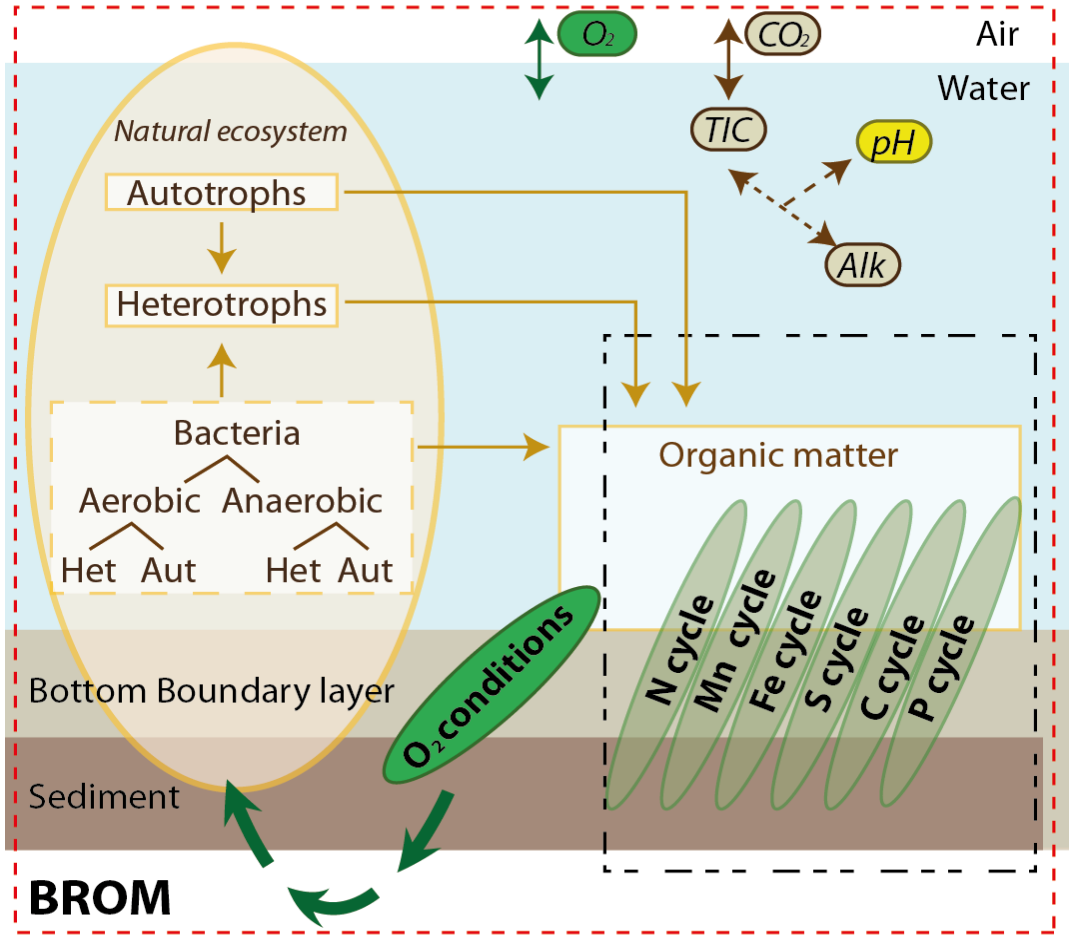
Bottom RedOx Model (BROM)

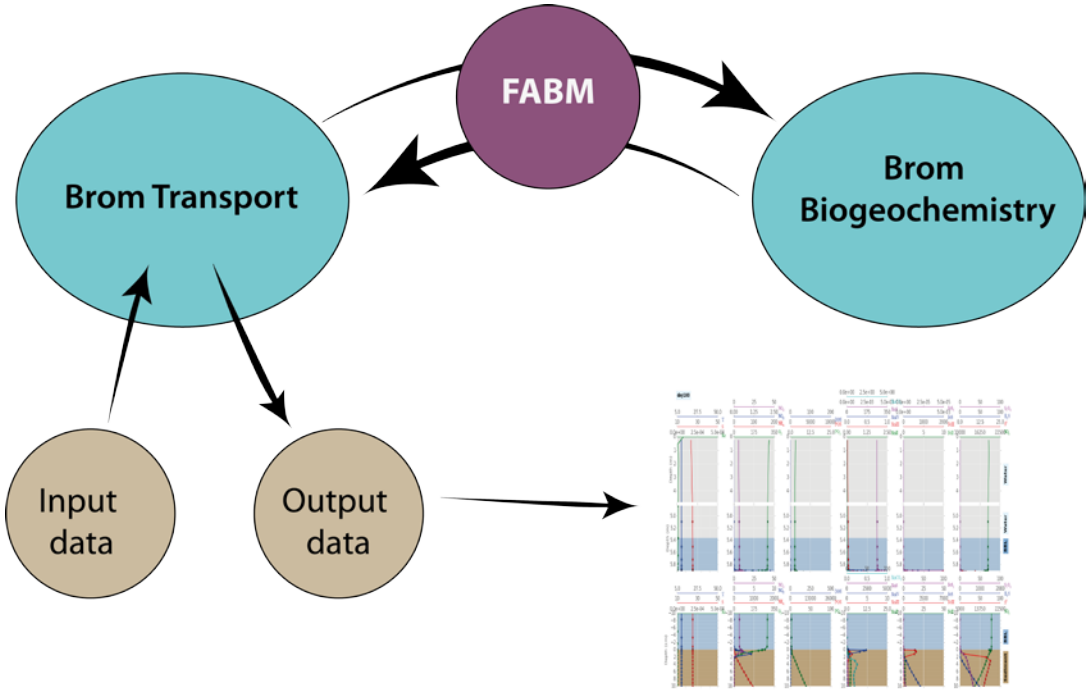


Benthic–pelagic biogeochemical model BROM combines a relatively simple ecosystem model with a detailed biogeochemical model in the water column, benthic boundary layer, and sediments, with a focus on oxygen and redox state.

BROM should be of interest for the study a range of environmental applications in addition to hypoxia, such as benthic nutrient recycling, redox biogeochemistry, eutrophication, industrial pollution from trace elements, organic loading, and ocean acidification.

Yakushev, E. V., Protsenko, E. A., Bruggeman, J., Wallhead, P., Pakhomova, S. V., Yakubov, S. Kh., Bellerby, R. G. J., and Couture, R.-M. 2017: Bottom RedOx Model (BROM v.1.1): a coupled benthic–pelagic model for simulation of water and sediment biogeochemistry, Geosci. Model Dev., 10, 453-482.

BROM consists of a transport module (**BROM-transport**) and biogeochemical module (FABM compartible **BROM-biogeochemistry**), allowing independent coupling to hydrophysical models in 1-D, 2-D, or 3-D.



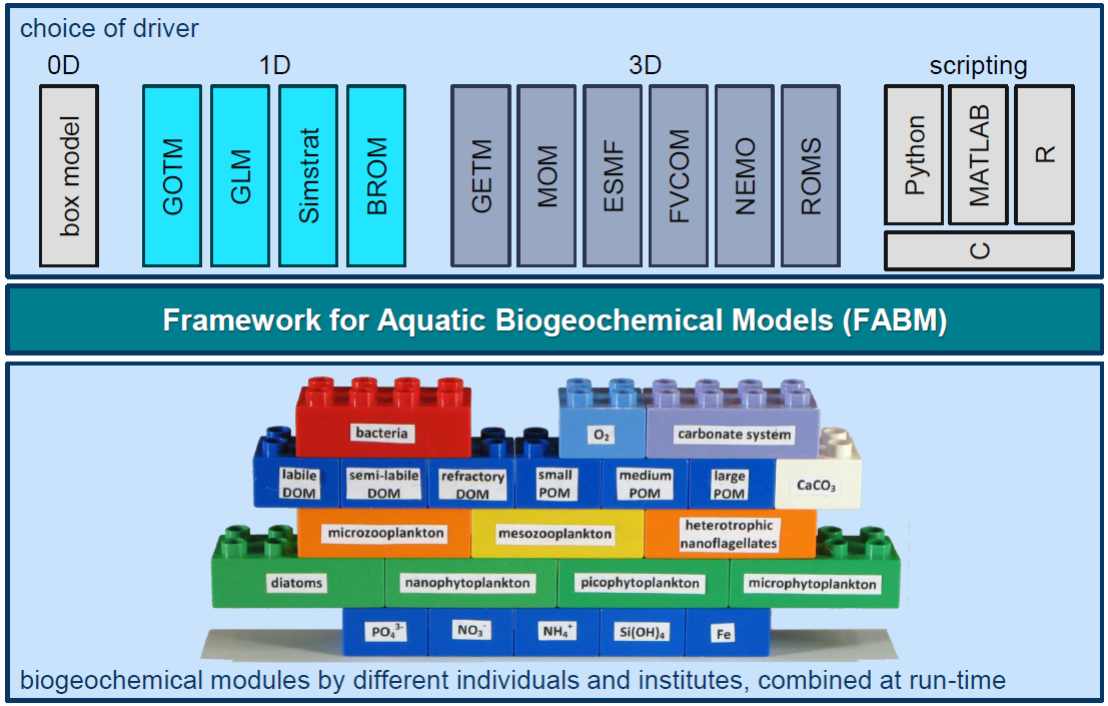
Model variables are passive non-conservative tracers

Model can be forced from:

- the sediment,
- the atmosphere,
- some depth in the water column (injection)

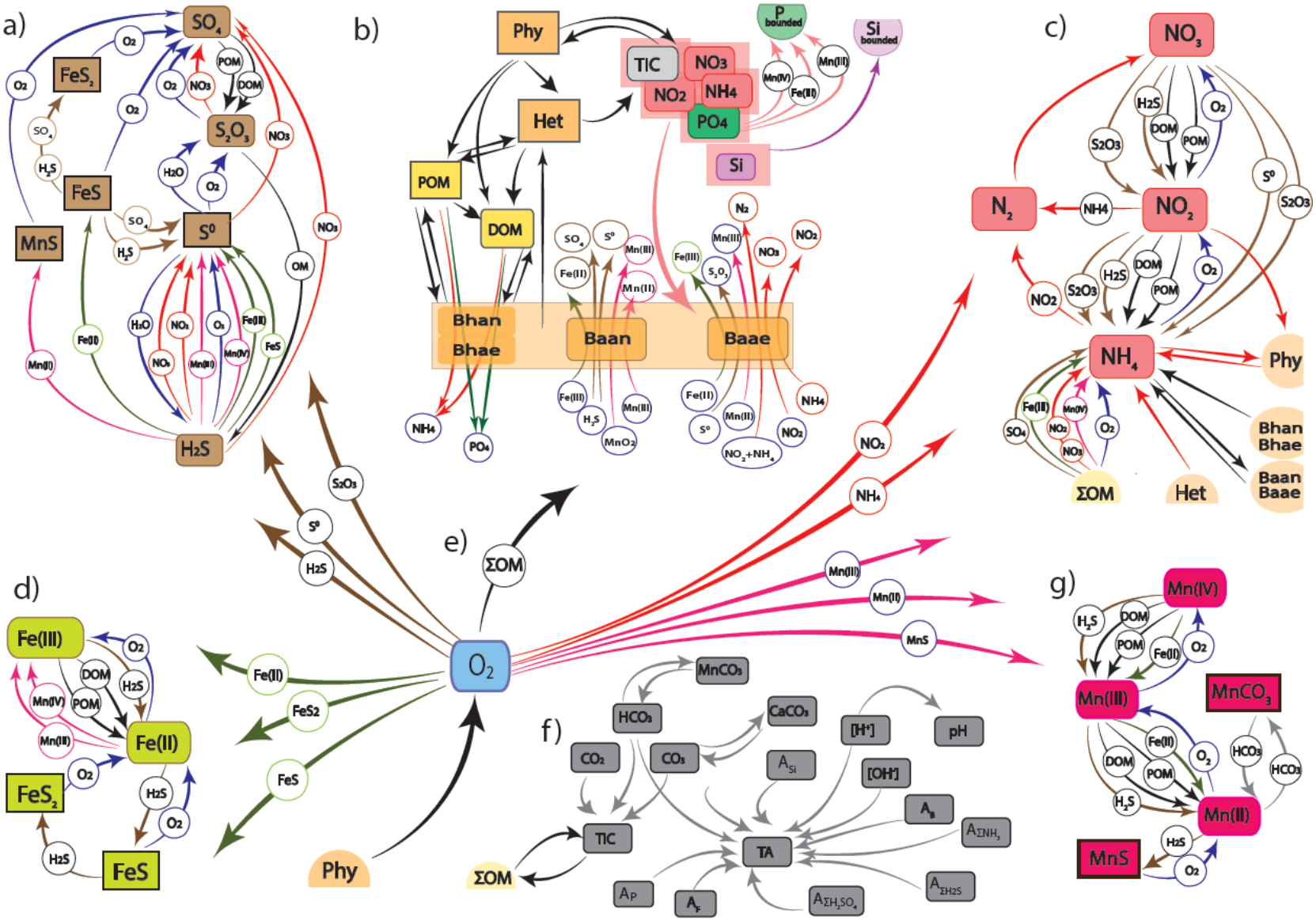
https://github.com/BottomRedoxModel/brom-git

Being a component of the Framework for the Aquatic Biogeochemical Models (FABM), BROM is divided into several modules (i.e. BROM-bio, BROM-nut, BROM-carb, BROM-S, Brom- Mn, BROM_Fe, BROM-bact etc.) that can be independently combined with a wide range of the existing and planning modules



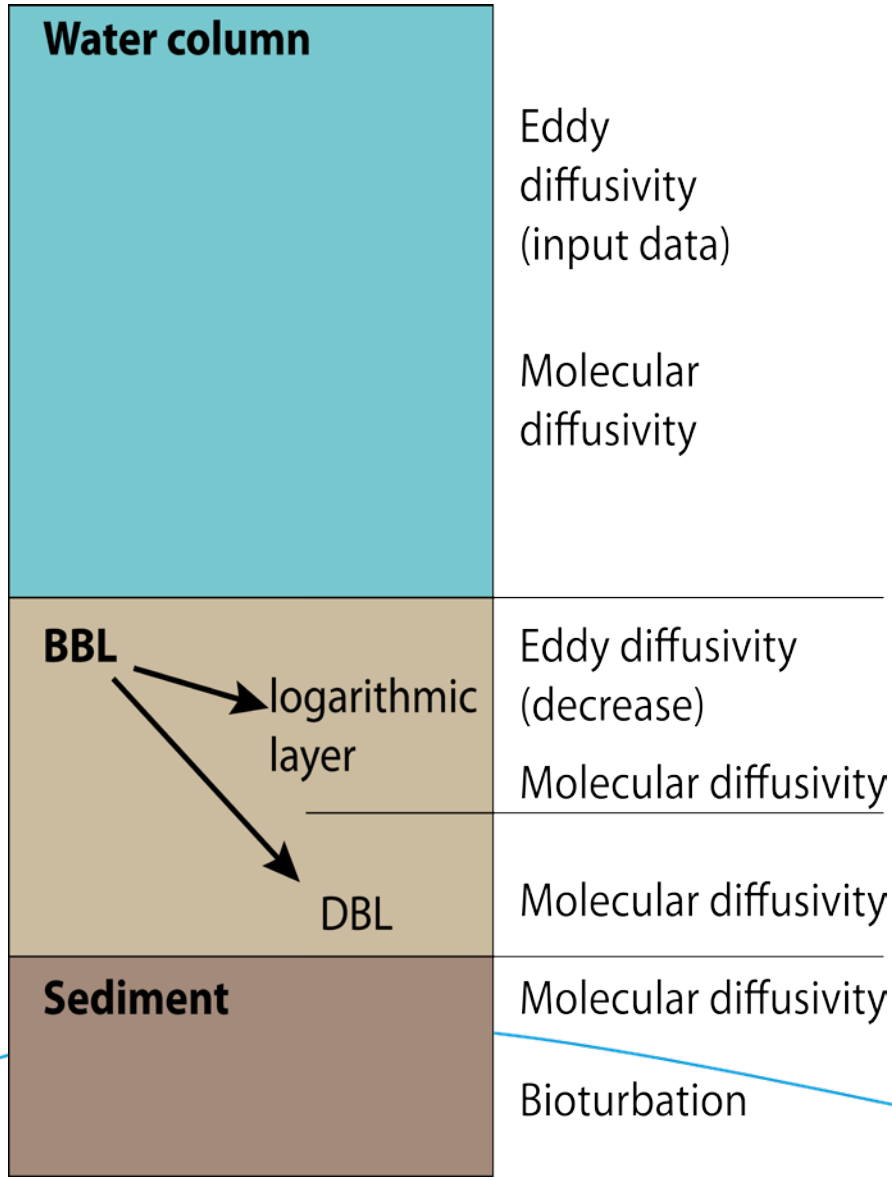
Bruggeman, J. and Bolding, K.: A general framework for aquatic biogeochemical models, Environ. Model. Softw., doi:10.1016/j.envsoft.2014.04.002, 2014.

BROM Biogechemistry



BROM considers interconnected transformations of species of N, P, Si, C, O, S, Mn, and Fe. OM dynamics include parameterizations of OM production (via photosynthesis and chemosynthesis) and OM decay via oxic mineralization, denitrification, metal reduction, sulfate reduction, and methanogenesis.

Model domain



1D vertical transport model
or
2D vertical transport model

16TH INTERNATIONAL CONFERENCE
ON CHEMISTRY AND THE ENVIRONMENT

Modeling influence of a fish farm at water column and sediment biogeochemistry with a 2-Dimensional Benthic-Pelagic model

Evgeniy Yakushev, Elizaveta Protsenko and Philip Wallhead

Oslo, June 19-21, 2017

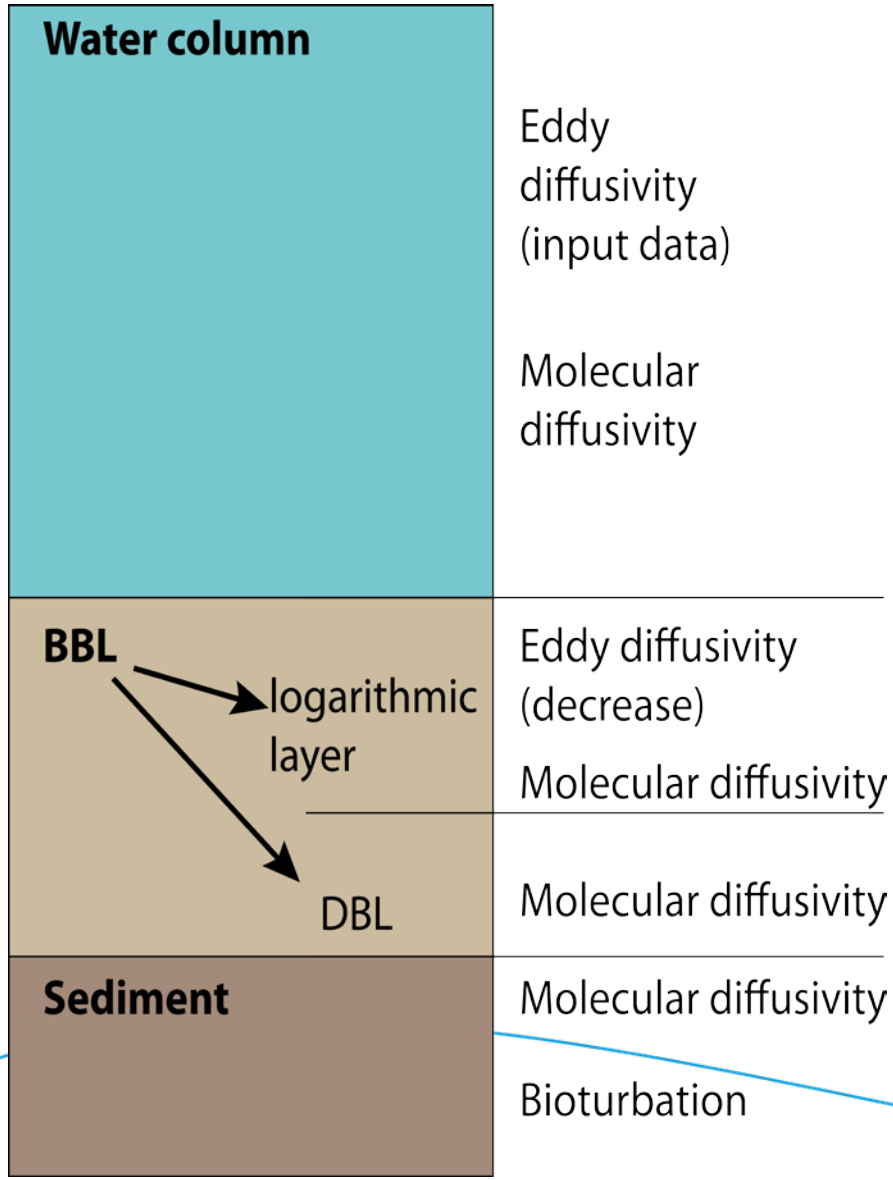
Objectives:

Develop and configure a model to simulate the effects of fish farm organic loadings in a 10 m – 100 m horizontal scale

Optimize model using experimental results and archive data.

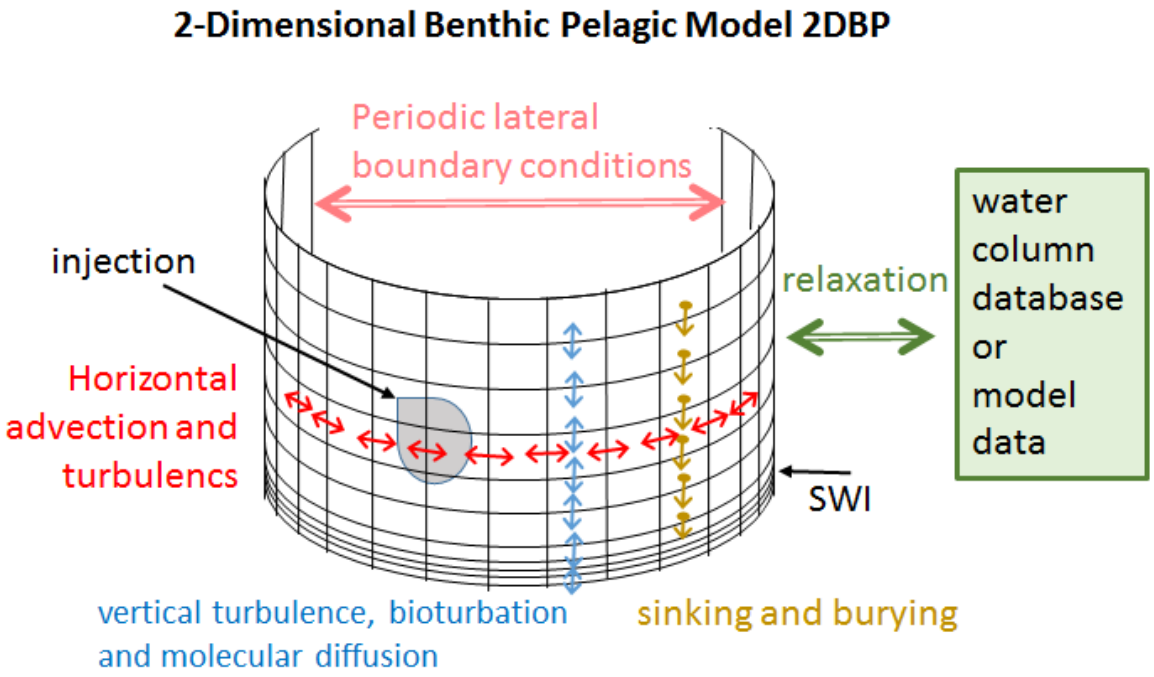
Quantify the effects of organic loading from fish farming on water column and sediment biogeochemistry.

Model domain



1D vertical transport model
or
2D vertical transport model

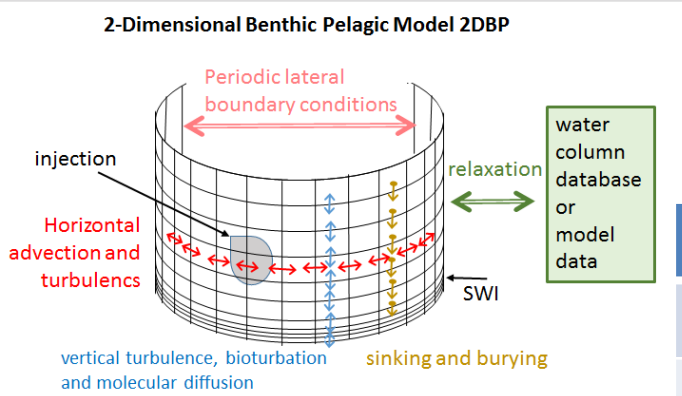
BROM-transport -> 2DBP



The vertical 2-Dimensional Benthic-Pelagic model 2DBP aims to study small scale horizontal effects in the water column and the sediments biogeochemistry (Fig.). This model domain covers water column and upper cms of the sediments with the changeable vertical resolution. The processes of horizontal advection, horizontal turbulence, vertical turbulence, sinking of particles and burying are parameterized. The model can be relaxated to the data from a data base or another model.

In this work the 2DBP was forced by results of calculations of the seasonal variability of temperature, salinity,
vertical turbulence, irradiance and advection components calculated with ROMS. We parameterized horizontally uniform rate of current along the transect, and the left boundary of the model domain was linked to the right boundary.

Model parameters



Water column

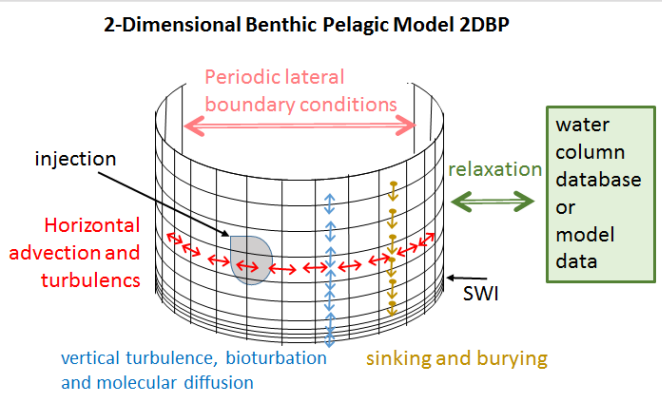
BBL

Sediment

```
k   z[k] dz[k] hz[k]
 1   0.0000 _o_   3.0000
 1 ===   3.0000 ===
 2   3.0000 _o_   5.0000
 2 ===   7.0000 ===
 3  10.0000 _o_   6.0000
 3 ===   5.0000 ===
 4  15.0000 _o_   7.5000
 4 ===  10.0000 ===
 5  25.0000 _o_  17.5000
 5 ===  25.0000 ===
 6  50.0000 _o_  25.0000
 6 ===  25.0000 ===
 7  75.0000 _o_  25.0000
 7 ===  25.0000 ===
 8 100.0000 _o_  37.5000
 8 ===  50.0000 ===
 9 150.0000 _o_  50.0000
 9 ===  50.0000 ===
10 200.0000 _o_  50.0000
10 ===  50.0000 ===
11 250.0000 _o_  50.0000
11 ===  49.7500 ===
12 299.7500 _o_  24.5000
12 ===  12.3929 ===
13 312.1429 _o_   0.2857
13 ===   0.2143 ===
14 312.3571 _o_   0.1429
14 ===   0.1059 ===
15 312.4630 _o_   0.0689
15 ===   0.0357 ===
16 312.4988 _o_   0.0025
16 ===   0.0025 ===
17 312.5013 _o_   0.0025
17 ===   0.0037 ===
18 312.5050 _o_   0.0050
18 ===   0.0075 ===
19 312.5125 _o_   0.0100
19 ===   0.0150 ===
20 312.5275 _o_   0.0200
20 ===   0.0200 ===
21 312.5475 _o_   0.0200
21 ===   0.0200 ===
22 312.5675 _o_   0.0200
22 ===   0.0200 ===
23 312.5875 _o_   0.0200
23 ===   0.0000 ===
```

ROMS	Forcing for hydrophysics
Observarions in VIII.2016	Low boundary
DB Copernucus	Relaxation to climatic data
1.55 kgC/m2/(15 days), (Corner et al., 2006)	POM injection (5 mmolN/sec for 22m cage diameter)
25 m	Horizontal resolution
3-50 m	Vertical resolution(water)
3-21 cm	Vertical resolution(BBL)
0.25-2 cm	Vertical resolution(BBL)

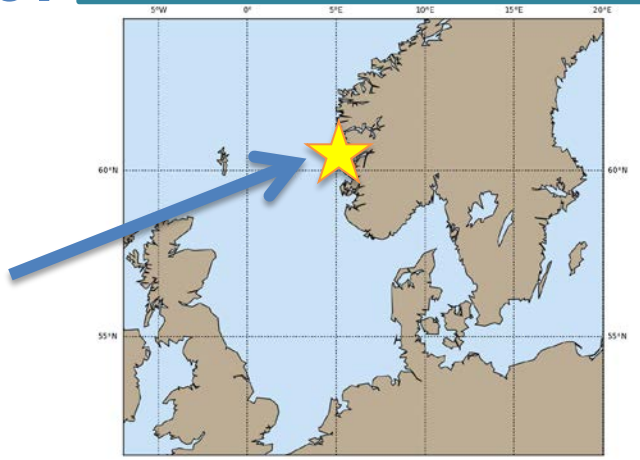
Model parameters

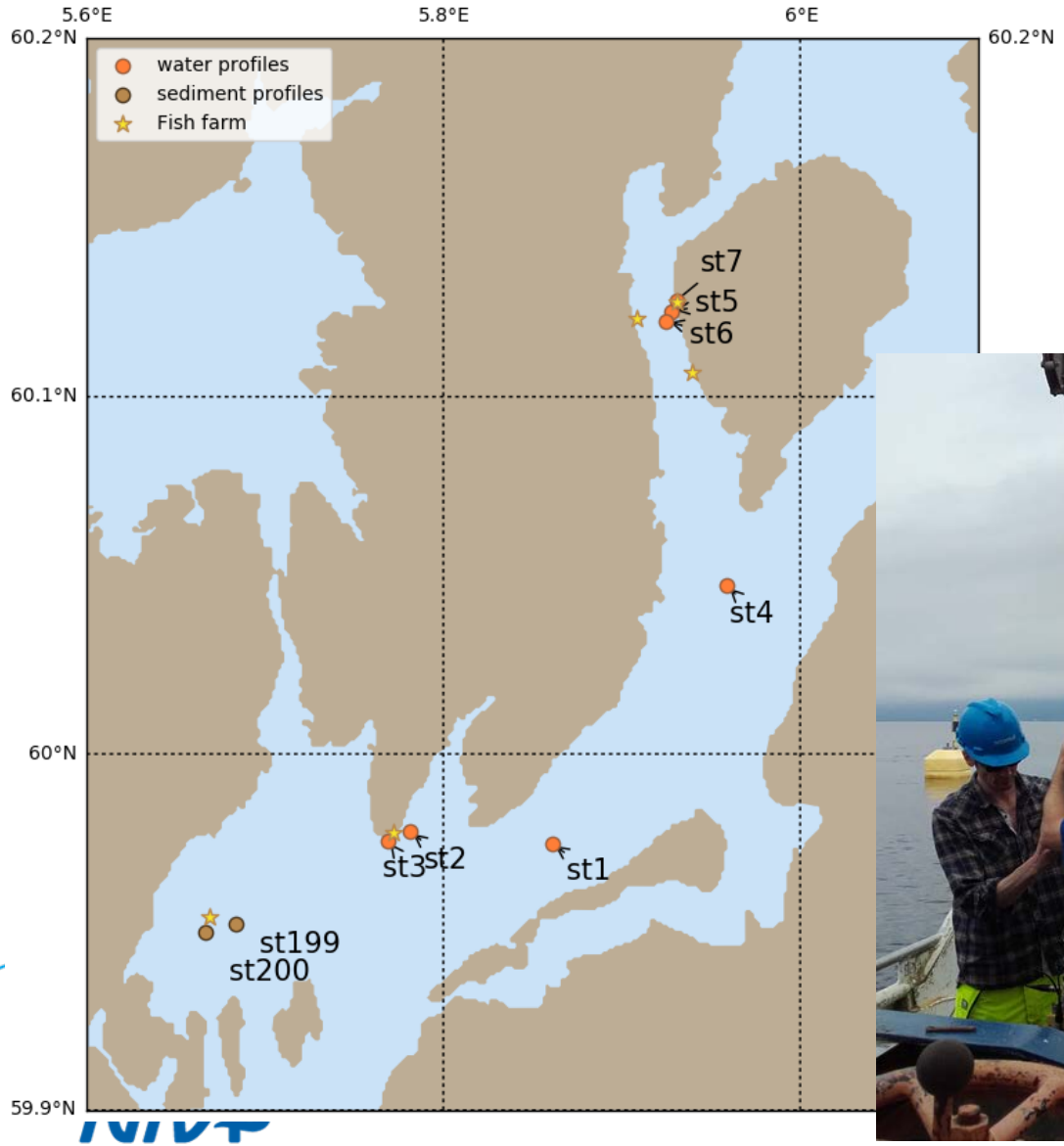


Forcing for hydrophysics	ROMS
Low boundary	Observarions in VIII.2016
Relaxation to climatic data	DB Copernucus
POM injection	1.55 kgC/m2/(15 days), (Corner et al., 2006), i.e. 5 mmolN/sec for 22m cage diameter
Horizontal resolution (31 columns)	25 m
Vertical resolution(water)	3-50 m
Vertical resolution(BBL)	3-21 cm
Vertical resolution(BBL)	0.25-2 cm

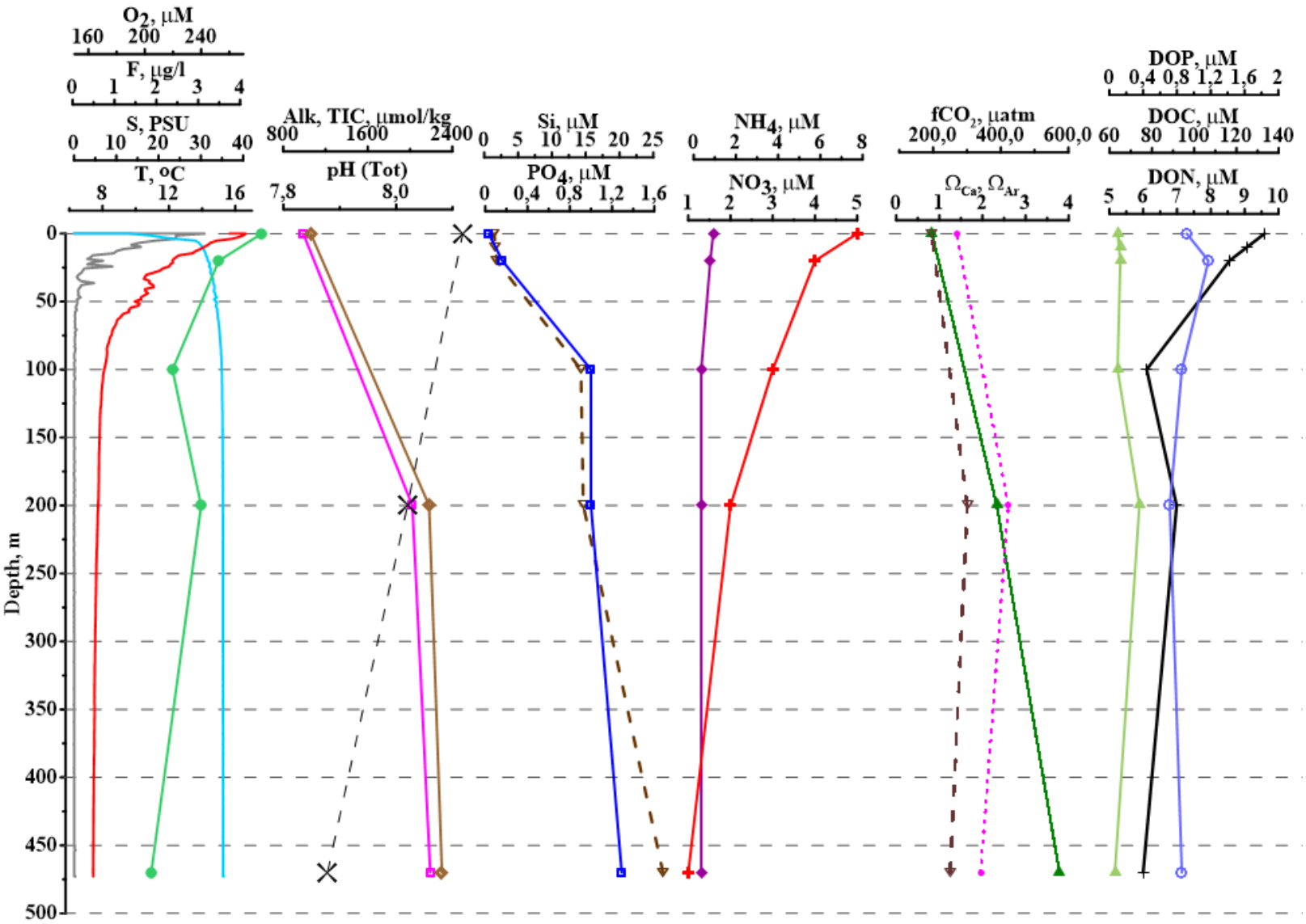
Haradangerfjord 25-27.08.2016:

OBSERVATIONS



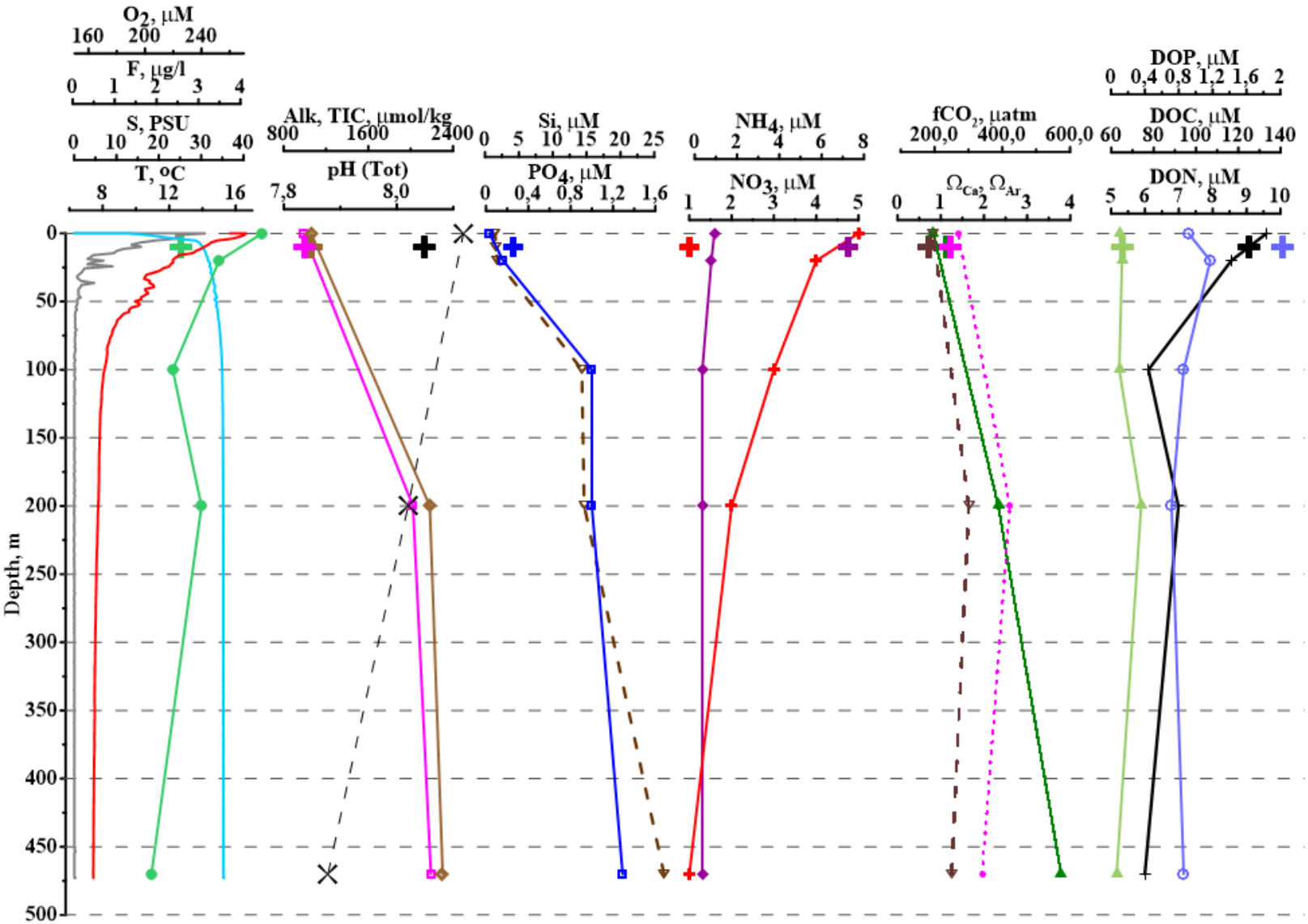


Water column



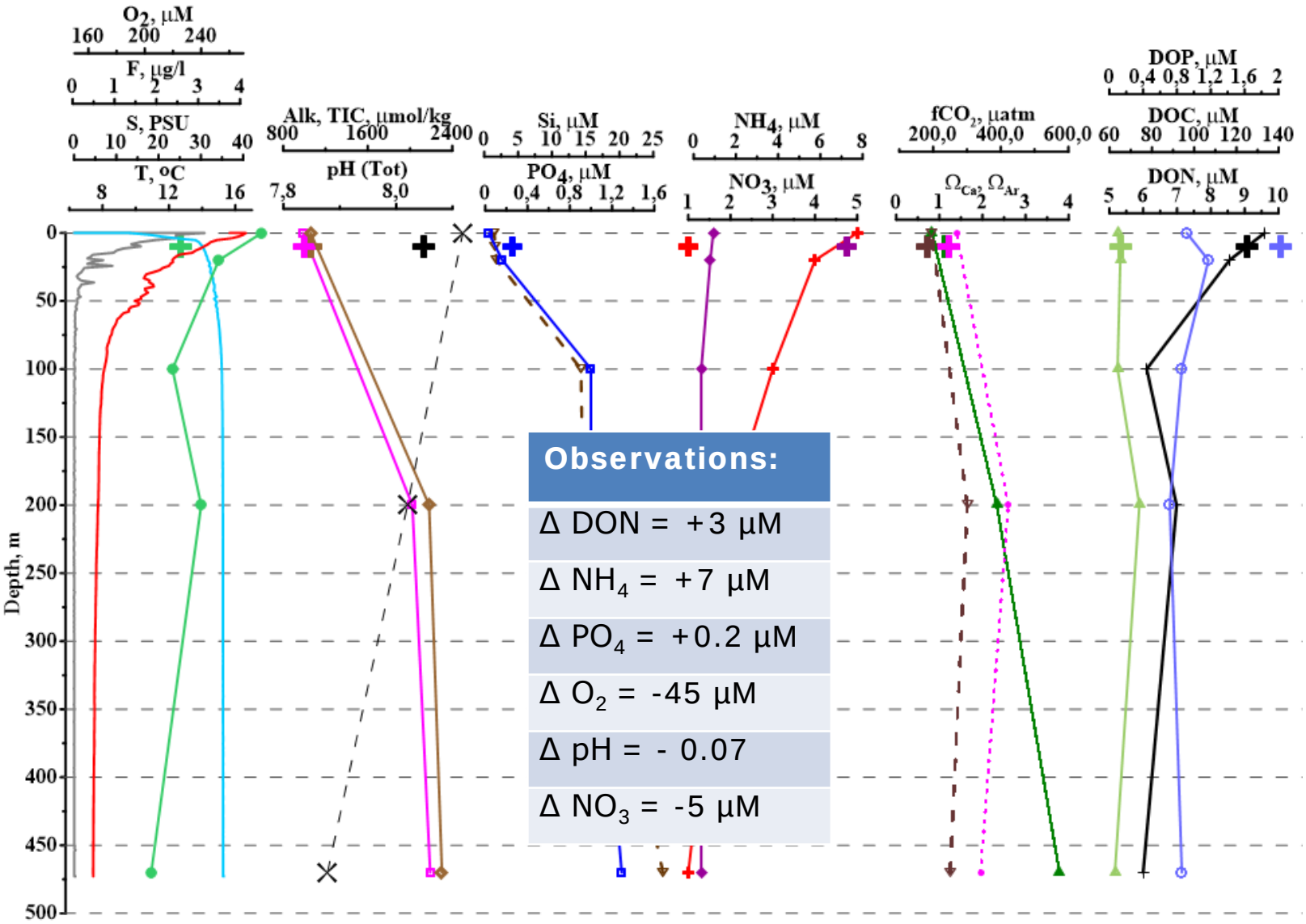
Vertical distributions of the physical and chemical parameters at a station at 500 m from the farm and at ~20 m from the farm.

Water column



Vertical distributions of the physical and chemical parameters at a station at 500 m from the farm and at ~20 m from the farm.

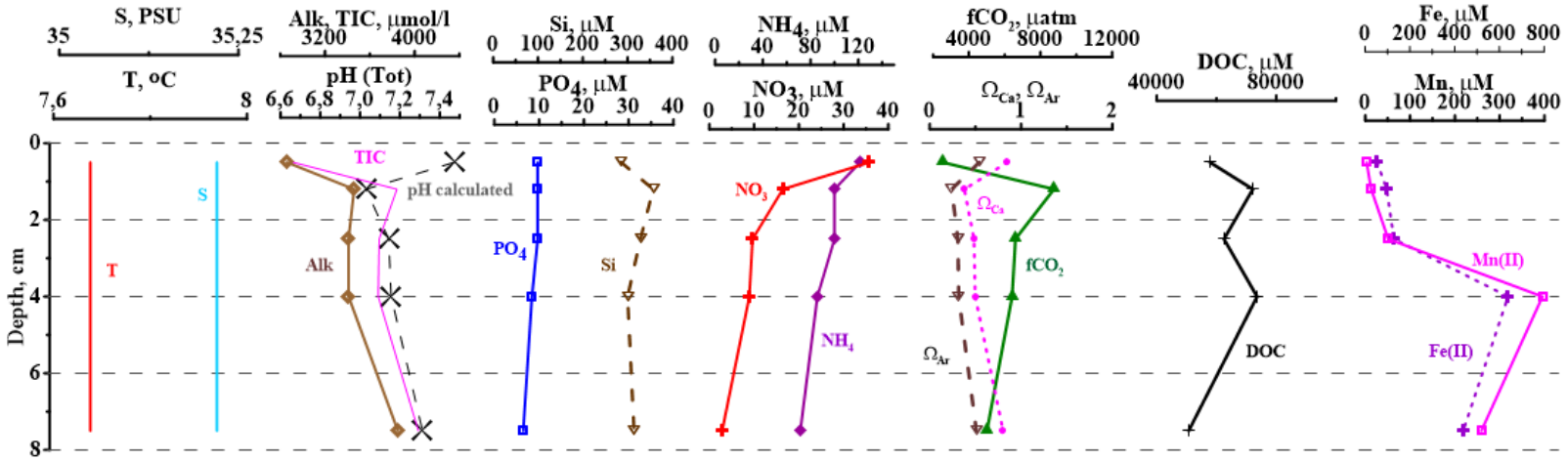
Water column



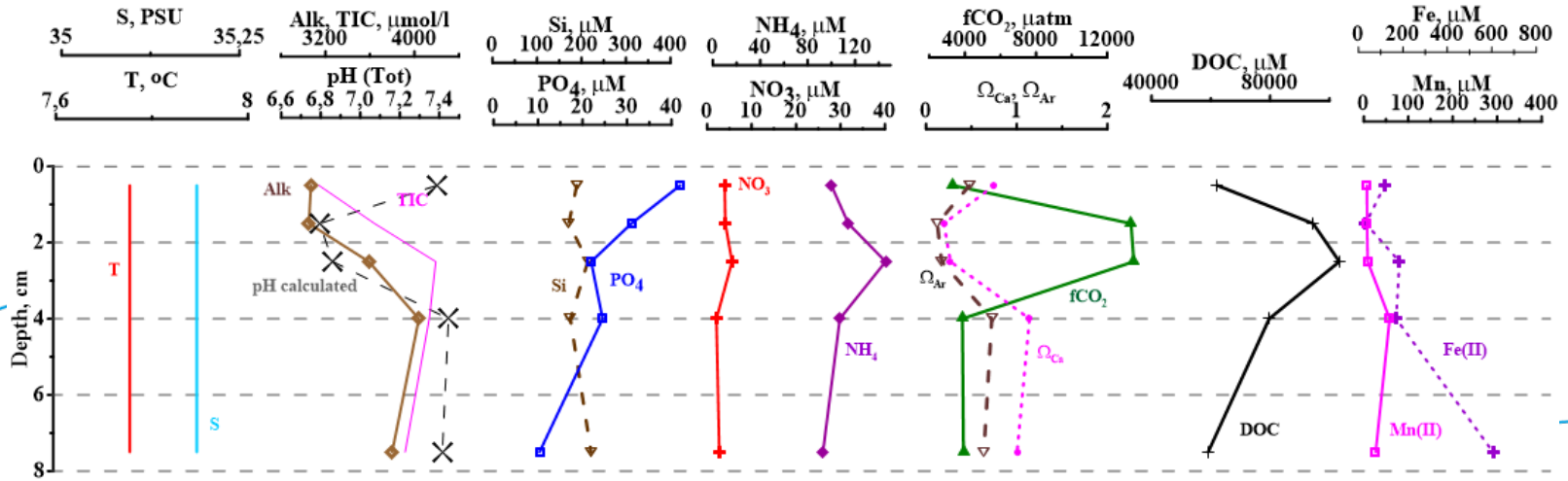
Observations:
Δ DON = +3 µM
Δ NH_4 = +7 µM
Δ PO_4 = +0.2 µM
Δ O_2 = -45 µM
Δ pH = - 0.07
Δ NO_3 = -5 µM

Vertical distributions of the physical and chemical parameters at a station at 500 m from the farm and at ~20 m from the farm.

Sediments

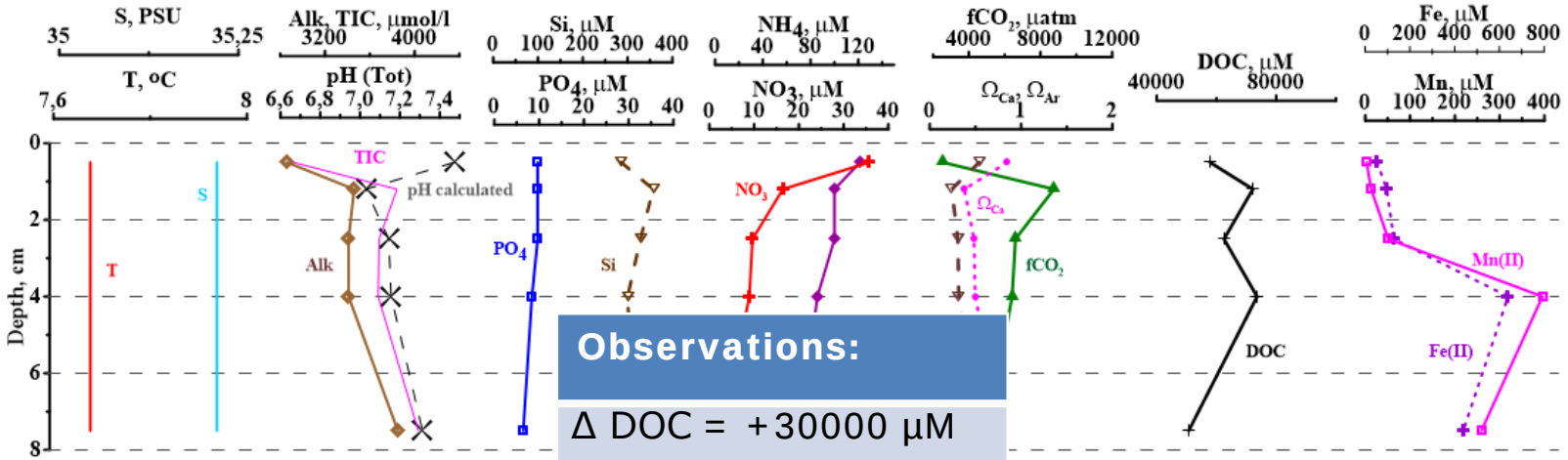


500 m from Farm



30 m from Farm

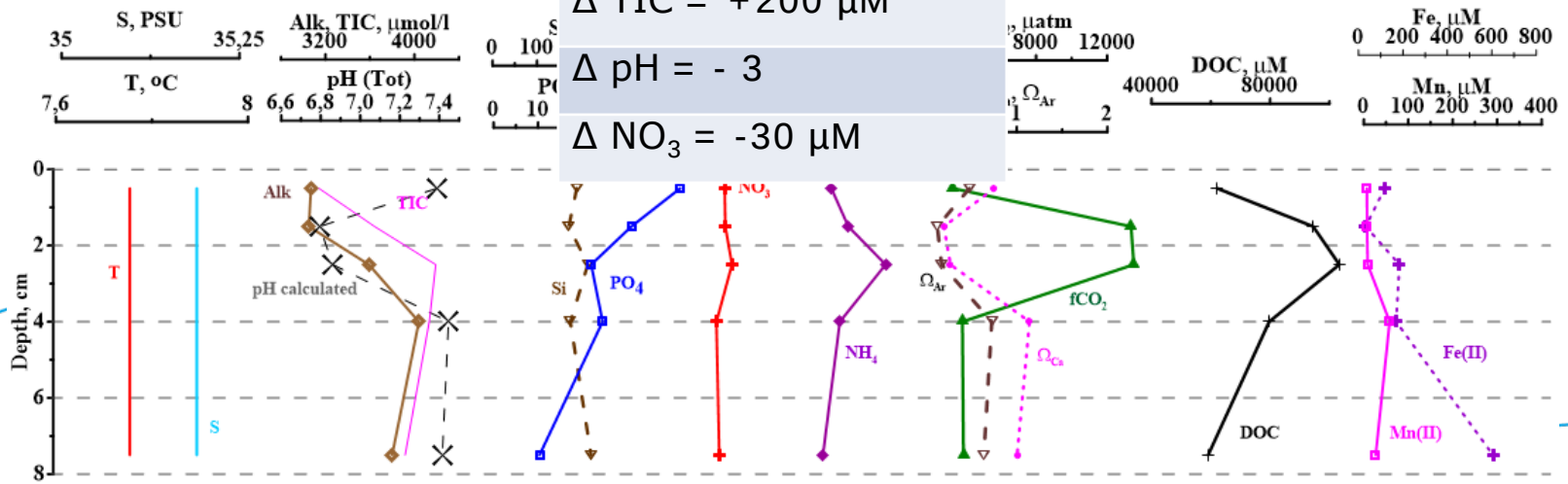
Sediments



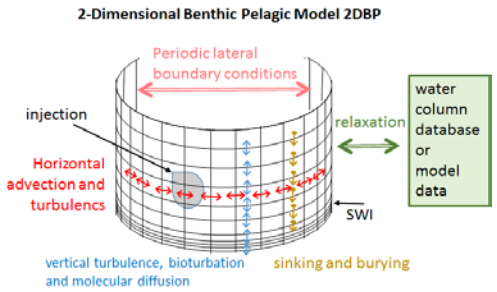
Observations:

- Δ DOC = +30000 µM
- Δ NH_4 = +15 µM
- Δ PO_4 = +30 µM
- Δ TIC = +200 µM
- Δ pH = - 3
- Δ NO_3 = -30 µM

500 m from Farm



30 m from Farm



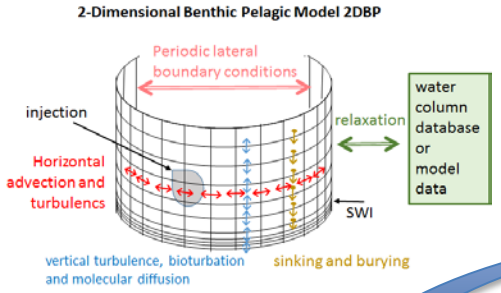
1. Baseline seasonality («Spin-up period»)

2. Validation against the observarions data.

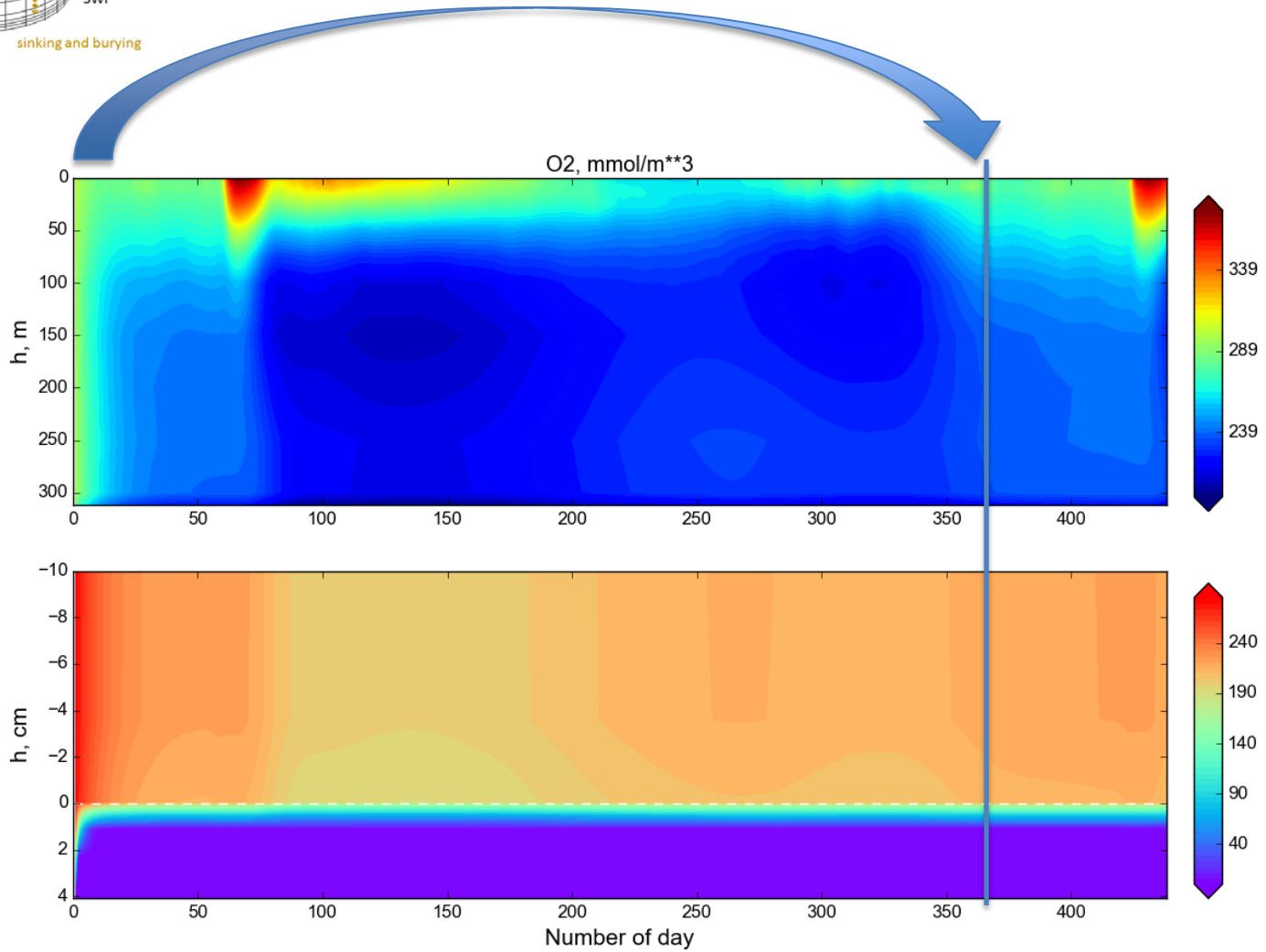
3. Numerical experiments

1. Spin-up

RESULTS

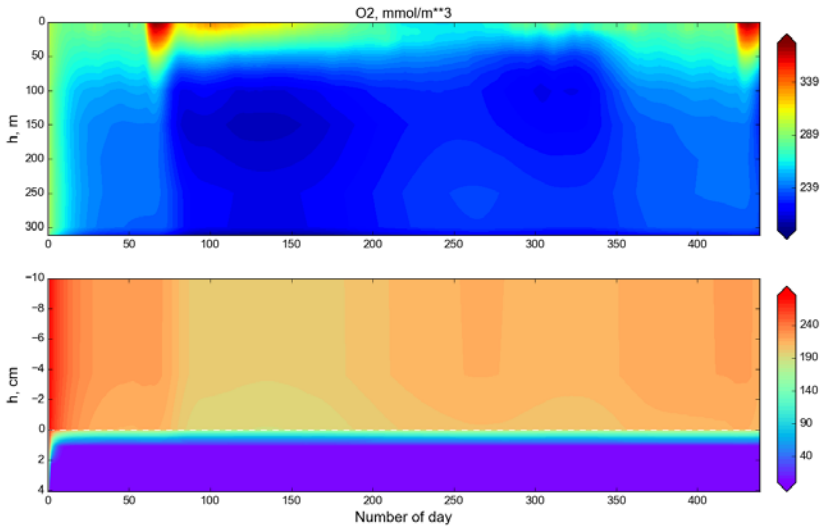


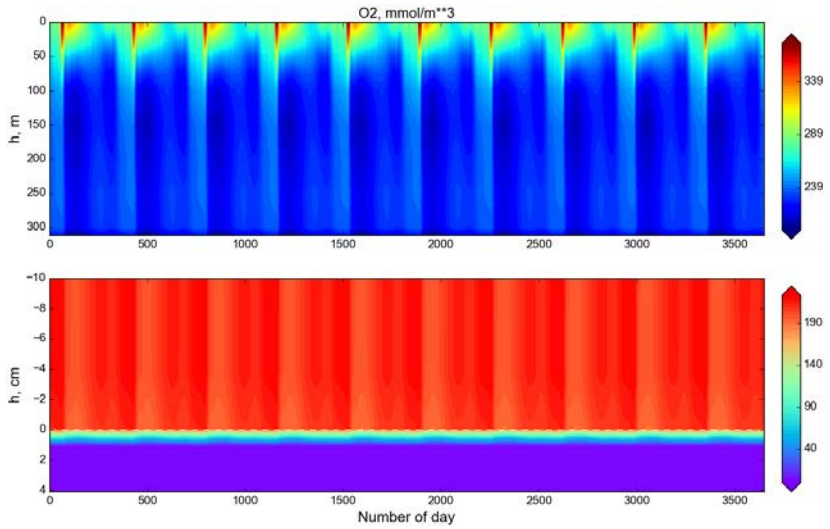
Initial conditions

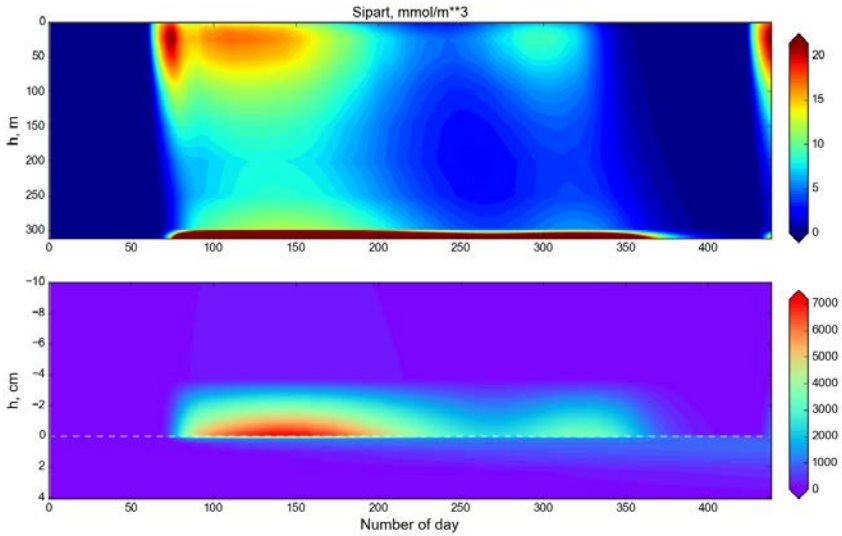


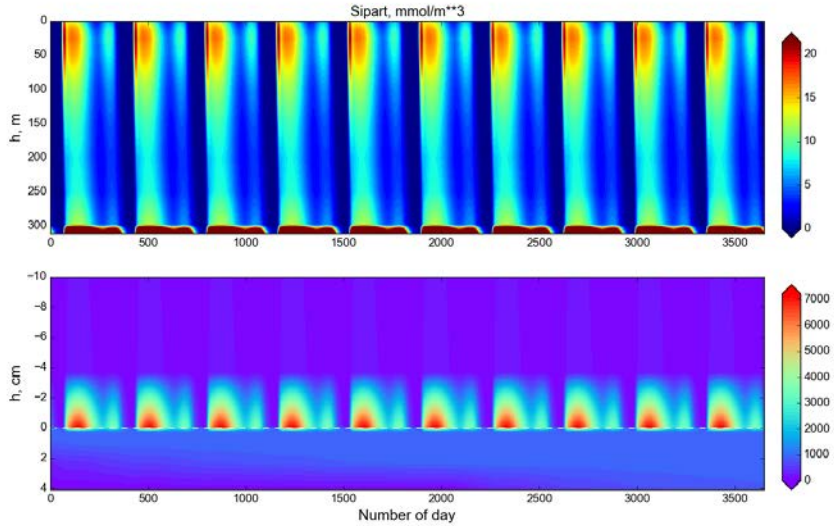
1. Spin-up

RESULTS





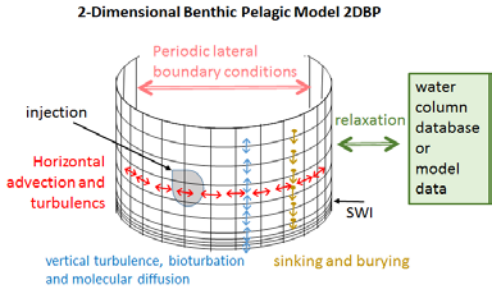


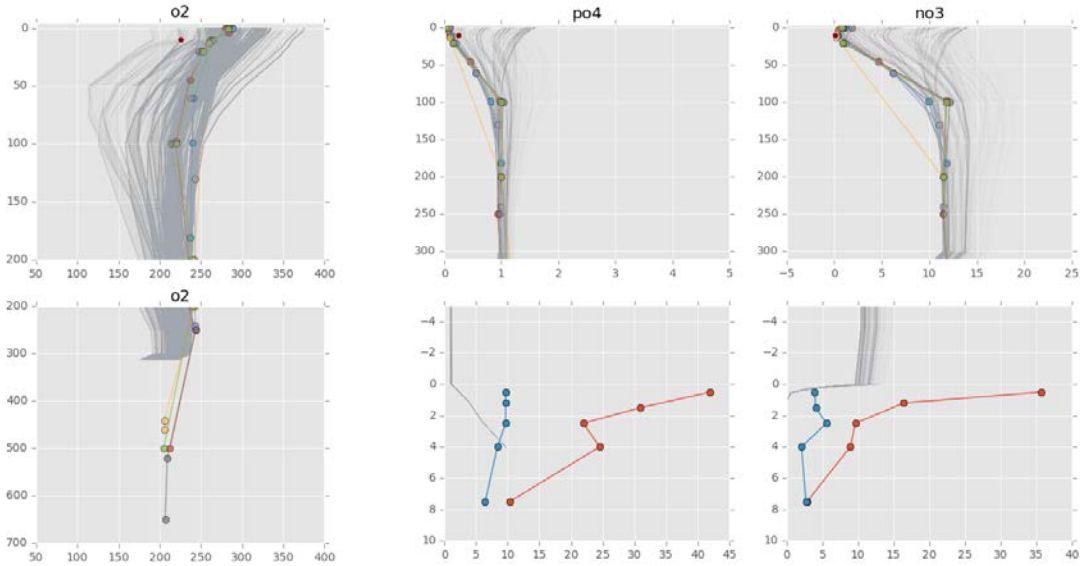


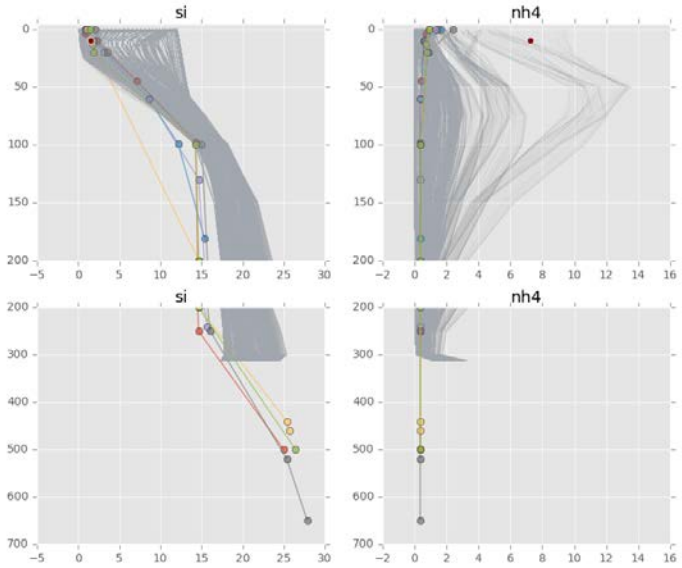
Baseline seasonality reached after ~20yr «Spin-up period»

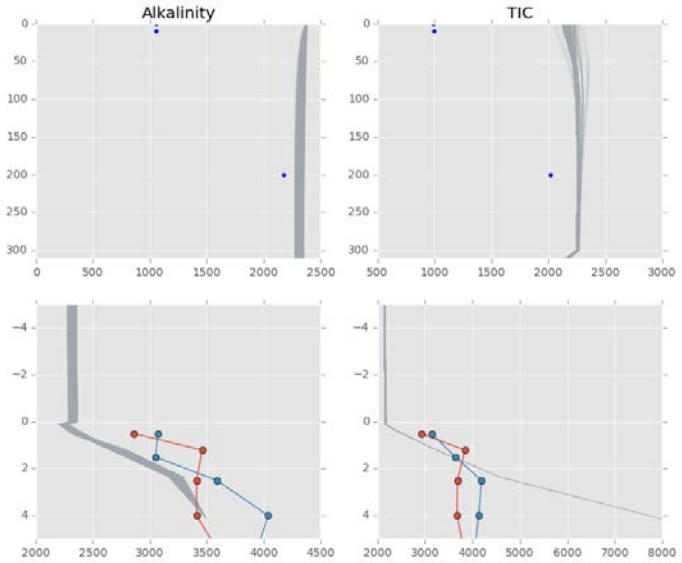
2. Validation

RESULTS





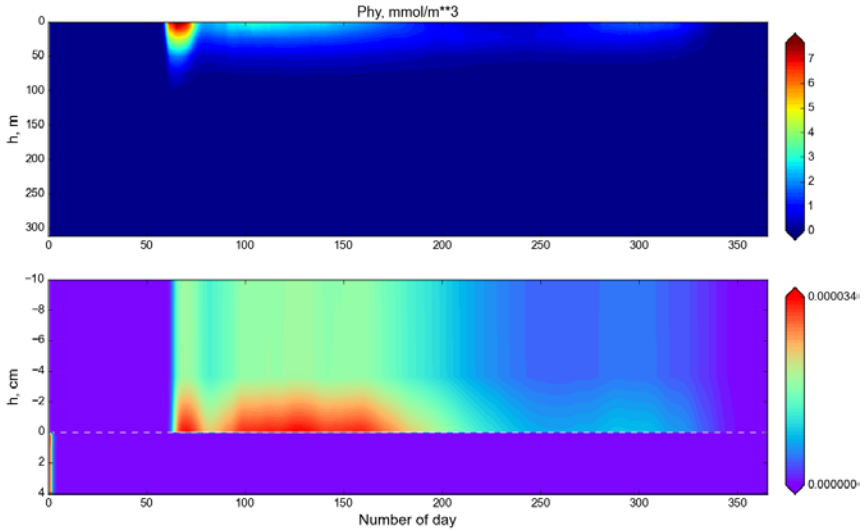


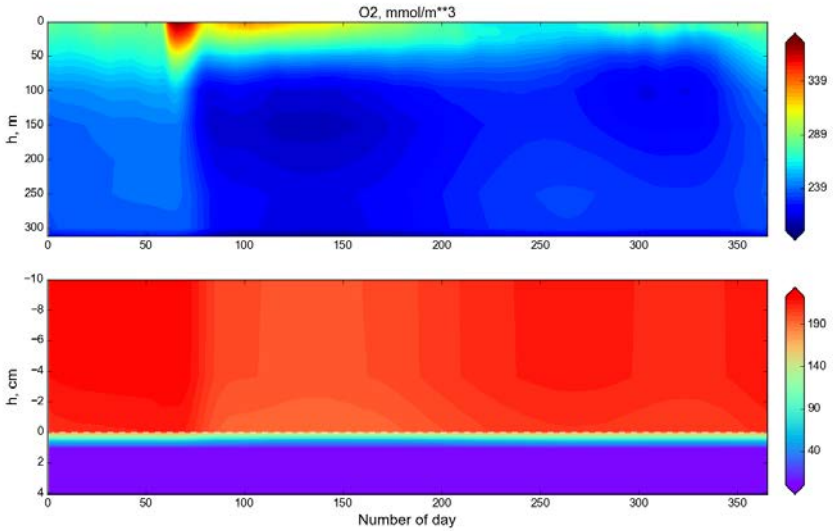


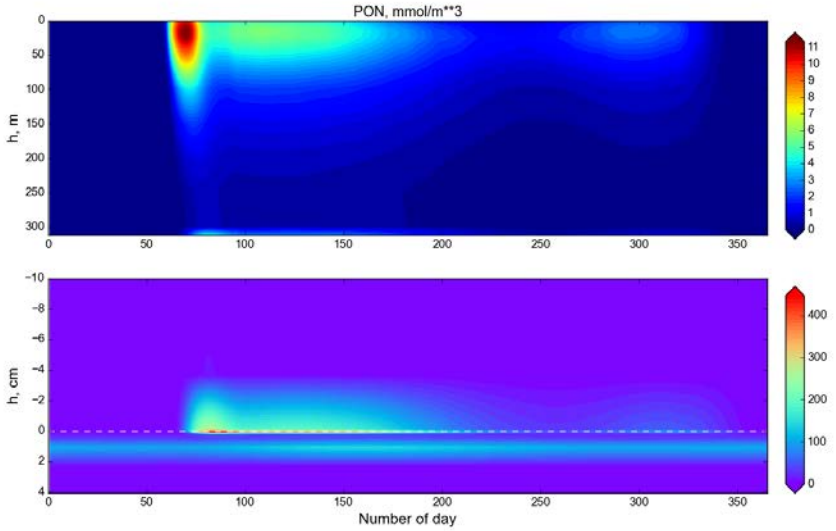
3. Experiments:

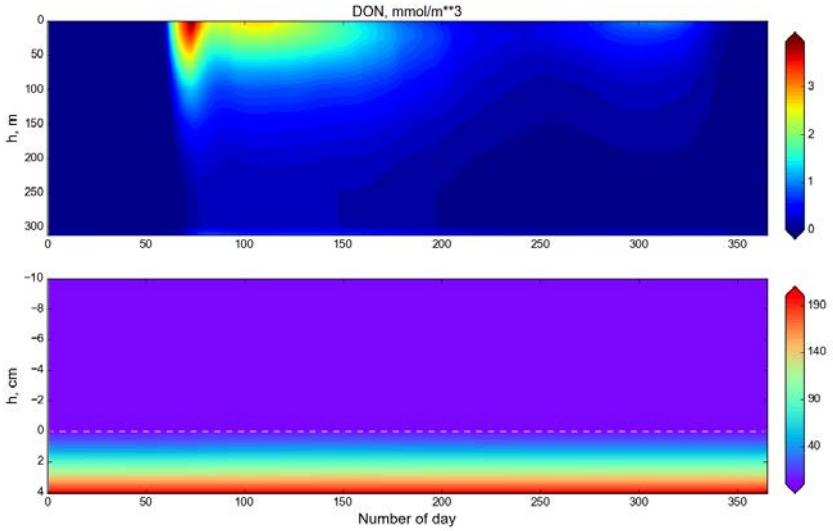
RESULTS

Natural variability





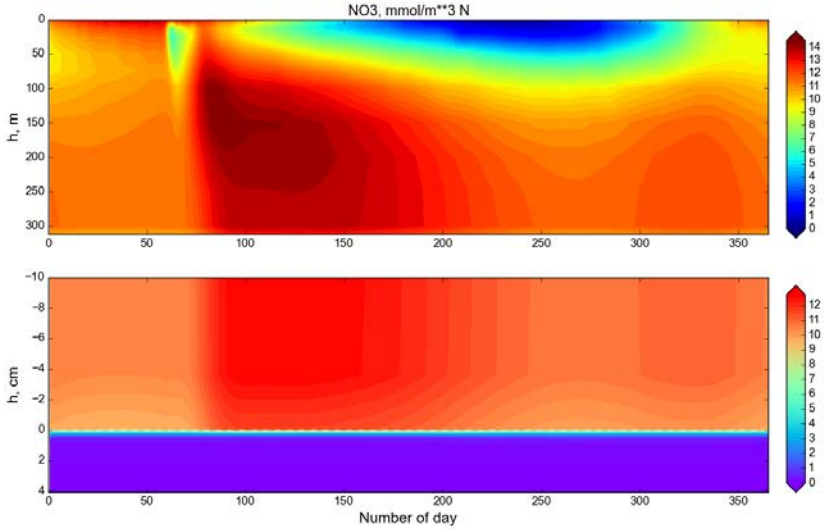


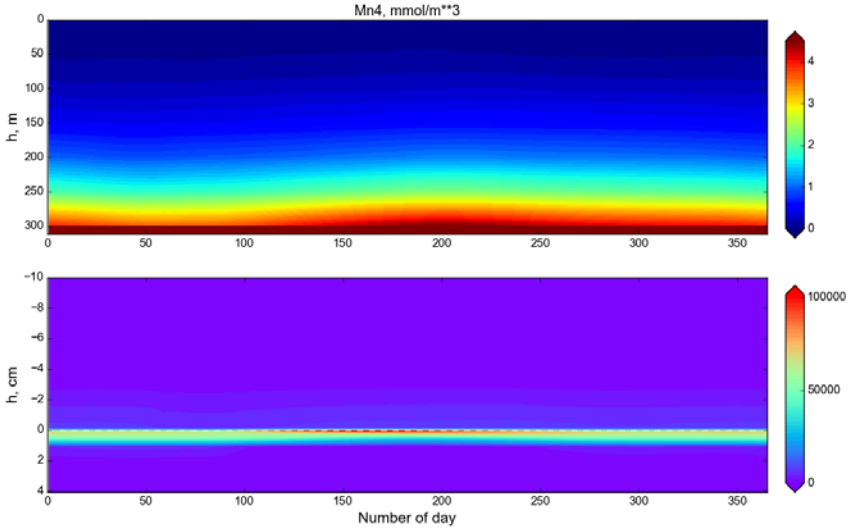


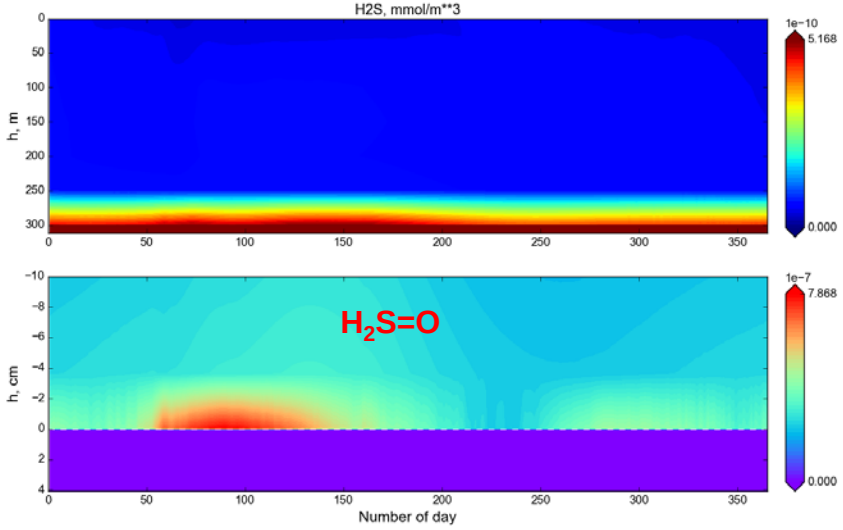
3. Experiments:

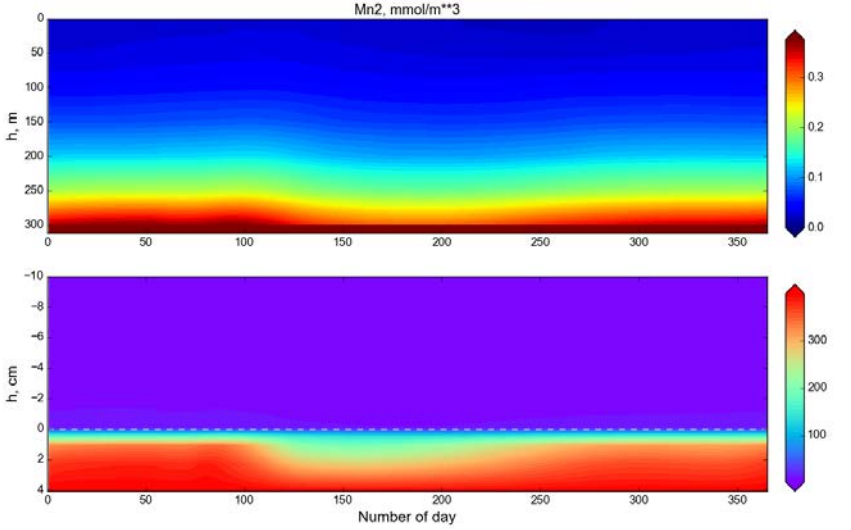
RESULTS

Natural variability





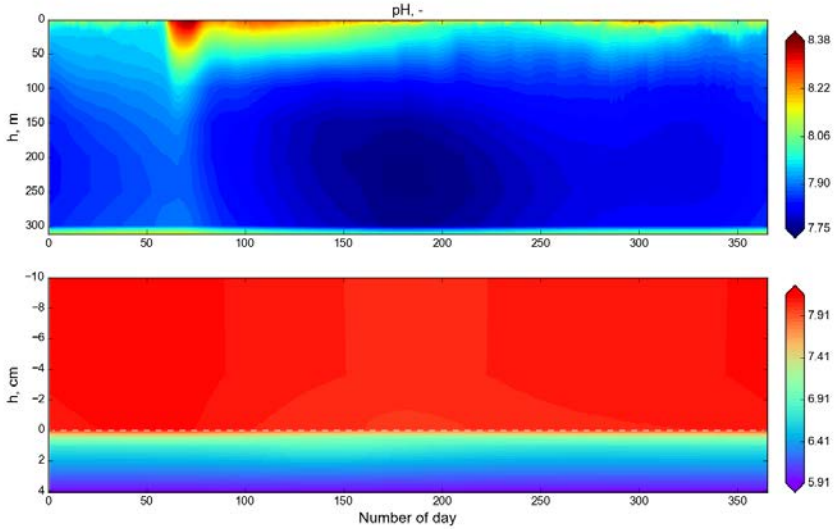


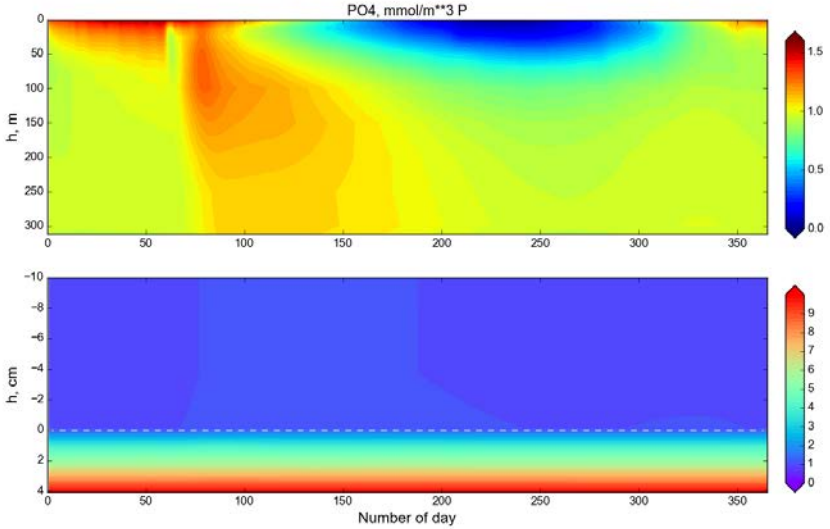


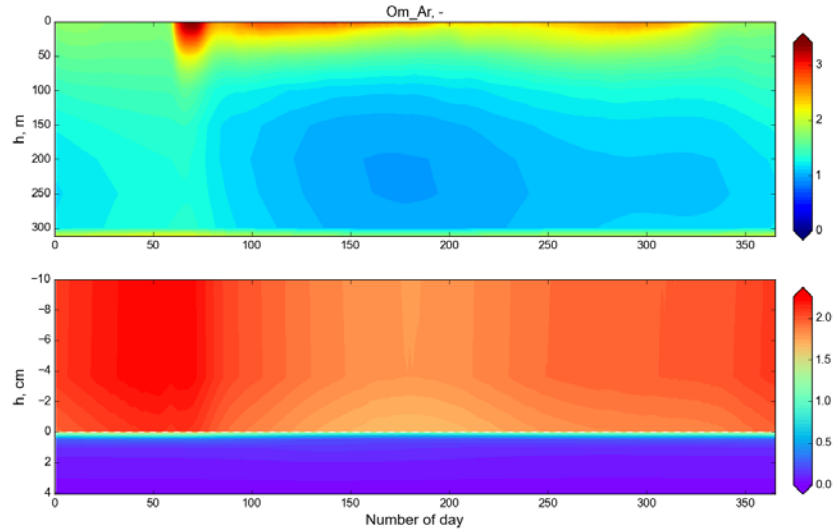
3. Experiments:

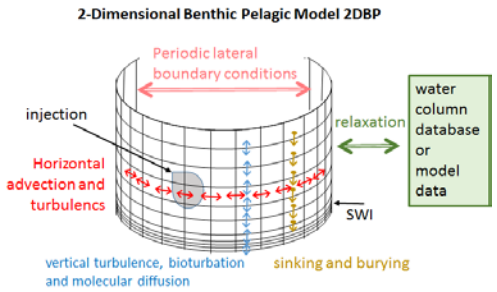
RESULTS

Natural variability





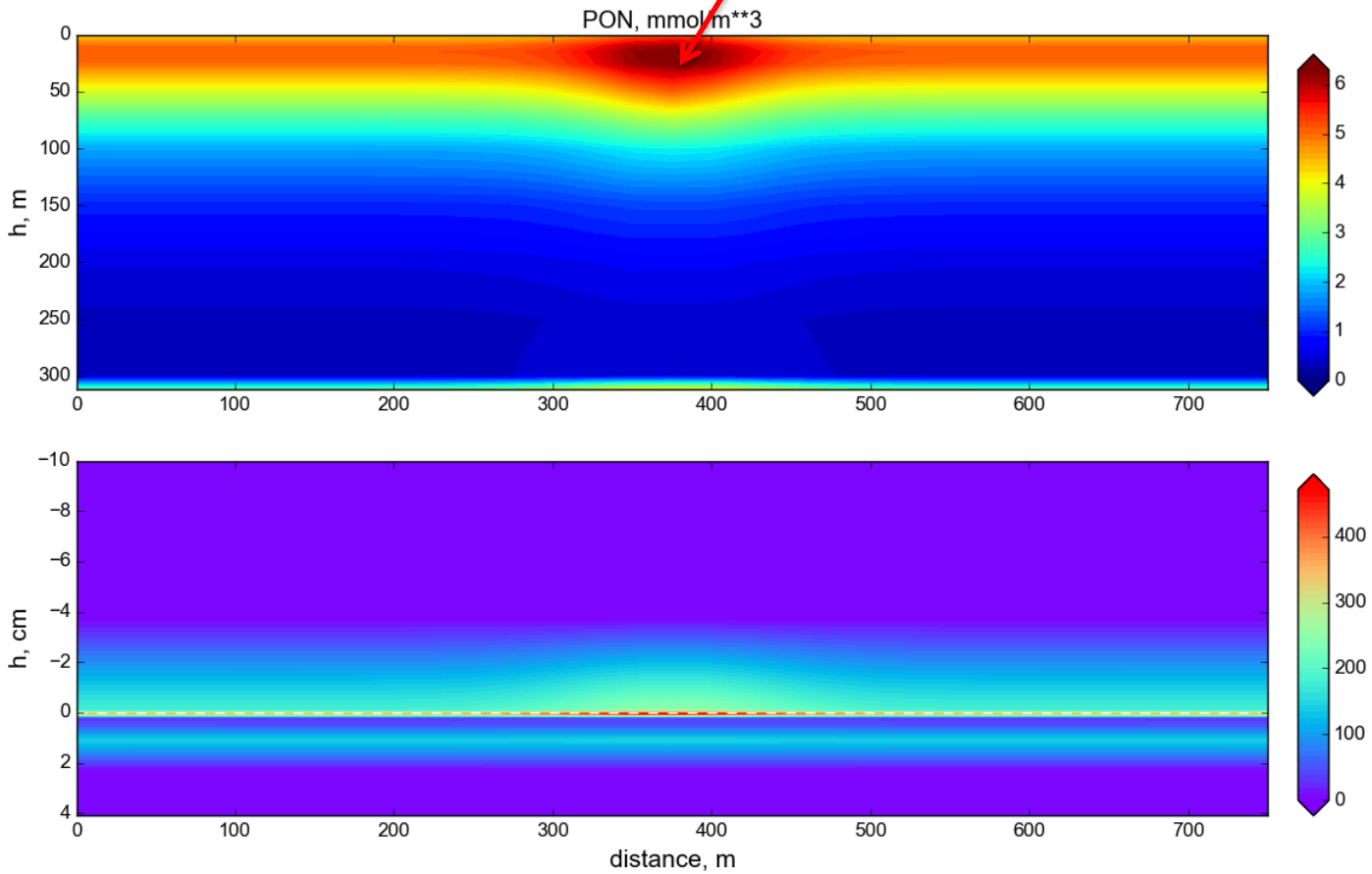




3. Numerical Experiments

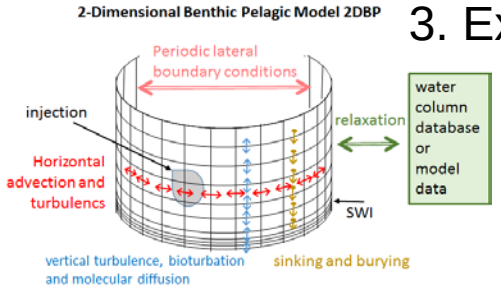
RESULTS

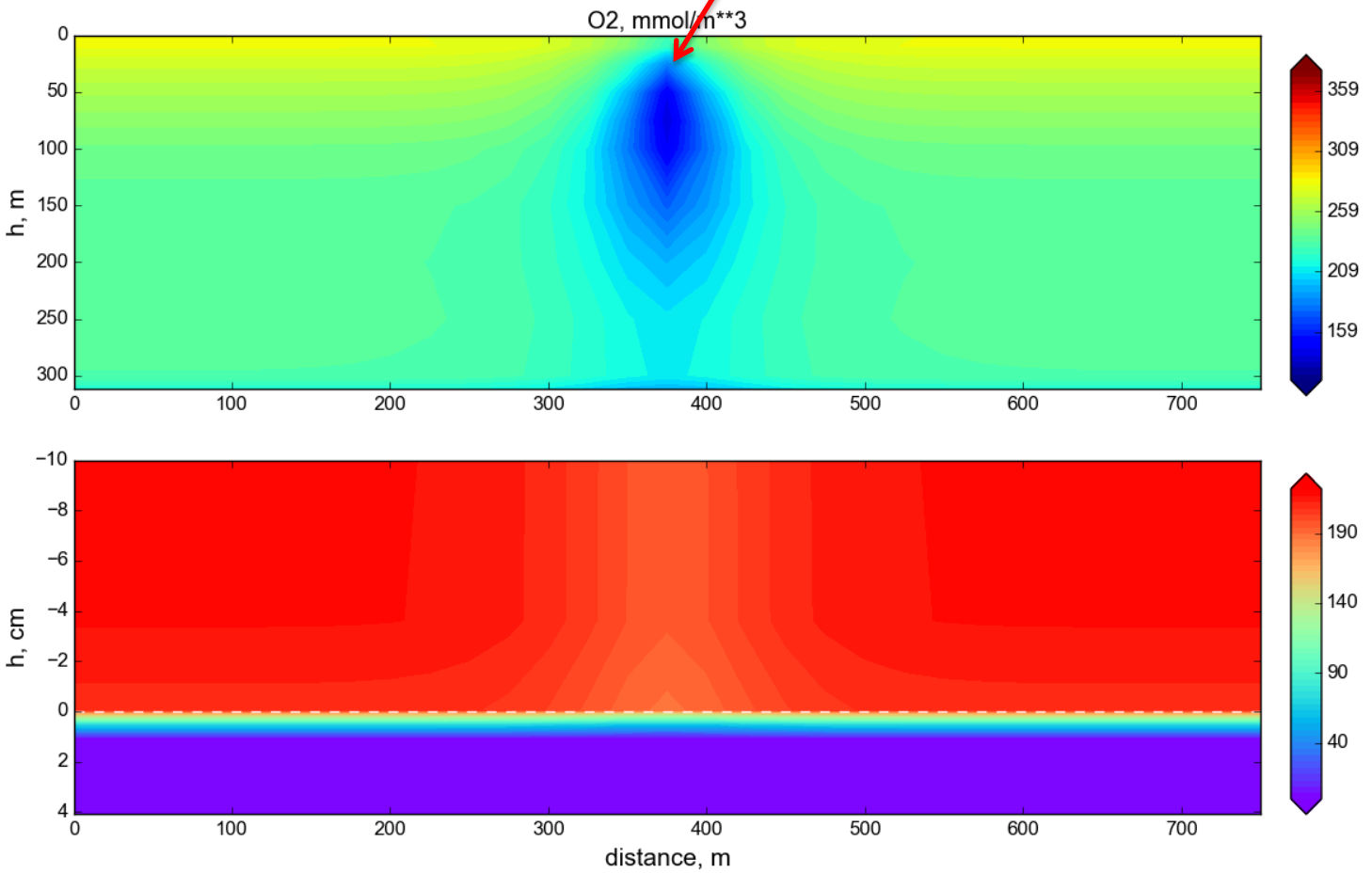
Injection of POM in 25 m wide column at 50 m (5 mmolN/sec)



Distributions along the transect. Day=140

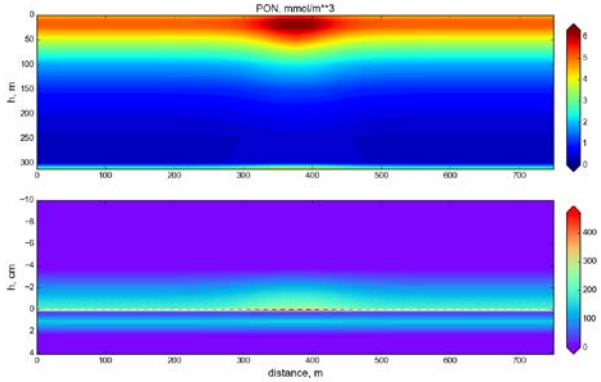
3. Experiments: 1 X farm

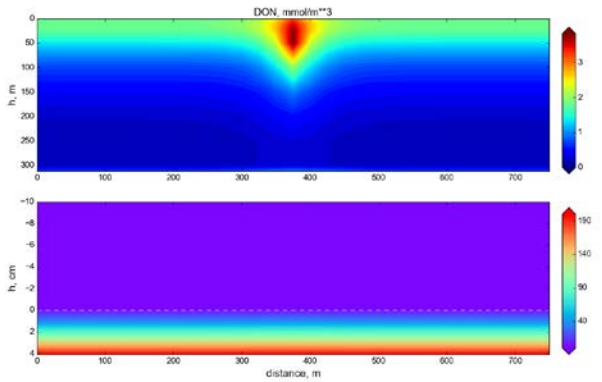


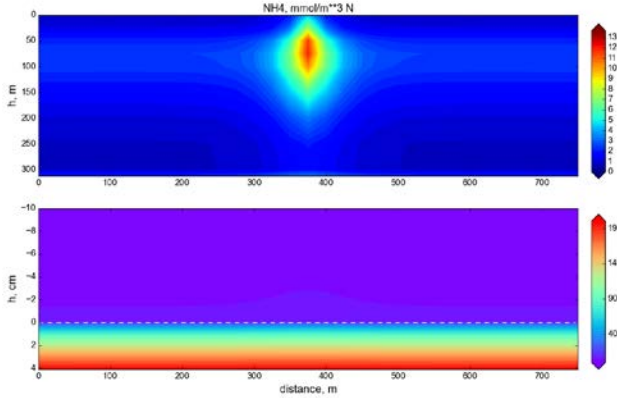


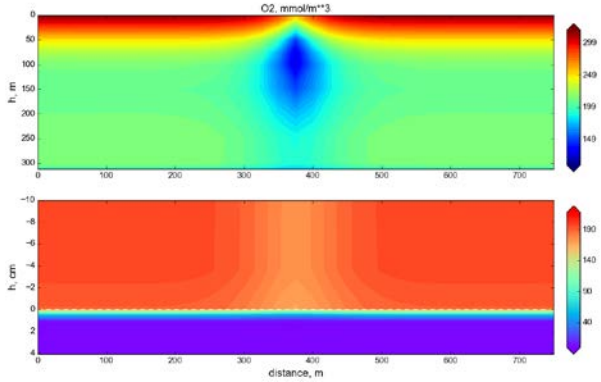
3. Experiments: 1 X farm

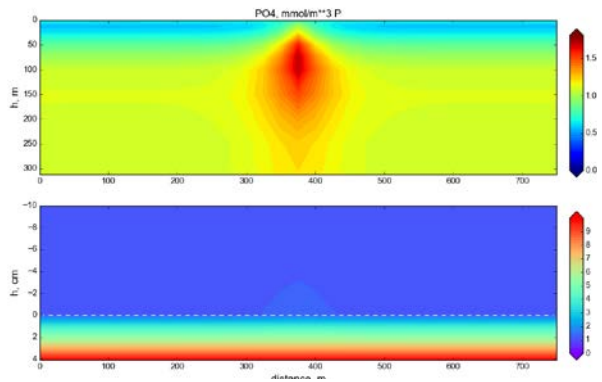
RESULTS

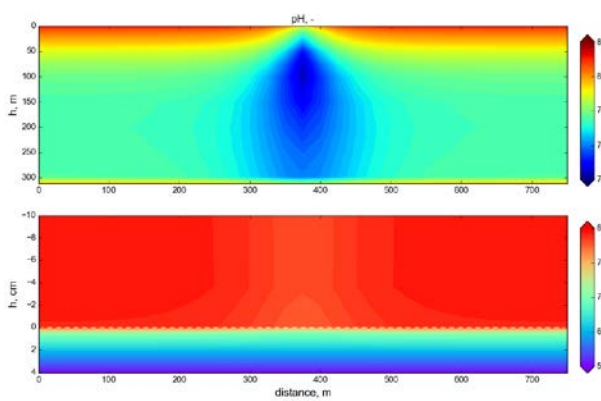


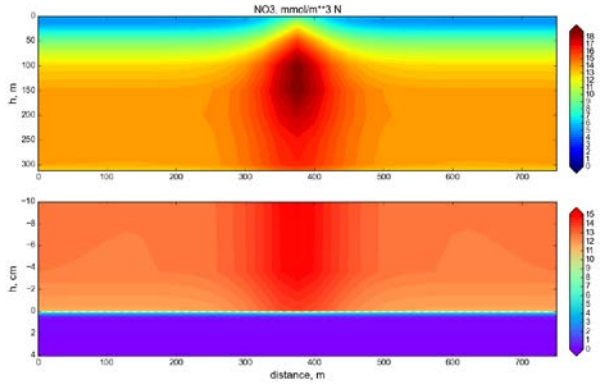


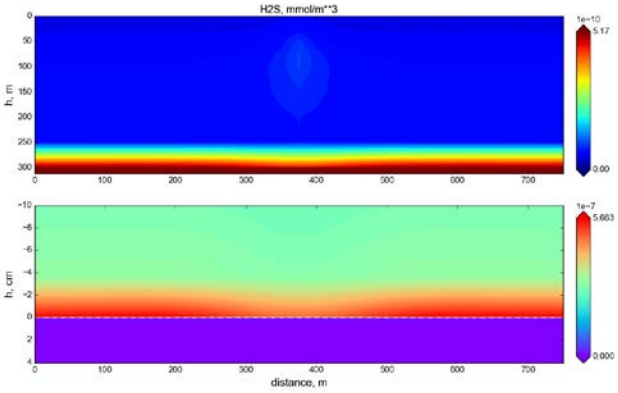


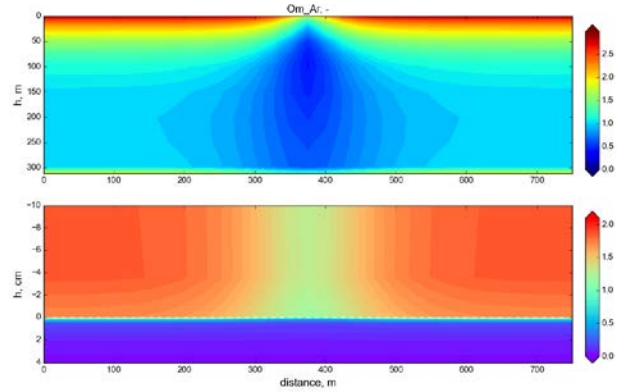






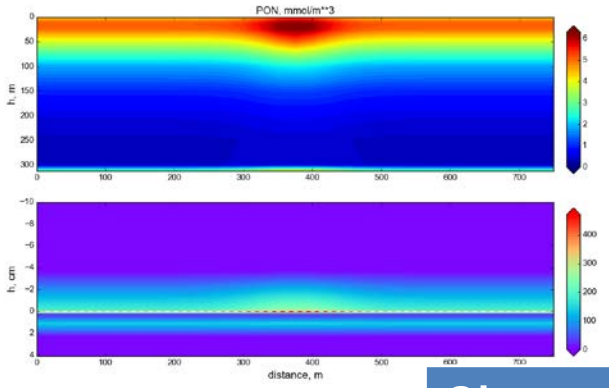




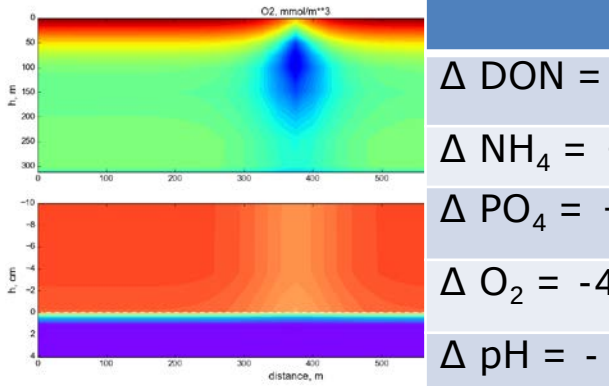


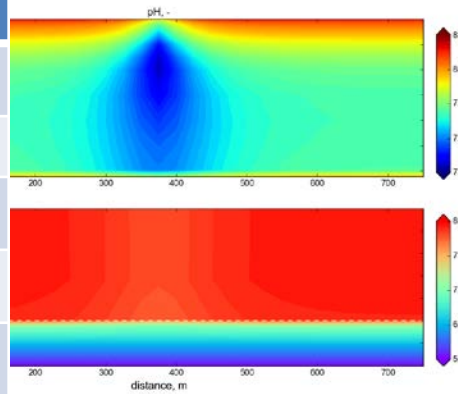
3. Experiments: 1 X farm

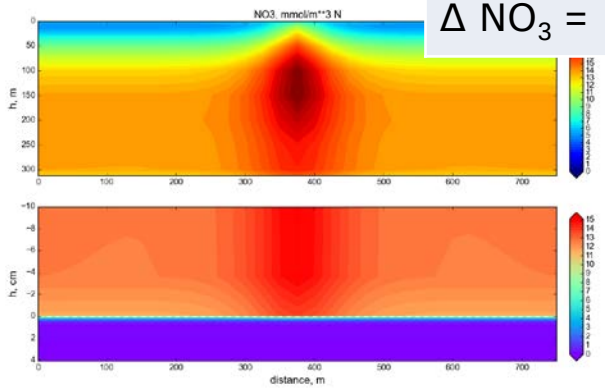
RESULTS

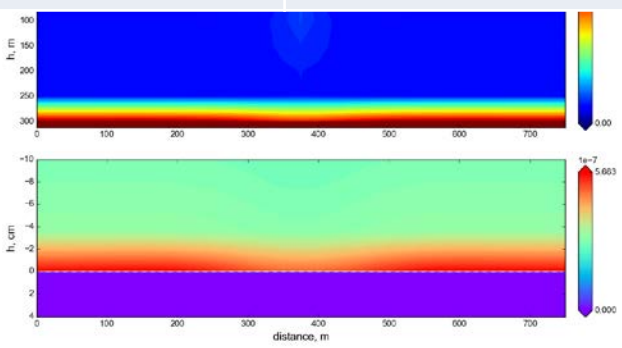


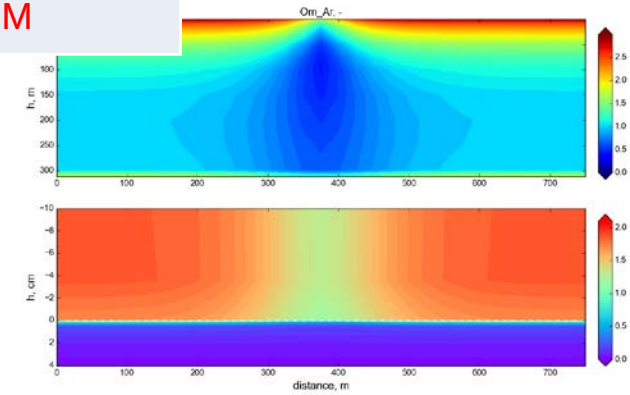
Observations:	Model:
Δ DON = +3 µM	Δ DON = +1.5-3 µM
Δ NH_4 = +7 µM	Δ NH_4 = +5-10 µM
Δ PO_4 = +0.2 µM	Δ PO_4 = +0.2-1.0 µM
Δ O_2 = -45 µM	Δ O_2 = -30-150 µM
Δ pH = - 0.07	Δ pH = - 0.1-0.5
Δ NO_3 = -5 µM	Δ NO_3 = +5-10 µM

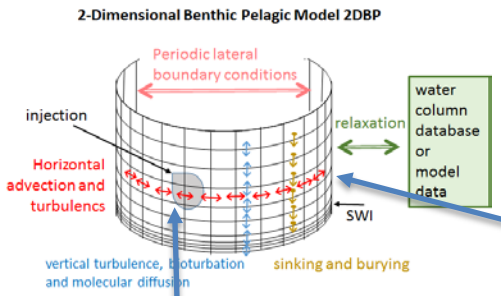






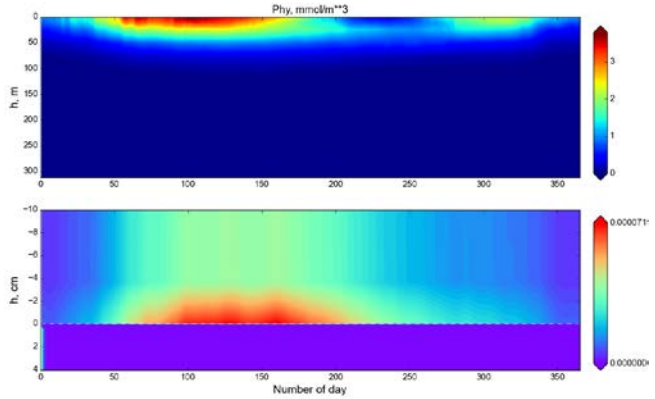


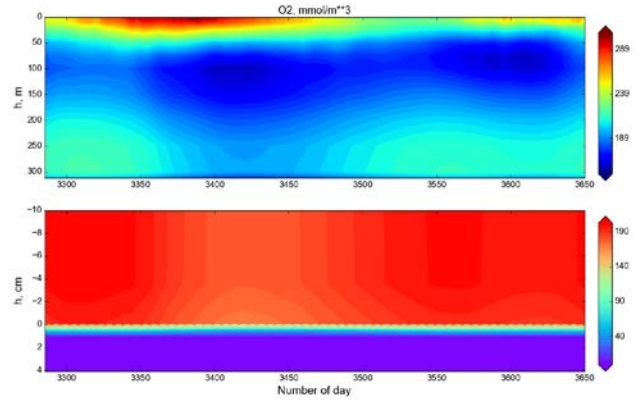




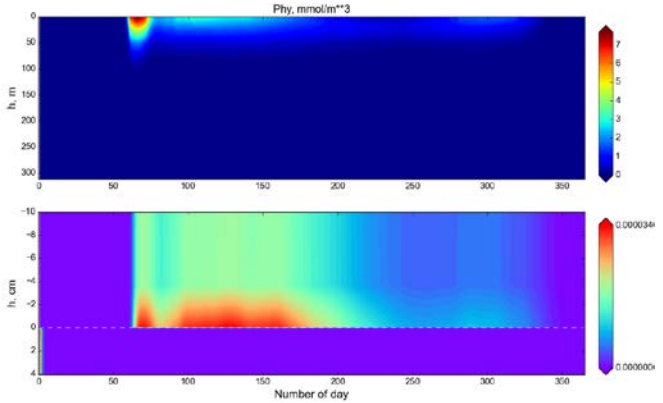
3. Experiments: 1 X

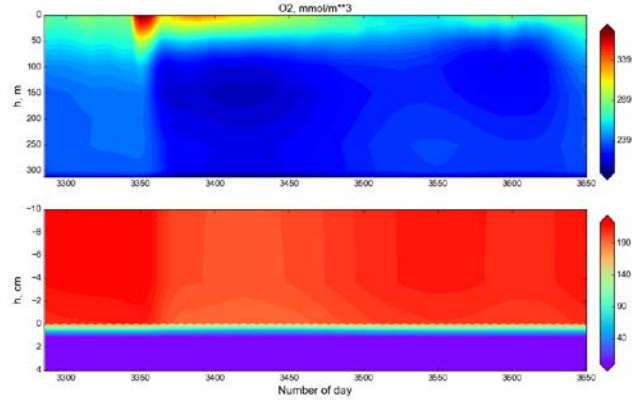
Eutrophication near the farm



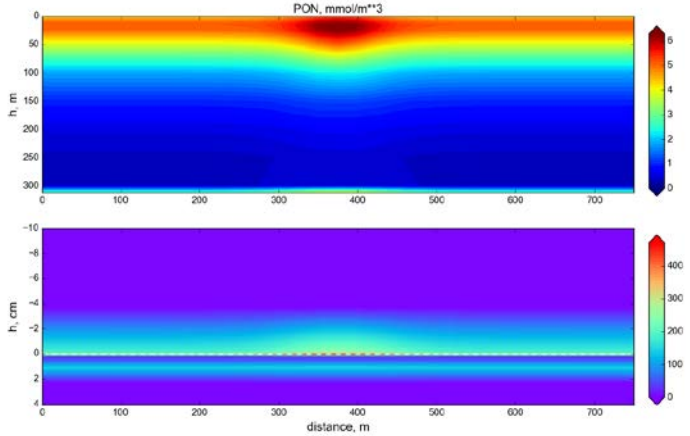


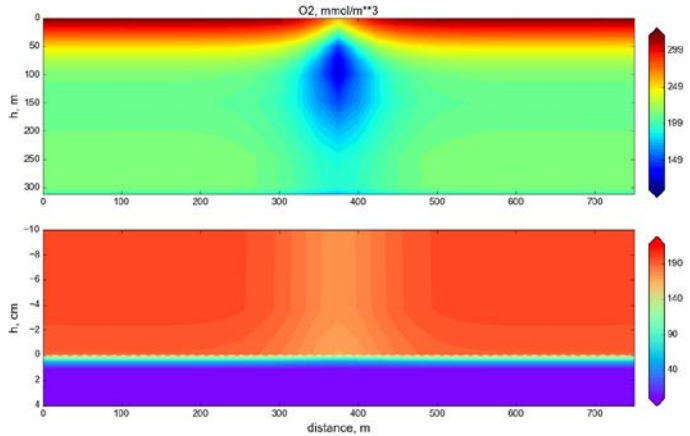
Natural variability

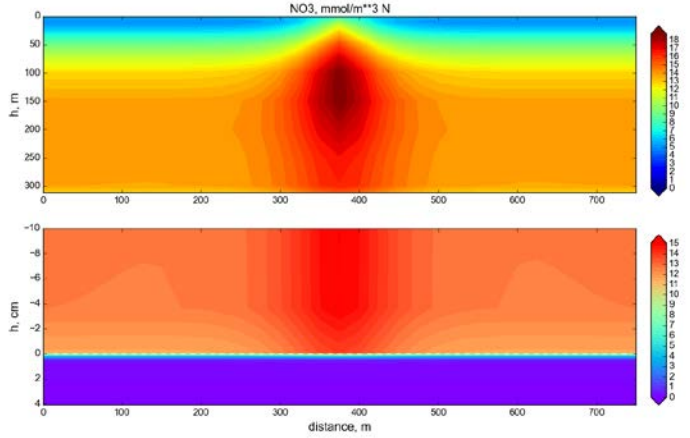




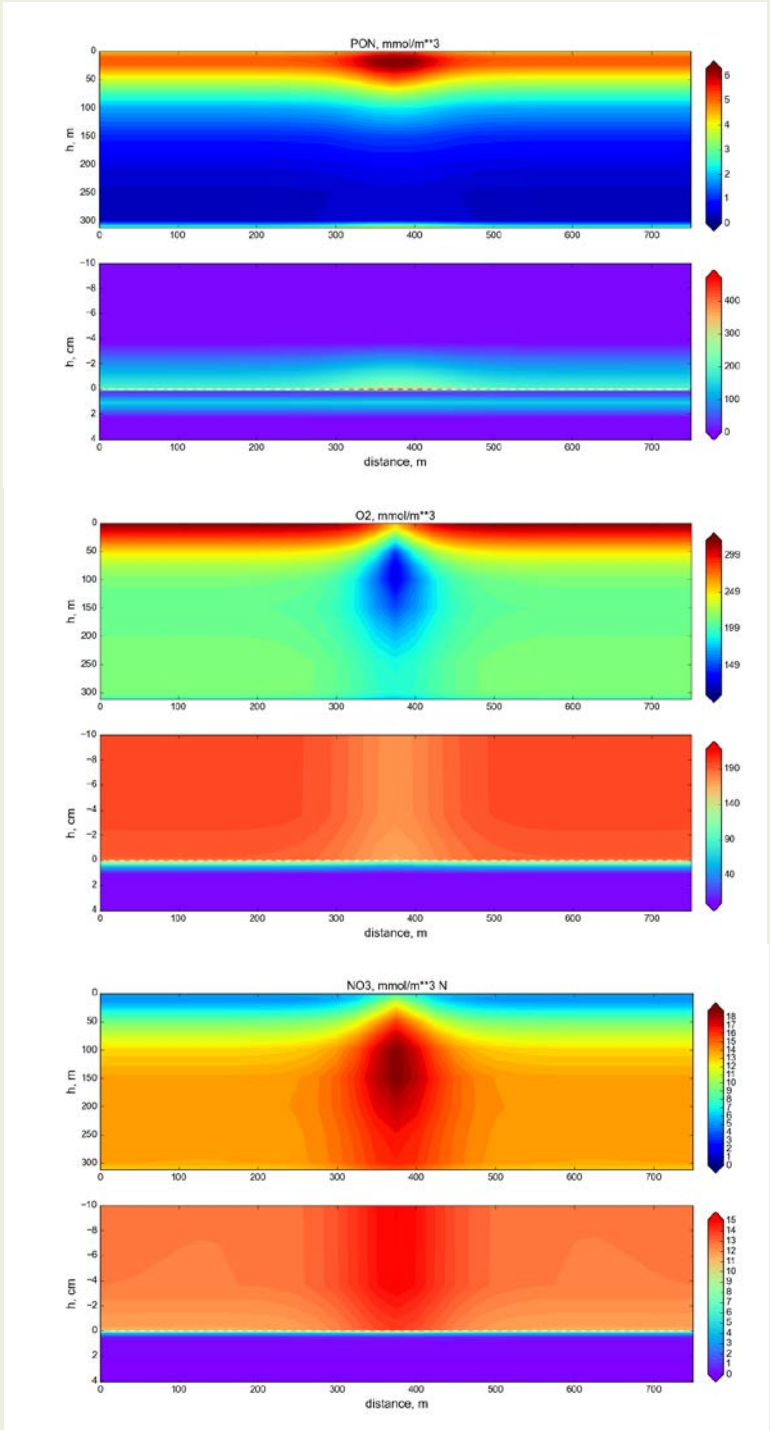
1 X


PON, mmol/m**3
h, m
h, cm
distance, m

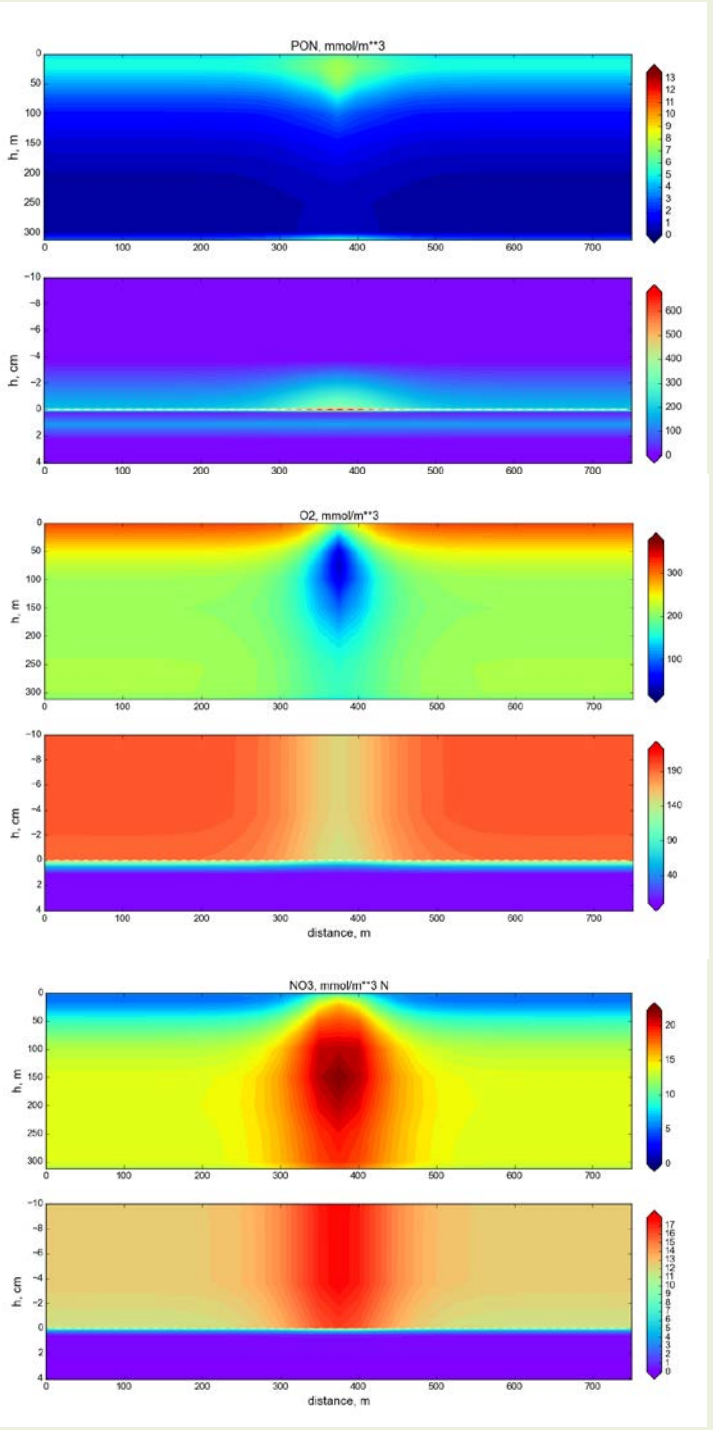

O2, mmol/m**3
h, m
h, cm
distance, m


NO3, mmol/m**3 N
h, m
h, cm
distance, m

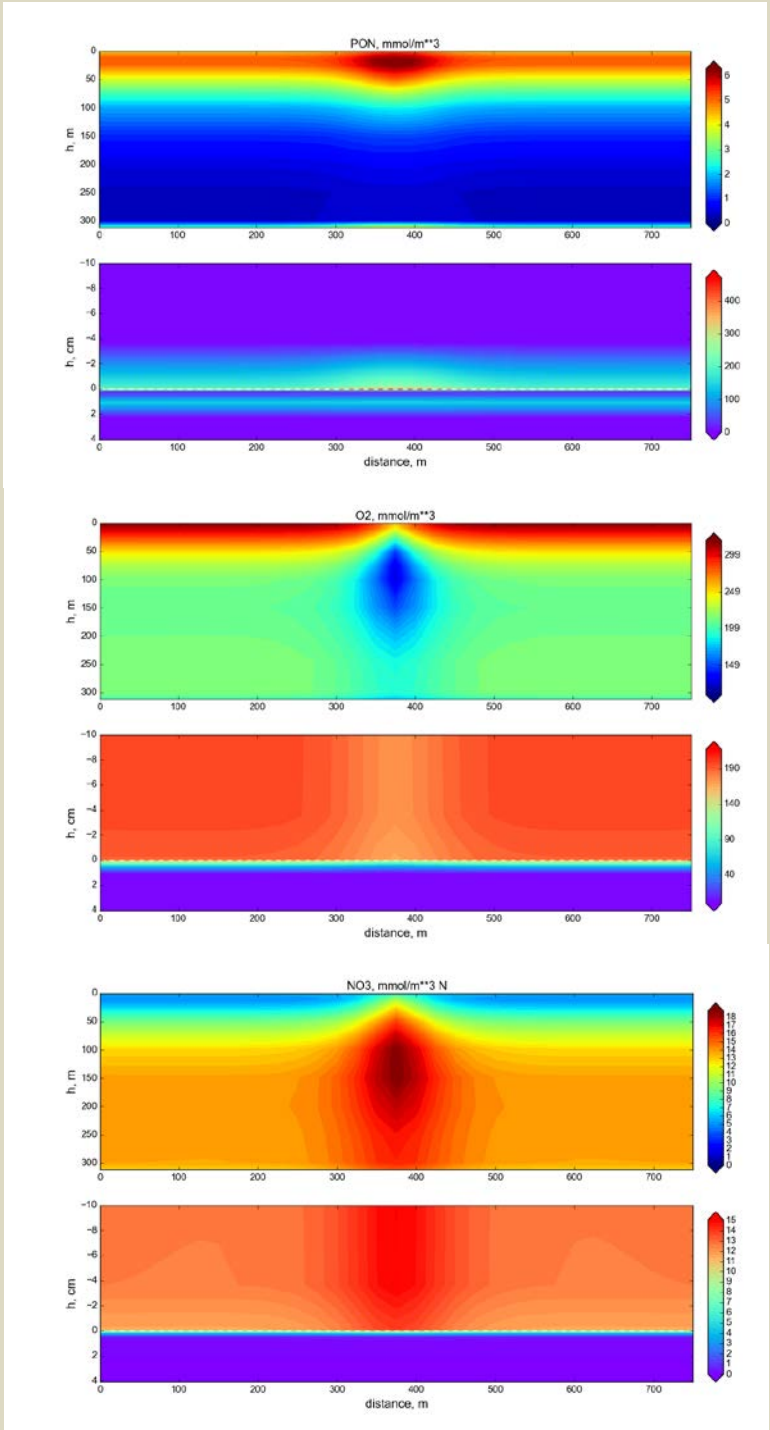
1 X


PON, mmol/m**3
h, m
h, cm
distance, m
O2, mmol/m**3
h, m
h, cm
distance, m
NO3, mmol/m**3 N
h, m
h, cm
distance, m

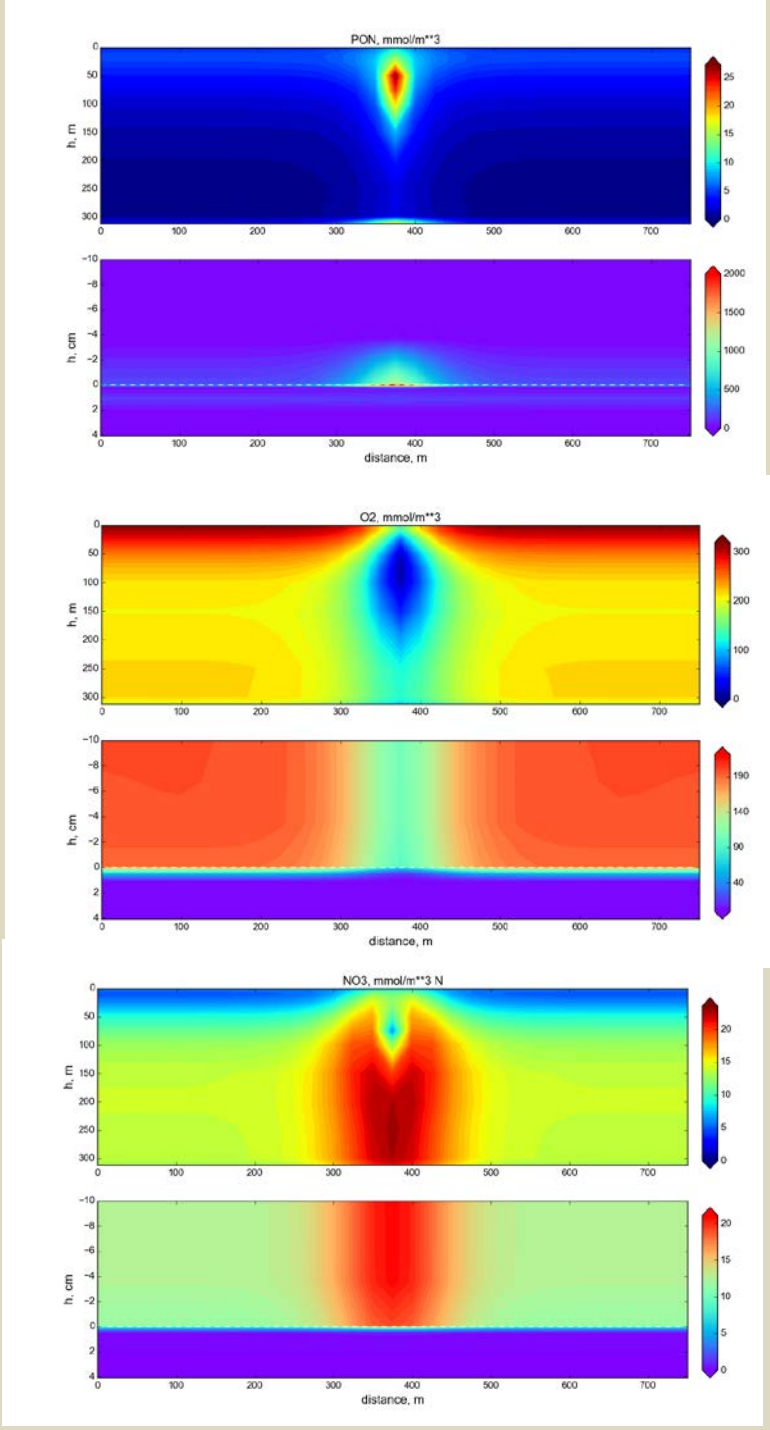
2 X


PON, mmol/m**3
h, m
h, cm
O2, mmol/m**3
h, m
h, cm
distance, m
NO3, mmol/m**3 N
h, m
h, cm
distance, m

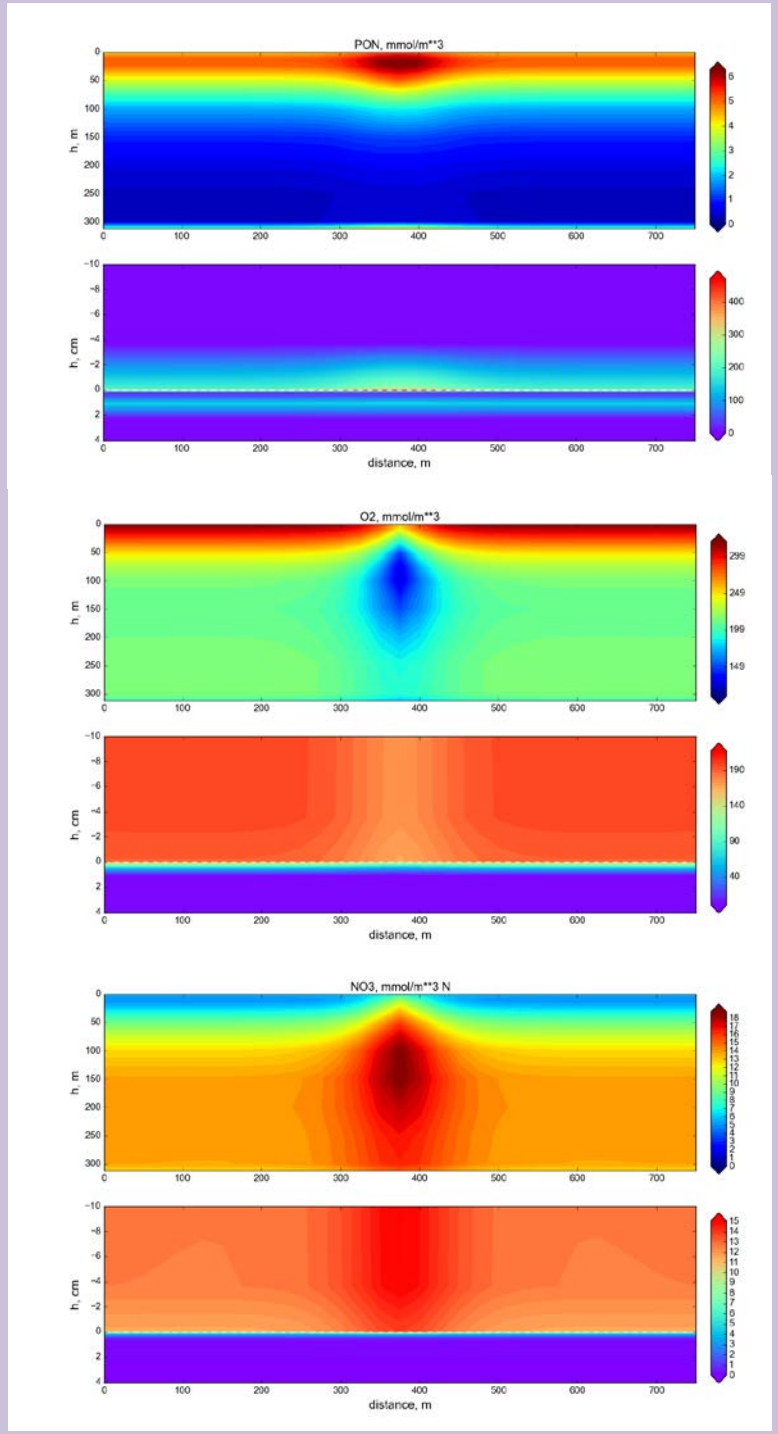
1 X


PON, mmol/m**3
h, m
h, cm
distance, m
O2, mmol/m**3
h, m
h, cm
distance, m
NO3, mmol/m**3 N
h, m
h, cm
distance, m

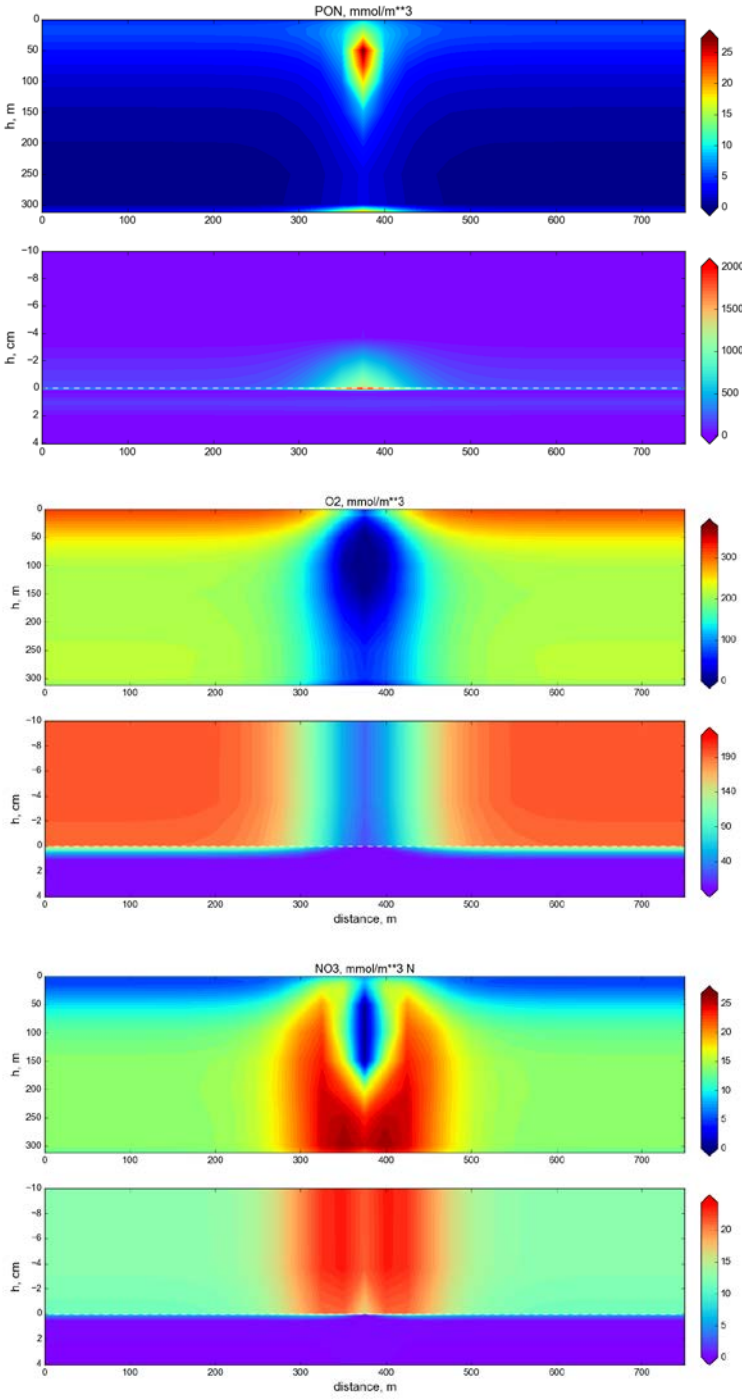
3 X


PON, mmol/m**3
h, m
h, cm
distance, m
O2, mmol/m**3
h, m
h, cm
distance, m
NO3, mmol/m**3 N
h, m
h, cm
distance, m

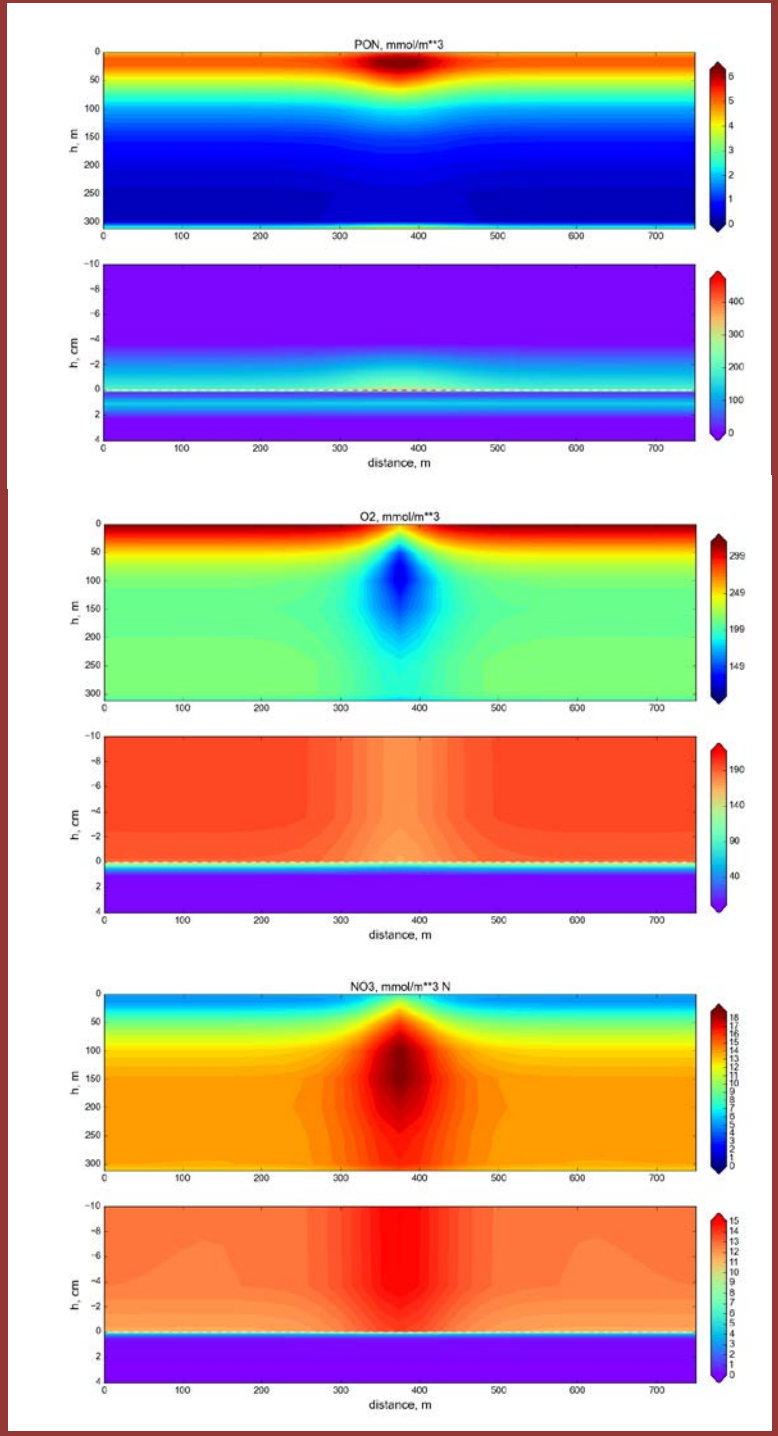
1 X


PON, mmol/m**3
h, m
h, cm
distance, m
O2, mmol/m**3
h, m
h, cm
distance, m
NO3, mmol/m**3 N
h, m
h, cm
distance, m

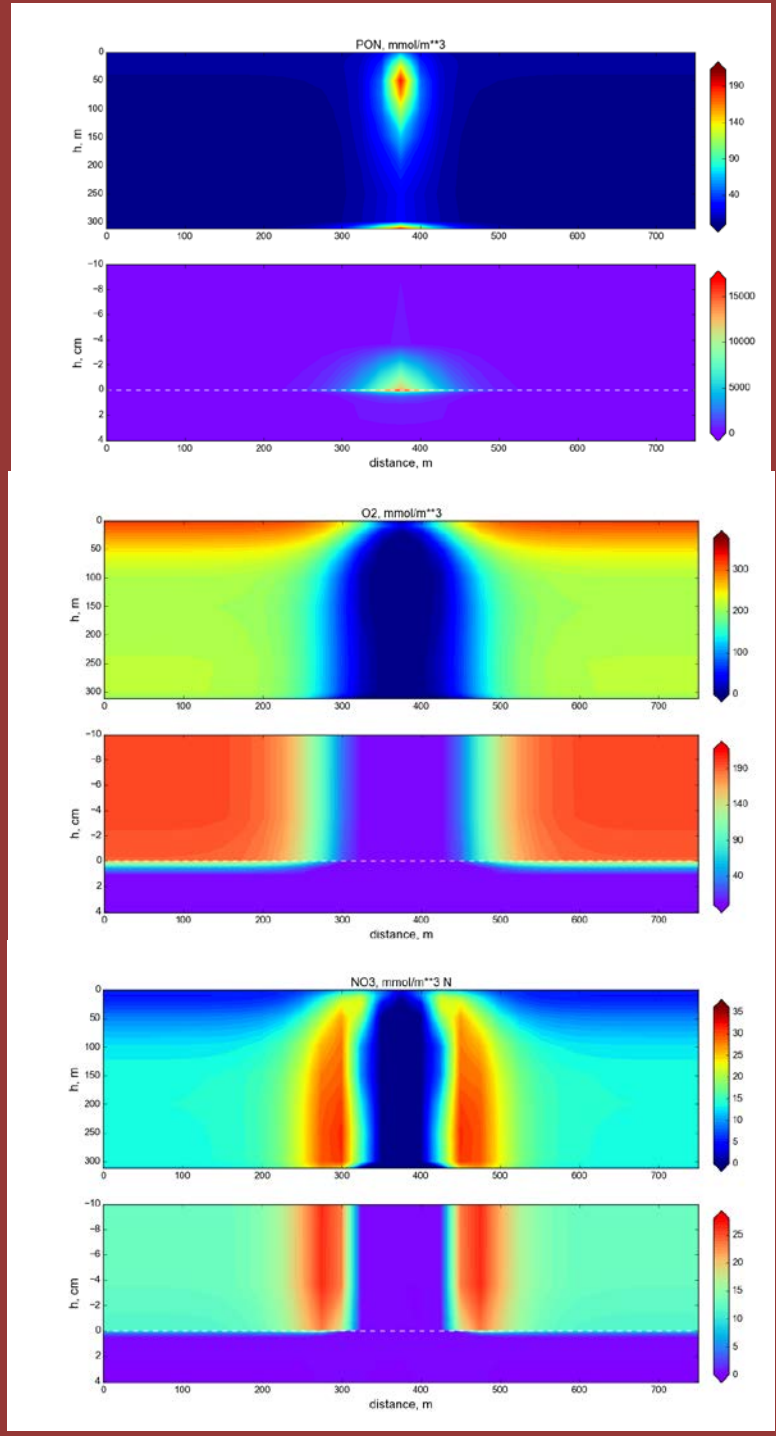
5 X


PON, mmol/m**3
h, m
h, cm
O2, mmol/m**3
h, m
h, cm
distance, m
NO3, mmol/m**3 N
h, m
h, cm
distance, m

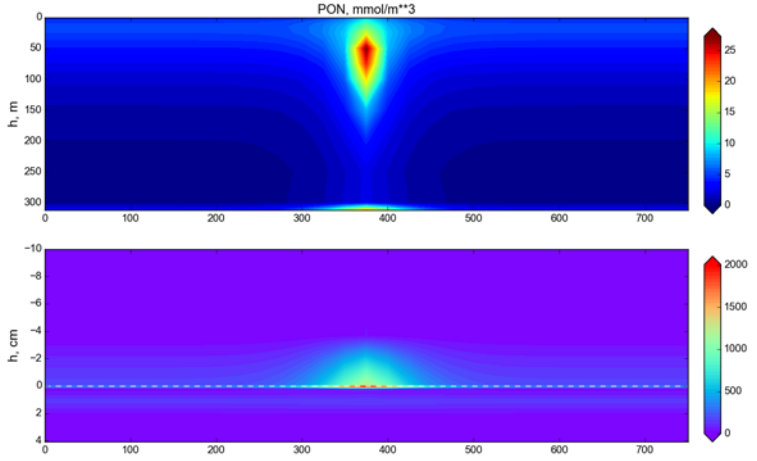
1 X

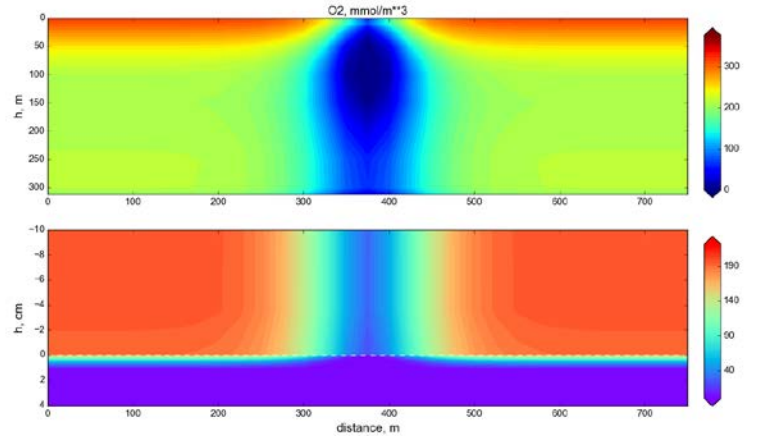

PON, mmol/m**3
h, m
h, cm
distance, m
O2, mmol/m**3
h, m
h, cm
distance, m
NO3, mmol/m**3 N
h, m
h, cm
distance, m

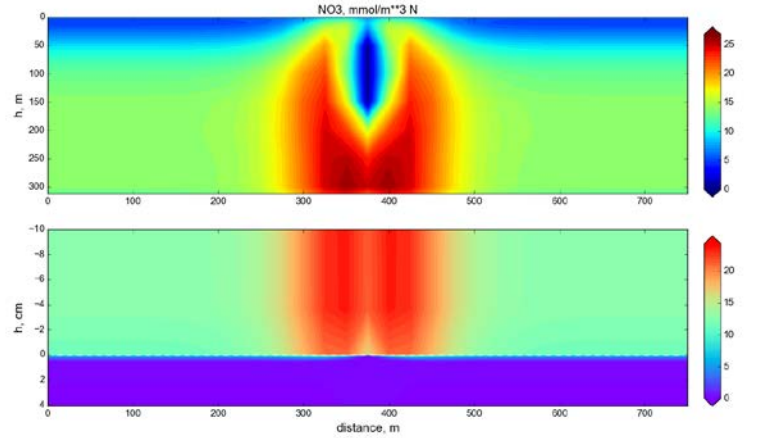
10 X


PON, mmol/m**3
h, m
h, cm
distance, m
O2, mmol/m**3
h, m
h, cm
distance, m
NO3, mmol/m**3 N
h, m
h, cm
distance, m

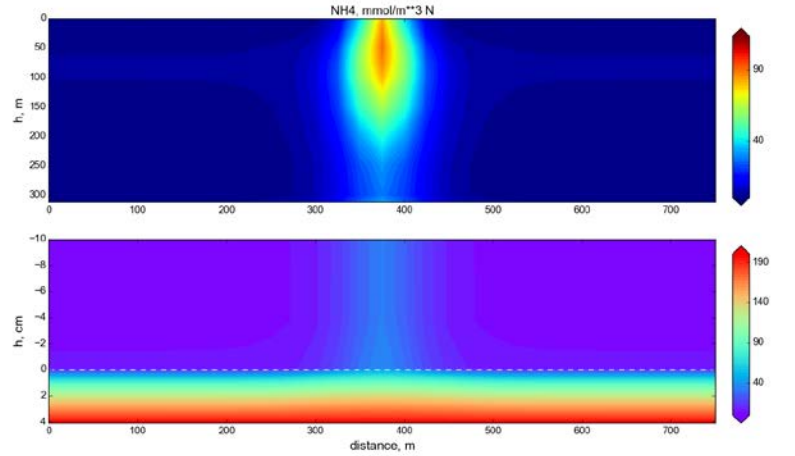
5 X

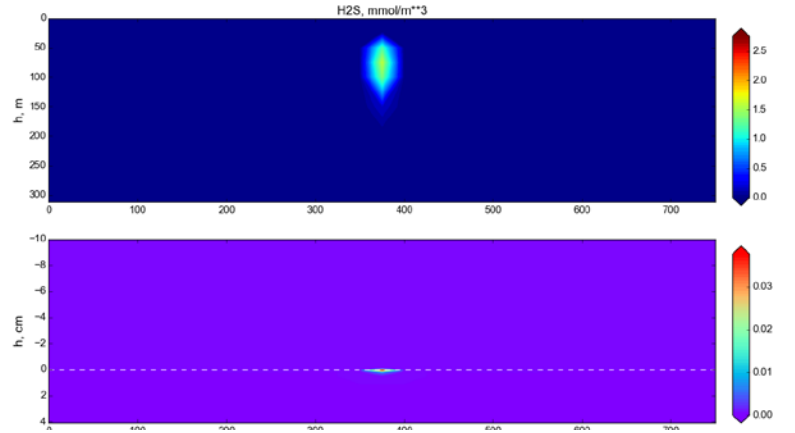

PON, mmol/m**3
h, m
h, cm

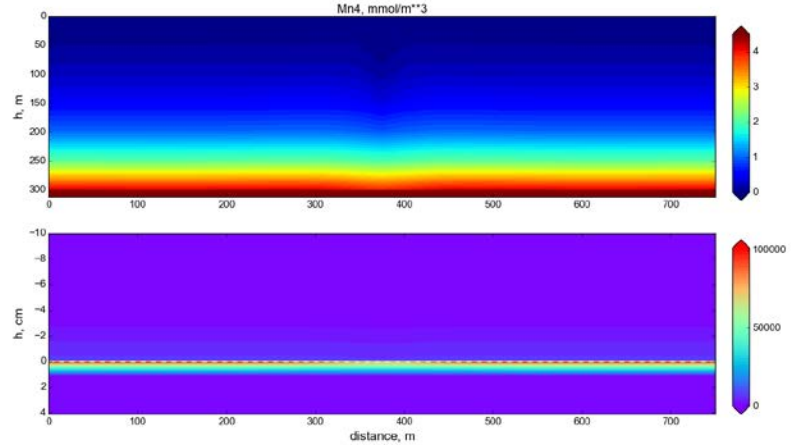

O2, mmol/m**3
h, m
h, cm
distance, m


NO3, mmol/m**3 N
h, m
h, cm
distance, m

5 X


NH4, mmol/m**3 N
h, m
h, cm
distance, m


H2S, mmol/m**3
h, m
h, cm


Mn4, mmol/m**3
h, m
h, cm
distance, m

CONCLUSIONS

- Model satisfactory reproduces the mechanism of changes in pelagic and benthic biogeochemistry due to an injection of OM from a fishfarm.

- Model allows to analyse consequences of the OM injection changes, i.e. to predict:
  - *volume of water affected;*
  - *area of the bottom affected;*
  - *extreme concentrations of substances in relation to the allowed permitable level.*

- Model can be an effective instrument of estimating of the carrying capacity of the water bodies.

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Thank you!

Yours modellers-on-board.