Ocean Biogeochemical Modeling

Jessica Luo, on behalf of the COBALT model development team

Q1: Concerning GFDL's core strength of building and improving models of the weather, oceans, and climate for societal benefits, how can GFDL leverage advances in science and computational capabilities to improve its key models? What are the strengths, gaps, and new frontiers?
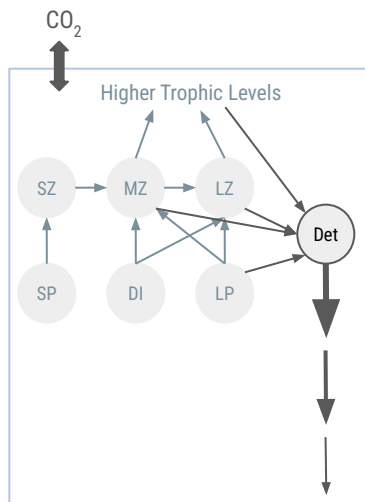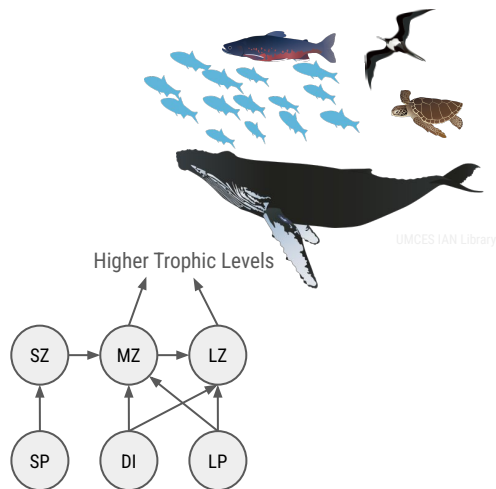
Dual goals in ocean biogeochemical model development

① Carbon

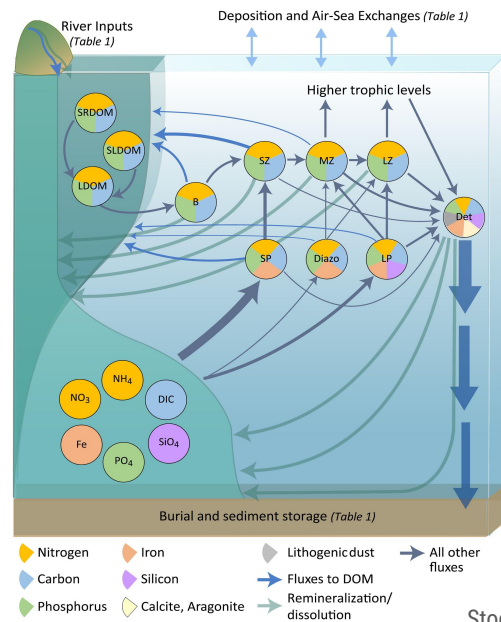② Ecosystems

Higher Trophic Levels
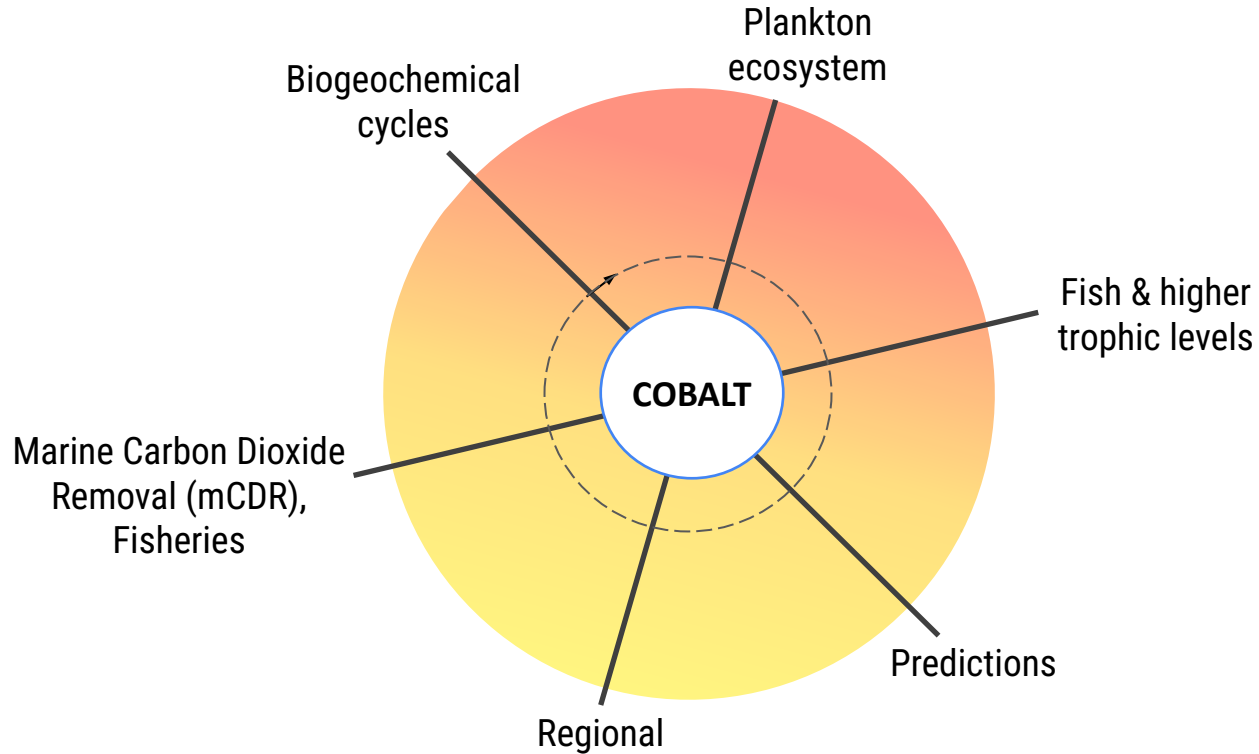
Higher Trophic Levels

UMCES IAN Library

Carbon, Ocean Biogeochemistry, and Lower Trophics (COBALT)

Stock et al. 2020
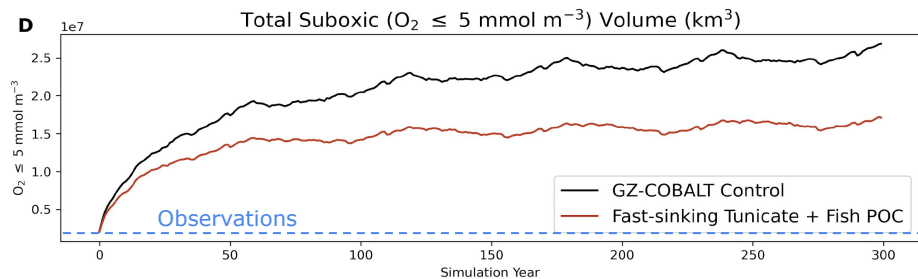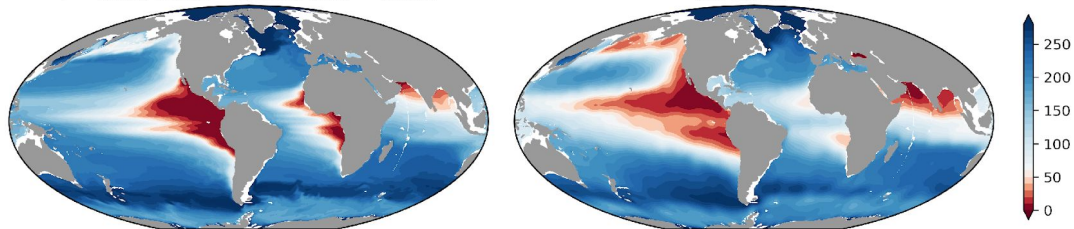
Ocean Ecosystem Modeling from R2X

Plankton ecology shapes ocean biogeochemical cycling

Fast sinking detritus decreases hypoxia expansion globally

Oxygen at 500m, Fast-sinking detritus (mmol m^{-3})
r = 0.93; rmse = 35.19; bias = 16.32

Observed Oxygen at 500m (mmol m^{-3})

D Total Suboxic ($O_2 \leq 5$ mmol m^{-3}) Volume (km^3)

Observations

— GZ-COBALT Control
— Fast-sinking Tunicate + Fish POC

Luo et al. 2024

Looking Forward

Towards COBALTv3.1
Additional phytoplankton group
Improved photoacclimation scheme
Variable N:P stoichiometry
(Stock et al. in review, JAMES)
Anammox
Improved river runoff carbon

Development of ECO-COBALT
Gelatinous zooplankton
Mixotrophy
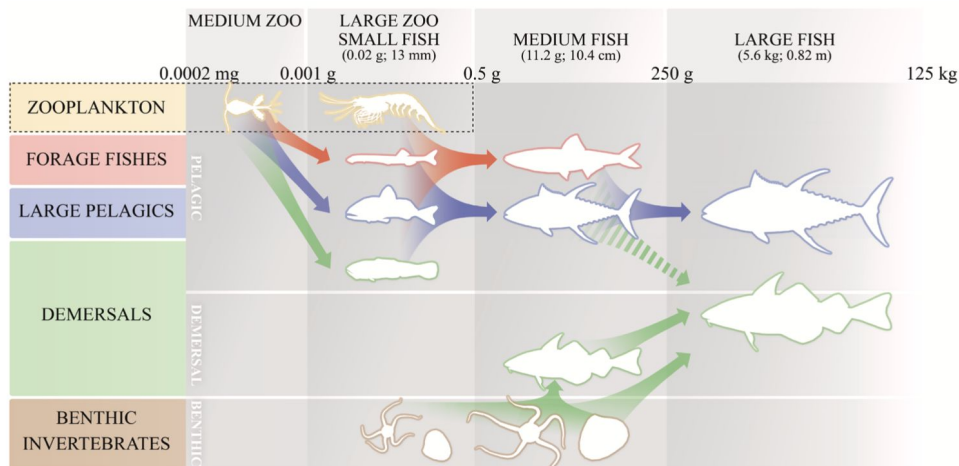Zooplankton diel vertical migration
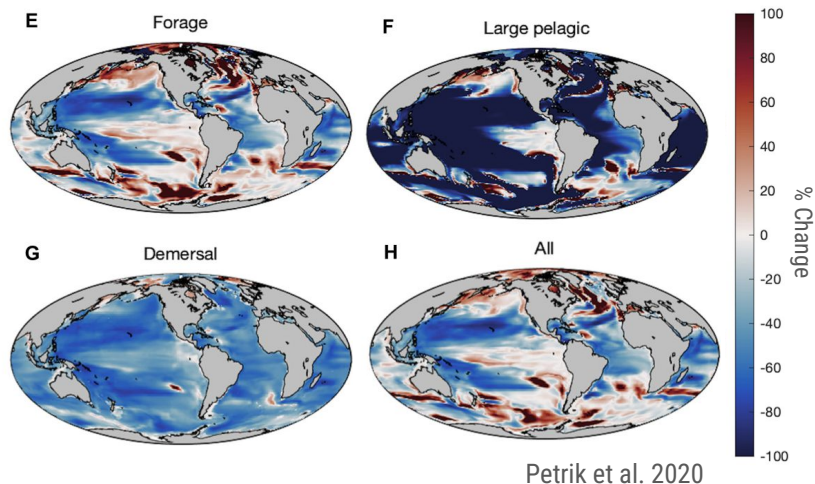Phytoplankton vertical migration
Fish

Fish modeling with FEISTY

Fisheries Size and Functional Type Model (FEISTY)
Offline fish model forced by COBALT outputs

Petrik et al. 2019, 2020
van Denderen et al. 2021

Changes in fish production by 2100 under RCP8.5

Petrik et al. 2020

Looking Forward

Two-way coupling between COBALT and FEISTY
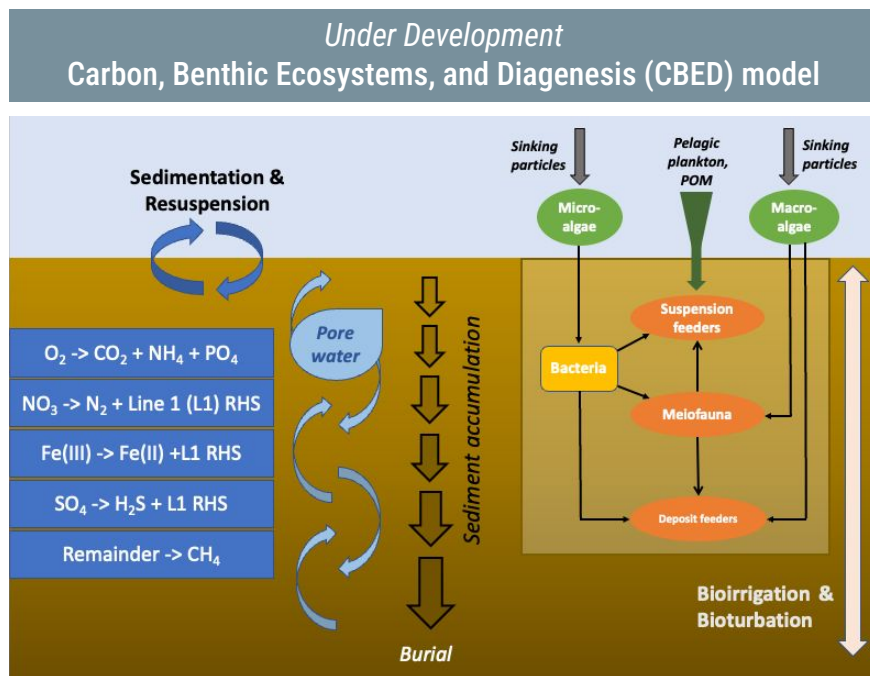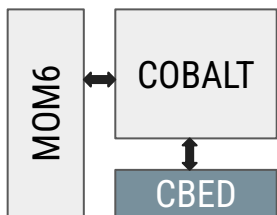
Regional applications

Role of the seafloor in coastal carbon, climate, & ecosystems

MOM6

COBALT

CBED

Under Development
Carbon, Benthic Ecosystems, and Diagenesis (CBED) model

Sedimentation & Resuspension

Sediment accumulation

$O_2 \rightarrow CO_2 + NH_4 + PO_4$

$NO_3 \rightarrow N_2 + \text{Line 1 (L1) RHS}$

$Fe(III) \rightarrow Fe(II) + \text{L1 RHS}$

$SO_4 \rightarrow H_2S + \text{L1 RHS}$

Remainder $\rightarrow CH_4$

Pore water

Burial

Sinking particles

Micro-algae

Pelagic plankton, POM

Sinking particles

Macro-algae

Bacteria

Suspension feeders

Meiofauna

Deposit feeders

Bioirrigation & Bioturbation

Improved process understanding on:

Impact of the seafloor on marine carbon dioxide removal (mCDR) strategies

Benthic-pelagic coupling

Timescales of organic carbon in the coastal ocean

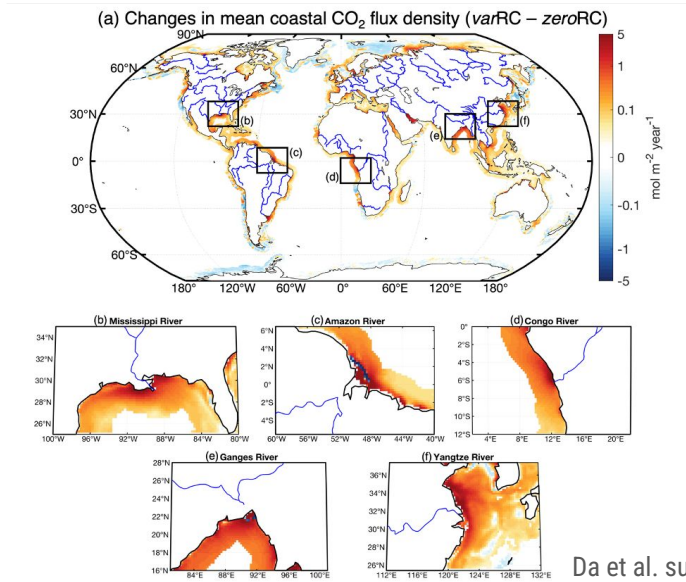Climate impacts on benthic ecosystems

See poster by Subhadeep Rakshit

NOAA
**GEOPHYSICAL FLUID DYNAMICS LABORATORY**

Marine biogeochemical cycles and Earth System interactions

Variable river alkalinity and DIC improves coastal CO_2 fluxes

(a) Changes in mean coastal CO_2 flux density (*var*RC − *zero*RC)

(b) Mississippi River (c) Amazon River (d) Congo River

(e) Ganges River (f) Yangtze River

Da et al. submitted, GBC

Bi-directional air-sea ammonia exchange: balance of acidification and nitrogen deposition

(a) 3.1 TgN yr^{-1}

gN m^{-2} yr^{-1}

(b) −0.2 TgN yr^{-1}
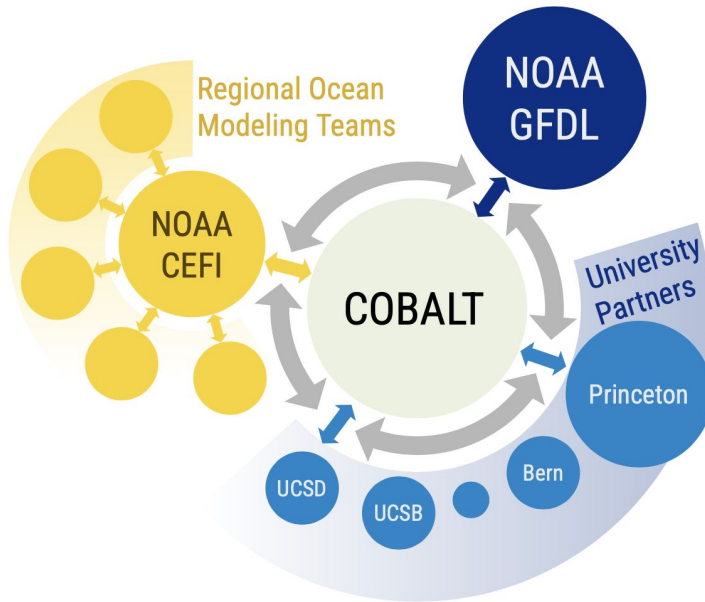
Change from preindustrial conditions [%]
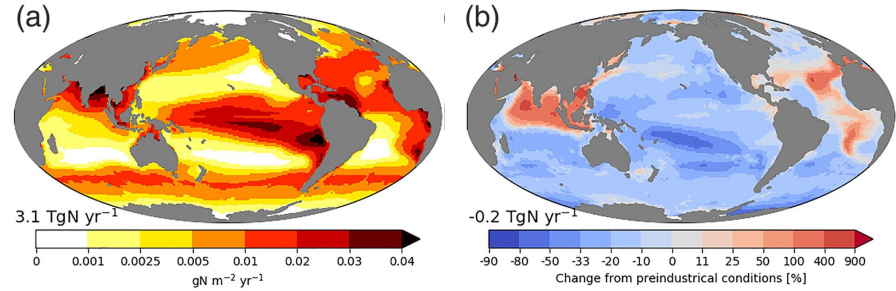
Paulot et al. 2020

Looking Forward

Air-sea interactions
Dust, Dimethylsulfide (DMS)
Land-to-Ocean Connectivity
Coupled biogeochemical cycles

Enabling a wide network of users and co-developers

Open development to accelerate science & applications

Ocean Biogeochemical Model Development at GFDL

Dual foci on Carbon Cycle and Ecosystems

Enabling activities ranging from Research to Applications, Research to Operations

Key Developments:

COBALT plankton ecosystem improvements

Fish modeling with FEISTY

Benthic biogeochemistry & ecosystem processes

Improvements in land-ocean and atmosphere-ocean coupling