Overarching System and NEMS

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NGGPS Annual Meeting
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Outline

- *Overarching System Team*
- NEMS and Model Coupling
- Code Management and R2X

NGGPS System Elements

NGGPS software delivery requires coordination across efforts:

- Integrative goals for science, predictive skill, and products
- Model component development
- Model component coupling
- Atmospheric physics and dynamics interface
- Workflow suite software elements (e.g. data assimilation, pre- and post-processing)
- Code management and repository strategy
- Performance and memory optimization
- R2X strategy

Changes in Approach

Current development at EMC differs from previous efforts in (at least) three major ways:

1. EMC anticipates leveraging more community–developed modeling components, and using development strategies based on *community modeling* (e.g. objective evaluation of components).
2. There are *more model components* anticipated than in previous EMC modeling systems, including wave and separate land components.
3. EMC is building a *unified infrastructure* – the NOAA Environmental Modeling System, or NEMS – to support multiple modeling applications and predictive time scales.

NEMS workspace:
http://cog-esgf.esrl.noaa.gov/projects/couplednems/

NEMS Basics

- The NOAA Environmental Modeling System (NEMS) is infrastructure for building coupled modeling systems
  - Examples of other coupled modeling systems: UK Met Office Unified Model, Community Earth System Model (CESM)
- NEMS is associated with a collection of model components
- External model components have a primary repository that is not at EMC
- In general, model components exchange data using the main NEMS mediator – often called a "coupler“
- Custom NEMS mediators are being built for special interactions, such as optimized 3D coupling of the upper atmosphere to the ionosphere

Introduction to NEMS:
http://cog-esgf.esrl.noaa.gov/projects/couplednems/introduction

NEMS Modeling Applications

- The model components in NEMS can be assembled into a number of different modeling applications, each associated with:
  - a purpose, such as seasonal forecasting
  - a set of model components
  - a set of parameters that represents a range of supported options, including grids and resolutions
- Different NEMS modeling applications can have different types and numbers of model components
- The same physical domain may be represented by different model components in different modeling modeling applications:
  - For example, in some NEMS modeling applications the ocean component may be HYCOM and in others it may be MOM5

Spreadsheet of NEMS modeling applications:
https://docs.google.com/spreadsheets/d/1RS-fTBYnfSIWrJYfalD2lAI-bUOGM0frNPEMIO_ND28/edit#gid=0

Modeling Applications and Components

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
5														
6	**NEMS Components**					**ATM**	**OCN**	**WAV**	**ICE**	**HYD**	**LND**	**AER/CHEM**	**IPM**	**CST**
7	**Modeling Application Name**	**Version**	**Delivery**	**NEMS Revision**	**Application Lead**	**Atmosphere**	**Ocean**	**Wave**	**Sea Ice**	**Hydraulics/ Hydrology**	**Land**	**Aerosol/ Chemistry**	**Ionosphere**	**Coast**
8	Component EMC Lead ->					Moorthi	Behringer(MOM5), Mehra(HYCOM)	Chawla	Wu, Grumbine(KISS)	Ek/Dong	Ek	Lee(PM2.5)	Yang	
9	Component External Lead ->						Griffies	Campbell	Bailey	Gochis		Lu	Maruyama	
10	UGCS-Weather	0.1				GFS	HYCOM (0.7deg)		CICE (1deg) or KISS		Noah-inline or Noah	GOCART-inline	IPE	
11	UGCS-Weather	Target				GFS	HYCOM (0.7deg) or MOM5/6 (1deg)	WW3	CICE (1deg) or KISS		Noah or Noah-MP	GOCART	IPE	ADCIRC
12	UGCS-SubSeasonal	0.1				GFS	HYCOM (0.7deg) or MOM5/6 (1deg)	WW3	CICE (1deg) or KISS		Noah-inline or Noah	GOCART	IPE	
13	UGCS-SubSeasonal	Target				GFS	HYCOM (0.7deg) or MOM5/6 (1deg)	WW3	CICE (1deg) or KISS		Noah or Noah-MP	GOCART	IPE	
14	UGCS-Seasonal	0.1	6/2015		Saha	GFS (T126)	MOM5 (1deg)		CICE (1deg) or KISS		Noah-inline	GOCART-inline		
15	UGCS-Seasonal	0.2	9/2015		Saha	GFS (T126, T254, T574)	MOM5/6 (1 deg, 0.5deg with 0.25deg tropics)	WW3	CICE (1deg, 0.5deg with 0.25deg tropics)		Noah-inline	GOCART-inline		
16	UGCS-Seasonal	0.3			Saha	GFS (T126, T254, T574)	MOM5/6 (1 deg, 0.5deg with 0.25deg tropics)		CICE (1deg, 0.5deg with 0.25deg tropics)		Noah-inline	GOCART-inline		
17	UGCS-Seasonal	Target			Saha	GFS (T126, T254, T574)	MOM5/6 (1deg, 0.5deg with 0.25deg tropics) or HYCOM (0.7deg)	WW3	CICE (1deg, 0.5deg with 0.25deg tropics) or KISS or SIS2	WRF-Hydro	Noah-MP	GOCART		
18	WAM	Target	4/2015	DREV49055	Naruyama	GFS/WAM								
19	WAM-IPE	0.1	4/2015	DREV49055	Naruyama	GFS/WAM							IPE uncoupled	
20	WAM-IPE	Target			Naruyama	GFS/WAM							IPE	
21	HYCOM-Ice	Target					HYCOM		CICE		Noah-inline	GOCART-inline		
22	Regional	0.1	8/2015		Black	GFS (T126)	HYCOM (0.7deg) or MOM5/6 (1deg)		CICE-1deg	WRF-Hydro uncoupled	LIS/Noah uncoupled			
23	Regional	0.2	12/2015		Black	GFS (T126) (tentative)	HYCOM (0.7deg) or MOM5/6 (1deg)		CICE-1deg	WRF-Hydro	LIS/Noah			
24	Regional	Target			Black	NMMB	POM			WRF-Hydro	LIS/Noah			

NGGPS / UGCS-Weather share components with other NEMS applications, so a holistic view of development is needed

Overarching System Team

Three main areas of activity:

- Model coupling
- Code management
- Coordination across NGGPS system elements

Charged with creating an associated 5-year plan to address the development of the overall framework for the NGGPS

Overarching System Team

Cecelia DeLuca *ESRL/CIRES/NESII*

Ligia Bernadet *NCAR DTC*

Anthony Craig *contracting for NESII*

Jim Doyle *NRL MRY*

Mark Iredell *NCEP EMC*

John Michalakes *NOAA NWS*

Gerhard Theurich *Fei Liu NRL/NESII*

Mariana Vertenstein *NCAR CGD/CESM*

In coordination with

+ EMC and external model component leads

+ modeling application leads, including NGGPS science/product lead

Outline

- Overarching System Team
- *NEMS and Model Coupling*
- Code Management and R2X

NEMS Infrastructure

- NEMS is built using Earth System Modeling Framework (ESMF) infrastructure software, which provides:
  - generation and application of interpolation weights, time management classes, and other utilities
  - data structures for representing fields, grids, and model components in a standard way
- The National Unified Operational Prediction Capability (NUOPC) Layer increases interoperability by adding behavioral rules to ESMF, including:
  - a standard way of representing build dependencies
  - a standard syntax for initialization and run phases
- NUOPC wrappers or "caps" contain translations of native data structures (e.g. grids, field data, time quantities) into ESMF data structures.

ESMF site: https://www.earthsystemcog.org/projects/esmf/
NUOPC Layer site: https://www.earthsystemcog.org/projects/nuopc/
Performance reports: https://www.earthsystemcog.org/projects/esmf/performance

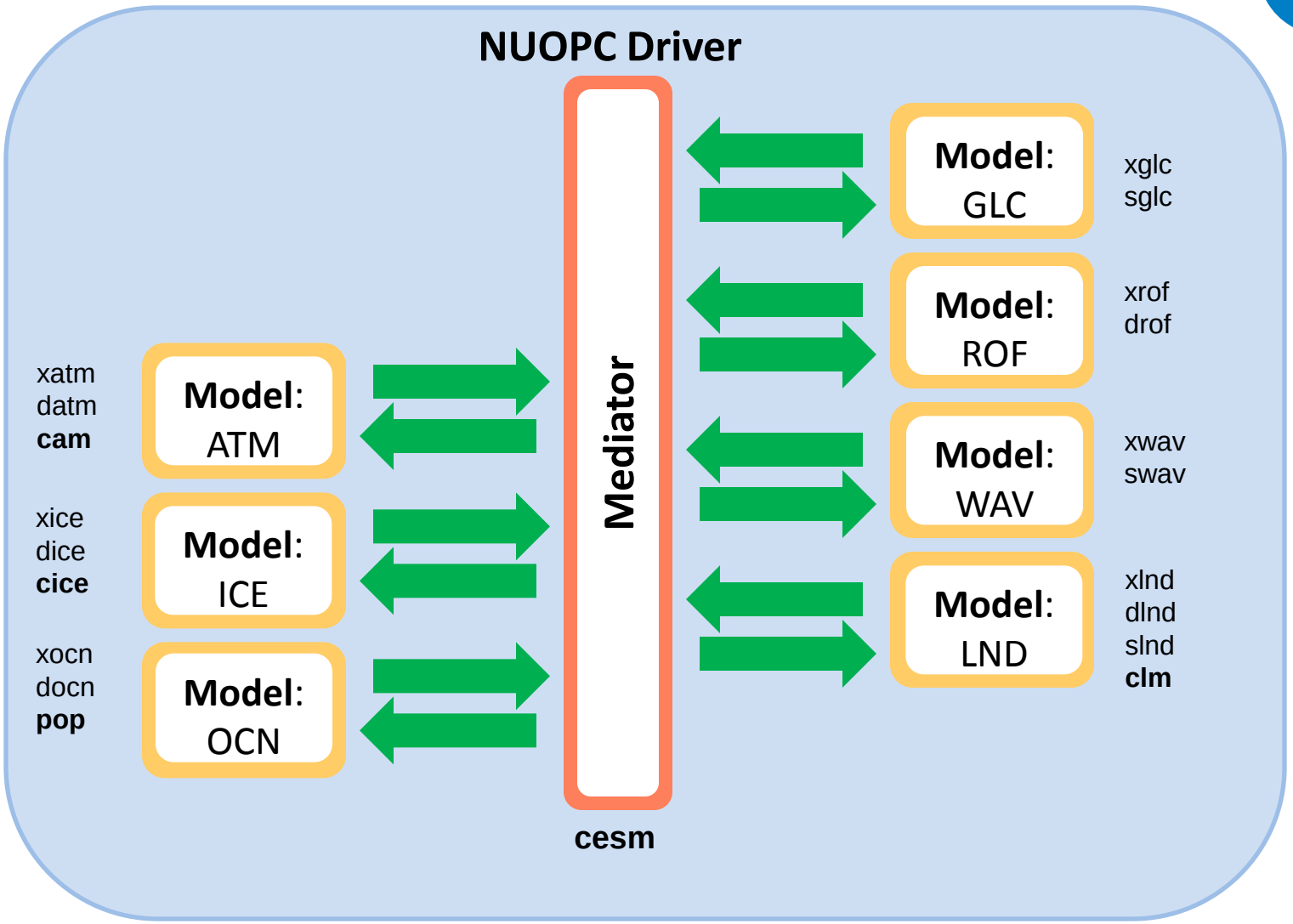
National Unified Operational Prediction Capability Conventions

NUOPC Layer rules are implemented using a set of generic components that represent the major structural pieces needed to build coupled models

NUOPC Generic Components	
Driver	Harness that initializes components according to an *Initialization Phase Definition*, and drives their Run() methods according to a customizable run sequence.
Connector	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.
Model	Wraps model code so it is suitable to be plugged into a generic Driver component.
Mediator	Wraps custom coupling code (flux calculations, averaging, etc.) so it is suitable to be plugged into a generic Driver component.

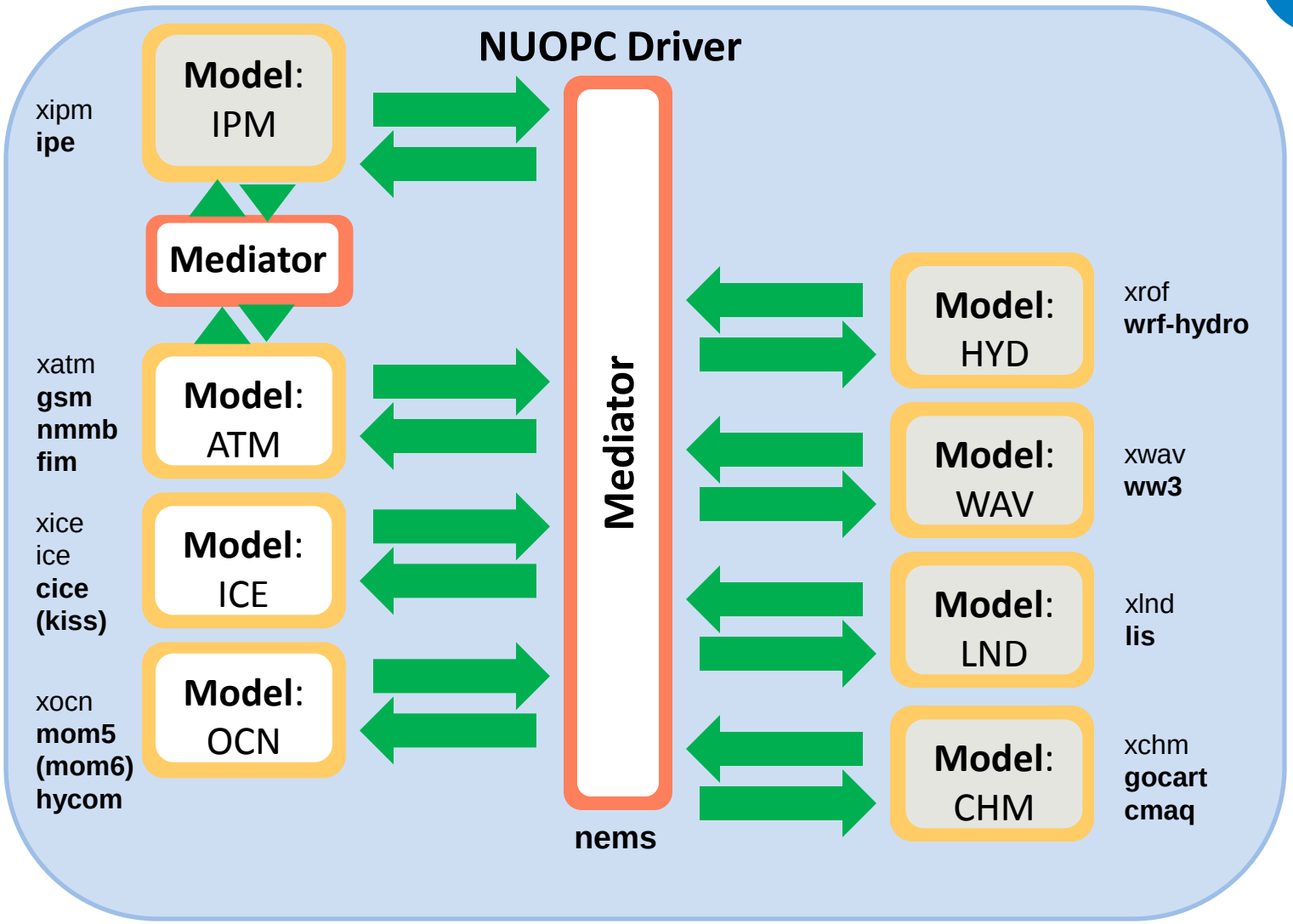
From Theurich et al., submitted 2015

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.

NEMS as a NUOPC Application



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

Earth System Prediction Suite Status

LEGEND

Compliant

(Completion date) In progress

Coupled Modeling Systems						
	NEMS	COAMPS / COAMPS-TC	NavGEM-HYCOM-CICE	GEOS-5	ModelE	CESM
				2015	2015	2015
Atmospheres						
GFS/GSM						
NMMB	2015					
CAM						
FIM	2015					
GEOS-5 FV				2015		
ModelE Atm						
COAMPS Atm						
NavGEM						
NEPTUNE						
Oceans						
MOM5				2015		
HYCOM					2015	
NCOM						
POP						
Ice						
CICE				2015	2015	
Wave						
WW3	2015	2015		2015		2015
SWAN						

The Earth System Prediction Suite (ESPS) is a collection of major weather and climate modeling codes that use ESMF interfaces with the NUOPC conventions

NEMS Mediator

- Currently set up for atmosphere-ocean-ice coupling, with stubs for wave, hydrology, and land components
- Slow (ocean) and fast (atmosphere and ice) coupling periods
- The mediator includes the following functions:
  - Connects fields whose standard names match
  - Accumulates and averages atmosphere and ice fields between calls to the ocean model
  - Merges fields with a generic merge method that allows for weighting
  - Performs custom coupling operations, along with unit transformations
  - Performs interpolation (fluxes are mapped bilinearly, states conservatively, higher order also available)

More information about the mediator:
http://cog-esgf.esrl.noaa.gov/projects/couplednems/mediator_design

Worksheet of planned coupling fields across all modeling applications:
https://docs.google.com/spreadsheets/d/11t0TqbYfEqH7lmTZ7dYe1DSCh6vOUFgX-3qvXgce-q0/edit#gid=0

Sample NEMS Configure File

```
##################################
# NEMS Run Time Configuration File  #
##################################
# MED #
med_model:                nems
med_petlist_bounds:       60 65

#ATM#
atm_model:
                  gsm
atm_petlist_bounds:       0 31
Processor layout

# OCN #
ocn_model:                mom5
ocn_petlist_bounds:       32 55

# ICE #
ice_model:                cice
ice_petlist_bounds:       56 59
```

Processor layout

```
# Run Sequence #
runSeq::
  @7200.0
    OCN -> MED
    MED MedPhase_slow
    MED -> OCN
    OCN
      @3600.0
        MED MedPhase_fast_before
        MED -> ATM
        MED -> ICE
        ATM
        ICE
        ATM -> MED
        ICE -> MED
        MED MedPhase_fast_after
      @
  @
::
```

Colors show actions performed by:

- Connectors (->)
- Mediator (MED)
- Models

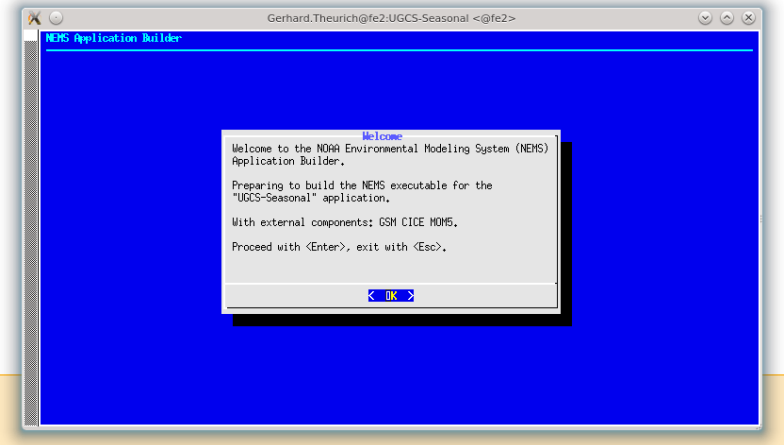
(@) indicates coupling timesteps

Assembling NEMS Modeling Applications

NEMS AppBuilder:

- Enables users to construct a specific, versioned modeling application from a versioned set of model components and configuration files from multiple locations.
- Helps to ensure that changes made to the different applications are coordinated as they get checked back into the NEMS repository.
- Implemented using SVN externals, can be used with git repositories

The AppBuilder is based on low-level terminal-based Unix utilities for maximum ease of use and portability. A command-line version will be available shortly.



More about the AppBuilder:
http://cog-esgf.esrl.noaa.gov/projects/couplednems/appbuilder

Running NEMS Applications

Component sets (compsets):

- A labeling system originated by CESM to distinguish different run configurations for many-component modeling applications.
- Labels are associated with scripts that pull together all the files and inputs needed to run the specified configurations.
  - standard runs can be set up easily and consistently
  - effective way to implement regression testing across a coupled system with many possible combinations of components
- Each modeling application is typically associated with multiple compsets.

More about compsets:
http://cog-esgf.esrl.noaa.gov/projects/couplednems/compsets

Using Compsets

Running Compsets:

```
./NEMSCompsetRun [COMPSET_LIST_FILE]
```

Compset syntax:

```
caselabel_architecture_model1[%opt1[%opt2[...[%optN]]]]_model2[...]
_..._modelN[...]
```

Where the file has the format:

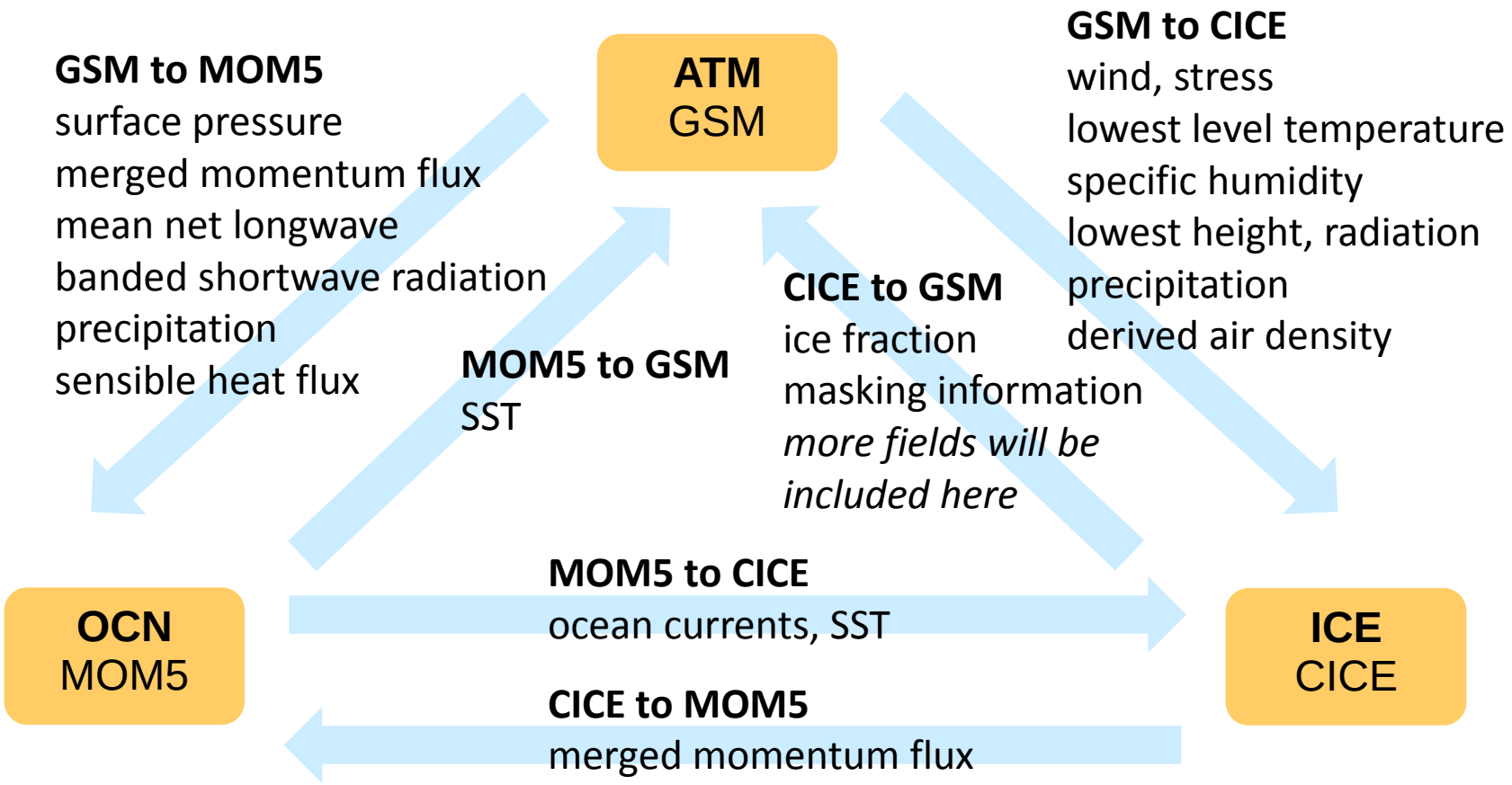
```
### List of compsets ###
########################

AMIP_sbys_gsm              ! stand-alone GSM - fake example
2009_nems_gsm_cice_mom5    ! NEMS mediator coupled GSM-CICE-MOM5
2011_sbys_gsm%wam          ! stand-alone GSM run as WAM
2011_sbys_gsm%wam%ndsl     ! stand-alone GSM run as WAM with NDSL
```

Supported compsets:
http://cog-esgf.esrl.noaa.gov/projects/couplednems/supported_compsets

UGCS Seasonal 0.1 Milestone

- A first version (0.1) of the Unified Global Coupled System (UGCS) targeting seasonal prediction was completed in June 2015.
- Three-way coupled atmosphere-ocean-ice system with GSM (T126) - MOM5 (1 deg) –CICE (1 deg)



UGCS-Seasonal 0.1 Initial Tests

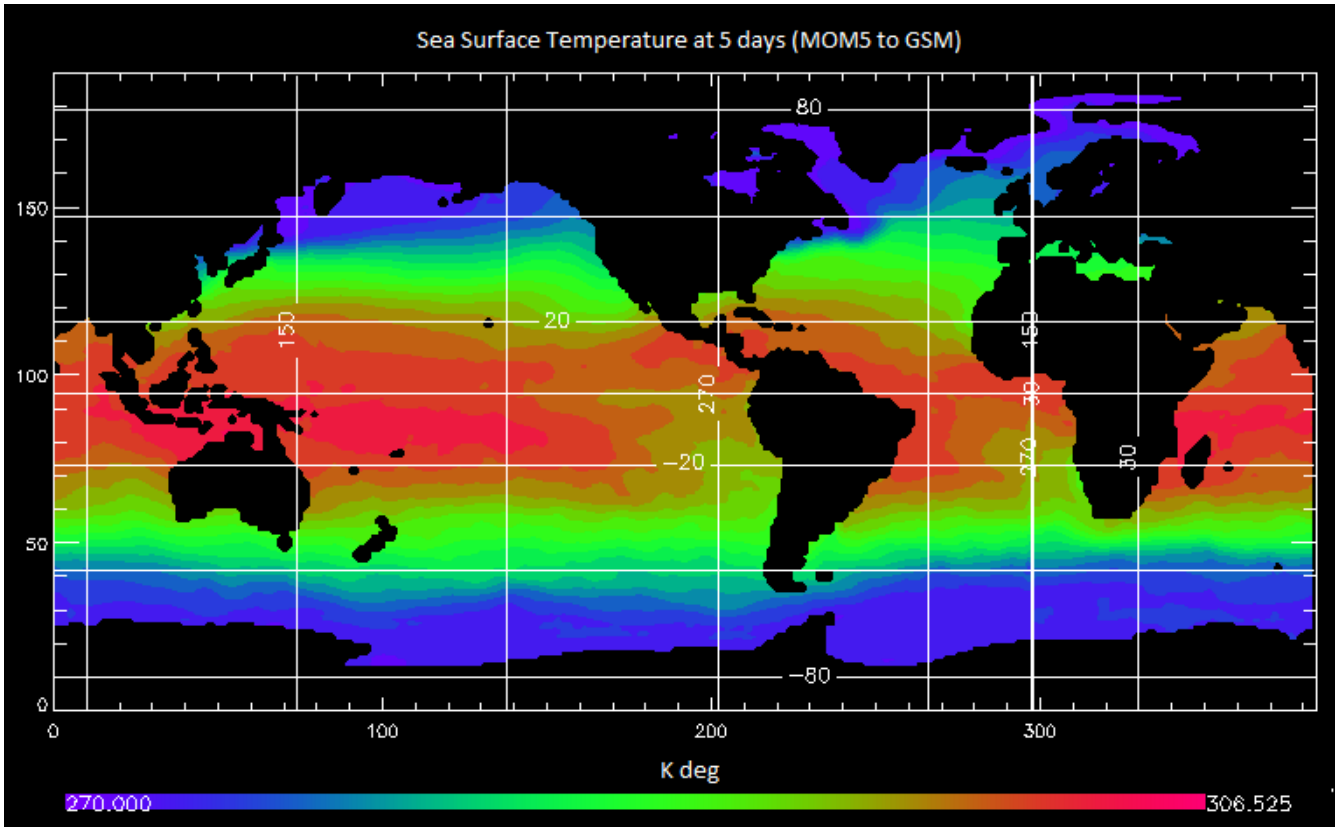


Image courtesy of Fei Liu, NOAA CIRES

- SST after 5 days of a 15 day run
- Focus so far has been on technical correctness
- Model initialization is not fully in place
- Next steps focus on adding grid resolutions and initializing from CFSR so comparative runs with CFSv2 can begin

Running UGCS-Seasonal 0.1

Run this test system by:

1. Use the AppBuilder to assemble UGCS-Seasonal 0.1:
   ```
   svn co -r 58214
   https://svnemc.ncep.noaa.gov/projects/nems/apps/UGCS-
   Seasonal/trunk UGCS-Seasonal
   ```
2. Select the compset: `2009_nems_gsm_cice_mom5`
3. Change `WLCLK` and `NDAYS` variables to the desired length of the run

More information about the UGCS-Seasonal 0.1 code:
http://cog-esgf.esrl.noaa.gov/projects/couplednems/drev58214

Outline

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- NEMS and Model Coupling
- *Code Management and R2X*

Code and Repository Management

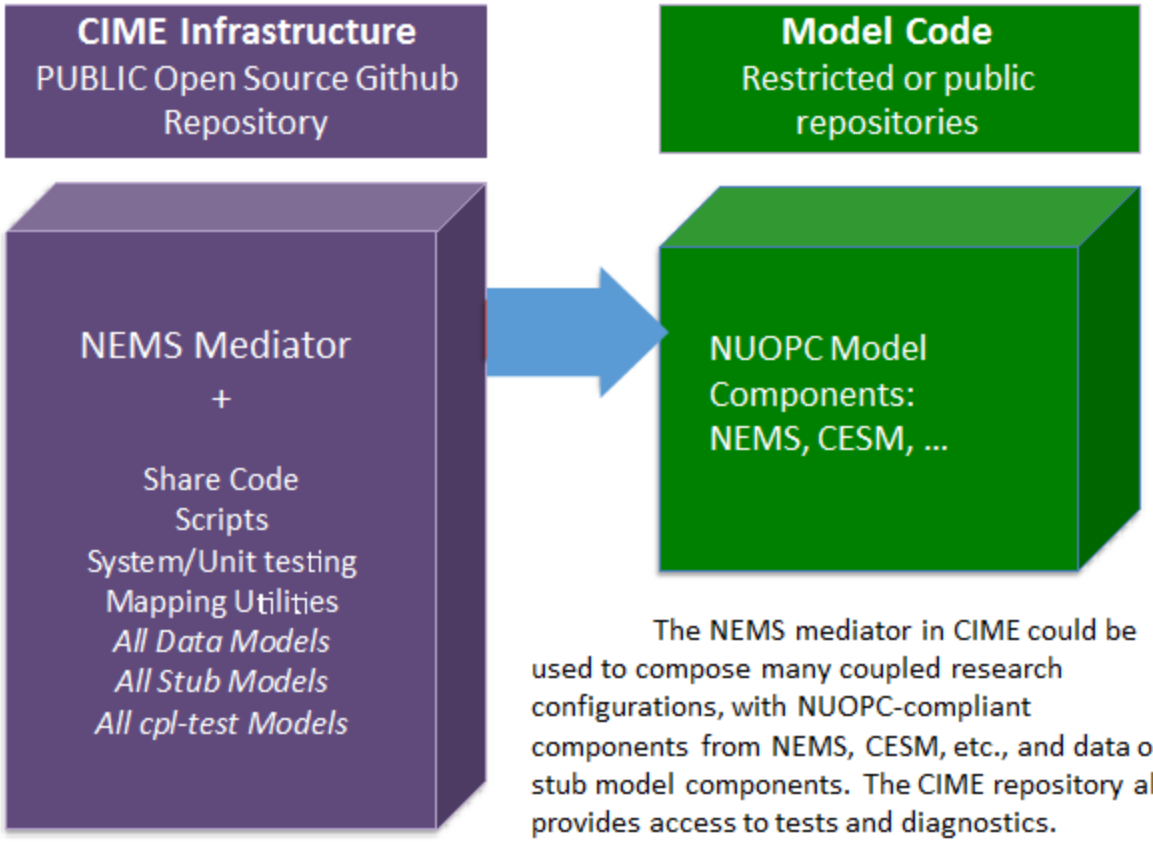
- Code management document initiated in early summer 2015
- Motivation included:
  - clarifying and reconciling terminology
  - version control software protocol (e.g. git and SVN)
  - version control software service (e.g. VLab, github)
  - how to organize NEMS repository directories
  - how to coordinate with external components
  - treatment of model components vs workflow components
  - treatment of infrastructure software vs scientific software
  - etc.
- Document will continue to evolve - expect many sections addressed by fall 2015

DRAFT NEMS code management document:
https://docs.google.com/document/d/1bjnyJpJ7T3XeW3zCnhRLTL5a3m4_3XIAUeThUPWD9Tg/edit#

Common Infrastructure for Modeling the Earth (CIME)

- CIME is a github community repository for storing infrastructure software
- Created by the CESM team but not specific to CESM software
- It includes:
  - coupling software (currently CESM coupler)
  - a scripting and testing environment
  - non-scientific (data, stub) versions of model components for development and controlled experimentation
- Proposal to store the NEMS mediator in CIME, where it can be treated like other community-developed components
  - NEMS components can be run within research workflows, with access to tests and diagnostics
  - NEMS mediator can be tested with a variety of components
  - NUOPC interfaces provide a link back to operational systems
- Issues with license and access requirements must be addressed

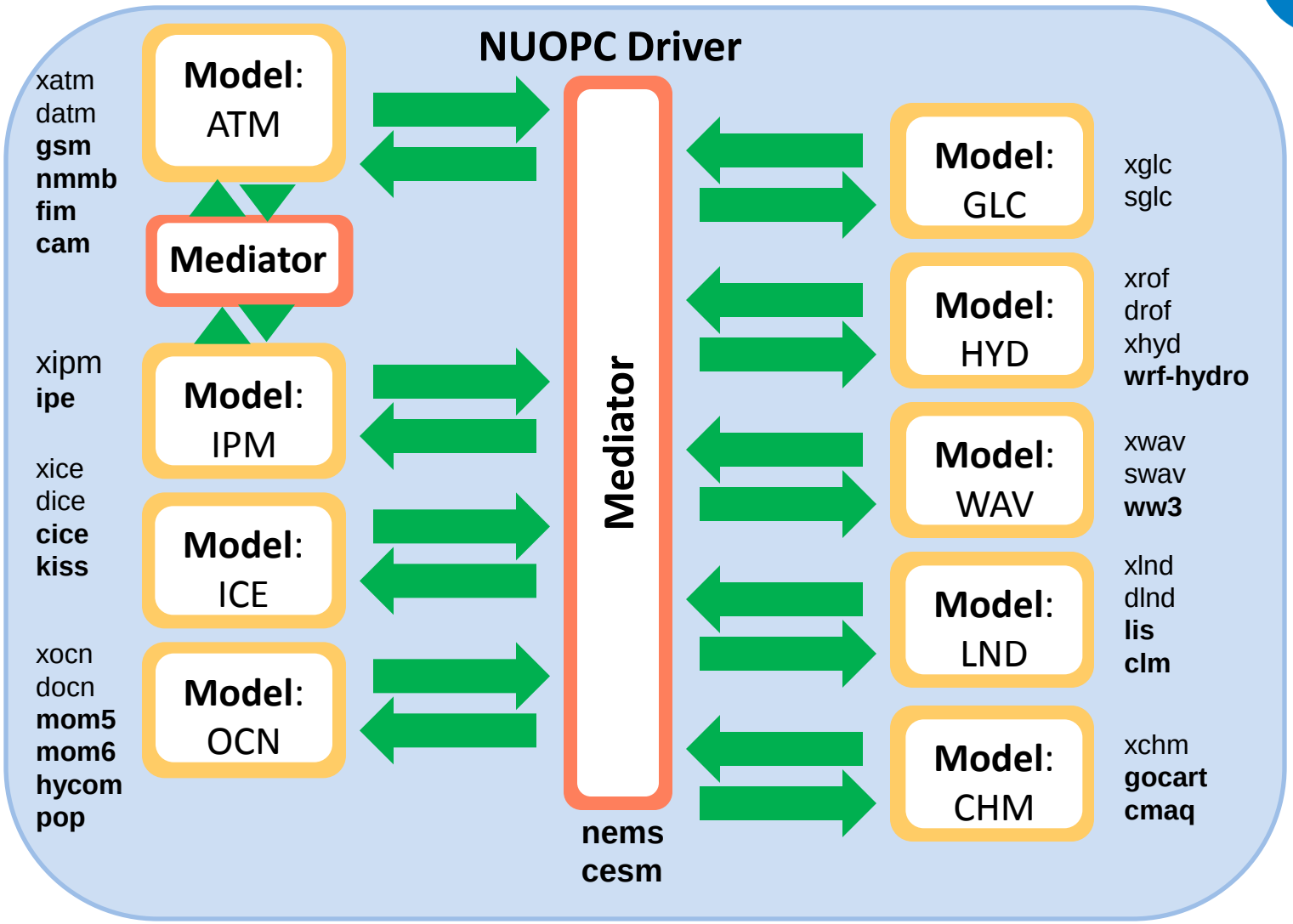
NEMS Mediator in CIME



The NEMS mediator in CIME could be used to compose many coupled research configurations, with NUOPC-compliant components from NEMS, CESM, etc., and data or stub model components. The CIME repository also provides access to tests and diagnostics.

A full standalone coupled model test environment can be downloaded and run, and non-scientific components replaced locally with prognostic versions

CIME-Enabled Research Testbed



- This is a proposal. Not all components will be able to work together!
- Scientific model component access is *not* handled through CIME.
- However, all components shown could interact in the same environment.

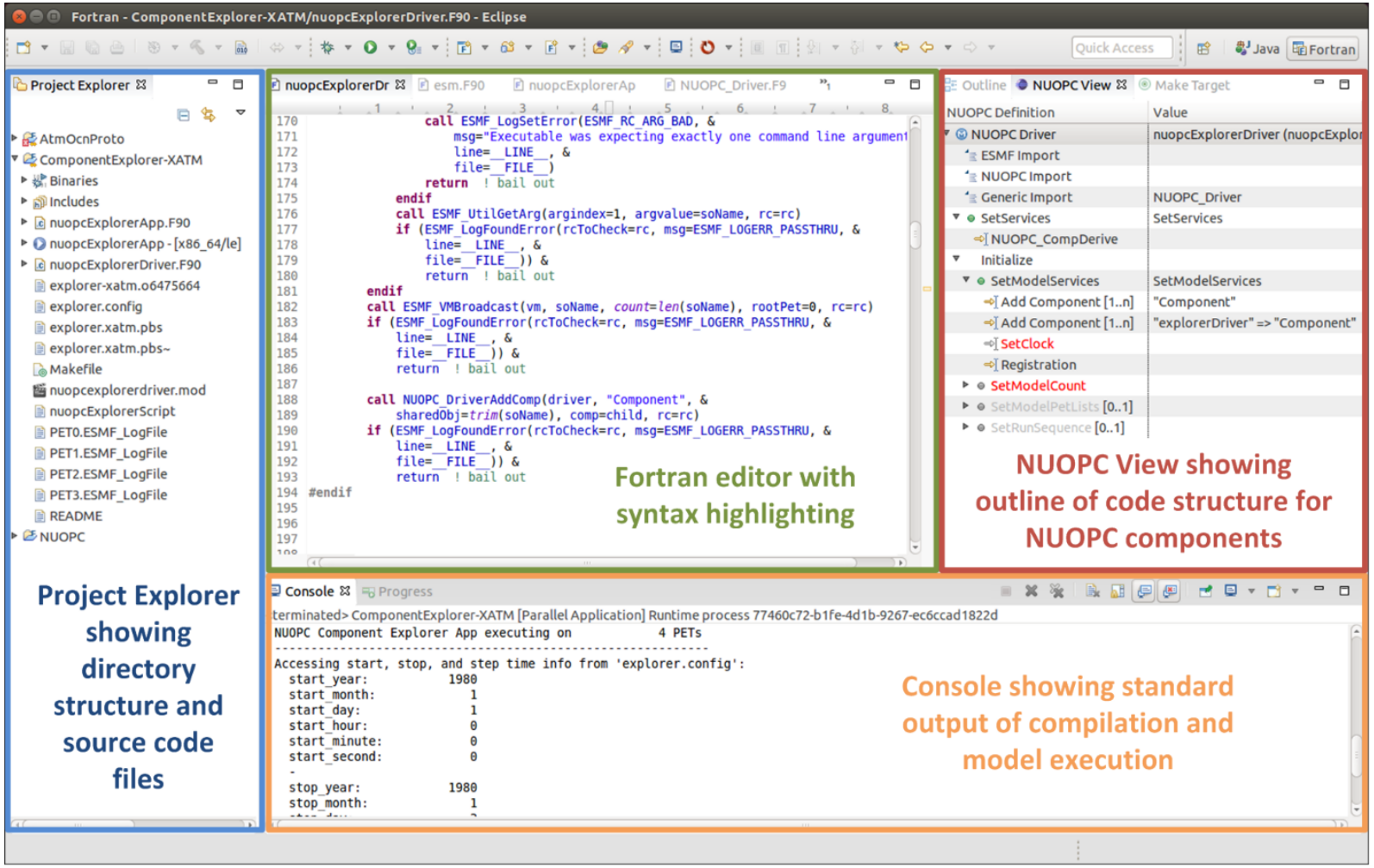
Cupid Development and Training Environment

Cupid is a tool designed to make ESMF training and development simpler, faster, and more appealing

- NOAA CIRES, GA Tech, and NASA GISS/GSFC collaboration
- Funded through the NASA Computational Modeling Algorithms and Cyberinfrastructure (CMAC) program – just received 2nd round of funding (Rocky Dunlap/NOAA NESII lead)
- Plugin for Eclipse-based "Integrated Development Environment" or IDE
- Customized for ESMF applications with NUOPC conventions
- First release in February 2015

More about Cupid: https://earthsystemcog.org/projects/cupid/

Cupid Development and Training Environment



- Cupid parses code and outlines coupled model structure
- Shows NUOPC compliance issues and generates code templates to satisfy NUOPC compliance

Coordination

- Weekly NEMS development call on Friday at 12MT/2ET – primary coordination mechanism
- New weekly sea ice call on Tuesday at 10MT/12ET
- Weekly land/hydrology call on Thursday at 12MT/2ET
- Occasional code management document calls

Plus

- Monthly overarching system team call, TBD

Most links in this talk are accessible from the main NEMS workspace:
http://cog-esgf.esrl.noaa.gov/projects/couplednems/

Thank you!

Any questions?