

# Earth System Modeling Framework Update

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# Outline

- CESM integration of ESMF and the NUOPC Layer as the coupling framework
- Community Mediator
- ESMF Release update



# CESM Next Generation Coupling Infrastructure

CESM is integrating ESMF/NUOPC infrastructure as the coupling framework for the next major release. It brings in **new coupling capabilities** and promotes **interoperability, collaboration** and **code sharing**.

A new NUOPC-compliant **driver** and **community mediator (coupler)** have been introduced.

Many compsets have been validated using the new infrastructure and new components are coming online.

# What are ESMF and the NUOPC Layer?

The Earth System Modeling Framework (**ESMF**) is **community-developed, community-governed** software for building and coupling geoscience model components. The National Unified Operational Prediction Capability (**NUOPC Layer**) is a set of extensions to ESMF that increases component interoperability.

## Custom Coupling

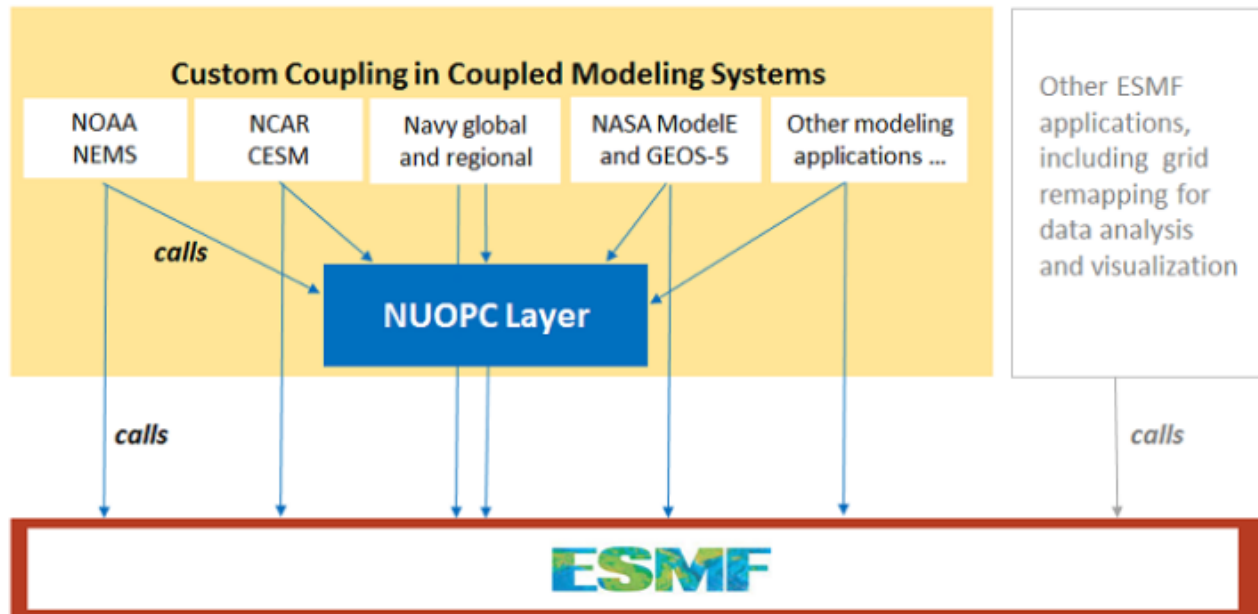
Centers use NUOPC Layer and ESMF calls to implement problem-specific technical and scientific choices

## NUOPC Layer

Adds standard behaviors to ESMF and enables components to interoperate

## ESMF

Provides generic utilities and data structures



# NUOPC “Out of the Box” Components

## Driver

### Driver

A Driver has one or more child components and is responsible for coordinating their initialization sequence and driving them through a customizable run sequence.

## Connector

### Connector

A Connector performs standard communication operations, in parallel, between other components, such as grid remapping and redistribution of data. Connectors have a field matching algorithm based on standard names.

## Model

### Model

A Model “cap” wraps a geophysical model code with standard initialization and run methods so it can be plugged into a Driver.

## Mediator

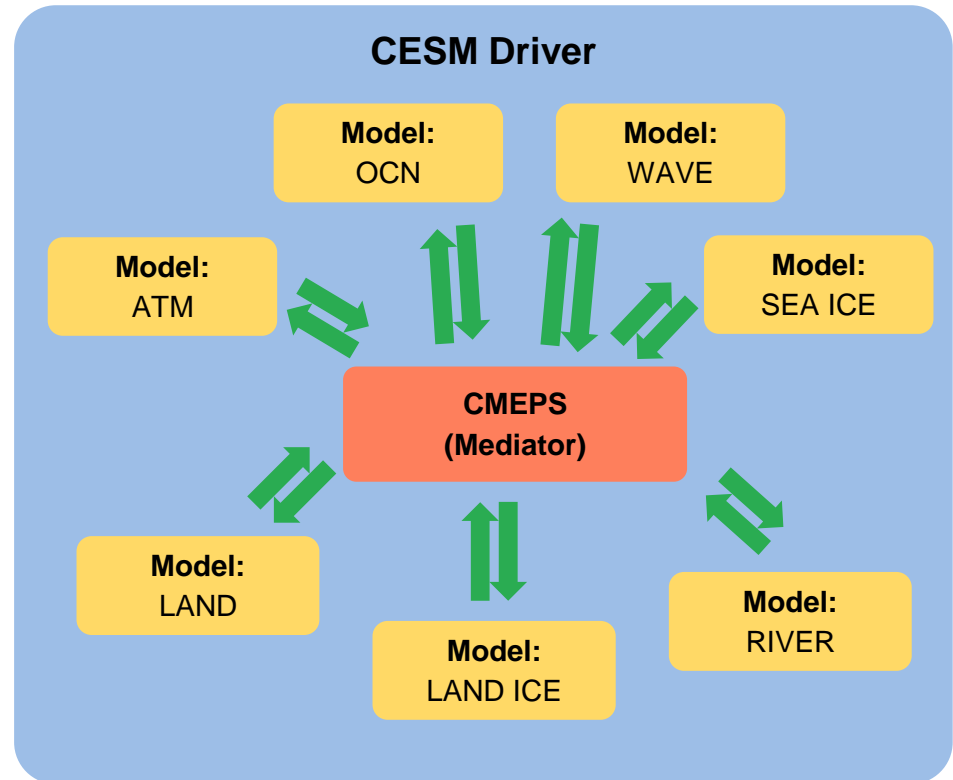
### Mediator

A Mediator contains custom coupling code such as flux calculations, accumulation/averaging, and merging of fields among several components.

# CESM Coupling Architecture

## Advantages for CESM:

- Online generation of remapping weights (no files!)
- Support for wide range of grids and meshes - multi-tile / cubed sphere, tripolar, gaussian, regional, general mesh
- Exchange grid option
- Automatic transfer of grids/meshes from components to the mediator/coupler
- Data driven run sequence; no more stub components
- Optimization options including reference sharing; component-level threading



## Example Run Sequence

```
@1800
MED med_phases_prep_ocn_accum_avg
MED -> OCN :remapMethod=redist
OCN
@900
MED med_phases_prep_atm
MED med_phases_prep_ice
MED -> ATM :remapMethod=redist
MED -> ICE :remapMethod=redist
ATM
ICE
ATM -> MED :remapMethod=redist
ICE -> MED :remapMethod=redist
MED med_fraction_set
MED med_phases_prep_ocn_map
MED med_phases_aofluxes_run
MED med_phases_prep_ocn_merge
MED med_phases_prep_ocn_accum_fast
MED med_phases_history_write
@
OCN -> MED :remapMethod=redist
MED med_phases_restart_write
@
```

- Run sequence is generated automatically and placed in your case: *nuopc.runseq*
- Simple syntax for specifying driver looping structure and order of component execution
- Components can have multiple named phases
- Run sequence can be changed without recompiling
- Replaces thousands of lines of driver code
- Sequential and concurrent execution

# NUOPC-compliant Components






NUOPC architecture used in other major modeling systems at NOAA, NASA, and U.S. Navy.

Eliminates need to write custom coupling code for each new component / modeling system.

CESM is collaborating on shared NUOPC “caps” for:

- MOM6
- CICE
- WW3

- NUOPC-compliant
- In progress

COUPLED MODELING SYSTEMS					
					
	NEMS	COAMPS and COAMPS-TC	NESPC	GEOS-5	CESM
Driver(s) and Coupler(s)	●	●	●	●	●
<b>ATMOSPHERE MODELS</b>					
CAM					●
COAMPS atmosphere		●			
GEOS-5 FV atmosphere				●	
GSM	●				
ModelE atmosphere					
NavGEM			●		
NEPTUNE		●			
NMMB	●				
<b>OCEAN MODELS</b>					
HYCOM	●		●		●
MOM	●			●	●
NCOM	●				

Complete table available at:  
<https://www.earthsystemcoq.org/projects/esps/>



# Community Mediator for Earth Predictive Systems (CMEPS)



# Community Mediator (CMEPS)

Goal: Deliver a flexible **NUOPC-based Mediator** (coupler) that can support CESM, NOAA Unified Forecast System (UFS) and NOAA/GFDL scientific coupling strategies and allow controlled experimentation using different coupling techniques.

- Should we couple components explicitly or implicitly?
- Should we use an exchange grid?
- Where and how should we compute fluxes (e.g., in mediator or components)?
- Which interpolation methods and options should we use?
- Which processes need to be able to run concurrently or on different grids?  
How should components be sequenced with the coupler?

CMEPS is being designed to flexibly support multiple coupling options.

# CMEPS v0.4 Milestone Release (in 2 weeks!)

- **Upcoming release of CMEPS** that supports:
  - CESM prognostic components and data models with multiple validated compsets; NOAA/UFS subseasonal-to-seasonal system with FV3GFS-MOM6-CICE5
  - ESMF Exchange Grid NOT yet integrated, but being optimized separately
- **Flexibility and extensibility of CMEPS**
  - field exchanges/mapping/merging defined in one “declarative” file
  - fluxes only computed if requested, at a granular level
  - components easily turned on/off (no stubs!)
  - grid/mesh received from each component at runtime - no hard coding or assumed geometry
  - modularity makes it easier to add code - each mediator “phase” is in a single file and new phases can be registered with a few lines of code

# ESMF Release Update



# ESMF Release Update

## ESMF 7.1.0r (last public)

- 2nd order conservative grid remapping
- Multi-tile grids, API shortcuts for cubed sphere grid creation and regridding to/from multi-tile grids
- Dynamic masking during the application of interpolation weights
- Extrapolation during grid remapping
- Read/write regridding weights from/to file
- NUOPC component hierarchies
- NUOPC shared field references

## ESMF 8.0.0 (September 2019)

- Simpler API for creating meshes, grid-to-mesh conversion, and mesh query methods
- Option to use MOAB mesh database internally for all interpolation options
- “Creep fill” extrapolation method
- “Packed” Field Bundle for interleaving model data arrays
- Bit-for-bit checking between ESMF versions
- RouteHandle reuse optimizations in NUOPC
- Extensible YAML format for NUOPC Field Dictionary

Not all features listed - see [full ESMF release schedule](#)

**Thank you!**

**Questions/Comments?**  
**[esmf\\_support@ucar.edu](mailto:esmf_support@ucar.edu)**

**ESMF/NUOPC training opportunities**  
**<https://earthsystemcog.org/projects/esmf/tutorials>**