Modelling systems in modeling systems in modeling systems

Carsten Lemmen[1], Y. Joseph Zhang[2], Hao-Cheng Yu[2], Zhengui Wang[2], Panagiotis Velissariou[3], Saeed Moghimi[3]

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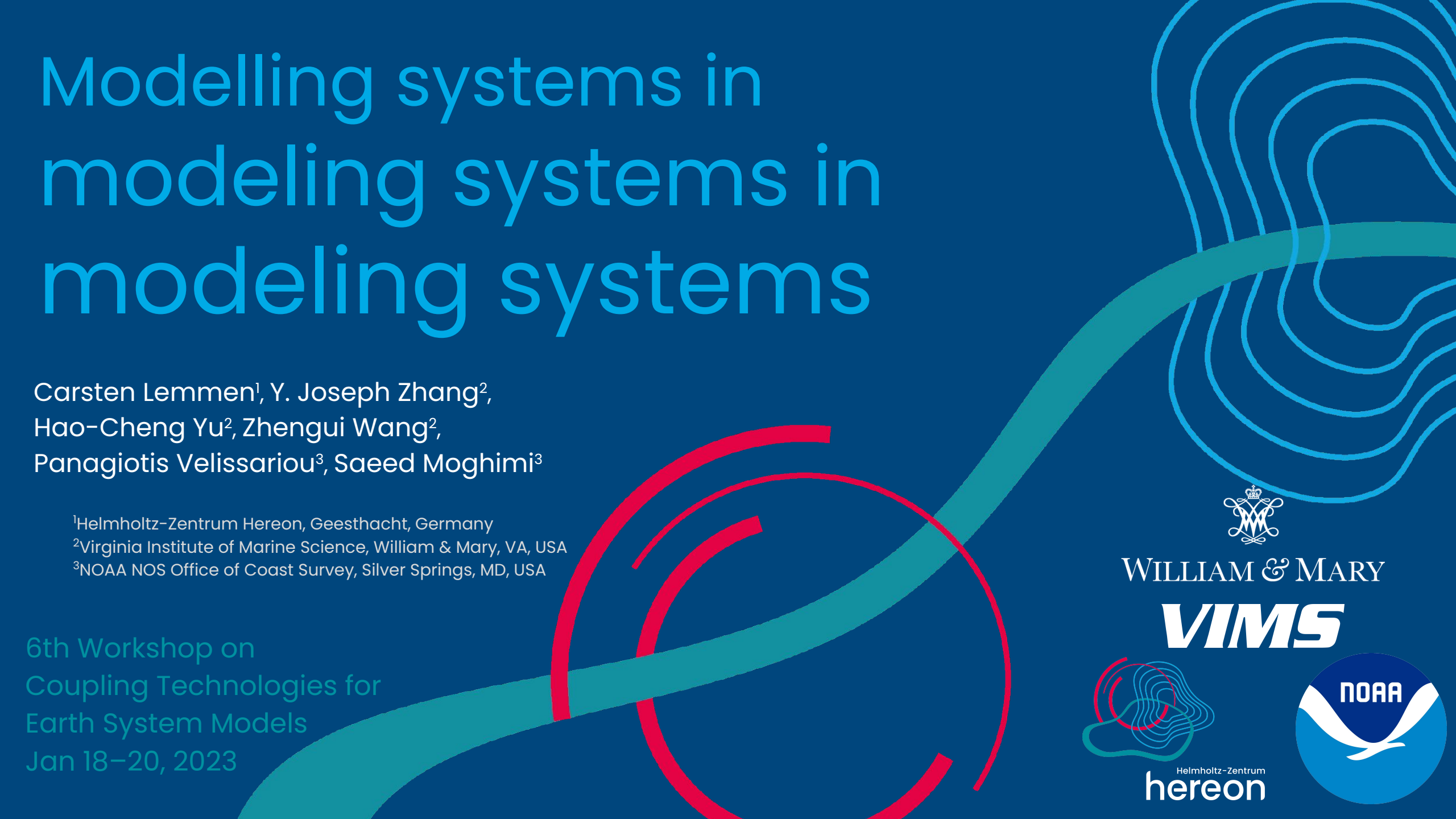
[3]NOAA NOS Office of Coast Survey, Silver Springs, MD, USA

6th Workshop on Coupling Technologies for Earth System Models
Jan 18–20, 2023



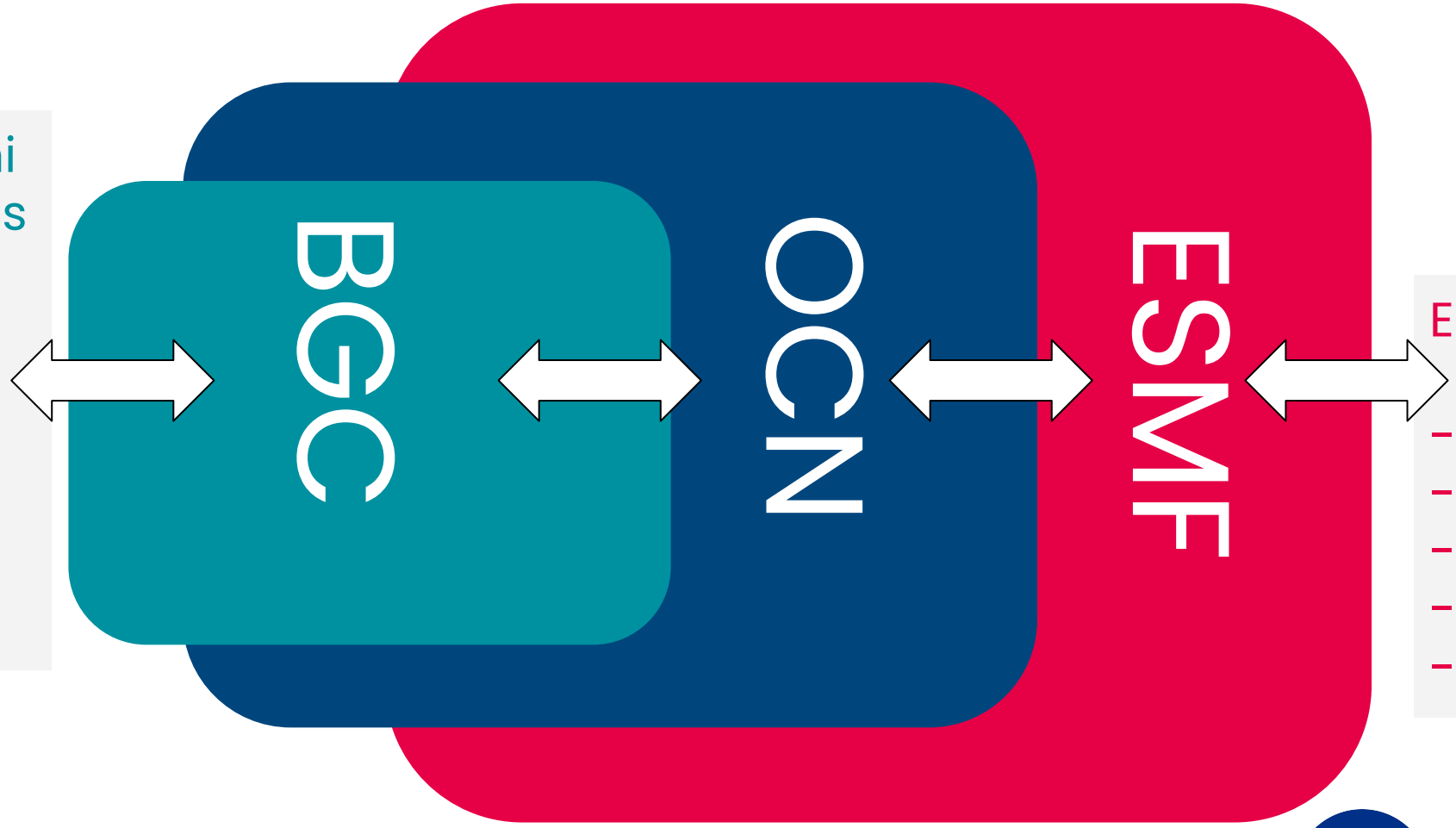
Modularity

FABM in SCHISM in CoastalApp

BGC framework in OCN framework in ESM framework

Biogeochemical Processes

Tracer
Aging
Ecology
Food web
Chemistry



Earth System

- Atmosphere
- Ocean
- Waves
- Runoff
- Cryosphere

FABM in SCHISM in CoastalApp

BGC framework in OCN framework in ESM framework

Biogeochemical Processes

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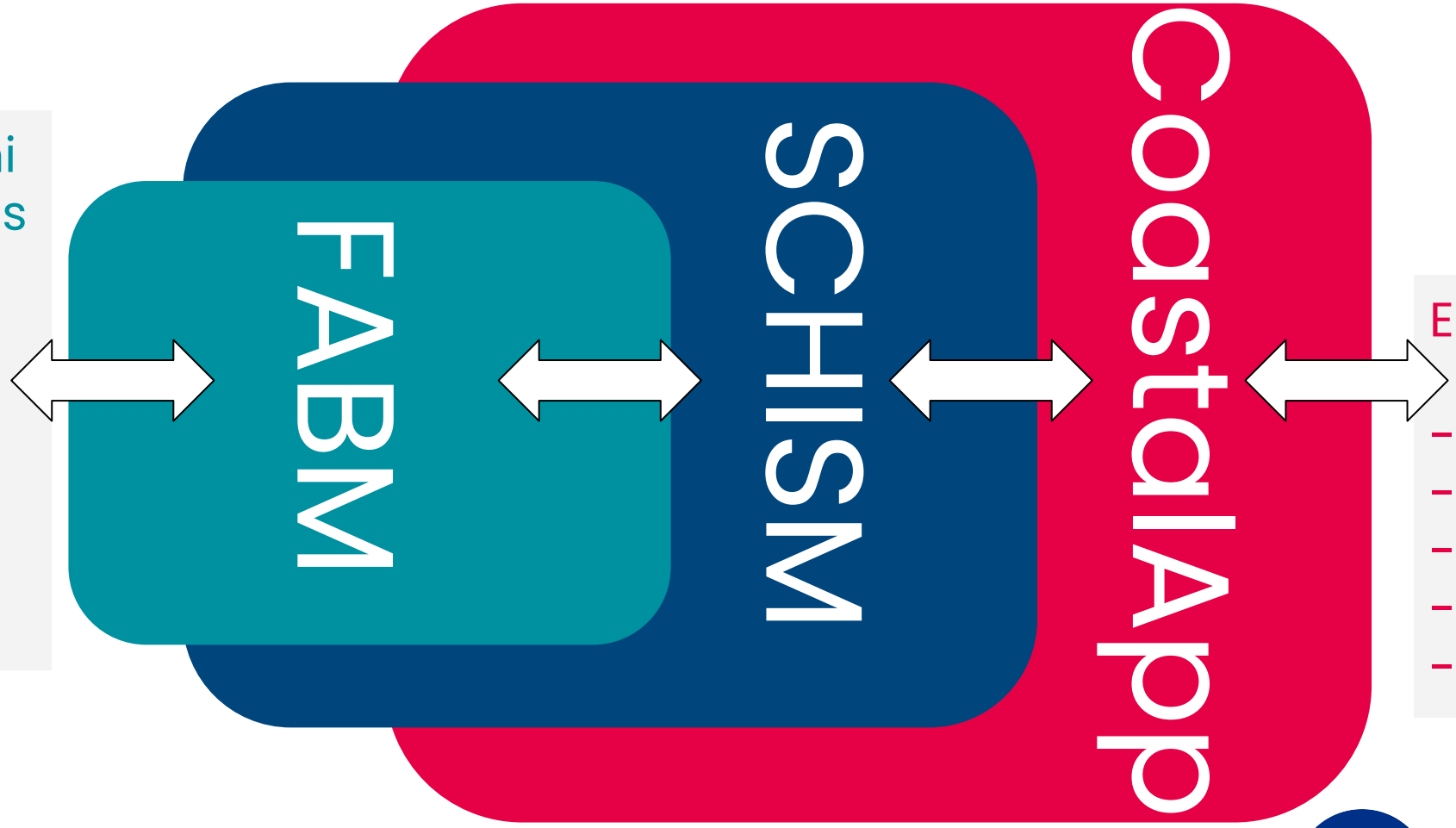
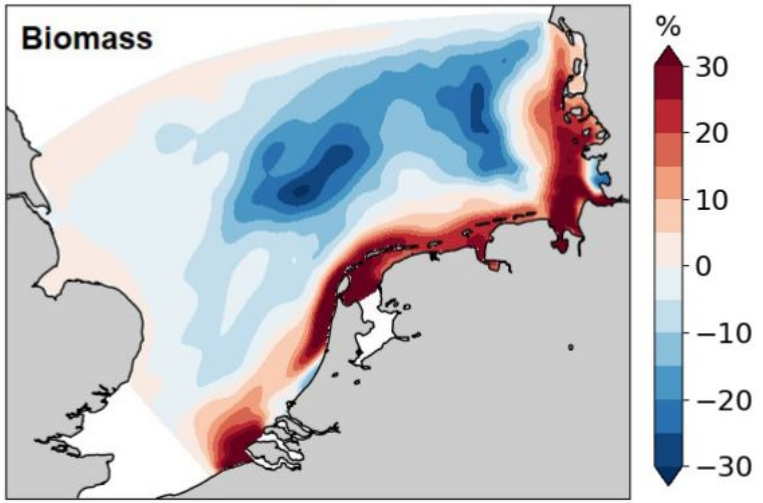


Earth System

- Atmosphere
- Ocean
- Waves
- Runoff
- Cryosphere

Why BGC in OCN in ESM?
Coasts in the Earth System

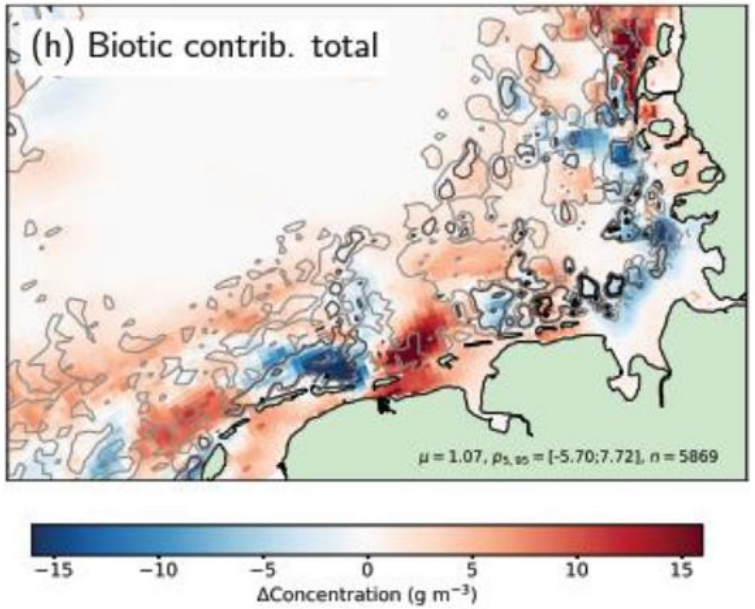


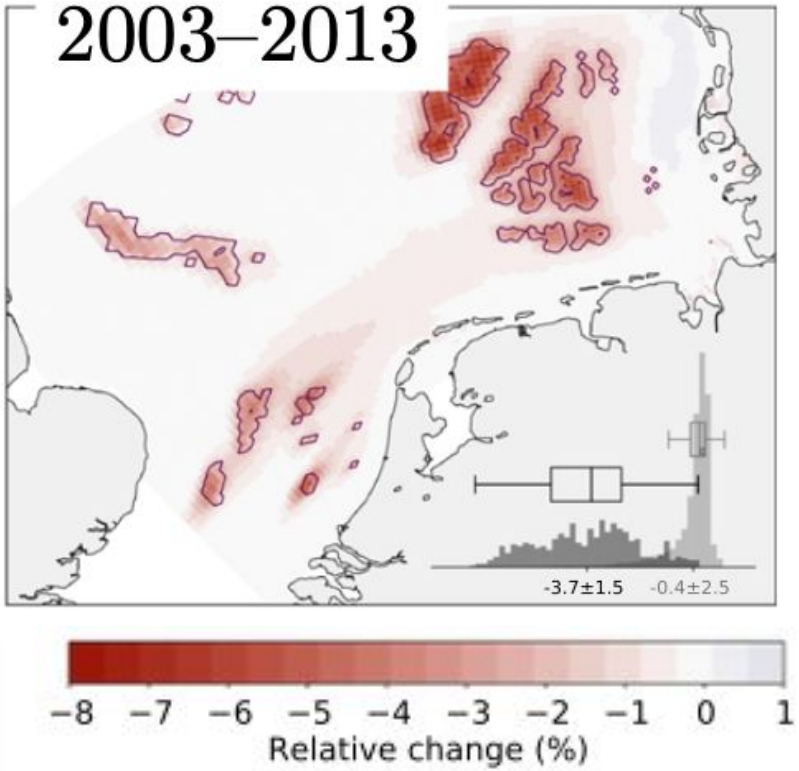
Xu et al. 2022 Front. Mar. Sci

Climate heating and de-eutrophication signal on NPP (last 40 years).
=> Global carbon storage and Blue Coasts.

Sensitivity of storm sediment stability on clam presence.
=> Nature-based solution, ecosystem restoration

Nasermoaddeli et al. Est. Coast. Shelf Sci





Slavik et al. 2019, Hyrdobiologia

Ecosystem productivity changed by offshore wind farms. => Nature-based solution, ecosystem restoration

But the ESM community made it really difficult!

.. for biologists and ecologists:

- lots of process uncertainty

- huge parameter space

- models not designed for ESM

- bottle to ocean (0D to 3D)

Geosci. Model Dev., 11, 915–935, 2018
https://doi.org/10.5194/gmd-11-915-2018

Geoscientific Model Development
Open Access
EGU

Modular System for Shelves and Coasts (MOSSCO v1.0) – a flexible and multi-component framework for coupled coastal ocean ecosystem modelling

Carsten Lemmen[1], Richard Hofmeister[1,4], Knut Klingbeil[2,a], M. Hassan Nasermoaddeli[3,b], Onur Kerimoglu[1], Hans Burchard[2], Frank Kösters[3], and Kai W. Wirtz[1]

… yet another ESMF usability layer and driver

NOAA VIMS Helmholtz-Zentrum hereon

Flexibility and Equitability

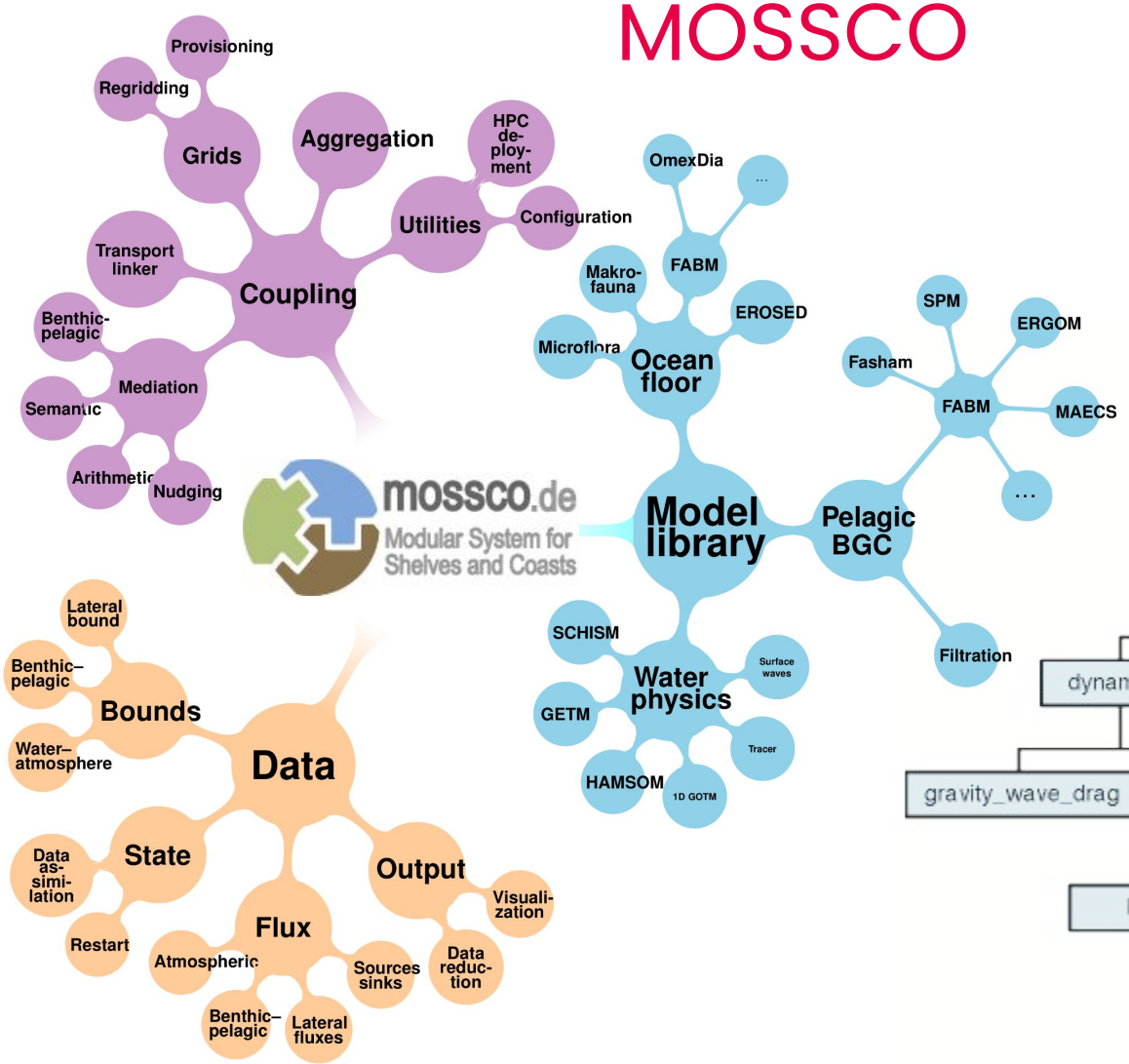
Flexibility means that the system itself is able to deal on the one hand with a **diverse** small or large constellation of coupled model components and on the other hand with different **orders of magnitude** of spatial and temporal resolutions; it is able to deal equally well with *zero- , one-, two-, three-dimensional* representations of the coastal system. Flexibility implies the capability to also *encapsulate* ***existing legacy*** *models* to create one or more different "ecosystems" of models. This feature should allow for the seamless replacement of individual model components, which is an important procedure in the continual development of integrated systems. Flexibly replacing components finally creates a test bed for model intercomparison studies.

Equitability means that all models in the coupled framework are *treated as* ***equally important***. This principle dissolves the primacy of the hydrodynamic or atmospheric models as the central hub in a coupled system. Also, **data components** are as important as process components or model output; any de facto difference in model importance should be grounded in the research question and not on technological legacy. As complexity grows by coupling more and more models, this equitability also demands that *experts in one particular model* ***can rely*** on the functionality of other components in the system without having to be an expert in those models as well.

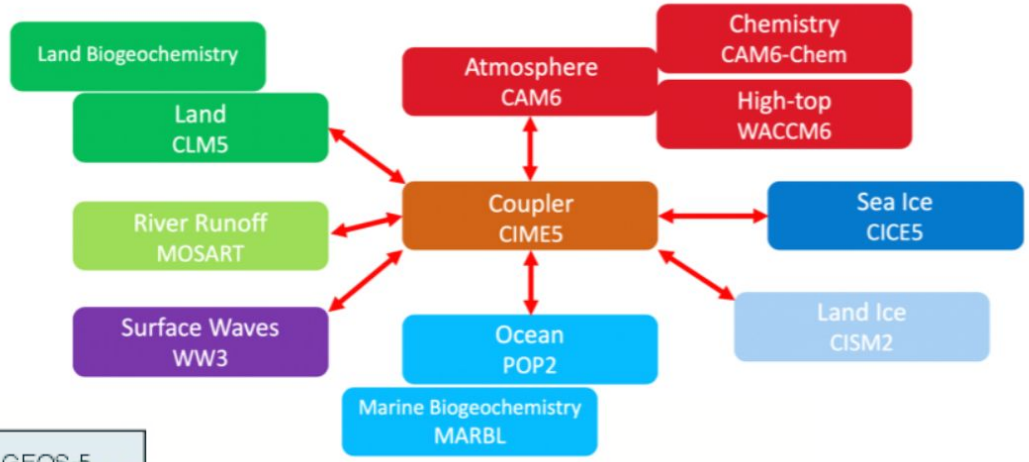
Geosci. Mod. Dev 2018

Modular domain and process coupling systems

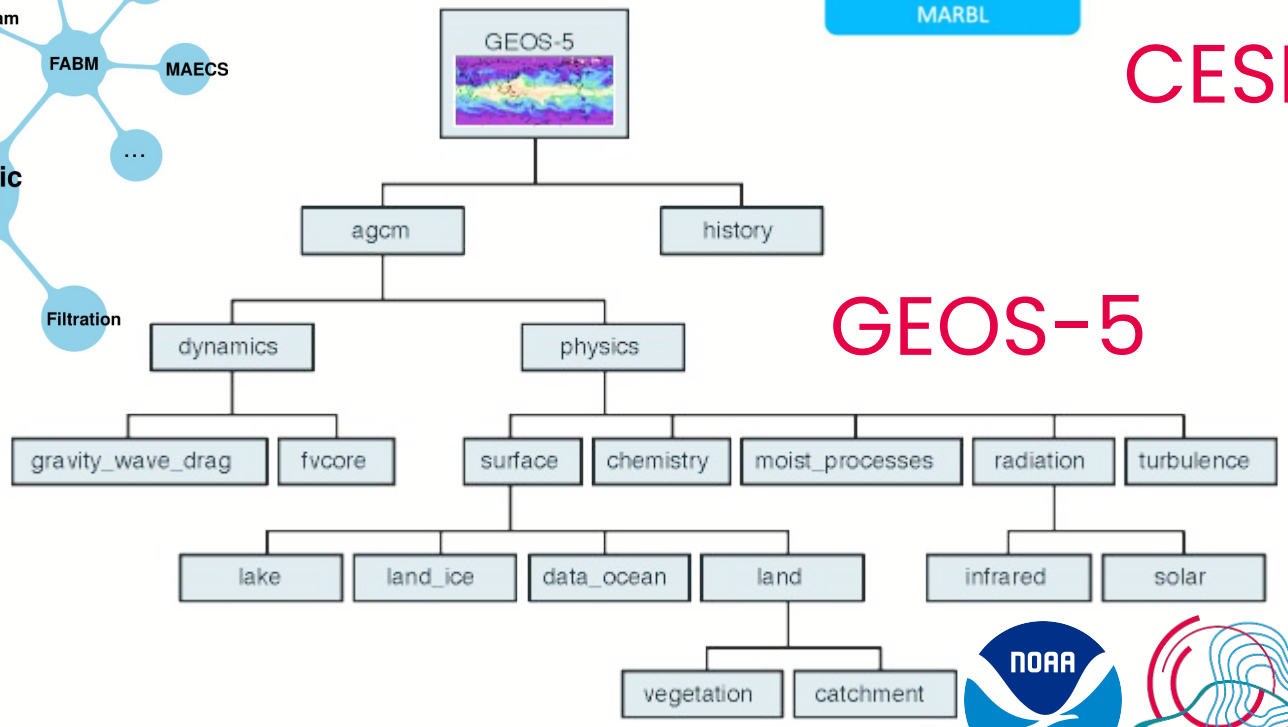
MOSSCO



CESM



GEOS-5



Taming a beast

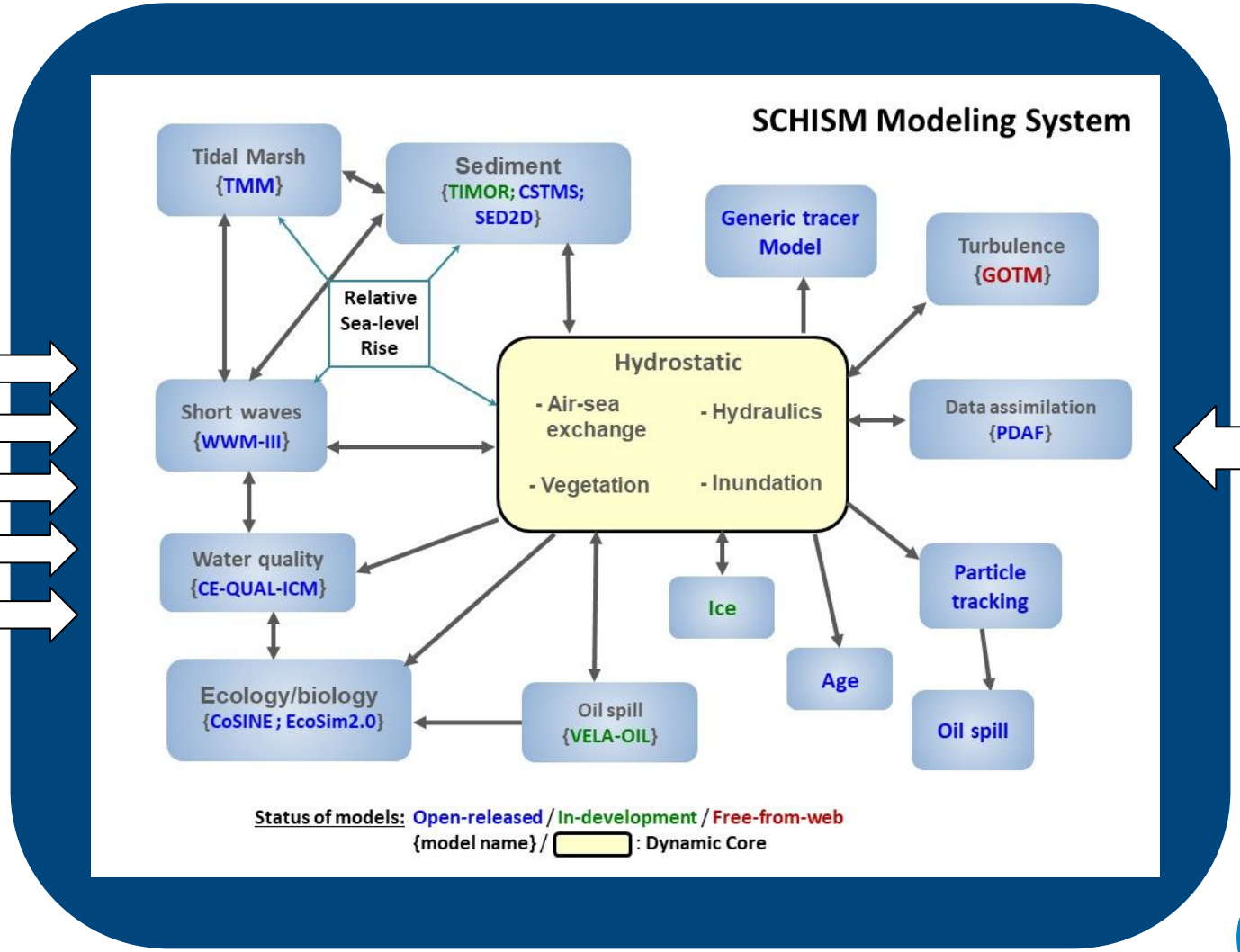
SCHISM Modeling System

Semi-implicit Cross-scale Hydroscience Integrated System Model

https://github.com/schism-dev/schism

Biogeochemical Processes

Tracer
Aging
Ecology
Food web
Chemistry



Earth System

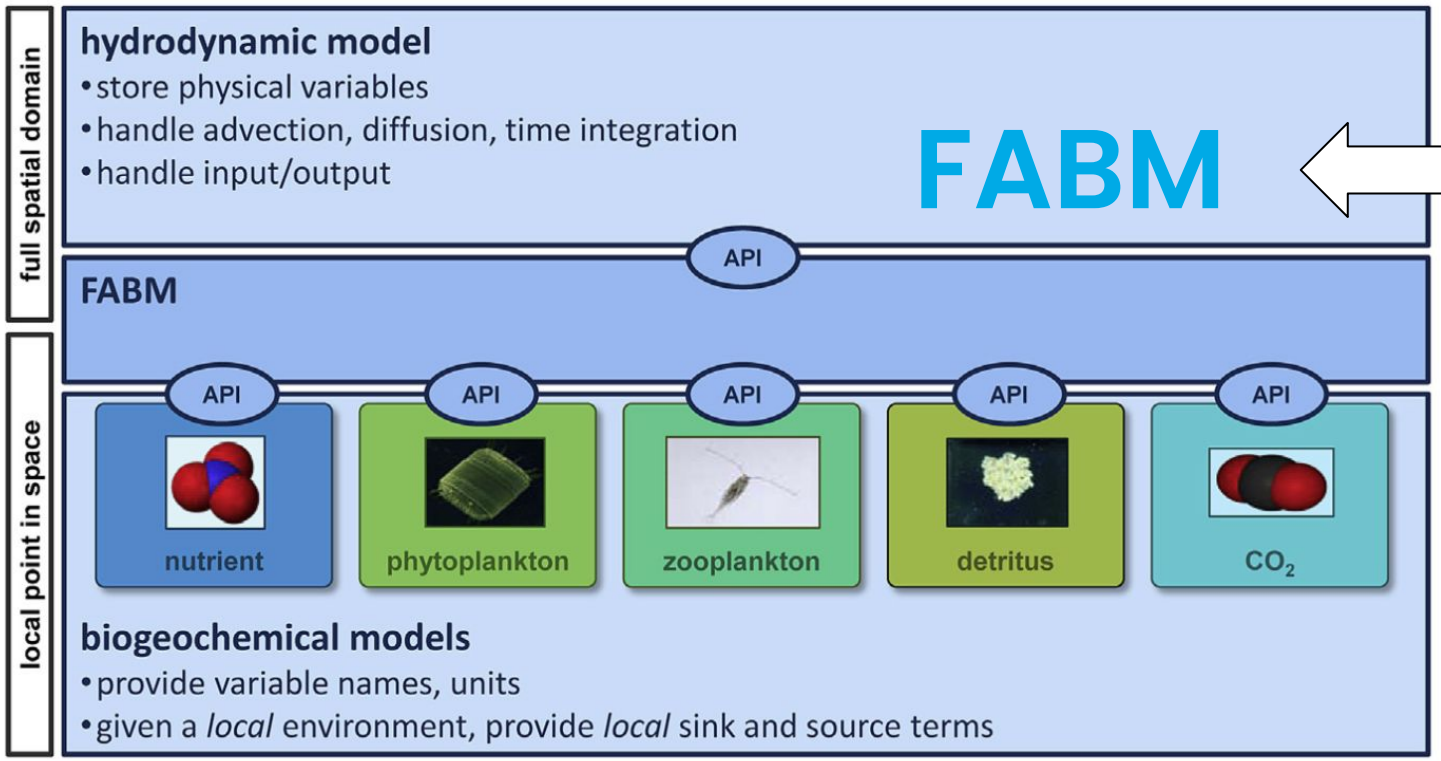
- Atmosphere
- Runoff

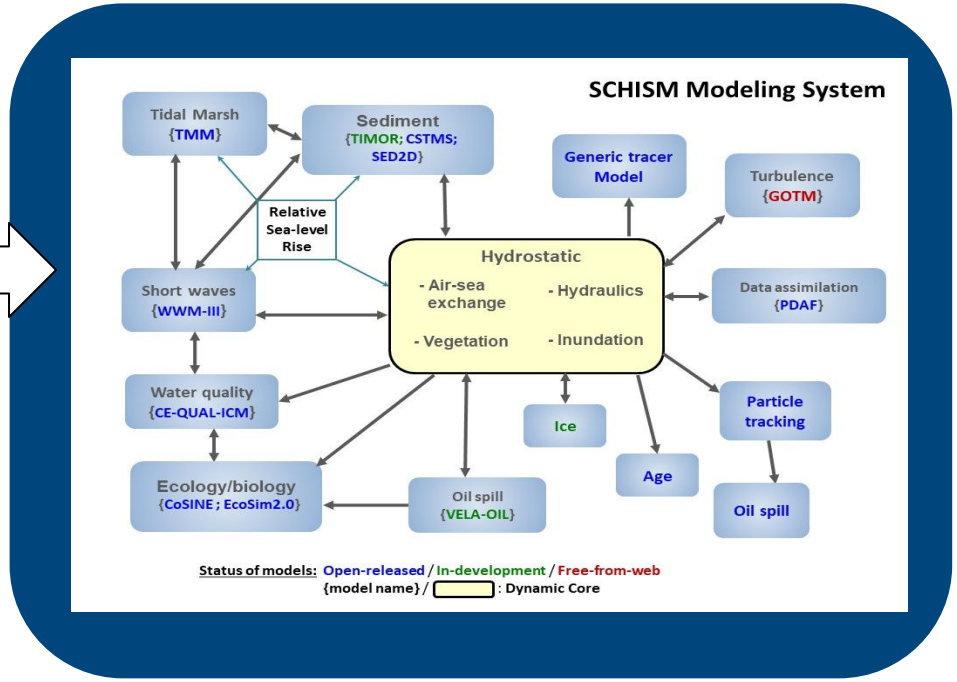
SCHISM/FABM System

Framework for Aquatic Biogeochemical Models

https://github.com/schism-dev/schism
https://github.com/fabm-model/fabm

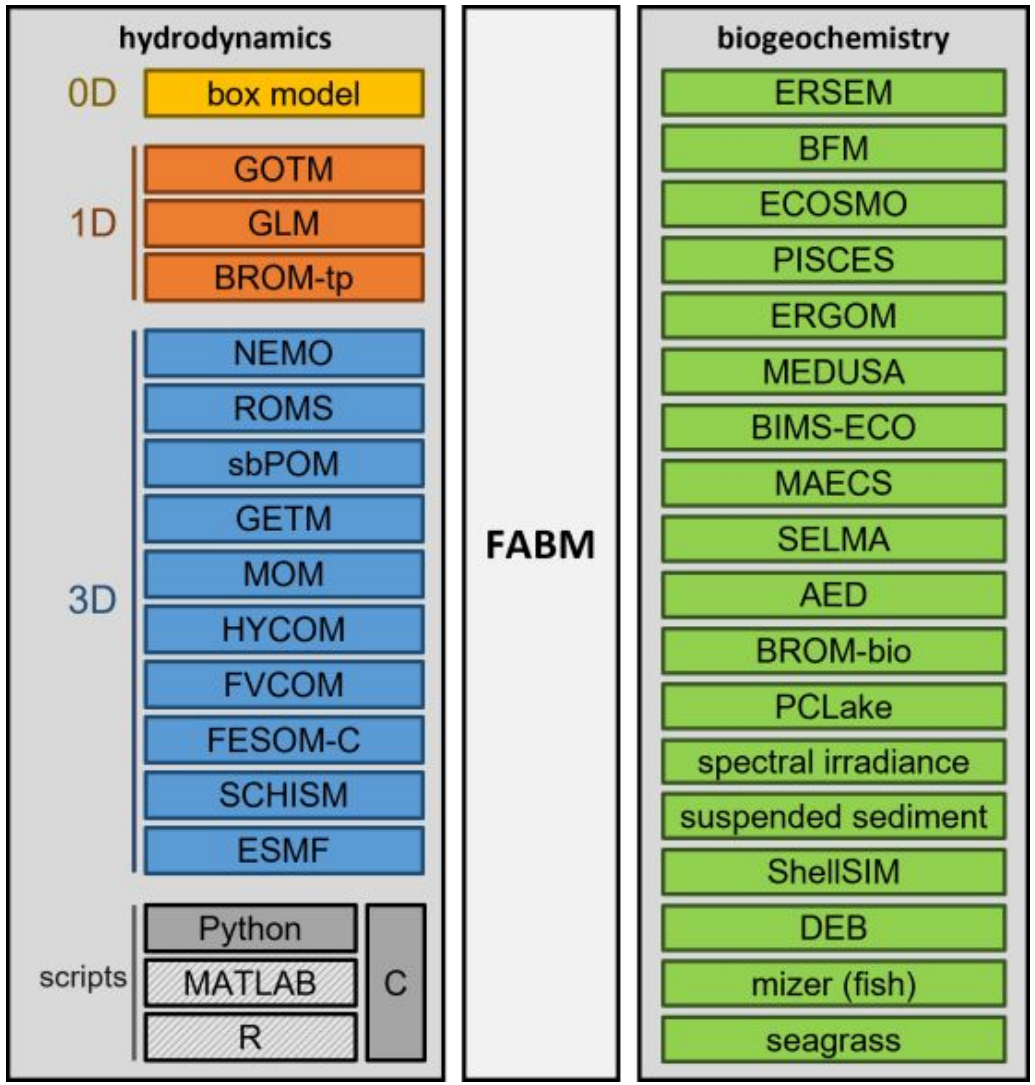
Bruggeman et al. 2014, Env. Mod. Soft.





FABM models and hosts

https://github.com/fabm-model/fabm



Your're a BGC modeler?

One BGC Fortran code maintained

- ❏ develop, test, quickview in python
- ❏ apply in 0D (bottle) to 3D (ocean)
- ❏ operate in different ocean models
- ❏ Scale to Earth System Models

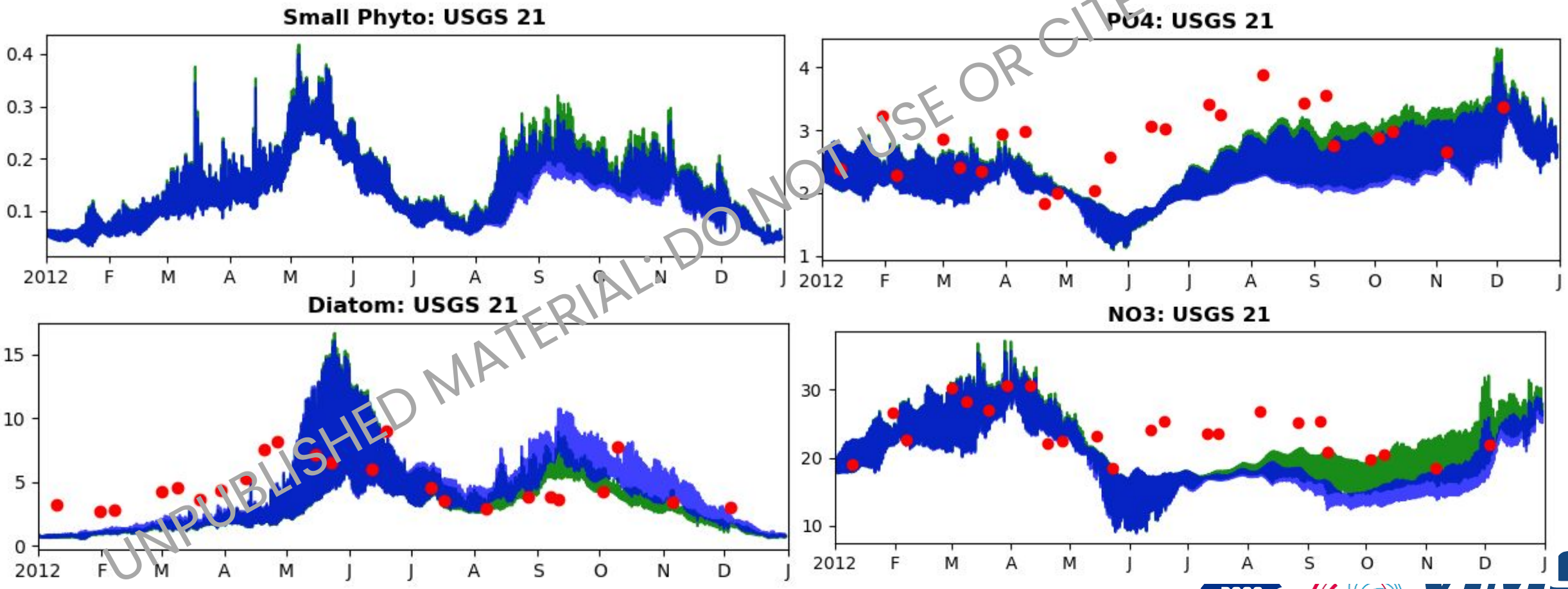
Your're a hydrodynamic modeler?

One host interface code maintained

- ❏ access full diversity of BGC models
- ❏ exchange BGC models
- ❏ transparent coupling of BGC models

SCHISM/FABM: COSINE

Hard-coupled vs. framework coupled

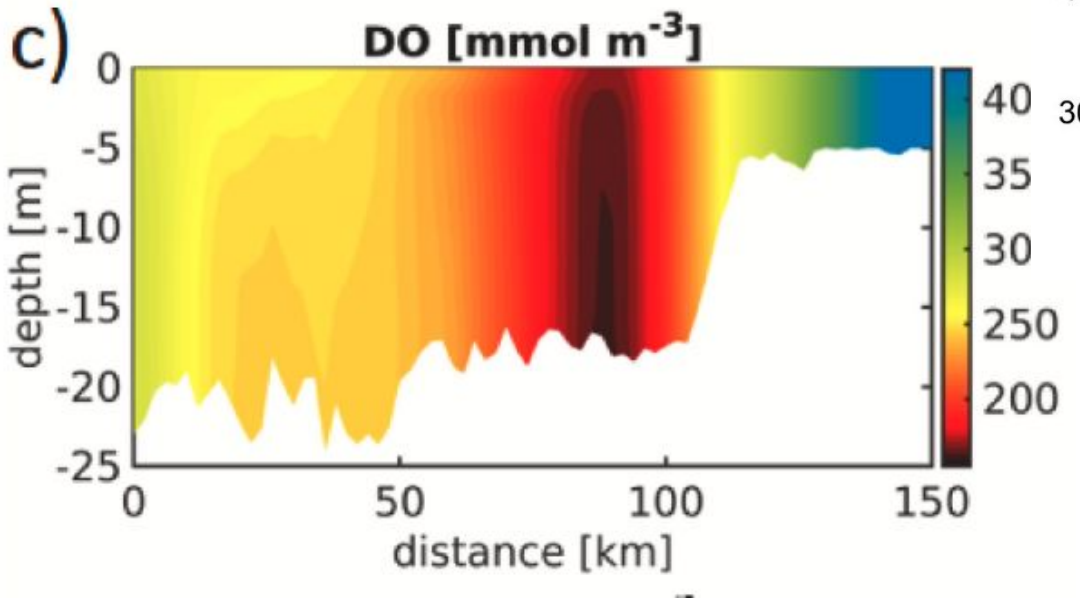


Lemmen et al. (Modeling systems)[3]

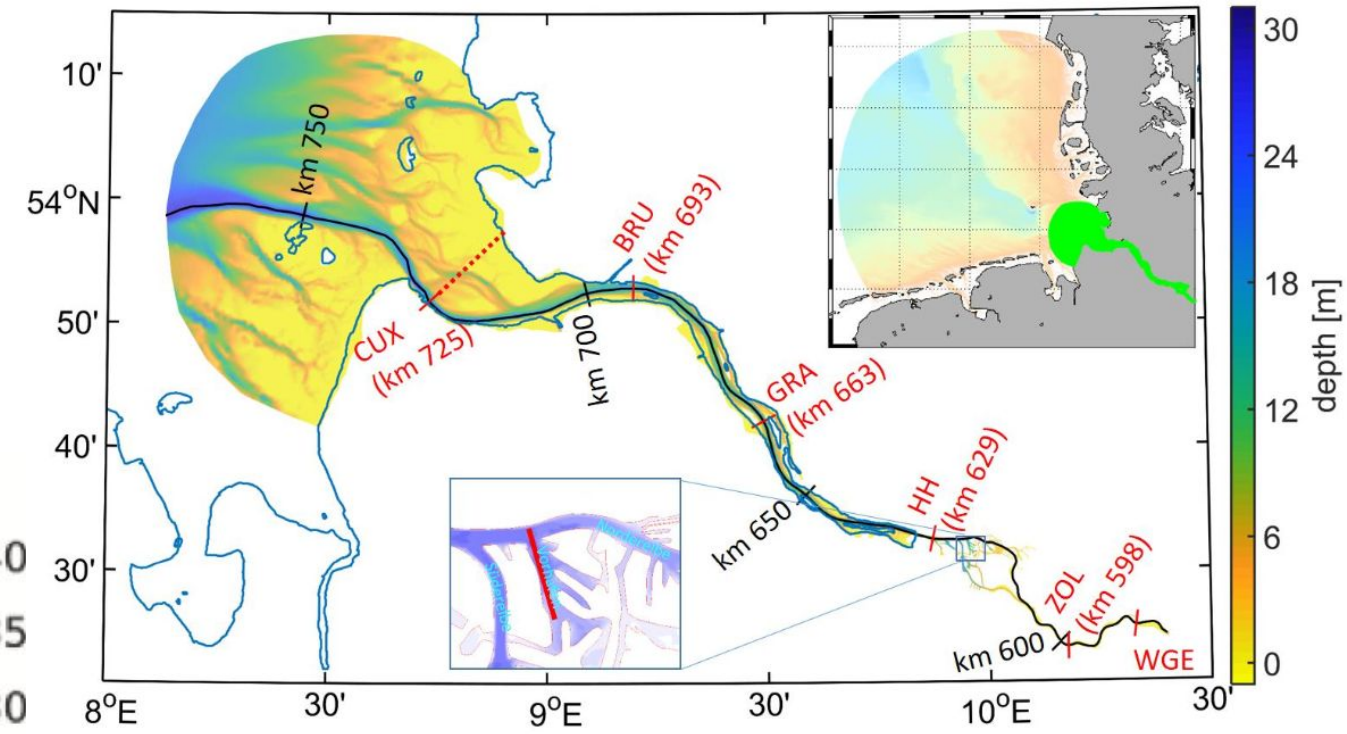
SCHISM/FABM: ECOSMO

Oxygen deficit

Oxygen minimum zone in Elbe estuary downstream of the Port of Hamburg



Pein et al. 2022, Cont. Shelf. Res



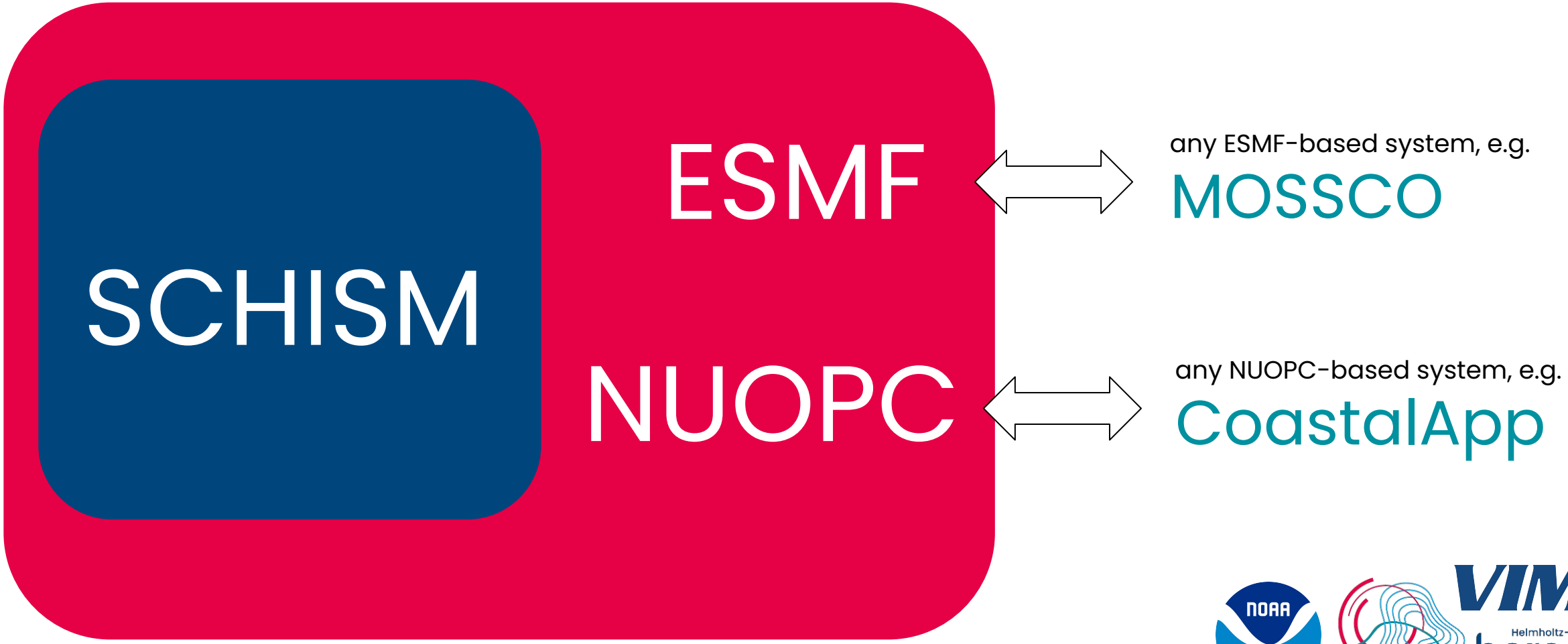
Seamless 2D-3D model setup for Elbe estuary including a detailed description of the Port of Hamburg Infrastructure

Pein et al. 2019 Biogeosci. Disc.

SCHISM ESMF/NUOPC caps

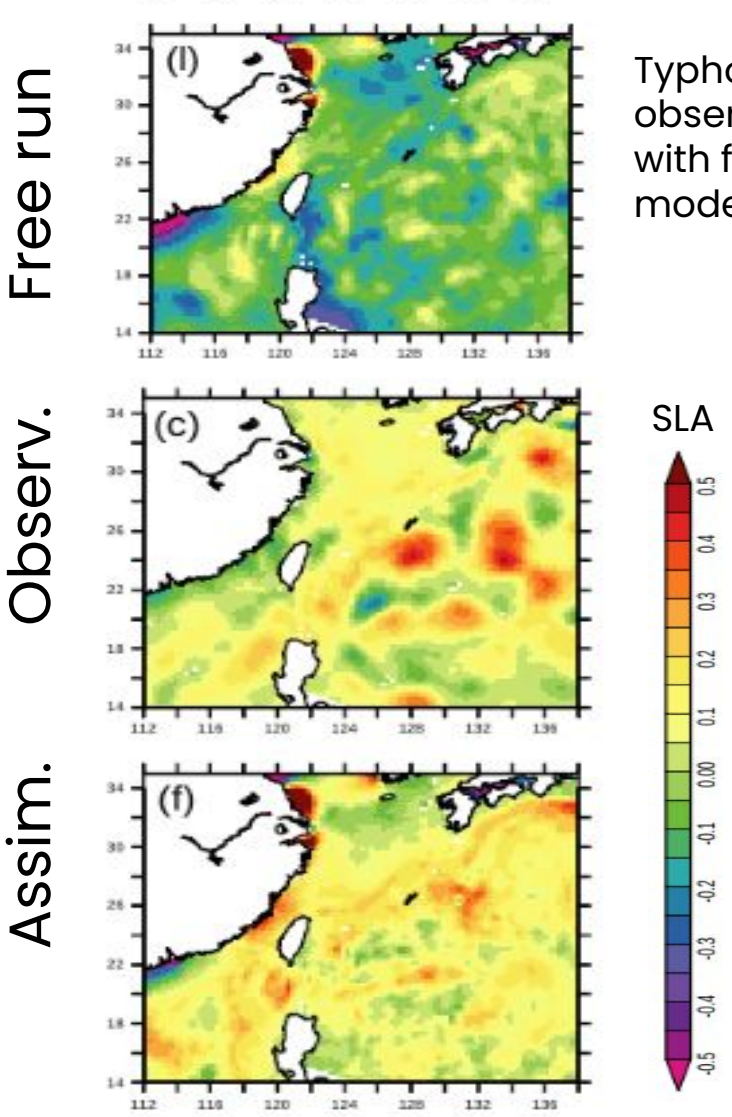
Earth System Modeling Framework

National Unified Operational Prediction Capability

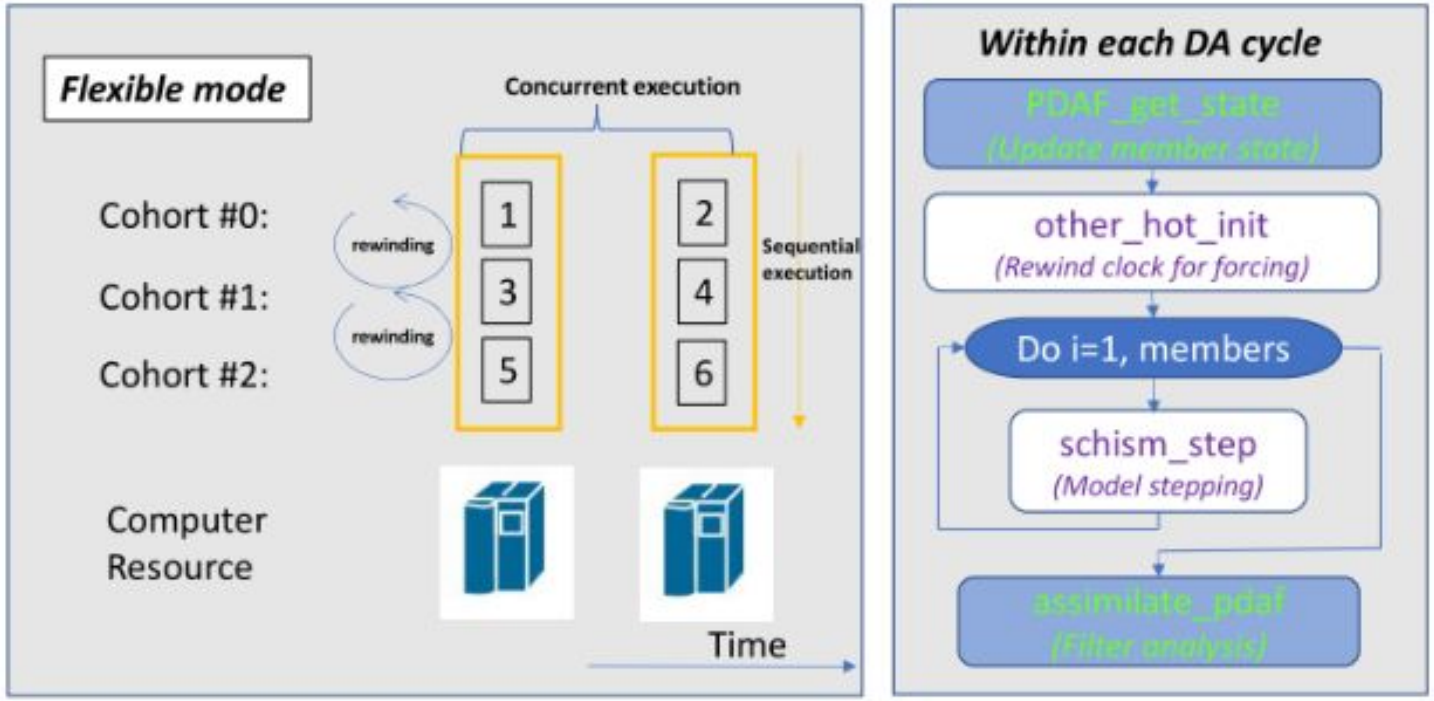


SCHISM/ESMF with PDAF

Parallel Data Assimilation Framework



Typhoon around Taiwan, observation contrasted with free and assimilated model runs

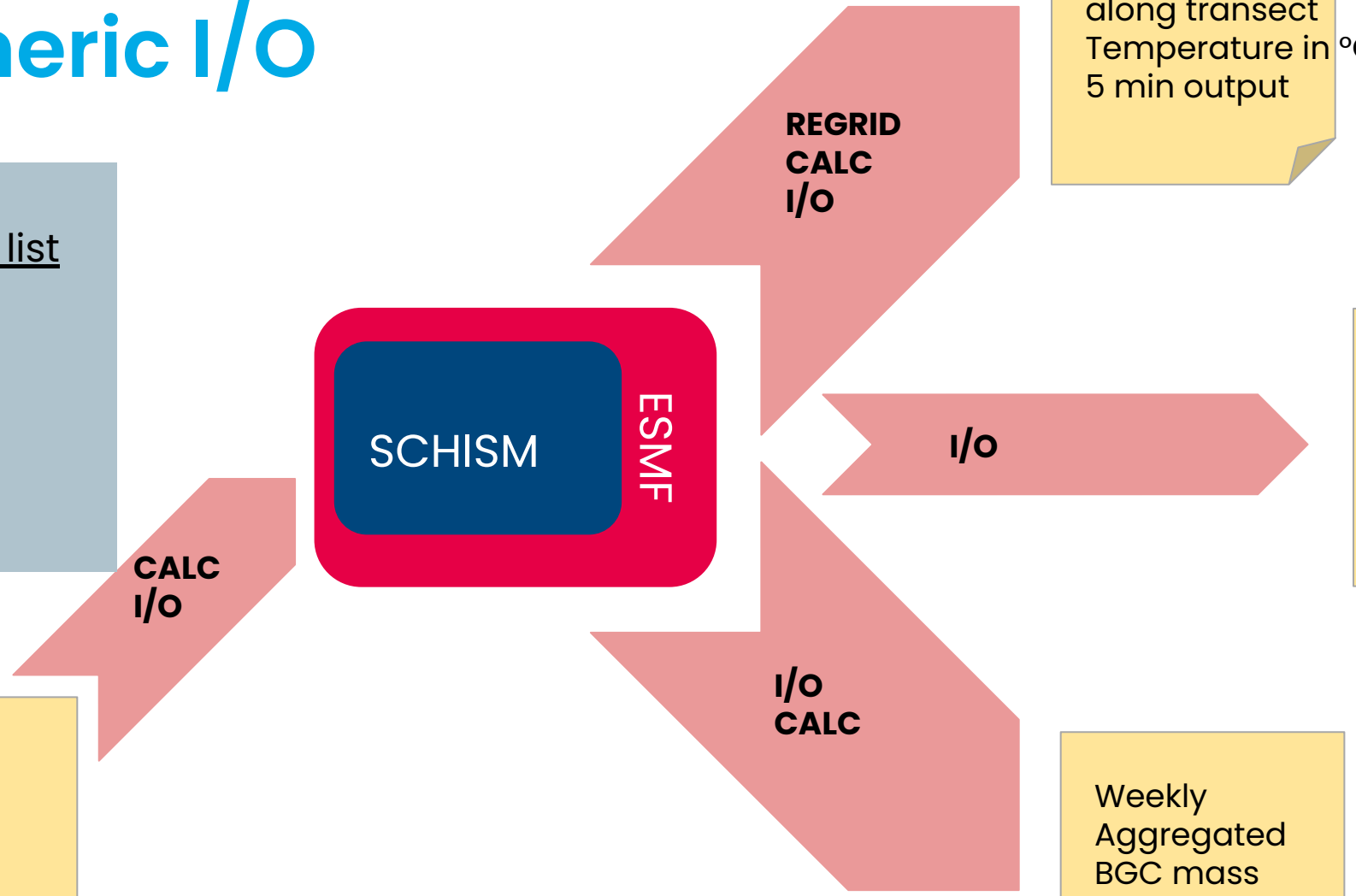


Exploitation of ESMF time scheduling capability to enable flexible SCHISM ensembles with data assimilation

Yu et al. 2022. EGU Sphere

SCHISM in MOSSCO
Generic I/O

MOSSCO 10 component list
1 x GRID
1 x REGRID
3 x CALC
3 x IO-out
1 x IO-in
1 x SCHISM



Surface
along transect
Temperature in °C
5 min output

Monthly
Full 3D
Hotstart

Daily
specific
humidity

Weekly
Aggregated
BGC mass

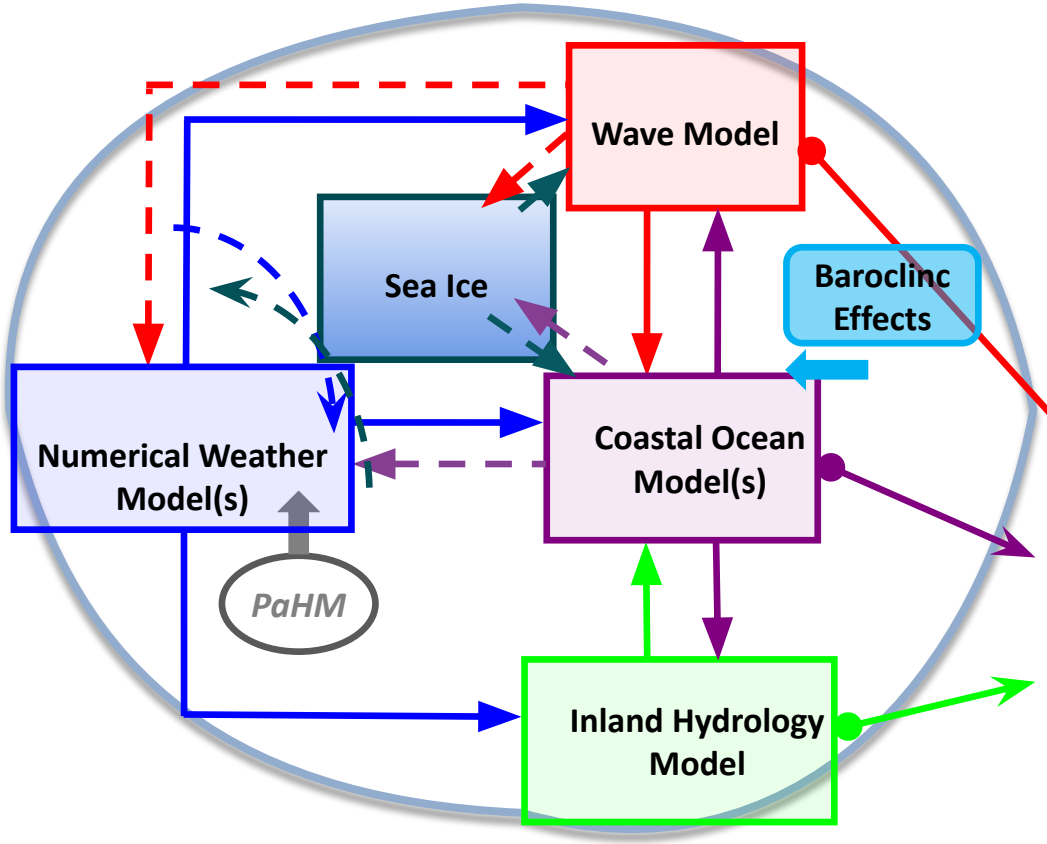
NOAA/NOS CoastalApp

Framework for coastal applications and regional forecasts

GitHub CoastalApp

tests passing | build passing | license CC0-1.0

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



Atmosphere	Ocean	Wave
ATMESH[1] (implemented)	ADCIRC[2] (implemented)	WW3DATA[1] (implemented)
PaHM[1] (implemented)	SCHISM[4,5] (in development)	WW3[3] (implemented)
HWRFcap[1] (in development)	FVCOM[6] (in development)	
HWRF (future capability)	BARDATA[1] (implemented)	
WRF (future capability)	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

- Navigation support
- Disaster mitigation
- Water Quality
- Sediment Transport

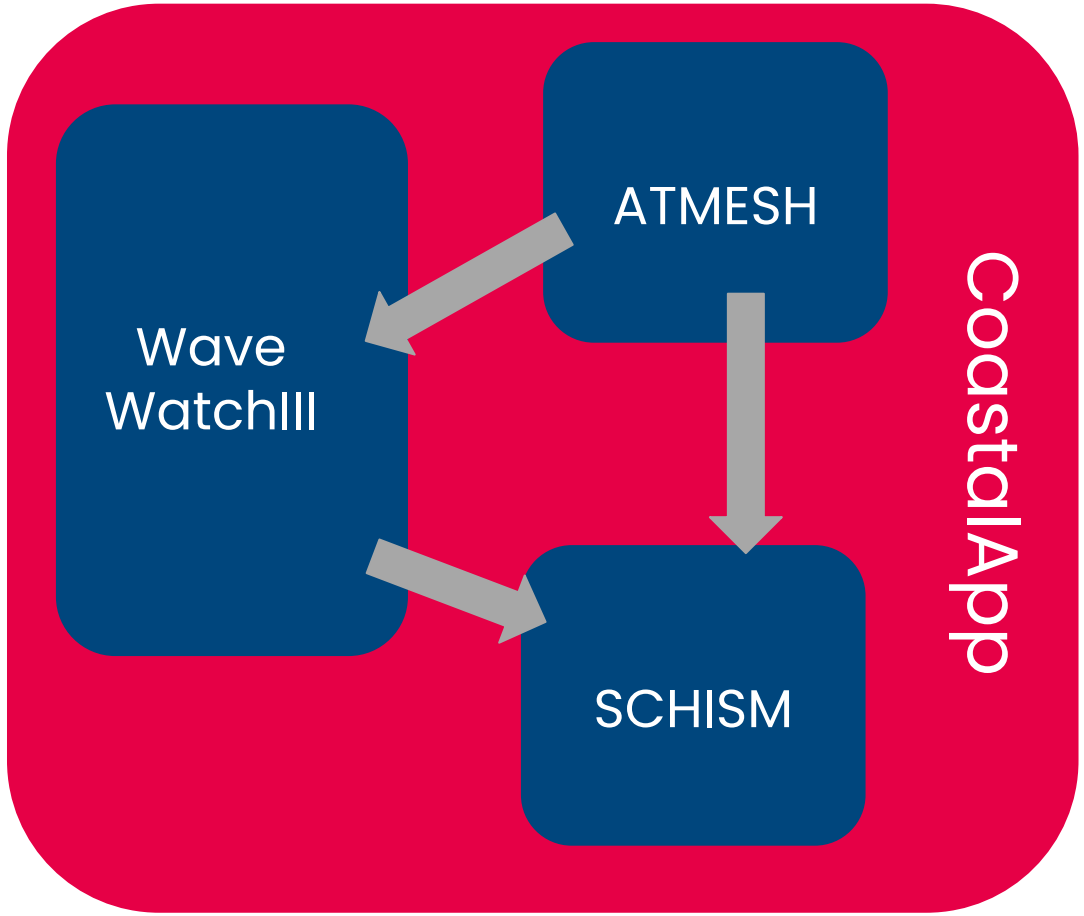
Product End User

- ❑ Data and active model components
- ❑ Flexibility to add components via NUOPC
- ❑ Portable

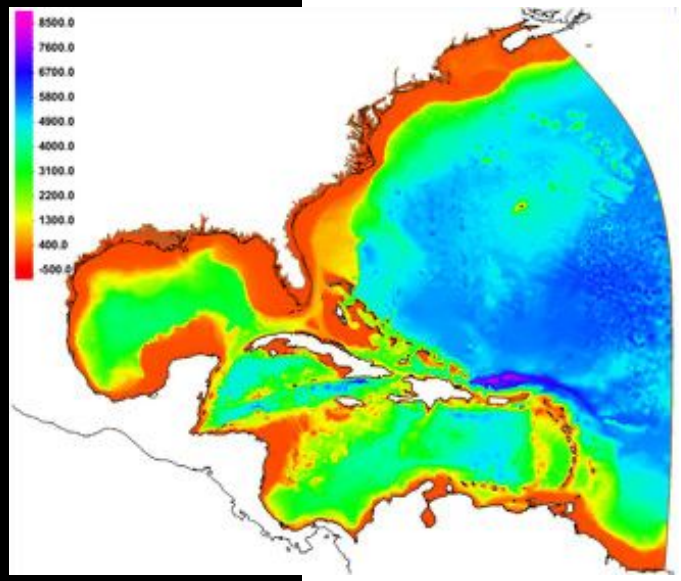
Implemented
In development/testing or future capability

Lemmen et al. (Modeling systems)[3]

SCHISM in CoastalApp
Test system




```
####  NEMS Run-Time Configuration File  #####

# EARTH #
EARTH_component_list : ATM OCN WAV
::

# ATM #
ATM_model:                      atmesh
ATM_petlist_bounds:             0 0
::

# OCN #
OCN_model:                      schism
OCN_petlist_bounds:             1 499
::

# WAV #
WAV_model:                      ww3
WAV_petlist_bounds:             500 999
::

# Run Sequence #
runSeq::
 @3600
   ATM -> OCN    :remapMethod=redist
   WAV -> OCN    :remapMethod=redist
   ATM -> WAV    :remapMethod=redist
   OCN -> WAV    :remapMethod=redist
   ATM
   OCN
   WAV
 @
::
```



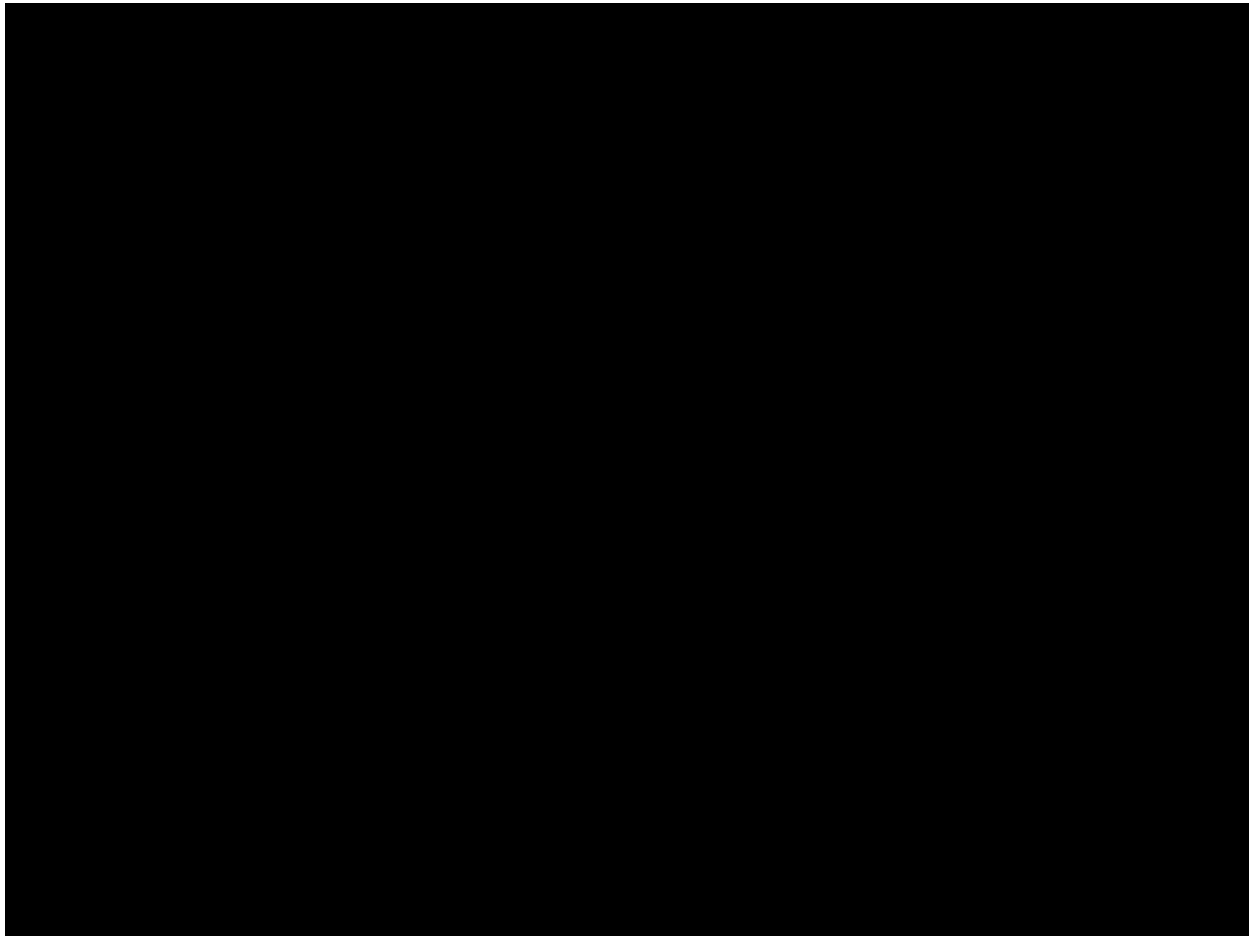
Eastern Atlantic

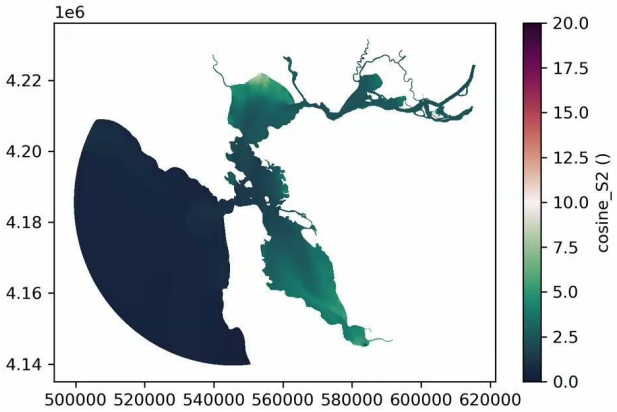
Hurricane "Florence"

Sep 2018

VIMS
Helmholtz-Zentrum hereon

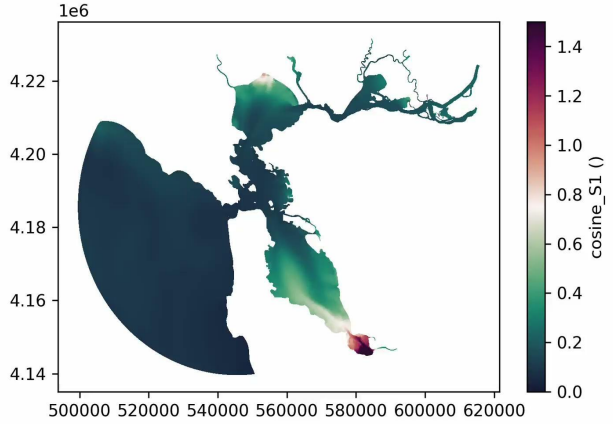
FABM in SCHISM in CoastalApp





Diatoms

Oxygen



Flagellates

VIMS
Helmholtz-Zentrum hereon

Summary

FABM

Integration of more BGC models

- ICM
- MAECS
- Macrobenthos

SCHISM

- ❑ Global mode
- ❑ Operational use
- ❑ Completing FABM
- ❑ Completing ESMF
- ❑ Adding BMI

Coastal App

- ❑ Completion of interfaces
- ❑ Operationalization
- ❑ CDEPS
- ❑ CMEPS
- ❑ Generic I/O

MOSSCO

- ❑ NUOPC/ESMX
- ❑ separate out components/caps
- ❑ make obsolete

→ Open, Seamless & Equitable Cross-Scale Earth System Model

Job advertisement

WILLIAM & MARY
CHARTERED 1693

FABM SCHISM CoastalApp

Postdoc:
Implementing the next-generation seamless 'creek-to-ocean' forecast model.

https://jobs.wm.edu/postings/51043

(still open)

NOAA VIMS Helmholtz-Zentrum hereon