Development of the Next Generation UFS Coastal Modeling Framework

Panagiotis Velissariou[1,2], Ufuk Turuncoglou[4], Yunfang Sun[1,3], Saeed Moghimi[1], Ali Abdolali[5,6], Dan Rosen[4] and Edward Myers[1]

[1] NOAA National Ocean Service, Office of Coast Survey (NOAA/OCS)
[2] University Corporation for Atmospheric Research (UCAR)
[3] Earth Resources Technology (ERT/SFI)
[4] National Center for Atmospheric Research (NCAR)
[5] U.S. Army Engineer Research and Development Center (ERDC/USACE)
[6] Earth System Science Interdisciplinary Center (ESSIC/UMD)

Unifying Innovations in Forecasting Capabilities Workshop
Emerging Applications – Coastal & Marine
July 24-28, 2023. Boulder, CO & Online

Contact: Panagiotis.Velissariou@noaa.gov

It takes a village to raise a child …

NOS Storm Surge Modeling Team

Saeed Moghimi, Panagiotis Velissariou, Soroosh Mani, Yuji Funakoshi, Greg Seroka, Georgios Britzolakis, Zizang Yang, Bahram Khazaei, Yunfang Sun, Fariborz Daneshvar, Edward Myers

Academic partners (>20 PIs, Scientists, Postdocs and PhD students)

- University of Notre Dame
- Virginia Institute of Marine Science
- Argonne National Laboratory
- National Center for Atmospheric Research
- Texas Advanced Computing Center
- Columbia River Inter-Tribal Fish Commission
- Louisiana State University
- Sandia National Laboratories
- University of Massachusetts – Dartmouth
- University of North Carolina at Chapel Hill
- Cooperative Institute for Great Lake Research
- Oregon State University

International partners

- Helmholtz-Zentrum Hereon, Germany
- Laboratório Nacional de Engenharia Civil, Portugal
- European Commission Joint Research Centre, Belgium
- International Hydrographic Organization
- United Nations

NOAA and agency partners

- National Ocean Service
  - The U.S. Integrated Ocean Observing System
  - Center for Operational Oceanographic Products and Services
  - National Geodetic Survey
- National Weather Service
  - Office of Science and Technology Integration
  - Environment Modeling Center
  - National Hurricane Center
  - Office of Water Prediction
- Oceanic and Atmospheric Research
  - Great Lakes Environmental Research Laboratory
  - Earth Prediction Innovation Center (EPIC)
- U.S. Geological Survey
- U.S. Environmental Protection Agency
- National Science Foundation

Industrial and cooperative partners

- NCAR/UCAR
- Spatial Front Inc
- Axiom

Contents

Contact: Panagiotis.Velissariou@noaa.gov

CoastalApp (Coastal Application)

https://github.com/noaa-ocs-modeling/CoastalApp

Contacts:

- Panagiotis.Velissariou@noaa.gov
- Saeed.Moghimi@noaa.gov

Introduction

CoastalApp is a modeling framework for coastal applications and regional forecasts. It consists of coupled modeling components that link the atmospheric, ocean and terrestrial realms under one common framework. CoastalApp is a flexible and portable modeling system. Flexibility means that additional modeling components can be added with ease and portability means that CoastalApp can be built and run under different computing environments and operating systems.

CoastalApp is based on the ESMF (https://earthsystemmodeling.org/) framework for building a NUOPC/NEMS coupling application that includes two types of components (a) 1-way and 2-way coupled modeling components (model source + NUOPC Cap) and (b) data components (NUOPC Cap only) that pass forcing data, as needed, via NetCDF files to the various models in CoastalApp. The application is based on its predecessor ESMF application `ADC-WW3-NWM-NEMS` (see Moghimi et. al) developed as part of the **Coastal Act** coupling project to determine wind versus water percentage losses caused by a Named Storm Event.

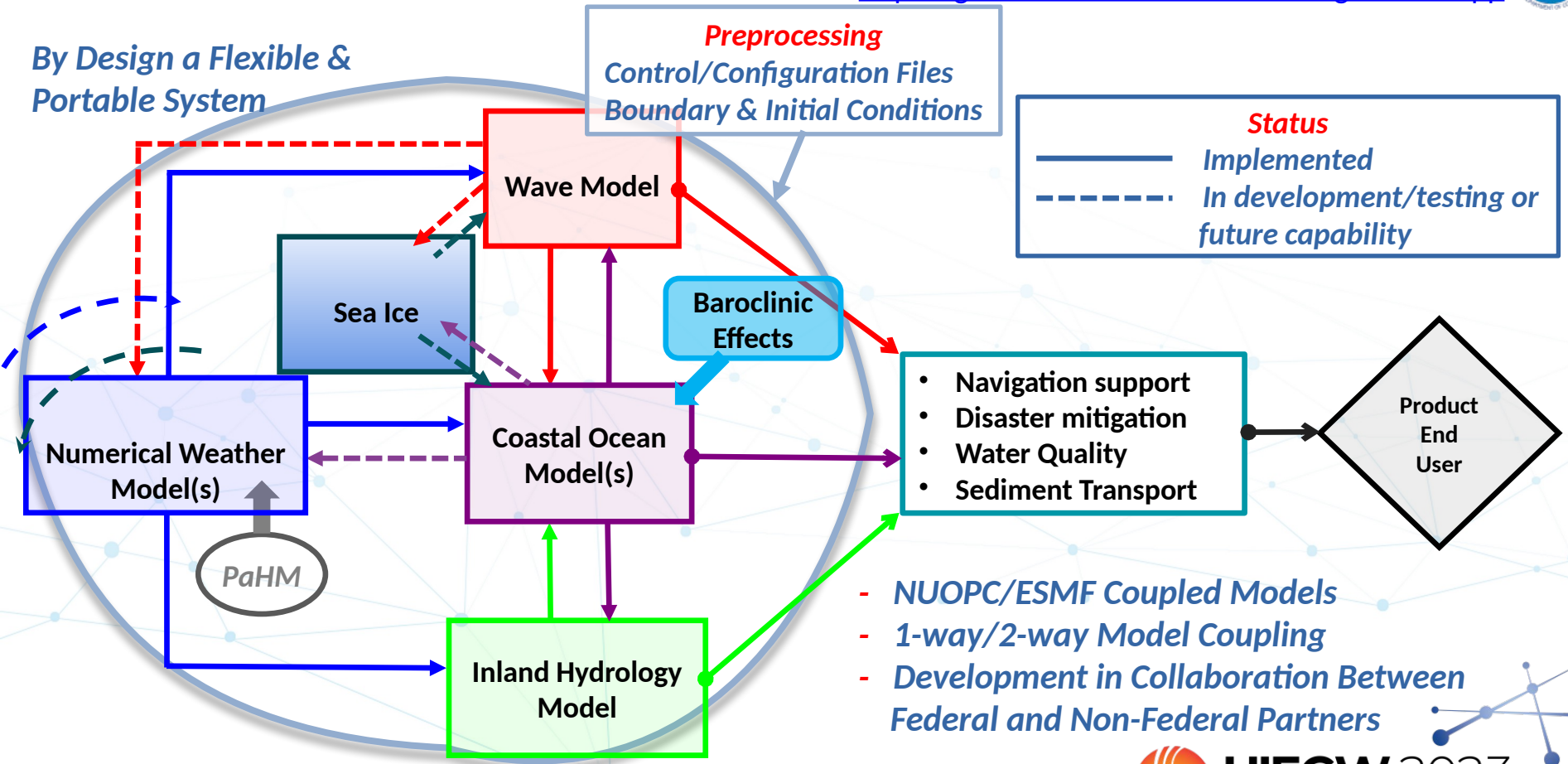
Accessing the individual modeling components

- ATMESH : https://github.com/noaa-ocs-modeling/ATMESH
- PAHM : https://github.com/noaa-ocs-modeling/PaHM
- ADCIRC : https://adcirc.org/, https://github.com/adcirc/adcirc (requires registration; please send an email request to Crystal Fulcher)
- SCHISM : http://ccrm.vims.edu/schismweb/, https://github.com/schism-dev/schism
- FVCOM : http://fvcom.smast.umassd.edu/, https://github.com/FVCOM-GitHub
- BARDATA: https://github.com/noaa-ocs-modeling/BARDATA
- WW3 : https://github.com/NOAA-EMC/WW3/wiki, https://github.com/NOAA-EMC/WW3
- WW3DATA: https://github.com/noaa-ocs-modeling/WW3DATA

CoastalApp: System Workflow

https://github.com/noaa-ocs-modeling/CoastalApp

By Design a Flexible & Portable System



- *NUOPC/ESMF Coupled Models*
- *1-way/2-way Model Coupling*
- *Development in Collaboration Between Federal and Non-Federal Partners*

CoastalApp: Modeling and Data Components

https://github.com/noaa-ocs-modeling/CoastalApp

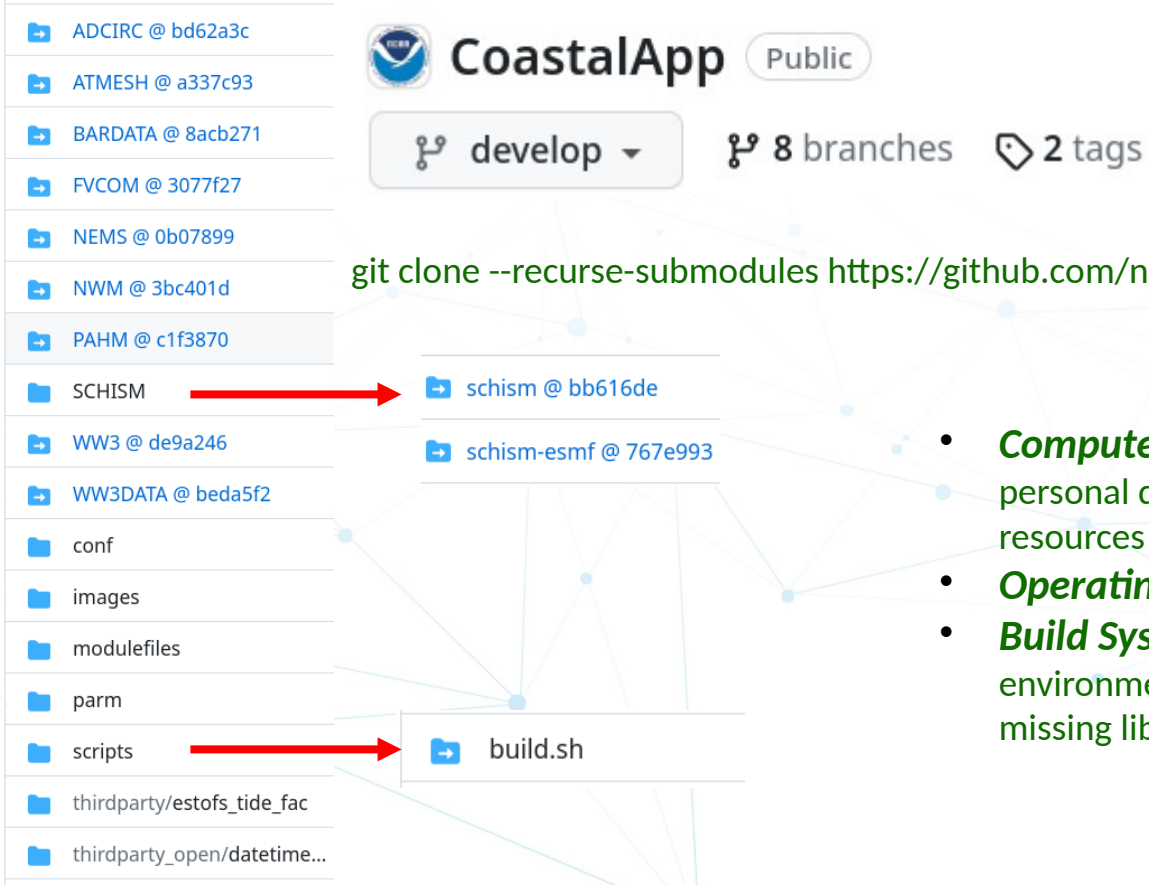
The components highlighted in red are not implemented or fully functional

Atmosphere	Ocean	Wave
ATMESH[1] *(implemented)*	ADCIRC[2] *(implemented)*	WW3DATA[1] *(implemented)*
PaHM[1] *(implemented)*	SCHISM[4,5] *(implemented)*	WW3[3] *(implemented)*
Atm. Model *(in development)*	FVCOM[6] *(implemented)*	
	BARDATA[1] *(implemented)*	
	CICE[7] *(in development)*	
NWM[8] *(in development)*		

1 NOAA/CSDL/CMMB
2 U. of Notre Dame
3 NOAA/NCEP/EMC
4 Virginia Institute of Marine Science
5 Helmholtz-Zentrum Hereon
6 University of Massachusetts – Dartmouth
7 Cooperative Institute for Great Lakes Research
8 NOAA/NWS National Water Center

CoastalApp: Directory Tree

https://github.com/noaa-ocs-modeling/CoastalApp



Contacts:

- Panagiotis.Velissariou@noaa.gov
- Saeed.Moghimi@noaa.gov


```
git clone --recurse-submodules https://github.com/noaa-ocs-modeling/CoastalApp.git
```

Support Matrix

- ***Compute Platforms:*** HPC clusters, personal desktops and cloud compute resources
- ***Operating Systems:*** Unix/Linux, MacOSX
- ***Build System:*** Bash, Module environment(s), Capabilities for building OS missing libraries

CoastalApp-testsuite (Tests for CoastalApp)

https://github.com/noaa-ocs-modeling/CoastalApp-testsuite

Contacts:

- Panagiotis.Velissariou@noaa.gov
- Saeed.Moghimi@noaa.gov

Regression tests for both *CoastalApp* and *UFS-Coastal*

Introduction

CoastalApp-testsuite contains comprehensive tests for the different modeling components implemented in CoastalApp. The test suite is used to run automated tests for the model and data components after an update in *CoastalApp*. There are two set of tests: (a) small scale tests that require very limited compute resources (e.g., the Shinnecock inlet cases) and (b) large scale tests that require extensive compute resources that can be run on a Cluster/HPC environment (e.g., the HSOFS cases). In any case, to run any of these tests the user is responsible to download and compile *CoastalApp* first.

Run Sequence

1. Change directory into CoastalApp-testsuite
2. Edit the file **regtest_list.dat** and uncomment the test cases you want to run
3. Edit (or create) an "environment file" (a sample can be found in templates/env_tests) that contains values for the different options used by the run script. The location of this file by setting the environment variable **TESTS_ENV_FILE** to point to the location of the newly created file (if env_tests is in the same location as `run_all.sh` there is no need to set the TESTS_ENV_FILE variable). If most of the option values remain the same between run sequences, it is convenient to have this file in place and only supply a few options to the script
   OPTIONAL STEP
4. Run the `run_all.sh` script to initiate the run sequence for the requested tests

Job Submission Managers

- **SLURM** with user supplied options
- **PBS** with user supplied options
- **mpirun/mpiexec** with user supplied options

CoastalApp-testsuite: Directory Tree

https://github.com/noaa-ocs-modeling/CoastalApp-testsuite

- florence_hsofs.adc_spinup
- florence_hsofs.atm2adc
- florence_hsofs.atm2adc2ww3
- florence_hsofs.atm2ww3
- florence_hsofs.ww3_multi
- florence_hsofs.ww3_nems
- ike_shinnecock.adc_spinup
- ike_shinnecock.atm2adc
- ike_shinnecock.atm2adc2ww3
- ike_shinnecock.atm2sch
- ike_shinnecock.atm2sch2ww3
- ike_shinnecock.atm2sch2ww3data
- ike_shinnecock.atm2ww3
- ike_shinnecock.sch
- ike_shinnecock.ww3

CoastalApp-testsuite Public

main | 3 branches | 0 tags

Contacts:

- Panagiotis.Velissariou@noaa.gov
- Saeed.Moghimi@noaa.gov

git clone https://github.com/noaa-ocs-modeling/CoastalApp-testsuite.git

- sandy_shinnecock.pam2adc
- sandy_shinnecock.pam2adc2ww3
- sandy_shinnecock.pam2ww3
- scituateharbor.atm2fvc2ww3
- scituateharbor.fvc
- templates

Component name abbreviations used in the testsuite:

atm	ATMESH data component
pam	PAHM model component
adc	ADCIRC model component
sch	SCHISM model component
fvc	FVCOM model component
ww3	WaveWatch III model component
ww3data	WW3DATA data component

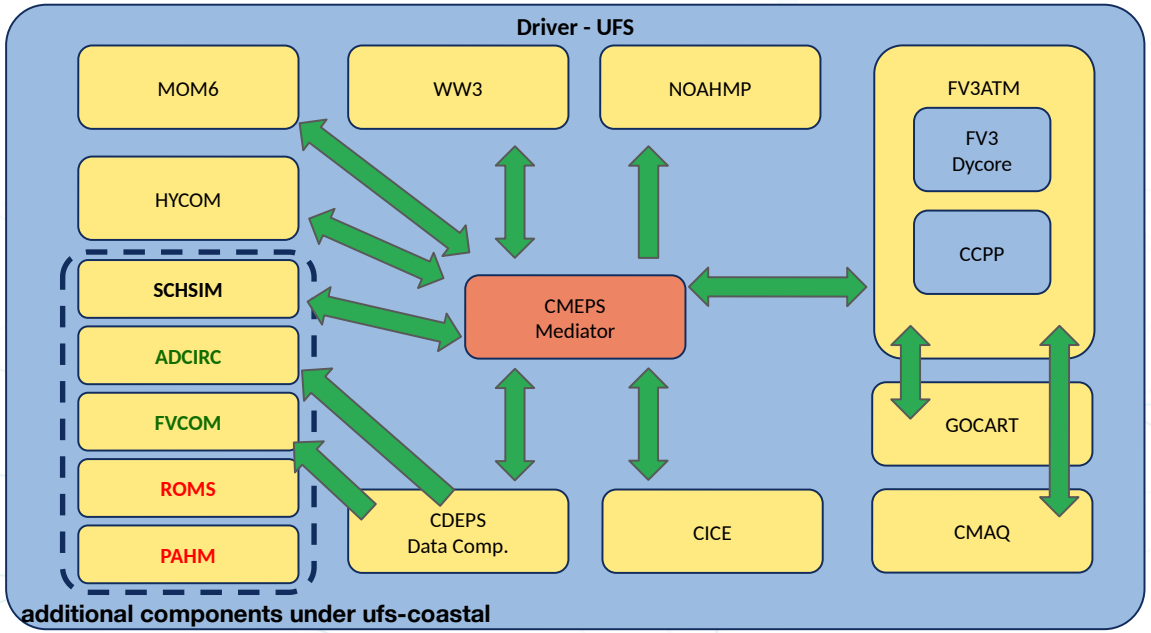
Multiple "testbed" platforms are supported:

- NOAA RDHPCS (hera)
- TACC (Frontera, Stampede)
- Mississippi State University (Orion, Hercules)
- Cloud (Parallel Works)

UFS-Coastal (Coastal Application)

UFS-Coastal

https://github.com/oceanmodeling/ufs-coastal/tree/feature/coastal_app



ADCIRC and FVCOM model components are under development
ROMS and PAHM are future model component capabilities

Contacts:

- Ufuk Turuconglu (turuncu@ucar.edu)
- Panagiotis.Velissariou@noaa.gov
- Saeed.Moghimi@noaa.gov

- At this point, only one-way configurations from CoastalApp-testsuite are ported to UFS-Coastal
- The two-way configurations will be ported individually from CoastalApp-testsuite to UFS RT framework
- The new application is using CDEPS as data component and replaces the ATMESH data component

UFS-Coastal: Directory Tree

https://github.com/oceanmodeling/ufs-coastal/tree/feature/coastal_app

- ADCIRC-interface
- AQM @ 37cbb7d
- CDEPS-interface
- CICE-interface
- CMEPS-interface
- CMakeModules @ cabd775
- FV3 @ 67e146d
- FVCOM-interface
- GOCART @ b94145f
- HYCOM-interface
- MOM6-interface
- NOAHMP-interface

ufs-coastal Public

forked from ufs-community/ufs-weather-model

- SCHISM-interface
- WW3 @ c4b1168
- cmake
- doc/UsersGuide
- driver
- modulefiles
- stochastic_physics @ 3bfa446

Contacts:

- Ufuk Turuconglu (turuncu@ucar.edu)
- Panagiotis.Velissariou@noaa.gov
- Saeed.Moghimi@noaa.gov

git clone https://github.com/oceanmodeling/ufs-coastal.git -b feature/coastal_app

Active Model Interfaces

- ADCIRC
- FVCOM
- SCHISM

Active Regression Tests

- ADCIRC (testing)
- FVCOM (testing)
- SCHISM (fully functional)

UFS-Coastal: Current Status

https://github.com/oceanmodeling/ufs-coastal/tree/feature/coastal_app

- UFS-Coastal is now a fork of UFS Weather Model (branch: feature/coastal_app)
  - It is maintained under Ocean Modeling Collaboration GitHub organization to have better collaboration with community
- Currently, following components are ported from CoastalApp to UFS-Coastal:
  - ADCIRC: unstructured mesh model to solve free surface circulation and transport
  - FVCOM: unstructured mesh finite volume ocean model
  - SCHISM: unstructured mesh model to solve baroclinic circulation across creek-lake-river-estuary-shelf-ocean scales
  - ATMESH custom data component is replaced with CDEPS

UFS-Coastal: Current Status (cont'd)

https://github.com/oceanmodeling/ufs-coastal/tree/feature/coastal_app

- UFS Weather Model uses CMake to build components
  - To that end, all models are wrapped with CMake build interface under UFS-Coastal
- SCHISM model NUOPC "cap" is slightly modified to work with CMEPS mediator. All the components under CoastalApp was coupled through the NUOPC connectors
- Tests under CoastalApp-testsuite have been ported to RT system one-by-one.

```
# ADCIRC tests
COMPILE | 1 | intel | -DAPP=CSTLA -DADCIRC_CONFIG=PADCIRC -DCOUPLED=ON | | fv3 |
RUN | coastal_florence_hsofs_atm2adc | | baseline |

# FVCOM tests
COMPILE | 2 | intel | -DAPP=CSTLW | | fv3 |

# SCHISM tests
COMPILE | 3 | intel | -DAPP=CSTLS -DNO_PARMETIS=OFF -DOLDIO=ON | | fv3 |
RUN | coastal_ike_shinnecock_sch     | | baseline |
RUN | coastal_ike_shinnecock_atm2sch | | baseline |

# WW3 tests
COMPILE | 4 | intel | -DAPP=CSTLW | | fv3 |
RUN | coastal_ike_shinnecock_atm2ww3 | | baseline |
```

UFS-Coastal: Issues

https://github.com/oceanmodeling/ufs-coastal/tree/feature/coastal_app

- We are actively working on ADCIRC and FVCOM model components to make their NUOPC "caps" compatible with CMEPS mediator
  - CMEPS uses mesh as a representation of model grid/mesh
  - CMEPS assumes that all the import and export fields connected from the component on element location (the default of *ESMF_FieldCreate()* is node)
  - ESMF has no support for ghost elements at this point
- We need to remove ghost elements from ADCIRC and FVCOM meshes and define import and export fields on element locations
- Need to generalize forcing provided by the CDEPS (ATMESH data atmosphere mode)
  - All the test cases that are aimed to simulate Hurricane Florence or Ike need to be forced with same forcing. This will allow us to compare the results and find possible issues with the configurations

UFS-Coastal: Plans

https://github.com/oceanmodeling/ufs-coastal/tree/feature/coastal_app

- Finalize work related to ADCIRC and FVCOM coupling interface and make them compatible with CMEPS
- Update already ported regression tests and create baseline for them
  - These tests will run regularly against the development in UFS Weather Model and in case of syncing UFS-Coastal with authoritative repository
- Add new tests for UFS-Coastal model components to cover the model components at least with single coupled test
- Modernize UFS-Coastal build system by using ESMX generic driver
- Implement isolated CI testing to each model components
  - This will benefit from *nuopc-comp-testing* composite GitHub action
  - Extend/improve *nuopc-comp-testing* composite GitHub action if it is required

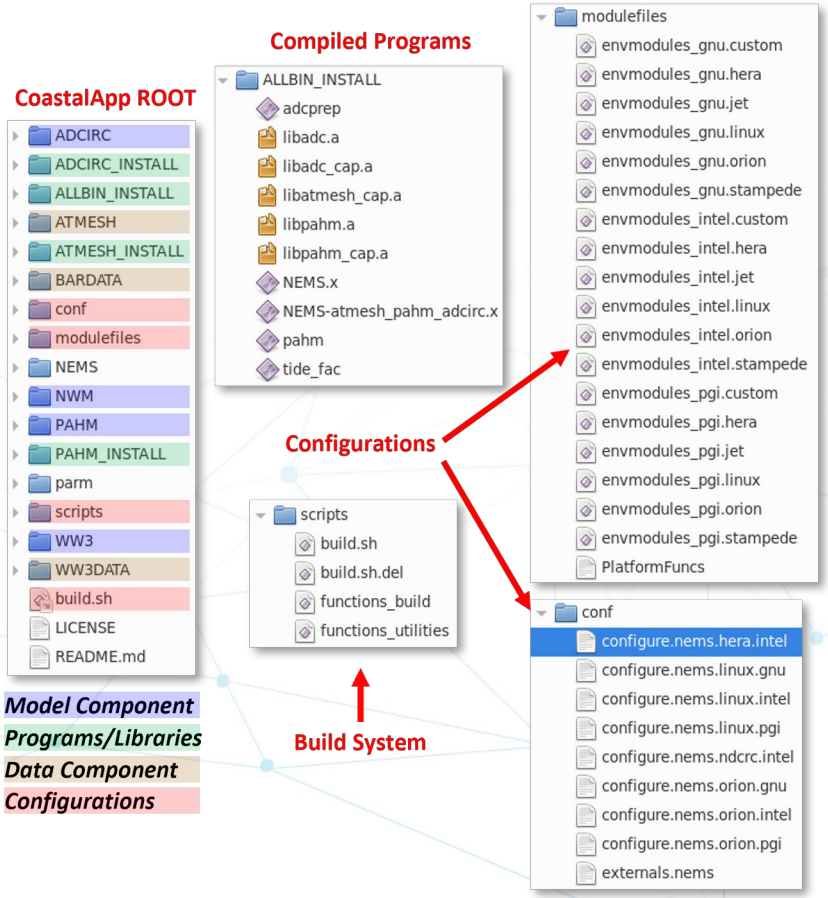
Thank you for your attention!

Contact: Panagiotis.Velissariou@noaa.gov

Additional Slides

Contact: Panagiotis.Velissariou@noaa.gov

CoastalApp: System Layout and Usage




```
Usage: "build.sh" [{-|--}option1{=|space}[option_value1]] [{-|--}option2{=|space}[option_value2]] ...

  -h|-help|--h|--help
    Show this help screen.

  -c|--c|-clean|--clean [=|space] "0|1|yes|no" (OPTIONAL).
    Only clean the already compiled CMake build system.
    Default: 0|no.

  -compiler|--compiler [=|space] "compiling_system" (OPTIONAL).
    The compiling system to use (gnu, intel, pgi).
    Default: intel.

  -component|--component [=|space] "component_list" (OPTIONAL).
    The component(s) to use (ATMESH PAHM ADCIRC NWM WW3DATA WW3 BARDATA).
    Default: "ADCIRC WW3DATA ATMESH".

  -build_exec|--build_exec [=|space] "executable_list" (OPTIONAL).
    The executables(s) to build (e.g. --build_exec="padcirc pahm").
    Default: none.

  -j|--j [=|space] "N" (OPTIONAL).
    Define the number of make jobs to run simultaneously.
    Default: 1.

  -par|--par|-parallel|--parallel [=|space] "0|1|yes|no" (OPTIONAL).
    Activate the use of parallel compilers.
    Default: 1|yes.

  -os|--os [=|space] "OS string" (OPTIONAL).
    The name of the Operating system.
    Supported OSes: linux macosx.
    Default: current OS.

  -plat|--plat|-platform|--platform [=|space] "platform" (OPTIONAL).
    The name of the compute HPC platform to consider.
    Selecting a platform, environment modules specific to that platform are loaded
    and corresponding environment variables are set.
    Supported platforms: custom, linux, macosx, cheyenne, gaea, hera, jet, orion, stampede, wcoss,
                         mistral, strand.
    Default: OS.

  -v|--v|-verbose|--verbose [=|space] "a,b,v,i,j,m,n" (any combination, OPTIONAL).
    Enable verbosity in the make files during compilation.
      a (all)       : all types of debugging output are enabled
      n (none)      : disable all debugging currently enabled
      b (basic)     : basic debugging and whether the build was successful or not
      v (verbose)   : a level above basic
      i (implicit)  : prints messages describing the implicit rule searches for each target
      j (jobs)      : prints messages giving details on the invocation of specific sub-commands
      m (makefile)  : enables messages while rebuilding makefiles
    Default:none.
```

CoastalApp: ModuleFiles

Typical modulefile

Compiler one of [gnu, intel, pgi]

```
CoastalApp/modulefiles
├── envmodules_intel.cheyenne
├── envmodules_intel.custom
├── envmodules_intel.gaea
├── envmodules_intel.hera
├── envmodules_intel.jet
├── envmodules_intel.linux
├── envmodules_intel.macosx
├── envmodules_intel.mistral
├── envmodules_intel.orion
├── envmodules_intel.stampede
├── envmodules_intel.strand
└── envmodules_intel.wcoss
```

```
#!/bin/bash-*-Shell-script-modules*-

##############################################################################
### Module File to load the required environment modules for the NEMS application
###
### Author: Panagiotis Velissariou <panagiotis.velissariou@noaa.gov>
### Date:   June 26 2021
##############################################################################


# This script is responsible for loading modules that are
# compatible with the NUOPC Layer version used in NEMS.


####################
### (1) Load all needed environment modules.
module purge
module load cmake
module load intel/2020 impi/2020
module load szip hdf5/1.10.5-parallel
module load netcdf/4.7.2-parallel

module load esmf/8.0.0


####################
### (2) Set some environments varaiables related to the loaded
###     modules and required to compile the NEMS application properly.
funcs="$( find . -type f -name "PlatformFuncs" | head -n 1 )"
if [ -f "${funcs}" ]; then
  source "${funcs}"

  get_env_hdf5
  get_env_netcdf
fi
unset funcs


########## BEG:: PLATFORM CUSTOMIZED SETTINGS ##########
# Is this needed in all systems?
# If file locking is not allowed in the filesystem, or the
# HDF5 locking mechanism is not compatible with the
# OS locking mechanism, then HDF5 (>=1.10.x) throws errors like
# access denied when trying to READ/WRITE NetCDF files.
# On some platforms HDF5 locking is disabled on other it is not.
# If you experience these problems uncomment the next line
# (this should be done automatically when loading this file - todo).
#export HDF5_USE_FILE_LOCKING=FALSE

export NETCDF_CONFIG=${NETCDFHOME:+${NETCDFHOME}/bin/nc-config}
export NETCDF_INCDIR=${NETCDF_INCLUDE_DIRS}
export NETCDF_LIBDIR=${NETCDF_LIBRARY_DIRS}

export ESMFMKFILE=${ESMFMKFILE}
########## END:: PLATFORM CUSTOMIZED SETTINGS ##########
```

Load Modules

Set Environment

Finalize (if needed)

CoastalApp: Build Workflow

```
Usage: build.sh [{-|--}option1{=|space}[option_value1]] [{-|--}option2{=|space}[option_value2]] ...

  -h|-help|--h|--help
    Show this help screen.

  -compiler|--compiler [=|space] "compiling_system" (OPTIONAL).
    The compiling system to use (gnu, intel, pgi).
    Default: intel.

  -component|--component [=|space] "component_list" (OPTIONAL).
    The component(s) to use (ATMESH WRF HWRF PAHM ADCIRC SCHISM FVCOM ROMS NWM WW3DATA WW3 ).
    Default: "ADCIRC WW3DATA ATMESH".

  -par|--par|-parallel|--parallel [=|space] "0|1|yes|no" (OPTIONAL).
    Activate the use of parallel compilers.
    Default: 1|yes.

  -plat|--plat|-platform|--platform [=|space] "platform" (OPTIONAL).
    The name of the compute HPC platform to consider.
    Selecting a platform, environment modules specific to that platform are loaded
    and corresponding environment variables are set.
    Supported platforms: custom, linux, macosx, cheyenne, gaea, hera, jet, orion, stampede, wcoss,
                         mistral, strand.
    Default: OS.
```

UFS-Coastal: Generic NUOPC Driver

https://github.com/oceanmodeling/ufs-coastal/tree/feature/coastal_app

- As a part of the project, ESMF/NUOPC layer is extended to include Generic NUOPC Driver layer, which is called as **E**arth **S**ystem **M**odel e**X**ecutable (ESMX)
- Aims to accelerate development of new NUOPC-based systems
- The ESMF 8.5.0 (targeted for end of July 2023) will have improved version of ESMX driver
  - It uses YAML based configuration files for build (*ESMX_Builder*) and run
- The UFS-Coastal build system will be restructured to replace existing UFS NUOPC driver with new generic driver implementation

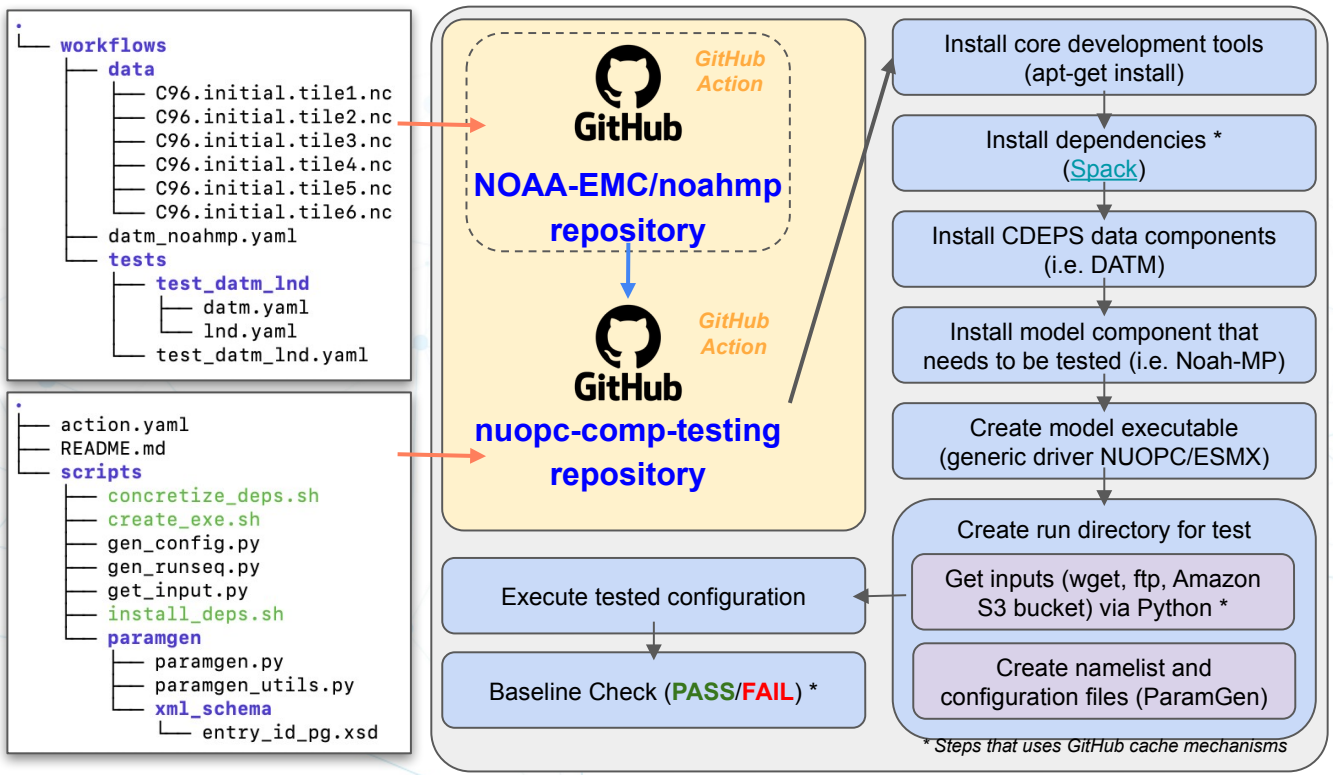
Example: DATM+LND

```
application:
  disable_comps: ESMX_Data
  link_paths: /home/runner/.spack-ci/view/lib
  link_libraries: piof
components:
  datm:
    build_type: none
    install_prefix: /test/app/cdeps/install
    libraries: datm dshr streams cdeps_share
    fort_module: cdeps_datm_comp.mod
  noahmp:
    build_type: none
    install_prefix: /test/app/noahmp/install
    fort_module: lnd_comp_nuopc.mod
```

UFS-Coastal: Testing NUOPC Components

https://github.com/esmf-org/nuopc-comp-testing

- New hierarchical testing capability for NUOPC components: nuopc-comp-testing



DATM+LND example