

ESMF/NUOPC Update

Cecelia DeLuca

CESM Workshop

June 21, 2016

- ESMF/NUOPC v7.0 and current work
- CESM collaborations
 - CESM NUOPC coupler option
 - CESM - HYCOM coupling
 - NEMS - CIME Pilot
- Earth System Prediction Suite (ESPS)

- ESMF grid remapping additions:
 - point cloud/observational data representation
 - first-order conservative regridding of concave quadrilateral cells
 - non-conservative regridding on mesh elements with more than four sides
 - the use of great circle lines when computing 3D bilinear interpolation weights on a sphere
- A new command-line tool, ESMF_Regrid, generates interpolation weights and applies them to an input data field
- The ESMPy(thon) grid remapping interface allows a Field to be filled with data from a NetCDF file, and Anaconda packages are available for easy installation of ESMPy on Linux and Darwin system
- Simplification and reorganization of the NUOPC interface, plus conveniences – namespaces for field exchange, clearer naming of phases
- PIO is on by default, and there are new asynchronous I/O prototypes

Work in Progress

- In ESMF v7, there is an option to use MOAB (Mesh Oriented datABase - DOE/Wisconsin project) as the underlying finite element mesh framework for conservative grid remapping - still evaluating MOAB as a replacement for the ESMF native FEM implementation (Bob Oehmke/CIRES)
- In ESMF v7, the ESMF virtual machine can recognize and allocate to heterogeneous resources – currently implementing logic to enable components to negotiate for accelerators (Jayesh Krishna/ANL)
- Implementation of higher order conservative grid remapping (Bob Oehmke/CIRES)
- Strategies for interpolation weight generation for very high resolution grids (< 0.10 degree global) (Peggy Li/JPL)
- Merger of NUOPC with the ESMF-based software used by NASA GSFC, called MAPL (Modeling Analysis and Prediction Layer) (Peggy Li/JPL, Atanas Trayanov/GSFC, others)

Background

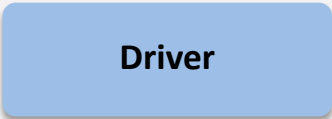



- CESM has included ESMF interfaces since CCSM4 – layered over existing MCT interfaces
- Updated to NUOPC interfaces for ONR-funded CESM-HYCOM coupling project – still layered over existing interfaces
- This hybrid NUOPC/MCT version is being used for high resolution HYCOM runs in CESM

A new effort is creating a CESM coupler that is based only on NUOPC software, which will make the hybrid code simpler and offer

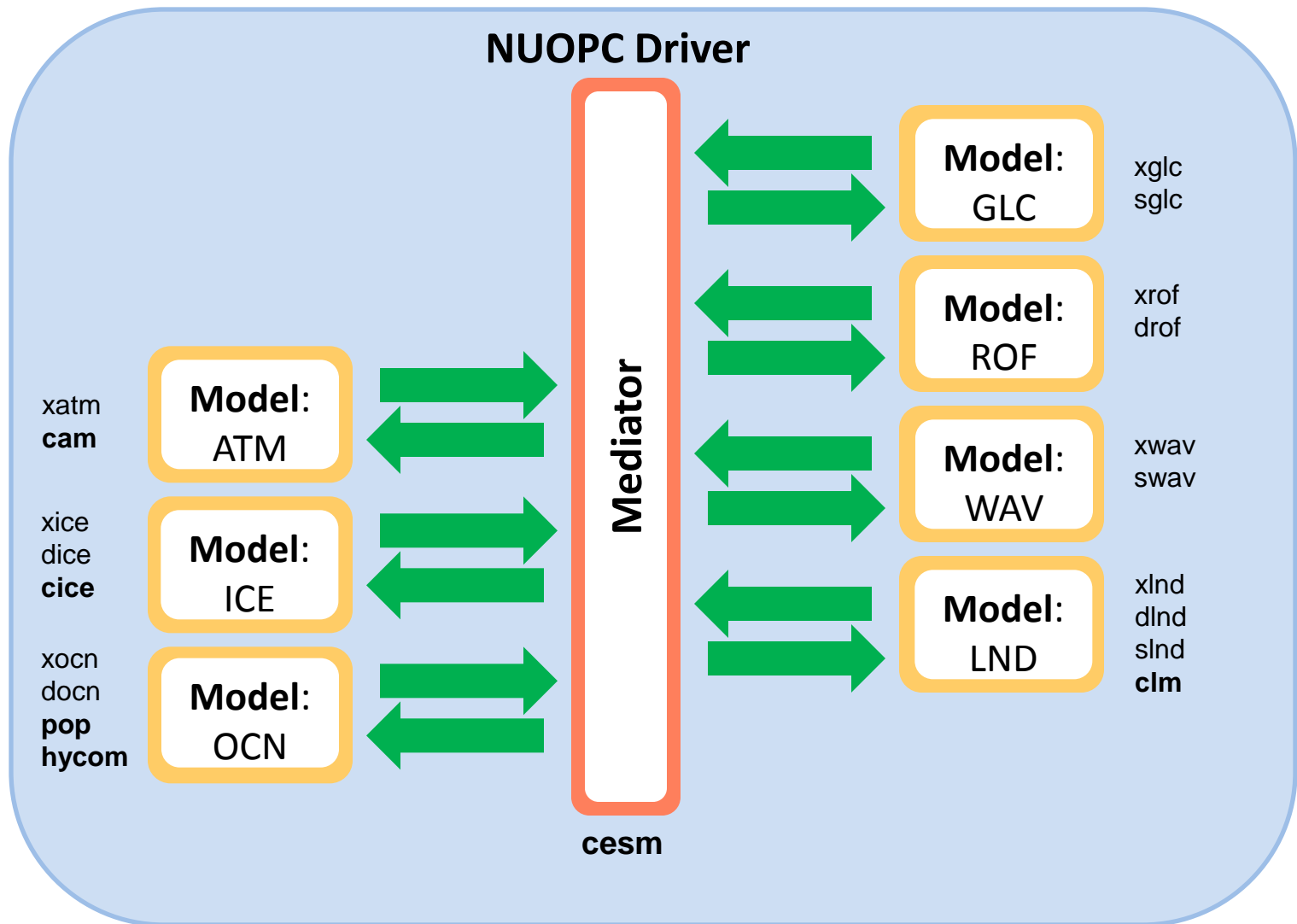
- During-run grid remapping
- Easily reconfigurable run sequence
- Support for coupling hierarchies
- Compliance checking and development tools
- Greater interoperability with other NUOPC components

National Unified Operational Prediction Capability (NUOPC) Layer

NUOPC Layer interoperability rules are implemented in ESMF applications using a set of **generic components** that represent the major structural pieces needed to build coupled models.

NUOPC Generic Components	
 <p>Driver</p>	<p>Harness that initializes components according to an <i>Initialization Phase Definition</i>, and drives their Run() methods according to a customizable run sequence.</p>
 <p>Connector</p>	<p>Implements field matching based on standard metadata and executes simple transforms (e.g. grid remapping, redistribution). It can be plugged into a generic Driver component to connect Models and/or Mediators.</p>
 <p>Model</p>	<p>Wraps model code so it is suitable to be plugged into a generic Driver component.</p>
 <p>Mediator</p>	<p>Wraps custom coupling code (flux calculations, averaging, etc.) so it is suitable to be plugged into a generic Driver component.</p>

CESM as a NUOPC Application



- NUOPC models and mediators are implemented as wrappers around existing CESM components and coupler/driver internals
- There are still issues (e.g. with passing scalars) that make the system not fully compliant, though it is bfb with the original implementation.

- In collaboration with FSU, NCAR, CIRES, U Miami and NRL, created “BHY” compsets for HYCOM in CESM running at a low resolution (1 degree) and higher resolution (0.10 degree), using hybrid NUOPC/MCT coupler
- Other components in BHY are Community Atmosphere Model (CAM), Community Land Model (CLM), CICE sea ice, HYCOM, and a River Transport Model (RTM).
- NUOPC version validates bit-for-bit with original CESM when using the POP ocean.
- Initial low resolution runs performed showed higher than expected overhead – 20-25%, reduced to 5% with optimizations focused on minimizing character comparison
- Memory scaling issues with high resolution runs were recently addressed
- 50 year low resolution runs completed, high resolution runs just starting

- The NOAA Environmental Modeling System (NEMS) mediator (coupler) will be integrated with other infrastructure in CIME so that the NEMS mediator can be run in a test environment that utilizes workflows for coupled models developed by the Community Earth System Model (CESM).
- The test environment with the NEMS mediator will be available for download to credentialed users and will be able to run with active model components from both NEMS and CESM (e.g. HYCOM, CICE) that satisfy ESMF/NUOPC interface requirements.

FY17 Deliverable: In collaboration with EMC and teams involved with NEMS development:

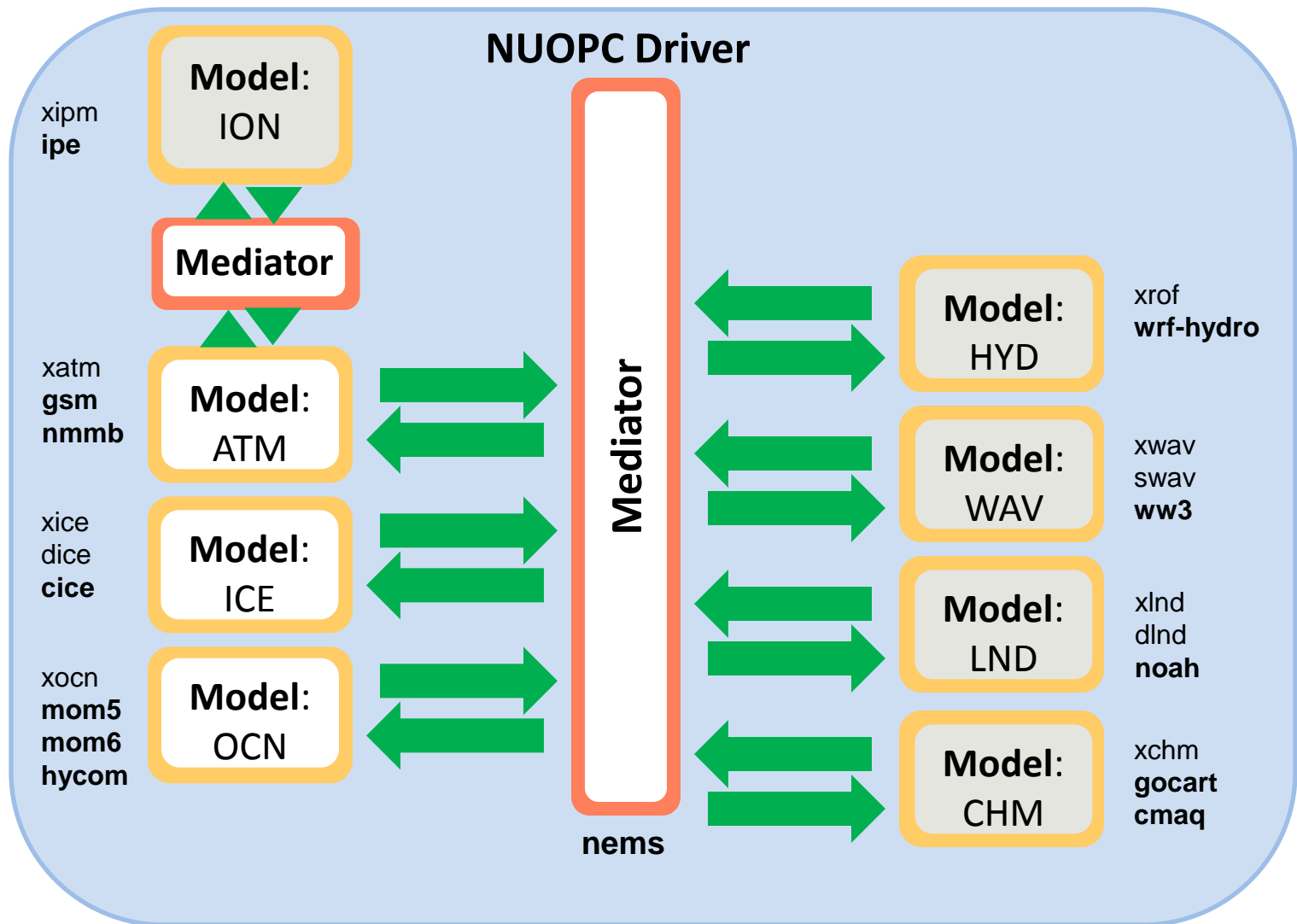
1. Establish a working, documented test system using the NEMS mediator with CIME *data models* and testing infrastructure.
 2. Demonstrate its use with a limited set of active components.
- Funded for FY17 under NOAA NWS NGGPS.

NEMS Unified Modeling

Modeling Application	ATM	OCN	ICE	WAV	LND	CHM	HYD	ION	CST
UGCS-Weather	0	0	0	0	0	0		0	0
UGCS-SubSeasonal	0	0	0	0	0	0		0	0
UGCS-Seasonal	0	0	0	0	0	0		0	0
WAM-IPE	0							0	
HYCOM-Ice (RTOFS)		0	0						
Wave Prediction	0			0					
Regional	0	0	0		0		0		
Regional Nest	0	0							
Regional Arctic	0	0	0						
CMAQ Air Quality	0					0			

- Above is a simplified version of the spreadsheet of NEMS applications:
https://docs.google.com/spreadsheets/d/1RS-ftBYnfSIWrJYfalD2IAI-bUOGM0frNPEMIO_ND28/edit#gid=0

NEMS as a NUOPC Application

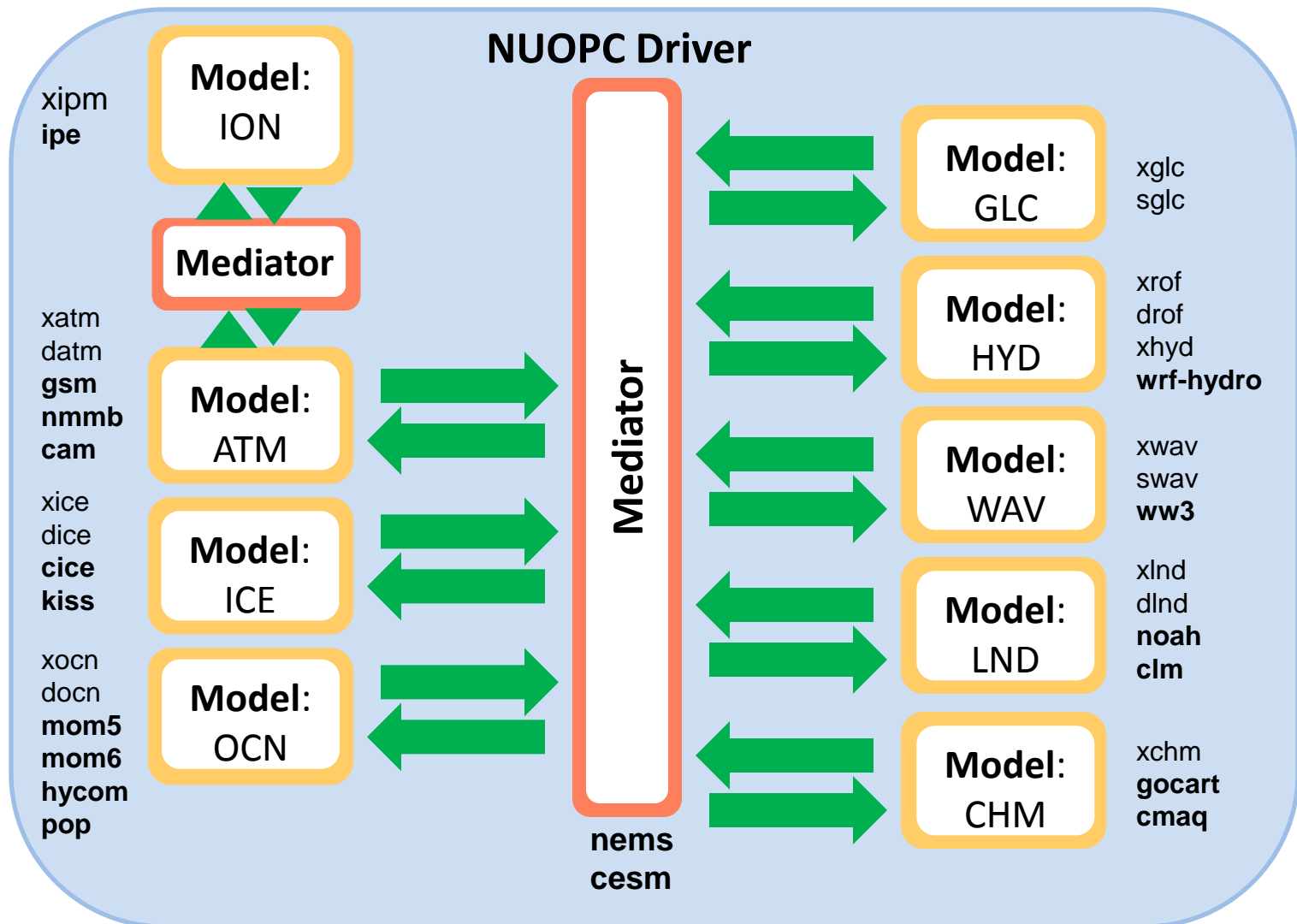


- Grayed out components are in progress.
- The NEMS mediator is used instead of the CESM mediator.

Why CIME?

- This mode of running the NEMS mediator will offer a broad community access to key elements of the NOAA operational system in an established, research-friendly environment – it will help to make the NEMS mediator a “community” component.
- Having a broader community run and test the mediator will improve its flexibility and reliability.
- Components will be run using ESMF/NUOPC standards, encouraging the implementation of research codes using the same standards as operations.

CIME-Enabled Research Testbed



- This does not exist yet. Not all components will be able to work together!
- Scientific model component access is *not* handled through CIME.

Earth System Prediction Suite

ESPS COUPLED MODELING SYSTEMS						
	NEMS and CFS	COAMPS	NavGEM	GEOS-5	ModelE	CESM
Model Driver	●	●	●	●	●	●
ATMOSPHERE MODELS						
GSM	●					
NMMB	●					
CAM						●
FIM	●					
GEOS-5 Atmosphere				●		
ModelE Atmosphere					●	
COAMPS Atmosphere		●				
NavGEM			●			
NEPTUNE			●			
OCEAN MODELS						
MOM5	●			●		
HYCOM	●		●		●	●
NCOM		●				
POP						●
POM	●					
SEA ICE MODELS						
CICE	●		●	●	●	●
KISS	●					
OCEAN WAVE MODELS						
WW3	●	●		●		●
SWAN		●				

LEGEND	
●	Components are NUOPC compliant and the technical correctness of data transfers in a coupled system has been validated.
●	Components and coupled systems are partially NUOPC compliant.

- *The Earth System Prediction Suite is a collection of federal and community models and components that use the **Earth System Modeling Framework (ESMF)** with interoperability conventions called the **National Unified Operational Prediction Capability (NUOPC) Layer**.*
- *ESMF standard component interfaces enable major U.S. centers to assemble systems with components from different organizations, and test a variety of components more easily.*
- *BAMS August 2016 paper – Theurich et al.*

Thanks to Sponsors

- ONR NOPP – CESM-HYCOM, accelerator-awareness
- HPCMP PETTT (Asynchronous I/O)
- NOAA CPO MAPP – NEMS development for seasonal prediction
- NOAA NWS NGGPS – CIME Pilot, NEMS development for weather prediction
- NASA CMAC – NUOPC in Model E, IDE development
- NASA MAP – NUOPC in GEOS-5 and ESMF development
- NSF EarthCube – Coupled land/hydrology

Questions?