: Composition in space

Lambda Networks

- Dedicated high speed links (1Gbps, 10 Gbps, etc)
- Being demonstrated in large-scale distributed visualization and data mining
- National Lambda Rail is currently under development

National Lambda Rail (NLR)
National Fiber Network-Home of the OptIPuter



Initial Coordinating Participants

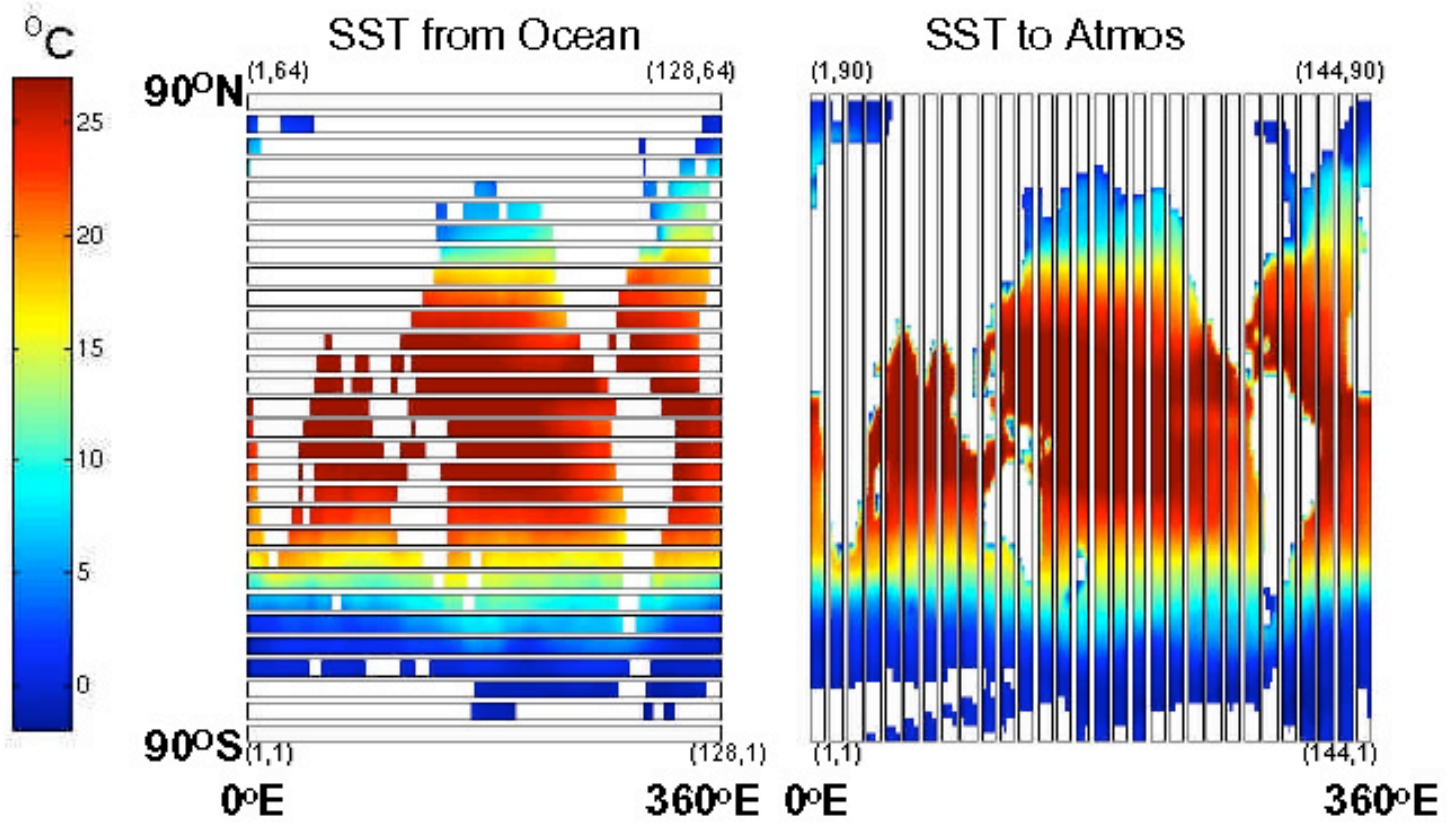
Objective: Coupling Earth System Model Components from Different Institutions

- Current approach: physically port source codes and their support environment such as libraries and data files to one computer
- Problems:
  - Considerable efforts and times are needed for porting, validating, and optimizing the codes
  - Some code owners may not want their codes viewed by others.

ESMF Facilitates Coupling Models from Different Institutions

SST is passed and regridded from MITgcm Ocean model to GFDL B-grid Atmosphere model

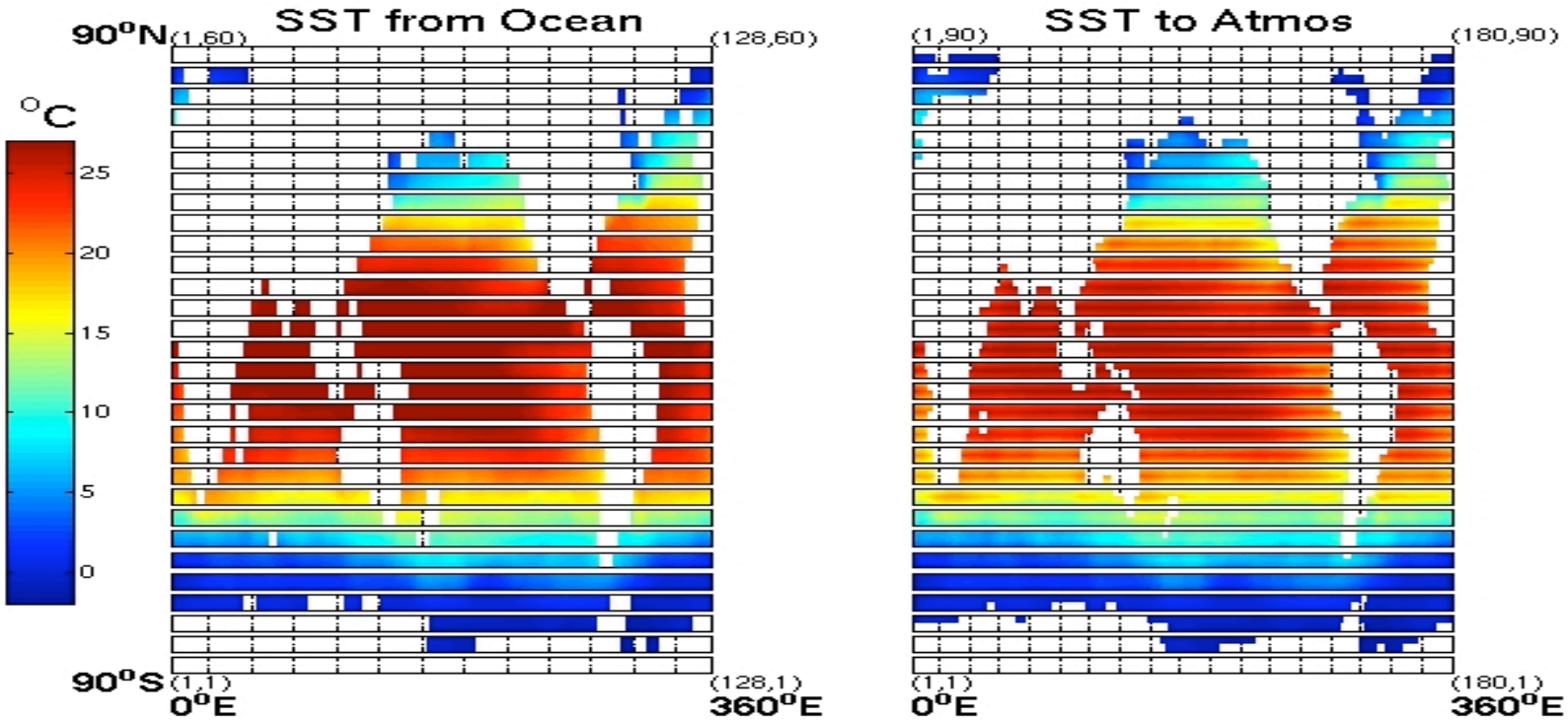
Performed at GFDL's SGI Computer



ESMF Facilitates Coupling Models from Different Institutions (continued)

SST is passed and regridded from MITgcm Ocean model to NCAR CAM model

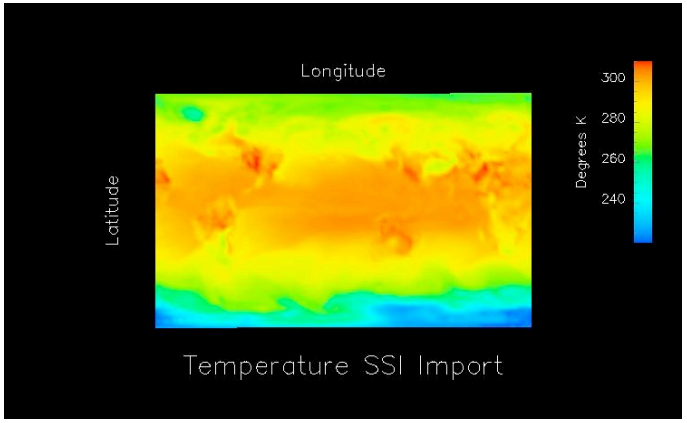
Peformed at NCAR's IBM Computer

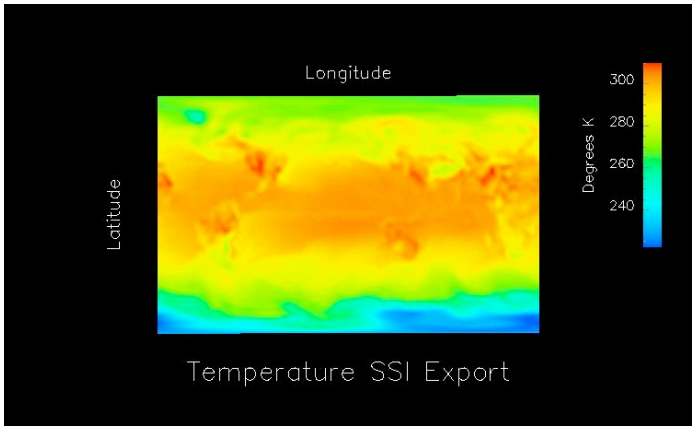


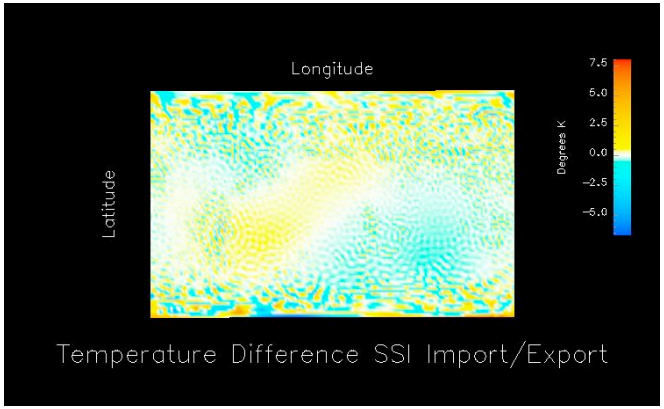
ESMF Facilitates Coupling Models from Different Institutions (continued)

NCAR CAM-produced temperature is passed to and assimilated in NCEPT SSI

Performed at NCAR's IBM Computer







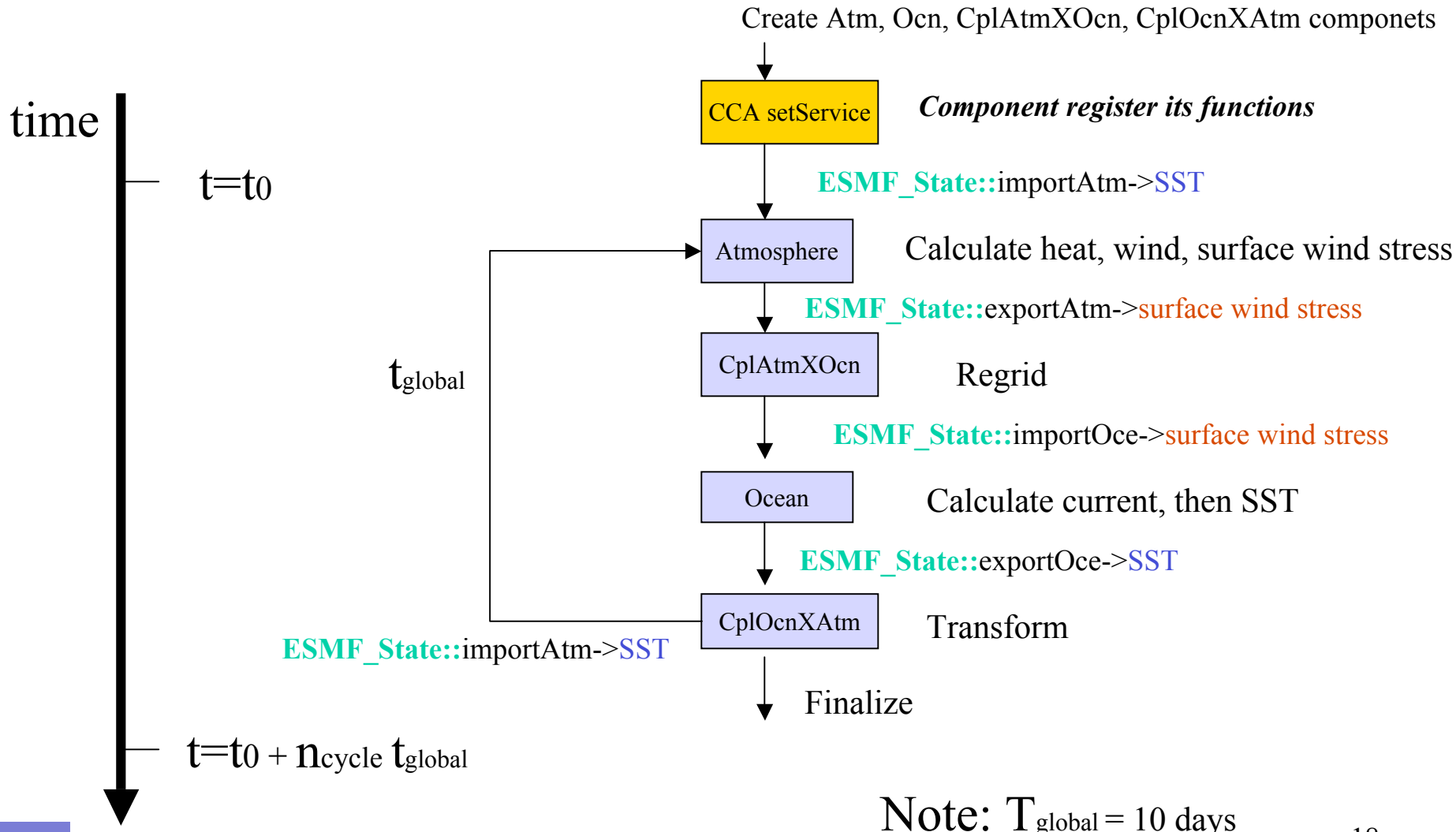
An Efficient Way of Coupling Distributed Models

- Use Grid Computing technology to couple model components located at their individual preferred locations

Relationship among Models, ESMF, CCA, Grid Computing

- CCA provides a generic way of supporting component interaction.
- ESMF specifies how climate model components should interact.
- Grid computing provides a standard way of component interaction via Grid (network)
- Using a typical sequential flow diagram for atmosphere-ocean coupling such as Cane-Zebiak model to illustrate the relationship.

Flow Diagram of Coupling Atmosphere and Ocean (Cane-Zebiak Model, well-known for predicting *El Nino* events)

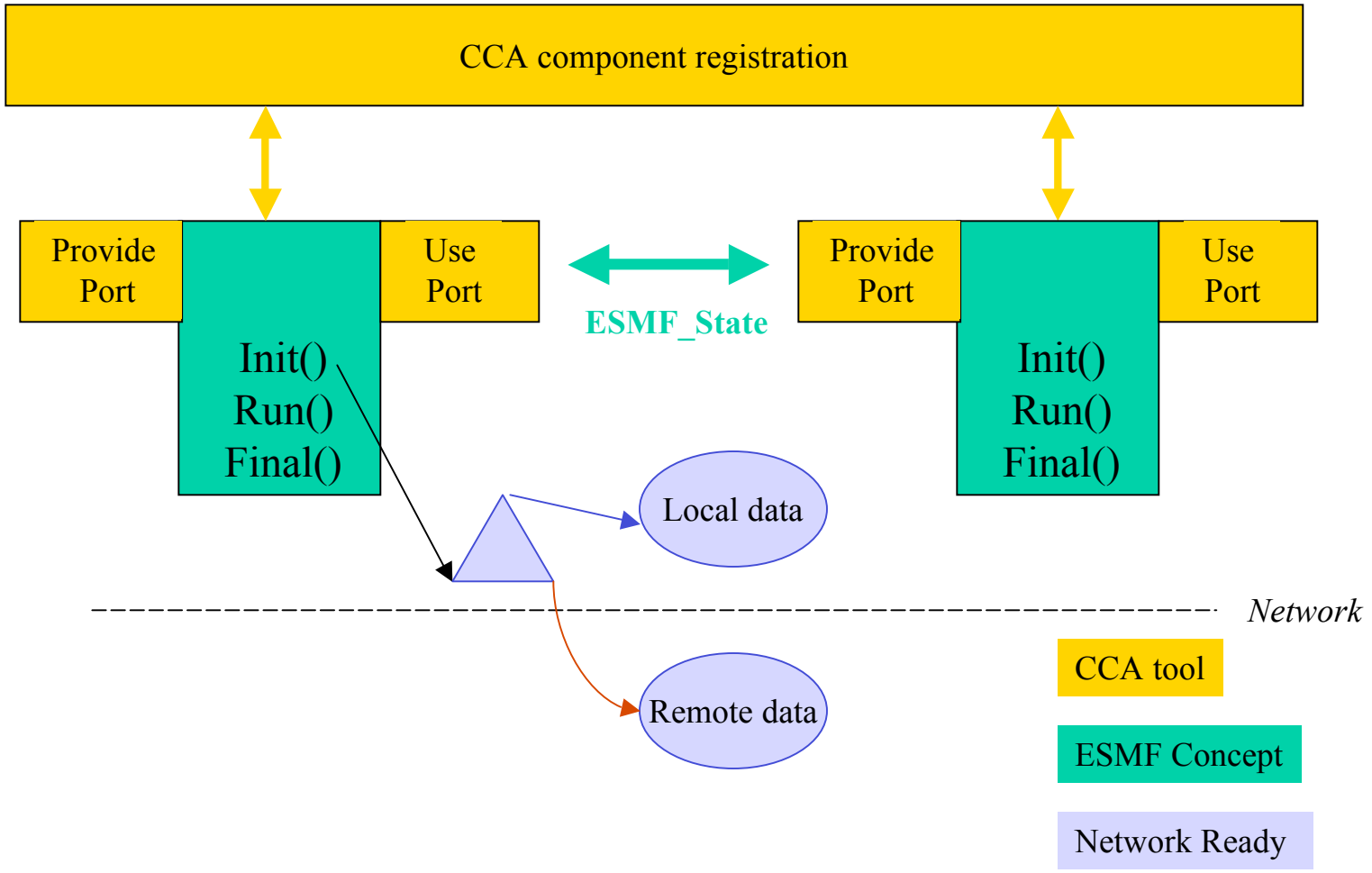


Note: T_{global} = 10 days

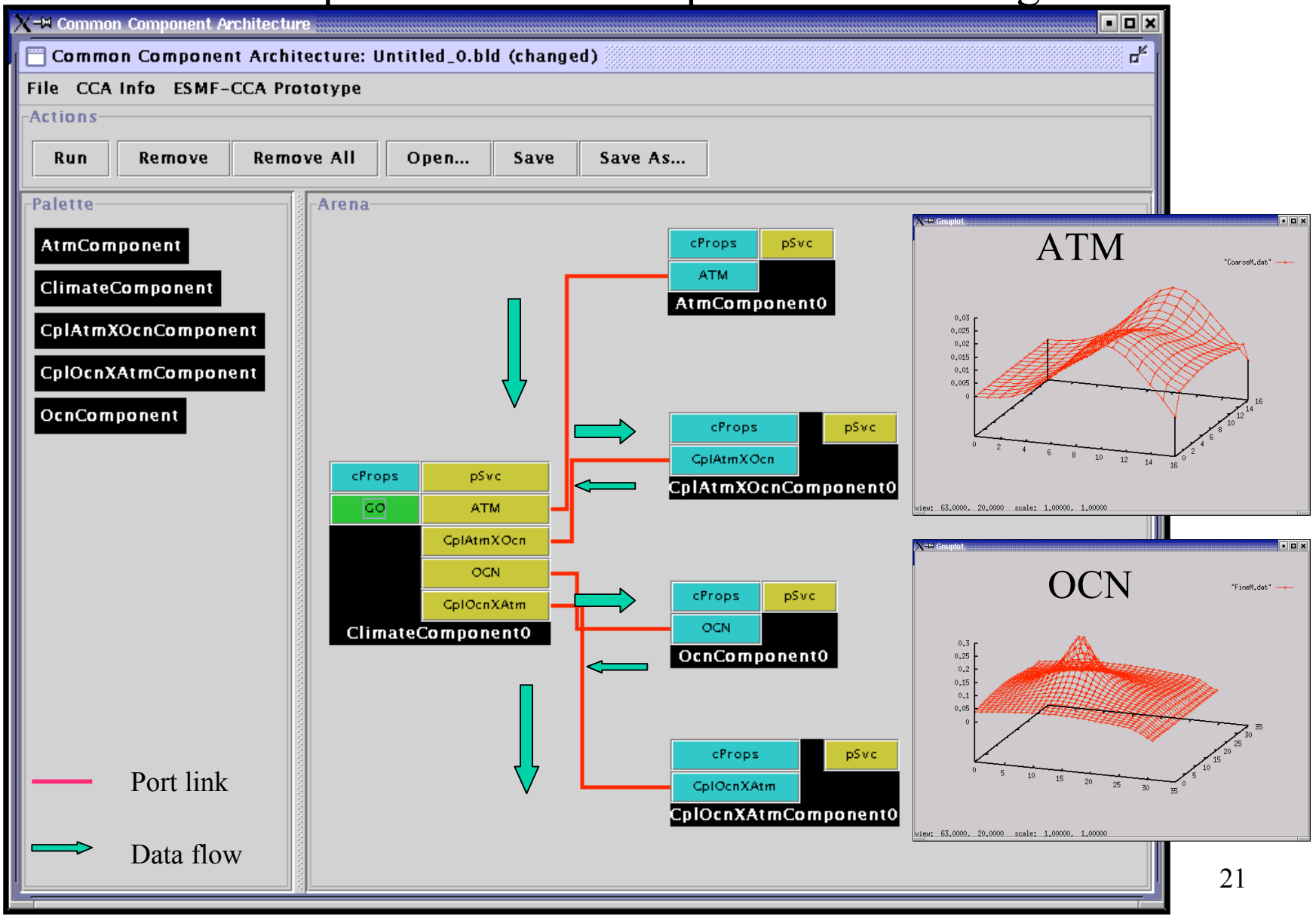
ESMF-CCA Prototype 1.0

- Goals:
  - Identify solutions and problems ahead of ESMF software development.
  - Ensure ESMF and CCA interoperable
- The prototype adopts:
  - CCA's component registration (setService)
  - CCA's component connection GUI.
  - Data is exchanged in a similar manner to ESMF_State
  - Standard functions of ESMF's component
    - Initialize(), Run(), Finalize()

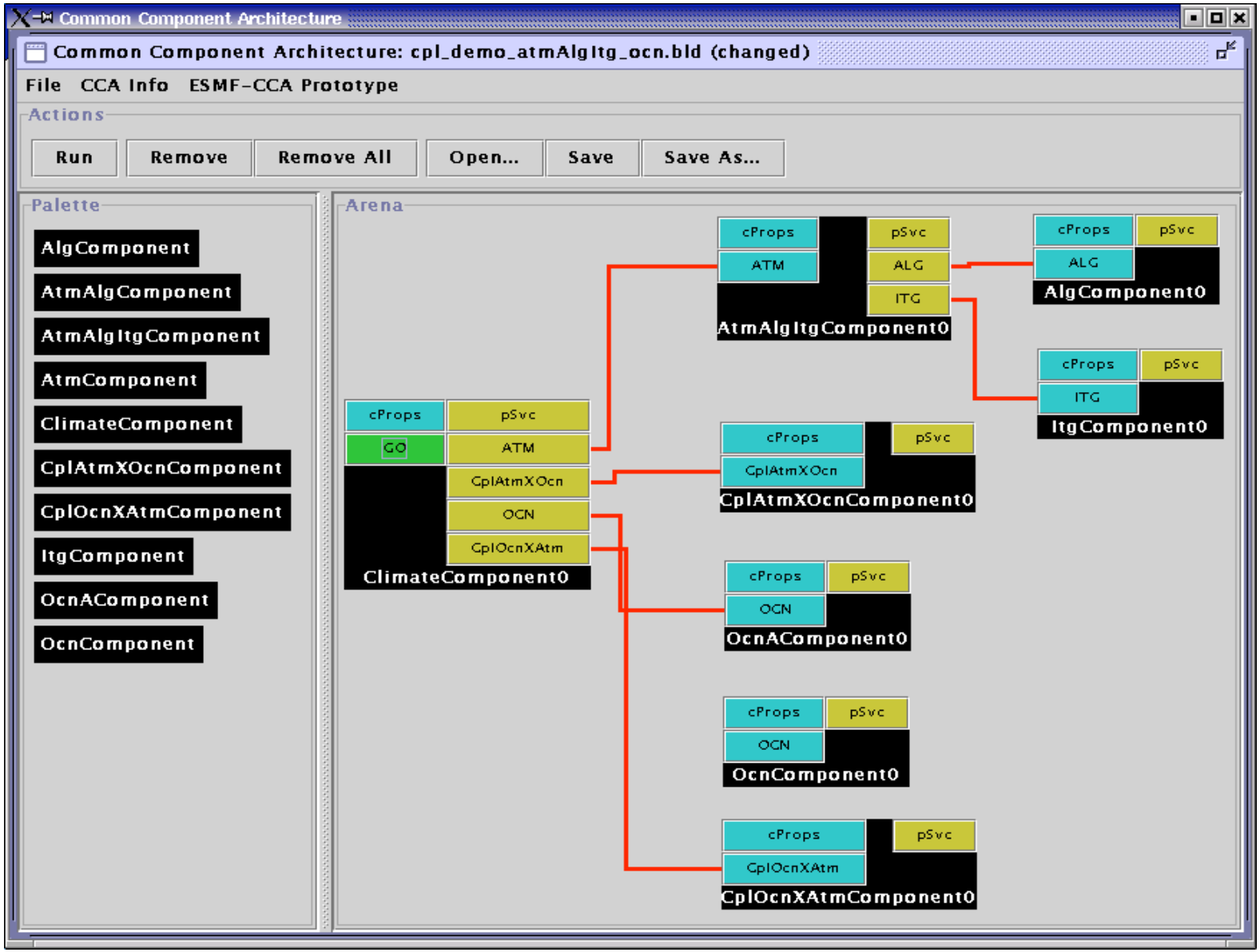
ESMF-CCA Prototype 1.0



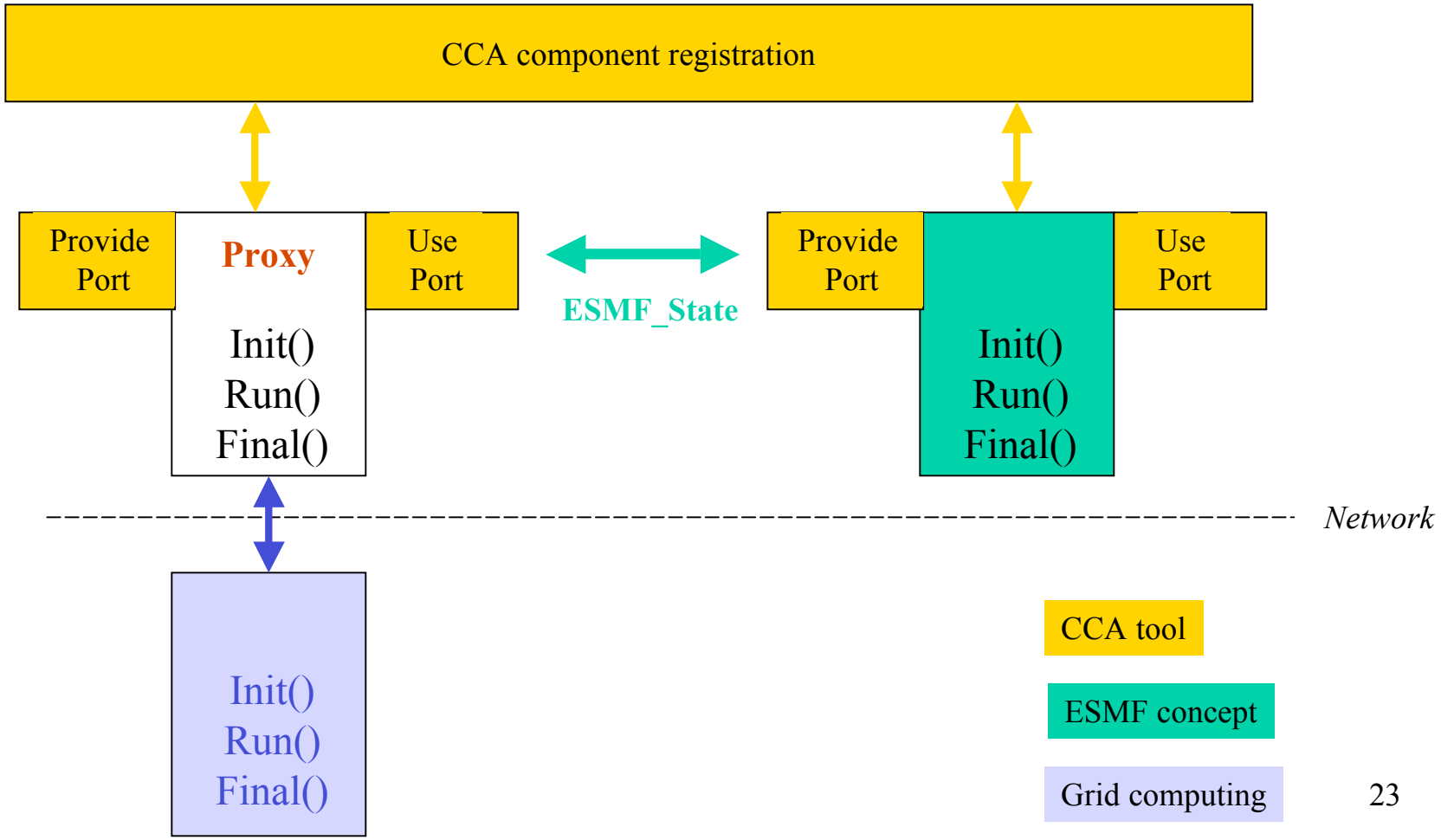
Component Relationship via CCA Wiring



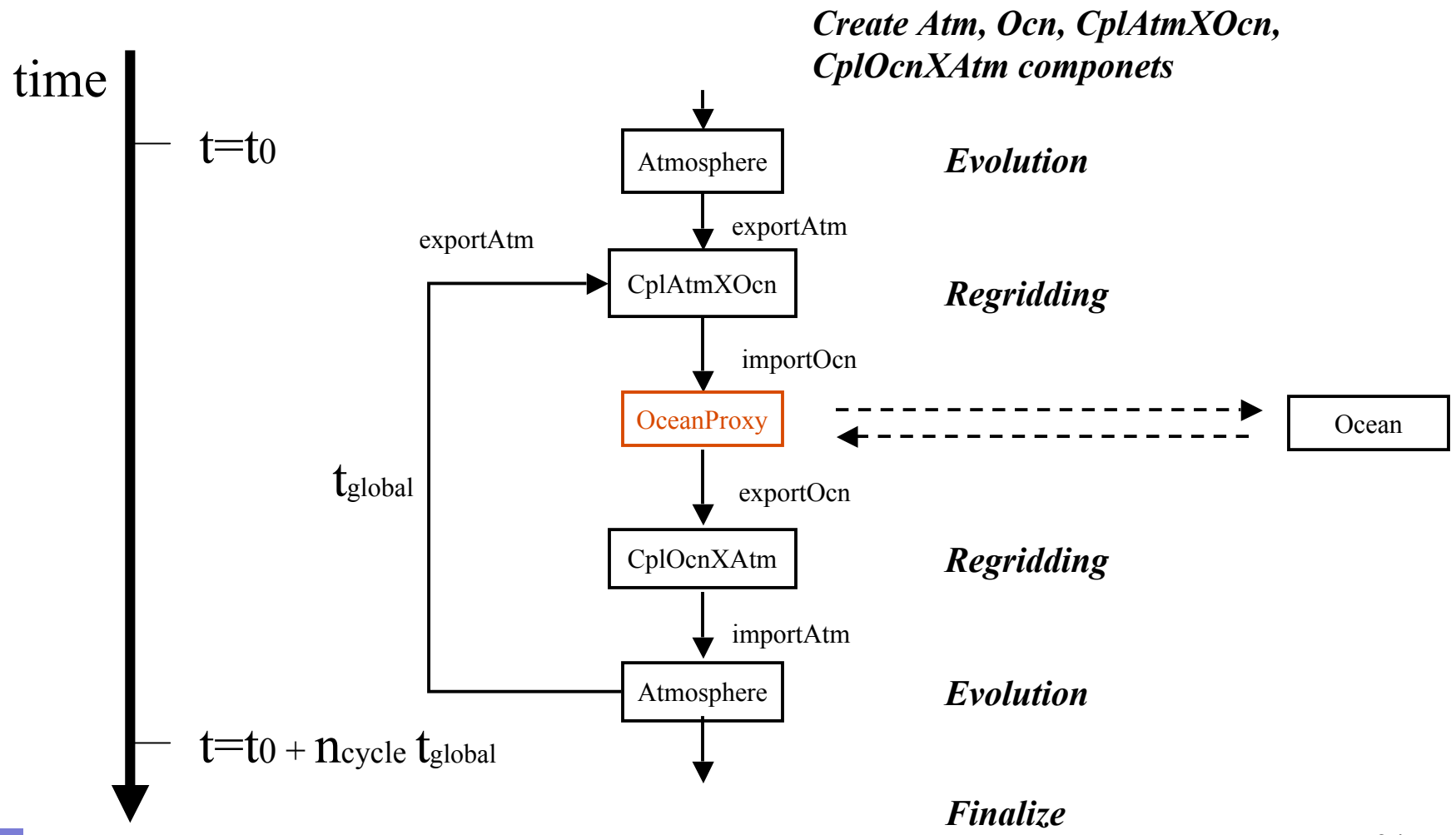
ESMF-CCA Prototype Including "Plug-And-Play" Subcomponent Component



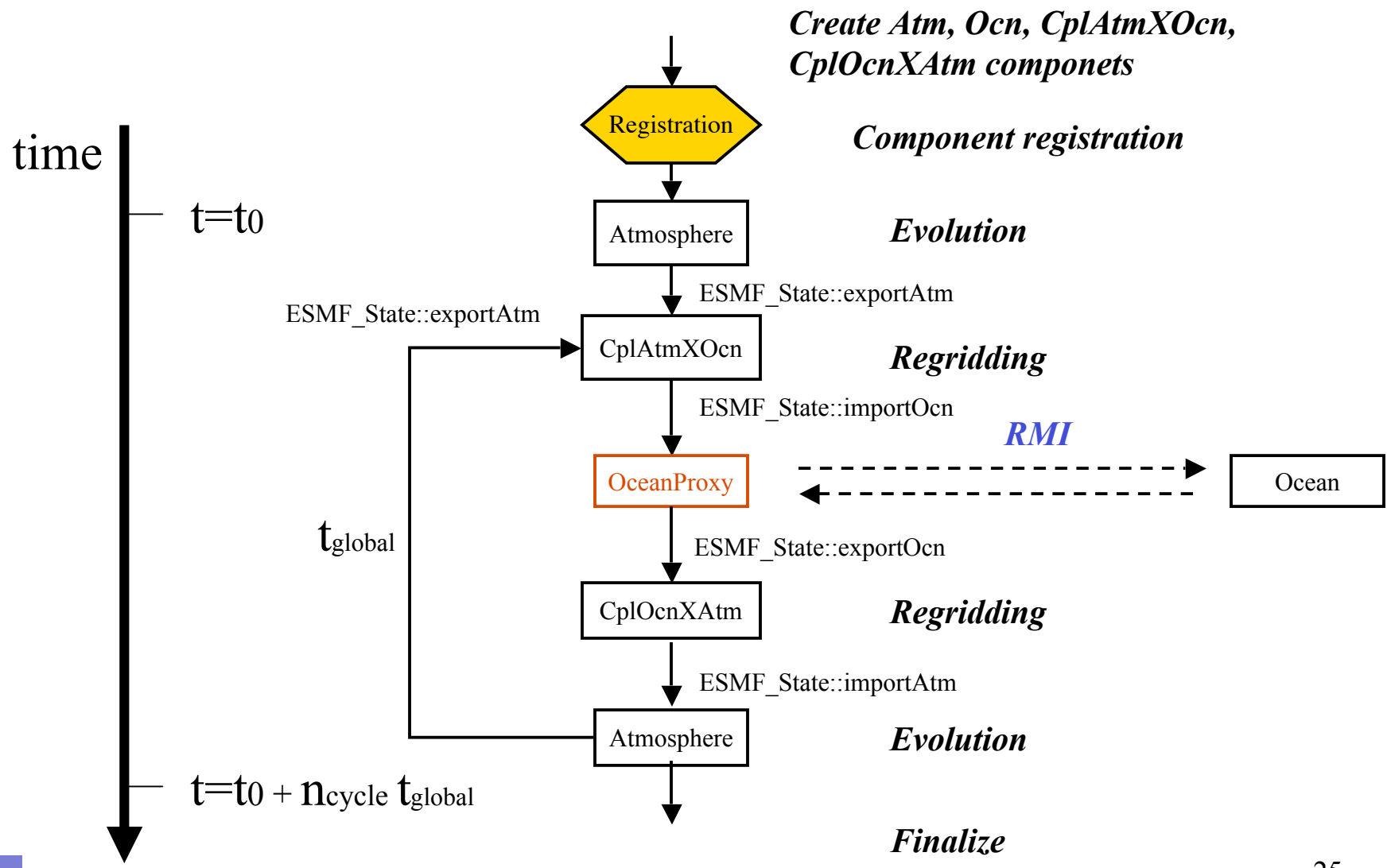
ESMF-CCA Prototype 2.0



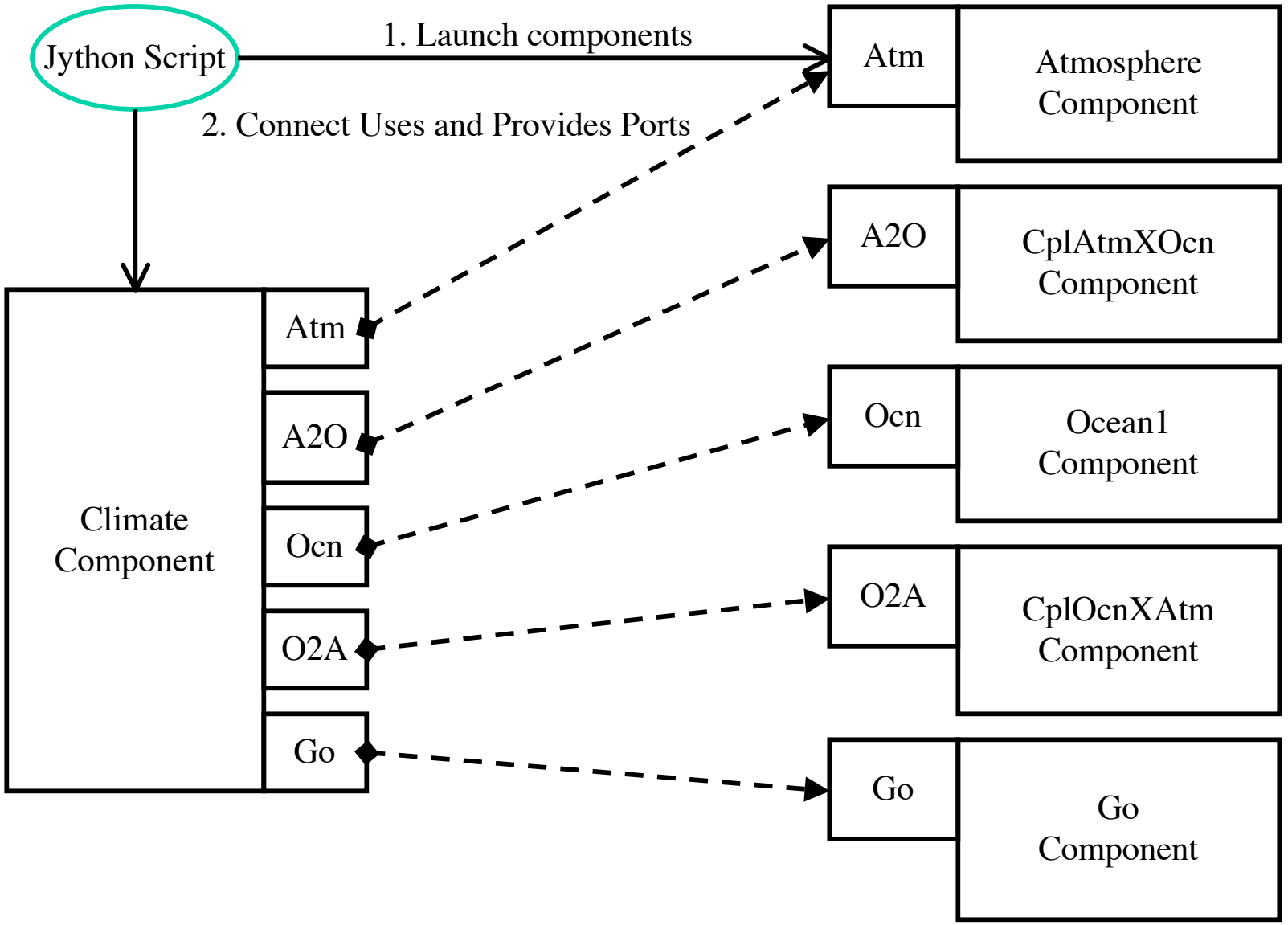
A sequential coupling between an atmosphere and a remote ocean model component



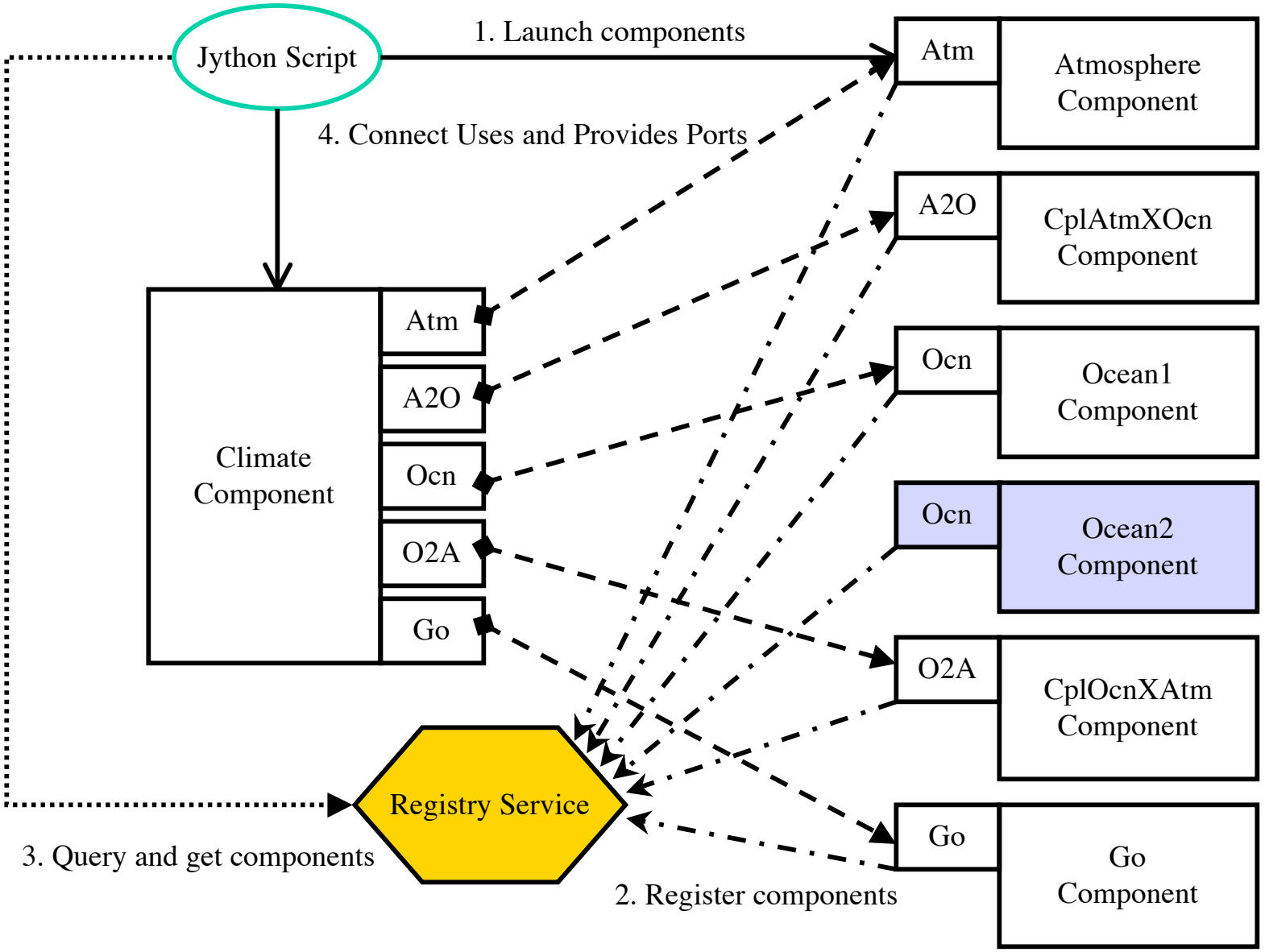
A sequential coupling between an atmosphere and a remote ocean model component implemented in the ESMF-CCA Prototype 2.0



Composing components without a third-party Registry Service



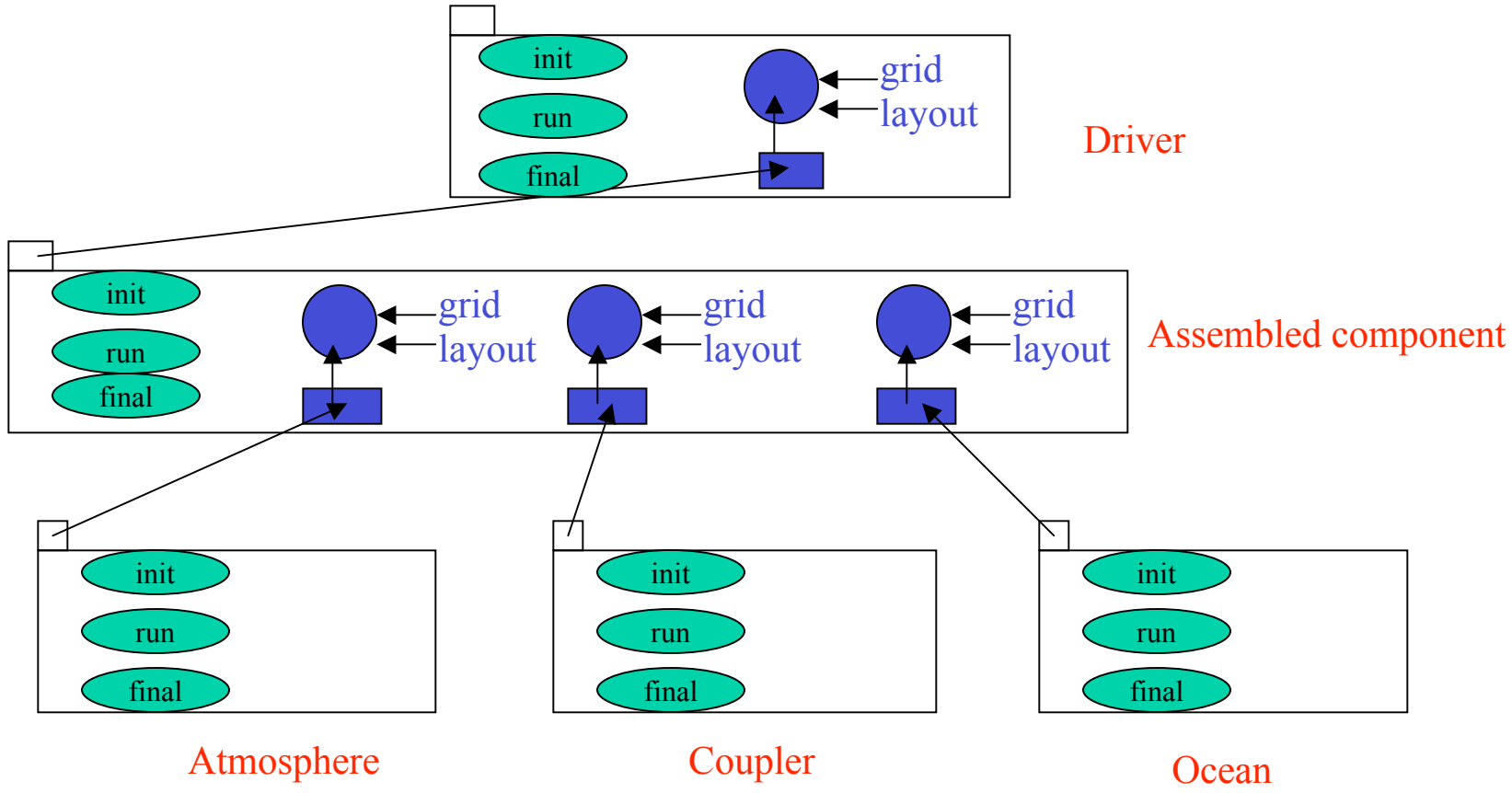
Composing components with a third-party Registry Service



Test ESMF-CCA Prototype 2.0

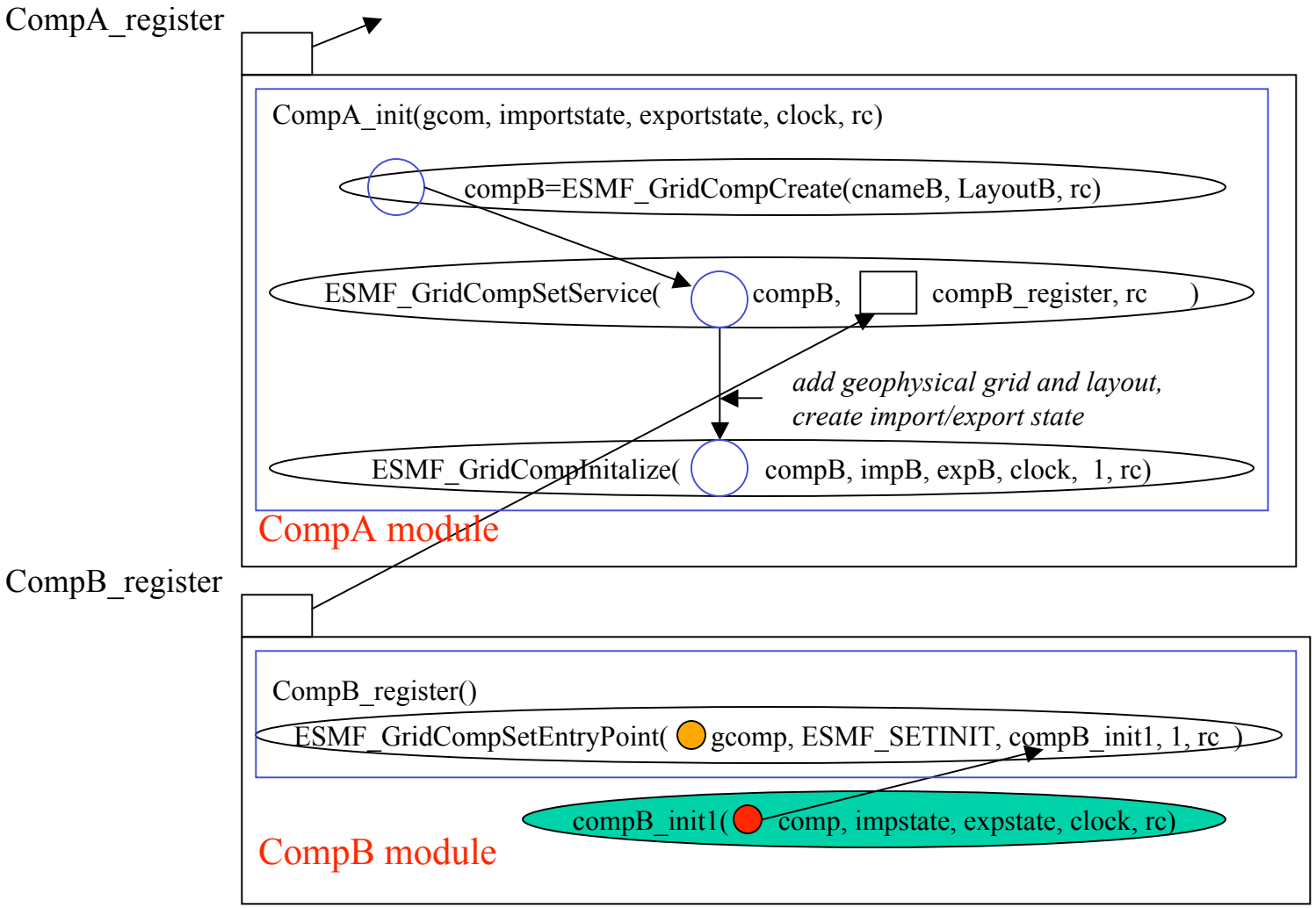
- We developed a Java stub code of a coupled Atmosphere-Ocean model and successfully integrated it into ESMF-CCA Prototype 2.0
  - Several coupled simulations are performed between two computers via SSH

A Coupled Atmosphere-Ocean Model in Terms of ESMF Component



Anatomy of ESMF Component

(Similar to a CCA component with a Provide-Port and implemented in C/F90)

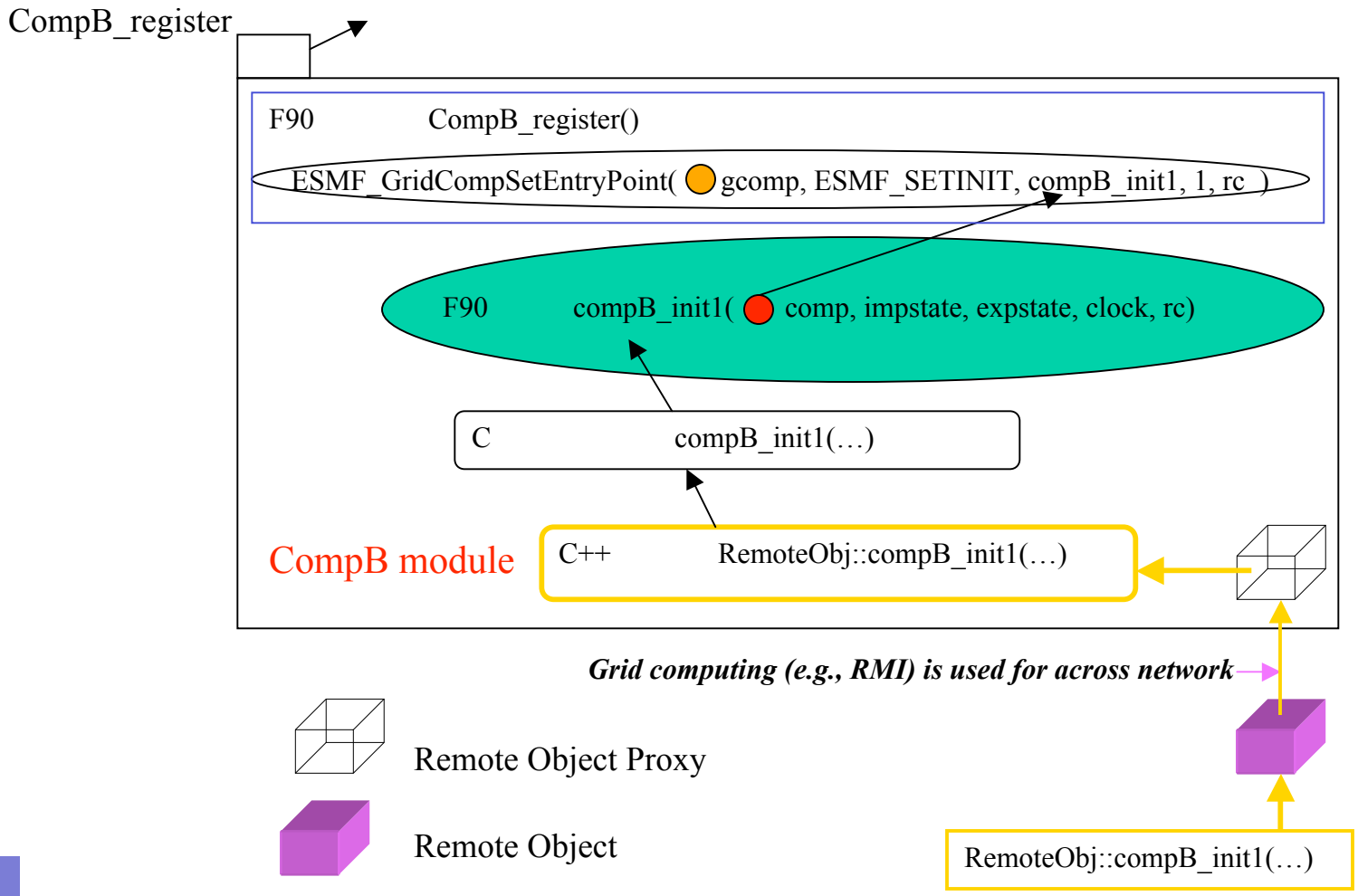


gcomp, comp of ESMF_GridComp type without personality (grid, layout, import/export state…)

compB of ESMF_GridComp type

One Approach for Grid-Enabled ESMF Components

→ Keep ESMF component interface and implement with Grid computing technology (hiding new technology/concept from a user)



Next Step

Time line

Past

- Frameworks (ESMF, CCA/Ccaffeine)
- ESMF-CCA 1.0
- Grid computing technology (ESMF, CCA/XCAT)
- ESMF-CCA 2.0

Now →

- Demonstrate with the stub code of a coupled atmosphere-ocean Model and an Ethernet network

Future

?

- Demonstrate with an ESMF-compliant coupled climate model and a Lambda network inside NASA GSFC
- Use third-party Grid service registry (e.g., NASA ECHO)

Summary

- Combination of component-based frameworks such as CCA and ESMF, Grid computing technology, and Lambda network make coupling Earth system models across network more feasible
- Based on CCA, ESMF, and Grid Computing, ESMF-CCA Prototype 2.0 is developed to demonstrate one user-friendly way of coupling Earth system models via Grid
- One approach for grid-enabled ESMF components is explored