FV3 training Q3FY2018
2018 June 12-14
NCWCP/NCEP, College Park, Maryland

# NEMS
## (NOAA Environmental Modeling System)
## and the ESMF and NUOPC layers it depends upon

**Mark Iredell**

**June 13, 2018**

# What is NEMS?

The **NOAA Environmental Modeling System (NEMS)** is a unified modeling system that supports multiple coupled modeling applications.

Each **coupled modeling application** is associated with a purpose, a set of model components, and a range of supported options including grids and resolutions. These are called **NEMS applications**.

A **unified infrastructure** means that many parts of NEMS are shared across modeling applications, including the build system, the coupling infrastructure, mediators, testing infrastructure, a common way of representing run configurations, and a common way to execute configurations.

# Some Forces Affecting NEMS Design

- Increase in number of modeling component types
  - e.g., atmosphere, ocean, ice, land, hydrology, wave, surge, ionosphere, chemistry
- Multiple options for each modeling component type
  - e.g., MOM5, MOM6, HYCOM, “data” ocean component
- Community components developed external to EMC
- Multiple configurations needed for controlled experimentation
  - standalone model
  - coupled with “data” component
  - coupled with limited feedbacks
  - fully coupled
  - ensembles
  - alternative parameterizations
  - different resolutions

# NEMS Nightly Regression Tests

*Sample downloaded June 11, 2018 from [http://www.emc.ncep.noaa.gov/projects/rt/](http://www.emc.ncep.noaa.gov/projects/rt/)*
*driven by https://vlab.ncep.noaa.gov/redmine/projects/nems-ext/repository/revisions/multi-app-test/entry/tests/apps.def*

| Test | Result | Age | Duration |
|---|---|---|---|
| xJet NEMSfv3gfs | PASS | 23:29:39 | 01:28:05 |
| sJet and vJet NEMSfv3gfs | PASS | 23:29:33 | 01:28:11 |
| Theia NEMSfv3gfs | PASS | 20:07:24 | 00:39:42 |
| Theia NEMSGSM | PASS | 20:22:55 | 00:24:08 |
| Theia HYCOM-GSM-CICE | PASS | 20:22:51 | 00:24:10 |
| Theia WW3-FV3 | PASS | 20:24:07 | 00:22:27 |
| Theia WW3-ATM | PASS | 20:03:21 | 00:43:08 |
| Theia GSM-MOM5-CICE5 | PASS | 20:10:28 | 00:36:15 |
| Theia FV3-MOM6-CICE5 | PASS | 20:17:34 | 00:29:22 |
| WCOSS Phase 1 NEMSfv3gfs | PASS | 18:03:35 | 01:10:05 |
| WCOSS Phase 1 NEMSGSM | PASS | 18:34:54 | 00:38:38 |
| WCOSS Phase 2 NEMSfv3gfs | FAIL | 17:38:15 | 01:35:13 |
| WCOSS Phase 2 WW3-FV3 | PASS | 18:12:14 | 01:00:40 |
| WCOSS Phase 2 WW3-ATM | PASS | 18:25:49 | 00:47:02 |
| WCOSS Phase 2 GSM-MOM5-CICE5 | PASS | 18:13:44 | 00:59:04 |
| WCOSS Cray NEMSfv3gfs | PASS | 17:03:34 | 02:10:15 |
| WCOSS Cray WW3-FV3 | PASS | 18:27:13 | 00:46:16 |

# Earth System Modeling Framework

The Earth System Modeling Framework (ESMF) was initiated in 2002 as a multi-agency response to calls for common modeling infrastructure.

**ESMF provides:**

- high performance utilities, including grid remapping, data communications, and model time management
- a component-based architecture for model construction

**ESMF Metrics**:

~7000 downloads

~100 components in use

~3000 individuals on info mailing list

~40 platform/compilers regression tested nightly

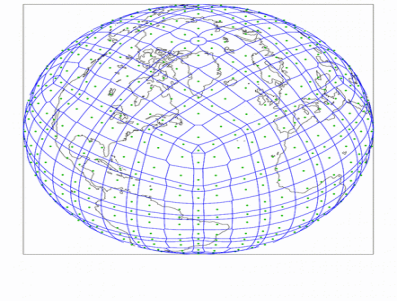
~6500 regression tests

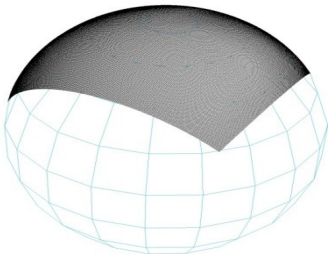
~1M SLOC


NUOPC is a software layer on top of ESMF 7+ that ensures interoperability of components. Most major U.S. modeling centers have adopted NUOPC conventions.

# ESMF Grid Remapping

- Uniquely fast, reliable, and general – interpolation weights computed in parallel in 3D space
- Supported grids:
  - Logically rectangular and unstructured grids in 2D and 3D, point clouds/observations
  - Global and regional grids
- Supported interpolation methods:
  - Nearest neighbor, bilinear, higher order patch recovery, and 1$^{st}$ order conservative methods
  - Options for straight or great circle lines, masking, and a variety of pole treatments
- Multiple ways to call ESMF grid remapping:
  - Generate and apply weights using the **ESMF API**, within a model
  - Generate and apply weights using **ESMPy**, through a Python interface
  - Generate weights from grid files using **ESMF_RegridWeightGen**, a command-line utility





# Standard Component Interfaces

ESMF/NUOPC components have three kinds of methods with standard interfaces:

- Initialize, Run, and Finalize

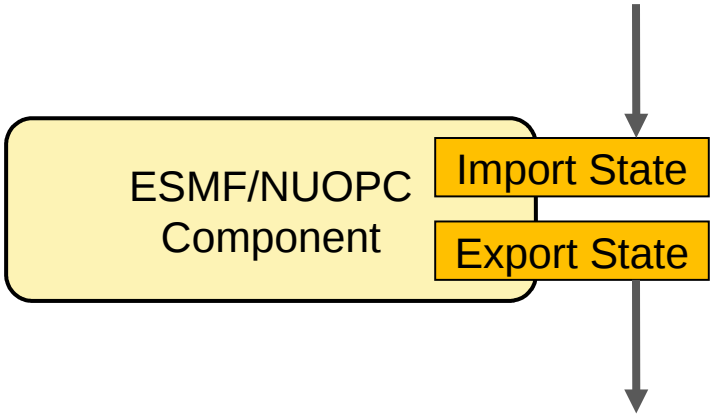
```
subroutine InitP1(comp, importState, exportState, clock, rc)
  type(ESMF_GridComp)   :: comp
  type(ESMF_State)      :: importState
  type(ESMF_State)      :: exportState
  type(ESMF_Clock)      :: clock
  integer, intent(out)  :: rc

  ! This is where the model specific setup code goes.
  rc = ESMF_SUCCESS

end subroutine InitP1
```

Interfaces are wrappers and can often be introduced in a non-intrusive and high-performance way. ESMF is designed to coexist with native model infrastructure.

# Components Share Data via Import and Export States



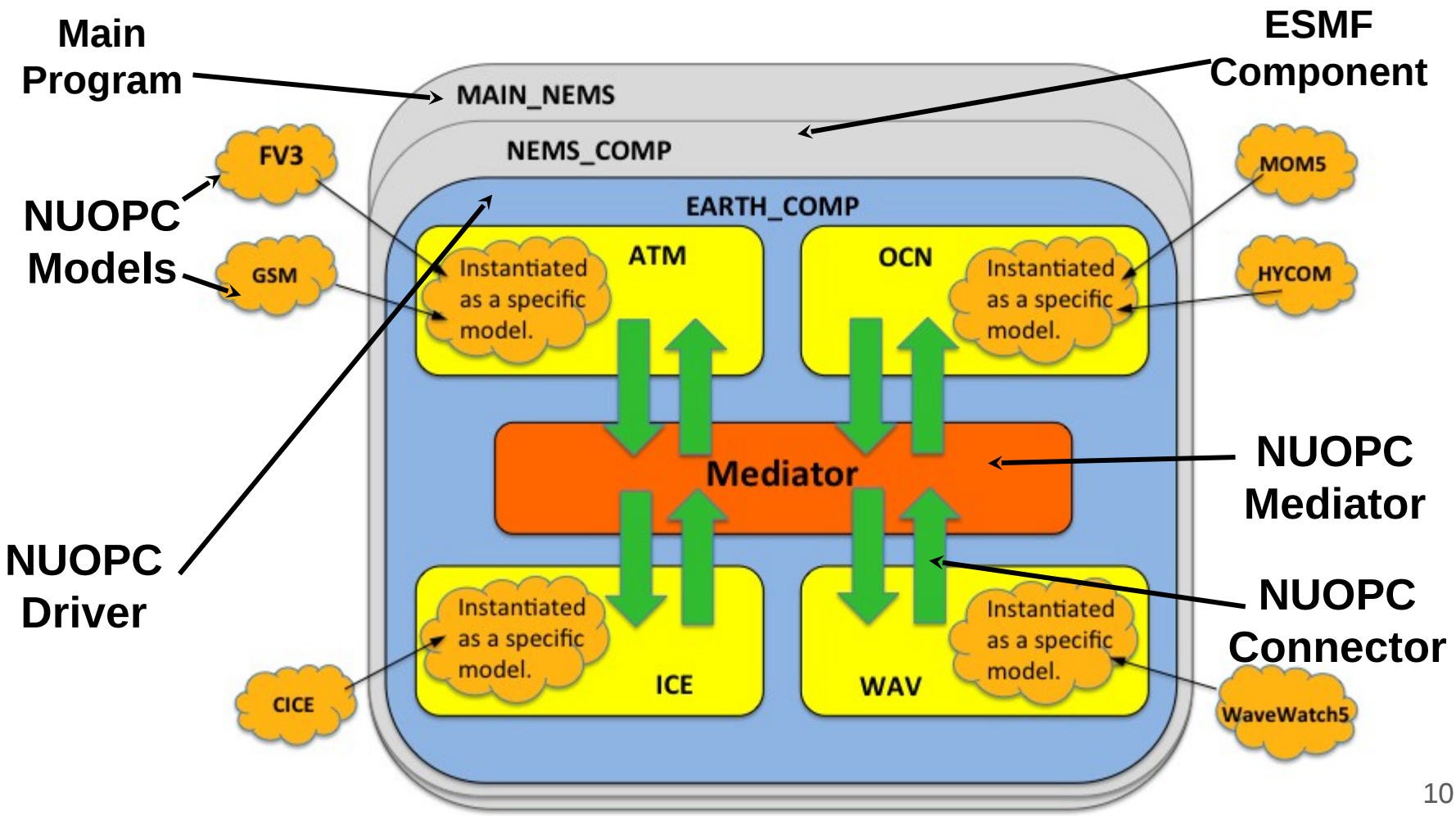

- **Components do not directly access each other's data**.
- The only way data moves in or out of a Component is via instances of the ESMF **State** class (`ESMF_State`).
- A State is a **container** for ESMF data types that wrap native model data.
- Model data can be **referenced**, avoiding duplicates and copies.
- **Metadata** (e.g., name, coordinates, decomposition) travels with data objects.

# NUOPC Layer Components

The NUOPC Layer's four **generic components** 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. 2016*


Main Program
MAIN_NEMS
ESMF Component
NEMS_COMP
FV3
NUOPC Models
GSM
EARTH_COMP
ATM
Instantiated as a specific model.
OCN
Instantiated as a specific model.
MOM5
HYCOM
Mediator
NUOPC Mediator
NUOPC Driver
NUOPC Connector
Instantiated as a specific model.
ICE
CICE
Instantiated as a specific model.
WAV
WaveWatch5

# NEMS Schematic

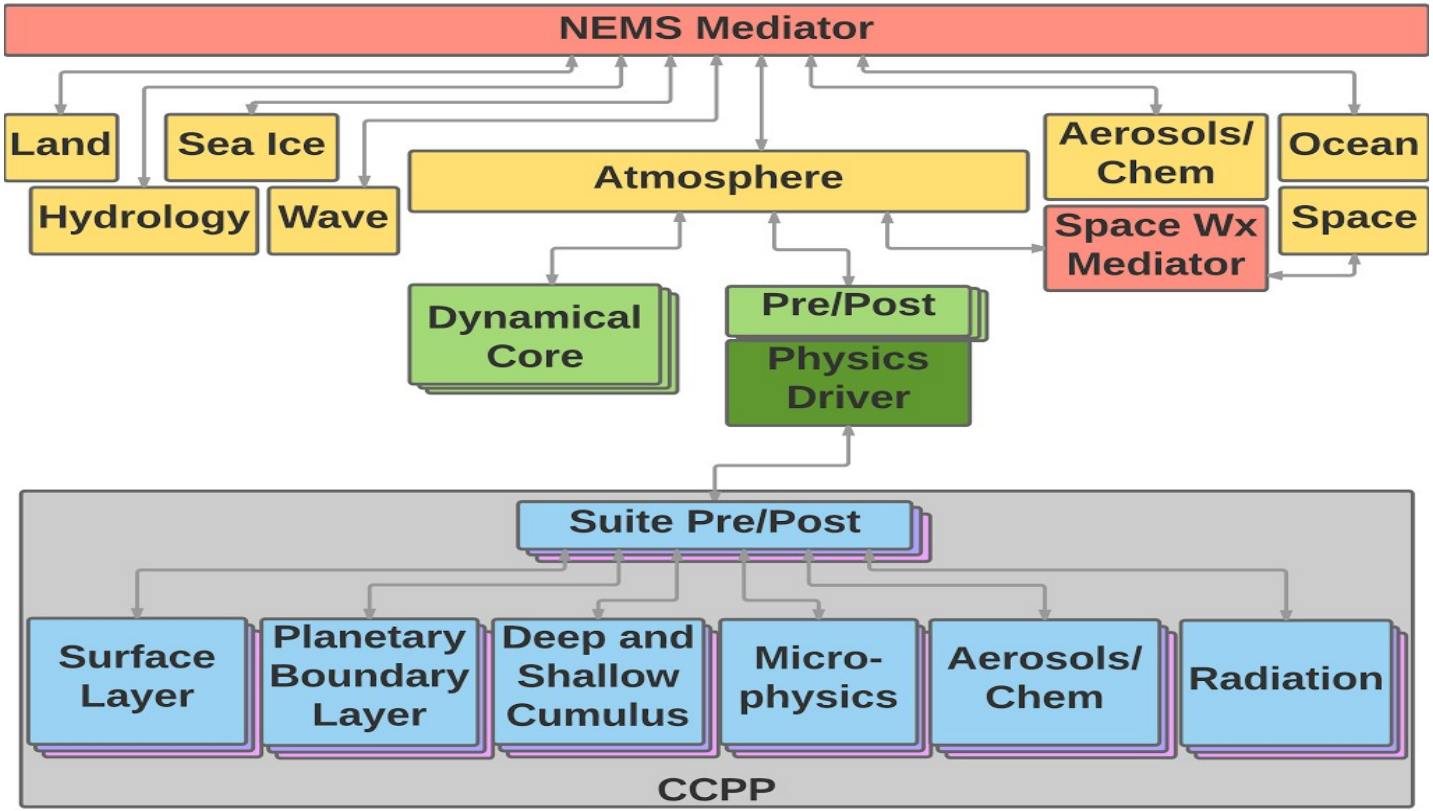



*Image courtesy of the Developmental Testbed Center*

# Sample NEMS Configure File (nems.configure)

```
################################
# NEMS Run Time Configuration File  #
################################
# EARTH #
EARTH_component_list: MED ATM OCN ICE

# MED #
med_model:                nems
med_petlist_bounds:     60 65

#ATM#
atm_model:              gsm
atm_petlist_bounds:     0 31

# OCN #
ocn_model:                      mom5
ocn_petlist_bounds:

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

Run sequence ingested into Driver

```
 # Run Sequence #
runSeq::
  @1800.0
    MED MedPhase_prep_ocn
    MED -> OCN :remapMethod=redist
    OCN
    @600.0
      MED MedPhase_prep_ice
      MED MedPhase_prep_atm
      MED -> ATM :remapMethod=redist
      MED -> ICE :remapMethod=redist
      ATM
      ICE
      ATM -> MED :remapMethod=redist
      ICE -> MED :remapMethod=redist
      MED MedPhase_atm_ocn_flux
      MED MedPhase_accum_fast
    @
    OCN -> MED :remapMethod=redist
  @
::
```

Colors show actions performed by:

tors (->)

or (MED)

coupling

# Role of the NEMS Mediator

- The Mediator is set up with ATM, OCN, ICE, LND, and HYD components.
- Slow (ocean) and fast (atmosphere and ice) coupling phases
- 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 conservatively, states bilinearly, 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

# Thanks