CMEPS

A New Coupling Infrastructure for CESM and NOAA Unified Forecast System (UFS)

Mariana Vertenstein
CESM Software Engineering Group

Rocky Dunlap, Jim Edwards, Ufuk Turuncoglu (NCAR)
Denise Worthen (NOAA/EMC)

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Outline

1. What is ESMF/NUOPC?
2. What is CMEPS?
3. What are its benefits to CESM and UFS?
4. What is its current status for CESM and UFS?
5. CMEPS and new ESMF based data model infrastructure (CDEPS)

1. What is ESMF/NUOPC?

What is ESMF/NUOPC?

ESMF (Earth System Modeling Framework)

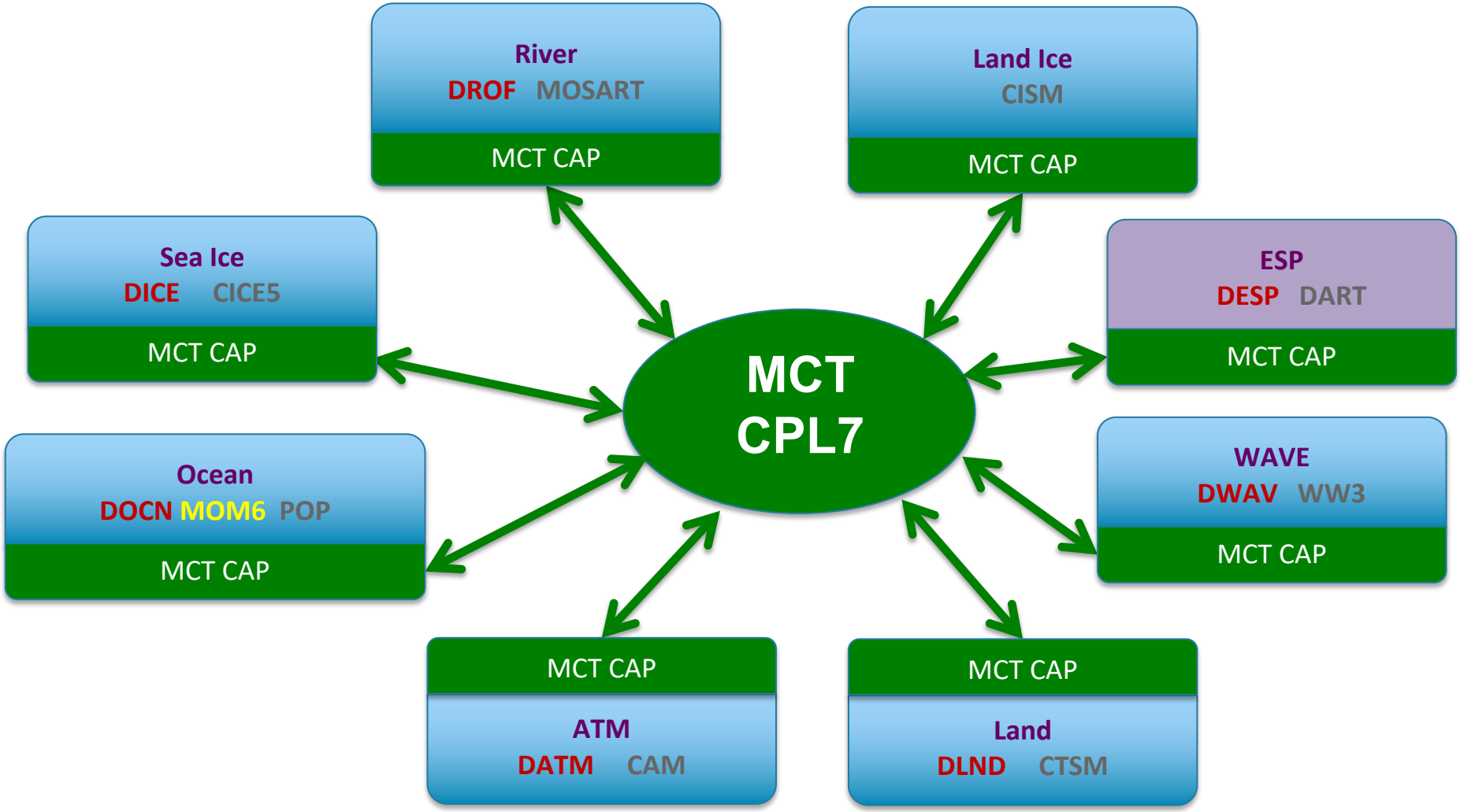
- An open source software for building climate, numerical weather prediction, data assimilation, and other Earth system software applications.
- Provides standard component interfaces and high-performance utilities such as grid remapping and parallel communication.
- Commonly used as as a coupling infrastructure layer for modeling systems made up of multiple components,
- The *de-facto coupling infrastructure* for Navy, NOAA, NASA and now CESM

NUOPC(National Unified Operational Prediction Capability)

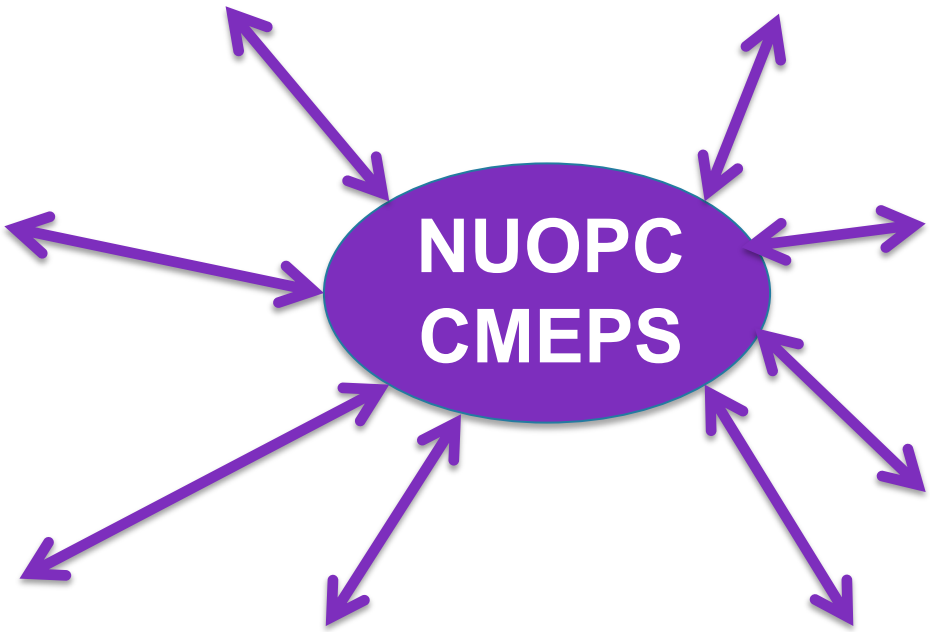
- A software layer on top of ESMF
- Provides conventions and new building blocks for using ESMF.
- Simplifies the technical interoperability of model components so they can be easily shared across different coupled systems

2. What is CMEPS?

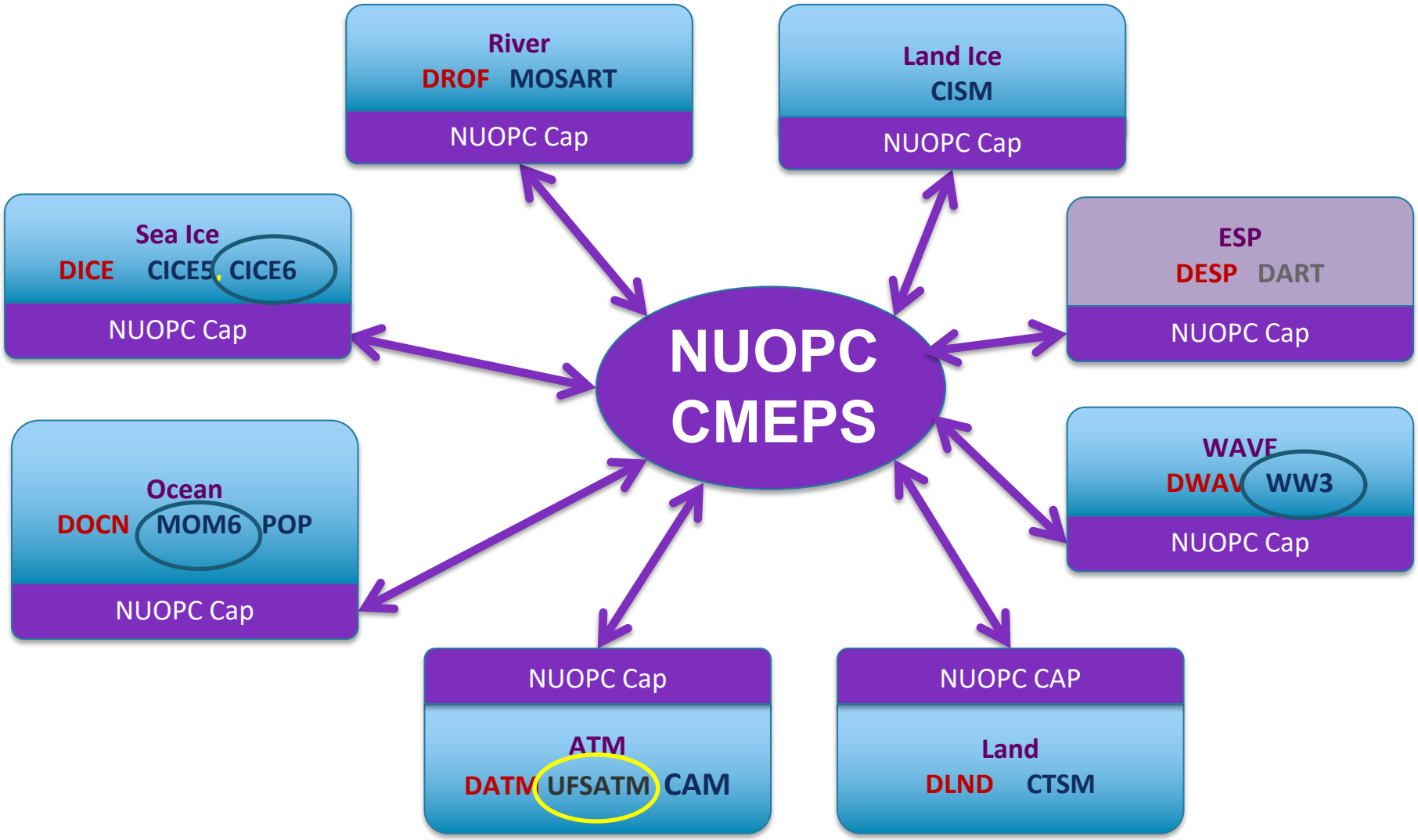
Current CESM2 Coupling
No clear separation between driver and "hub"



CMEPS is now just another component and can be shared
Drivers can be model specific



CMEPS enables new functionality and collaborations



What is in the CMEPS name?

Community Mediator for Earth Prediction System

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

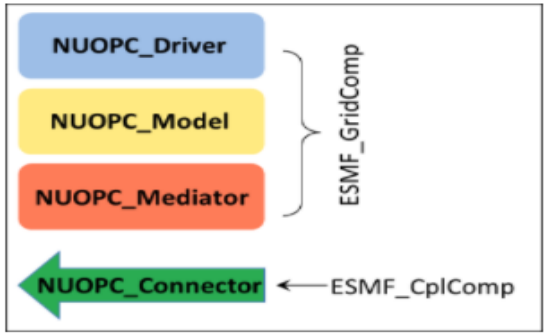
- **Earth Prediction Systems**
  - Currently being used in NCAR's Community Earth System Model (CESM), NOAA's UFS Subseasonal-to-Seasonal application, and NOAA's Hurricane Analysis and Forecast System (HAFS)

3. Benefits of CMEPS

CMEPS Provides New Coupling Capabilities

Mediator:

- Parallel online generation of remapping weights - no more mapping files!

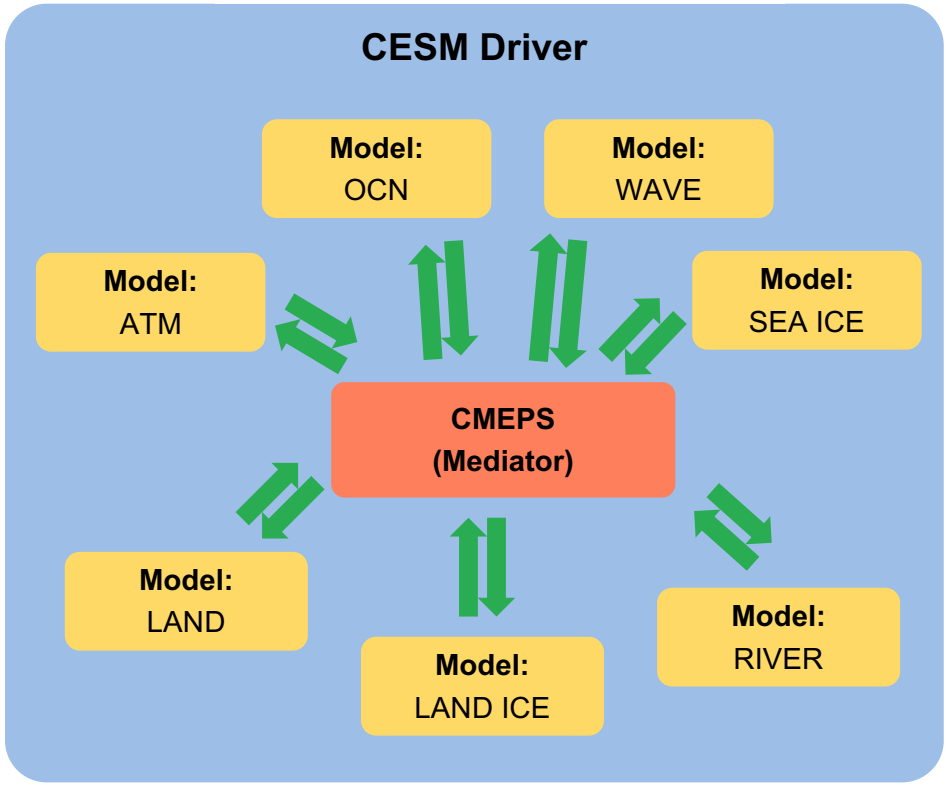


Driver

- Data driven run sequence -can easily see lags in model evolution

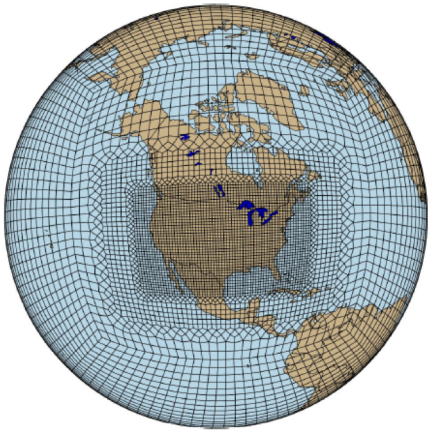
Connectors:

- Automatic transfer of grids/meshes from components to the mediator
- Optimization options including reference sharing and component-level threading



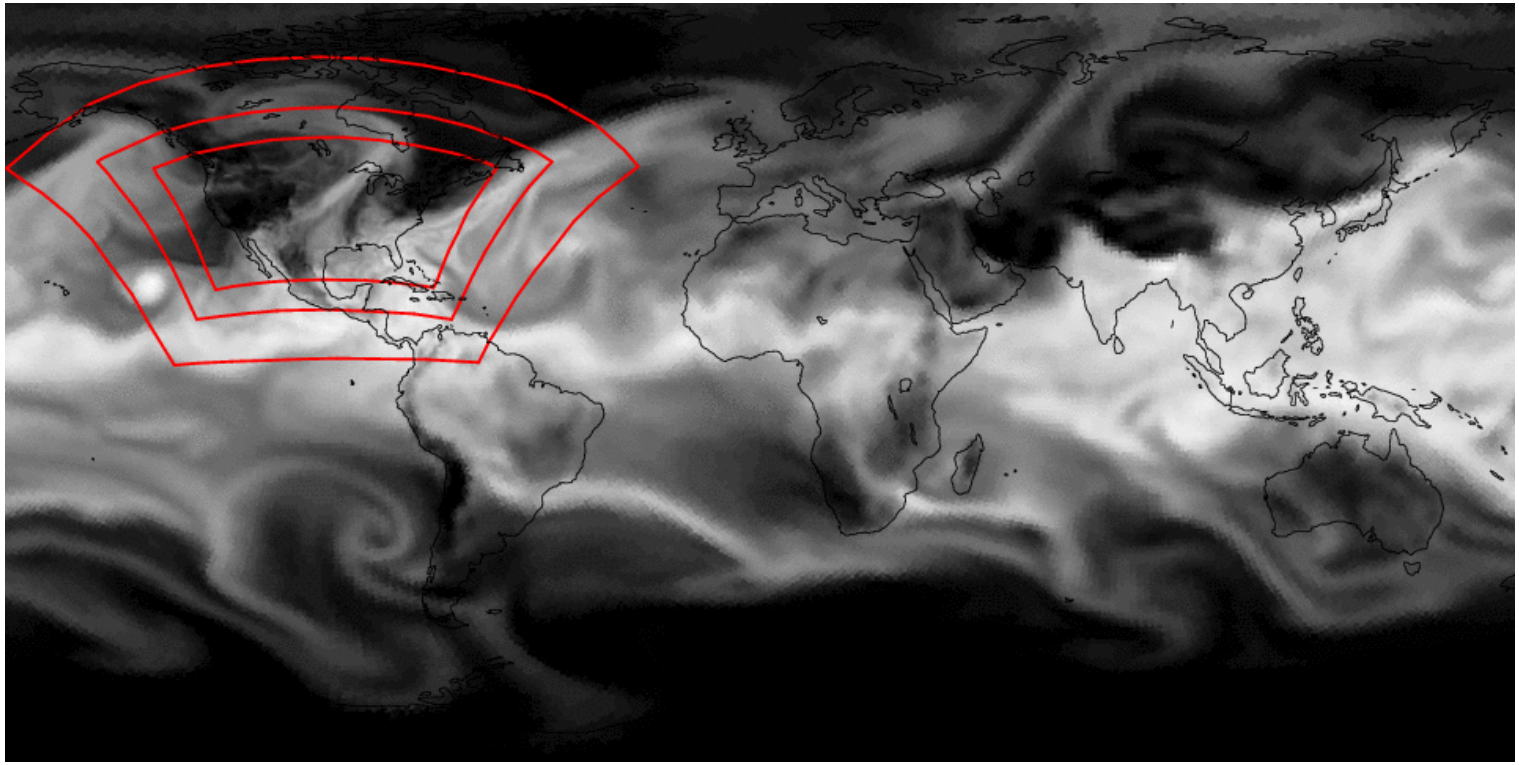
Run-time generation of mapping weights will make experimenting with regionally refined grids easier

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
- 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

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
@
```

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

Benefits of Sharing a Mediator

- CMEPS currently targets CESM and NOAA/UFS needs
- Unified CAPS (e.g. CICE6, MOM6) standardize coupling
- CMEPS collaboration helped find and resolve bugs in both the mediator and in components that are shared between the modeling system (e.g. MOM6, CICE6)
- Exercising CMEPS with different components and coupling strategies results in much more robust system

4. Status of CMEPS

Status of CMEPS

CESM:

- All CESM components are now CMEPS compliant
- Easily swap data and components thereby enabling hierarchical model development (selective activation of feedbacks)
- Validation is underway
- Upcoming introduction of exchange grids for atm/ocn flux calculations

NOAA: UFS S2S application:

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

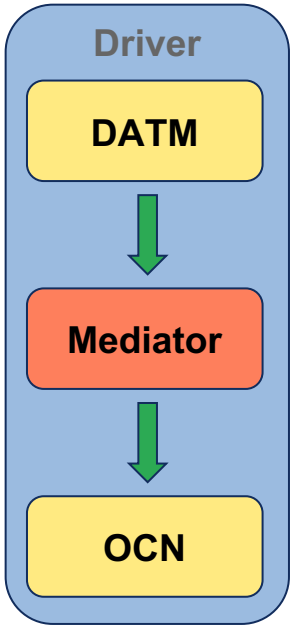
NOAA UFS Hurricane application

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

5. CDEPS - New CMEPS Compliant Data Models

Data Models Support Hierarchical Model Development

- Hierarchical model development approach enables developing/building a modeling system systematically
- Provides ability to turn feedbacks on and off
  - Using forcing data eliminates coupling feedbacks
- Reduces computational overhead for development
  - Enables faster development cycle
- Reduces time spent in debugging and testing
  - Debugging can be done by isolating desired components
  - Lightweight reproducer/s for problems can be setup



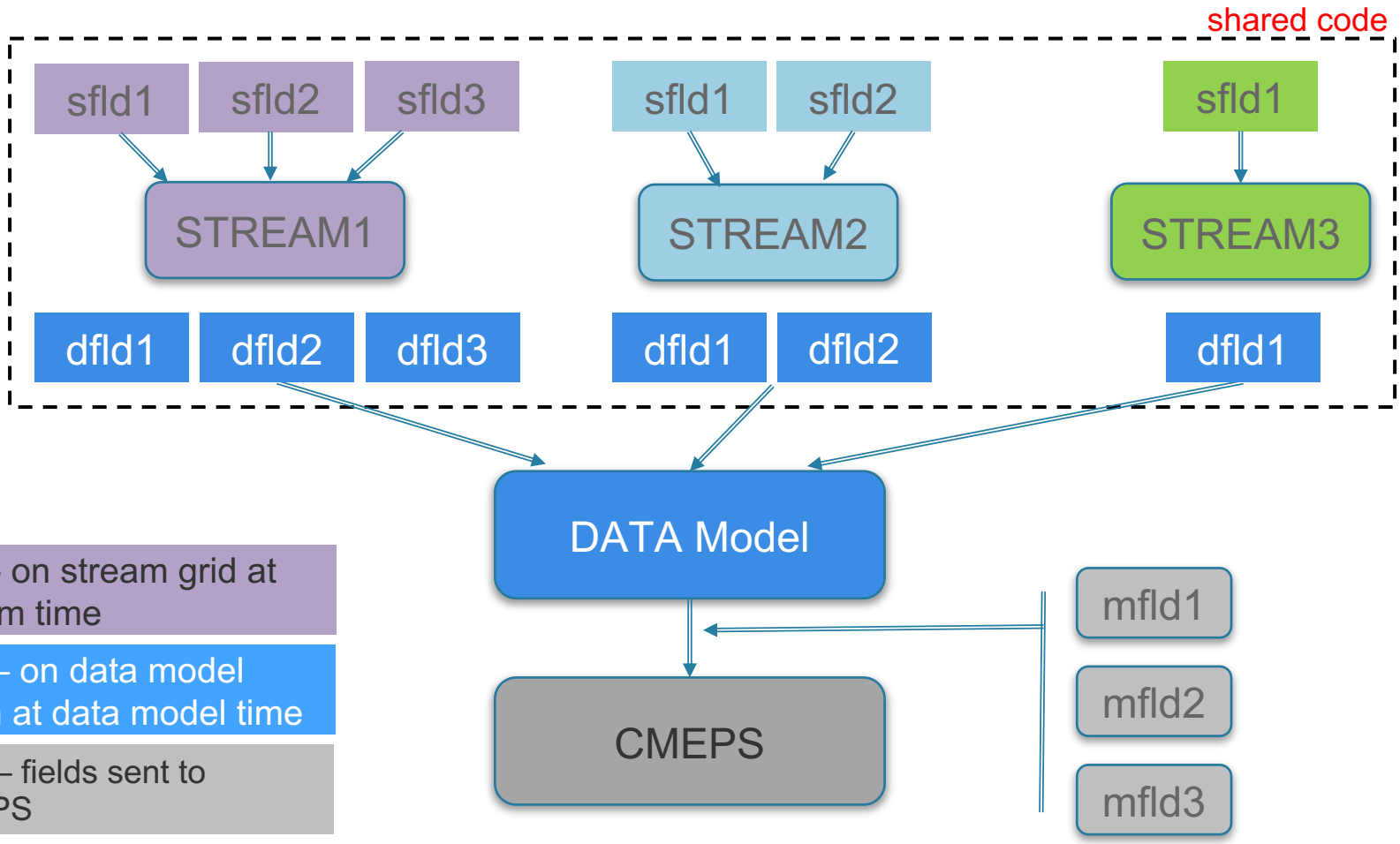
New ESMF-based Data models

Community Data Models for Earth Predictive Systems

https://github.com/ESCOMP/CDEPS

- New data model functionality based on ESMF/NUOPC
- Compatible with CMEPS
- Regridding capability between forcing data mesh and model mesh
  - Online regridding between forcing data and model mesh
  - Multiple regridding options including conservative regridding
  - Ability to easily regrid between two horizontal grids with multiple model levels
  - Ability to do 3d regridding
- Modularity for science specific data model functionality
- Data model share code has interface that can be called directly from prognostic component code base

CDEPS Data Flow

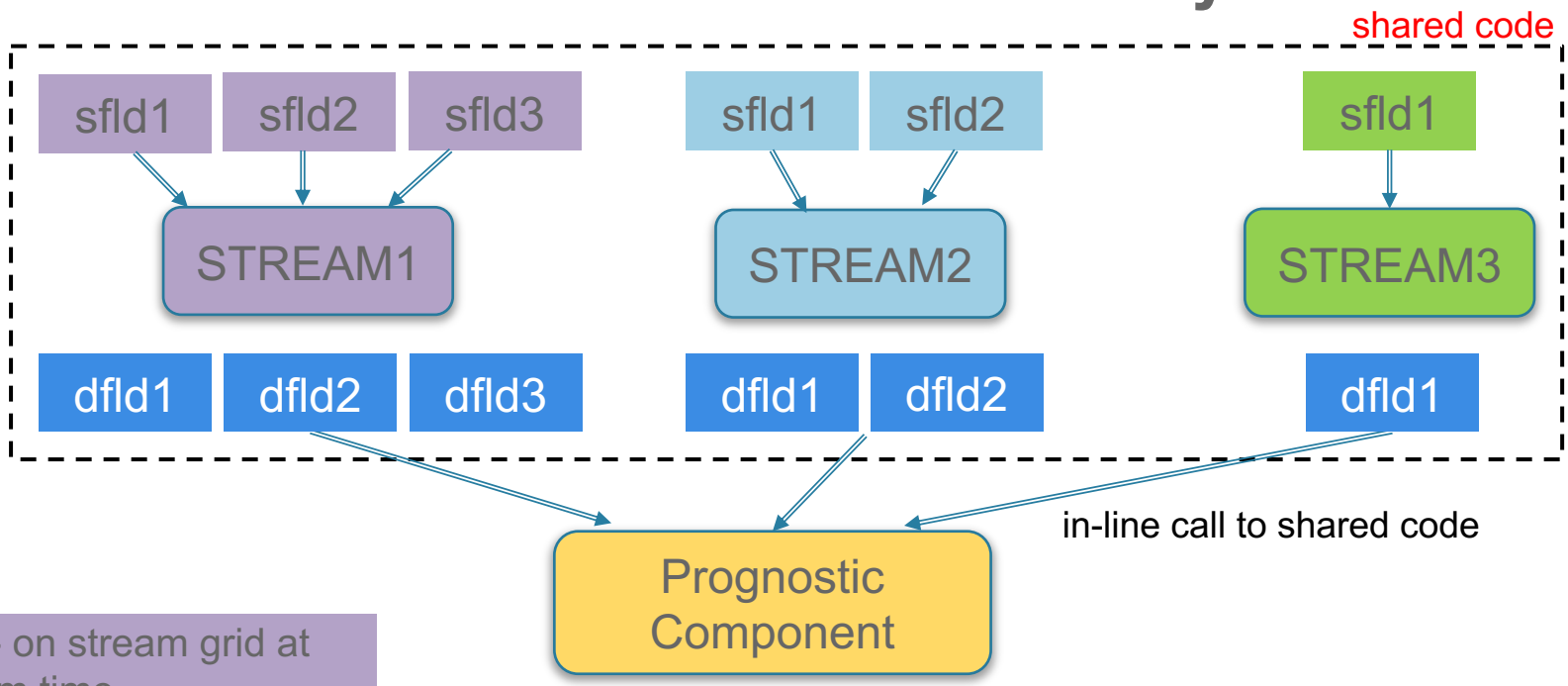


sfld - on stream grid at stream time

dfld – on data model mesh at data model time

mfld – fields sent to CMEPS

CDEPS In-line Functionality



sfld - on stream grid at stream time

dfld – on data model mesh at data model time

Thank you

Questions?