Modular System for Shelves and Coasts (MOSSCO)

Science applications and unstructured representation

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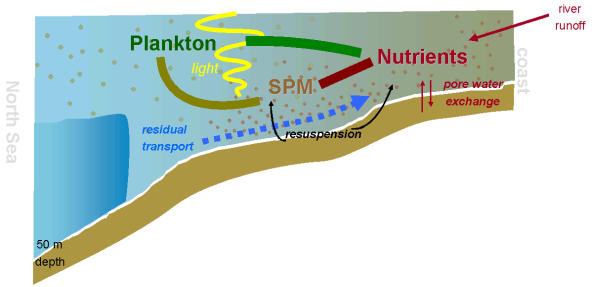
Coasts are interfaces



→ Different domains and scales
→ Different disciplines and communities
→ Different tools and models $\Longrightarrow$ diversity

Models are not made for interfaces

"up to now, there has been no coastal modelling environment that enables a modular and flexible process (model) integration and cross-domain coupling at the same time and that is open to a larger community of independent biogeochemical and ecological scientists."

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

Geoscientific Model Development
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EGU

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

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Modular approach to the system $\Longrightarrow$ MOSSCO

Science questions

1. What are important feedbacks in coastal systems?
2. What determines coastal nutrient gradients and variability?
3. How to value the ecosystem service of nutrient retention (WDF/MSRL) ?

Specifications

1. Integrate different disciplines, esp. coastal engineering
2. High granularity: couple many (10+) different components
3. Integrate over scales from lab to regional ocean
4. Get a new model to HPC regional in minutes

Do different

1. Emphasize biological/social on par with physical processes
2. Dare to leave expertise local and let loose of control

Concept 1: Flexibility

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-, and 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 in replacing components finally creates a test bed for model intercomparison studies.

Concept 2: Equitability

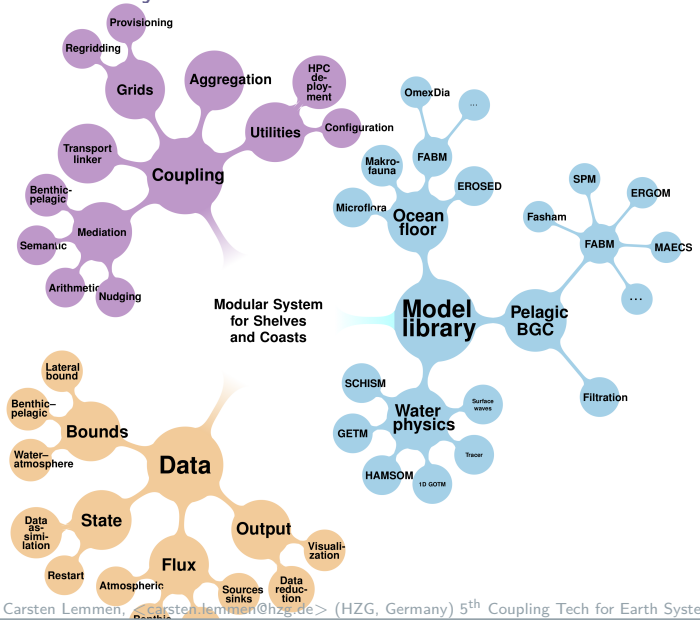
Equitability means that all models in the coupled framework are ***treated as equally important*** and that none is more important than any other. This principle dissolves the primacy of the hydrodynamic or atmospheric models as the central hub in a coupled system. Also, ***data components are as important 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.

Up and running in minutes

```
#! /bin/bash

export MOSSCO_DIR=$HOME/MOSSCO/code
export MOSSCO_SETUPDIR=$HOME/MOSSCO/setups
export NETCDF=NETCDF4

git clone --depth=1 git://git.code.sf.net/p/mossco/code $MOSSCO_DIR
git clone --depth=1 git://git.code.sf.net/p/mossco/setups $MOSSCO_SETUPDIR

make -C $MOSSCO_DIR external    # download external codes

mkdir -p $HOME/opt/bin
export PATH=$PATH:$HOME/opt/bin
ln -sf $MOSSCO_DIR/scripts/mossco.sh $HOME/opt/bin/mossco # "installation"

cd $MOSSCO_SETUPDIR/helgoland  # choose a Helgoland 1D setup
mossco jfs                     # starts a 1D pelagic-sediment simulation
```

(c)

Granularity



Upscaling from 1-dimensional . . .

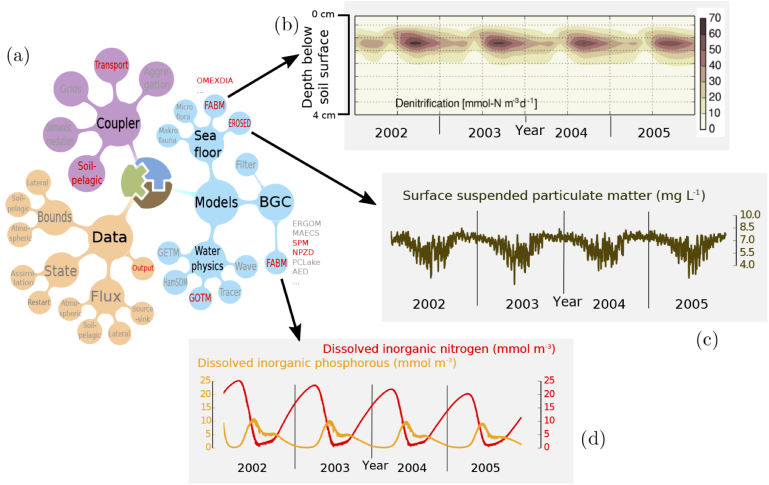


Figure 1: Benthic-pelagic nutrient dynamics

. . . via 2-dimensional . . .

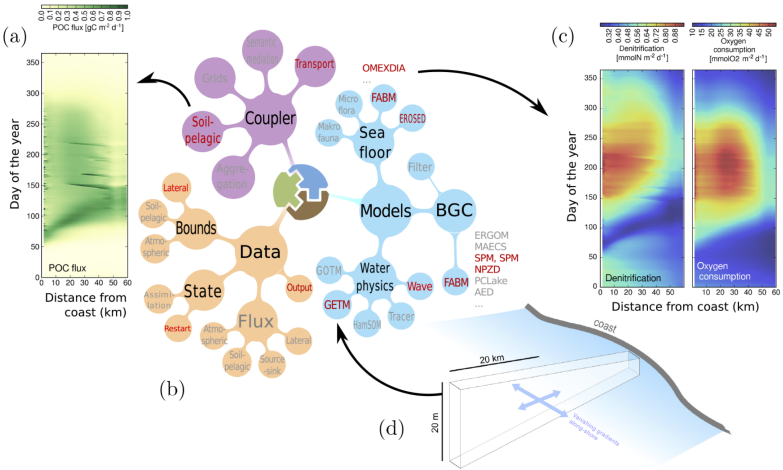


Figure 2: Near-shore suspended material pumping

. . . to full 3-D example

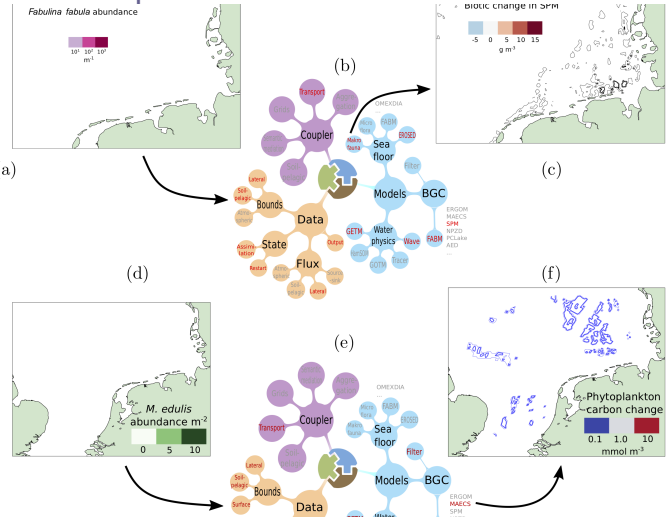


Figure 3: 3D coastal apps

Unprecedented simulated spatial variability

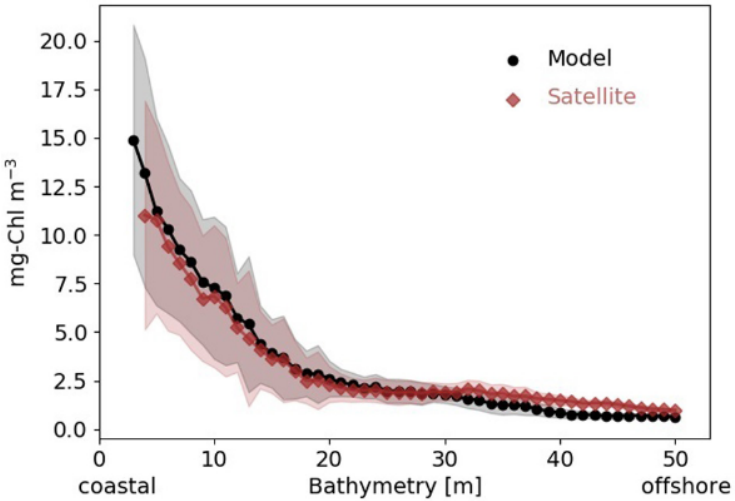
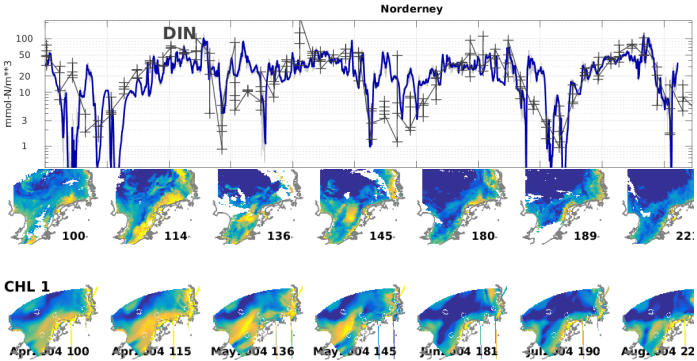


Figure 4: Satellite-model comparison 1997–2012, Xu et al. 2020

Unprecedented simulated temporal variability



Examples

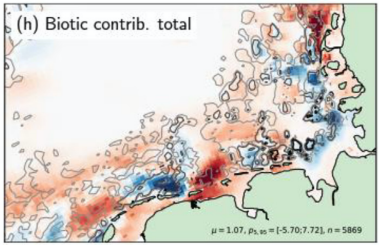


Figure 5: Biotic sediment (de-)stabilization

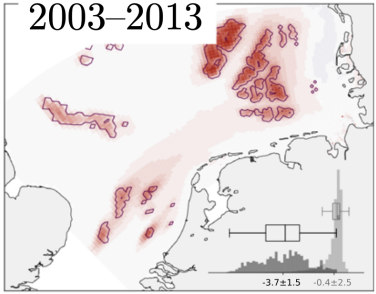
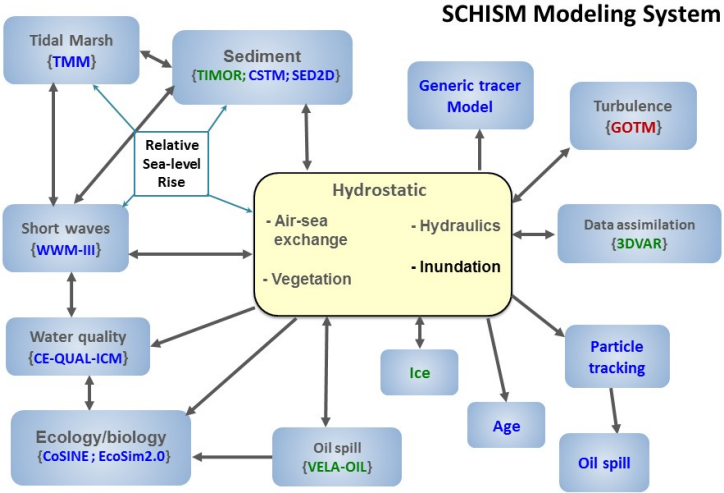


Figure 6: Biotic NPP filtration

Semi-implicit Cross-scale Hydroscience Integrated System Model



Taming the beast

FABM interface - process coupling

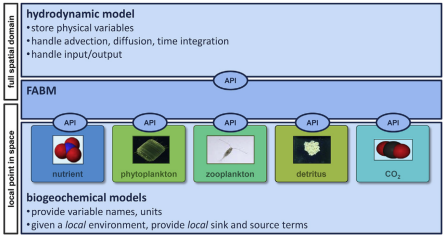


Figure 8: FABM API, Bruggeman et al. 2014

ESMF and NUOPC caps - domain coupling

- → standalone code
- → regridding, modular I/O through MOSSCO
- → generic FABM hosts, need transport hook

SCHISM Elbe + FABM/ECOSMO

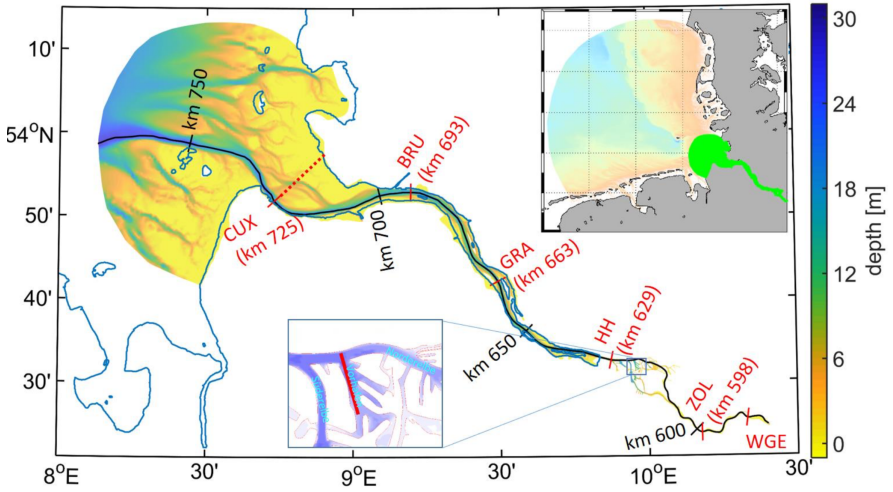


Figure 9: Elbe biogeochemistry simulation, Pein et al. 2019

We wanted to do something "simple" . . .

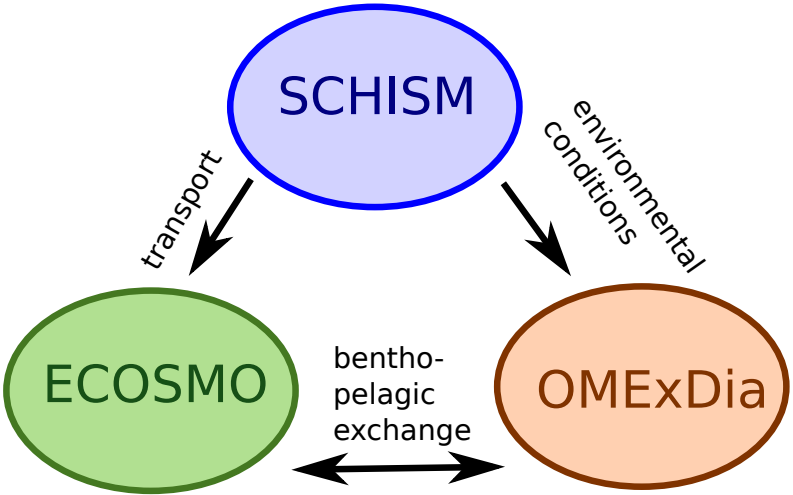
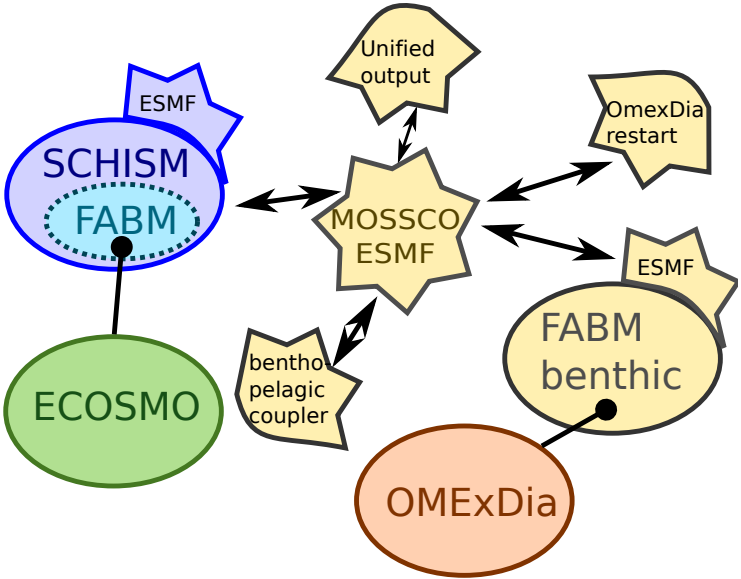


Figure 10: This is what we wanted to do

And ended up with this!



Status

New models

- → ROMS
- → mitGCM { color="orange"}
- → FESOM-coastal
- → SWAN
- → ICON
- → Macrobenthos
- → Sea grass
- → PDAF
- → WRF/NEMS

New couplers

- → CCA/CSDMS
- → OASIS3-MCT (GCoast)
- → Regridding
- → NUOPC convergence

New applications

- → Multistressors
- → Land use, social simulation

Some reading

→ Xu et al. (2020) Less Nutrients but More Phytoplankton: Long-Term Ecosystem Dynamics []. Front. Mar. Sci. 7:662. https://doi.org/10.3389/fmars.2020.00662

→ Wirtz (2019): Physics or biology? Persistent chlorophyll accumulation in a shallow coastal sea []. PLOS ONE, February 22, https://doi.org/10.1371/journal.pone.0212143

→ Slavik et al. (2018): The large scale impact of offshore windfarm structures on pelagic primary production []. Hydrobiologia, pp 1–19, https://doi.org/10.1007/s10750-018-3653-5

→ Lemmen et al. (2018): Modular System for Shelves and Coasts (MOSSCO v1.0) – a flexible and multi-component framework [], Geosci. Model Dev., https://doi.org/10.5194/gmd-2017-138

→ Nasermoaddeli et al. (2018): A model study on the large-scale effect of macrofauna [], Estuar. Coast. Shelf Sci., https://doi.org/10.1016/j.ecss.2017.11.002

→ Pein et al. (2019): Nitrogen cycling in the Elbe estuary [], Biogeosci. Discuss., https://doi.org/10.5194/bg-2019-265, 2019.