

CMEPS – A New Coupling Infrastructure for CESM

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Outline

- **What is CMEPS?**
- **What are its benefits to CESM?**
- **What is the current status of CMEPS?**
- **New CDEPS - ESMF based data model infrastructure**



What is CMEPS?

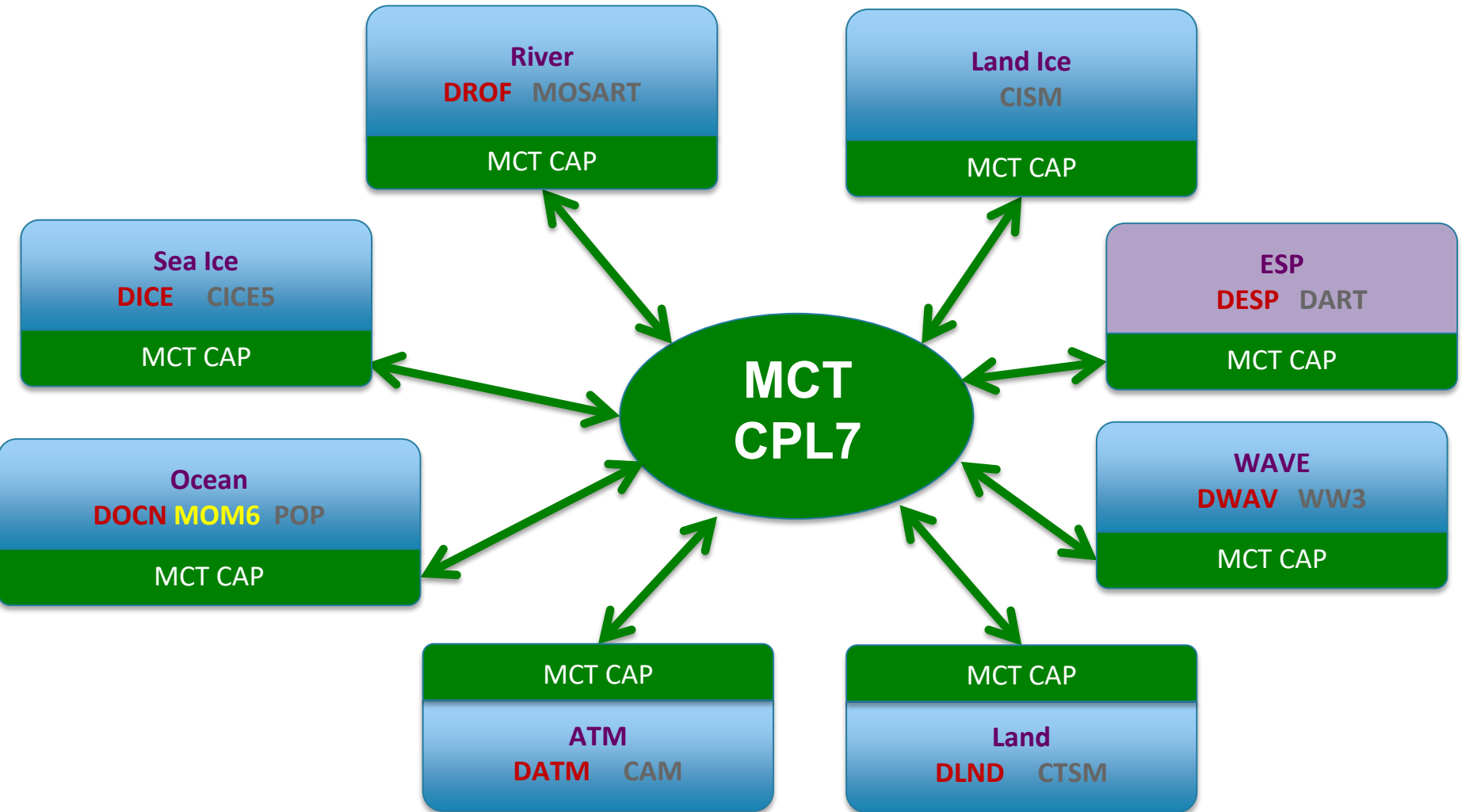


What is ESMF and NUOPC?

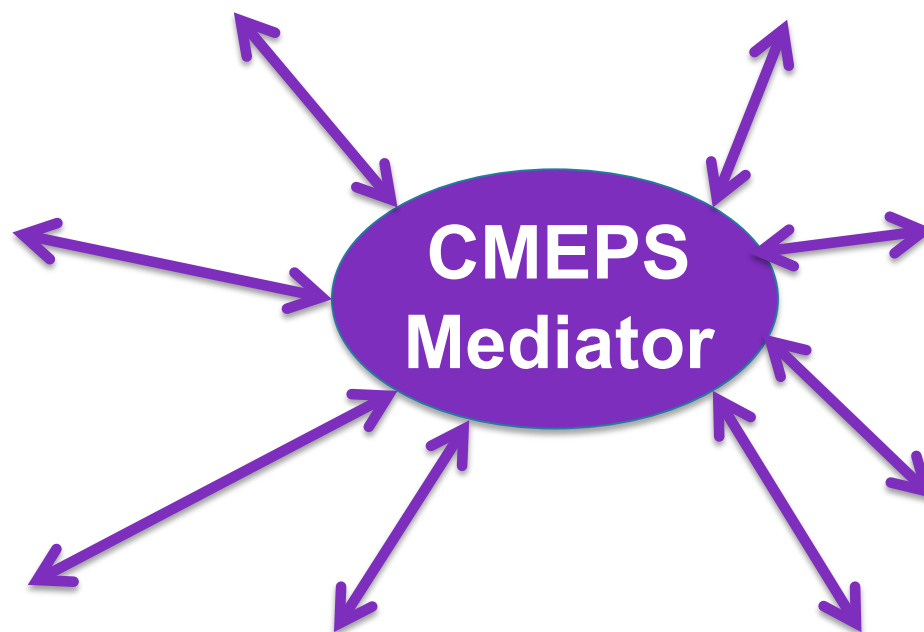
- **ESMF** (Earth System Modeling Framework) is an open source software for building climate, numerical weather prediction, data assimilation, and other Earth system software applications.
 - Provides standard **component interfaces** and **high-performance utilities** such as grid remapping and parallel communication.
 - Is commonly used as as a **coupling infrastructure layer** for modeling systems made up of multiple components,
 - Is the de-facto coupling infrastructure for Navy, NOAA, NASA and now **CESM**
- **NUOPC** (National Unified Operational Prediction Capability) is a software layer **on top of ESMF** that provides defines conventions and new building blocks for using ESMF.
 - **Simplifies the technical interoperability** of model components so they can be **shared across coupled systems** .

Current CESM Coupling

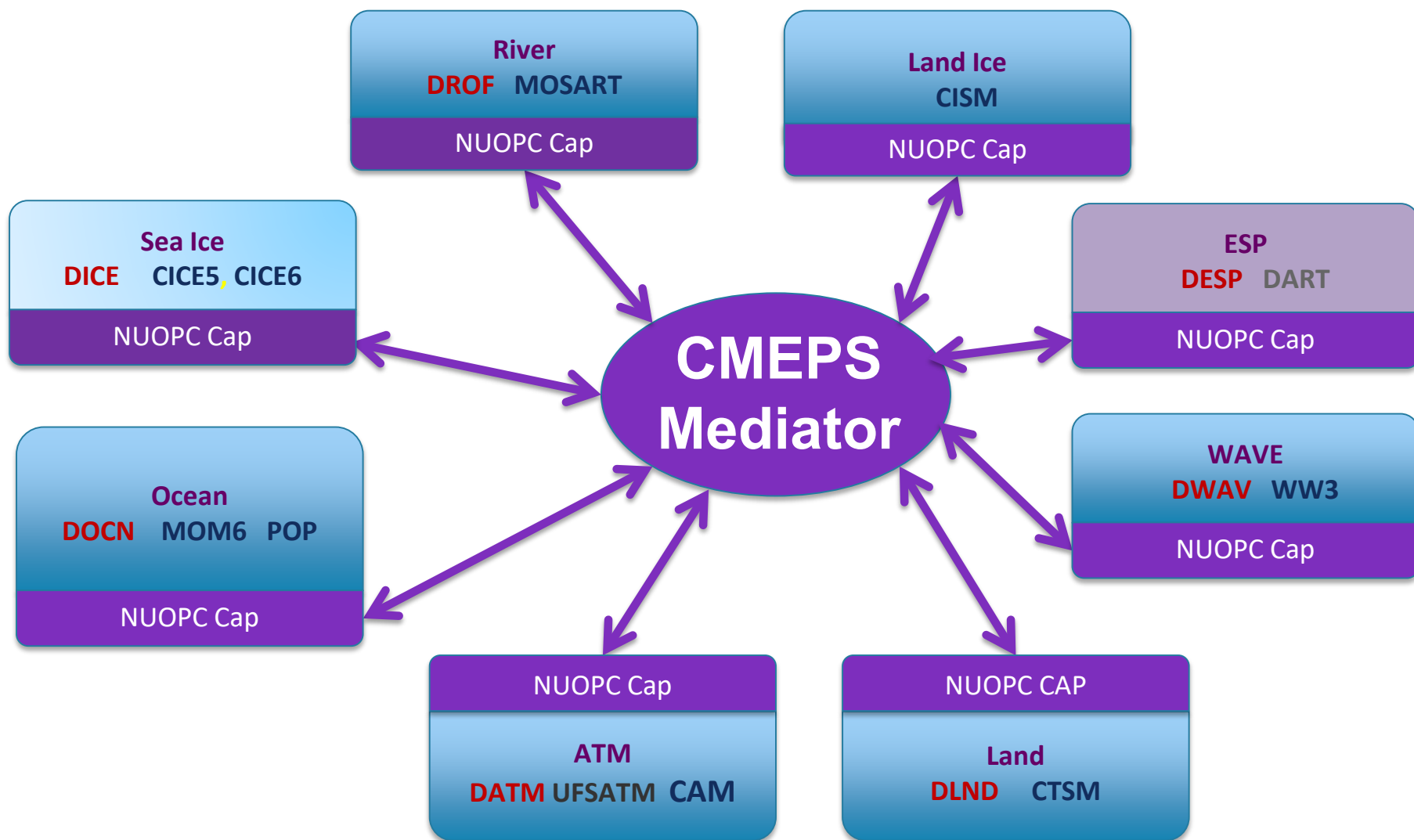
data components permit flexible activation/deactivation of feedbacks



CMEPS Mediator is now just another component!



CMEPS enables new functionality and collaborations



What is in the CMEPS name?

Community Mediator for Earth Prediction Systems

<https://github.com/ESCOMP/CMEPS>

- **Community**

- collaboration between NCAR, NOAA/EMC, and NOAA/GFDL
- developed openly on GitHub to allow community code contributions and encourage collaboration and innovation

- **Mediator**

- A NUOPC-compliant coupler designed to flexibly couple configurations of atmosphere, land, ocean, wave, sea ice, and land ice components using a hub-and-spoke architecture

- **Earth Prediction Systems**

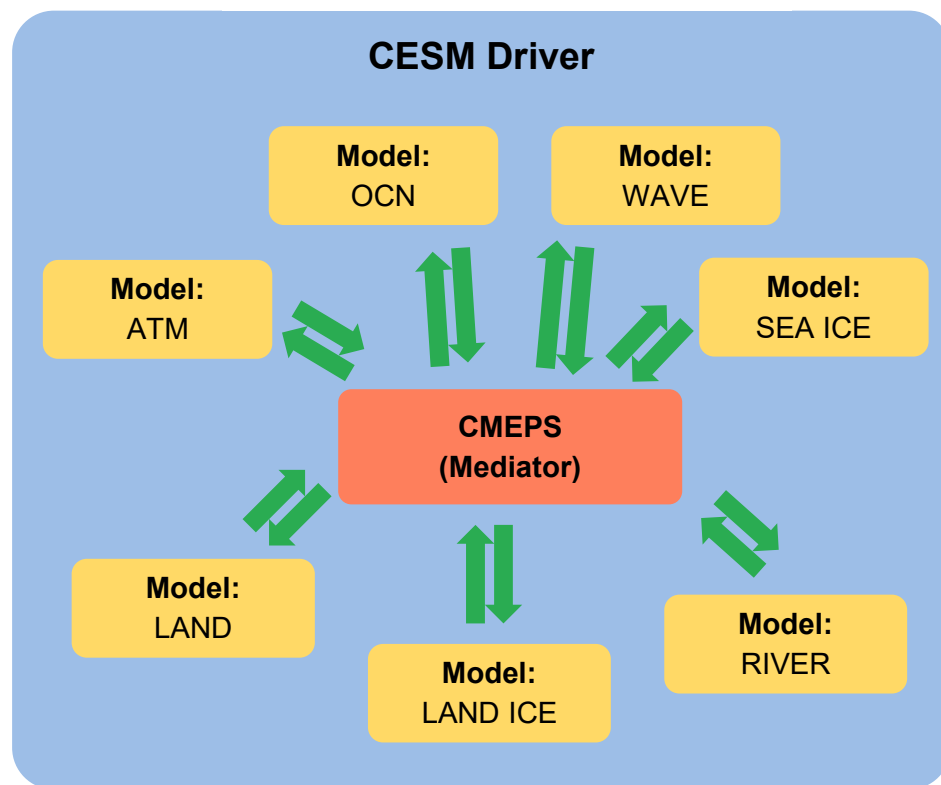
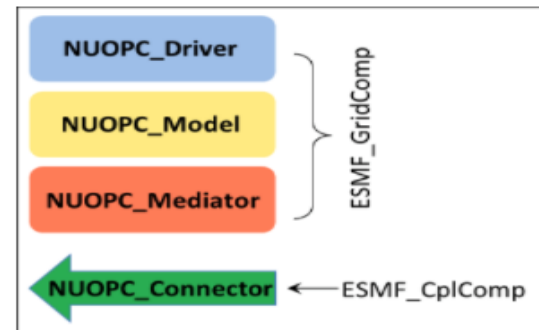
- NCAR's Community Earth System Model (CESM)
- NOAA's Unified Forecast System (UFS)
 - Subseasonal-to-Seasonal application
 - Hurricane Analysis and Forecast System (HAFS) application

What are the benefits to CESM?

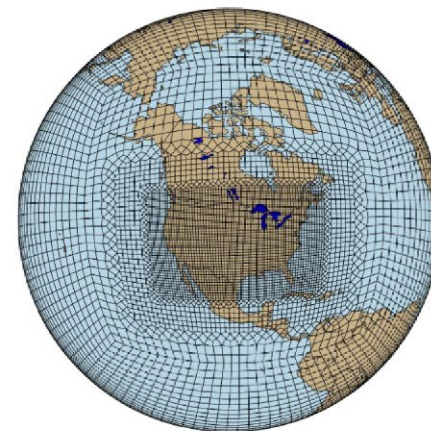


CMEPS Provides New Coupling Capabilities

- **Mediator:**
 - Parallel online generation of remapping weights - no more mapping files!
 - Upcoming new exchange grid option in mediator for atm/ocn flux calculation
- **Driver:**
 - Data driven run sequence -can easily see lags in model evolution
- **Connectors:**
 - Automatic creation of connectors transfer of data between components and mediator
- **Optimization Options:**
 - Including reference sharing and component-level threading

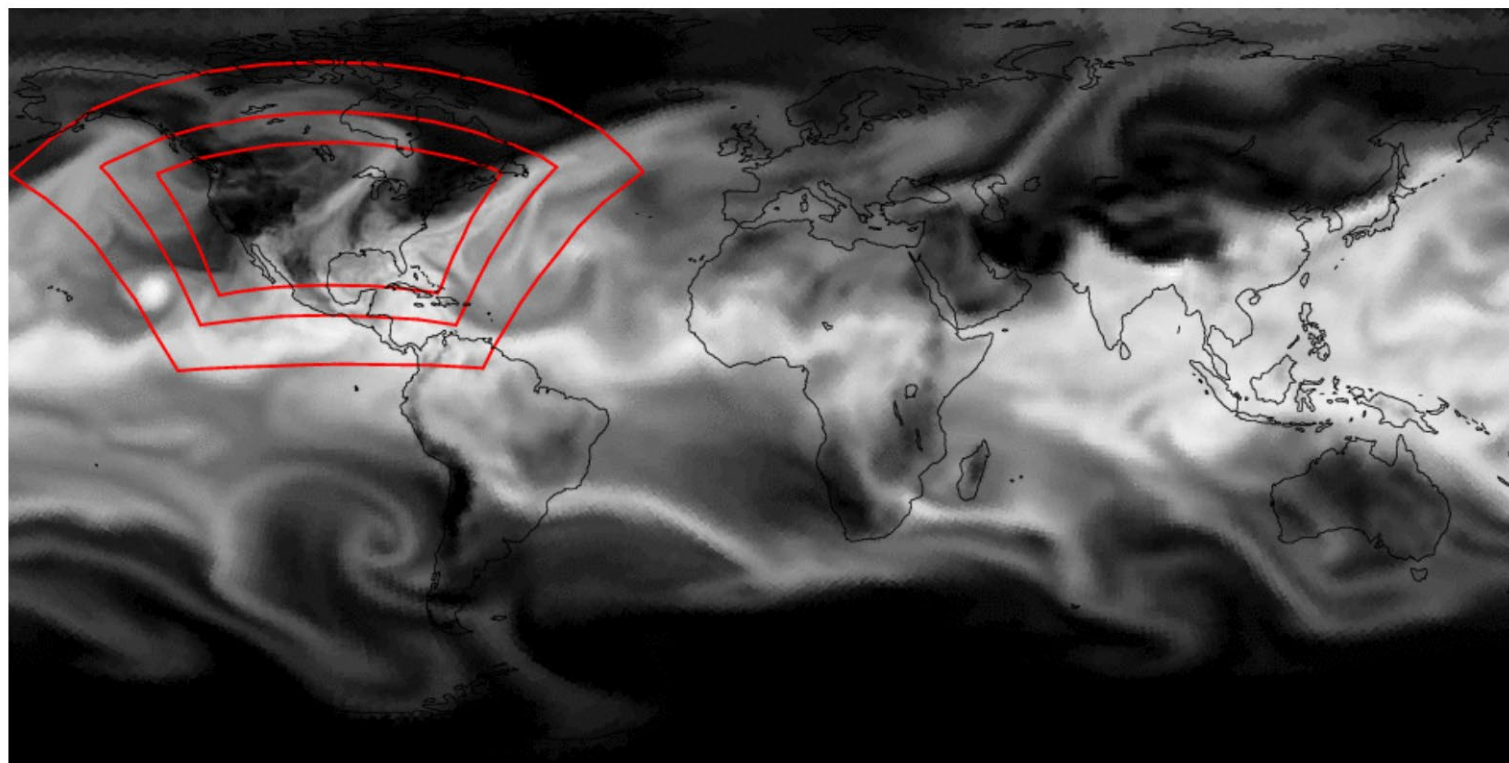


Run-time generation of mapping weights will
make experimenting with regionally refined grids
easier including 2nd order conservative



Regional refinement in CAM6 (AMIP) with the
Spectral Element (SE) dynamical core

Precipitable water 23 Sept – 03 Oct 1981; 111 km -> 14 km



Colin Zarzycki and Andrew Gettelman

Easy to See and Modify 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
@
```

- Current MCT CPL7- run sequence is *several thousand lines* of complex code
- CMEPS - run sequence is generated automatically and placed in your \$EXEROOT as *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
- Sequential and concurrent execution are configurable

Easy to See and Modify Run Sequence

```
@1800
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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
@
```

- Simple syntax for driver looping structure - component coupling frequency and order of component execution
- Connectors that transfer data between mediator and components are generated automatically – no user code is needed
- Components can have multiple named phases
- Run sequence can be changed without recompiling
- Sequential and concurrent execution in separate runtime configuration

What is the current status of CMEPS in CESM?



Status of CMEPS

What can we now run in CMEPS :

CESM: All CESM components and compsets

- All prognostic and data components have NUOPC caps – continued capability for hierarchical model development development
- Validation done for MOM6 core-forcing configuration
- Validation done for data components
- Extensive validation of all other CESM components this summer
- Upcoming introduction of exchange grids for atm/ocn flux calculations

NOAA UFS S2S application: UFSATM--MOM6--CICE5&6

- CMEPS coming into NOAA UFS as new operational coupling infrastructure for S2S application

NOAA UFS Hurricane application : UFSATM--HYCOM--WW3

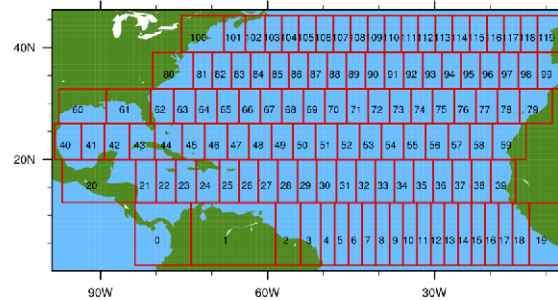
- Will enable regional grids with moving nests in one coupling infrastructure

CMEPS and New CESM Components

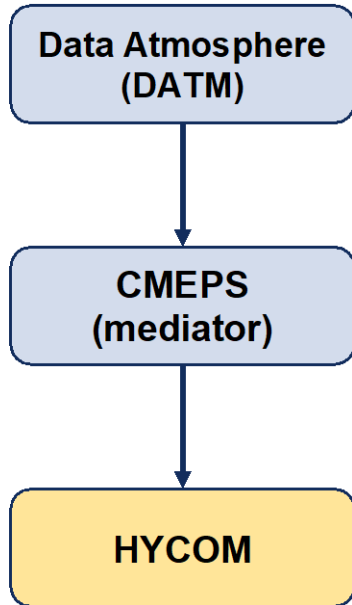
- New CICE6
 - CMEPS cap created and will be shared with UFS (like MOM6)
- New river model (Mizuroute)
 - runs on more accurate Hydrologic Response Units rather than regular grids and will enable dynamic lakes and reservoirs
 - cap created for river model (Mizuroute) – and experimentation with CMEPS is underway
- New coupling of CICE to recent WW3 code base
 - Sending to CICE, the wave elevation spectrum (25 frequencies at each gridpoint) and wave to sea ice stress
 - ESMF permits sending each frequency as an undistributed dimension in the field bundle – so do not need to send 25 new fields

HYCOM+Data Atmosphere using CIME/CMEPS

- **New application for HAFS**
 - <https://github.com/ESCOMP/ufs-hafs-app>
 - **Components:** CIME, CMEPS and HYCOM (more will come UFS-ATM, WW3)

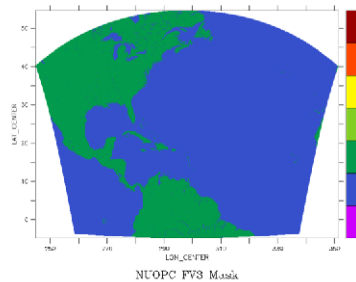


HYCOM Domain Decomposition for HAFS app



CORE.2 NYF:
lwdn, swdn, swup
prec, slp, shum, tbot, u, v

COUPLING_MODE = hafs



- **HYCOM cap**

- <https://github.com/hafs-community/HYCOM-src>
- Shadow-grid approach is implemented to overcome land-eliminated domain decomposition

- **CIME data components**

- ERA5 (ECMWF's last reanalysis product) is developed as new data stream to support high-resolution apps.

New CDEPS - ESMF based data model infrastructure



New ESMF -based Data models and CDEPS

Community Data Models for Earth Predictive Systems

<https://github.com/ESCOMP/CDEPS>

- New data model code is based on ESMF/ NUOPC and will provide much needed new capabilities
- New regridding capability
 - Online regridding between streams mesh model mesh
 - Multiple regridding options including conservative regridding
 - Ability to easily regridding between two horizontal grids with multiple model levels
 - Ability to do 3d regridding
- Simpler stream xml file definition – all streams in one file
- New modularity for science specific data model functionality
- Compatible with CMEPS
- Data model share code has interface that can be called directly from prognostic component code base

Questions?

